International Bentonite Longevity (IBL) project: overview

Introduction

The Kunimine Industries (KIC) Tsukinuno (Japan) bentonite mine is a source for Miocene age Na-bentonite (with Ca-bentonite near-surface) and the site holds great potential for studying processes of direct relevance to safety cases (SC) for radioactive waste repositories which will utilise bentonite as part of their multi-barrier safety system (see Table 1).

The Tsukinuno mine and its environs (Figure 1) are ideal for studying long-term, safety-relevant bentonite processes, including:

- bentonite erosion – both extreme case (river erosion at the surface – Figure 2) and more repository relevant at depth in the tunnels where water conducting features contact the bentonite
- saturation state – natural saturation states of bentonite in differing environments (on the surface and at varying depths underground, dry and wet host rock conditions) for comparison with ongoing short-term, laboratory and underground rock laboratory (URL) tests
- bentonite density changes (swelling and heave) due to exposure to groundwaters/ meteoric waters
- bentonite water interaction processes with fresh and deeper groundwater chemistries e.g.
  - changes in layer charge
  - cation exchange capacity (CEC)
  - exchangeable cation composition (ECC)
- bentonite reaction with mudstone and siltstone host rocks
- bentonite fracturing (and self-sealing) – see Figure 3
- the behaviour of bentonite under repository relevant hydrostatic and lithostatic pressures

In the Tsukinuno area, some 21 bentonite layers vary in thickness from a few cm to ca. 7 m, can provide information of relevance to the scales of the:

- buffer and backfill of the engineered barrier system (EBS)
- tunnel/shaft plugs and seals
- borehole seals

In addition, bentonite compositions vary, providing the potential for studying processes in relation to various initial states of the buffer/backfill/plugs/seals.

Mining has been ongoing at the site for several decades, so providing:

- direct access to surface exposures (Figure 2)
- access via drifts and shafts to bentonite exposures in the working mine (Figure 4)
- access to existing/new drillcores (Figure 5)

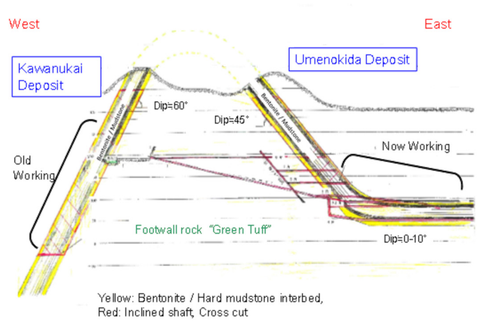

Figure 1: cross section of the Tsukinuno bentonite mine (courtesy KIC)

Figure 2: view of surface exposures of siltstones and bentonites in the bed of the river immediately NW of the Tsukinuno mine

Figure 3: example of bentonite/host rock fracture in the Tsukinuno mine

Figure 4: typical view of the spacious mine tunnels which allow easy access for sampling

Table 1: examples of the features present in the Tsukinuno mine, their relevance to the repository Safety Case and the associated FEPs (Features, Events and Processes)

Feature	Safety Case relevance	Examples of FEPs of interest
Several water-conducting fractures at depth in the mine allow direct examination of groundwater/bentonite interaction and erosion	Potential to study groundwater/bentonite interactions and saturation rates and erosion/ colloid production	• bentonite saturation • water-rock (clay) interaction • cation exchange • colloid formation • bentonite erosion • bentonite swelling/sealing etc.
Bentonite deposit outcrops at the surface, including in nearby river bed	Potential to study the above processes at very low salinity	• bentonite saturation • water-rock (clay) interaction • cation exchange • colloid formation • bentonite erosion
Bentonite occurs as bands with varying thicknesses (from few cm to ca. 7 m)	Repository relevant size, scale effects (same process can be studied within different bentonite beds)	• clay – rock interaction • bentonite based buffer and backfill designs • bentonite tunnel plug and seal designs • bentonite borehole seal designs
Unlike in open bentonite quarries (pits) at the surface, in the mine, bentonite occurs at various depths (0 – ca. 400m below ground surface)	Repository relevant depth (and hydrostatic and lithostatic pressures)	• bentonite saturation • groundwater flow • groundwater diffusion • cation exchange
Hosted by sandy siltstone and mudstone	Brittle host rock: fractures and water conducting features	• advection/diffusion • water-rock (clay) interaction.
Area has faults cutting bentonite bearing rocks	Presence of deformed bentonite	• faulting • bentonite deformation • host rock deformation
Some of the bentonites are much drier than others	Evidence of long-term unsaturated bentonite?	• bentonite saturation rates • potential impact of bentonite inhomogeneity

