
Russian-German Cooperation in Developing a Methodological Approach for Disposal Site Selection in Hard Rock Formations

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1. INTRODUCTION

In response to a request by the Russian Ministry of Atomic Energy (MINATOM), in June 2001 the German Federal Ministry for Economy and Technology (BMWi) and MINATOM agreed to enter into an R&D cooperation regarding radioactive waste disposal. In this context a first joint R&D project dealing with "Site Investigation Requirements for a HLW Repository in Hard Rock Formations" (Anforderungen and die STandortERkundung für HAW-Endlager im Hartgestein - ASTER) was launched in January 2002.

The project is funded by the German Federal Ministry for Economics and Technology. The Russian participants are MINATOM's leading institute regarding geological disposal issues, VNIPI Promtekhnologii in Moscow, the Khlopin-Institute in St. Petersburg, the Mining-Chemical Combine in Sheleznogorsk (Krasnoyarsk-26) and the Production Combine Mayak.

On the German side, DBE TECHNOLOGY GmbH, Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) and Gesellschaft für Anlagen- und Reaktor-sicherheit mbH (GRS) are co-operating.

Subject of this project are MINATOM's plans to dispose of vitrified HLW of the Mayak Combine in a porphyry formation near Mayak and conditioned high-level waste sludge from former weapon plutonium production at the Mining Chemical Combine Sheleznogorsk (Krasnoyarsk-26) in the Nizhnekansk granite formation. For both disposal projects site investigation programmes were initiated a few years ago.

The objective of the Russian-German cooperation project is to develop a methodological approach in regard to a well-justified guidance for future site investigation and selection programmes. The present paper provides a brief summary on the status of both Russian disposal projects and describes the methodological approach, which has been implemented in the joint working programme.

Following MINATOM's principle to select disposal sites closely to the waste generators, geologic explorations have been conducted in the Krasnoyarsk region at at the Nizhnekansk granite formation close to the Mining Chemical Combine Sheleznogorsk (Krasnoyarsk-26) and in the Chelyabinsk region, in Ozersk close to the Mayak Combine during the recent 15 years. As a mandatory stage in the development of underground disposal facilities the construction of an underground laboratory has been anticipated. Since both sites are characterized by typical fractured hard rocks (granites, gneiss, porphyrytes) several aspects regarding the project objective are similar:

- development of disposal technology elements;
- assessment of natural and antropogenic impacts on rock properties;
- investigations of site suitability in terms of conformance with safety requirements.

Thus, a parallel treatment seems reasonable for the purpose of the recent project.

2. NIZHNEKANSK GRANITE FORMATION

The Nizhnekansk Granite Formation (Fig. 1) is located in the south of the Yenisei ridge at the lower part of the Kan river. This is one of the largest granite formations in Central Siberia with an area of more than 1500 km². It is composed of granitoids of diverse composition with prevailing granites and granodiorites.

