CHAPTER 12

HUNGARIAN APPROACH FOR FINAL DISPOSAL OF HIGH LEVEL RADIOACTIVE WASTE

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12.1 INTRODUCTION

In Hungary, nuclear power provides a substantial portion of the total electricity produced in the country. The Paks Nuclear Power Plant (NPP) contains four VVER-440 nuclear reactors, each capable of producing 460 MW of electricity. This plant regularly produces more than 40% of the electricity consumed in Hungary. There is currently no plan to increase the electrical generating capacity of Hungary, but if future additions to nuclear-based electrical generation were to be made, they would significantly increase nuclear power's share of electricity consumed.

Fuel for the Hungarian NPP, as is the case for all other East European VVERs, has been supplied in the past by the ex-Soviet Union. As part of the fuel agreement, the Soviet Union was obliged to take back and dispose of all spent fuel (using another supplier would leave Hungary with the problem of high level waste disposal). In the past, Hungary was glad to have the problem of disposal dealt with in this way. Now, although contracts for fuel supply and return are still in force, Hungary is less certain how long this "comfortable arrangement" will last.

The shipment of spent fuel for 1992 was ready for dispatch but has been delayed due to problems with transport through the Ukraine. It is understood that Russia, while they may still be prepared to take and process spent fuel, will now send the high level waste back to Hungary for disposal. The cost of such disposal will be charged to the Paks NPPoperation and, therefore, future costs are likely to increase.

This likely interruption of the current spent fuel disposal route may lead to a fairly immediate problem in Hungary. The spent fuel ponds will be totally full by the end of refueling in 1995. It is therefore necessary for a new program for removal of fuel from the ponds to be implemented before the 1996 refueling to avoid the necessity to shutdown the reactors.

The current intention is to build an interim storage facility to hold spent fuel after it has completed five years of cooling in the ponds. In 1993, a decision was made to construct a Modular Vault Dry Store at Paks based on the GEC Alsthom design, which was first used at Fort St. Vrain (USA). At some point in the future, the fuel would either be packaged for direct disposal, or reprocessed outside the country and the high level vitrified waste returned to Hungary for disposal.

As insurance against the waste remaining in Hungary or being returned after reprocessing, it is highly desirable to proceed by planning for possible disposal of spent fuel some 50 years or more in the future.

Normally, the siting of any HLW repository should be started by screening the entire country for suitable locations. However, as a result of preliminary investigations, Hungary has a geological formation that is considered at least as a national "treasure." This is a siltstone, an Upper Permian red-colored formation, covering some 150 sq. km. Its thickness from borehole drilling is about 800-900 m.

Based on preliminary assessments and technical considerations, the use of the Permian Boda claystone formation in the Mecsek Mountain area is being considered for HLWdisposal. To evaluate the suitability of this formation as a location for a waste repository, investigations have started with the technical assistance of the Atomic Energy of Canada, Ltd.

12.2 SPENT FUEL CHARACTERISTICS

The radioactivity and heat output of a spent Paks NPP fuel assembly is similar to spent fuel assemblies from other pressurized water reactors for the same burnup. However, the geometry and components of these fuel assemblies are different from those of fuel assemblies from other pressurized water reactors. Two types of fuel assemblies are used in the Paks NPP, the operational assembly and the follower part of the absorbers. Both types have a hexagonal cross section with a key dimension across the flat side of the hexagon of 144.2 mm.

Each assembly contains 126 fuel rods in a hexagonal array and surrounded by a hexagonally shaped tube. This tube is fabricated from an alloy containing 97.5% zirconium and 2.5% niobium. The fuel rods consist of UO_2 pellets contained in a tube made from a 99% zirconium and 1% niobium alloy. The inside and outside diameters of the cladding tube are 7.72 mm and 9.15 mm, respectively. The assembly top head, nozzle units and spacers (10 per assembly) are made from stainless steel. The overall length of the operational fuel assembly is 3,217 mm and the active length is 2,470 mm. The total weight of the operational assembly is 215 kg, which includes 120.2 kg of fissile material. The differences between the Paks NPP fuel assembly and a typical pressurized water reactor fuel assembly would not preclude direct disposal of the spent Paks assemblies in a repository.

Assuming a 30-year operational life for each reactor unit and no change in the fuel cycle, 15,316 spent fuel assemblies will be discharged from the Paks NPP.

