

Actual state of the site characterisation programme of the Boda Siltstone Formation

A Bodai Aleurolit Formáció telephely-jellemzési programjának jelenlegi állapota

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(4 Figures)

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Tárgyszavak: Bodai Aleurolit Formáció, telephely minősítés, nagy aktivitású hulladék, Magyarország, végleges elhelyezés, Rövidtávú Program

Abstract

Since 1993 an extensive geological research programme has been carried out in an attempt to characterise the BSF. The aim of the programme is to prepare for the final disposal of HLW produced at the Paks Nuclear Power Plant. At the beginning of 1999 the final report was completed the professional results of the three-year programme (Short-Term Project). On the basis of the investigations done so far, there is no evidence demonstrating the unsuitability of the BSF (indicating that no further research is necessary). Besides the introduction of the most significant facts of final report, the article gives a brief description of the three-year-project, including the economic, regulatory and public acceptance background, project-specific professional circumstances, and the possibility for making further progress.

Összefoglalás

1993 óta kiterjedt geológiai kutatási program irányult a Bodai Aleurolit Formáció megkutatására, aminek célja a Paksi Atomerőműben keletkezett nagy radioaktivitású hulladékok elhelyezésének előkészítése. 1999 elején elkészült a három éves (rövidtávú) program szakmai eredményeket bemutató zárójelentése. A már elvégzett kutatások alapján semmi olyan bizonyíték nem merült fel, ami kizárná a Bodai Aleurolit alkalmasságát vagy megkérdőjelezná a kutatások folytatásának szükségességét. A zárójelentés lényegének ismertetése mellett röviden leírjuk a három éves programot, beleértve a gazdasági, a szabályozási és a lakossági elfogadási hátteret, a program-specifikus szakmai körülményeket és az előrelépési lehetőségeket.

Introduction

At on time, the high level radioactive waste (HLW) produced during the operation of Paks Nuclear Power Plant (NPP) was delivered to the Soviet Union. As an outcome of the changed political situation Hungary has had to reconsider its back-end strategy. As a temporary solution the first module of an Interim Modular Vault Dry Store was constructed on the site of the NPP.

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However, no final decision was made on the back-end strategy. This is why, at present, we are still not familiar with the composition, form and quantity of wastes to be disposed. However, there is a total professional consensus on the necessity for the final disposal of some part of the HLW (as the last phase of all options and depending on its type and quantity with regard to the preferred option).

Since 1993 surface and URL-based siting for HLW disposal in Hungary has concentrated on a Permian Mudstone called the Boda Siltstone Formation (BSF). It is situated in SW Hungary, west of the city of Pécs. The detected extension of this candidate host formation exceeds 150 km², and its maximal thickness is between 700–900 metres (Fig. 1). The last three-year stage of the preliminary site characterisation (called the Short-Term Project) was finished at the beginning of this year and no evidence was discovered which might exclude the potential suitability of this candidate host formation. However, the information derived from the first investigations do not allow a final conclusion to be made on the geological suitability of the BSF. Nevertheless, a country-wide screening (performed in 1997) did not discover either a similar or a better candidate than the BSF for HLW disposal.

Organisational, regulatory and public-acceptance background of the Short-Term Project

The whole three years of the Short-Term project can be characterised as a transition period: the financial and organisational conditions have changed several times. The new Nuclear Energy Act resulted in considerable and positive legislative changes; however, these can only be utilised during the next research period. At the end of last year a new agency was established (Public Agency for Radioactive Waste Management – PURAM) for determining the radwaste management policy of Hungary and organising the R&D and PR-activities. The costs are covered by the Central Nuclear Monetary Fund.

Licensing the establishment and operation of a URL located in the area of an uranium mine was relatively simple. During the preparation of the research plan there no requirements relating to the special task set up by the authorities. The relevant executive decree was published only at the end of 1997. In spite of changing the legal environment, the investigations were under the continuous control of the authorities and independent expert-boards. The best international knowledge served as a basis for this control.

People in this area have been living together with uranium mining for more than 40 years. Consequently, the establishment and operation of an URL has not caused fear on the part of local inhabitants. We believe that this positional advantage can be maintained by conscious and continuous PR activity.

