IPHAP: a new natural analogue of bentonite alteration by cement leachates

I.G. McKinley[1] W.R. Alexander[2], C.A. Arcilla[3], H. Kawamura[4] Y. Takahashi[5]

1. McKinley Consulting, Baden/Dättwil, Switzerland

Corresponding author: ian@mckinleyconsulting.ch

2. Bedrock Geosciences, Auenstein, Switzerland

3. University of the Philippines, Quezon City, Philippines

4. Obayashi Corporation, Tokyo, Japan

5. NUMO, Tokyo, Japan

ABSTRACT

A concept is currently being developed for an International Philippines Hyperalkaline Analogue Project (IPHAP), which will examine the processes associated with the alteration of bentonite by hyperalkaline fluids of the type that may leach from cement or concrete included in a repository. This paper provides an outline of the requirements and goals of the analogue, some general background on the bentonites and associated hyperalkaline waters under consideration and identifies a range of potential sites where such bentonite alteration might be studied.

1. INTRODUCTION

Bentonite is one of the most safety-critical components of the engineered barrier system for the disposal concepts developed for many types of radioactive waste. The choice of bentonite results from its favourable properties – such as plasticity, swelling capacity, colloid filtration, low hydraulic conductivity, high retardation of key radionuclides – and its stability in relevant geological environments. However, bentonite – especially the swelling clay component that contributes to its essential barrier functions – is unstable at high pH. This led to some repository designs (especially for disposal of HLW or SF) that exclude use of concrete from any sensitive areas containing bentonite, due to the fact that it reacts with groundwater to produce leachates with pH up to about 13.

Such an option of avoiding the problem by constraining the design was considered acceptable during early, generic studies but, as projects move closer to implementation, it is increasingly recognised that constructing extensive facilities underground without concrete – a staple of the engineering community – would be difficult, expensive and potentially dangerous for workers. This is especially the case in countries like Japan, where a volunteering approach to siting a HLW repository means that repository construction could be in a technically challenging host rock.

A further area of concern involves TRU (or other high toxicity / long half-life ILW), particularly if this is co-disposed with HLW/SF. TRU waste contains large inventories of cementitious materials and hence, in principle, could pose a risk to the EBS of HLW/SF, even if concrete was excluded from the HLW part of the repository (e.g. scenarios discussed in Projekt Entsorgungsnachweis; Nagra 2002). Indeed, some designs of the EBS for various kinds of ILW include a bentonite layer, which is planned to act as an external barrier around concrete structures To date, there has been no comprehensive demonstration that the performance of such a barrier can be assured for relevant periods of time (e.g. Umeki, 2007).

Recently, therefore, there have been extensive efforts to better understand the interactions of hyperalkaline fluids with bentonite, coupled with studies aimed at reducing the risk by development of low alkali cement formulations. The greatest challenge is bringing the information produced by laboratory (conventional and URL) and modelling studies together to form a robust safety case. This is complicated by the inherently slow kinetics of such reactions and the commonly observed persistence of metastable phases for geological time periods (for a good overview of the issues involved, see Metcalfe & Walker, 2004). Clearly, this is an area where analogues could play a valuable role – bridging the disparity in realism and timescales between laboratory studies and the systems represented in repository performance assessment.

2. ANALOGUE CONCEPT

An initial literature search sponsored by RWMC of Japan indicated that no useful information on this topic could be "mined" from past studies and hence the option of a new project was examined. The basic idea was to use a "top-down" approach to identify sites where bentonite deposits have been exposed to relevant hyperalkaline water for very long periods. Especially given the interest in low pH cements, the focus was on sites that have natural waters with pH in the appropriate range (around 10-11). As indicated in Fig. 1, the cement leachate is simulated by natural hyperalkaline water, which, if the timescale of interaction can be determined, allows the models that are being developed to quantify the specific processes shown in the figure to be tested. The challenge is to maximise the value of this test, by assuring that materials and boundary conditions are as similar as possible to those in a repository.