12.3 OPTIONS FOR SPENT FUEL MANAGEMENT

Paks NPP Ltd. had two contracts with the Soviet Union (now Russia): one, on the governmental level, addressing the fresh fuel supply; and the other, a private, low-level contract covering the shipment of spent fuel back to Russia. Furthermore, in April 1994, a new protocol was signed between the governments of Russia and Hungary complementing the earlier governmental contract. The protocol confirmed that the fresh fuel for Paks NPP will be supplied by Russia, and Russia is ready to receive Hungarian spent reactor fuel. In spite of the new protocol, the Hungarian government was not able to ship spent fuel to Russia in 1994. Because of current difficulties and the fact that the protocol does not contain a guarantee that Hungarian spent fuel will be returned to Russia, there is a very low probability that long-term shipment of Paks NPP spent fuel to Russia will be realized. Therefore, it is assumed that in the long term, the return of spent fuel to Russia will not be possible.

The Hungarian government and Paks NPP Ltd. had to consider developing a program to manage the spent fuel assemblies from the existing Paks NPP and from any future nuclear power placed in operation in Hungary. This program would be similar to spent fuel strategies of other small VVER operators, such as the Czech and Slovak Republics and Finland. It is also consistent with the current international tendency of each country operating nuclear reactors to develop an independent high-level waste management strategy for storage and disposal.

The options available to Hungary for the management of spent fuel include: reprocessing, direct disposal or a deferred (wait and see) decision between these two options. In the latter case, the spent fuel would be stored in Intermediate Spent Fuel Store (ISFS) for approximately 50 years. Each of these options, for the backend of the fuel cycle, requires a geological repository for disposal of HLW. For the reprocessing option, the waste forms would be vitrified fission products, plutonium waste (if mixed oxide fuel is not acceptable) and eventually fuel assemblies (when the fissile material can no longer be recycled). For the direct disposal option, the waste form would be one or more types of spent fuel assemblies in containers. For the wait and see option, the waste form will depend on whether reprocessing or direct disposal is selected as the management strategy at the end of the storage period.

12.4 GEOLOGICAL FORMATIONS TO BE EVALUATED

The long-term management of high-level radioactive waste has only recently become an issue in Hungary. Concurrent with the attempts to return spent fuel to Russia, a decision was made to erect an ISFS at Paks NPP, and this facility is now being constructed. The decision concerning the spent fuel management option at the end of the interim storage period has not been made.

Because of the geology of Hungary, only a limited number of potentially suitable disposal sites for high level waste are available within the country. One of these is a Permian claystone deposit called the Boda Claystone Formation near the city of Pécs in Southwestern Hungary. The uranium mine is located in a Permian sandstone formation close to part of this claystone formation. The formation has also been investigated as a potential host for low-level waste disposal. When high-level disposal became a concern for Hungary, the Mecsek Ore Mining Company proposed that the Boda Claystone Formation, of Permian age, be investigated for its suitability as host rock for a Hungarian nuclear waste repository. Information about the lithology and structure of the overlying sandstone has been collected during uranitun mining over the past 40 years.

Useful information about, the groundwater flow conditions of the sandstone has also been collected from the mining operations. About 50 boreholes were drilled from surface to investigate the uranium deposits in the sandstone. Four boreholes have penetrated the underlying Boda Claystone Formation to considerable depths (a few hundred meters). Two of these boreholes were drilled in 1991 to 1200 m depth to obtain information about the vertical characteristics of the claystone over most of its thickness. In 1993, a specific study program was started within the framework of the National Waste Disposal Program to further examine the Boda Claystone Formation. The following activities have been carried out under this program:

- several underground core drilled boreholes;
- an access tunnel (280 m length), about 80 m into the Boda Claystone);
- systematic sampling in the tunnel;
- geological mapping (and documentation) of the tunnel walls including the subsequent tunnel faces;
- hydrogeological boreholes, corresponding measurements, and collection of water samples;
- rock mechanics measurements during the excavation of the tunnel, and after completion;
- geophysical measurements;
- geochemical, mineralogical and geomechanical laboratory investigations in affiliated institutions; and
- laboratory testing of water samples.