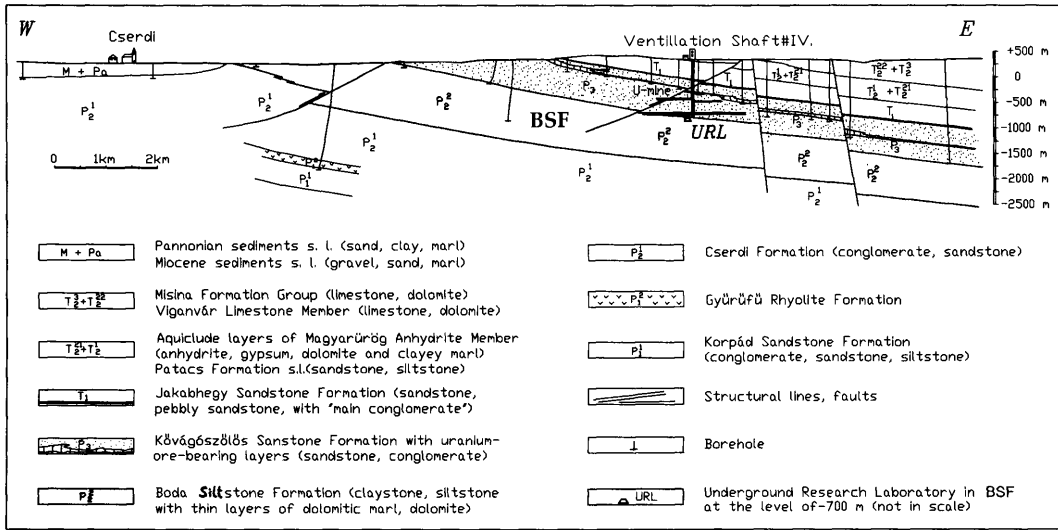


Fig. 1 W-E geological cross-section of Western Mecsek Anticline

1. ábra A Nyugat-Mecseki Antiklinális Ny-K-i irányú metszete

Project-specific professional circumstances:

As a result of geological exploration connected to the uranium ore mining, BSF is located in an area of the country which has undergone the most detailed study. Prior to the first research phase the amount of information on the BSF and its geological environment exceeded, with respect to the degree of the knowledge-level, any other potential formation in the country.

The geometry of the potential host formation presented a very advantageous situation for the investigations. In the framework of the Short-Term Project the geological and hydrogeological investigations on the weathered surface – including the drilling activity and the extended in situ URL-based – experiments could be performed and evaluated simultaneously. The spatial variability of the parameters – mainly the depth dependence – were described numerically. Using surface geophysics and drilling research methods, the investigation could also be extended to the formation underlying the BSF as well. These possibilities, in combination with laboratory test programmes and evaluation-interpretation activities including geomathematics and numerical modelling, provided site-specific efficiency for collecting and evaluating information.

The URL in the BSF is located at a depth of more than 1050 m depth below the surface (Fig. 2). The virgin rock temperature exceeds 50 °C. The pore water pressure is about 90 bars, and the maximal principal rock stress component exceeds 30 MPa. Several special thermal-mechanical-hydraulic processes and effects on the geological barrier could also be studied and understood under relatively high rock-temperature, rock-stress and water-pressure conditions.

The exploratory-tunnel and the exploratory boreholes drilled from the tunnel allow in-situ studies to be made of almost all the respective rock types and beds of the BSF, given that they have different geological, hydrogeological and geotechnical features. However, the geometric extension of the investigations has so far been limited, so the potential migration pathways from a repository in the BSF to the biosphere will be situated in similar rock types and beds (Fig. 3).

The largest professional disadvantage for the waste management project is that Hungary has still not decided the final back-end strategy. For this reason a lot of essential information is needed for planning the investigations; furthermore, information for the performance assessment of site is still missing.

Key issues of the Final Report

The plan for the Short-Term Project was prepared in co-operation with AECL. Its main aim is to provide essential information for answering the following questions:

- Geological evolution (sedimentation, diagenetic and post-diagenetic processes, tectonic history, etc.).
- Geometrical suitability, homogeneity, possibility of spatial extrapolation of the results.
- Primary isolation capabilities of the formation.

- Excavation-modified isolation properties (i.e. the processes of the Excavation Disturbed Zone).
- The rock body as a host media for the technical facility planned for a long life-span.
- Long-term stability and the possibility for the punctual extrapolation of the results.

