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Interactive comment on "Steady State Non-isothermal Well Flow in a Slanted Aquifer: Mathematical formulation and Field Application to a Deep Fault in the Xinzhou Geothermal Field in Guangdong, China" *by* Guoping Lu and Bill X. Hu

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Hydrol. Earth Syst. Sci. Discuss.,https://doi.org/10.5194/hess-2018-624-RC2, 2019© Author(s) 2019. This work is distributed underthe Creative Commons Attribution 4.0 License. Interactive comment on"SteadyStateNon-isothermal Well Flow in a Slanted Aquifer:Mathematical formulation and Field Application toa Deep Fault in the Xinzhou Geothermal Field inGuangdong, China"byGuoping Lu and Bill X. Hu Anonymous Referee #2Received and published: 15 April 2019

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Commentïij Ž In the manuscript, an analytical solution is proposed to analyze steady state non-isothermal well flow in a slanted aquifer. The analytical solution is then applied toa case study to explain some data. The topic is interesting and is appropriate for apossible publication to HESS. However, due to several weaknesses about the organi-zation of the manuscript, its writing, the English language or about the mathematicaldevelopments or the application to the case study, I do not recommend to accept themanuscript. It needs to be reorganized and rewritten to clarify different points beforethat a possible publication could be considered. Details of my reviews are given below. ResponseïijŽ We did a reorganization and a thorough editing for the manuscript. We made every effort to addressing the comments to improve the manuscript. Specifically, we added assumptions for the equations. We clarified the procedures for obtaining the permeability data for the deep fault. We also addressed the possibility of natural convection of geothermal water in the field site of deep fall.

In summary, we made the following changes. 1. we have re-organized the text in putting the site description to a new section Case Study. 2. We added a cross section of the field site as in Figure 5b. 3. We have modified Table 1 (density and viscosity data) to make it stand out for our novel formula of viscosity at the very start of the note. 4. We added a discussion section for the effect and implication from borehole drilling fluid. The text is from the previous site description section.5. We addressed the concern that natural free convection in a geothermal field of a deep fault. And 6. We added assumptions to the analytical solutions.

We believe we have fully addressed the review comments. The paper is sound in terms of science and writing.

CommentïijŽ 1) The manuscript is messy, difficult to read and to understand. It needs to bereorganized and much better written. For instance, in the introduction the first sen-tences are written like an abstract, before describing the site and the objectives of thestudy. But the objectives of the work appear without a clear idea about the contextand about the state of the art. It seems more based on some data gathered from afield

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site than a clear and comprehensive understanding of a scientific question. Anintroduction clearly written should clearly state the context of the work, the scientificquestions addressed and the method proposed to solve them. This is an examplefrom the introduction, but the other parts of the manuscript requires also to be reor-ganized and clarified (see below). ResponseïijŽ Thanks for your time for the comments. but the word messy is overly harsh. We have partially re-organized the text. The introduction has been re-organized and the site description has been moved to the case study to improve the structure of the paper. We revised to improve the context.We reworked the scientific problem as: “Field studies have shown that a geothermal field is active in geothermal water outflow with a central area of high temperature and a periphery of dramatically lowered down water temperatures. We want to find out how the temperature effect plays out in the dynamic geothermal water flow to wells in the deep fault geothermal field, and what method can be used to characterize the geothermal flow in the fault zone to improve understanding of the deep fault.”

CommentïijŽ 2) Furthermore, the English language needs to bethoroughly proof-read and re-written. I recommend finding a native English speaker toassist with this component. ResponseïijŽ We have edited the text thoroughly to improve the flow of English. We believe the revised manuscript is sound. Thanks.

CommentïijŽ 3) Some references are missing, especially in the fieldof geothermal flow associated to fault zones. Some very general references aboutgeothermal applications are given in the manuscript, but, for instance, the followingreferences could be more appropriately cited :Malkovsky, V. .I., and F. Magri (2016),Thermal convection of temperature-dependent viscous fluids within three-dimensionalfaulted geothermal systems: Estimation from linear and numerical analyses, WaterResour. Res.,52, 2855–2867, doi:10.1002/2015WR018001. Zhao, C., B. E. Hobbs, A.Ord, S. Peng, H. B. MC, L. Liu (2004), Theoretical investigation of convective instabilityin inclined and fluid-saturated three-dimensional fault zones, Tectonophysics.,387(1–4), 47–64, doi:10.1016/j.tecto.2004.06.007 These are only examples. About flow inslanted aquifer, some other references could be also of interest. ResponseïijŽ ïijůe added these papers (Malkovsky and Magri, 2016; Zhao et al., 2004), to go with the ones we already have had for fault-zone flow characterizations. Relevant discussion is made. Thanks!

