Record of workshop

"Assessing the suitability of host rock"

Developing practical approaches to assess site characteristics influencing repository design and PA

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Yokohama, 7-8 October 2010

Background

JAEA has initiated activities within its second medium-term plan (five years) this April. For the last five years of our first medium-term plan, we have been focusing on performance assessment methodology development and its applications, based on site-specific data obtained from the surface investigations at the Mizunami and Horonobe URL sites. Both URL programmes have now advanced from surface-based investigations to the construction and operation phases.

One of the important goals in our second medium-term plan is to provide a comprehensive methodology for repository assessment based on descriptions of specific sites. To meet this goal, we are now reviewing and evaluating the progress during the first medium-term, with the aim of producing a detailed action plan that optimises the linkage between site investigations, design/engineering and assessment; this is coupled to further development of our URL programmes.

In this context, this international workshop with selected partner organisations was organized to discuss development of practical approaches to identify and assess the key geological characteristics of suitable host rock influencing repository design, operational procedures and assurance of operational / post-closure safety. This short note briefly outlines key points arising from discussions at the workshop (in bullet form, using the Chatham House rule of recording input without explicit attribution of source). Appended are:

1. Programme of the workshop
2. List of attendees
3. Presentations made on Day 1 (powerpoint)
4. Summary of output of Day 1, with a synthesis in the form of an argumentation model
5. Presentations made by groups in the form of AMs
6. Integrated workshop summary and wrap up (powerpoint).

Key points arising from Day 1

Ishikawa-san opened the workshop and gave an overview of the Japanese programme.

Presentations

1. Introduction of the goals, format and expected output from this workshop – **K.Miyahara**

A key issue to be discussed at the structured brainstorming will be how to treat uncertainty.

Q. How can we have the exercise without having the host rock information and a repository design concept? *We will have presentations about the Mizunami and Horonobe URLs; we are aware that neither has been considered as a site for the repository, but we can use them as representative Japanese geological environments in non-excluded areas (on the basis of siting factors) to focus discussions. The NUMO concept catalogue provides a basis for HLW disposal, which has been the main focus of work to date.*

Q. Can we think about site evolution for the case of siting in a volunteer host rock? *We assume that the PIA is selected based on the exclusion criteria: therefore some of the long term evolution problems, i.e. volcanically active regions, can be avoided.*

Q. Slide 16 – need to define what the role of the regulator is and, in particular, what their input is in terms of the site selection and the timescale of the project? *Regulators are involved from the beginning of site selection, and expected to particularly focus on how to treat uncertainties. Nevertheless, discussion before the brainstorming will involve defining what the role of the regulator in terms of site selection would be for this particular exercise.*

Q. The discussion will depend on the progress of the site selection – which stage should the brainstorming focus on, PIA or DIA? *The only fixed boundary condition corresponds to the present time, so a key issue is how we focus effort now, before volunteers come forward. Nevertheless, the URLs that we will use are at an advanced stage and much information is known, so we can cover phases up to the very critical stages of selection of DIAs and then the final repository site.*

Comment - The location and quantification of uncertainty is too important to just be with the regulator – it should be covered by all 3 groups. Also it is good to have some site in mind for the discussion, for example discussing the exclusion criteria will be much easier if there is a site being considered. Suggest using the real data for the URLs. (As clarified subsequently and noted above, this defeats the point of the exercise: the extent of use of the URLs is not a starting point, but an issue to be considered in the group work).

2. Presentation of the leading experiences of URLs and Repository projects

    a. Sedimentary rock – S. Vomvoris

    - The Swiss and Japanese step-wise approaches can be compared i.e. selection of at least two sites is comparable in some ways to the change from PIA to DIA, but the process to get to PIAs in the first place is fundamentally different.

    - The next steps for Nagra will include ranking the 6 nominated siting regions.

Q. Slide 17 – the specific indicators outlined in the table seem to be selective? *They are all important from an engineering perspective. Each criteria must be associated with a specified safety function. The background to how the specific indicators were chosen can be outlined if required.*

Q. Definition of the 49 indicators on Slide 13– contains a set of parameters or FEPs e.g. pH (a measurable parameter) but also colloids, how are these measured? *The table only includes the 'buzz-words', but there is a supporting document that explains the indicators and how they are measured.*

For the colloids example, the basic concern is the extent to which the host rock might allow for colloidal transport. As here, Not all indicators can be covered by numerical arguments, but might lead to a more qualitative description.