To fulfil this aim in the framework of the Short-Term Project more than 100 different investigation methods were applied. The Final Report of the project was

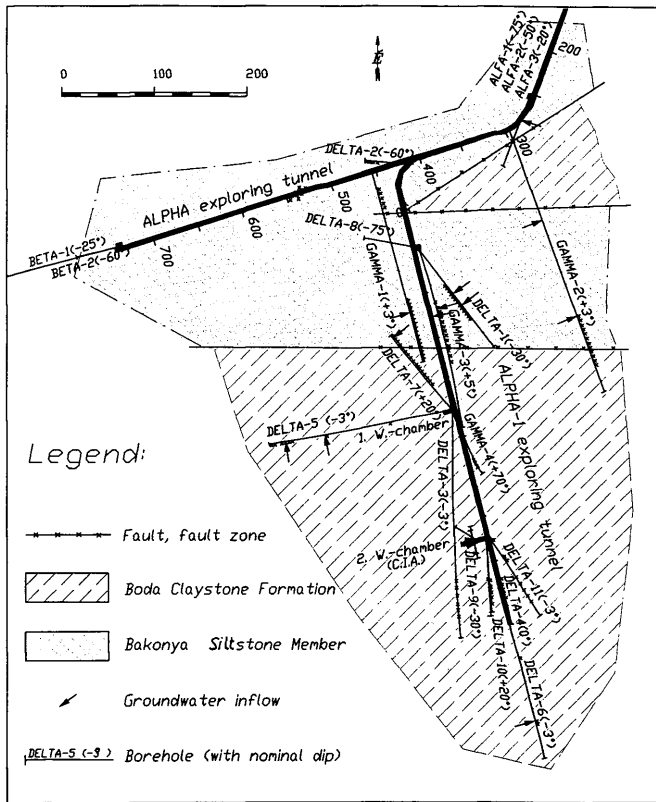


Fig. 2 Map of the exploring tunnels and more important underground boreholes of URL

2. ábra Az URL feltáró vágatainak és a legfontosabb földalatti fúrások térképe

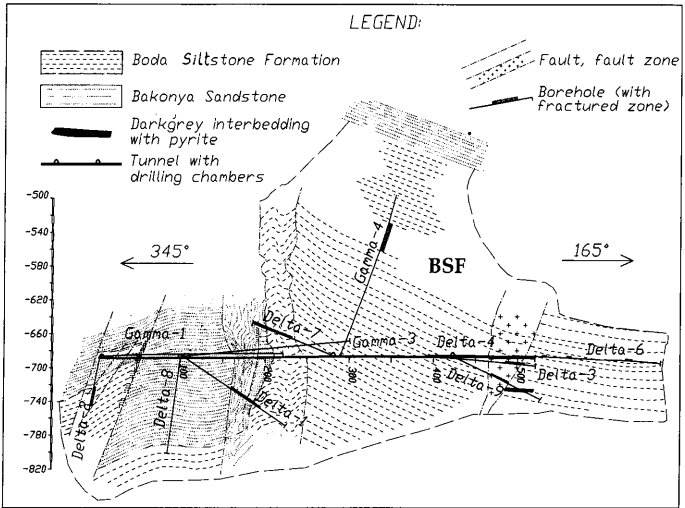


Fig. 3 Geological cross-section in the vertical plane of the Alpha-1 exploratory tunnel

3. ábra. Az Alfa-1 kutatóvágat földtani szelvénye

completed during the second half of last year. It consists of 9 Volumes (about 1600 pages in total). The following sections provide brief information on the key issues of this report.

Geological evolution

The modern features of the BSF have evolved through geological processes. Sedimentation, diagenesis as well as the most important geodynamic-tectonic events were analysed accurately with special regard to stress and thermal history. The study was extended to the geological environment of the whole South-Trans-Danube. As a result of systematic and integrated evaluation of the collected data we were able to identify the history of the BSF and the structure of the formation was also determined.

Sedimentation took place in a special alkaline lacustrine environment, under extreme climatic and geochemical conditions. During the late period of diagenesis the layers of the formation were buried at a depth of 3.5–4.5 km, under temperatures between 160–180 °C. This situation has resulted in the over-consolidated character of BSF.

Hitherto, relics of four tectonic periods each with different features have been discovered by the detailed surface and underground geological mapping.

