Update: The international Stripa project

A progress report from the test station in an old Swedish iron mine

by Hans Carlsson

The Stripa project is an international co-operative project carried out in an abandoned iron mine located in central Sweden. Conducted deep underground in crystalline rock, the project concerns research in a realistic environment of different matters connected to disposal of highly radioactive wastes from nuclear power generation. The Stripa mine is only a test station, and there is no intention to use or store any radioactive material in it.

The project is carried out as an autonomous one under the sponsorship of the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA). It is managed by the Division of Research and Development of the Swedish Nuclear Fuel and Waste Management Company (SKB) under the direction of representatives from each participating country. Participating countries are Canada, Finland, France, Japan, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

The project was initiated in 1980. Some investigations are now complete and the remainder will be done during 1986. However, negotiations regarding additional investigations, resulting in a prolongation of the project, are under way. Experiments are carried out mainly at the 360-metre level in massive, grey to light-red, medium-grain granite.

Research programme 1980–86

The Stripa project includes a number of sub-projects with different objectives, budgets, and time schedules. Essentially, the research is concentrated in the following areas:

- Detection and mapping of fracture zones
- Groundwater conditions and nuclide migration
- Bentonite clay as backfilling and sealing material.

Mr Carlsson is with the Swedish Nuclear Fuel and Waste Management Company (SKB), Division of Research and Development, in Stockholm.

The results obtained are presented in quarterly, internal and technical reports. An international symposium, where the experiments and results were presented, was organized in June 1985. The proceedings of the symposium are available through the OECD Nuclear Energy Agency.*

Detecting and mapping fracture zones

During the long periods nuclear wastes remain radioactive, the possibility of the release of radionuclides from the repository and their transport to the biosphere must be assessed. The only probable release mechanism is dissolution and transport in flowing groundwater. The dominant flow of groundwater is taking place in existing fracture zones and it is, therefore, of utmost importance to characterize these zones.

The objective of the "crosshole investigation" is to develop and test geophysical and hydraulic methods and instruments for the purpose of detecting and mapping fracture zones. Electromagnetic (radar), seismic, and hydraulic (sinusoidal) techniques are developed and tested.

The investigations are carried out in both single and multiple boreholes, called crosshole measurements. Different kinds of signals are transmitted through the rock. A disturbance such as a fracture zone will affect the transmission. The location and orientation of fracture zones may be determined by performing tests from a large number of sections in the boreholes.

The major part of the investigations are carried out in a specially designed borehole configuration at the 360-metre level at Stripa. A volume of rock, some 3 million cubic metres, has been accessed by a fan array of six boreholes, where the distance between the holes varies up to a maximum of 200 metres. A comprehensive programme of "standard" single-hole investigations has been performed in these holes to provide a database with which results obtained with newly developed methods can be compared.

* The address is 38, Boulevard Suchet, 75016 Paris, France.

New radar system

A new borehole radar system has been constructed and tested at Stripa resulting in distinct reflections from the existing fracture zones as far away as 100 metres from the boreholes. Results so far have demonstrated the great potential of the borehole radar system in the investigation of fracture zones. It is particularly encouraging that most zones seem to reflect radar waves very well.

All zones previously derived from core maps and logging data were discovered during the analysis of the radar measurements and several new zones also were found. All major reflections have been taken into account, which proves that the method works consistently.

In summary, the radar system has proved very efficient in detecting and describing fracture zones. Much work remains on the physical description of fractured regions, but it is clear that the purely geometrical problem of describing their orientation can be reliably handled.

