CREATION AND PLAN OF AN UNDERGROUND GEOLOGIC RADIOACTIVE WASTE ISOLATION FACILITY AT THE NIZHNEKANSKY ROCK MASSIF IN RUSSIA

T. A. Gupalo
All Russian & Design Institute of Production Engineering
Moscow

K. G. Kudinov
Mining Chemical Combine
Zheleznogorsk

L. J. Jardine
Lawrence Livermore National Laboratory

J. Williams
Department Of Energy

ABSTRACT

This joint geologic repository project in Russia was initiated in May 2002 between the United States (U.S.) International Science and Technology Center (ISTC) and the Federal State Unitary Enterprise "All-Russian Research and Design Institute of Production Engineering" (VNIPIPT). The project (ISTC Partner Project 2377) is funded by the U.S. Department of Energy Office of Civilian Radioactive Waste Management (DOE-RW) for a period of 2-1/2 years.

ISTC project activities were integrated into other ongoing geologic repository site characterization activities near the Mining and Chemical Combine (MCC K-26) site. This allowed the more rapid development of a plan for an underground research laboratory, including underground design and layouts. It will not be possible to make a final choice between the extensively studied Verkhne-Itatski site or the Yeniseiski site for construction of the underground laboratory during the project time frame because additional data are needed. Several new sources of data will become available in the next few years to help select a final site. Studies will be conducted at the 1-km deep borehole at the Yeniseisky site where drilling started in 2004. And in 2007, after the scheduled shutdown of the last operating reactor at the MCC K-26 site, data will be collected from the rock massif as the gneiss rock cools, and the cool-down responses modeled.

After the underground laboratory is constructed, the data collected and analyzed will provide the definitive evidence regarding the safety of the proposed geologic isolation facilities for radioactive wastes (RW). This data will be especially valuable because they will be collected at the same site where the wastes will be subsequently placed, rather than on hypothetical input data only.

Including the operating costs for 10 to 15 years after construction, the cost estimate for the laboratory is $50M. With additional funding from non-ISTC sources, it will be possible to

complete this important facility and to extend the use of the underground models developed there to other future sites such as for low-level waste, near-surface disposal of solid wastes.

INTRODUCTION

It is widely recognized that it is a long and complex road to appropriately resolve the problems of the management of spent nuclear fuel (SNF) and RW resulting from past, current, and future operation of both civilian and military facilities. No simple universal solution for managing SNF has been found and implemented in either the U.S. or Russia, or in other countries. Moreover, it is clear that the resolution of this issue requires the joint efforts of scientists and experts of all countries concerned. Only through collaborative efforts can the protection of health and safety and the environment be ensured.

Solutions to SNF and RW management problems should be developed considering nonproliferation principles, as well as scientific, technical, geologic, long-term safety predictions of the geologic isolation of SNF and RW, and any other particular concerns that individual countries with nuclear power may have in order to dispose of SNF and RW.

Presently, two general SNF and RW management approaches exist worldwide, specifically:

- Direct geologic disposal of SNF (open cycle), e.g., in the U.S., Sweden, Finland;
- Reprocessing of SNF and recycling of fissile materials and disposal of radioactive waste (closed cycle), e.g., in France, the United Kingdom, Japan, and Russia.

Irrespective of the specific strategy for SNF or RW management, it is important to ensure the safety of all nuclear power stages and create safe and reliable geologic repositories for long-term isolation of high-level RW or SNF. Regardless of the chosen fuel cycle (closed or open), an underground final isolation facility for SNF or RW is the most problematic element of RW management strategy. If the closed fuel cycle is chosen, there will be a need to dispose of treated high-level waste resulting from reprocessing in a geologic repository. If the open cycle is chosen, there will be direct disposal of spent fuel in a geologic repository after its long-term surface or underground storage. In summary, no matter what the future holds for nuclear power, it is essential to develop technologies for safe, prolonged storage of SNF and the creation of facilities for long-term and ultimate geological isolation of RW or SNF that have already been generated or may be generated in the future.

It should be noted that many countries with nuclear power may not be able to develop their own national geological repositories; therefore, an acceptable solution might be the development of international facilities to take in spent nuclear fuel from such countries. However, the implementation of this kind of international project must be harmonized with the national interests of those countries which possess the necessary conditions for the development of their own storage and geologic disposal facilities for radioactive waste and spent nuclear fuel.

The Ministry of the Russian Federation of Atomic Energy (Minatom) and the U.S. DOE and their supporting institutes and national laboratories have addressed many issues related to the long-term isolation of SNF and disposal of RW in geologic formations, including environmental, radiological, physical, and other safety issues in the past decades.