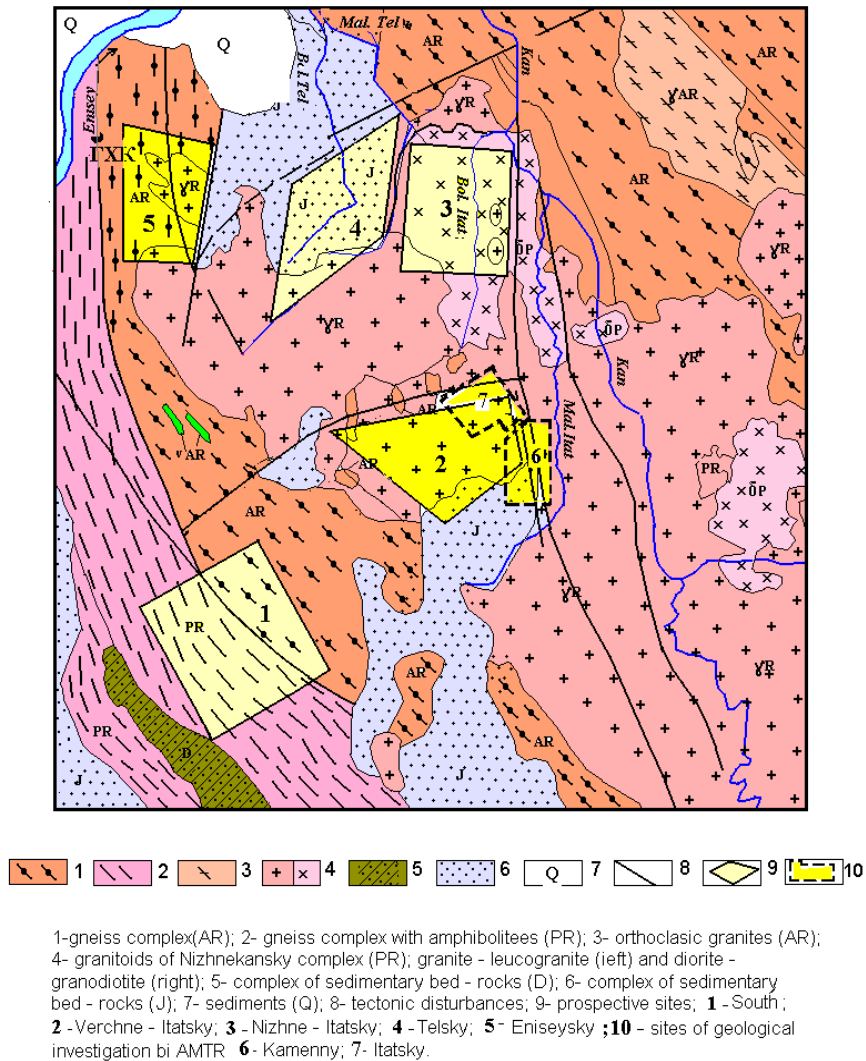


Figure 1: Investigation area Nizhnekansk Granite Formation

Based on a comprehensive geological and geophysical analysis of the territory a number of areas have been selected as offering certain promise. Thus the Verkhneitatsky area was explored in detail, and within its limits two sites were selected: Itatsky and Kamenny. Within the territory of these two sites 37 boreholes with depths from 5 to 25 m and two completely cored boreholes 703 m (Kamenny) and 505 m (Itatsky) deep were drilled. Cores were analysed accordingly.

The geophysical investigations at the cored boreholes included:

- caliper logging
- magnetic susceptibility logging
- density gamma-gamma logging
- gamma-logging
- impedance logging
- thermometry
- borehole magnetometry
- resistivity
- flow meter survey under batch and flow conditions
- acoustic logging

The complex of terrestrial geophysical investigations involved magnetic survey, gravitational exploration and electro prospecting.

The comprehensive analysis of the cores revealed that the geological sections explored by the boreholes differ drastically in facial composition of granitoids, petrophysical properties, degree of tectonic disturbance, intensity and scale of post-magnetic, hydro-thermal-metasomatic and strain transformation development.

Based on the investigations performed by the Khlopin-Institute and local geological organizations, VNIPI PT demonstrated the feasibility of an underground disposal facility for solidified high level waste (600 m³) and reprocessing waste fractions of the future RT-2 plant (350m³ – cesium and strontium, 250m³ – rare earth elements, 300 m³ – fission products). The final selection of a disposal site will be made after completing geological explorations at each design stage in compliance with the regulatory requirements.

3. TERRITORY OF THE MAYAK COMBINE

In the 70s, in response to the pressing radioactive waste management problem at the Mayak Combine, VNIPI PT initiated feasibility investigations regarding the disposal of solidified HLW from the radiochemical production that are comprised of nitrate solutions, suspensions, aqueous-tail, drainage-desorptive and other solutions. The volume of vitrified waste for geologic disposal has been estimated at 6,400 m³ with two main fractions: “cesium-strontium” - 2600m³, “rare earth and fission fragments” - 3900 m³.

In cooperation with institutes of the Russian Academy of Science and local geological organizations comprehensive feasibility studies were carried out regarding repository construction both at the production site of the Mayak Combine and at neighboring territories.

Based on the currently available geologic-geophysical data, four sites were selected. At one of them in the North-East of the Karachai lake – “Mars-2” (Fig. 2) 21 boreholes were drilled including:

- 6 exploratory boreholes at the production site (296 to 1199.2 m deep);
- 5 observation boreholes at the production site (50 to 300.7 m deep);
- 3 exploratory boreholes at the supposed tectonic dislocation 300.3 to 460.2 m deep);
- 4 exploratory boreholes at the controlled area (150.7 to 1200.3 m deep);
- 3 observation boreholes at the production site (200.6 to 1200 m deep).