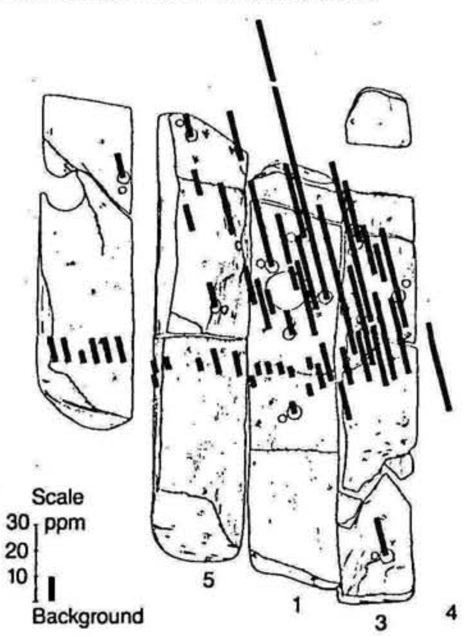
Hydraulic testing

The hydraulic testing component of the "crosshole investigation" involves the transmission of various hydraulic signals between two or more boreholes. As the signal passes through the water-bearing rock, it is modified by the interaction between fractures and rock matrix. Mathematical interpretation of perturbations to the signal allows various relevant hydrogeological parameters to be quantified. The crosshole testing is a combination of "standard" interference techniques and the more novel sinusoidal method. In addition, almost all forms of active single borehole testing have been used including constant flow, constant pressure, slug, and pulse tests.

The testing system is designed to operate at the 360-metre level in the Stripa mine, but is equally suited to perform hydrogeological measurements in any mine cavity in which water pressures exceed atmospheric pressure.

A seismic crosshole survey has been carried out at Stripa and now interpretation of data and a comparison with radar and hydraulic measurements are under way. However, seismic investigations may be carried out at distances up to 500 metres or more between the transmitter and the receiver, making the Stripa mine less suitable as a test site. In addition to Stripa, the site Gideå, located in the northern part of Sweden,therefore is used as a complementary test site. The geology at the Gideå site has previously been thoroughly investigated by SKB within the programme to select a potential repository site for spent nuclear fuel.

Surface concentration of caesium-210



To help predict migration of radionuclides in rock, scientists injected tracers into a single fracture, then monitored their movements in sample holes drilled along the fracture. Shown here is the distribution of caesium around the injection point. (Credit: SKB)

Groundwater conditions and nuclide migration

Part of the investigations at Stripa are aimed at determining the evolution of the Stripa groundwater and to establish a general programme for water sampling and analysis in crystalline rock. Water samples are taken from a maximum depth of 1200 metres below the surface. One primary conclusion reached in these studies so far is that different dissolved constituents will provide different residence times. This is because they have different origins and different evolutionary histories that may or may not be related to the overall evolution of the groundwater itself. Age determinations of groundwater should therefore be interpreted with this in mind.

To be able to predict the migration of radionuclides with the groundwater in the rock fractures, the processes involved must be understood. To quantify them, data from flow and transport in real fractures under realistic conditions are needed. Models used for prediction must include descriptions of the important processes and mechanisms.

The migration modelling in the safety analysis for a repository in granitic rock is based on the assumption that if and when any radionuclides are leached from the waste, practically all important radionuclides will interact chemically or physically with the bedrock and will thereby be considerably retarded. The magnitude of this retardation depends upon the flow rate of the water, the uptake rates, and equilibria of the reactions, as well as the surface area in contact with the flowing water.

In an investigation called "migration in a single fracture", both non-sorbing and sorbing tracers,

As part of experiments to track water flows, scientists used this experimental drift covered with plastic sheets for water sampling. (Credit: SKB)

simulating radionuclides, were injected into a single fracture. The arrival times and concentrations of these tracers were monitored in sample holes drilled along the fracture at a distance of about five metres away from the injection point. In addition, samples from the fracture near the injection point were excavated by diamond drilling. Results from field tests, together with supporting laboratory tests, show that two mechanisms are of importance for the magnitude of the retardation of the migrating radionuclides:

- Diffusion into the rock matrix adjacent to the fracture and subsequent sorption on the inner surfaces
- Channelling within a fracture, i.e., only certain parts of the fracture conduct water.

The first mechanism considerably enhances the bedrock's capacity to retard the radionuclides. The second mechanism counteracts the first by reducing the contact surface between the flowing water and the bedrock. It may also give rise to "fast" channels.

Large-scale migration test

A large-scale tracer migration experiment currently is in progress at Stripa. The objective is to get an understanding of the spatial distribution of water pathways in crystalline rock over a long distance (up to 50 metres).

