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Final and safe storage of nuclear waste materials is one of the critical problems that must be solved in a satisfactory manner before the use of nuclear power can be developed to its full potential. One promising way is to place the waste products deep underground in some rock formation such that whatever migration process may take place, dangerous amounts of radioactivity cannot reach the biosphere.

Investigations have been carried out for several years on the possibility of using mined caverns in salt, and the review of the WIPP project that is part of this special session has revealed the status of current developments in the salt formations in New Mexico. Only recently has work been started on non-salt rocks, and thus it is appropriate that this special session should also focus on the possibilities of using other rock types for nuclear waste storage.

One of these is granite and the Lawrence Berkeley Laboratory (LBL) is now in its third year of participation in a Swedish-American cooperative project of investigations in a large granite rock mass adjacent to an abandoned iron-ore mine at Stripa, Sweden. The American part of the cooperative work program under LBL direction consists of three main activities supported by an auxiliary program of support investigations. The objectives of this program are:

1. To conduct large-scale field experiments in granite in order to establish design parameters for waste repositories in hard rock and make safety assessments for such facilities;
2. To develop new instruments and technqiues that are capable of producing the required data despite the hostile environment that results from high temperatures over long time periods;
3. To collect experimental data necessary both for the development and validation of predictive models; and
4. To promote the international exchange of information and ideas.

One of the most critical problems in designing an underground repository for high-level nuclear wastes is to determine the level to which temperatures can be raised in the rock mass without having undesired effects. The problem is being approached at Stripa from two standpoints: (1) full-scale heater experiments, and (2) time-scaled heater experiments.

The full-scale heater experiments are designed to permit the investigation of the short-term temperature effects in granite using full size canisters with electric heaters that can simulate the energy output of radioactive waste. The time-scaled heater experiment is designed to examine the long-term thermal loading effect by compressing the time scale in the ratio 1:10, such that each year of data collected will yield 10 years of equivalent data in terms of the full-scale heater experiments. These experiments were put in operation from June to August 1978, and extensive intrumentation has been provided to measure the thermal and mechanical response of the granite rock.

Some very important results have already been obtained. The predicted temperature fields for both experiments were calculated before turning on the heaters using only a laboratory measurement of the thermal diffusivity and a mathematical model appropriate for the known geometry and boundary condition. The agreement between predicted and measured temperature fields over the past several months since these experiments started is excellent. This is true for both full-scale and time-scaled results, and is a good indication that in designing waste repositories there should be no problem in predicting the thermal response.

This good agreement between theory and practice has not been observed in our attempts to predict the mechanical response of the rock masses adjacent to the heaters. In both the full-scale and time-scaled investigations, it has become apparent that the discontinuities play a major role in controlling the mechanical behavior. For example, measurements of thermally induced displacements are only one-quarter to one-half what one would predict from a model based on intact rock. In other words, if we are going to be able to make reliable predictions of stress field in designing waste repositories, we must understand how such stresses are affected by the behavior of the fracture systems.

A third major effort at Stripa is that of investigating the fracture hydrology. Not only do the fractures affect the thermo-mechanical response of the rock mass, but they provide the main pathways for radionuclides to migrate away from the repository. Since there can be different kinds of discontinuities (joints, fracture zones, shear zones) in crystalline rock, a very careful series of field investigations has been setup and is now being carried out at Stripa. The approach that we are pursuing is to determine the permeability of the fractured rock mass assuming that the fractures can be represented as two-dimensional planar conduits with appropriate consideration for roughness and contact area and that the fractures are not randomly distributed in orientation but form sets.

To check the accuracy of the permeability determination, we have designed an unusual experiment using a 30 m length of underground tunnel at Stripa, wherein we will measure the actual rate of seepage into the tunnel and the hydraulic gradients present in the walls. From these data, we can calculate the global permeability of the surrounding rock mass and compare this result with that obtained by more conventional means.

The results of the LBL project at Stripa have revealed how important it is to have access to a full-scale, test facility. The complex problems that are associated with understanding the thermo-mechanical effects as well as the hydrology of fractured crystalline rock can only be solved in such a facility.

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