Subsurface temperature pattern and fluid flow vector in the Hohi geothermal field, Kyushu

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It is very important to estimate the regional fluid flow for the evaluation of amounts of recharging water and heat to the reservoir from surrounding areas. The regional fluid flow can be estimated from subsurface temperature and permeability distributions using the numerical simulator of heat and two-phase fluid flow. The Hohi geothermal field, Kyushu, is chosen as the model field for this study because many drill holes have been carried out and subsurface temperature and permeability distributions are pretty well reconstructed. The outline of simulation modeling of geothermal fluid flow is as follows.

1) Geometrical parameters

The data files of horizontal and vertical plane girding are made from positions of cross-sections, boundary condition and topographic data files. The horizontal plane is divided by 250 m meshes with additional 4 km extends at both ends, and the vertical plane by 100 m interval from surface to -2,000 m asl and larger intervals step by step with depth until -5,000 m.

2) Geological modeling and permeability distribution

The values of permeability and porosity are allocated to all meshes based on hydro-geologic criteria: permeable formations, less permeable formations (cap rocks) and pre-Tertiary basement (subdivided by water critical temperature, 374 deg C). The permeability is fixed as 1.0 x 10-15 m2 for permeable formations, 1.0 x 10-17 m2 for poor permeable formations (so-called cap rock), 1.0 x 10-17 m2 for pre-Tertiary formation lower than 374 deg C, and 1.0 x 10-19 m2 for pre-Tertiary formation higher than 374 deg C respectively, with reference to the conventional reservoir simulation.

3) Initial values and boundary conditions

Subsurface temperature distribution was calculated by the relaxation method (Tamanyu et al., 1995), and it is adopted for the fluid flow simulation as fixed temperature data. This assumption is no problem in the case of slow fluid flow that satisfies the heat equilibrium between host rock and fluid. The initial pressure is assumed as hydro-static pressure. The temperature of surface is fixed as 12 deg C. The boundaries of both sides and bottom are closed against mass and heat transfer. However, additional 4 km extensions on both sides are set to avoid the artificial edge effect at the simulation.

For the fluid flow simulation, subsurface temperature distribution is calculated first using 38 borehole logging data, and then fluid flow vectors are calculated along 8 cross sections. The comparison between calculated fluid flow pattern and existing conceptual model indicates that the calculated flow vectors are well reconstructed generally by this simulation. The distribution map of fluid flow vectors suggests that heat transfer in Quaternary formations is mainly controlled by fluid flow, whereas heat transfer in pre-Tertiary basement by heat conduction.