HYDROGEOLOGICAL PROFILES. SITE «M-2»

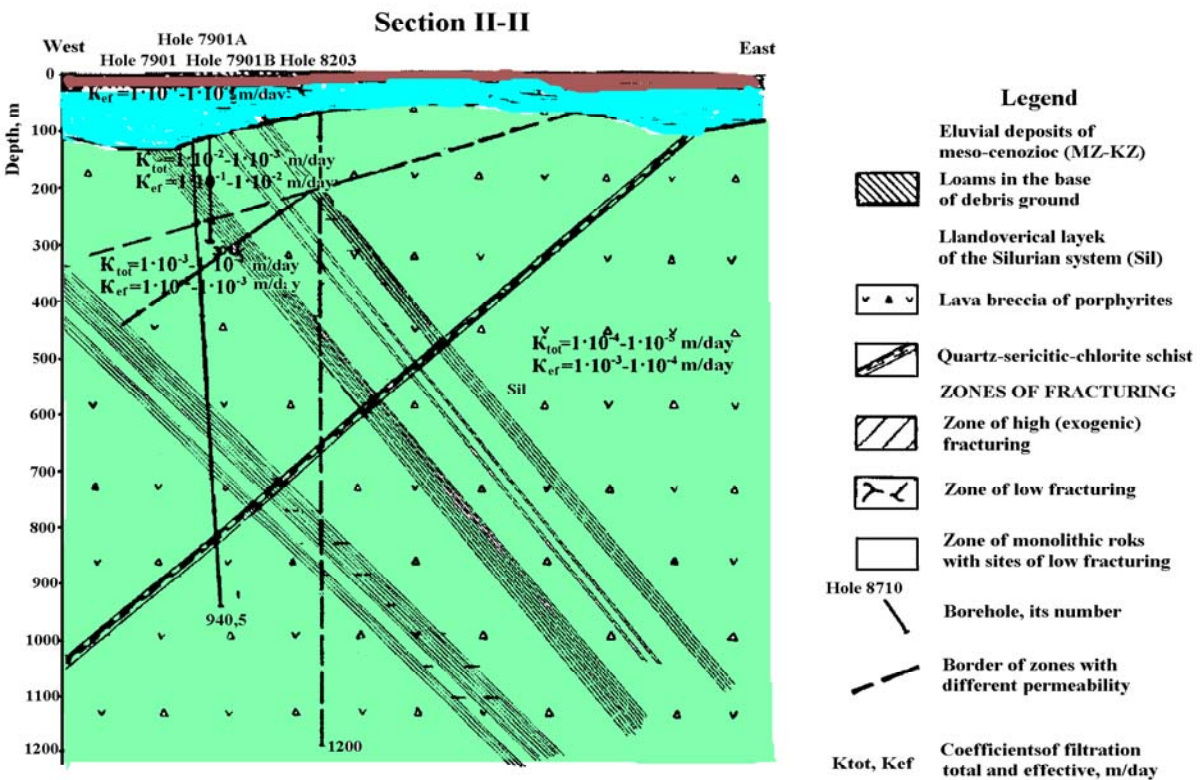
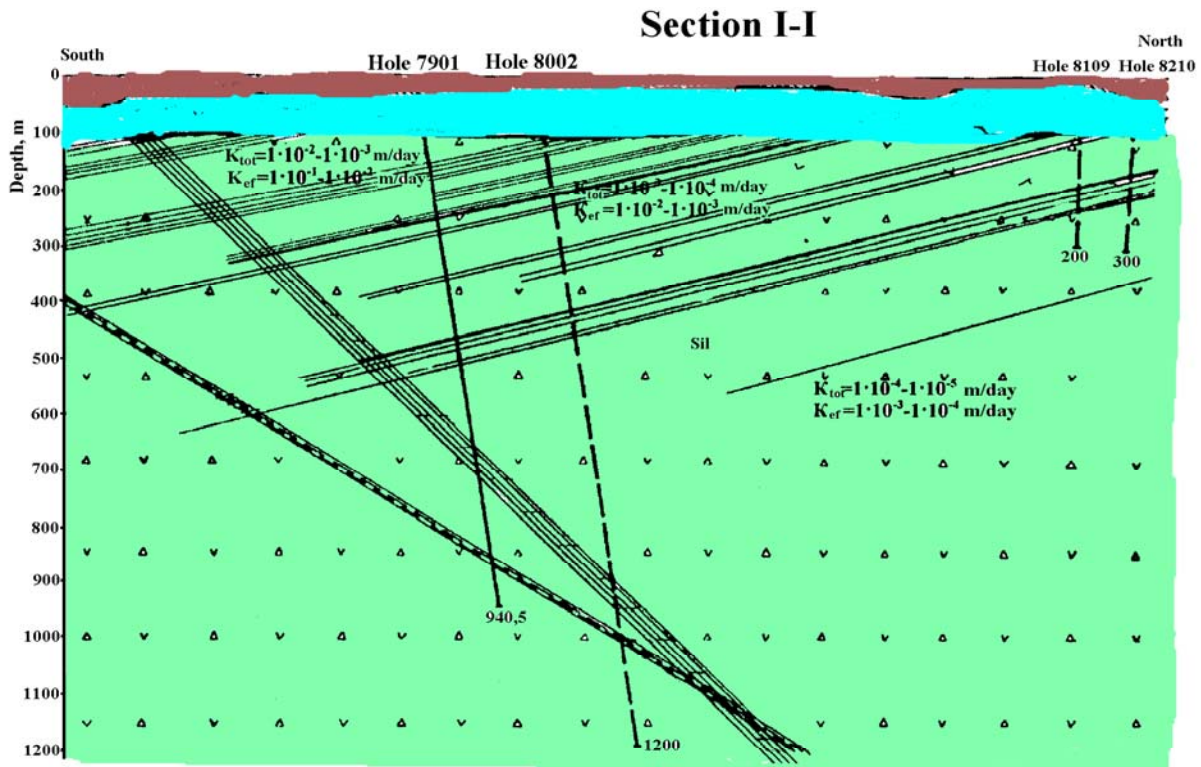


