THE NEW CONCEPTUAL MODEL IN BODA HLW/SF PROJECT, S-HUNGARY

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Abstract

Boda Claystone Formation (BCF) is a middle-Permian, overconsolidated, highly indurated sedimentary formation that has been considered as potential host rock for final disposal of the Hungarian HLW/SF. Between 1994 and 1999 an extensive characterisation programme was performed using URL-based methods in a site which was the world's deepest URL at that time. Following the obligate closure of the URL, a systematic site-selection programme was started at 2003 covering the whole known extension of BCF (>150 km^2). Because of the last long-term conceptual plans of characterisation programme created at 1994, the Hungarian Public Agency for Radioactive Waste Management (PURAM) initiated a systematic revision. This work started at September 2007. The new conceptual model helps to review the projects and their connections to the surface and subsurface survey, URL, implementation, operation and closure of repository.

Key words: BCF, conceptual model, knowledge management

Introduction

The Boda Claystone Formation (BCF) had been investigated as a target area of geological disposal of radioactive waste since the early 90s. Multiple reasons of the preliminary selection were the following:

- The horizontal and vertical dimensions of the BCF, one of the main part of the 4 000-5 000 m thick Permian (280-190 My) sedimentary sequence of the West Mecsek Mts. consists consolidated terrestrial – fluvial – lagoonal pelitic and chemical sediments, are approx. 150 km^2 and 700-900 m respectively, and hence, geometrically favourable.
- BCF has been deposited below of the uranium ore-bearing sandstone formation having been mined for 42 years. Utilising the facilities and infrastructure of the uranium mine, the formation was explored very quickly at the depth of 1 050 m.
- Because of the huge amount of information collected from BCF and its geological environment by the exploratory tunnel (URL from 1994-1999) and the underground boreholes drilled from the uranium mine, the knowledge of BCF was much higher than any other potential formations in Hungary.

Although, this preliminary selection seemed quite good, country-wide screening, which was performed in 2000 (BIT Ltd by Kovács and by Haas, 2000), had to confirm this choice.

Site selection

The first step of two-step country-wide screening was the elimination of the inadequate formations using some soft criteria, like geometry, localisation and hydrodinamical behaviour. During the next stage, detailed analysis of previously non-eliminated formations was carried out (Table 1).

Table 1. **Evaluation table of formations by selection suitable HLW/SF host rock** (BIT Ltd by Kovács and by Haas, 2000)

Formation				
Considerations	**No.**	**Type**	**Weight (1 to 5)**	**Value**
Geometrical suitability of formation				
Horizontal area of formation with adequate thickness	1.1.	quantitative	3	
Lowest horizontal expense	1.2.	quantitative	3	
Horizontal area of formation with adequate thickness regarding the limiting factors	1.3.	quantitative	5	
Stratigrafical thickness of the formation with suitable horizontal area	1.4.	quantitative	4	
The thickness of the formation with suitable horizontal area in the investigated depth range	1.5.	quantitative	5	
Primary confinement performance of the formation and its geological environment				
The complexity of potential host rock and its geological environment	2.1.	qualitative	5	
Direct evidence of subsistent isolation in geological timescale (or the lack of it)	2.2.	quantitative	5	
Average permeability of the main rock (intact matrix)	2.3.	quantitative	5	
Incidence and importance of tectonical events affected on the development of coherent flow pattern	2.4.	qualitative	4	
Incidence and importance of interbeddings affected on the development of coherent flow pattern	2.5.	qualitative	4	
Incidence and importance of other postgenetic discontinuities caused by physical-chemical influences (e.g. dissolution, channeling) affected on the development of coherent flow pattern	2.6.	qualitative	4	
Incidence and importance of bioturbation affected on the development of coherent flow pattern	2.7.	qualitative	4	
Average permeability of regional discontinuities which are most unfavourable for the nuclide transport processes	2.8.	quantitative	5	
Influence of recent stress regime on the self-sealing processes	2.9.	qualitative	5	
Relationship between the regional flow pattern and the potential host rock	2.10.	quantitative	5	
Hydrogeological character and possible role of overlay and underlay rocks in the safety concept of the site	2.11.	qualitative	3	
Recent Eh of primary porewater	2.12.	quantitative	5	
Recent pH of primary porewater	2.13.	qualitative	4	
Sorption and exchange capacity of the rock matrix of the potential host rock	2.14.	qualitative	5	
Sorption and exchange capacity of the filling material of the hydrodinamically most unfavourable discontinuity	2.15.	qualitative	5	
Natural gas occurrences in the potential host rock and their affect on radionuclide transport	2.16.	qualitative	3	
Primary microbiological activity and its affect on the radionuclide transport	2.17.	qualitative	3	