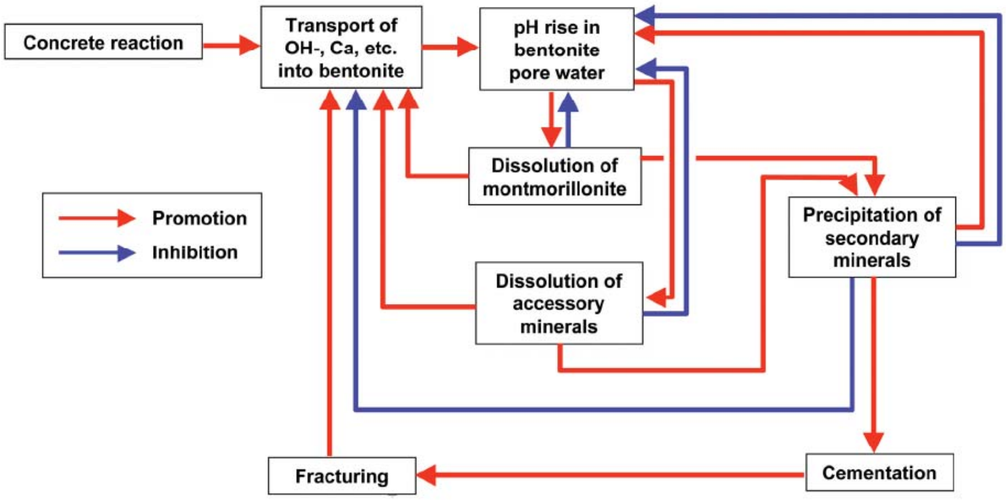

Figure 1: Some of the important processes involved in bentonite alteration (from Metcalfe and Walker, 2004); at the analogue site, natural hyperalkaline springs simulate concrete leachate in the analogue project.

In principle, there are a number of locations worldwide where such an analogue might be found, including Cyprus, Japan and the Philippines. Based on a multi-attribute analysis, considering factors such as probability of finding suitable locations, relevance to Asian programmes, opportunity for training, low risk of disrupting calls for volunteers and cost-effectiveness, the Philippines was selected as the preferred option and has since been the focus of more detailed literature studies and a limited number of field investigations to confirm fundamental feasibility.

3. GEOLOGICAL SETTING AND SITE SELECTION

All hyperalkaline groundwaters studied so far in the Philippines originate from the 20 or so known ophiolite bodies, which are widely scattered throughout the archipelago (see Figure 2). The hyperalkaline pH values (generally between pH 10 and 11) observed in the groundwaters are a product of the serpentinisation of the ophiolites, a reaction which has several possible pathways with the exact reaction pathway depending on Mg content of the precursor olivine/pyroxene or serpentine product, CO_2 fugacity, water-rock ratio, Ca^{2+} content of groundwater, etc.

The serpentinite mineral assemblages are very strongly reducing and the hyperalkaline waters are often effervescent with H_2 and/ or CH_4 gas. Some of the reaction pathways are also strongly exothermic, frequently producing hydrothermal groundwaters which are often used as therapeutic springs in the Philippines.

To date, a data-mining exercise has been carried out reviewing the literature with search parameters that include both aspects of the target geology and also themes of relevance to national radwaste management programme. Factors considered include:

- ophiolite terrains
- hyperalkaline groundwaters
- commercial bentonite deposits
- H_2 or CH_4 gas in groundwaters
- evidence of microbial activity
- thermal groundwaters
- tuffaceous deposits
- coastal sites
- logistics (e.g. potential support from local mining operations).

This exercise has already identified several promising sites and, to date, three preliminary field assessments have been carried out at Palawan (around E118,000 N010,000 on Figure 2), Panay (around E121,000 N012,500) and Luzon (around E120,500 N014,500). The groundwaters show the typical wide range in chemistry which is generally associated with similar serpentinite-associated groundwaters (eg McKinley et al., 1988; Neal and Shand, 2002) but the site in Luzon, at Mangatarem, in the sedimentary carapace of the Zambales ophiolite, is particularly promising due to the presence of bentonites, zeolites and tuffs in the immediate vicinity of confirmed hyperalkaline groundwaters.