Figure 2: Hydrogeological profiles of site M-2 at Mayak

During drilling and after its completion the trial filtration measurements were performed, as well as borehole and ground geophysics. Cores were logged and photo documented in field conditions. The lithologic-petrographic composition and rock-mechanical properties were determined by laboratory tests. The thermo-mechanical rock properties were tested both under laboratory and field conditions.

The types and scope of the performed investigations include:

- drilling of 21 boreholes with a total length of 10,202.7 meters;
- coring and visual logging of cores from 10,150 meters;
- core photo documenting of 9,900 meters;
- petrographic analysis of rock microsections – 1,000 pc.;
- analysis of physico-mechanical and thermophysical rock properties under laboratory conditions – 2,500 measurements;
- determination of thermo physical rock properties under in-situ conditions in 3 boreholes;
- filtration tests– 110 pump tests;
- comprehensive geophysical borehole logging – 60,200 meters;
- geophysical surface survey – 10 km².

As a result, the geological structure and hydrogeological conditions of the rock massif were investigated in detail. This allowed the modeling of radionuclide migration processes in low-fractured media in order to evaluate the impact of the disposed wastes on the environment and formed the basis for the conceptual design of the proposed underground laboratory at the site.

4. OBJECTIVE OF THE RUSSIAN-GERMAN COOPERATION PROJECT

The objective of the cooperation project is to develop scientifically and technically justified guidance for future disposal site investigation and selection at a relatively early stage of the evolution of two geological disposal programmes in hard rock formations. However, social and other non-technical issues are beyond the scope of the project, although such aspects are also relevant for the selection of an appropriate region as disposal site. This decision has been already taken for the corresponding Russian nuclear disposal programmes. Thus, it is intended to provide the methodological basis for a well-focussed site-investigation and selection programme and to define the next exploration steps in order to support further site confirmation and performance assessment efforts to the largest possible extent.

In order to achieve these objectives the participating German organisations will contribute recent expertise gathered from earlier repository planning, performance assessment and site screening programmes in hard rock. In addition, the project will benefit directly from the methodological approach in site confirmation, which had been developed for the Gorleben repository project before it was interrupted in 2000, as well as from latest results of the scientific discussion within the German expert group AkEnd (Arbeitskreis Endlagerung – Working group final disposal) on site selection criteria.

