

Response to reviewer #1 (Dr. L. Scesi)

- In the section “Site description and data collection” (page 1993), the Authors make a geological description of the area and say that there are: “numerous thrust faults” having a NE-SW direction and a “normal fault” having a N-S direction (seeing the fig. n. 3 this fault, from North to South, has a NNW-SSE and NW-SE direction). It is very important to well define the faults directions for defining the fluxes. After, they show a rose diagram that represents 67 joints measured in 1978 at 1 outcrop of the Jentse member. From this diagram the Authors say that it is possible to notice a prominent set of joints (having a NW-SE direction with dips between 65° - 80° to the SW) and another set (less important) having a NE-SW direction with steeply dips towards NW.

Response:

Thanks for the comment. We are sorry for the confusion in regard to the directions of fault and joints. The direction “NE-SW” in the following texts are typos: “...numerous trust faults that essentially trend parallel to the bedding (NE-SW) and ...” (line 21, p. 1993) and “the most convex of the NE-SW trust...” (line 26, P. 1993). According geological analysis by Tseng (1978), the fault and joints should have “NW-SE” direction. Therefore, those texts are modified as “...numerous trust faults that essentially trend parallel to the bedding (NW-SE) and ...” and “the most convex of the NW-SE trust...”. In addition, the Chingshuihsi fault has NW-SE direction and thus the text “There is a normal, N-S striking Chingshuihsi fault...” is modified to “There is a normal, NW-SE striking Chingshuihsi fault...” (line 25, p. 1993).

- At page 1994 they write that the “predominant joints” are aligned perpendicular to the strike of the strata (what is the strike of the strata? I have not found this information in the text, besides a rose diagram allows to see only the azimuth (dip direction) or the direction but not the dip).

From the subsurface data, the Authors say that the rock is interested by many joints having a NW-SE direction (directions = 335° - 155° and 320° - 140°) with very high dips ($\sim 90^{\circ}$) and that “outcrops near the area of thermal manifestations also reveal that faults run parallel for almost 100 to 150 m striking $N30^{\circ}$ W and $N35^{\circ}$ W (direction = 330° - 150° and 325° - 145°)”. From these descriptions I imagine that in the area the most important (and predominant from the hydrogeological point of view) set of joints has a NW-SE direction, according to the “normal fault” direction and with the all other faults and discontinuities set. At page 2000 the Authors say that the most prominent set of joints has a W-E

direction. I don't understand, what is the correct direction, dip and dip direction of prominent set?

Response:

- “Predominant joints are aligned perpendicular to the strike of the strata...” means that the joints dip steeply and almost perpendicular to the strata.
- The dip direction and the dips in the text are based on the contour diagram in Tseng (1978) which is now added in the manuscript as Fig. 4b.
- According to Tseng (1978), the strike of most prominent set of joints is $N25^{\circ} W$ and $N40^{\circ} W$ dips between $75^{\circ} - 90^{\circ}$ to SW and the strike of the Chingshuihsi fault is about $N30^{\circ} W$ and $N35^{\circ} W$. The strikes of the most important set of joints and the fault are almost parallel. However, Tseng (1978) did not provide the dip direction and the azimuth of the fault. From the analysis of geologic, gravity, and magnetotelluric data by Tong et al. (2008), the fault system is $N21^{\circ} W$ and dips 80° to NE. We adopt this result and add it in the manuscript since it is integrated by many geophysics data and borehole information.
- Besides I think that the exam of 67 joints surveyed (in 1978!!) in only 1 (!!) outcrop is not sufficient to do a statistical distribution of the sets!! In a so big area, characterized by faults and folds, it is necessary to collect a lot of structural data to know very well the distribution of the joints!! I suggest the Authors to see the paper: “Insight into the Geothermal Structure in Chingshui, Ilan, Taiwan” (2008) written by Lun-tao Tong, Shoung Ouyang, Tai-Rong Guo, Ching-Ray Lee, Kou-Hsin Hu, Chun-Li Lee, and Chun-Jao Wang. *Terr. Atms. Ocean. Sci.*, Vol. 19, No. 4, 413- 424. In this paper there is a good reconstruction of the conceptual model of the area. By this reconstruction it is clear that the geothermal reservoir might be associated with the fracture zone of Chingshuihsi fault and that this structure has a NW-SE direction (strike) and a dip of 80° to NE (and not to NW as written by Authors). The dip direction (towards NE) is also evident by its trend on the geological map. The cross-section, reported in Fig. 2, represents a too old interpretation of the geological features (Chiang, 1979!!). In the last few years (32 years!) many technologies (especially geophysical) developed and helped to improve the geological knowledge.

Response:

- Thanks for the suggestion. The strike of the Chingshuihsi fault is described as $N21^{\circ} W$ and dips 80° to NE in the revised manuscript according to the geological analysis from Tong et al. (2008).

- Figure 2 represents a conceptual hydrologic feature of the Chingshui hydrothermal system. Although it is not new, it can however delineate the conceptual map of the fractured system.
- At page 2000 the Authors speak about 5 sets (not described before): what is the dip and dip direction of these sets? From the fig 4 it is impossible to define them.

Response:

These 5 sets are not the joint sets. They are the results of anisotropic analysis from different well sets as shown in Table 2. The aim of anisotropic analysis is to figure out whether the formation in Chingshui geothermal area is anisotropic or not. The results of those 5 sets of anisotropic analysis using anisotropic model of Papadopoulos (1965) demonstrates that there is no obvious evidence of the existence of anisotropy in this formation.