Table 1. **Evaluation table of formations by selection suitable HLW/SF host rock**
(BIT Ltd by Kovács and by Haas, 2000) (Cont'd)

Formation				
Considerations	**No.**	**Type**	**Weight (1 to 5)**	**Value**
Secondary confinement performance of the formation				
Occurrence and incidences of non-recultivated boreholes and other underground structures and their affect on the target zone	3.1.	qualitative	5	
Extension of excavation disturbed zone (mostly in hydraulical respect) in the intact host rock	3.2.	qualitative	4	
Extension of excavation disturbed zone (mostly in hydraulical respect) in the discontinuities, which principally weaken the isolation properties	3.3.	qualitative	5	
Possibilities for the elimination of axial flow patterns in EDZ and demonstrability of it	3.4.	qualitative	5	
Oxidation and corrosion influence of brine on the different type of radioactive waste, waste package and engineered barriers	3.5.	qualitative	5	
Thermal stability of host rock in the neighbourhood of HLW/SF	3.6.	qualitative	5	
Radiation stability of host rock in the neighbourhood of HLW/SF	3.7	qualitative	4	
Influence of drying caused by excavation and ventilation on the mechanical and hydrodynamical parameters of host rock	3.8	qualitative	4	
Stability and degree of alteration of hydrochemical parameters affected on the isolation potential by the influence of mining (pH buffer capacity, spreading of oxidative zone)	3.9.	qualitative	5	
Stability of host rock as a geological barrier against the geochemical and anthropogenic effects caused by mining (solubility, influences of hypersalinity, tolerance for acids and alkalines, etc)	3.10.	qualitative	4	
Thermal conductivity of the host rock	3.11.	quantitative	5	
Influences of antropogenic microbiological activity on the geochemical and transport parameters of host rock	3.12.	qualitative	4	
Long-term stability of the formation and its geological environment				
Evaluation of temporal variability of hydrogeology in geological past	4.1.	qualitative	4	
Slow crustal movement's velocity, direction and probable long-term affect on the known flow patterns of the investigated area	4.2.	qualitative	5	
Evaluation of seismicity of the investigated area	4.3.	qualitative	5	
Probability of re-activation of faults and fracture systems in the investigated area	4.4.	qualitative	5	
Influences and results of the probable geodynamical events on the isolation behaviour of host rock and the long-term working of geological barrier	4.5.	qualitative	5	
Jeopardy of volcanism in the investigated area on the basis of quaternary and recent volcanic activity	4.6.	qualitative	5	
Features of the rock body as a host media of the technical facility planned for long lifetime				
Theoretical possibility for constructing the repository with needed capacity in the investigated depth interval	5.1.	qualitative	5	
Geotechnical aspects of shafting and drifting	5.2.	qualitative	3	
Long-term behaviour of surrounding rocks of drifts and shafts	5.3.	qualitative	5	
Oxidation and corrosion influences of brine and weathering on the corrosion of different type of applied materials and equipment	5.4.	qualitative	5	
Retrievability of HLW/SF during the post-closure phase	5.5.	qualitative	5	
Possibility for constructing of surface facilities of the repository	5.6.	qualitative	3	