Q. Slide 15 – concerned with 'ease of characterization of the rock' – is this either very optimistic or it is a very simple rock? *This means the ease of characterization of the host rock from the surface – again it is simplified in the table. It's not whether you can drill boreholes, it is whether the surface features indicate that the geology is not complex and hence the subsequent characterization effort is expected to be problematic.*

Comment – the focus of the workshop is how we use the development of site selection criteria in other programmes to further site characterization for implementation in Japan. We have identified a large range of indicators for the Swiss case, but they will be specific for the geology and the repository concept involved.

b. Fractured hard rock – J. Andersson

- SKB are very much based on the next licensing step, hence less concerned about respect distances to major fault zones and more on local flow properties. This is very much a consequence of the dominant safety case role played by longevity of the Cu overpack.

Q. The repository concept is based on the KBS-3 design. Also SKB have other repository concepts,: have the approaches described also been applied to the alternative concepts? *The KBS-3H is also investigated as a potential development for implementation: even if it is not in the license application, the described KBS-3V safety concept is also applied and most of the requirements on the host rock are the same.*

Q. The proposed design may not the best solution – but the public often require the best solution, so how do you get public acceptance and regulator acceptance? *In the legislation, the requirement is for BAT (Best Available Technology): clearly the basic design needs to demonstrate that it is BAT, but the details of implementation may be sufficient even if there is room for improvement. Therefore, for some aspects of the design, the demonstration of BAT will come later.*

Q. Even if all of the components aren't proved, can you make the final decision to emplace it anyway – using a safety risk? *Absolutely this can be used, the regulators may need more information than this, but this is an important aspect to remember*.

Q. Is it true that the EDZ has less weighting that previously thought? *In the license application this is still an important issue to be considered. Nevertheless, the EDZ is often talked about and its significance not understood, which depends on the host rock and what aspect of the EDZ you are considering. It is important to specify which parts of the EDZ are important for specific rocks and designs.*

Q. Do the criteria presented for spent fuel also apply to other waste disposal programmes in Sweden (i.e. SFR, SFL) to maintain consistency? *In the planning work, this approach and thinking is being implemented, but a lot of the design decisions have already been made, especially for the operational SFR, so it is much trickier. In the KBS-3 system, the backbone of the safety is the longevity of the copper canister, so you can base the arguments around this. In other disposal system,s the safety arguments come from many different areas so it's not as easy.*

Q. Three safety function indicators are chosen for the copper canister – can you outline the process of

how these items were chosen? Why and how do you identify the important items? *It is based on the experience of evaluating the KBS-3 system for almost 30 years. You have to consider the FEPs influencing the longevity of the canister and carry out consequence analysis: it's the entire assessment that comes to this conclusion, it's not easy!*

Comment regarding the EDZ issue – in Äspö and Grimsel the EDZ has been studied and shown not to be significant for such crystalline settings, particularly as the onion type EDZ that could lead to continuous flow paths. However perhaps existing fractures through this zone might be changed. In sedimentary rocks, this is different and should be considered and thought about separately.

3. Requirements and preferable features for the selection of host rocks - S. Suzuki, S. Kubota, K. Ishiguro, H. Tsuchi

    - Slide 4 – goal: screening the potential volume available at a site for the emplacement of the waste forms and EBS in specified host rock.
    - Isolation safety function can be fulfilled by selecting a suitable site.
    - Discussion points were identified.

Q. The requirements described include 'capacity and engineering/economical constraints for the repository' – can you explain this? *Both related to the feasibility of the design: so it is possible to locate a suitable setting for the facility – always consider the economical constraints. Engineering is also related to feasibility – e.g. construction or technology constraints.*

Comment to the first discussion point "what is the difference in the concepts of "host rock" from "natural barrier"?" In the Yucca Mountain project the host rock was the formation in which the repository was sited. The natural barrier was split into two areas – the geological formations above and below the repository system.

Q. THMC – do you also consider the R factor (radiological)? *For the engineering feasibility with respect to the host rock it isn't, but for the safety case it will be.* But in terms of the effects on the EBS etc? *It was considered in the design of the over-pack, the considerations are based on H12, which outline these requirements. It is considered but not outlined in the THMC discussion here as direct radiation effects in the far field are insignificant for this HLW concept with a thick steel overpack.*

Q. Components for safety functions – are the repository concepts outlined first and then the safety functions determined? Or are the safety functions determined first? *At first the IAEA approach is used to outline the safety functions i.e. isolation: once a site is selected they will be re-assessed and will depend on the design concept*.