So far, the investigations from this exploratory tunnel and two previous deep surface boreholes, BAT-4 and BAT-5, indicate that the Boda Claystone Formation is a highly compact rock unit of very low overall permeability ($<10^{-10}$ m/sec). Based on an understanding of the faults, fractures and their relative movements from studies of the overlying uranitun bearing sandstone, it is believed that most of the faults in the claystone are sealed and filled with calcite, barite, gypsum and clay minerals. The accumulated data suggests there are only a few widely spaced fault zones in the Boda Claystone Formation. Methods to determine the location, orientation, extent and hydrogeologic characteristics of these faults are currently being assessed.

The objective of all the above studies was a preliminary characterization of the Boda Claystone Formation as a potential host rock for a high-level radioactive waste repository. The results obtained so far confirm the geochemical and hydrogeologic suitability of the claystone for HLW disposal and favor further investigation of this claystone formation. This is particularly the case in view of the fact that there is not a wide choice in Hungary of suitable geological formations (size and quality) for a HLW repository.

12.5 GEOLOGICAL STRUCTURE OF THE AREA

The Western Mecsek Mountain Permo-Triassic inlier is bounded to the north, south and east by three left-lateral, strike-slip faults. These enclose gently eastward-plunging (~10°) folds. A broad anticline, flanked by smaller synclines, contains the detailed area of interest, and is bounded to the north by a 30° south-dipping reverse fault, and to the south by a 50° north-dipping reverse fault. Both of these faults strike east-northeast and are paralleled by lesser reverse, normal and oblique-slip faults with high intermediate to subvertical dips that are connected by splays in some cases. A further set of east-dipping normal faults strike north-northwest, perpendicular to the anticlinal axis.

The stratum of interest, the Boda Claystone Formation, is a silty claystone at least 800 m thick. This is a lacustrine deposit set within a sequence of fluvial sandstones all of which were deposited in a semi-arid climatic environment. The claystone is bounded beneath by a conglomeratic sandstone (Cserdi Formation) concordantly gradational over 100 m. It is bounded above by another conglomeratic sandstone (Kövágószölösi Formation), which contains the uranium deposits mined by Mecsekurán Ltd. This upper contact is gradational over 40 m but is discordant in places.

The Boda Claystone Formation is exposed at the surface over an area of about 20 km^2 near the village of Boda. In order to evaluate this formation, it will be necessary to study the entire unit, down dip from the surface outcrop towards Shaft IV (transportation and ventilation)