5. METHODOLOGICAL APPROACH

The methodological approach that has been implemented in the recent cooperation project is based on the understanding that a detailed site characterisation shall provide all necessary and accessible information on the geological conditions of the concerned site in order to perform a site specific performance assessment for the considered repository concept. As regards, the selection of the most appropriate site from several alternatives by detailed site investigation should allow to identify the site with the best performance.

The relationship between the main geological site properties and repository performance is either obvious, well known or at least has been subject of intensive scientific investigations. Based on this knowledge, various site selection criteria have been developed in the past, e.g. low permeability and sufficient stability of the considered host rock, low groundwater movement, low seismic activity etc. One of the most recent criteria that have been subject of an intensive scientific debate are the criteria, which have been developed by the German expert group AkEnd. However these criteria are quite general and cannot be used as sufficient guidance for a detailed site characterisation and confirmation, since they

have been developed primarily for the identification (pre-selection) of potentially suitable sites and/or regions.

The derivation of guidelines for a sufficiently detailed and well-focussed site investigation is an extremely complex task, which cannot be solved universally. Thus, it can be solved only based on already existing site data and by using a reference concept for the repository design and performance assessment. The overall idea for the applied methodological approach can be summarised in following steps (Fig. 3):

1. Developing a preliminary geological model including a long-term geoscientific prognosis for the site, in order to identify gaps in the understanding of the local geology
2. Developing a conceptual repository design based on available design constrains (waste data, host rock properties, etc.)
3. Developing a reference model for performance assessment purposes based on the preliminary geological model of the site and conceptual repository design
4. Analysing of the impact of the site geology on the feasibility of the repository design and on repository performance
5. Deriving geologic requirements to the site
6. Developing guidelines for further site investigation

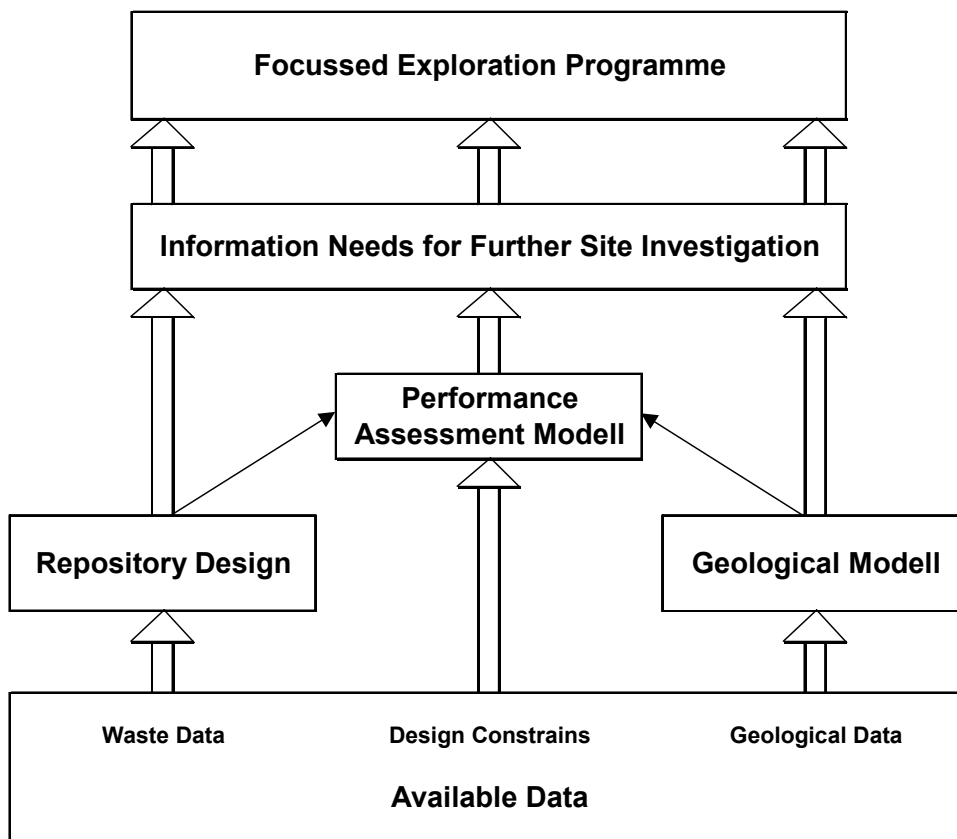


Figure 3: Overall Methodological Approach

Considering available host rock properties and waste data a conceptual repository design for both disposal sites has been developed. It considers the emplacement of stainless steel containers with conditioned heat generating high-level waste in a mine in about 18 m deep boreholes, which are accessible by an upper and a lower drift (Fig. 4). The upper drift will be used for transportation and emplacement operations, while the lower drift provides major advantages in borehole drilling and keeping the emplacement area dry before repository sealing. The waste containers will be embedded in bentonite.