Table 1. **Evaluation table of formations by selection suitable HLW/SF host rock**
(BIT Ltd by Kovács and by Haas, 2000) (Cont'd)

Formation				
Considerations	**No.**	**Type**	**Weight (1 to 5)**	**Value**
Features of the rock body as a host media of the technical facility planned for long lifetime				
Factors and processes jeopardising the long-term stability of the surface facilities and shaft structures of repository	5.7.	qualitative	4	
Geothermal gradient of the investigated area and the *in situ* rock temperature in the investigated depth	5.8.	quantitative	3	
Flooding possibilities during the operation of the repository	5.9.	qualitative	4	
Natural radioactive element content of the host rock	5.10.	qualitative	2	
Social, political and economical effects of the site-characterisation programme and the possible establishment of repository				
Average density of population in the investigated area	6.1.	quantitative	4	
Social acceptance of the results of site characterisation	6.2.	qualitative	5	
Recent degree of prospection	6.3.	qualitative	5	
Estimated construction and operation costs including the transport costs of HLW/SF	6.4.	qualitative	5	
Influence of site development on the recorded and potential mineral resources	6.5.	qualitative	5	
Influence of site development on the economics and land use of the region	6.6.	qualitative	4	
Influence of site development on the human environment	6.7.	qualitative	2	
Possibilitiy of employment of skilled manpower	6.8.	qualitative	1	
Environmental effects of the site-characterisation programme and the possible establishment of repository				
Possible influences of research and the establishment of the repository on the protected/securable geological environments	7.1.	qualitative	4	
Possible influences of research and the establishment of the repository on the protected/securable natural environments	7.2.	qualitative	4	
Possible influences on environmental protection of the operating surface facilities	7.3.	qualitative	3	
Possible influence of pollution of subsurface waters on the operation of repository	7.4.	qualitative	1	
Evaluation (sum of values)				**0**

As the result of the detailed analysis the BCF has approved the best potential host rock for disposal of HLW/SF and the surface research was able to begin in a 45 km^2 area. This was designated from the known extension of BCF using only geometrical considerations and divided into three different blocks (Figure 1).

The repository model

Because of the last long-term conceptual plans of characterisation programme created in 1994, the Hungarian Public Agency for Radioactive Waste Management (PURAM) initiated a systematic revision. This work started in September 2007 under the leadership of MECSEKÉRC Ltd. For systematic overview of the processes and their evolution in time a new model was created which is shown in Figure 2.

Figure 1. **Three blocks of BCF** (Kovács, 1999)

