Underground Research Facility in Highly Anisotropic Rocks, Bukov URF, Czech Republic

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The disposal concept in the Czech Republic assumes the construction of a deep geological repository in crystalline rocks (granites, migmatites). While the in-situ parameters of granitic rocks have been studied extensively by a large number of research facilities, those of highly metamorphic rocks have not, to date, been described in detail. This contribution addresses the current stage of repository development in the Czech Republic together with the construction of and initial geological investigation at the new Bukov Underground Research Facility (Bukov URF).

I. DISPOSAL CONCEPT AND CURRENT STAGE WITH REGARD TO DISPOSAL IN THE CZECH REPUBLIC

The disposal strategy for heat-generating nuclear waste in the Czech Republic assumes the direct disposal of spent fuel in steel-based canisters in crystalline host rock at a depth of 500m. The total waste package inventory will be approximately 6000 containers with spent nuclear fuel and 3000 concrete containers with other radioactive waste. The operational phase of the repository will be 80 years or so and the opening of the repository is planned for 2065.

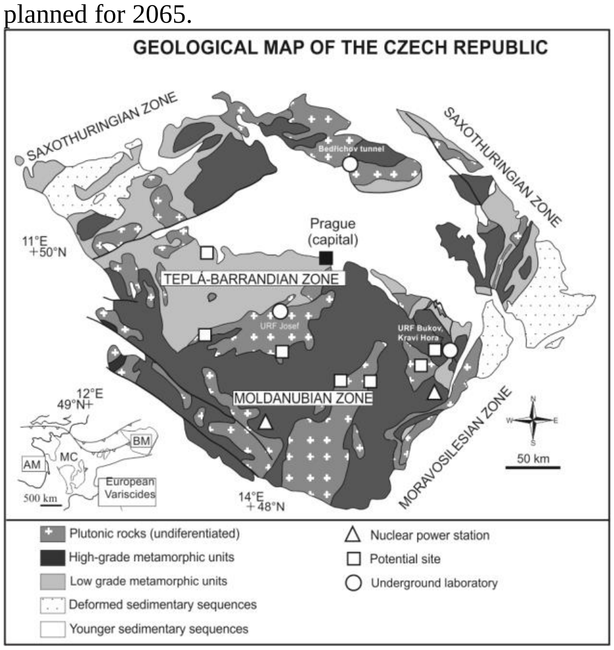

Fig. 1. The schematic geological map of the Czech republic with the localization of potential sites and underground laboratories

I.A. Potential localities

Following initial screening of a number of localities in the early 1990s, RAWRA (The Czech Radioactive Waste Authority) defined 7 areas (Fig. 1) to be subjected to further multidisciplinary investigation. The localities were chosen based on the Swedish concept due to similarities between the geological conditions of that country and the Czech Republic. Six of the localities are located in granitic rock (with a crystallization age of between 515-320Ma) and one is made up of high-grade metamorphic rock (migmatites, granulites). All the potential sites are located in geologically stable environments with a minimum of faults and high levels of predictability in terms of the rock environment.

I.B. Site selection process

Currently RAWRA, in its capacity as the national waste repository authority, is involved in three key projects which are aimed at supporting the site selection process. The first of the projects is dedicated to scientific support for safety assessment evaluation purposes and includes the construction of synthetic geosphere models (e.g. hydrogeological models, structural-geology models, geotechnical models etc.) and the evaluation of the localities in terms of various criteria (e.g. safety, socioeconomic, political etc.). The result will consist of the creation of detailed safety assessment reports for each potential locality. The second project concerns the engineering aspects of the future repository, the stability of the engineered barriers and an initial feasibility study. Both of these projects require primary data that will be provided by the third project called “Exploration of 7 localities, phases I, II, III” which is a classical terrain-based project focused on obtaining primary geological data. Phase I (2014-2016) involves the gathering of surface-based data only (e.g. geological mapping, hydrogeological analysis, geophysics etc.) and will result in a reduction of the number of potential localities to 3 or 4. Phase II (2017-2019) will involve deep borehole drilling for the verification of the geophysical data, and further complex geological investigation work, following which the number of candidate localities will be reduced to 2. Phase III (2020-2025) will focus on providing data based upon which the government will select a final site in 2025. In addition, important primary data for the

Exploration project will be provided by RAWRA's underground generic research program.

