Utilization of magnetotelluric data for evaluation of geothermal reservoir condition associated with EGS water injection in Japan

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ABSTRACT

Enhanced Geothermal Systems (EGS), with artificial water injection into the geothermal reservoir is one of the effective methods to avoid these problems. A 5-year research project, name of "Technology Development for Geothermal Reservoir Evaluation and Management" funded by JOGMEC, Japan was started in 2013. An MT survey was conducted at 116 sites and 3D inversion was performed by using the 3D inversion code WSINV3DMT. The optimum model also indicates quite a good matching with resistivity logging data in this zone. It is notable that seeking for the minimum data misfit model is not the best way to choose the optimum model probably due to the observation errors in the MT data. To evaluate the sensitivity of MT responses associated with water injection, we calculated the change of MT responses caused by water injection by using a reservoir simulator, STAR. As a result of simulation, detectable change of apparent resistivity associated with water injection is estimated at the observation sites near the injection well. The result indicates that the continuous-MT observation is effective for monitoring geothermal reservoir associated with water injection.

Keywords: EGS, Geothermal reservoir, MT3D inversion analysis, injection water monitoring, STAR reservoir simulator

1. Introduction

Imbalance between the steam production from a geothermal reservoir and natural water recharge to the reservoir causes not only shortage of steam production for electricity generation but also corrosion of surface facilities by superheated steam and highly acidic fluid produced from the geothermal reservoir. Enhanced Geothermal Systems (EGS), with artificial water injection into the geothermal reservoir is one of the effective methods to avoid these problems. A 5-year research project, name of "Technology Development for Geothermal Reservoir Evaluation and Management" funded by JOGMEC, Japan was started in 2013. The purpose of the project is to make a guideline for better understanding of the effects of artificial water injection in to a geothermal reservoir and/or a hot spring aquifer, based on numerical simulation and model verification. The test field of this project was setting at the Okuaizu geothermal

area, which is located in western Fukushima Prefecture, Japan.

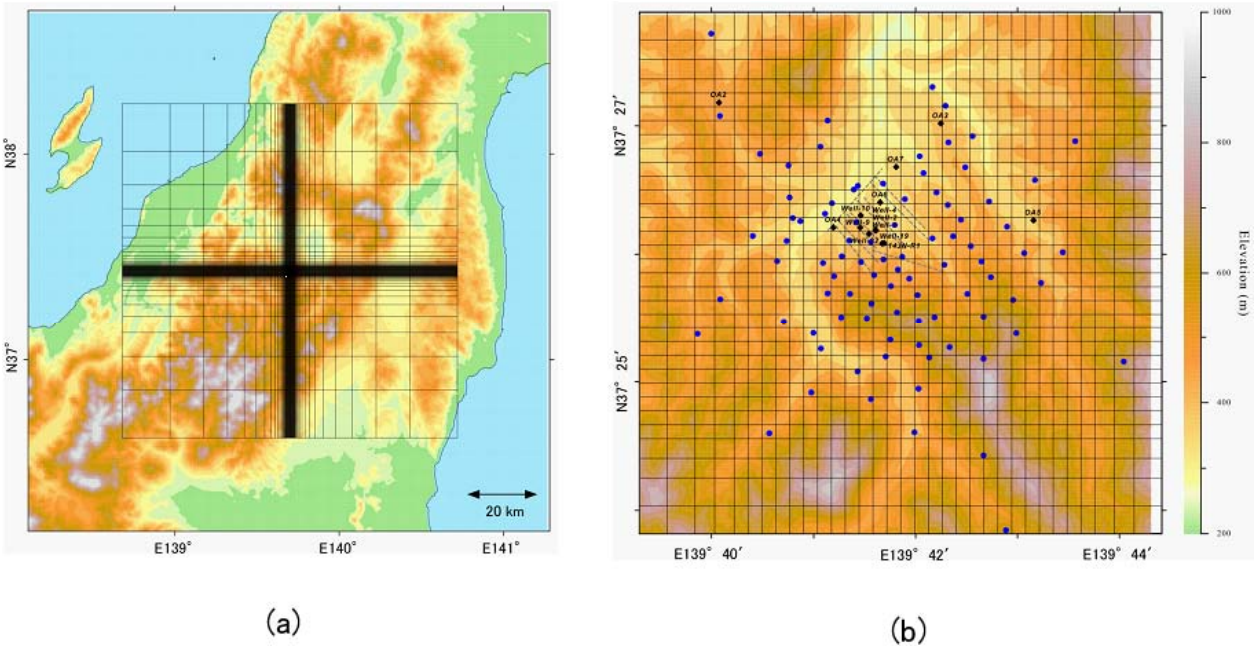


Fig. 1 Grid image of MT3D analysis. (a) Whole horizontal grid image, (b) Central part of the grid image

