DEVELOPMENT OF NON-INTRUSIVE MONITORING TECHNIQUES – ESDRED & TEM PROJECTS AT MONT TERRI AND THE GRIMSEL TEST SITE

Authors: B. Breen[1], M. Johnson[1], B. Frieg[2], I. Blechschmidt[2],
E. Manukyan[3], S. Marelli[3], H.R. Maurer[3]

[1] Nuclear Decommissioning Authority (United Kingdom), (NDA);[2] National Cooperative for the Disposal of Radioactive Waste (Switzerland), (Nagra); [3] ETH Zürich, Department of Earth Sciences (Switzerland), (ETH)

Abstract

Non-intrusive monitoring using remotely applied geophysical methods could facilitate repository monitoring without affecting the passive safety of the Engineered Barrier System (EBS). It would also avoid problems with failure of monitoring sensors located within the EBS, whose repair or replacement would disturb the near-field. However, non-intrusive monitoring poses various technical challenges. NDA, Nagra and ETH are investigating the application of seismic tomography as a non-intrusive monitoring technique at Mont Terri and the Grimsel Test Site.

Developing non-intrusive techniques in conjunction with conventional *in situ* or wireless techniques provides a means of calibrating non-intrusive techniques and demonstrating their performance and applicability.

1 Introduction

The EC Integrated Project, ESDRED (Engineering Studies and Demonstration of Repository Designs) was commissioned to promote a common European vision in terms of technologies applicable to various repository designs for the disposal of heat-generating radioactive waste (such as spent nuclear fuel and high-level waste (HLW)) in geological formations. The project aims to achieve this by fabricating and testing full-scale prototypes of technologies for:

- waste emplacement;
- buffer construction and emplacement; and
- sealing of disposal cells or drifts.

Repository monitoring is a fundamental component of national disposal programmes, and is an important constituent of the ESDRED project. Monitoring has a role to play through all phases of repository development, from the establishment of baseline conditions, through construction and operation of a repository (to ensure operational safety), through to closure and post-closure. Parameters such as temperature, groundwater inflow, humidity and radioactivity might be monitored.

A key principle identified by the European Union Thematic Network Study on the role of monitoring states that "*monitoring must be implemented in such a way as not to be detrimental to long-term safety*" (ETN, 2004). The development of effective non-intrusive techniques for repository monitoring would provide methods for monitoring without affecting the passive safety of intact repository barriers. Non-intrusive, remote monitoring also avoids problems associated with the failure of monitoring sensors located within the EBS, which can only be repaired or replaced by disturbing the near-field of the repository system.

A programme of monitoring will be carried out throughout the phases of repository development and might employ a variety of techniques, as appropriate, which are intrusive to varying degrees. For example, conventional, direct monitoring might incorporate sensors emplaced within the repository excavations (and perhaps within the EBS). The output from these sensors would be transmitted through wires to observation points. Whilst such approaches are commonplace in a variety of industrial applications and would be applicable during the construction and operation phases of the repository, both data collection and data transmission activities would have the potential to compromise the passive safety of the repository and the EBS, and therefore, would not be applied post-emplacement.

A less intrusive approach would employ wireless data transmission, sometimes referred to as through-the-earth, (TTE) transmission. This approach might make use of conventional or novel monitoring sensors, but, importantly, the integrity of engineered and natural repository barriers is maintained by transmitting the data remotely using, for example, radio frequency signals. Research in this area is ongoing by a number of waste management organisations. Key challenges include the reliability and lifetime of wireless data transmitters, particularly their power supply. These factors, which include the continued integrity and reliability of the monitoring sensors, the data transmitters, sustaining the power supply for wireless transmission of data and the ability to transmit data through many hundreds of metres of solid rock, may limit the scope of monitoring by this method.

Under ESDRED Module 1, a programme was implemented to non-intrusively monitor an existing Nagra experimental demonstration, the HG-A experiment, at Mont Terri. Following consideration of repository concepts, monitoring objectives and potential non-intrusive techniques, ESDRED Module 1 partners concluded that cross-hole seismic tomography was the most promising technique to investigate changes in the backfill and saturation conditions of a micro-tunnel.

A group of partners, (NDA, Nagra, Andra and Solexperts AG) recognised a further opportunity for developing *in situ* monitoring techniques utilising the construction and testing programme of a low pH shotcrete plug confining a saturated bentonite buffer constructed in granite at the Grimsel Test Site (GTS) under ESDRED Module 4. The partners initiated Project TEM (Testing and Evaluation of Monitoring Techniques) at Grimsel to provide a unique opportunity for simultaneous comparison of three monitoring methods - wired signal transmission from the EBS, wireless data transmission using magneto-inductive techniques, and observation through non-intrusive cross hole seismic tomography techniques. This approach provides a means of calibrating and verifying non-intrusive techniques with more researched, better understood techniques and helps to demonstrate their performance and applicability. The novelty of TEM is that the application of each of these techniques is also tested under realistic conditions.