II. UNDERGROUND GENERIC RESEARCH PROGRAM

The generic research program is focused on the detailed testing of the crystalline rock concept. Generic laboratories serve as training centers for staff members, experimentation involving mock-up experiments and the development of methodologies for the study of rock conditions in underground environments. One of the most important aspects of generic research consists of the testing of the validity of data collected from the earth's surface and the approximation of such data to depths at which the construction of the repository is envisaged. RAWRA has close connections with three underground research centers: the Josef Gallery, the Bedřichov Water Supply Tunnel and the Bukov Underground Research Facility (Fig. 1).

II.A. Bukov Underground Research Facility - construction phase

The Bukov underground generic laboratory is located in the eastern part of the Czech Republic near the Kraví hora candidate repository site and adjacent to the Rožná uranium mine at a depth of 600m below the earth's surface. From the geological point of view the facility is located in the northeastern part of the Moldanubian Zone of Variscan orogen and composes migmatitized paragneisses with amphibolite layers. The felsic granulites display the same deformational history as that of the nearby Kraví hora candidate locality.

The laboratory is currently under construction and when completed will consist of a 300m-long connecting cross gallery with a profile of $9.2m^2$ leading from the access shaft and the underground facility itself consisting of a 45m-long large-profile chamber and a gallery niche system with a total length of 35m (see Fig 2). Rock bolts will be used to provide support for the underground sections supplemented with yieldable TH arches in areas exhibiting more complicated geological conditions. Two exploration boreholes of 150m have been drilled in the access tunnel for geophysical and hydrogeological monitoring purposes.

II.B. Characterization program

The initial scientific program will concentrate on the characterization of the site from the geological, geomechanical and hydrogeological points of view. The results will serve as input material for synthetic geosphere models which will, in turn, serve for the precise positioning of the various experiments included in the research program. The characterization program will include the following research areas:

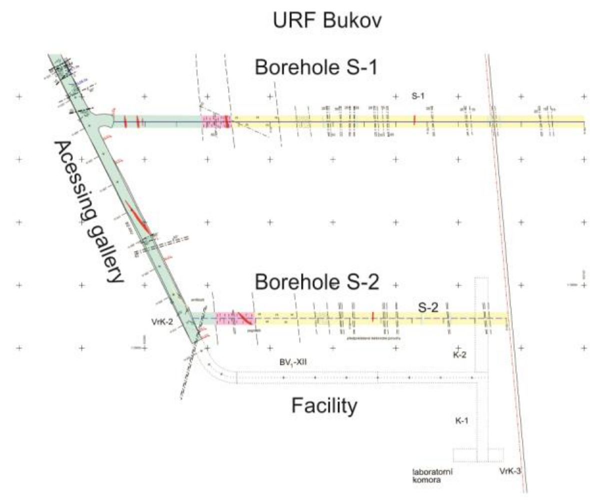

Fig. 2 The final design of the URF Bukov

II.B.1. Complex geological characterization

The application of a range of geological methods will be aimed at obtaining a multidisciplinary description of the host rock in order to assist in determining the optimum location for the performance of the experimental program. Geological characterization comprises geological and structural mapping and the deciphering of the temporal, spatial and thermal evolution of the ductile and brittle pattern. Subsequent more detailed characterization will concentrate on more specialized study fields e.g. the radiometric dating of the fault system, the evolution of micro-fractures within the rock etc.

II.B.2. Geotechnical

The geotechnical program will consist of three specific areas: (i) stress monitoring, (ii) geotechnical laboratory testing and (iii) seismic monitoring. The stress measurements will allow for the prediction of the stability of the rock mass as well as for the determination of stress changes during the excavation process. Geotechnical testing will comprise a range of methods that will serve for initial rock mass characterization purposes and for the provision of input data for further geotechnical modeling. Seismic monitoring will be concerned with the potential reactivation of the fault system during blasting and the identification of any induced seismic activity that might occur as a result of local mining operations.