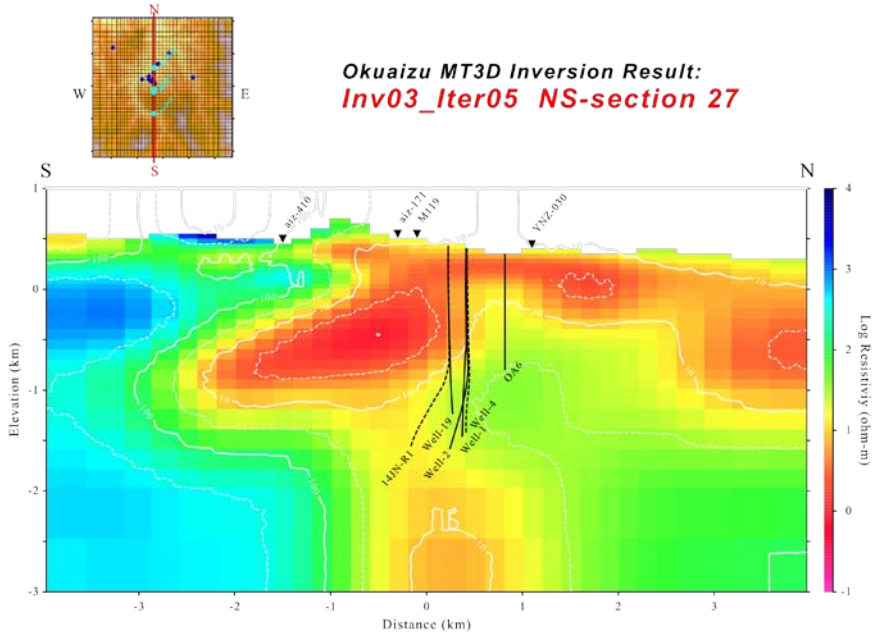


Fig. 2 A cross-section of the optimum model's resistivity (NS cross-section)