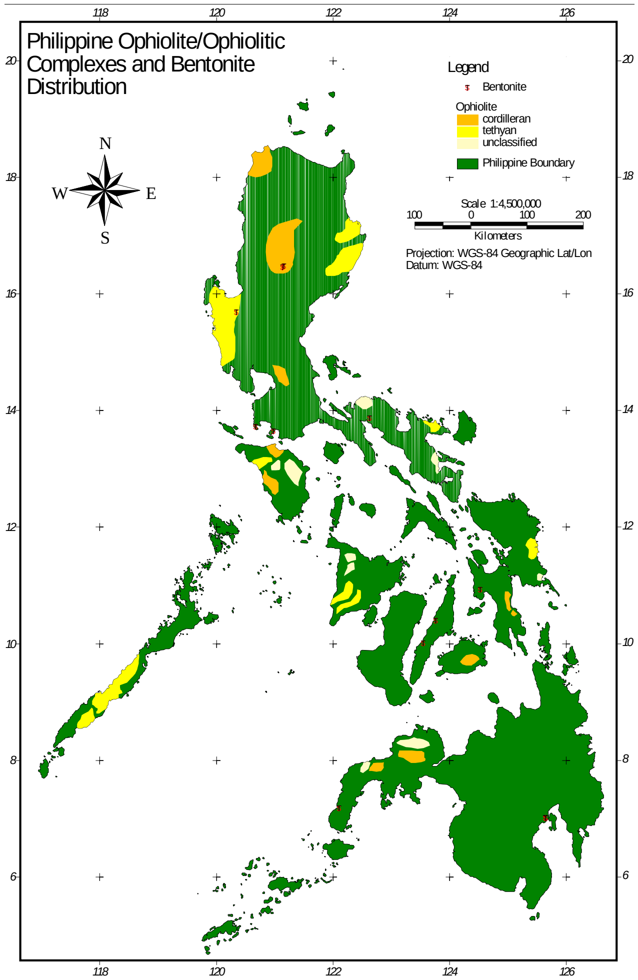

Figure 2: Distribution of ophiolites and commercial bentonite deposits in the Philippines.

4. STATUS AND FURTHER PLANS

Given the widespread interest in the topic covered by this study, an outline has been developed for an International Philippines Hyperalkaline Analogue Project (IPHAP), which has been discussed with a number of potential partner organisations. There is particular interest in the option of optimising the operation of this project to maximise the extent of transfer of experience to younger staff (widely acknowledged to be a problem in many national waste management programmes). Although a lot of groundwork has been done, it is hoped to establish international teams who will actually implement this project – more senior experts acting as mentors and providing assistance only as and when it is required. Such an operational procedure may involve some inefficiencies, but these would be more than balanced by the benefits in providing an opportunity to build-up and transfer "tacit" knowledge (e.g. see discussion in Kawata et al, 2006).

In order to allow maximum flexibility for the project teams, most practical details of the project have been left open. Nevertheless, some probable boundary conditions are likely to be:

- Planned 3 year project duration (long enough to form the basis of Ph.D. or M.Sc. projects), with a possible maximum extension of a further 2 years; this is based on the experience that clear deadlines help to focus projects.
- Maximum number of partners around 4-5 (to avoid excessive burocracy); flexible conditions for collaboration including both co-funding (particularly of work in the Philippines) and contribution of services in kind (e.g. analytical support)
- Work divided between project teams – geological / hydrogeological site characterisation, geochemistry / mineralogy of bentonite interaction, modelling and model testing, coordination & logistics; integration will be ensured by annual project workshops
- Comprehensive, quality assured documentation will be given high priority and quarterly / annual reports will ensure all information obtained is distributed to all partners
- Final project reports would be complemented by production of a set of reviewed technical papers – possibly published as a special issue of a journal (as was the case, for example, with the Poços de Caldas project)
- Efforts would be made to use project output also for communication with the general public.

For the specific case of Korea, such a project might be very convenient in terms of location, timely in that it offers opportunities for training younger staff who might be later involved in the licensing of deep geological repositories and advantageous as allows increasing collaboration with organisations from Japan and other advanced programmes in this particularly important topic

ACKNOWLEDGEMENTS

This study was initiated within a project to develop an integrated natural analogue programme in Japan, which was funded and coordinated by RWMC. Developing the IPHAP proposal and initial fieldwork in the Philippines has also been assisted by the participation of NUMO and would have been impossible without logistical support by staff of the National Institute of Geological Sciences of the University of the Philippines.

REFERENCES

Kawata, T., Umeki H. and McKinley I. G. (2006). 'Knowledge Management: The Emperor's New Clothes?' Proc. 11th International High-Level Radioactive Waste Management Conference 2006, Las Vegas, Nevada, April 30-May 4, pp.1236-1243.

McKinley, I.G., Bath, A.H., Berner, U., Cave, M. and Neal, C. (1988). Results of the Oman analogue study. Radiochim. Acta, 44/45, 311-316.

Metcalfe, R., Walker, C. (2004). Proceedings of the International Workshop on Bentonite-Cement Interaction in Repository Environments 14–16 April 2004, Tokyo, Japan. NUMO Tech. Rep. NUMO-TR-04-05, NUMO, Tokyo, Japan.

Nagra (2002). Project Opalinus Clay: Safety Report. NTB 02-05, Nagra, Wettingen, Switzerland.

Neal, C., Shand, P. (2002). Spring and surface water quality of the Cyprus Ophiolites. Hydrology Earth System Sci., 6, 797-817.

Umeki, H. (2007). Holistic assessment to put mobile radionuclides in perspective. Proc. MOFAP workshop, in press.