Q. What about gas production and transport? *This consideration is based on radionuclide migration in water, gas will be produced when the canisters corrode, which is considered in the H12 concept. If gas gets into the buffer, it can migrate into the rock without causing significant perturbation. For TRU waste, gas production may cause other effects. The THMC effects discussed here are only for HLW.*

4. Strategy of conceptual model development based on site characterization – H. Umeki

    - Synthesis data flow diagrams are based on a large amount of tacit knowledge, which is

currently not well documented. The ISIS project will aim to capture this tacit knowledge.

Q. There are two parts to the site information – the first part is integration of site understanding and the second part is how to develop a SDM. Why do you combine both of these in this presentation? It means understanding the site characterization but also the system evolution of the site environment over various time ranges? *In our definition, the SDM can cover all these aspects –including also relationships between repository design and PA etc. The SDM should be based on complete understanding of a site: so current work is studying how to integrate all relevant aspects.*

Comment – SDM conventionally represents current understanding of current site conditions. But in order to do this you have to do some investigations of other timescales i.e. paleaohydrogeology to check modeling results etc. Dynamic evolution of the systems should be incorporated.

Comment –agree that it is better to focus on several models, and possible more than one SDM to maintain, recognize and assess alternatives. The completeness of alternative models should also be discussed.

Comment –there is also another side to the SDM which is not mentioned in the presentation: there are always restrictions in terms of time and money so there is a need to focus and prioritize the issues that you need to determine. In real site characterizations this is very important. Presently JAEA are outlining an idealized method, in reality this will be discussed and re-assessed when there is a site in terms of priorities, cost and time.

Q. Who do you envision will be making the SDM? There are tools to link databases, 3D models, etc., but you have to integrate all of the information into one understanding and a machine cannot currently do that. Will this be done by a group of experts in the implementing organization or one leader/super-scientist?! *The SDM is developed as a supporting system by the site team(s); the users will mainly be distributed throughout the implementing organization. The information will be integrated and this helps the users (including the general public) better understand the significance of site characterization output. It was noted that in other programmes, i.e. Yucca Mountain, the whole programme has input into the SDM, therefore a huge amount of information goes into it. Many programmes have a SDM, the definitions of it may differ, and how much confidence is placed on the SDM may also vary.*

5. Possible siting environment description at the surface-based investigation and the shaft excavation phases

    a. Mizunami Underground Research Laboratory, an example of fracture rock - *S. Takeuchi*

Q. When looking at any site, can you look at all the fractures and clearly separate the major fracture zones and the smaller fractures, or are there a lot of intermediate fractures? *It's difficult to determine. There is a few meter-thickness of damaged zone, which could be recognized as major fracture zone. But usually it is difficult to determine the scale of the features from geological evidence from the tunnel. This area needs more consideration.*

Comment – the results show that the features identified can sustain flow and that you can measure transmissivity across the features. This show that the smaller features are connected almost all the way to the large features. If you were to take the measurements and do fracture network modeling, then you would add all the information together and average it. What you are showing is that, if you do one large

scale long-term test, then you will see the larger features - so you don't need to do small scale testing as the small scale features will all be affected by the larger feature that you have already identified. This issue should be discussed further.

b. Horonobe Underground Research Laboratory, an example of sedimentary rock - *T. Iwatsuki*

Q. It was stated that the surface investigations would take 5 years – what are the uncertainties associated with this number? *This is difficult to answer – it's not known and probably very site specific.*

Q. For the R&D galleries how were the projects chosen? Are these the most important issues to investigate if you were to build a repository at a site with features like Horonobe? *We have many models for the hydrogeological, chemistry properties, etc. collected to date, so the actual results from these projects will be used to feedback and verify the technical findings of the first phase in appropriate area undergrounds. Such knowledge would be indispensable for actual geological isolation project.*

Q. In Mizunami, grout is used to control the inflow into the shaft – is this used here? *We already have emplaced low-alkaline cement grout to stop groundwater inflow at the depths deeper than 250 m of ventilation shaft.*

Q. Did the model that predicted the 7x larger inflow take into account this grouting? *At 250m there is a high conductivity zone, this increases the inflow and could be seen when we went through/near this zone. The model does not take into account of grouting explicitly.*

Q. Is the inflow being a factor of 7 higher an uncertainty issue or is it a failure of prediction? *Model predictions were carried out by using several concepts and various input parameters. A factor of 7 out is one of the results. The hydraulic properties of nature can vary by many orders of magnitude. We modify the model by several realistic input parameters close to observed inflow data.*

6. Case studies based on JAEA's URLs site description - An approach of the host rock assessment methodology, focusing on undisturbed rock surrounding the repository - *A. Sawada*

