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Hydrology and Earth System Sciences Discussions

Interactive comment on "Scale dependency of fractional flow dimension in a fractured formation" *by* Y.-C. Chang et al.

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General comments

The study develops an approach, combining Generalized Radial Flow model with a heuristic optimization scheme, SA, to determine the fractional flow dimension and hydrogeologic parameters of a fractured medium. The Authors say that hydraulic structures and flow paths are complex in a fractured media and that an appropriate way to investigate the hydrodynamic behaviour of a fracture system is to determine the hydrogeological properties, such as the flow dimension, and aquifer parameters simultaneously. The Authors analyze a set of field data obtained from four observation wells at Chingshui Geothermal Field in Taiwan for determining the hydrogeologic properties of the fractured formation. In my opinion the paper is rather good, but there are many

inconsistency from a geological point of view. I think that the Authors have developed a model without having a valid reconstruction of the conceptual model of a studied area; this is fundamental to correctly apply the model and to understand the results. In the "specific comment" I will try to explain better my thought.

Specific comments

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. 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°) and that "outcrops near the area of thermal manifestations also reveal that faults run parallel for almost 100 to 150 m striking N30°W and N35°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? 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

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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 Chingshuihis 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. 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. 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, anisotropous 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,

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having K1, K2, K3 as semiaxes, and to evaluate the anisotropy vector Kr =(Kr = |k1/k3 k1/k2 k2/k3|) 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 essencial to know very well the carachteristic of the medium and to reconstruct the conceptual model of the studied area.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 8, 1987, 2011.