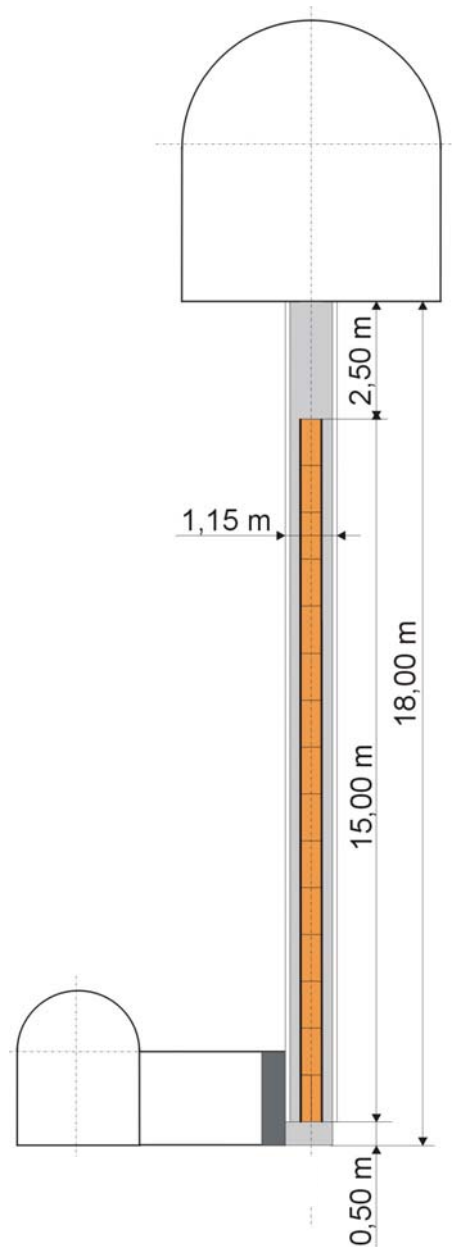


Figure 4: Conceptual design for HWL borehole disposal

It is assumed that the boreholes will be arranged in the emplacement area in a hexagonal structure (Fig. 5) which is recognised as optimal in terms of highest borehole density and considering existing thermal limitations on the bentonite buffer and on the host rock. Based on the assumption, that the maximum bentonite and host rock temperature should not exceed 100 °C the minimal distances between the boreholes will be calculated using FLAC-3D for the conservative symmetric case, which defines the required size of the emplacement area. Furthermore the bentonite buffer design will be checked against the maximum hydrogen build up pressure from container corrosion in order to ensure a sufficient gas permeability and to exclude buffer fracturing.