This paper provides a discussion of results obtained to date from non-intrusive monitoring experiments carried out at Mont Terri and the GTS. Section 2 provides a description of work carried out under ESDRED Module 1, to develop cross-hole seismic tomography at the Mont Terri facility in Switzerland and describes the main results obtained to date. The experimental monitoring work carried out at the GTS is described in Section 3, together with a discussion of the main results.

2 Non-intrusive Monitoring at Mont Terri

2.1 Background

The HG-A experiment is one of a number that have been undertaken in the Opalinus Clay rocks of the Mont Terri underground rock laboratory (URL) in Switzerland. The HG-A experiment is designed to mimic the evolution of a sealed disposal tunnel, replicating the phases of buffer saturation and gas generation (following corrosion processes of the disposal canister). The aims of the HG-A experiment are to identify gas migration and to measure gas migration through the host rock (the Opalinus Clay geology) and along the engineered seals of a filled tunnel.

Investigations in the HG-A experiment focus on a 1m diameter micro-tunnel, which is back-filled with a coarse grained sand mixture (∅ 2 - 6 mm grain size) and closed with a hydraulic mega-packer. There is nothing in the tunnel to represent the wasteform or a metallic waste package. Several phases of study are planned representing backfill emplacement, saturation of the micro-tunnel and gas generation. The phases of study investigated to date are listed in Section 2.2.

For the non-intrusive studies, the degree of saturation, gas storage and pressure build-up, and its effects on the geophysical data is monitored over the various phases of the HG-A experiment, using cross-hole seismic tomography. The aim of the experiments was to investigate differences in the seismic data due to variations within the micro-tunnel (both its content and physical condition). Signal generation and recording take place in two boreholes drilled perpendicular to the micro-tunnel.

2.2 Experimental Set-up for Non-Intrusive Monitoring

The experimental setup is shown in Figure 1 (a) and (b) below. The Opalinus Clay host rock is known to be highly anisotropic. To a first approximation, the geology of the study area for the HG-A experiment is transversely isotropic about a steeply tilted axis of symmetry, which is illustrated in Figure 1 (a).

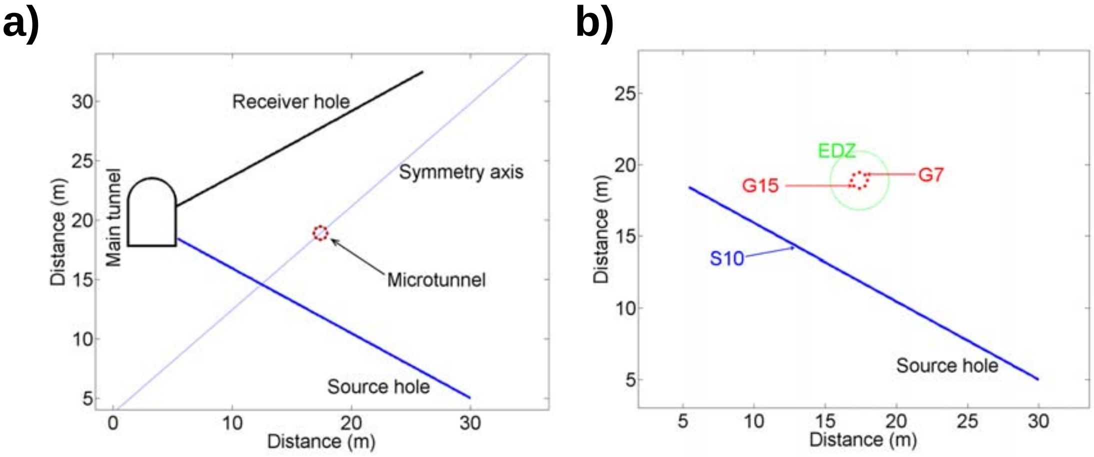

Figure 1: (a) Schematic layout of the non-intrusive seismic tomography experiment at Mont Terri. In this figure, the symmetry axis about which the Opalinus Clay is approximately isotropic is shown. (b) Experimental setup showing positions of the source at 10 m length along the borehole (S10), geophones G7 and G15 and a sketch of the micro-tunnel EDZ.

A 1 m diameter micro-tunnel, which constitutes the target to be monitored, is situated between two water-filled boreholes. One borehole is inclined upwards and the other downwards. The micro-tunnel is oriented perpendicular to the plane of the boreholes. A high frequency P-wave sparker source fired every 0.25 m in the downward-directed borehole was used to generate seismic waves recorded on a 24-channel hydrophone array located in the upward-directed borehole. The hydrophones were spaced at 1 m intervals. By shifting the array three times at intervals of 0.25 m and repeating each shot, a 96-channel hydrophone array with 0.25 m element spacing was synthesized. The energy from each source shot was also recorded on eight vertical-component geophones (natural frequency 100 Hz) distributed around the micro-tunnel wall within the plane of the boreholes, as illustrated in Figure 1(b).