- In the “concluding remarks”, the Authors say that the flow dimension increases with the distance between the pumping well and the observation well. This is normal and obvious, because in a rock mass it is necessary to consider the “elementary representative volume” ERV. This is the minimal volume to take into consideration to study the hydrogeological features of a rock, such that the medium can be considered sufficiently homogeneous and isotropic. If the considered domain is smaller than the ERV (characteristic for every studied area), all parameters change as a function of the distance. Personal comments From the hydraulic point of view, rock masses are heterogeneous, anisotropic and discontinuous media. As water flow in rocks occurs mainly along discontinuities, the exact knowledge of their distribution and of their characteristic parameters (aperture, roughness, infill, persistence, spacing, etc.) is fundamental to find the features that describe the fluid flow, in particular as far as the hydraulic conductivity assessment is concerned. Generally the hydraulic conductivity of a rock mass is expressed as a tensor. In this way it is possible to build the conductivity ellipsoid, having K_1 , K_2 , K_3 as semi-axes, and to evaluate the anisotropy vector $K_r = (K_r = |k_1/k_3 \ k_1/k_2 \ k_2/k_3|)$ that shows the relation among the hydraulic conductivities along the different directions in space (Scesi L., Gattinoni P. (2009): “Water Circulation in Rocks” Springer ISBN: 978-90-481-2416-9). According to my experience it is very difficult to apply methodologies developed for a porous medium to a fractured one. In any case, it is essential to know very well the characteristic of the medium and to reconstruct the conceptual model of the studied area.

Response:

The definition of the representative elementary volume (REV) given by Jacob Bear (e.g., Bear 1972, 1979) is different from the reviewer's viewpoint. The REV is a volume over which all the medium characteristics (variables and parameters) become single or representative values. The size of REV generally includes a sufficient number of pores and is much smaller than the size of entire flow domain (p. 19, Bear, 1972). The CGF has a dimension of 260 m in width and 1.5 km in length (Tong et al., 2008) and thus the issue of REV is not a problem in our paper.

The CGF is regarded as homogenous since it has well-developed fractures in the slates. In addition, as mentioned in Chiang et al. (1979), all well test data inspected in CGF resemble homogeneous reservoir data. An anisotropic analysis for the observation wells based on the anisotropic model of Papadopoulos (1965) was performed to verify that consideration. Four sets of combination data obtained from three observation wells and one set of five-well composite data are analyzed based on Papadopoulos' model. The analyzed results are shown in Table 2. The most prominent set of joints strikes are about -50° and -65° from the W-E direction (x-axis in Table 2). Those results demonstrate that the major transmissivities have similar direction as the prominent joints in sets 1 to 3. Theoretically, the directions of major transmissivity should be in the direction of prominent joints in all set of experiments. However, the directions in sets 4 and 5 are inconsistent with the direction of prominent set of joints in Fig. 4. The major direction of transmissivity in set 4 is even perpendicular to the direction of prominent set of joints. Those results indicate that besides faults and joints, there might be a highly well-developed fracture or micro-fracture network in the field. In addition, the results also demonstrate that the principal directions of transmissivities are different in all sets of wells and there is no obvious evidence to show the existence of anisotropy in this field. The GRF model is therefore applied to the CGF because it might be homogeneous and isotropic based on the field description and anisotropic analysis.

Table 2 Anisotropic analysis of the drawdown data from CGF.

	1	2	3	4	5
Set	9T, 12T, 14T	4T, 12T, 14T	4T, 9T, 12T	4T, 9T, 14T	All wells

$T_{\xi\xi}$ (m ² /min)	8.574	9.95	1.48	1.087	1.081
$T_{\eta\eta}$ (m ² /min)	6.31×10^{-4}	5.0×10^{-4}	1.5×10^{-3}	1.4×10^{-3}	1.4×10^{-3}
θ	-36°	-43°	-86°	53°	-19°

* $T_{\xi\xi}$ and $T_{\eta\eta}$ are the major and minor principal directional components of the transmissivity tensor; θ is the angle between the x-axis and the direction of the major principal transmissivity.

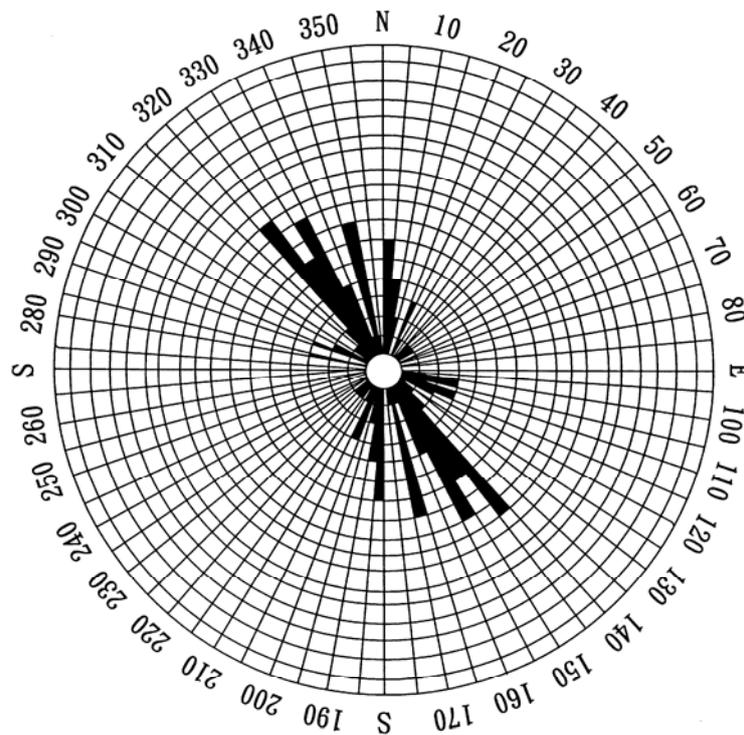


Fig. 4. Rose diagram of 67 joints of Jentse member in the Chingshui geothermal area (Tseng, 1978).

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