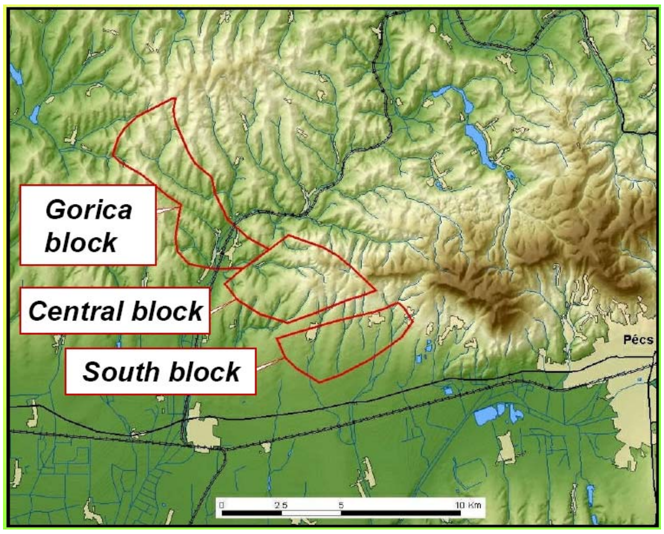
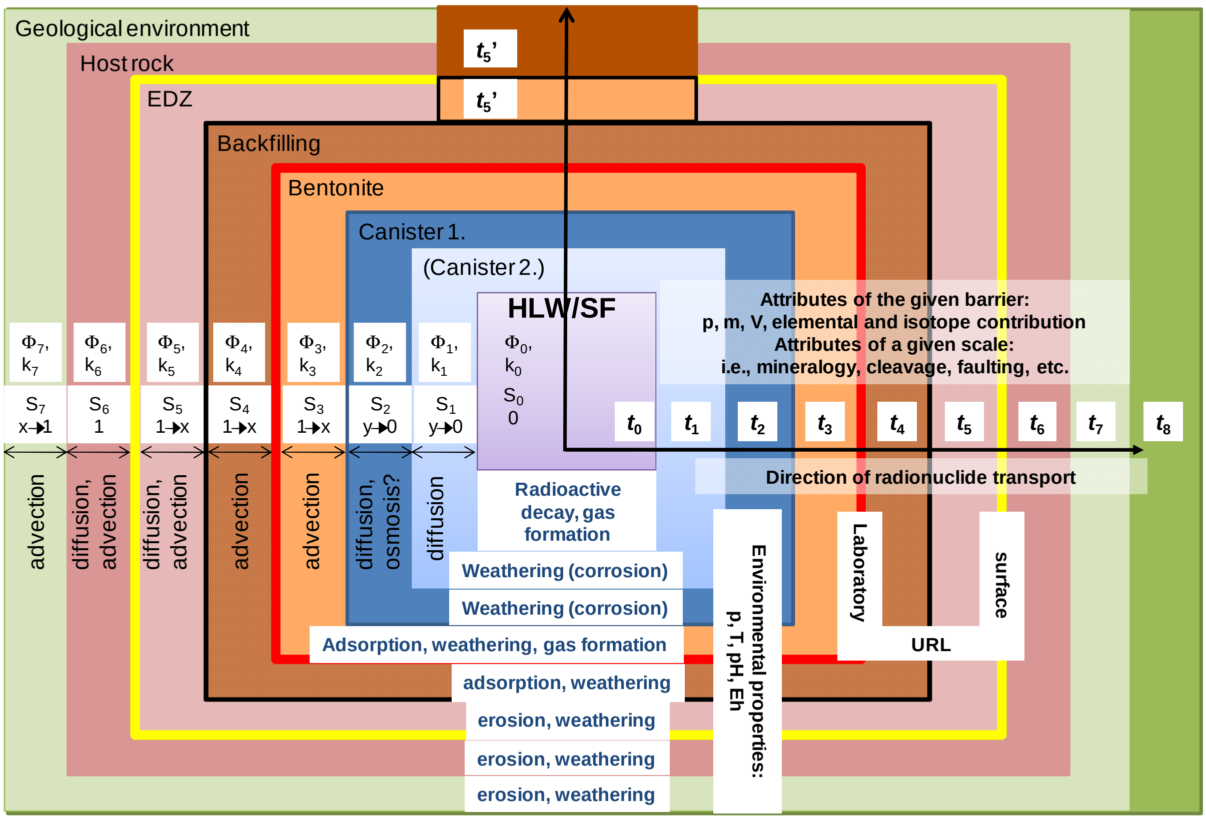


Figure 2. **The new conceptual model of BCF Project**



The basis of the model is the temporal radionuclide transport of HLW/SF to the biosphere through different artificial and natural barriers. The following nest of barriers (box model) can be defined: the HLW/SF is surrounded by a canister or container (1st barrier), which is embedded in a bentonite or other material with high adsorption capacity (2nd barrier). The bentonite could partly be in direct contact with EDZ because of the imperfect contact with air or brine or with backfilling (3rd barrier). The backfilling is in a direct connection with EDZ (4th barrier), which is the damaged part of the repository (5^{th} barrier) and surrounded by different aquiferous layers (6^{th} barrier) being in direct contact with biosphere, and hence with the human environment. Every barrier has specific, scale-dependent (e.g. fractured porosity, mineralogical inhomogeneity, radioactive series etc.) and general properties (e.g. hydrodynamical, geotechnical, chemical etc. characteristics). These characteristics can be changed in time depending on the change of pressure, temperature, water saturation and concentration. The transport characteristics (diffusion, advection etc.) as well as chemical reactions being active between two barriers and in the inner parts of barriers can also be predicted. Supposing that the radionuclide-transport tends to move toward the biosphere, the actual properties of a given time period should be considered in a model. In a particular time, the speed of radionuclide transport is determined by the most effective properties of the given barriers. This model can be used for:

- Enumerating the features of the site.
- Indicating all the properties and processes to be studied either in laboratories or *in situ*, as well as the irrelevant ones in the given situation and/or time interval (FEP).
- Estimating the effect of different disasters and unexpected events (acceleration of transport).
- Gaining the available and required information from the beginning of the research to the closure of the site (information and knowledge management).

This model is thought to be a general-purpose one, in any nuclear waste repository project it is worth being embedded to a human social and technical structure.

The pillars

Although this model was quite good to overview the processes, their evolution, the knowledge base and partially the FEP in case of repository, it doesn't show the circumstances which act on designing the repository and make the site accepted. Hence, the model had been inserted into the social environment. The social environment from the point of view of repository could be divided into 3 parts: the legal and technological environment, the safety – and environmental – assessment, and the informatical background (information and knowledge management). The legal and technological pillar is responsible for revision and update of data the datum, design the site and the conviction of the social environment (PR) see in Figure 3. The safety and environmental assessment is responsible for "systematically analysing the hazards associated with the facility and the ability of the site and designs to provide the safety functions and meet technical requirements"(IAEA/NEA, 2004) (Figure 4). The informatical background, which means not only informatics, but also expert activity, ensures the safety data acquisition and handling, the background information of datum (metadatabase), the knowledge base of the site and related information (analogues), and the visualisation of results (3-D presentation, guides, etc) (Figure 5). For collecting, managing and using this amount of data a Unified Information System (UIS) has been implemented containing GIS database, Relational Research Database (RRD) and Research Portal (RP), which has to be used by all contributors of this project. The Integrated Report System (IRS) helps users in collecting information from different sub-databases, visualising the objects from where the given data came in the reconnaissance map and presenting the area in 3-D. Simultaneously IRS can give short information and metadata, as well. The development of this system is in progress.

Figure 3. **The "REVISION" pillar**

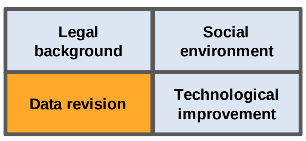


Figure 4. **The "Safety and Environmenta Assessment" pillar**

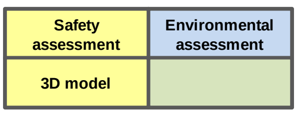
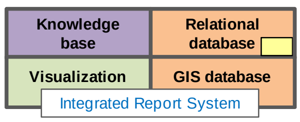