Geometric suitability

As an outcome of geological evolution the detected extension of the candidate host formation exceeds 150 km² and its thickness varies between 700–900 metres. Investigations focused on the central region, covering 55–60 km². Inside this area the homogeneity of the confinement properties were also verified by geomathematics. This analysis excluded an approximately 150 metres thick bottom series with uncertain confinement-properties and a weathered 30–50 metres thick outcrop area.

The presence of abandoned cavities of closed uranium ore mines represent the most important site-specific risk factor. Therefore the repository must be located at a safe distance from these cavities. This requirement, and the protection zone around the inhabited areas, reduce the potentially suitable area for a repository. In spite of the limitations, the potentially suitable zone has a 30–35 km² horizontal extension and a 600 m vertical one. Information provided by the Short Term Programme has not made it possible to determine the location and the depth of the repository within this potentially suitable zone.

Primary confinement capabilities

Virgin confinement features of the BSF are determined by a 35–50% clay-mineral content, dominantly Illite (30–40%). The Chlorite content in the clay accounts 5–10%. Smectite content is generally below the detectable limit, but smectites also occur in outcrops in the weathered zone and inside the deformation band of faults.

The bulk-porosity of the rock-samples is low (0.6–1.4%). The water-conductivity of intact rock bodies determined by in-situ hydrodynamic tests varies between 10⁻¹¹–10⁻¹³ m/s. These test results refer to diffusion-dominating transport conditions.

Given the paleo-stress state, it can be deduced that the self-healing processes must have been a general phenomenon prior to late miocen-pliocen period. Recently, at a 1000 m depth, almost all the tectonic zones have been characterised as having permeability-values of 10⁻¹⁰ m/s. Younger faults occur only rarely; these younger faults produce visible water inflows. Their permeability varies between 10⁻⁸–10⁻⁹ m/s. Slow, advective pollutant transport should be assumed to take place along these young faults.

Of course, the above-mentioned hydrogeological characterisation of the different tectonic generations is only a preliminary result. At present, we do not have sufficient information to understand properly the fundamental flow and transport processes concerning numerous different types of discontinuity. In-situ tracer tests were not performed during the Short-Term Project.

Several in-situ and laboratory test methods provided favourable information with regard to the modern geochemical environment, the stress field and the migration of radioactive-elements/ions as well. Preliminary 2D and 3D hydrodynamical models were applied and validated by the data collected in

connection with the surface-based hydrogeological mapping for the study of the regional, intermediate and local flow-patterns.

Excavation-modified confinement properties:

Special attention was paid to the determination of physical, geochemical and microbiological changes in the Excavation-Disturbed Zone.

Besides the numerous separate in-situ test series, it is really important to emphasize the so-called Complete Instrumental Array (Fig. 4; here the mechanical, hydraulic and thermal state-transitions within the EDZ caused by tunnelling were recorded simultaneously. The results were interpreted in an energetically uniform system. According to the results of 3D-coupled numerical modelling the average, quasi-isotropic permeability of EDZ increased by up to 5×10^{-8} m/s. Pressure changes extended over 20 metres according to back-calculations. This back-calculated value fits in with the measurements done in other areas, even in the earlier tectonic zones.

A special self-healing effect of (technical origin) was discovered in the course of the tunnelling in connection with the Complete Instrumental Array. As a result of this there has been a rearrangement of the stress field and the location of the joints.

Chemical and geochemical features of the pore water flowing towards the cavities have been modified considerably. For example, the TDS increased to 6–8 g/l, and was oxidised. Microbiological investigations were started in the frame of the Short-Term Project.

Geotechnical features

The unexpectedly favourable geotechnical features for exploring tunnels can also be attributed to the mineralogical-petrographical properties. Namely, the absence of swelling clay minerals and the presence of microcrystalline Silica and Albite have given considerably better strength properties to the BSF in comparison to another potential argillaceous host rock formations (Albite content varies between 20–45%). The stress state is also advantageous. In spite of the great depth the openings have been shown to be stable in the long-term, inside the tectonic zones as well. This has been verified by deformation-monitoring. The only problem was a rock-falling effect which had a gradually decreasing intensity. This effect terminated within 1–2 weeks after the excavation. However, a slow creep was also recorded over the following 6–8 months.

The tunnels crossing the BSF were supported primarily with rock bolts. The volume of the subsequent maintenance was very small.

