Investigation of Uncertainty in Hydrogeologic Modeling of Flow and Transport in a Large, Saturated Granitic Rock Mass

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RESEARCH OBJECTIVES

The objectives of this project are: (1) to evaluate the uncertainty involved in modeling flow and transport in a large granitic rock mass, and (2) to seek ways of reducing that uncertainty.

APPROACH

A number of international research organizations are participating in this project. Each has been building a model and conducting simulations of groundwater flow and transport using the same set of information from a site in the Tono area of Gifu, Japan. The base data set is an accumulation of the past several years' field investigations and include geological, hydrological, geophysical, and geochemical data. As a new set of data becomes available, predicted flow rates and particle travel times through the model are compared among the different models. So far, flow rates and travel times differ by three to four orders of magnitude. One focus of the study is to find the cause of these differences among the models. Another focus is to evaluate how much the model improves as new data become available.

In our conceptual model, we use stochastic permeability and porosity distributions to represent fractured rock as an effective continuum. Only large-scale features such as fault zones, lithologic layering, natural boundaries, and surface topography are incorporated deterministically. Because the effective porosity of a large rock mass cannot be measured directly, it has to be estimated indirectly from several different types of data, using scientific judgment. Another large uncertainty stems from the hydraulic properties of faults, although some inferences can be made from measured hydraulic heads.

ACCOMPLISHMENTS

We have built and continuously updated a model that generally satisfies the observed pressure-head data. We have made use of temperature measurements to distinguish between two plausible boundary conditions for the model. The most recent update to the model was made using large-scale dynamic-pressure-disturbance data, which prompted us to increase the effective porosity value by fifty fold. We also expanded the boundary of our 4 km × 6 km × 3 km model to build a 9 km × 9 km × 2 km model. The latter appears to better define a hydrological basin. We used an inversion program, iTOUGH2, to estimate the permeability of a major fault by matching the steady-state head distribution.

SIGNIFICANCE OF FINDINGS

Our findings indicate that the hydraulic structure of the fault likely resembles a sandwich, with a low-permeability core and high-permeability zones on both sides of the core. This structure may generally describe reverse faults in a crystalline rock. Also, borehole temperature data may be used to reduce the uncertainties of a hydrological model. Finally, large-scale pressure disturbance data may be used to infer the effective permeability and porosity of a large fractured rock mass.

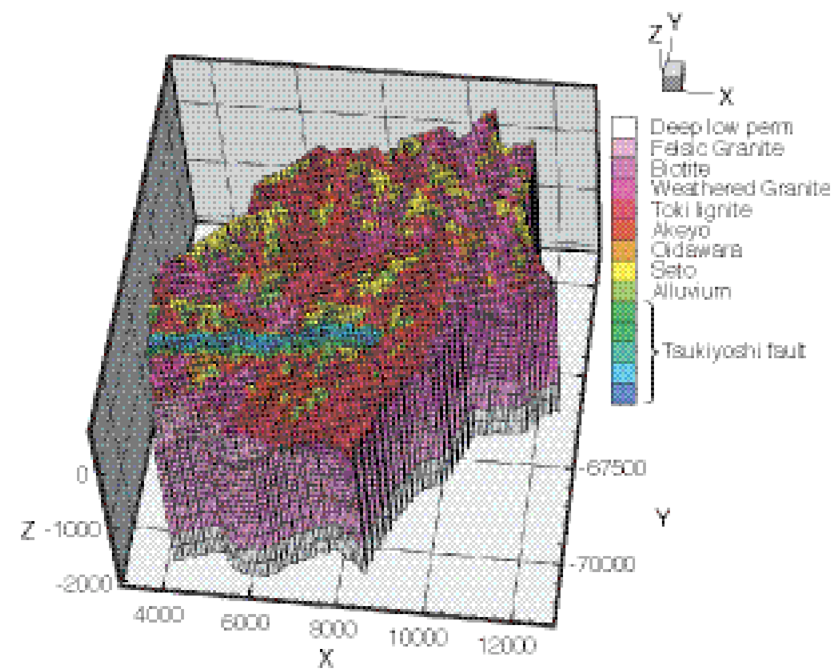

Figure 1. Three-dimensional perspective view of the model used for the TOUGH2 and iTOUGH2 simulations of the 9 km × 9 km × 2 km region. Material types are color-coded.

RELATED PUBLICATION

Doughty, C., and K. Karasaki, Constraining hydrologic models using thermal analysis. In: Proceedings, Rock Mech. Symp., Japan Society of Civil Engineers, Tokyo, Japan, January 23–24, 2003.

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