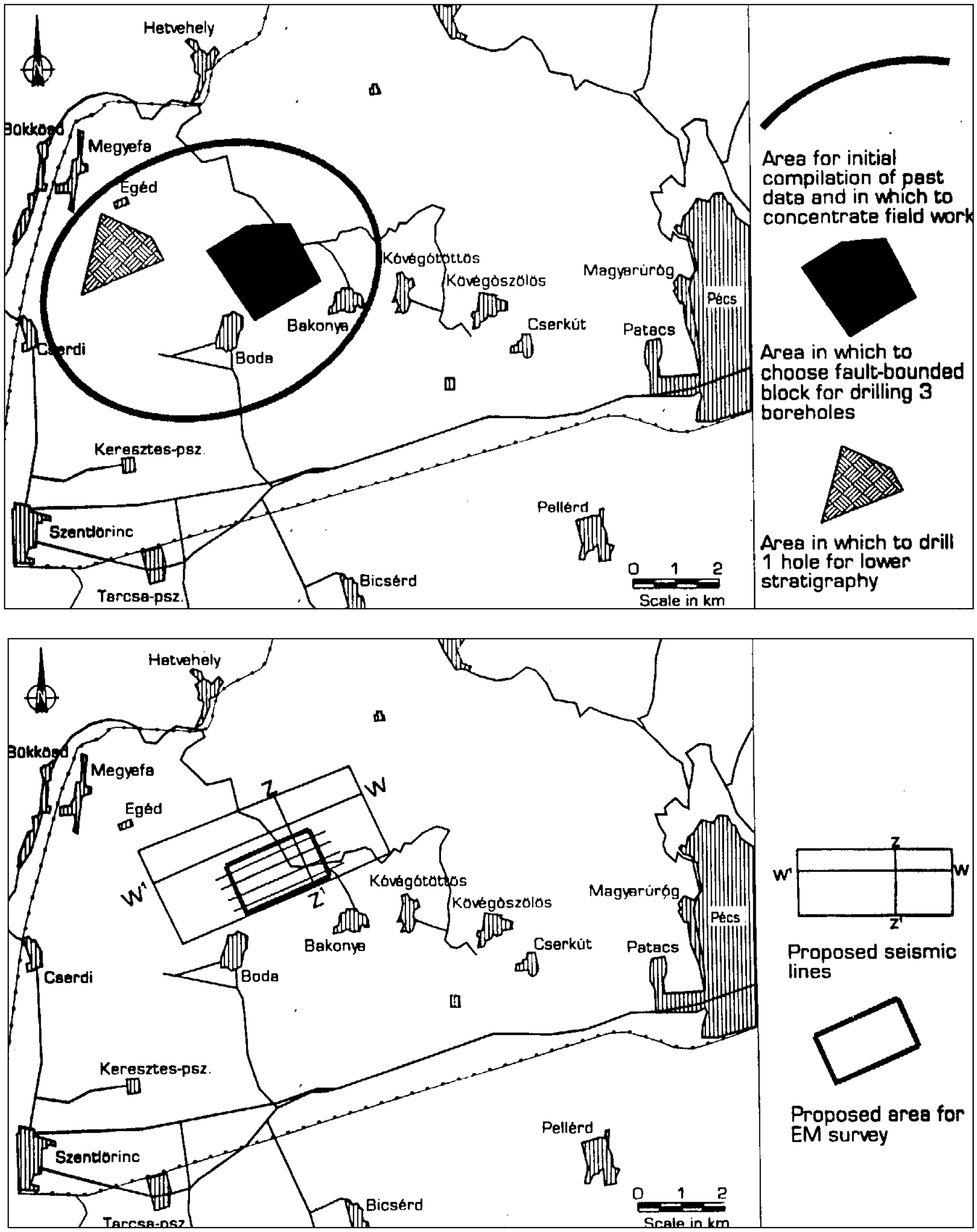

Figure 12.1. Proposed surface geological and geophysical investigations.

and Shaft V (transportation). This will define a candidate area of approximately 40 to 50 square kilometers, as shown in Figure 12.1. The tentative regional study area is marked on Figure 12.2 by boundary IJKL. It is estimated to contain about 40 cubic kilometers of Boda Claystone Formation with an average thickness of 800 m, in which exploration can be carried out for the selection of possible disposal sites. The northern boundary could be extended further to I'J', if necessary.

Being a lacustrine deposit, the Boda Claystone Formation, probably varies lithologically over much larger distances laterally than vertically. It contains several stratigraphic members in the vertical, stratigraphic

Figure 12.2. Geological map showing proposed study area.

section, without obvious boundaries but with slightly different properties. In general, the chemical composition is quite uniform throughout stratigraphically; it is composed of quartz and feldspar with a high clay content and a significant amount of fine grained hematite. The claystone has a higher quartz content in the upper part of the formation, and the matrix contains up to 10% primary dolomite in layers 1-10 cm thick. The claystone is generally oxidized but a few unoxidized layers are evident in the geologic logs of some boreholes drilled from the surface. These layers can be at least up to 20 m thick.

Knowledge of the location, extent and hydrogeologic properties of fault zones and fractures within the Boda Claystone Formation is of critical importance in selecting a suitable location for a high-level waste repository. Based on geologic mapping of the overlying sandstone in the uranium mine, it is clear from a WSW-ENE cross-section that the 700 to 900 m thick claystone stratum may be offset by a number of WSW-ENE trending fracture zones. This claystone may also be affected by north-south trending subvertical faults. From recent mapping in the "Alpha" exploratory tunnel at the 1100 m depth in the mine, two dominant sets of mesoscopic fractures have been observed in the Boda Claystone Formation. These fractures are filled with calcite and clay minerals, and are apparently sealed to groundwater flow. It will be essential to develop a much more detailed understanding of the lithological, hydrogeological, geophysical, geochemical and geomechanical conditions of this claystone and adjacent formations and crosscutting faults to develop performance assessment models in order to evaluate different areas of the Boda Claystone Formation for a high-level waste repository.

12.6 CHARACTERIZATION PROGRAM OUTLINE

The region of the Boda Claystone Formation that has been identified as a potential siting area will require a comprehensive characterization program to select the preferred disposal site. The existence of an access tunnel from the uranimn mine into the claystone at 1100 m, provides an opportunity to characterize some potentially important vertical structures that could act as groundwater pathways through the claystone. Thus, the characterization program for this particular area in the Boda Claystone differs from the program that would be developed for a site or formation where there is no existing underground access.