II.B.3. Drill core analysis

The aim of the drill core analysis program will be to develop methodology to be used in the subsequent deep-borehole research program in 2017; it will involve the application of optical scanner and hyperspectral analysis methods.

II.B.4. Transport properties of the rocks

The determination of the transport properties of the surrounding rock will serve for the laboratory testing of radionuclide sorption and migration from a depth at which the construction of the repository is envisaged.

II.B.5. Hydrogeological properties of the rock mass

An understanding of the behavior of water within the repository system is crucial in terms of safety case considerations. Hydrogeological studies therefore include the monitoring of water influx and the evolution of the chemical and physical properties of water collected from the surrounding rock. Borehole hydrogeological tests, tracer tests and water pressure tests will be conducted during the experimental phase.

II.B.6. Synthetic geosphere models

The application of the methods described above will result in the construction of the following synthetic geosphere models:
3D structural-geological model
3D hydrogeological model
3D geotechnical model

II.C. Preliminary results of rock-mass characterization

II.C.1. Geology

The ductile structural pattern in the laboratory is defined by two superimposed regional metamorphic fabrics: (i) earlier, steeply dipping foliation that is heterogeneously reworked into (ii) gently to moderately dipping metamorphic fabric. The brittle structural pattern can be described as interaction between two main fault systems: (i) the older steeply dipping N-S trending fault zones that are cut by (ii) younger moderately dipping faults and joints that are associated with water influx into the tunnel.

II.C.2. Geotechnical

During blasting operation rock samples were tested for their geotechnical properties. The previously described high ductile anisotropy of the rocks resulted in anisotropy of the geotechnical properties, particularly the velocity of ultrasonic waves (6.8km.s^{-1} in the section parallel to the foliation in contrast to 6.09km.s^{-1} in the section perpendicular to the foliation) and heat conductivity (2.85 Wm^{-1}K^{-1} in the section parallel to the foliation and 2.64 Wm^{-1}K^{-1} in the section perpendicular to the foliation). The tensile strength perpendicular to the foliation is half (6.78MPa) that measured in the parallel section (14.33MPa). This anisotropy should be taken into account during the projection phase in such highly anisotropic rocks. A filtration coefficient in the order of 10^{-11} confirmed the ability of the rock to act as a natural barrier system. Unfortunately, this coefficient does not take into account larger scale structures e.g. joints and faults.

II.C.3. Hydrogeological properties of the rock mass

Initial hydrogeological monitoring revealed water of the Ca-Mg-HCO_3 type with a relatively high pH value of 7.9 - 8.5 and a total mineralization value of 220 – 310mg/l. Radiocarbon dating of the water sample showed that the conventional age of the water fluctuates at around 22 thousand years. It can be assumed that a large proportion of the groundwater is of pre-Holocene age, that it underwent typical transformation during long-term contact with tectosilicates and that it probably contains a small proportion of actively flowing water with a residence time in the order of tens of years.

II.D. Future experimental program

The future experimental program will focus on the following main research areas:

I. The long-term stability of the canister

The Czech disposal concept assumes the use of steel-based canisters which will be tested in an environment with high water influx and temperatures of up to 90°C

II. Ground water migration experiments

Water is a crucial factor for all types of repositories. A water migration experiment will be conducted in order to determine fluid pathways and to define the structures (faults, joints) that are critical in terms of potential radionuclide migration. This experiment will provide a link between structural and hydrogeological modeling.

III. Testing of the horizontal and vertical disposal concepts

Both of these disposal concepts have been considered in terms of the design of the future Czech repository. It is planned that the testing of these concepts will provide data essential for the final technical design of the repository.

IV. CONCLUSIONS

The construction of the Bukov Underground Research Facility is fundamental in terms of the characterization of rock masses intended for the construction of a future radioactive waste repository in the Czech Republic. The facility is ideally located for this purpose, i.e. it is 600m beneath the earth’s surface in a crystalline rock environment. The research that will be conducted at the facility will make a significant contribution to a more detailed understanding of the processes that will take place within the repository over its lifetime.

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