The U.S., Japan, the Russian Federation (RF), and the European Atomic Energy Community signed the Agreement that established ISTC in Moscow in October, 1994. These countries were

later joined by the Republic of Georgia, the Republic of Armenia, the Republic of Belarus, the Republic of Kazakhstan, the Kyrgyz Republic, Norway, and the Republic of Korea.

On June 16, 1995, the U.S. DOE and ISTC signed a Memorandum of Agreement to cooperate in approved agreements that facilitate the nonproliferation of nuclear weapons and nuclear weapons expertise. The current project is one of these joint ISTC projects.

BACKGROUND

The U.S. has been studying issues of the geologic isolation of RW and SNF for several decades. The development of a geologic repository is the objective of the U.S. program for management of spent nuclear fuel and high level radioactive waste.

After several years of studying various types of geologic settings, in 1987, the U.S. Congress directed the DOE to confine their studies to the Yucca Mountain Site in Nevada, and approved the Yucca Mountain site as the candidate site for a potential geologic repository. In 2002, the President signed the Congressional Joint Resolution making the Yucca Mountain site designation effective.

In addition, the U.S. waste isolation pilot plant (WIPP), located in southwest New Mexico, is the first facility in operation for ultimate isolation of RW. The WIPP project was approved by the U.S. Government on March 26, 1999. The approval was granted to start deep geologic disposal of transuranic waste resulting from defense programs in 650-meter-deep, layer-like salt formations. The WIPP site is the world's first facility that has no analogues as a solution to the problem of deep geologic disposal. The following should be especially noted:

- The site was developed specifically for transuranic waste.
- It is one of the few long-term repositories arranged in salt layers for any type of waste.

The Russian Federation has also conducted many surveys aimed at choosing an appropriate site for construction of geologic repositories over the last decades. As a result of these surveys, it was concluded that the prospective sites to be considered for geologic isolation of high-level waste and some types of SNF were the sites at Scientific-Production Association Mayak in the Chelyabinsk region and the Nizhnekansky granitoid massif in the Krasnoyarsk region. The granitoid massif in the Krasnoyarsk area is currently regarded as the priority candidate site for the potential long-term storage of waste containing long-lived radionuclides and unreprocessable SNF for the RF.

With the modest funding available, significant progress has been made toward fulfilling the joint project objectives. ISTC Partner Project #2377, "Development of a General Research and Survey Plan to Create an Underground RW Isolation Facility in Nizhnekansky Massif," funded a group of key Russian experts in geologic disposal, primarily at VNIPIPT and MCC K-26. [1] The activities under the project were targeted to the creation of an underground research laboratory which was to justify acceptability of the geologic conditions for ultimate isolation of high-level waste in Russia. In parallel, work was under way with Minatom's financial support to characterize alternative sections of the Nizhnekansky granitoid rock massif near the MCC K-26 site to justify the possibility of creating an underground facility for long-term or ultimate isolation of RW and SNF. [2] The result was a synergistic, integrated set of activities that advanced the geologic repository site characterization and development of a proposed

underground research laboratory better than could have been expected with only the limited funds from ISTC Partner Project #2377 funded by the U.S. DOE-RW. [3–5]

Four objectives were set for the project:

1. Generalize and analyze all research work done previously at the Nizhnekansky granitoid massif by various organizations.
2. Prepare and issue a declaration of intent (DOI) for proceeding with an underground research laboratory in a granite massif near the MCC K-26 site. (The DOI is similar to a Record of Decision in U.S. terminology).
3. Proceeding from the data obtained as a result of scientific research and exploration and design activities, prepare a justification of investment (JOI) for an underground research laboratory in as much detail as the available site characterization data allow. Consider the possibility of the substantiated selection of a specific site for the underground laboratory at this stage. (The JOI is similar to an advanced conceptual design or preliminary design in U.S. terminology).
4. Perform a preliminary safety assessment of the geologic isolation of radioactive waste and unreprocessable SNF in the Nizhnekansky massif.

RESULTS

Objective 1: The DOI for the Underground Laboratory

The DOI summarizes the results of all studies performed toward achieving the objectives above. After preparation, it was submitted to and approved by the Krasnoyarsk region authorities, MCC K-26, in 2002, and signed by the deputy minister of Minatom (now the Federal Atomic Energy Agency) on October 4, 2002. The purposes of the underground research laboratory to be constructed at the prospective site for conducting geologic and prospecting work are considered in the DOI, which justifies the location for SNF and RW isolation with great reliability. The following two sites were chosen for the designed disposition facility based on the results of many years of investigations: the Verkhne-Itatsky site (220 km^2) and the Yeniseisky site (70 km^2).