So far, seismic tomography measurements have been performed to study six sets of conditions within the micro-tunnel:

1. air-filled,
2. dry sand-filled,
3. 50 % water-saturated sand-filled,
4. nearly fully water-saturated sand-filled,
5. fully water-saturated sand-filled (several months later),
6. fully water-saturated sand-filled and pressurized to 6 bars.

2.3 Repeatability of Measurements

Informative monitoring using seismic tomography requires high levels of quality control. Both the source pulse (including its coupling) and the coupling of the receivers must be consistent throughout all experiments. A consistency check was carried out for the repeatability of signals generated by the source. The results indicated a high level of repeatability for the source signal, when detected by either the hydrophones using a cross-borehole method, or using the geophones in the micro-tunnel as detectors.

A similarly favourable level of reproducibility was observed when experiments using the geophones were repeated at different times (implementing the same set of conditions). However, the reproducibility of data between experiments using the hydrophones was more limited. The signal characteristics arising from two identical experiments carried out differed significantly, probably due to changes in the coupling between the hydrophones and their surroundings. These variable coupling conditions will need to be accounted for during full waveform inversion analysis.

2.4 Travel-time Inversion of Cross-hole Hydrophone Data

Tomographic images may be obtained from seismic data through either travel-time inversion (considering only the travel times from the first arriving waves), or full waveform inversion (which takes into account the entire waveform including amplitude and phase). To date, tomographic data have been analysed by travel-time inversion, based on the velocity of seismic wave propagation through the media between the source and the receivers. Development of novel full waveform modelling and inversion schemes to analyse the data obtained is ongoing.

A travel-time inversion of the hydrophone data using the kinematic anisotropic code of Zhou and Greenhalgh (2008) was undertaken for the experiment in which the micro-tunnel was filled with dry sand. For an inversion cell size of 0.60 m, the recovered density-normalized elastic moduli (anisotropic parameters a_{11}, a_{13}, a_{33}, and a_{44} in Figure 2) highlight the strongly anisotropic nature of the medium. When converted to the Thomsen parameters, these values correspond to ε and δ estimates of up to 0.55 and 0.88, respectively. The inversion results demonstrate that the axis of symmetry is inclined at about 41 degrees to the horizontal. Relatively low seismic velocities are observed ~2 m from the borehole collars (as represented by the very low a_{11}, a_{13}, and a_{44} values at the lower ends of the boreholes in Figure 2). This could be the result of excavation damage or desaturation around the gallery 04. The primary features in the tomograms, which are predominantly aligned perpendicular to the symmetry axis, represent layering of the Opalinus Clay.