The experimental site is located at the 360-metre level. Water flows constantly into the drift at this level since it is located well below the water table. Conservative (non-sorbing) tracers are injected into this water flow. The test site consists of two intersecting drifts with a total length of 100 metres. Three vertical injection holes have been drilled upwards to a depth of about 70 metres. Injection of tracers is carried out from a total number of nine separate zones in these holes with a higher permeability than the average rock. The entire roof and parts of the drift walls are covered with plastic sheets which are used for water sampling for further analysis.

Preliminary data from the large-scale migration test indicate that water does not flow uniformly in the rock over the scale considered. It is obvious that the water flow cannot be described as a homogeneous porous media flow at this scale. Instead, channelling seems to play an important role.

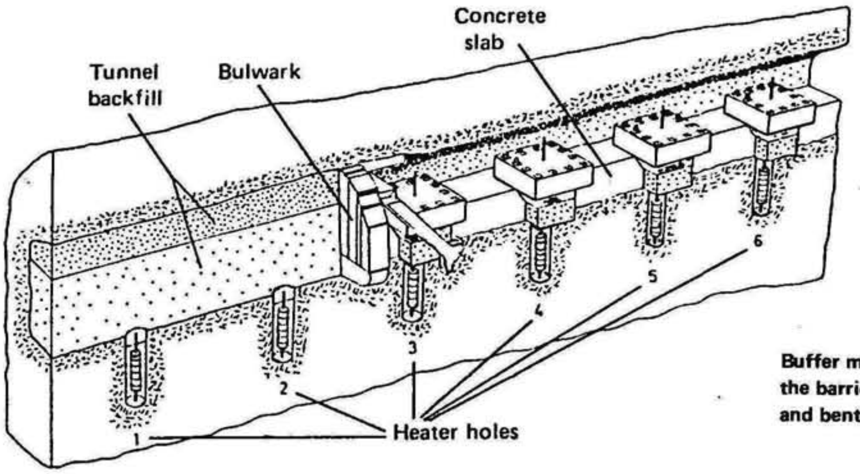
Buffer and sealing tests

The "buffer mass test" was initiated in 1980 and was completed in 1985. Six large boreholes, with a diameter of 0.75 metres and a depth of about 3.5 metres, were used as deposition holes for simulated waste canisters surrounded by highly compacted bentonite with a mixture of sand and bentonite as overlay. Part of the experimental drift was completely filled with the sand/bentonite mixture.

The purpose of the test was to verify the suitability and predicted functions of bentonite-based buffer materials under realistic conditions. Thus, temperatures, water uptake, swelling, and water pressures were measured. The heater power was set to 600 watts, but supplementary tests at elevated power, 1200 and 1800 watts, also were carried out. The deposition holes were excavated after time periods ranging from 10 to 40 months and the bentonite mass was carefully examined. In the same way, the filled-in portion of the drift was excavated after 33 months of testing.

Most field work was completed during 1984. The experiment has been very successful and shows that the bentonite fills all voids after water saturation and swelling and thus verifies previously obtained laboratory data.

A number of tests now are investigating bentonite clay as a sealing material for boreholes, shafts, and tunnels.



Buffer mass tests were done to verify the barrier function of bentonite and bentonite/clay mixtures.

The purpose of the borehole sealing experiment is to test the application technique and the maturation rate of the bentonite, as well as the adhesion of the clay material to the rock. Boreholes are equipped with cylindrical blocks of highly compacted bentonite surrounded by perforated copper pipes, or with pipes made of a steel net.

Water-bearing fractures, or fracture zones intersecting shafts and tunnels, also may be sealed or isolated by highly compacted bentonite. In the shaft sealing experiment, two bentonite plugs are separated by a sand-filled injection chamber simulating a water-bearing fracture. The evaluation is made by comparing the injection flow with that of a preceding reference test with concrete instead of bentonite plugs.

Highly compacted bentonite also is investigated for the purpose of sealing a highly fractured water-bearing zone crossing a drift. The water-bearing fracture zone is simulated by water pipes embedded in sand. All preparations are completed and the initial testing, even at high water pressures (3MPa), shows that the sealing capacities of the bentonite are very good and in accordance with predictions.

Technical references

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- *Stripa Project — Executive Summary of the Phase I Activities,* SKB, Stockholm (in press).
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