The final tracer test for the HPF

The final tracer test for the HPF will take place in winter 2003. For this test, a suite of safety-relevant radionuclides will be injected into the flow field. Some of these radionuclides are thought to be strongly retarded by the rock and they will take a long time to pass through the flow field.

To better understand the changes induced by the cement leachate, it is planned to inject a specially formulated resin to stabilise the rock mass and then remove large (38 cm diameter) cores of the resin-impregnated shear zone.

The cores removed from the rock will be carefully cut into sections and subjected to very accurate radiography techniques, which allow us to “see” exactly where the radionuclides are most retarded in the rock.

The sections will then be sent to laboratories around the world for further detailed analysis. This will include further radiochemical analysis and examination of secondary minerals that have formed during the two years of high-pH circulation.

These techniques are similar those carried out as part of the RRP (Radionuclide Retardation Project) at the GTS. The images below are of the overcoring process and a photomicrograph of a fluorescent resin injected shear zone (in UV light) from the RRP (the bright areas represent open space or pores, the black solid minerals).

Overview of the HPF

The Hyperalkaline Plume in Fractured Rock (HPF) experiment examines the effect of the release of high-pH leachates from a cementitious radioactive waste repository on the hydrochemical conditions and radionuclide retardation in the surrounding host rock.

Why do we get hyperalkaline plumes?

In the case of low- and intermediate-level radioactive wastes and many chemo-toxic wastes, most current repository designs envisage the use of large volumes of cementitious materials to immobilise the waste and to backfill the repository. We know from studies of nature (e.g., natural cements in Jordan) and in laboratories that leaching of cements and concrete produces fluids initially concentrated in NaOH and KOH (pH > 13) and later in Ca(OH)$_2$ (pH > 10). These high-pH cement leachates can cause changes to the local groundwater systems and the retardation properties of the surrounding rock. Changes may have a positive effect – e.g., fractures / channels become blocked by alteration products, or may be negative if inert fracture coatings develop which block access to the rock matrix.

Future cement studies at the GTS

New experiments involving cement are proposed as part of the next phase of work at the GTS. This study will look at the behaviour of cementitious repositories over multi-decade timescales and will build upon the successes and lessons learned from the HPF experiment. These studies will be of direct relevance to repository performance assessment. In addition, a parallel examination of low alkali (pH 10-11) cement leachate interactions with the host rock is planned.
In situ field test at the GTS

The HPF experiment takes place within the radiation controlled zone at the GTS. Since 2001, a shear zone has been altered by the addition of a high-pH fluid to the groundwater.

The test area was hydraulically characterised before the start of the high-pH alteration with a series of dipole tracer tests. Periodic tracer tests utilising radionuclides have also taken place during this time to monitor the gradual changes to the hydrological conditions.

Chemical and physical parameters (pH, Eh, electrical conductivity, pressure and temperature) are measured at the inflow and outflow of the flow field. Specialised testing equipment monitors the hydraulic conditions in the shear zone. The system also allows for periodic injection of radionuclides into the shear zone.

Radionuclides are measured with a state-of-the-art gamma ray spectrometer. The spectrometer is kept in a climate controlled box to ensure optimum operating conditions.

All radionuclide injections are carried out according to the strict guidelines of the Swiss Radiation Protection Regulations.

It is, in itself, a technical feat to keep this long-term experiment running due to the corrosive properties of the high-pH solution and problems of blocking of extraction tubes due to the low flow rates in the system.

Experimental results to date

The HPF in situ experiment is still ongoing and there are two more injections with radionuclides planned. The results obtained to date already give a unique picture of the hydrological and chemical evolution of a repository host rock altered by high-pH fluids.

Injection of high-pH fluid has taken place since April 2001 and, since then, the pressure required to inject this fluid has risen steadily. This is a result of fractures/channels becoming blocked as secondary minerals precipitate following reaction between the leachates and the rock. This has resulted in the rise in injection pressure we see opposite.

Similarly, changes in the breakthrough behaviour of tracers can also be seen as many of the small channels become blocked. Thus, as only the large, open channels allow the tracer to pass through, the flow becomes focused and breakthrough occurs quicker.

Initial Conclusions

The information displayed above suggests that the high-pH plume may influence the evolution of a repository through time. Changes to the groundwater flow paths in and around the test zone are clear.