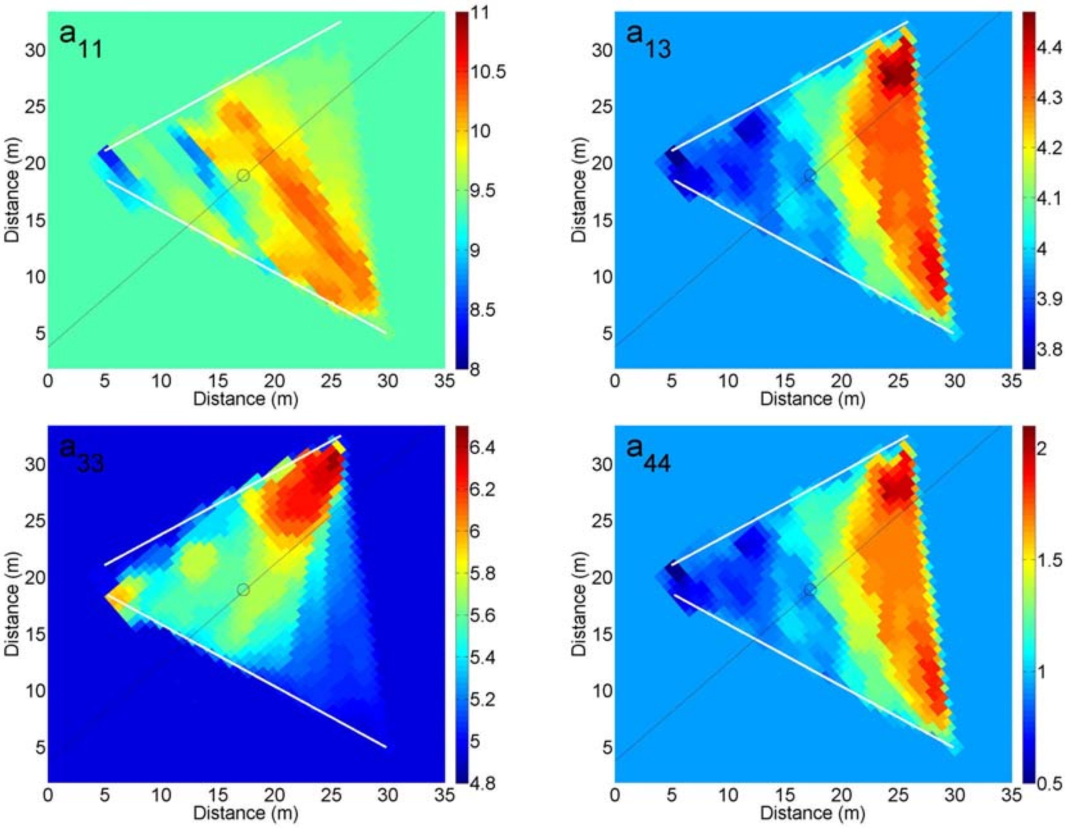

Figure 2: Inverted density-normalized elastic moduli a_{11}, a_{13}, a_{33}, and a_{44} for a tilted transverse isotropic medium. The black circle identifies the position of the micro-tunnel. The straight black line denotes the axis of symmetry inclined at about 41 degrees to the horizontal.

Parameter a_{33} exhibits a pronounced positive anomaly at the upper end of the receiver line. It is supported by elevated values of a_{13} and a_{44} but the origin of this anomaly is unknown.

As expected, travel-time inversion is unable to detect the micro-tunnel because of its small diameter (Figure 2). This observation is supported by a travel-time inversion of data from the fully saturated micro-tunnel experiment. The results from this experiment were virtually identical to the tomograms in Figure 2.

2.5 Travel-time and Waveform Differences in the Micro-tunnel Geophone Data

Unlike the cross-hole data collected using hydrophones in an adjacent borehole (Section 2.4), recordings from geophones emplaced directly in the micro-tunnel show significant differences as the experimental conditions are varied. We see variations not only in the travel-times but also in the polarity and character of the first arrivals. For the six different experiments (1) to (6) described in Section 2.2, Figure 3 displays early portions of seismograms from geophones G15 and G7 with the source at the 10 m position S10, as shown in Figure 1 (b). Since the seismic signal has not traversed the micro-tunnel when it reaches the G15 geophone, differences in the travel-time data at this location can only be attributed to changes in the excavation damage zone (EDZ) of the micro-tunnel.

For experiment (1) (empty micro-tunnel), the geophones were poorly coupled to the micro-tunnel, yielding unreliable seismograms. Figure (a) shows that G15 seismograms are very similar for experiments 2, 3, and 4, indicating that the micro-tunnel EDZ is not initially affected by water ingress into the micro-tunnel. In contrast, the G15 arrival times and waveforms for experiments 5 and 6 are quite different from those of experiments 2, 3, and 4. This variation for the last two experiments may arise because the micro-tunnel has, by this point, been fully saturated for a long time, allowing water to enter the micro-tunnel EDZ. This would lead to resaturation and probable to swelling of the Opalinus Clay (Bossart and Nussbaum, 2006) and a consequent increase in seismic velocities within the micro-tunnel EDZ.

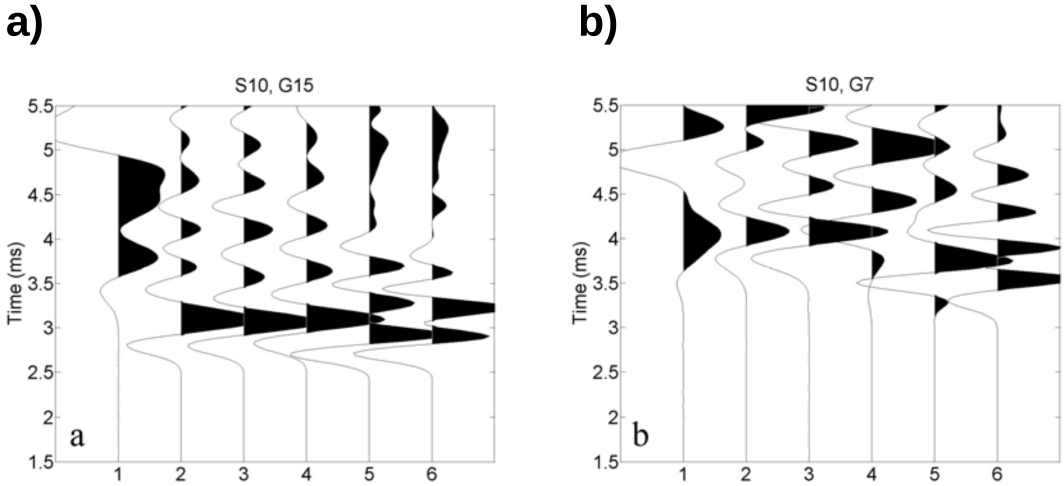

Figure 3: Early arrivals for shot position 10 recorded at geophones (a) G15 and (b) G7. The traces were recorded during experiments (1) to (6) described in Section 2.2 (numbered along the *x*-axis).