The waste-generated near-field heat processes have not been studied yet; presumably, the BSF has a relatively low heat sensitivity due to its thermal history.

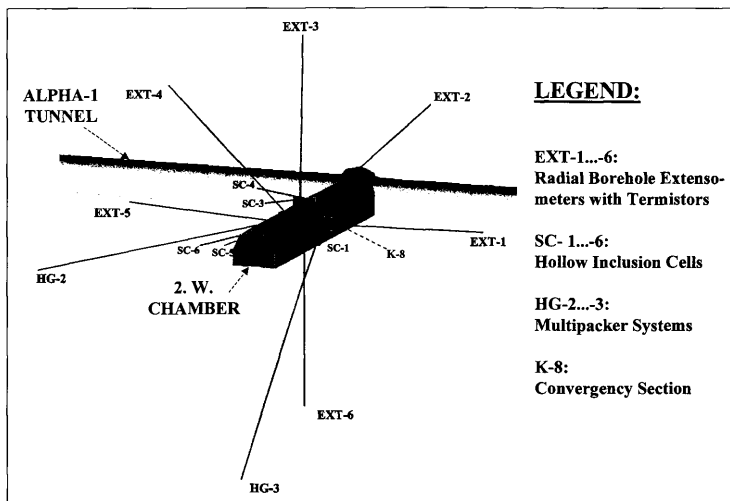


Fig. 4 Geometry of the installed measuring devices in the Complete Instrumental Array

4. ábra. A mérőműszerek térbeli helyzete a teljes műszer-rendszerben

Long term stability

Two more considerable subtasks were performed concerning the possibility of the extrapolation of the results with respect to time and long-term risks in the framework of the Short-Term Project:

- Cognition with regard to the velocity and direction of slow crustal movements (using geological mapping and geophysical methods) and their influence on the confinement properties.

- Data acquisition for the assessment of the long-term seismic risk of the site.

The nature and velocity of the modern geological processes, hitherto known in the surroundings of the BSF, allows a conclusion which shows that considerable changes of the hydrogeological and flow system will not occur over the next 100 000 years. Site-specific surplus risks, in comparison with other potential sites of Europe, were not identified.

Conclusion

According to the results of the investigation which went on intensively for seven years – which extended into the most significant tectonic zone of the area,

applying in-situ methods – no evidence was found which could exclude the suitability of this potential host formation. The geometric size of the BSF, its confinement and the geotechnical features examined so far, can be regarded as favourable and suitable for the planned purpose, even when it is compared with the situation in other countries.

Possibilities for stepping forward

The performance of the Short-Term Project represents a great advance towards final, integrated characterisation of the BSF as a potential host formation. But it's really clear, that this period was only the first step. Information of essential importance is still missing.

Characterisation programmes of the candidate/reference argillaceous sites of EU and OECD countries are supported by strong international co-operation. Such co-operation would be essential important for Hungary in order to avoid professional, licensing and public acceptance problems.

The next step would be to work out the plans of the long-term programme for the characterisation of the BSF using the information gathered during the last three years. For the implementation of a successful long-term project several measuring devices and methods, as well as evaluation and Quality Assurance/Quality Control methods should be developed further or obtained. Some of the most important items: so far the first version of the performance-assessment has not been carried out. On other hand, the more developed performance-assessment – necessarily taking into consideration the disposal concept – is to be planned later and some other recently lacking information has to be obtained (the results of in situ tracer tests, biosphere-parameters).

For an effective site-characterisation the investigation methods should be optimised in accordance with all professional goals. URL-based, in situ methods are indispensable for answering some of the above-mentioned questions. Due to the essential questions, which can only be answered with underground investigations, it is really necessary to preserve the possibility of underground research. Therefore a proposal has been completed which targets the development of a research station by upgrading and extending the existing URL and separating this from the uranium mine which is to be closed. This upgraded URL was intended to serve the long-term project and it could have fulfilled its task with whole functionality. Yet, although all professional, economical and public-acceptance arguments supported the proposal on continuing the URL-studies here, the governmental decision terminated this project.

However, the cancellation of the project does not imply a rejection of the potential suitability of the BSF. The characterisation programme is likely to continue by using surface-based investigation methods. Nevertheless, at present the schedule of these activities is uncertain.

Due to Hungary's efforts to join the European Union, this professionally and politically critical issue is to be treated in such a way that it is internationally acceptable and conforms to EU norms.