The characterization activities are part of a long-term program that could take 7 to 15 years to complete before a final disposal site in the Boda Claystone is approved. However, there is a need to determine whether or not a long-term program should be initiated in the Boda Claystone. The objective of this short-term program is to consolidate the information that has been gathered during 40 years of mining related activities in this region, collect new information from selected target areas and develop a comprehensive geotechnical model for the region.

Very slow groundwater movement or diffusion within pores and fractures in the Boda Claystone Formation, surrounding the site eventually chosen for the repository, is expected to provide an effective barrier to the release and migration of repository contaminants. Adsorption on the clays in the rock matrix and fracture fillings is also expected to be a major factor in retarding the contaminants. Thus, a thorough knowledge of the groundwater flow and diffusion paths through the claystone and adjacent rock formations is required to determine the likely pathways for radionuclide migration from potentially suitable repository locations to the human environment.

The main problem in characterizing the candidate area is to choose a location for the repository such that the hydrogeologic and geochemical conditions will delay and impede the release and migration of repository contaminants to the accessible human environment. This will involve both surface and underground evaluations of the Boda Claystone Formation and the overlying and underlying sandstone formations in the candidate area.

A major emphasis in the site characterization program would be on developing an understanding of the physical and chemical conditions of the groundwater pathways in the claystone and determining how these conditions interact with the fluid flow conditions in the overlying and underlying rock formations. Another emphasis would be on determining any future change or disruptions that could affect these flow conditions. Still another emphasis would be on determining how any future changes or disruptions, during the construction or operational stages of the repository or during the time frame of concern for long term assessments of performance, could affect groundwater movement in the Boda Claystone Formation.

Because this claystone has a very low primary permeability, yet is situated in a geologic setting that has been faulted and fractured, it will be necessary to determine the geometry and hydraulic properties of the fracturing at different scales within the formation to develop an understanding of the groundwater flow conditions. The groundwater regime in the overlying Permian sandstone has been dramatically affected by the uranium mining activity, and therefore, it will differ from original conditions. The disturbed hydrogeological regime in the overlying Permian sandstone may have altered the groundwater conditions in the Boda Claystone, and these effects will also need to be evaluated.

The data gathered from these activities and data already collected by Mecsek Ore Mining Company, and other Hungarian institutions can be used to select a preferred site for a HLW repository within the potential siting area. There are two possible alternatives that would affect the characterization program. They are:

- the preferred repository site is close enough to the uranium mine so that the site can be accessed from the mine; or
- the preferred site is located such that a new access from the surface would be necessary or preferred.

If the preferred repository site is chosen near the location of the uranium mine in the overlying sandstone so as to be accessible from the mine, the local characterization program would include some surface boreholes to provide information immediately around the repository. However, the majority of the characterization program would probably be conducted underground from currently existing and new access tunnels.

If the preferred repository site is located away from the uranium mine where new access from the surface is required or preferred, the initial characterization will be mainly from the surface into the undisturbed portion of the Boda Claystone Formation and will progress logically to underground characterization activities as new access to the underground is constructed.

Under normal circumstances, a characterization program to select a preferred site for a HLW repository would initially be surface based, followed by an underground evaluation program at the preferred site using exploratory shafts and tunnels. This is the approach recommended by Davison et al., for the Canadian nuclear fuel waste disposal concept. In the case of the Boda Claystone Formation, the underground environment has already been accessed by an underground tunnel at 1100 m depth from the adjacent uranium mine, thus providing the opportunity to conduct further underground characterization activities, if there are both cost and technical advantages to doing so.

Because the area presently under consideration as a nuclear fuel waste disposal site is relatively large (40 km^2), both surface-based and underground characterization programs are recommended. One of the normal advantages of a surface-based characterization program is that the underground environment is relatively undisturbed prior to excavation. This allows background measurements of the undisturbed conditions at the site to be obtained from a network of surface-based characterization boreholes, and allows the construction of a detailed model of the groundwater regime at the site. Predictions of drawdown resulting from shaft sinking and the excavation of exploratory tunnels can be made and compared to actual measurements to assess the accuracy of the hydrogeological model.

