Dear Editor and Reviewer #1:

We would like to thank Reviewer #1 for your constructive comments concerning our manuscript entitled "Transport mechanisms of hydrothermal convection in faulted tight sandstones" (egusphere-2022-1185). We have addressed each question and comment. The responses to these comments are listed below and the revised manuscript with tracked changes is also submitted.

[0] The authors perform numerical simulation of a geothermal system and the interaction between a deep fault, lateral faults with a sandstone reservoir. The study aims to explain high observed temperatures in the Piesberg quarry, Germany using a sensitivity analysis around the fault and reservoir properties. My comments are mainly about clarification and publication is recommended after a minor revision.

Answer: All of Reviewer #1's comments are adopted to improve the scientific quality of our manuscript.

[1] Eq 1: Can you explain what Sm is? I assume it should be based on porosity, fluid density and their compressibilities and that you then can go from a time derivative of mass to a time derivative of pressure. However, is Sm then pressure dependent or assumed constant? Some definitions and assumptions should be given. You also seem to assume single phase.

Answer: 1) The "S_m" is the constrained specific storage of the porous media (Pa^{-1}). The S_m comprised a mechanical alteration in response to pressure and is assumed as a constant given by $S_m = (1-n)/K^s + n/K^l$ with porosity n (-), the bulk moduli of solid K^s and of liquid K^l (Pa) (Watanabe et al. 2017).

2) Yes, we agree with you. Based on assumptions about the constant porosity, temperature/pore pressure-dependent fluid density, and constant compressibility (i.e., reciprocal of the S_m) of porous media (Tables 1, 2 and equation (4)), our model can be run from the time derivative of mass to the time derivative of pore pressure.

3) Yes, only single-phase liquid flow is considered in this study.

All the above information has been added to "Chapter 2.2.1 Governing equations".

[2] What is the index m in q_m?

Answer: The index 'm' has been removed for clarification reasons. The $\boldsymbol{q}$ is the Darcy velocity in the porous media ($m \cdot s^{-1}$).

[3] Eq3 Does 'effective' also include the fluid?

Answer: Yes, the 'effective' terms include the fluid and solid phases. All the 'effective' terms have been revised as detailed terms of fluid and solid phases due to clarification reasons.

[4] The density should vary with temperature. Can you comment on how that was modeled?

Answer: The fluid density is a temperature/pore pressure-dependent variable. The polynomial function fitting experimental data for pure water in the liquid phase is used to compute fluid density over temperature and pore pressure ranges of 273.15 ~ 1273.15 K and 0 ~ 500 MPa (Linstrom and Mallard 2001). The detailed polynomial function has been added in "Chapter 2.2.2 Numerical model".

[5] 175 Can the authors give the definition of Rayleigh number and its importance? What determines its value?

Answer: Linear stability analysis based on Rayleigh number (Ra) calculations offer a useful tool to determine the onset of thermal convection (Nield and Bejan 2017). The Ra is a dimensionless number to characterize the fluid's flow regime and is defined as the ratio of buoyancy and viscosity forces multiplied by the ratio of momentum and thermal diffusivities:

$$Ra = \frac{k\left(\rho^l\right)^2 c_{\mathrm{p}}^l \boldsymbol{g}\beta\Delta TH}{\mu[n\lambda^l + (1-n)\lambda^s]}$$

where k is the permeability (m^2), ρ^l is the fluid density (kg·m^{-3}), c_p^l is the specific heat capacity of fluid (J·m^{-3}·K^{-1}), $\boldsymbol{g}$ is the gravitational acceleration vector (m·s^{-2}), β is the coefficient of fluid thermal expansion (K^{-1}), ΔT is the temperature variation (K) over the porous media height H (m), μ is the fluid dynamic viscosity (Pa·s), n is porosity (-), λ^l and λ^s are the heat conductivity of the liquid and solid phases (W·m^{-1}·K^{-1}). The above information has been added to the "Chapter 2.3 Simulation cases".

[6] Table 1: Please add mathematical symbols for identification with the model parameters.

Answer: The mathematical symbols of the model parameters have been added in Table 1 for identification.

[7] 188 The kappa values have not been defined as far as I can see. What do they represent? What are the indexes MF and SST? If they correspond to values in table 1, the abbreviations should be listed there as well.