Significant waveform and travel-time changes from experiment to experiment are observable at geophone G7, as shown in Figure 3 (b). These variations arise because seismic data collected at G7 is a function of two waves which follow slightly different paths. One wave passes directly through the micro-tunnel and is therefore influenced by the fill material. The other wave is diffracted around the micro-tunnel and is thus influenced primarily by the micro-tunnel EDZ. The first wave to arrive depends on the geophone location in the micro-tunnel, as well as the state of the micro-tunnel and the EDZ. In addition, waves travelling directly through the micro-tunnel strike geophone G7 from below, whereas waves travelling around the micro-tunnel wall strike geophone G7 from above, thus providing the potential for polarity changes and marked amplitude variations that depend upon the arrival times of each wave.

Seismic studies using geophones emplaced *in situ* within a micro-tunnel are therefore capable of distinguishing the EDZ of the micro-tunnel from the surrounding environment and distinguishing changes in the conditions in the micro-tunnel as well, both directly and indirectly (through changes in the behaviour of the EDZ).

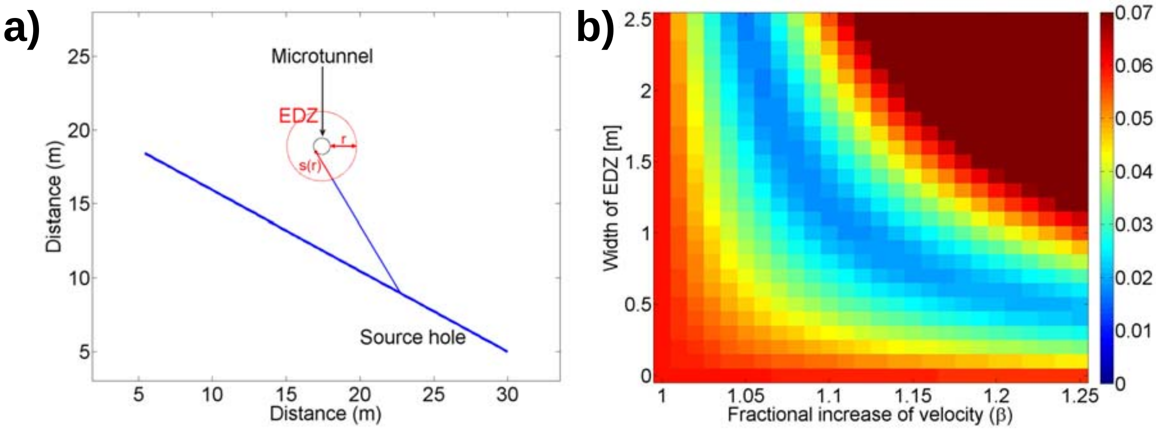

Figure 4: (a) Straight-ray approximation: First arriving wave propagating from the source to the geophone along an approximately straight line has a lower velocity inside the EDZ (red section of the ray). (b) Root-mean-square errors (ms) between observed travel-time differences (experiments 2 and 5) for all source positions, and the predicted differences based on equation (1).

Attempts have been made to determine information about the micro-tunnel EDZ from the corresponding travel-time data. Assuming a straight ray-path, the travel-time difference Δt of first arrivals between the experiments 2 and 5 can be written as:

$$\Delta t = s(r)\,(1 - 1 / \beta) / v \tag{1}$$

where v is the velocity of Opalinus Clay in the micro-tunnel EDZ under dry conditions, β is the fractional increase of velocity in the EDZ caused by the presence of water, r is the width of the EDZ, and $s(r)$ is the length of ray that passes through the EDZ, as illustrated in Figure 4 (a). By varying β and r systematically, we attempted to find an optimal combination of the two parameters that explained all observed travel-time differences. As shown in Figure (b), there exists a clear trade-off between β and r minimising the misfit, such that *a priori* information on one of the two parameters is required for a unique solution.

2.6 Conclusions of Non-intrusive Experiments to date at Mont Terri

The results of seismic investigations on the HG-A experiment at Mont Terri suggest that cross-hole travel-times do not enable information to be gathered about the state of a 1 m diameter micro-tunnel that lies midway between source and receiver boreholes separated by distances of 5-30 m. In contrast, data recorded on geophones mounted within the micro-tunnel provide diagnostic information about the micro-tunnel fill and the state of the micro-tunnel EDZ. Changes in the micro-tunnel fill and EDZ result in marked variations in seismic wave arrival times, polarities and waveforms. A full waveform inversion of the combined geophone and hydrophone data will be undertaken as part of this study to fully assess the imaging capabilities of seismic tomography for this type of application.

3 Non-intrusive Monitoring at the Grimsel Test Site

3.1 Background

Following on from ESDRED, several partner organizations identified a further opportunity for developing monitoring techniques under repository conditions, by utilizing the construction and testing programme of a low pH shotcrete plug being constructed in granite at the Grimsel Test Site, under ESDRED Module 4.