Figure 5: on-going surface exploratory drilling in the vicinity of the Tsukinuno mine

Conclusions

The International Bentonite Longevity (IBL) project is currently in the data mining and detailed planning phase and, in 2018, it is intended to progress to further phases of in-depth examination of several processes of direct relevance to repository EBS longevity. These include:

- bentonite erosion: both repository SC relevant systems deep in the mine and an extreme case in a local river bed
- assessment of swelling behaviour: how does it differ in the unconfined systems representative of the repository operational phase and in the confined systems representative of the repository post-closure phase?
- bentonite saturation states: by looking at bentonite occurrences at repository relevant depths, some open questions can be addressed. For example, examining saturation states under relevant lithostatic stresses and representative deep groundwater fluxes will enable improved conceptualisation of bentonite-groundwater processes so that SC applications would be more realistic
- bentonite faulting/fracturing and deformation: fracturing and faulting of bentonite is relevant to scenarios where EBS/tunnels seals and plugs/borehole seal clay components are disturbed by seismic events. Fracturing can be also caused by drying and be related to saturation process (see above).
- stakeholder communication: material will be produced which can be utilised for more general, technical and non-technical communication purposes
- technical development: assessment of approaches for minimising sample damage to bentonite cores to define their relevance to future radioactive waste R&D, including sub-sampling laboratory material and drilling cores from full-scale experiments in URLs and future natural analogue sites

Further reading

Alexander. W.R. (2017). Sealing site investigation boreholes: Phase 2. The use of natural, industrial and archaeological analogues in support of the borehole sealing project, Amec Foster Wheeler Report 202580/07 for RWM Ltd, Harwell, UK.

Alexander, W.R., Börgesson, L., Hedström, M., Jefferies, N. & Wilson, J. (2017). Sealing Site Investigation Boreholes: Phase 2. Aspects of the evolution and longevity of bentonite seals. Amec Foster Wheeler Report 202580/09 for RWM Ltd, Harwell, UK.

Alexander, W.R., Reijonen, H.M., MacKinnon, G., Milodowski, A.E., Pitty, A.F. & Siathas, A. (2017). Assessing the long-term behaviour of the industrial bentonites employed in a repository for radioactive wastes by studying natural bentonites in the field. Geosciences Special Issue on Geological Disposal of High Level Radioactive Waste - The Relationship between Engineered and Natural Barriers, eds. R.Lunn, S.Harley, S.Norris & J.Martinez-Frias. Geosciences 7, 5. http://doi:10.3390/geosciences7010005

Kuno, Y., Kamei, G. & Ohtani, H. (2002). Natural colloids in groundwater from a bentonite mine – correlation between colloid generation and groundwater chemistry. MRS Proceedings, 713, JJ8.4.1–JJ8.4.8.

Reijonen, H.M. & Alexander, W.R. (2015). Bentonite analogue research related to geological disposal of radioactive waste – current status and future outlook. Swiss Journal of Geosciences 108, 101-110. http://doi.org/10.1007/s00015-015-0185-0

Reijonen, H. & Marcos, N. (2017). Chemical erosion of bentonite buffer – do we observe it in nature? In Norris, S., Bruno, J., Van Geet, M. & Verhoef, E. (eds) Radioactive Waste Confinement: Clays in Natural and Engineered Barriers. Geological Society of London, Special Publication 443. http://doi.org/10.1144/SP443.13.

Reijonen, H.M., Ito, M. & Alexander, W.R. (2017). International Bentonite Longevity (IBL) project: an introduction. Proc. NAWG-15 Workshop, Prague, 22-25 May, 2017. SURAO Technical Report 2017-XX, SURAO, Prague, Czech Republic (in press).

Takagi, T., Koh, S.M., Song, M.S., Itoh, M. & Mogi, K. (2005). Geology and properties of the Kawasaki and Dobuyama bentonite deposits of Zao region of northeastern Japan. Clay Mins. 40, 333-350.

Geological Survey of Finland

H.M.Reijonen[1], M.Ito[2] & W.R.Alexander[3*]
[1.] Geological Survey of Finland (GTK), Espoo, Finland
[2.] Kunimine Industries, Miyagi, Japan
[3.] Bedrock Geosciences, Auenstein, Switzerland
*corresponding-: author russell@bedrock-geosciences.com

Lay-out: Harri Kutvonen