CommentïijŽ 4) The calculationsin section 4 and 5 are simple, but the boundaries conditions used should be clarified.The aim of the manuscript is to propose a coupling between head and temperaturevariations, but it is not clear how varies temperature in figure 4 and 5. Line 262, it isassumed that the temperature is linearly varying along the flow direction. But why thisis necessary, how this is justified ? It should be clarified and explained. Some equa-tions should be checked, in particular equation 1b which is incorrect in this form. ResponseïijŽ The assumptions for the linear and radial flows are: In a horizontal or an inclined aquifer,radial thermal flow also has several assumptions for its features. The aquifer is continually distributed with a uniform thickness. The permeability of the aquifer is uniform, leading to inference of an uniform thermal property. The aquifer is assumed to have a single source, leading to the fact that the temperature field with smooth temperature variations.

In Figures 4 and 5 the temperature changes are smooth and gradual, with the aquifer is assumed to have only one heat source. Therefore, the assumption for temperature is not necessary to be linear.

We have checked the formulations in all the equations. We have removed the equation (1b). Equation (1b) was not used actually used any way; it is there for completeness of the flow of none steady state.

CommentïijŽ 5) Itis difficult to understand from section 6 and figure 5 how analytical results from section 5 are applied to the field case. This should be clarified as well as the geometry of the aquifer and the assumptions used for the calculations. ResponseïijŽ We added text to clarify the utility of analytical solution to the field site. We added a cross section of the field site to enhance understanding the of fault zone (Fig.6 in revised version). The fault plane for the deep fault is assumed to have a flat surface, slightly curved to the south at the western end, based on borehole data in the field site. Assumptions are made for applications of analytical solutions (Eqs. 11,12) to the Xinzhou geothermal field. The fault is approximated to have uniform properties such as thickness, permeability. The temperature distribution between boreholes is resulted from a single heat source so that the temperature changes are smooth and the trend is known. In this case study we used the linear interpolation to approximate the actual inter-borehole temperature. The linear approximation for temperature is expected to have negligible error, because of the steady state nature of the flow field condition. A more rigorous approximation could have obtained a better fit for temperature, for example, a second-order of polynomial function. But it is hard to find the data for the fit of the curve.

We added the above text in the revision to the analytical sections ((Section 4.1; 4.2, revised version)

CommentïijŽ 6) How is calculated the faultpermeability ? Permeability values are given (line 392) and largely discussed (section7.2). It appears as a major result (line 45-46 in the abstract and 475-477 in the conclu-sion), but it should be explained how permeability is calculated. ResponseïijŽ The fault permeability calculation is discussed in details (Section 5.3, revised version). The assumptions are also provided.

CommentïijŽ 7) Moreover, in suchpermeable fault zone, with such temperature gradients, one may expect natural freeconvection to occur. This should be discussed since conditions for flow and pressuredistribution in the fault zone (slanted aquifer) should control the response observed inthe deep borehole. Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2018-624, 2019 ResponseïijŽ In light of the flow field with the permeable fault, one would think whether the temperature and pressure condition could lead natural free convection to occur. The flow condition in the top part of the deep fault system is predominantly upward. There is no field evidence that natural convection occurs in this field site at the scale of this size

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scale of about 800 m across.A simulation in regional scale of the deep fault reaching 7 km deep, the flow field shows that the upper part is dominantly up-swelling flow while, the down-drawing flow occurs near the bottom part of the deep fault. More detailed investigation is referred to Lu et al. (2017). We added the above text in the revision to the end of permeability calculation section (Section 6.3 in the revised version).

Lu, G., Wang, X, Xu,F., Li,F., Wang,Y., Qi,S.,Yuen,D.: Deep geothermal processes act through deep fault and solid tide in Xinzhou geothermal field in coastal Guangdong,China, Physics of the Earth and Planetary Interiors, 264, 76–88, 2017, http://dx.doi.org/10.1016/j.pepi.2016.12.004.

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