The component of interest was a short wall of bentonite blocks wedged at the end of a tunnel by a low pH shotcrete plug. As the bentonite becomes saturated, it swells, creating pressure within the confined zone behind the plug. The swelling process changes the elastic properties of bentonite substantially, such that changes may be detectable using cross-hole seismic techniques.

Monitoring of this experiment was initiated under Project TEM (Testing and Evaluation of Monitoring Techniques). This study provided an opportunity for simultaneous comparison of three monitoring methods: conventional wired signal transmission from the EBS, wireless data transmission using magneto-inductive techniques, and observation through non-intrusive geophysical techniques.

3.2 Numerical simulations

To establish the technical requirements for accurately measuring seismic waveforms under varying water-saturation conditions, a suite of numerical simulations have been performed using a time-domain isotropic elastic modelling code (Bohlen, 1998). These simulations are aimed at determining if seismic waves travelling between pairs of boreholes placed at some distance around a tunnel would be affected significantly by bentonite swelling caused by changing water-saturation conditions. For the sake of computational efficiency, the experiments were restricted to two dimensions. Several simulations were performed using source and receiver boreholes inclined at different angles with respect to the tunnel axis. Source and receiver (hydrophones) spacings along the boreholes were chosen to be 0.25 m.

To achieve the necessary spatial resolution, a source wavelet with a dominant frequency of 3 kHz was considered. Such a wavelet has dominant wavelengths for P-waves of about ~1.7 m and ~0.2 m in the host rock and air dried bentonite (water content = 10 – 13 %), respectively.

It was apparent from the simulations carried out, that large variations in the transmitted portions of the wavefield and in the reflections/diffractions from the bentonite-rock interface are readily apparent in the wavefields and seismic sections. Most importantly, variations in the seismic signal arising as a result of the changing properties of the bentonite primarily affect the waveform amplitudes, rather than first arrival times. Consequently, as for the experiments carried out at Mont Terri, it was observed that full-waveform inversion approaches are required for monitoring the desired changes (in this case, in the properties of the bentonite plug).

3.3 Experimental Set-up

A 1 m wide bentonite plug has been wedged at the end of a 3.5 m diameter tunnel by a 4 m wide concrete plug for experiments as part of ESDRED Module 4. This set-up can be seen in Figure 5.

Based on the results from the numerical simulations, the borehole layout in Figure 5 was implemented. Six boreholes were equally spaced around the perimeter of the main tunnel to ensure sufficient redundancy for the transmitted wavefields and good angular coverage for the reflected wavefields. The borehole lengths were chosen to be 25 m. A high-frequency sparker was employed as the seismic source. It was fired sequentially every 0.25 m along boreholes 3, 4, and 5. Three 24-channel hydrophone streamers with 1m spacing were simultaneously deployed in the upper boreholes 1, 2, and 6. The hydrophones were spaced at 1 m intervals. By shifting the streamers three times at intervals of 0.25 m and repeating each source, a 96-channel hydrophone streamer with 0.25 m element spacing was simulated.

Five experiments have been carried out under varying conditions at the end of the tunnel. The first two experiments were performed before and after emplacement of the dry bentonite block and concrete plug. Subsequently, the bentonite block was repeatedly watered, and the seismic experiments were repeated 1, 4, and 10 months after the initial watering. Continuous measurements of the total pressure within the bentonite block have indicated that the swelling process has been quite slow. Even after 10 months, only a small amount of expansion (c. 1MPa) had been recorded.