Q. 'Design' is used in e.g. design methodology – what do you mean by the design? Design for what – range of depths etc? *Design could range from the overall repository design to that of the EBS, but at the early stages of the investigation the most important thing is large scale repository design.* The repository design is important – but what is the meaning of the repository design – it includes many things! Which parts? *At the early stage, focus is on the general layout. It's an important question, as what areas of the design you focus on will change what you study.*

Q. There are requirements when selecting the DIA – how does the study relate to this? *There are many requirements that must also be considered. The other presentations have already addressed these, i.e. how to treat hydrogeology and this presentation does not address this directly.*

Comment –the expected uncertainty is discussed: it is important to use the term uncertainty carefully. It may be better to state that you expect a 'degree of uncertainty', and then check and verify this. It is important to be very careful in terminology - before you start, you need to know what you don't know!

Comment on rock classification methodology in relation to the radionuclide retardation. It's a very

interesting point – SKB spent a lot of time and effort to classify the retardation factor of various rock types – how to you integrate all of this information into the calculations of radionuclide transport? Having done that, you have to consider how to validate the results. Japan is not using a single parameter to show retardation performance, but using parameter ranges for assessments.

7. Case studies
    a. Mizunami Underground Research Laboratory, an example of fracture rock - *T. Kunimaru*

Q. What are the objectives of this project and what are the investigation and R&D plans at both URLs?
This will be output from the brainstorming session and will be discussed further tomorrow.

Comment – JAEA's work in Kamaishi is very good and is well reported in the literature. One point was that the flow and transport are highly compartmentalized, which it a very important concept to bear in mind. The whole fracture network won't be active, just certain parts of it.

Q. Different in-situ tracer test – is there systematic series of tests at different scales?
Q. The characterization of host rock will also need consideration of humic acid, carbonates etc. Is the strategy of the characterization of the host rock to measure the concentrations of these, or just the radionuclide migration?
Q. Slide 19 – assume this is an artist's view of how this can be set up – in reality it is not this simple. What are you trying to study?
All of these questions relate to the future work programme, which is the topic for tomorrow.

Comment - When given a site, then you obtain data, make models as detailed as possible, then validate the model against data. Also it is important to check which data was necessary and which data was not obtained. It is then possible to argue that some of the processes are not so important, so when the PA model is developed you can exclude these processes. Which data was actually utilized in the models and which were not necessary for the PA model? This is really important to consider when investigating actual sites – results from URLs should provide output for the actual sites on what is important to measure and investigate. This needs to be made clearer.

Comment - We are not going to have the URLs as repository sites, so we need to develop a more general idea about fractures in host rocks. We are now beginning to understand the fractures in the URLs, which can be useful for future sites. We can distinguish between different fractures, and classify them into groups – this may also help with future repository sites. The problems related with crystalline rocks are being addressed – but there are still areas that could be investigated; for example can we include the repository panels across faults in a real repository site? These types of question are very important and will help to answer narrow down the criteria for the repository.

    b. Horonobe Underground Research Laboratory, an example of sedimentary rock - *K. Maekawa*

Comment – it was indicated that for transport, travel time is an important index for fractured rocks. The radionuclide travel time is important, as the delay times may be large and important. In the sedimentary rocks here, the radionuclide travel time still an important consideration, but the actual water velocity may be less important.

Comment - If using real data from Horonobe, you must consider effects of climate change and changes to groundwater systems, especially by the coast.

Q. For this kind of analysis, did you consider potential repository layout or depth in selecting the host rocks? *Only horizontal layout was used – it is important later to also consider the entire volume of the rock and the effect of depth. The objective of this study is to show a methodology, not evaluation.*

Comment – a good example on how to apply methodologies, but can you foresee any tests that you can do now to validate whether your predictions are true? What are the next steps?
Comment - Indices are used to characterize the rock – if you decide to change the model and do it in stochastic sense – how would this affect your results? Perhaps areas of stability would be illustrated.
Again these questions relate to the future work programme, which is the topic for tomorrow.