Answer: The kappa values had been first defined in Line 155 of "The typical parameterization of main fault permeability (κ_{MF}) and sandstone permeability (κ_{SST}) are 10^{-13} m^2 and 10^{-15} m^2, respectively". The subscript MF means the main fault and the subscript SST represents sandstone. The abbreviations are also added in Table 1.

[8] 205 What is meant by 'initial temperature' in this case? Do you mean based on boundary conditions before flow is accounted for or simply an assumed geothermal gradient? Rather than 'initial temperature', do you not really mean 'initial guess' since you are only interested in the dynamic steady state? A thermal anomaly sounds to me a difference from an expected trend if the circumstances were as everywhere else, e.g. no faults etc. Is that what

you mean?

Answer: Yes, we are interested in the dynamic steady state of the hydrothermal convection systems. However, heat conduction dominated the heat transfer in the whole system before the onset of hydrothermal convection. Therefore, the initial temperature is derived from the steady-state simulation of pure heat conduction to avoid the effects of initial temperature perturbation on mass transport and heat transfer. The initial temperature distribution where the fluid flow is not accounted for is dependent on the surface temperature, basal heat flow, heat conductivity, and porosity of porous media.

[9] Can you define mathematically how you define the initial state based on your main equations?

Answer: The initial condition of the thermal field is derived from the steady-state simulation of pure heat conduction to avoid the effects of initial temperature perturbation on mass transport and heat transfer. The solution for the steady-state simulation of pure heat conduction in our model is shown as follows:

$$T_{initial}(z) = T_{top} + \frac{Q_{BHF} \cdot z}{n\lambda^l + (1-n)\lambda^s}$$

where $T_{initial}(z)$ is the initial temperature at the depth of z (m), T_{top} is the fixed surface temperature (°C), and Q_{BHF} is the imposed basal heat flow (W·m^{-2}). The above information has been added to the "Chapter 2.2.2 Numerical model".

[10] 224 A mathematical definition of Pe number should be given earlier so it is clear how the parameters are combined.

Answer: The Peclet number is calculated as the ratio of the heat flow rate by convection to the heat flow rate by conduction for a uniform temperature gradient (Jobmann and Clauser 1994), as follows:

$$Pe = \frac{\rho^l c_p^l \boldsymbol{q} L}{n\lambda^l + (1-n)\lambda^s}$$

where *Pe* is the Peclet number and *L* is the length scale of the fluid flow (m). The above information has been added to the "Chapter 2.3 Simulation cases".

[11] In the figures showing temperature vs depth it would be good to include the observed anomaly of the Piesberg quarry one wants to explain since the sensitivity analysis can indicate which parameter is more likely to explain it. For example, figure 7 shows that a high fault permeability is needed to explain a high temperature. Is it within range? Alternatively you could discuss how your model explains the observations more quantitatively in 4.2. Can you state something certain about what is needed for such explanation? If the fault is needed, what properties

must it at least have to realistically explain the observations? Which mechanisms or parameters are less important?

Answer: 1) The observed minimum thermal anomaly of 270 °C in the Piesberg quarry has been added to the related sensitivity analysis figures (Figures 4, 7, 10, 11). The zoomed part in these figures shows that temperature-depth profiles located at the right side of the intersection point of the dashed line (i.e., at 4.4 km depth and 270 °C) meet the observed thermal anomaly.

2) Chapter 4.2 has been revised to quantitatively explain the kilometer-scale thermal anomaly. "The observed results show that the measured thermal anomaly can be reproduced only if the κ_{MF} is equal to or greater than 10^{-15} m^2, meanwhile, the ratio of $\kappa_{SST\_horizontal}$ to $\kappa_{MF\ horizontal}$ is equal to or greater than 1. Thus, the magnitude of the κ_{MF} and the ratio of $\kappa_{SST\_horizontal}$ to $\kappa_{MF\ horizontal}$ are the determinative factors of the formation of the kilometer-scale thermal anomaly (270 ~ 300 °C) in the Piesberg Quarry than the lateral regional flow." and other information has been added to the "Chapter 4.2 Implications for the kilometer-scale thermal anomaly in the Piesberg Quarry and comparable reservoirs".

Reference

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