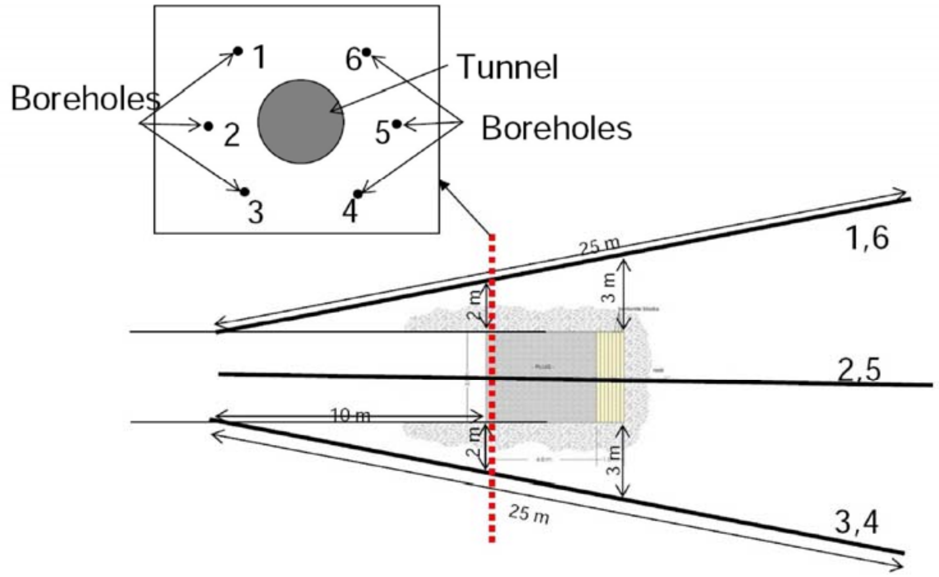

Figure 5: The GTS experimental configuration. A relatively thin bentonite block (yellow) is wedged at the end of a tunnel by a concrete plug (grey). Receiver boreholes: 1, 2, 6; source boreholes: 3, 4, 5.

3.4 Results

Initial inspections revealed that the recorded data were characterized by a surprisingly wide band of frequencies. However, seismic sections generated by sources at exactly the same position and recorded by a fixed-location hydrophone streamer revealed the presence of incoherent high frequency energy. This was examined quantitatively by performing a coherence analysis. Uniformly high coherence values are observed in the 1-4 kHz range (corresponding to minimum wavelengths of ~1.3 m and ~0.13m in the host rock and dry bentonite, respectively), with an abrupt decrease in values at higher frequencies. Low coherence values for the higher frequencies are evidence for random noise that needs to be eliminated before subjecting the data to inversion. Elimination of this noise was achieved by simply passing all data through a 1-4 kHz bandpass filter.

Selected seismic sections from the five experiments are presented in Figure 6. The left column displays typical source gathers, whereas the right column displays typical receiver gathers. These gathers demonstrate that the first arrival times and many later phases are practically identical for the different experiments, but that important changes in the waveforms are observed. Such differences can be attributed to:

1. changes in the bentonite due to the varying water-saturation conditions,
2. variable source signatures, or
3. variable receiver coupling to the host rock.

Most likely, the differences are a combination of all three effects. For logistical reasons, the hydrophone streamers were inserted into plastic pipes that were then inserted into the boreholes. The hydrophones and pipes were left in the boreholes during the first three experiments. After the third and fourth experiments, it was necessary to separately remove the hydrophones and pipes, such that the entire insertion procedure had to be repeated for the fourth and fifth experiments. Figure 6 shows that the receiver gathers for the first three experiments were very similar, whereas those for the fourth and fifth experiments differed somewhat. This observation suggests that receiver coupling effects are very important. Consequently, a waveform inversion scheme needs to be devised that accounts for variable receiver coupling.