For the characterization of the Boda Claystone Formation, the fact that many of the potential faults extending down from the overlying sandstone formation are sub-vertical means that they are better accessed and instrumented using sub-horizontal boreholes that are easily drilled from the underground. However, there are significant operational problems associated with conducting characterization activities from the underground. Firstly, there may be limitations on the drilling of long exploratory boreholes underground due to technical factors. The drills presently used underground at the uranium mine are apparently limited to drilling boreholes to a maximum length of 300 m. Suitable equipment to drill longer, and perhaps larger diameter boreholes would need to be acquired. In addition, the ambient rock temperature at the depth of the present access tunnel into the Boda Claystone Formation is about 45° C. If this exploratory tunnel is advanced further into the claystone, the distance to the closest shaft will increase, and with it the problem of cooling and ventilating the working areas.

The present laboratory tests and measurements from the exploratory access tunnel were finished by the end of 1994. Based on the encouraging results of these characterization activities, further investigation of the Boda Claystone Formation as a host formation for HLW disposal was recommended; there is not an abundant choice of suitable geological formations (size and quality) in Hungary for siting and for economic reasons.

The activities recommended for characterizing the Boda Claystone Formation, both surface-based and underground, have been organized according to discipline and/or activity. For both approaches these include: geological mapping, geophysical surveys, exploration drilling, hydrogeological monitoring and testing, geochemical and hydrogeochemical studies, *in situ* stress determinations, site modeling and model validation, laboratory testing and analyses, and seismic risk analyses.

In addition, it is recommended that full-scale, *in situ* tests be conducted underground in representative geological conditions. Such tests could include: radioactive migration testing, excavation response studies, thermal studies and tests, thermal studies on rock behavior, testing of mining methods related to minimizing the disturbed zone, and ground support methods in the Boda Claystone Formation.

12.7 SHORT-TERM CHARACTERIZATION PROGRAM

A short-term characterization program is proposed as part of the activities being carried out to investigate the suitability of the Boda Claystone Formation as a host rock for a high-level nuclear waste repository. The objective of the short-term study is to gather, analyze and interpret existing and new information on this formation in order to decide whether to begin a long-term investigation of the claystone as a suitable high-level, radioactive waste disposal medium.

The current situation regarding geoscience investigations in the Boda Claystone Formation is as follows. Data from previous investigations carried out during the development of the mine, some going back as far as 40 years, are available. There are also several investigations in progress at the present, and the necessity of initiating some entirely new investigations or repeating earlier surveys, where the results were not satisfactory in the present context, has been recognized. Analysis and interpretation of all of the above described data will be required in order to make a decision on a long-term characterization program. To assist in the compilation of these data, a computerized database will have to be established, so that data are available, on a systematic basis, for compilation, interpretation and modeling.

The field component of the proposed short-term program will consist of surface as well as underground activities. The latter are divided into two phases; the first phase of the underground activities will not include further excavation, whereas the second phase will be based on additional excavation.

There are certain time constraints on the short-term program, due to the governmental decision to close the uranium mine by 1997. All field activities, both surface and underground, must be completed in a two-year period, commencing in May 1995. Analysis and interpretation of field data must be completed within a reasonable time period after March 1997.

The short-term characterization program will concentrate on confirming the important processes controlling groundwater flow and possible radionuclide, transport in the Boda Claystone Formation. Particular attention will be paid to developing an understanding of the occurrence and geotechnical properties of tectonic zones, or fracture zones, within the claystone. Knowledge of the location, extent, hydrogeological properties, geochemical properties and geomechanical properties of tectonic zones and fracture zones within the Boda Claystone in the candidate siting area is needed to develop models of the groundwater flow pathways within the Boda Claystone Formation in order to conduct assessments of the long-term safety and performance of a repository in the claystone.

Investigations carried out over the past 40 years during the development of the uranium mine, indicate that the Permian sandstone overlying the Boda Claystone Formation is cut by a series of inclined fracture zones. Based on geological mapping, these fracture zones may be spaced as close as 50 to 200 m. Evidence from the "Alpha" tunnel, at the 1100 m level of the mine indicates that these fracture zones are water bearing but that the blocks of Boda claystone bounded by these fracture zones are relatively impermeable. There is no information on the occurrence, distribution or hydrogeological and geochemical characteristics of these fracture zones within the Boda Claystone Formation. The short term characterization program involves performing some surface-based characterization studies (including deep borehole drilling) near the outcrop area of the claystone and by performing some underground characterization studies in the existing exploratory tunnel into this formation from the 1100 m level of the uranium mine.