The sites are characterized by the following important features:

- A quiet tectonic regime and low density of tectonic lineaments;
- No limitations for the use of natural resources;
- Comparatively small distance to the Krasnoyarsk MCC production site.

A prospective site for the construction is to be determined after detailed engineering, geological, and hydrogeological research within the potential sites, as shown on Figure 1.

Objective 2: The JOI for the Underground Laboratory

Substantial progress has been made toward development of the underground construction project and various layouts related to technical solutions in the JOI stage. In view of the insufficient

volume of data characterizing the Yeniseisky site, it is impossible to choose an exact place to locate the underground laboratory during the limited ISTC Project 2377 time period of 2-1/2 years.

It is of principal importance to obtain additional data with which to make the site selection decision and to comprehensively evaluate the prospective site. This data will come from the results of the construction and investigations of the deep borehole. Planning for the 1-km deep borehole drilling project at the Yeniseisky site has been completed, and specialists began drilling activity in 2004. The current cost estimate for the underground laboratory is US$50M, including the operating costs for 10 to 15 years after construction (Figure 2).

Objective 3: Performance Assessment Modeling, Engineered and Natural Barriers and MCC K-26 Site Analogue

Performance assessment modeling, model development, and engineering barrier testing are under development. The geologic studies have established planned underground laboratory and repository depths of 550 m (Figure 3).

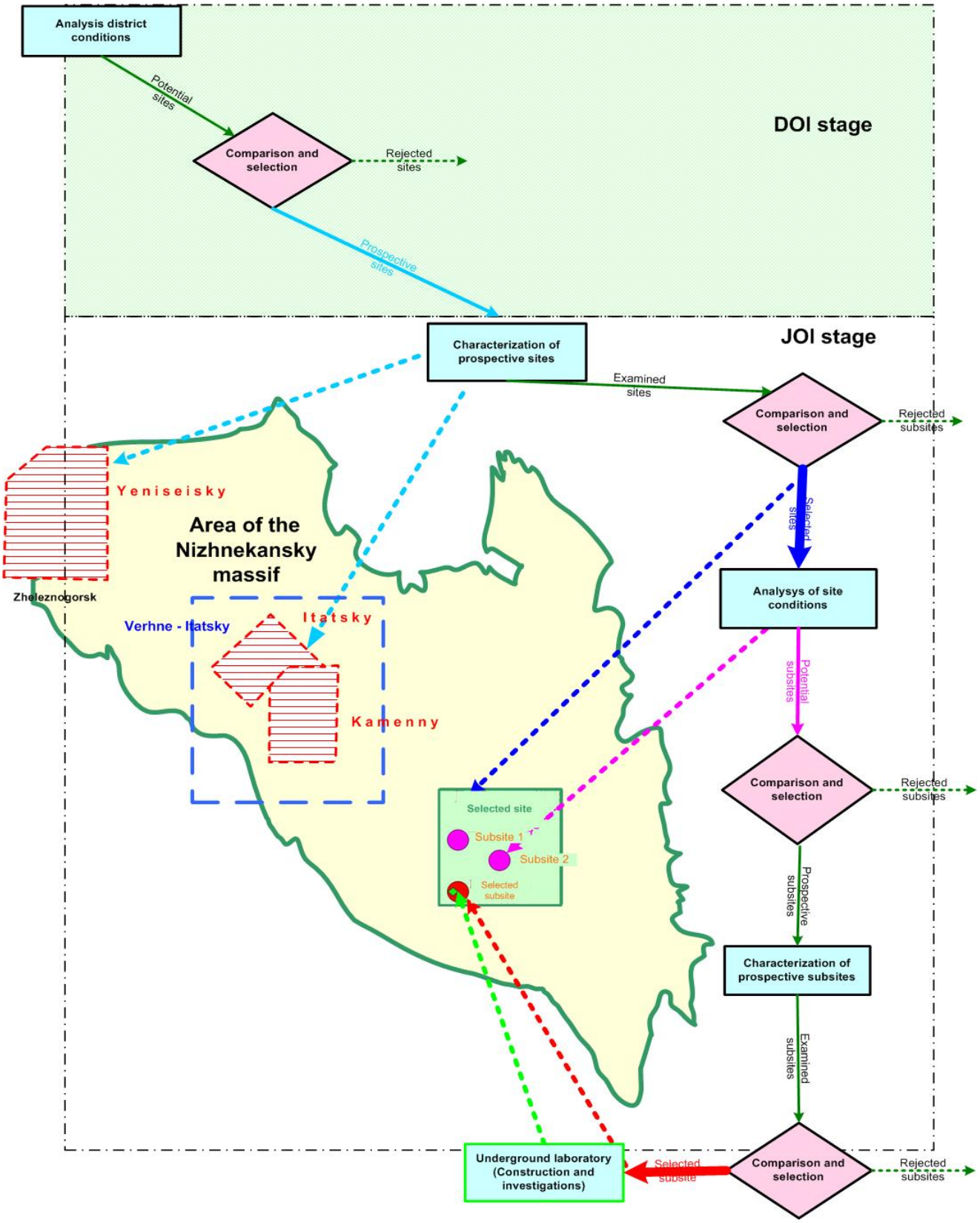
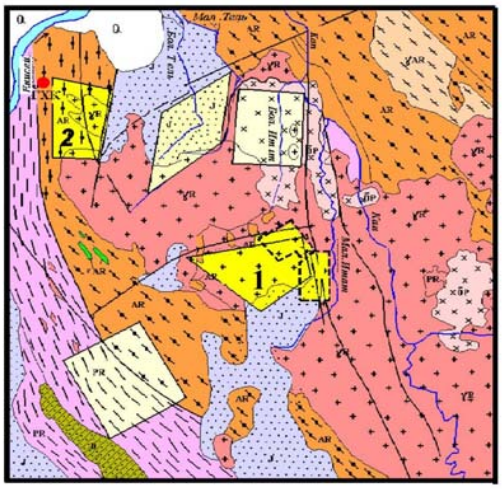