General Discussion

- Cannot have site characterization programme without direction – if you don't know what you need to understand, then there is a danger that the programme will undertake unnecessary R&D.
- Hydrogeology has been highlighted many times today – but it is not the only consideration. We need to ensure that the other areas are also being addressed.
- It is not easy to have very specific guidelines when there is no site and no design concept. One way is to advise NUMO on methods, another is to advise the URL's on what they can learn and pass onto a real site (considered tomorrow).
- Intended field activities in URLs to verify or validate PA models have to be carefully considered. In a PA model you simplify processes, geometry and parameters: when trying to explain an experiment you need to consider all relevant components of the system. One should be careful when defining experiments in-situ - you can verify model parameters etc with the in-situ experiments but the detail in the PA models cannot be provided by experiments. This is a very important point, distinguishing 2 types of experiments – those for PA and those for demonstration of understanding and contributing to public acceptance.
- Fracture classification methods are often simplified, often not possible to measure all of the faults in the same way. Have to identify the fracture distribution first
- In-situ tests, lab tests at URLs and models are all dynamic – we need to consider future processes but also scientific development, as this will also advance over time.
- Majority of group has hydro and geology focus – interesting to observe what is being done in other areas of the industry, i.e. waste forms. There are similarities in the development process, particularly for new waste forms and new engineered barriers. First they try to understand what will occur in a specific environment, then they make models and validate them, then they work to develop a testing procedure when they actually have waste forms, effectively to check the performance of the waste form. The SDM development process is very similar, which is beneficial from both the implementer and regulator point of view. Nevertheless, the link between such models of system understanding and the PA model is still not clear. Regulator confidence may be improved by a more detailed interface, but this requires to have a better established concept design and site.
- The safety functions that the geology provides need to be more clearly stated. The interfaces between the EBS and geology need to be clear.
- URLs provide the data and lines of evidence to support the safety case. Integration of

information and arguments for safety cases from URLs should be utilized. The last PA model is now 20 years old: a key question may be the extent to which new URL data can support production of a new PA model.

- Aim is to help JAEA design the next phase of URL experiments? Experiments are currently based on H12, where we know which parameters are important – although these may have associated uncertainties. In designing the next generation of experiments, can't base them on H12 – need to advance into unknown areas.

Appendix 1

October, 7th (Thursday)

Topical status overview: Developing practical approaches to assess geological structures influencing repository design, operational procedures or assurance of operational / post-closure safety

Chair; Johan Andersson

10:15-10:30 Welcome address (15) *H. Ishikawa (JAEA)*

10:30-10:50 Introduction of the goals, format and expected output from this workshop (10+10) *K. Miyahara (JAEA)*

10:50-12:00 Presentation of the leading experiences of URLs and Repository projects

1) Sedimentary rock (20+15) *S. Vomvoris (Nagra)*

2) Fractured hard rock (20+15) *J. Andersson*

12:00-13:00 lunch

13:00-13:30 Requirements and preferable features for the selection of host rocks (20+10) S. Suzuki, S. Kubota, K. Ishiguro, H. Tsuchi *(NUMO)*

13:30-14:10 Strategy of conceptual model development based on site characterization (25+15) *H. Umeki (JAEA)*

14:10-15:10 Site description at the surface-based investigation and the shaft excavation phases

1) Mizunami Underground Research Laboratory, an example of fracture rock (20+10) *S. Takeuchi (JAEA)*

2) Horonobe Underground Research Laboratory, an example of sedimentary rock (20+10) *T. Iwatsuki (JAEA)*

15:10-15:30 Coffee break

15:30-17:00 Case studies based on JAEA's URLs site description

An approach of the host rock assessment methodology, focusing on undisturbed rock surrounding the repository (20+10) *A. Sawada (JAEA)*

Case studies

1) Mizunami Underground Research Laboratory, an example of fracture rock (20+10) *T. Kunimaru (JAEA)*

2) Horonobe Underground Research Laboratory, an example of sedimentary rock (20+10) *K. Maekawa (JAEA)*

17:00-17:30 Discussion

October, 8th (Friday)

Chair; Ian McKinley

10:00-10:45 Rapporteurs' summary and synthesis (30 + 15) *I. McKinley & H. Takase*

Structured brainstorming (in groups, using an argumentation modelling approach) *All*

- Develop host rock requirements on engineering and long-term safety
- Classify the host rock structures for stepwise identification of suitable rock volumes due to practical measurement techniques
- Illustrate practical feedback from requirement evaluation to site characterisation, design and modelling strategy

10:45-11:00 Introduction and allocation of participants to groups

11:00-14:00 Group work (coffee & sandwiches available)

14:00-15:30 Presentation of group output

15:30-16:00 Summary & wrap-up

Appendix 2 List of Participants: (40～50)

1) Foreign organisations (～10)

Bilateral collaborators with JAEA

- Nagra: Stratis Vomvoris, Irina Gaus
- LBNL: Chin-Fu Tsang, Kenzi Karasaki
- UCB: Joonhong Ahn

Consultants

- Ian McKinley
- Johan Andersson

2) JAEA (～20)

3) Other Japanese organisations (～20)

NUMO, JNFL, CRIEPI, RWMC, JNES, AIST, Private companies….

Professors…..

Consultant

- Hiroyasu Takase