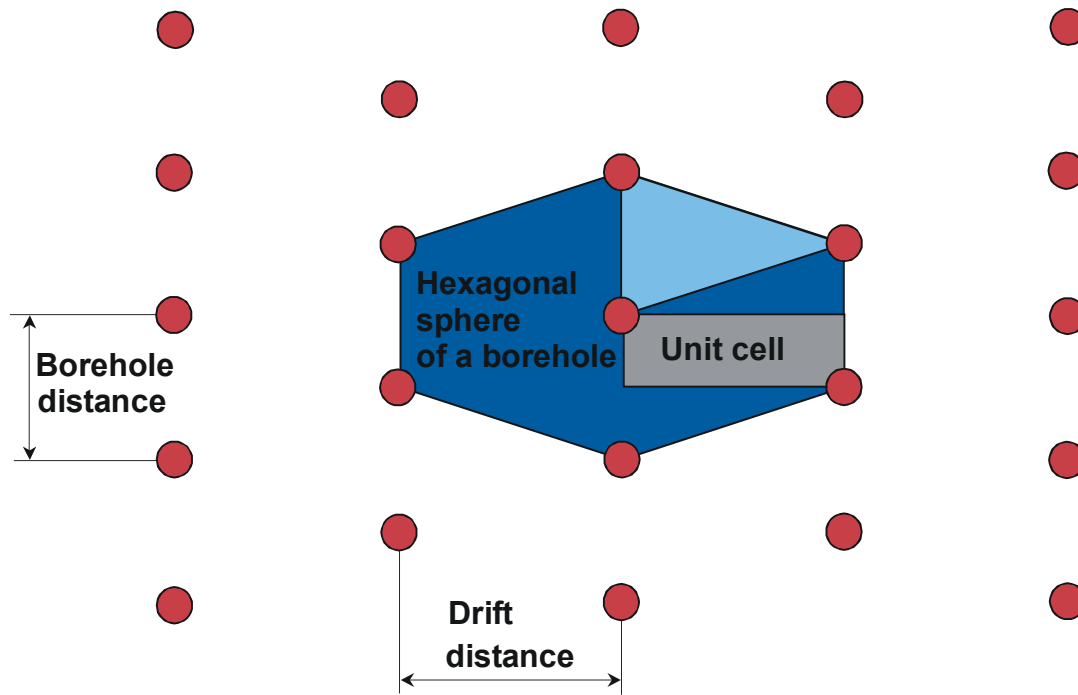


Figure 5: Arrangement of the emplacement area with boreholes

Based on the preliminary geological models, generic hydrogeological models have been developed for a site at the Nizhnekansk granite massive (Fig. 6) and for a porphyry site at Mayak (Fig. 7), which will be implemented as numerical ROCKFLOW models. After testing the groundwater flow models they will be upgraded by radionuclide release and transport models which serve as the basis for the performance assessment. Repository performance will be tested using standard biosphere models for the exposure of reference persons to contaminated groundwater and internationally accepted dose and risk limits.

On this basis the impact of the geological site conditions on the feasibility of the repository design and on repository performance will be analysed in respective calculations by varying corresponding model parameters, such as repository depth, host rock properties, density and width of fractures, distances from major disturbances etc.. Based on this analyses, requirements for suitable disposal sites will be derived.

In addition, a list of necessary site-specific information will be compiled that shall be gathered during the next site investigation phase and which is needed for designing the repository and for assessing its performance at the considered site with real data.

The developed requirements for a suitable site will be implemented in a further exploration programme in order to identify a more concrete site. A sufficiently detailed site characterisation programme that is focussed on the information required for repository design and performance assessment will extend this programme and be completed by recommendations for appropriate investigation methods, geophysical tools etc.