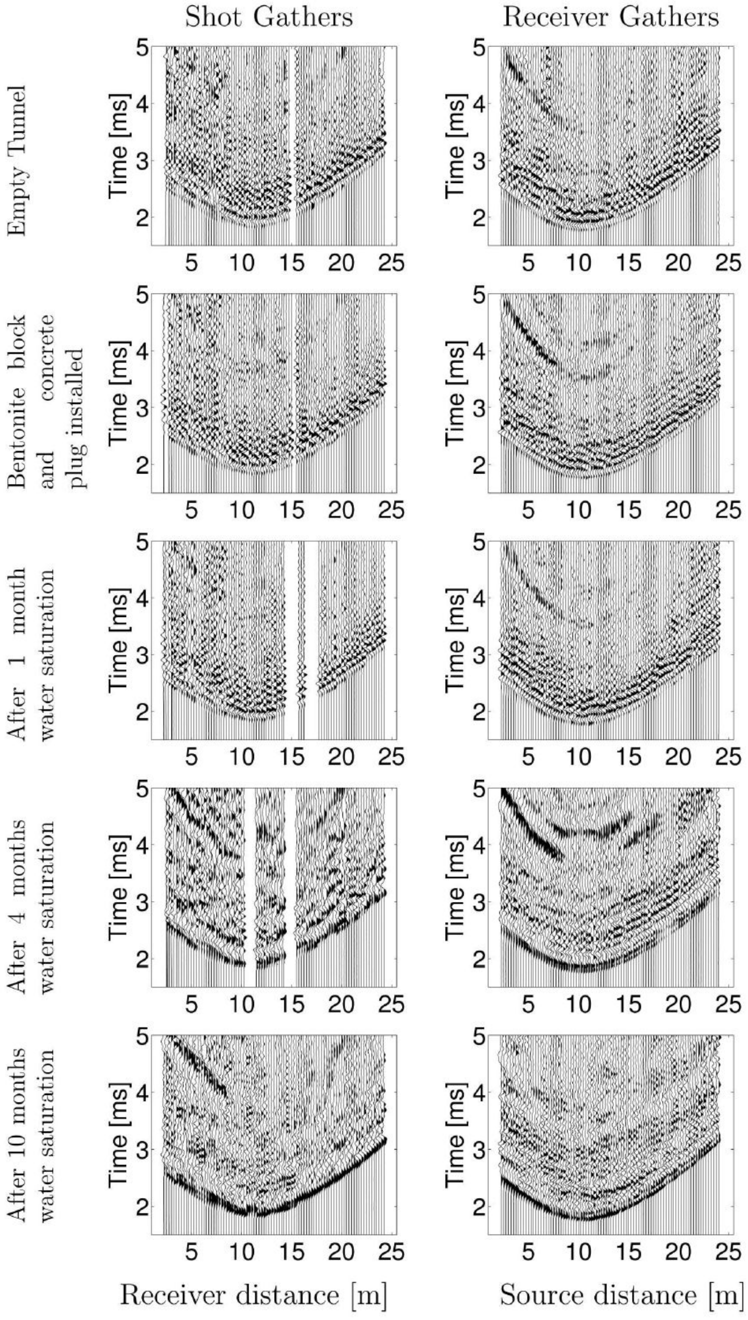

Figure 6: Representative source gathers (left panels) and receiver gathers (right panels) extracted from the five data sets recorded over a 10-month period ending in December 2007. A 1-4 kHz Butterworth (4^{th} order) bandpass filter has been applied to the raw data.

3.5 Conclusions of Non-intrusive Experiments to date at GTS

Numerical simulations demonstrate the feasibility of employing cross-hole seismic tomography for the non-intrusive monitoring of bentonite subject to varying water-saturation conditions. Field experiments suggest that the quality of the recorded cross-hole seismic data (*i.e.*, their high signal-to-ambient-noise ratios and high frequency contents) is suitable for high-resolution tomographic studies. Comparisons of data recorded during repeat experiments indicate that variable source and receiver coupling have a significant effect on the seismic waveforms. Since it is not possible with the chosen experimental setup to keep the coupling conditions constant between the individual experiments, a possible solution would be to develop a waveform inversion algorithm that accounts for the variable coupling conditions.

4 Conclusions

There are benefits in being able to monitor what is occurring within the EBS, once waste has been isolated, without compromising the integrity of the EBS. Development of non-intrusive monitoring techniques to improve our capability and confidence in these techniques will enable options of more robust and assured monitoring of waste once isolated. The development of practical applications which mimic disposal conditions provide opportunities to test and develop monitoring systems to improve our understanding of the capabilities of these systems particularly to detect relatively small changes over longer timeframes.

This programme, initiated under the EC IP ESDRED programme and continued under Project TEM has applied seismic tomography employing full waveform analysis to improve our understanding of the capability of this technique. The work undertaken confirms:

- High-resolution seismic measurements for monitoring radioactive waste repositories are generally feasible.
- Repeatability of the measurements is most critical for monitoring purposes.
- Geophones installed close to the target area proved to be most helpful for identifying temporal changes.
- The equipment employed for this project produced highly repeatable seismic source signatures, but the coupling of the borehole hydrophones turned out to be surprisingly variable.
- The useful bandwidth of the seismic signals extends from up to 4 kHz for the geophones installed in the micro-tunnel and from 1 to 4 kHz for the borehole hydrophones.
- Changing conditions within the HG-A micro-tunnel have minimal effect on the travel times of waves travelling from the source borehole to the receiver borehole. In contrast, effects of changing conditions within the micro-tunnel are very pronounced on recordings from geophones directly installed in the micro-tunnel.

References

Bohlen, T., 1998. Interpretation of Measured Seismograms by Means of Viscoelastic Finite Difference Modelling. PhD thesis, Kiel University.

Bossart, P. and Nussbaum, C., 2006, Rock-water interactions in the Opalinus Clay, based on research in the international Mont Terri Rock Laboratory: 4th Swiss Geoscience Meeting, Abstracts.

ETN, 2004. European Commission, Thematic Network on the Role of Monitoring in a Phased Approach to Geological Disposal of Radioactive Waste, Contract No. FIKW-CT-2001-20130, 2004.

Nagra, 2005. Non-intrusive monitoring experiment at Mont Terri rock laboratory, Proposal to ESDRED Module 1 Partners.

Nicollin, F., Gibert, D., Bossart, P., Nussbaum, Ch.. and Guervilly, C., 2008 Seismic tomography of the Excavation Damaged Zone of the Gallery 04 in the Mont Terri Rock Laboratory, *Geophys. J. Int.*, 172, pp 226-339.

Zhou, B. and Greenhalgh, S.A., 2008. Non-linear traveltime inversion for 3-D seismic tomography in strongly anaiostropic media, *Geophys. J. Int*,. 172, pp 383-394.

Acknowledgement

The authors of this paper would like to acknowledge the contributions from the European Commission in co-funding this work as part of the sixth EURATOM Framework Programme for nuclear research and training activities (2002-2006) under contract FI6W-CT-2004-508851 and to the Mont Terri Project in hosting of the experimenmt at the Mont Terri URL.