Determination of the cap rock integrity in the Çanakkale-Tuzla hydrothermal system from inversion of magnetotelluric data by using particle swarm optimization

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SUMMARY

Earthquakes of tectonic or magmatic intrusion origin around a geothermal field sometimes inflict irreversible damage to the caprock and cause temperature drop in reservoir temperature by altering the integrity of the cap rock structure. In a healthy reservoir, intact caprock seals the reservoir, maintains temperature and pressure build up for better well yield, and prevents cold water of overlain aquifers entering the system. The integrity of the caprock with these characteristics ensures the long-term preservation of a reservoir. However, loss of caprock integrity or weaken sealing capacity leads to leakage in and around the reservoir and reduces the sustainability and economic feasibility of a geothermal reservoir. Therefore, the geometry and integrity of the caprock are important, and any means of inspecting a caprock integrity is valuable for sustainable exploitation of a geothermal reservoir.

Caprock is usually identified with its striking conductive nature, which occurs because of mineral alteration and high clay content. Usually, the thickness of the caprock, which is usually several times less than its depth, is difficult to discern with the utility of conventional inversion techniques because of the structural complexity emanating from the non-sealing nature of the caprock. Starting model dependency as required for the conventional inversion methods usually forces the inversion procedure to produce a final model that is trapped about a local minimum due to the gradient of an objective function that is explicitly evaluated by a numerical method. On the other hand, evaluating partial derivatives with respect to the model parameters in some non-linear mathematical models may be impossible, or approximate schemes may not yield a sensible solution.

This study is n attempt for identifying the integrity of the caprock after the earthquake of Mw=5.3 on January 6, and subsequent swarms until March 26, using magnetotelluric data at Tuzla, Çanakkale geothermal field. One-dimensional magnetotelluric modeling approach with higher resolution for determining caprock structure compared to two- or three-dimensional modeling was carried out using particle swarm optimization (PSO) as an alternative to conventional inversion techniques. PSO is one of the modern global optimization methods based on a metaheuristic approach and has been recently preferred to overcome the subtle difficulties encountered in modeling geophysical data. Our modeling approach appeared to be successful in determining the caprock geometry, and the findings further strengthened our conviction that PSO is a powerful modeling technique for the MT data obtained on a geothermal field. It is critical that the modeling results provide important hypotheses for the loss of caprock integrity above a speculative magmatic intrusion, which extends to the hydrothermal reservoir above non-sealing caprock, and possibly triggers seismic events on the Tuzla fault.