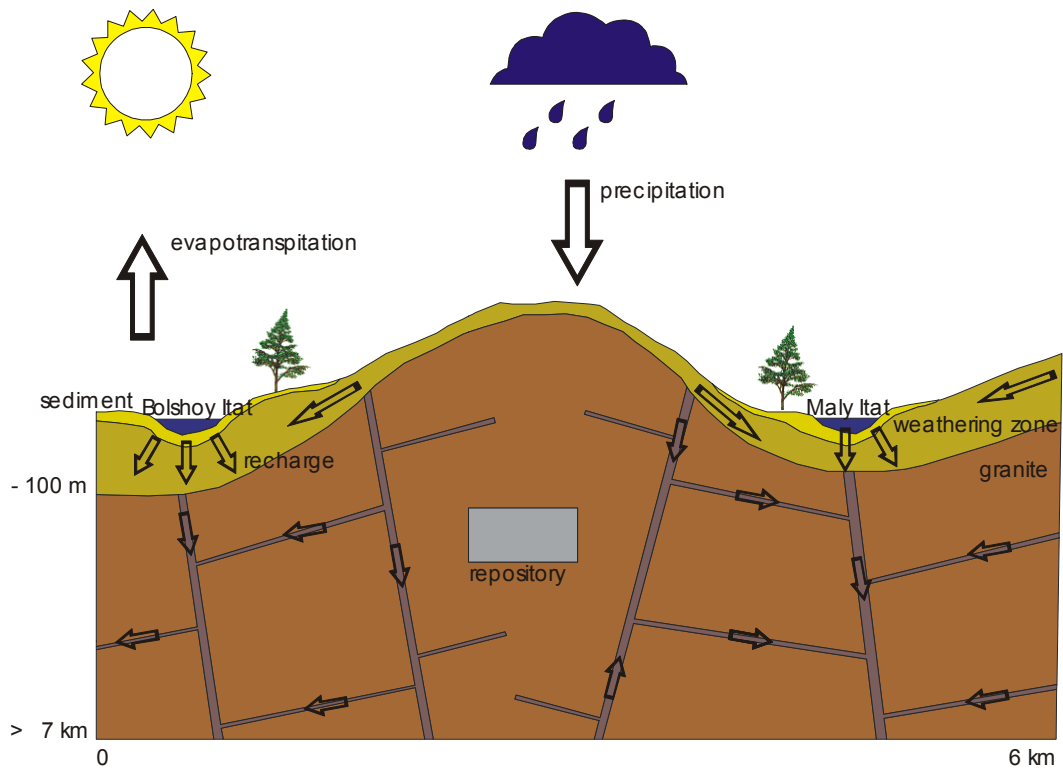


Figure 6: Generic hydrological model of a site at the Nizhnekansk granit formation

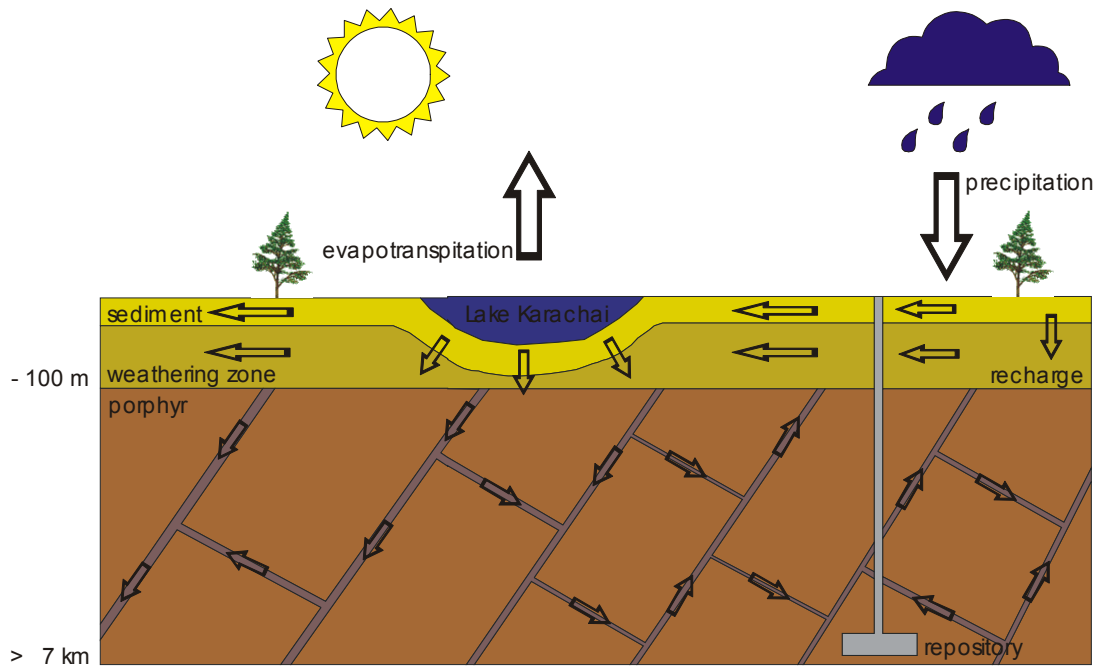


Figure 7: Generic hydrological model of a porphyry site near MAYAK

6. BENEFITS OF THE RUSSIAN-GERMAN COOPERATION

The cooperation between Russian and German experts should help on the one hand to improve and streamline further Russian site characterisation efforts regarding both corresponding sites and to focus on the issues, which are relevant for site selection and confirmation. Thus, it would help to design a time and cost effective exploration programme.

On the other hand the methodological basis to be developed and tested within the recent project can be transferred to other disposal site investigation programmes in different host rock formations as well. Thus it could be used for the optimisation of further site characterisation efforts for alternative sites in Germany. In addition the testing of the considered methodological approach on two specific hard rock formations in Russia offers a lot of insights and provides an interesting opportunity to extend the knowledge base regarding host rock formations, which according to the recent German nuclear disposal policy shall be considered as alternatives to rock salt.

The overall objective is to apply a safety related methodology, as favoured by all countries using nuclear power, to the Russian site selection programme in hard rock in order to structure and to focus the site investigation programme on the aspects of long-term safety. Consequently this has an impact on the individual disposal concepts as well as on the backfilling and sealing strategies also.