At present, little is known of the faults and fracture network in the Boda Claystone Formation at the depths proposed for the repository. This information can best be obtained by borehole drilling, combined with geophysical surveys and with some detailed geological mapping of fault subcrops if access is available. Also, hydrogeological investigations and hydrogeochemical sampling in the boreholes will be very important components of subsurface characterization. Analysis and collation of existing data through a database will also be very useful.

Because of the time constraint, only a largely conceptual model of the controls on groundwater flow through the Boda Claystone, as opposed to a partly idealized deterministic model, can be developed. Therefore, the surface investigations are to be concentrated in a few areas (at least two) from which a good understanding of the principal factors controlling the flow of groundwater can be obtained.

It is suggested that the surface geological investigations (surface mapping) be confined to the same area as the proposed geophysical surveys. The two principal objectives of surface mapping are to:

1. determine the location and conduct fault-rock characterization for the subsurface projection of faults in the Boda Claystone, especially those that are potential drilling targets. This can be achieved by detailed mapping, from outcrops or trenches, of topography, mesoscopic fractures, rock alterations and fracture fillings. This work will be concentrated in the area in which a fault-bounded block is likely to be chosen as a drilling target.
2. determine the general character and history of ductile, brittle deformation of the Boda Claystone, and decide whether lithologic variation is likely to be important. For example, the bedding attitude data in the underground tunnel into the Boda Claystone from the 1100 m level of the mine suggest crossfolding in the claystone with a NWto NNWplunge. Such zones of folding may be centers for more concentrated mesoscopic fracturing.

Drilling and geoscientific and geotechnical characterization of four deep boreholes from the surface is proposed. Three boreholes are to be drilled to investigate conditions and to characterize the bounding faults within two adjacent fault-bounded blocks within a 3-4 km radius to the northeast of the village of Boda. Borehole depths would depend on the actual location chosen, but two of them should be 500-700 m deep. The third should be at least 1300 m deep and penetrate the sandstone footwall. The fourth borehole is to be drilled approximately two km northwest of Boda within the outcrop of the Boda Claystone Formation. This hole is also expected to be about 1300 m in depth to obtain hydrogeologic information in an area expected to have sparse faulting. This borehole should penetrate well into the footwall and be used to characterize the lower members of the Boda Claystone Formation, geoscientifically and geo-technically.

12.8 CONCLUSIONS AND PROSPECTS

In 1993, the decision was taken to develop a relatively inexpensive access from the existing mine to study the adjacent formations. This involved developing and servicing an exploratory access tunnel from the uranium mine into the Boda Claystone Formation. This exploratory access was completed in 1994. The tunnel has been used to conduct a preliminary research program to study the *in situ* characteristics and properties of the claystone. These data have contributed to assessing the potential suitability of the Boda Claystone for high-level waste disposal in terms of safety assessment and repository design. The results from these preliminary studies have continued to confirm the geochemical, geomechanical and hydrogeologic suitability of the Boda Claystone as a host media for high-level waste disposal in Hungary.

As the Boda Claystone Formation has been identified as a potential high-level waste disposal site, experts are now developing a thorough program to assess its suitability. This will require that sufficient data be gathered on the characteristics of the claystone to select appropriate location(s) for a repository and to complete a safety assessment for a repository at each location. An extensive database of geologic formations exists for the area of the uranium mine, both from the previous surface-based exploration programs as well as from the underground characterization program. Much of information is relevant to understanding conditions in the Boda Claystone beneath the uranium bearing Permian sandstone. The structural information on jointing and fracturing is particularly relevant to the identification of suitable locations for a high level waste disposal repository.