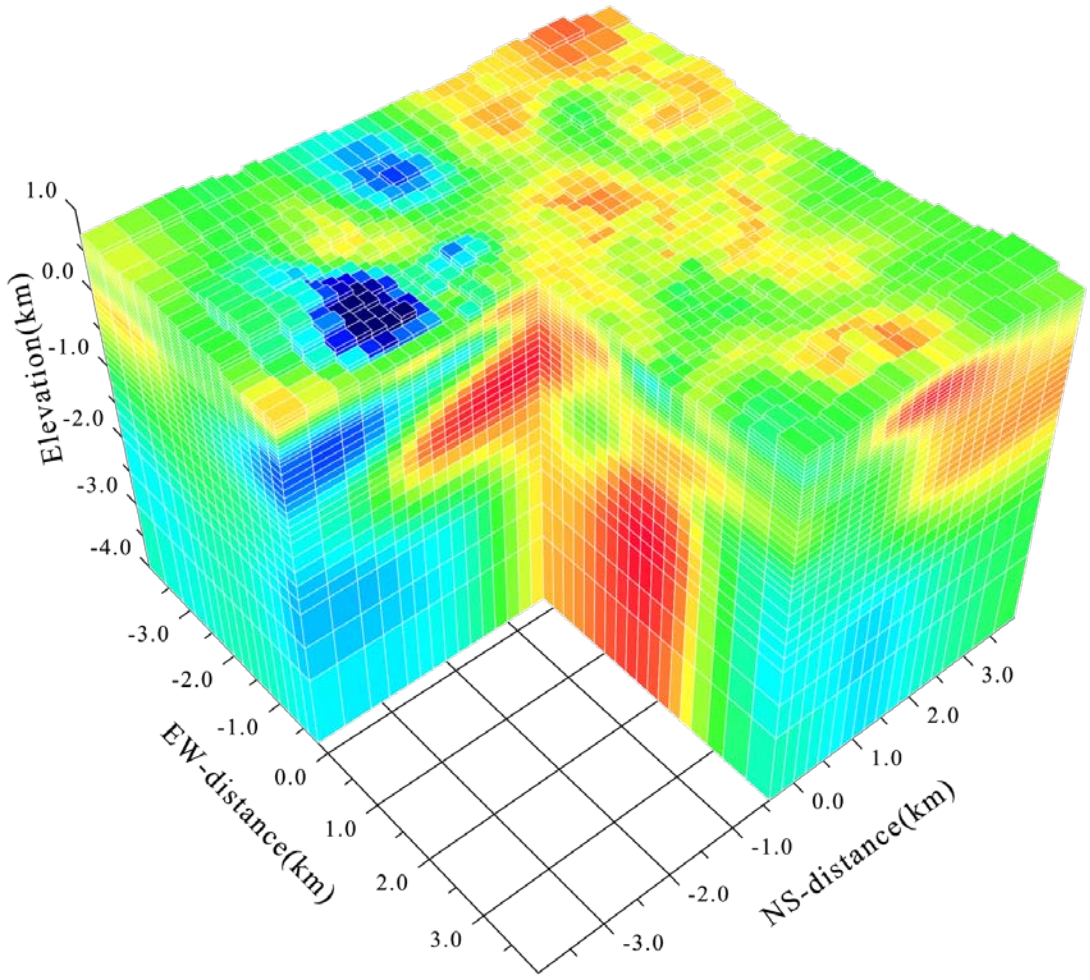


Fig.3 A 3D birds view of the optimum model's resistivity

2. MT survey and 3D analysis

An MT survey was conducted at 116 sites and 3D inversion was performed by using the 3D inversion code WSINV3DMT (Siripunvaraporn et al., 2005a; Siripunvaraporn et al., 2005b). We utilized 14 resistivity logging data in the area, for the selection of the optimum resistivity model, based on the RMS misfit between the logging data and the 3D resistivity model. The optimum resistivity model indicates that the shallow part around a hot spring area and along major faults in the geothermal area show low resistivity (1 to 10 ohm-m), and the main geothermal reservoir near the injection well shows medium resistivity (10 to 100 ohm-m). The optimum model also indicates quite a good matching with resistivity logging data in this zone. It is notable that seeking for the minimum data misfit model is not the best way to choose the optimum model probably due to the observation errors in the MT data.

3. Estimation of MT responses associated with water injection by using STAR simulator

In order to perceive the change of the geothermal reservoir condition associated with water injection, we plan to conduct a continuous-MT monitoring at the Okuaizu geothermal area from August 2016. To evaluate the sensitivity of the survey, we calculated the change of MT responses caused by water injection by using a reservoir simulator, STAR (Ishido, T and Pritchett, J. W., 1999; Pritchett, J. W., 1995). STAR can calculate not only resistivity change of each grid associated with water injection but also apparent resistivity and phase at each observation site on the surface grid. As a result of simulation, detectable change of apparent resistivity associated with water injection is estimated at the observation sites near the injection well. The result indicates that the continuous-MT observation is effective for monitoring geothermal reservoir associated with water injection.

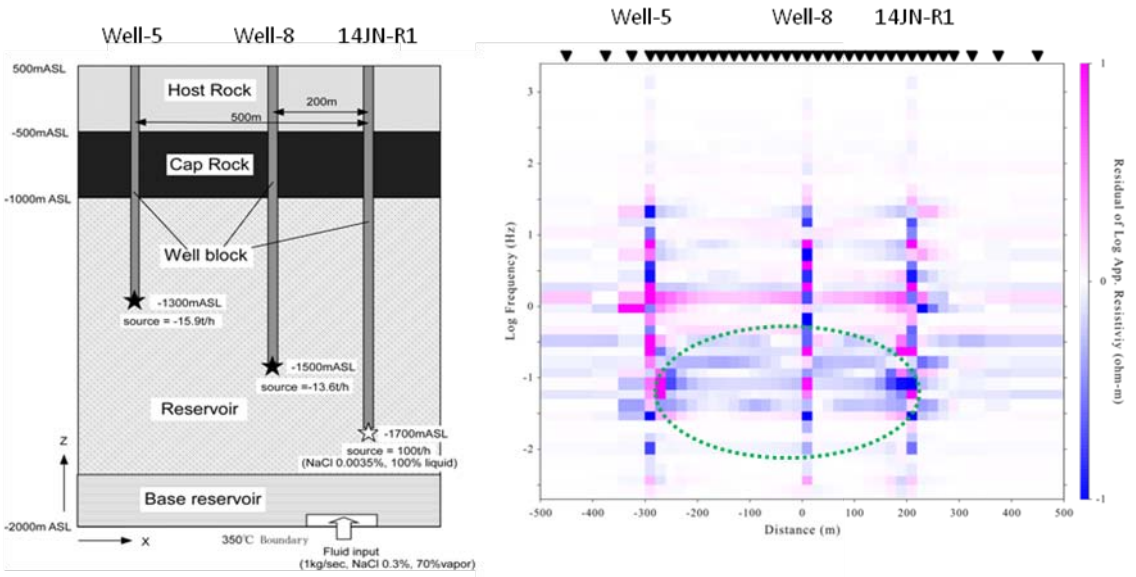


Fig. 4 Grid and parameters setting image (left) and a result of the STAR simulation (residual resistivity) (right). The well-5 and well-8 are production well and 14JN-R1 is injection well.

4. Sammary

We conducted 116 sites of MT survey and performed 3D inversion analysis at EGS site in Japan. he optimum resistivity model indicates that the shallow part around a hot spring area and along major faults in the geothermal area show low resistivity (1 to 10 ohm-m), and the main geothermal reservoir near the injection well shows medium resistivity (10 to 100 ohm-m). The optimum model also indicates quite a good matching with resistivity logging data in this zone.

To evaluate the sensitivity of MT responses associated with water injection, we calculated the change of MT responses caused by water injection by using a reservoir simulator, STAR. As a result of simulation, detectable change of apparent resistivity associated with water injection is estimated at the observation sites near the injection well. The result indicates that the continuous-MT observation is effective for monitoring geothermal reservoir associated with water injection.

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