Estimating Large-Scale Permeability by Using Independent Lines of Evidence

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RESEARCH OBJECTIVES

In hydrogeological characterization of sedimentary rocks, the hydraulic properties of faults and caprock structure play a key role in determining the flow and transport through the formation. Although the reliability of a hydrogeological model usually increases with the amount of geologic and hydrogeologic data obtained (mainly from boreholes), it is nonetheless important to construct a model using limited available data at an early stage of the field investigation, and continue to refine the model as more data become available. The objective of this study is to develop an effective methodology for refining and improving a model incorporating both hydrologic and nonhydrologic data.

APPROACH

The numerical inversion code iTOUGH2 was applied to a 40 km × 40 km × 5 km area of the Horonobe Underground Research Laboratory (URL) site in Hokkaido, Japan. The basic hydrogeological model was constructed using existing geological survey data, assuming a low-permeability caprock. The top boundary was set as the fixed head boundary at the ground surface, and the bottom and lateral boundaries were closed. Using the steady-state hydraulic head distribution from some ten boreholes as the observation data, the permeability of the caprock was calculated using numerical inversion.

The steady-state hydraulic head distribution was well reproduced by the model. However, the recharge estimate from river flow data indicates that the average permeability of the hydrogeologic model should be approximately 20 times larger than the original estimate based on borehole tests. In addition to hydraulic head data, groundwater temperature data at the nearby hot spring and the salt concentration data at two boreholes were available. Using all these data, we carried out heat flow and saltwater washout simulation with TOUGH2-EWASG, varying the permeability values. The initial salt concentration was set as that of seawater throughout the model, and the top boundary was set as that of a constant freshwater boundary.

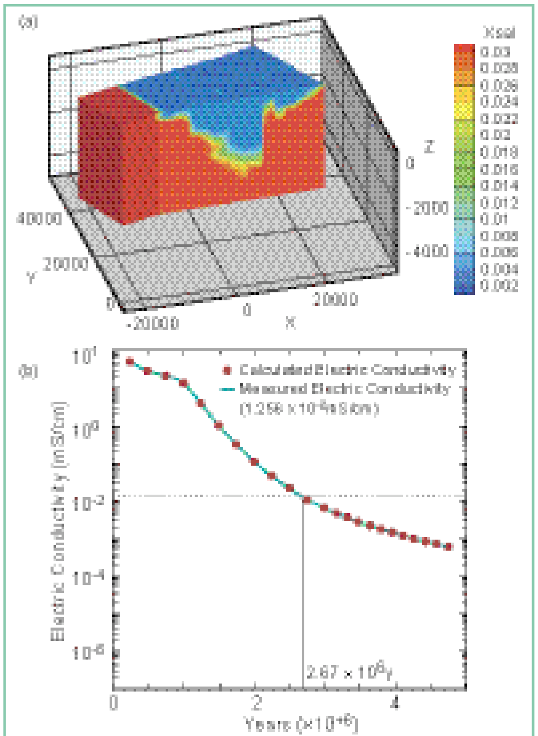

Figure 1. Result of saltwater washout simulation: (a) salt concentration distribution after 2 million years; (b) time-dependent change of electric conductivity at a monitoring borehole

ACCOMPLISHMENTS

Results from the hydrothermal simulations indicate that the permeability should be increased by ~20–50 times to match the temperature data observed in the borehole at the nearby hot spring area. This result is consistent with the permeability estimation based on the recharge rate.

Saltwater washout simulation with the increased permeability also corroborates the 20-fold increase. Figure 1 shows the salt concentration distribution after 2 million years and the electric conductivity distribution along a monitoring borehole. After 2.7 million years, the salt concentration matches with the observed electrical conductivity data. The geological survey indicated that the age of the sedimentary rocks in this area is no more than several million years.

SIGNIFICANCE OF FINDINGS

This work is an example of how independent lines of evidence can be used to enhance confidence in a hydrologic model. Hydrothermal and salinity simulations both corroborated a substantial increase in the average permeability, based on the river flow data. These results show that the use of nonhydraulic data for the calibration of a hydrological model can reduce uncertainties in the large-scale model, enabling a more realistic model to be constructed.

RELATED PUBLICATIONS

Ito, K., K. Karasaki, K. Hatanaka, and M. Uchida, Hydrogeological characterization of sedimentary rocks with numerical inversion using steady-state hydraulic head data—An application to Horonobe site. Journal of Japan Soc. of Engineering Geology, 45 (3), 125–134, 2004. Berkeley Lab Report LBNL-53760.

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