The most probable way for radionuclides, that are sealed in a deep geological repository to reach humans and the environment is by transport in groundwaters through the pores and cracks in the rock surrounding the repository. Therefore, one major requirement in characterizing possible repository sites in the Boda Claystone Formation is to quantify the important processes governing the transport and absorption of radionuclides within the groundwater systems in the rock mass as well as the engineered barriers used in the repository. Groundwater movement in rocks such as the Boda Claystone is mainly controlled by the presence or absence of fractures, the permeability and interconnectivity of these fractures, the permeability and porosity of the unfractured rock, and groundwater pressure gradients. The chemistry of the groundwater, the rock matrix, and minerals within the fractures also govern the potential transport of radionuclides within groundwater. Therefore, the presence of open fractures (joints and bedding planes), fracture zones and processes that can change their hydraulic or chemical properties, must be understood for repository siting and design.

Two underground facilities are likely to be necessary for the characterization of a site and the design of a repository in the Boda Claystone Formation. The first facility is the Underground Characterization and Test Facility (UCTF) that is being started with the construction of the Access Tunnel from the Mecsekurán uranium mine into the claystone. It will be used to provide information on the suitability of the claystone as a repository medium as well as preliminary repository design information, and to train staff, develop methods and study design and safety issues. Because it is located near the uranium mine and the contact between the sandstone and the claystone, it is likely to be in a disturbed environment.

The second facility is a repository characterization facility (RCF), to be located at the preferred repository site, which would be constructed late in the site characterization stage. It would provide access to the repository rock volume for final assessment of the site suitability, and for commissioning and longer-term coupled interaction tests on repository systems and components. It would be incorporated into the repository design so that its excavations would become part of the repository and would not interfere with the repository operation.

The UCTF will be located in a section of claystone that likely has been influenced by the mine construction and operation. In particular, the groundwater pressures, flows and chemistry in the sandstone, and perhaps the claystone, are likely to be affected by the presence of the mine. As there has not been a long-term hydrogeological monitoring program in the sandstone and claystone near the mine, the original groundwater conditions and the magnitude and areal extent of the disturbance caused by mining activities over time are not known.

Without this information, studies and demonstrations that require regional groundwater conditions as a step in planning or in performance and safety related analyses may not be possible with the limited data gathered from the UCTF. These studies will have to planned as part of RCF activities at a preferred repository site where these data can be collected. However, significant groundwater studies can still be done in the UCTF to:

- develop and demonstrate the equipment, instrumentation and procedures for drilling and monitoring groundwater conditions in boreholes;
- install monitoring systems in new and existing boreholes to study the hydraulic connections in fractured rock; and
- observe the pressure and chemistry changes that occur when new boreholes and excavations are done.

These are valuable and necessary studies in preparing for the characterization of a potential repository site, and for the environmental and safety assessments. These studies will also be used to select the methodologies that should be applied in the characterization and assessment studies that will be conducted at the preferred repository site.

Also, it is our understanding that the mine operations have been confined to the sandstone formation. This may make it possible to assess the impact of a large "drain" (i.e.,. the mine in the sandstone and the UCTF in the claystone) on the pore water pressures within the Boda Claystone Formation. If it can be demonstrated that the pore pressures in this claystone have been only slightly affected by the presence of the mine and the development of the UCTF, this information can be used to demonstrate the large-scale low permeability of the claystone, an attractive characteristic for waste disposal. This type of *in situ* information can only be obtained by monitoring the response of the groundwater system to construction of underground excavations such as the access tunnel and the UCTF.

The effects of the mine excavations on the mechanical conditions in the claystone around the UCTF will probably not significantly influence the studies and demonstrations that may be planned for the facility. However, the proximity of the UCTF to the contact between the sandstone and the claystone may have to be considered in analyzing the data from UCTF studies and in extending the results to a potential repository site elsewhere in the claystone.

The second underground facility, the repository characterization facility (RCF), would be constructed at the preferred repository site during the later stages of repository site characterization to conduct tests: (a) to confirm the suitability of the site for disposal; (b) complete the repository design; and (c) refine and test repository systems and components. The RCF design would be integrated into the repository. As the repository site will likely be several kilometers away from the uranium mine and away from any other underground excavations, it should have a relatively undisturbed groundwater environment. In the site characterization program at the potential repository site, the regional characterization and the long-term hydrogeological monitoring would be done prior to any underground excavation so the baseline hydrogeological and chemical conditions would be known. The changes in these conditions caused by additional borehole drilling, and by the excavation and testing in the RCF would be known. The changes in these conditions caused by additional borehole drilling, and by the excavation and testing in the RCF would be measured and could be used to develop and test computer models that will be used to predict the performance of the groundwater system.

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