A Novel Method to Estimate Fracture Permeability: Combining microseismic observational data and reservoir engineering model

*Meihua Yang[1,2], Yusuke Mukuhira[2], Takatoshi Ito[2]

1. State Key Laboratory of Oil and Gas Geology and Exploitation, Chendu University of Technology (China) , 2. Institute of Fluid Science, Tohoku University (Japan)

Effective utilization of geothermal resources is crucial to realize a sustainable society. Geothermal resources are widely present in Japan and the western United States, and the usage of geothermal resources are gradually increasing with many efforts. Meanwhile, the exploration and exploitation of geothermal resources in China has gradually developed. One of the challenges in conventional/next generation geothermal development (Enhanced/Engineered Geothermal System: EGS) is to understand the hydraulic properties of the geothermal reservoir. We often attempt to measure the hydraulic property (permeability or diffusivity) by wellbore tests or by using indicators such as migration of microseismicity. However, these quantities are often interpreted as representative value of hydraulic property for entire reservoir. Meanwhile, geothermal fluid circulates or flows in the existing/nucleated fracture system where permeability varies depending on condition of each fractures. Geothermal fluid is extracted from those permeable fractures very locally throughout production well drilled into the specific part of reservoir. Therefore, we need to have the best estimates of permeability for each fracture (local permeability) beyond representative permeability (global permeability). In addition, it is important to consider how the hydraulic properties can be affected by changes in the state of stress in the subsurface. This information is beneficial for design of geothermal energy extraction system and understanding of hydrology in the reservoir.

In this paper, we propose a novel method to estimate permeability of each individual fractures which experience shear slip at hydraulic stimulation. The spatiotemporal distribution of reservoir fluid pressure will be estimated using microseismic data. Using a hydromechanical fractured reservoir model, we will invert for the shear-dilation enhanced permeability change that controls the evolution of pressure along fractures and faults.

The first step is to estimate pore pressure distribution with microseismic data from real EGS field and observe how pore pressure migrated within single fracture (Figure 1 left: coloured circles). Meanwhile, using the hydromechanical fractured reservoir numerical model, we simulate pore pressure distribution within one fracture of given permeability and evaluate the evolution of hydraulic properties during a stimulation treatment (Figure 1 right: coloured sold lines). Therefore, we can use parameters from observational data as input parameters into hydromechanical model and estimate the best permeability which explain observed pore pressure distribution. We will also simulate all microseismic clusters and estimate permeability of each fractures. Then analyse the fracture permeability distribution (permeability mapping) in the study area.

In this research, it is the first attempt to estimate local permeability for each fracture. So far, only global permeability can be estimated by wellbore test or microseismic data and this permeability is not effective for each fracture in subsurface. Information of local permeability is quite valuable for designing a sustainable energy extraction system. Local permeability information also brings the way to model the flow of geothermal fluid in the reservoir, which is important for long-term management of geothermal resources.

Keywords: Permeability, Microseismic, Reservoir engineering model