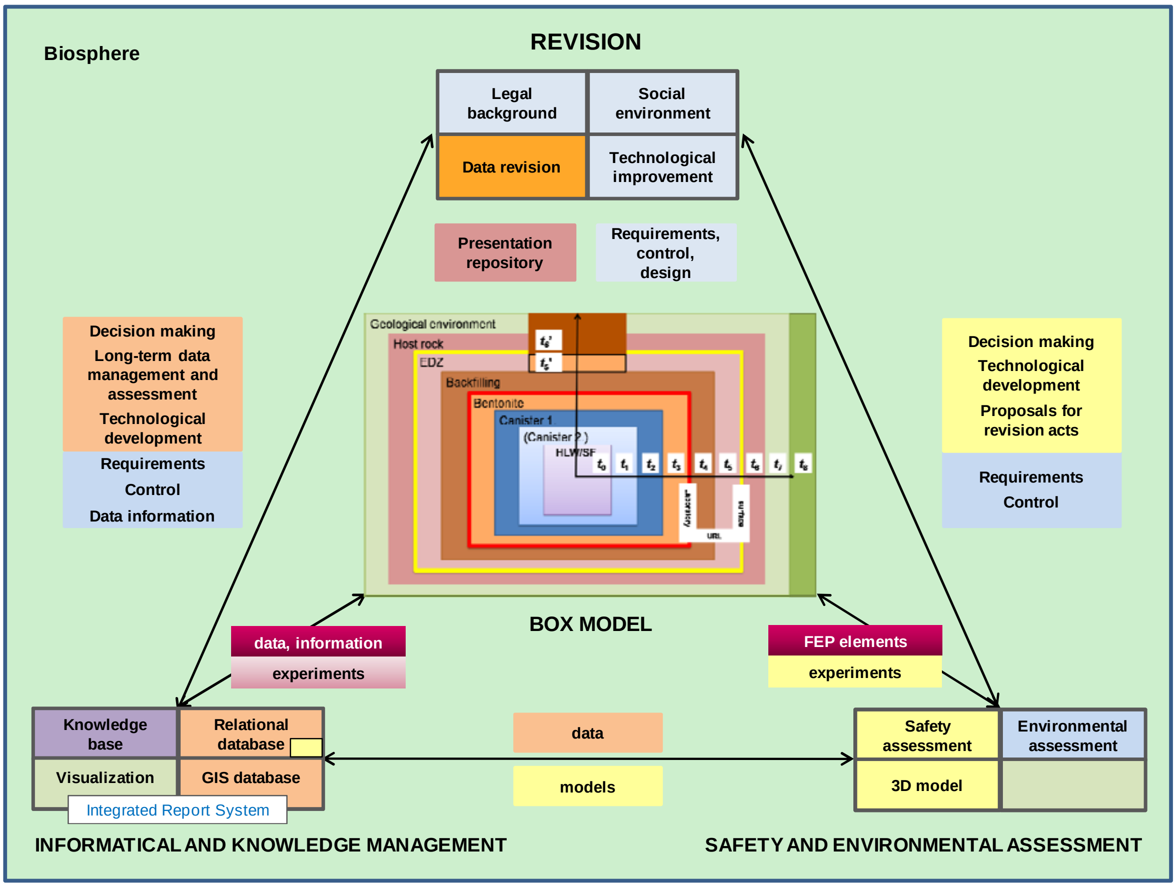
Figure 5. **The "Informatical and Knowledge Management" pillar**



The network

The network between the model and pillars is unequivocally definable (Figure 6.). In the centre of this system could be found the model that is changed in different stages of research and the complexity of the model is growing with time. The informatical background comprises the relational and GIS database, the knowledge base and the visualisation system. In this pillar the main accentuation is given to the data of modelling and safety studies. Another task is to support the decision making with reports and visualisation. It is also very important to demonstrate the project to the general public, and to manage the long time knowledge and information preservation. The role of the safety assessment is to analyse risks in long time interval, indicate the problems and set task, as well as help the decision making. The assignments of the social and technical environment to make decisions, revising the technological, informatical and legal background *quasi* continuously and building own requirements in the safety assessments and informatics during designing the repository. Depending on the phase of the project, all the pillars get information from the repository (model), monitoring and control the processes, and it demonstrates the project.

Figure 6. **The network between model and pillars**



Conclusion

The goal of the new conceptual model of the BCF Project was to overview the processes, features and events during the evolution of research, operating, closure, and post-closure stage of repository and but also applicable for:

- Enumerating the knowledge, and hence, the gaps in knowledge.

- Overview the social background and its effect on the project.
- Optimising the possible scenarios (events and their effects in time) with regard to the evolution of processes.

Because of the symmetry, the main advantage of this system is that any element (pillars and model) can be moved to the centre, in this way the actual state of the project can be studied from a given point of view.

Aknowledgements

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