Fig. 1. Algorithmic scheme of site selection for RW isolation

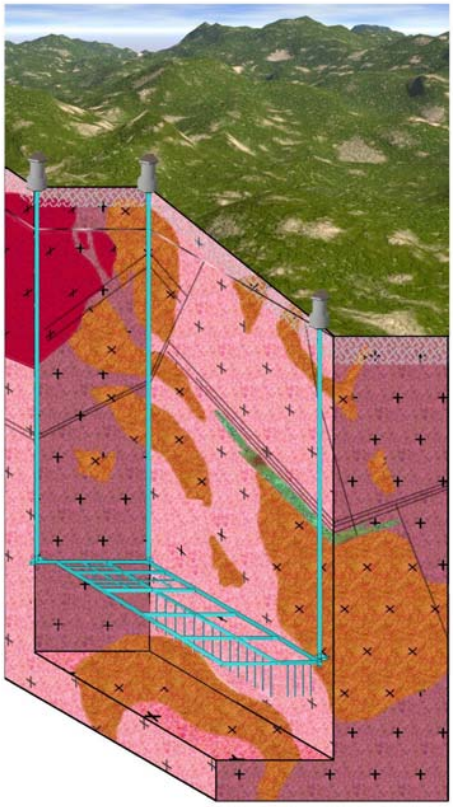
POTENTIAL SITES FOR CREATION RW GEOLOGICAL DISPOSAL IN THE AREA OF NIZHNEKANSKY ROCK MASSIF



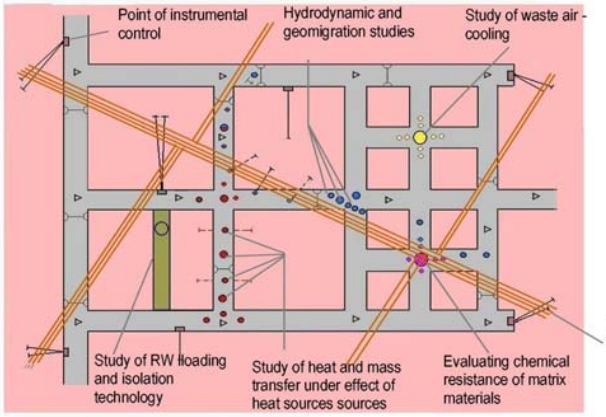
1 – gneiss complex (AR); 2 – gneiss complex with amphibolites (PR); 3 – ortoclasic granites (AR); 4 – granitoids of Nizhnekansky complex (PR); granite – leucogranite (ieft) and diorite – granodiorite (right); 5 – complex of sedimentary bed – rock (D); 6 – complex of sedimentary bed - rock (J); 7 – sediments(Q); 8 – tectonic disturbances; 9 – prospective sites; 10 –sites of geophysical investigation bi AMTR.

PROSPECTIVE SITES : 1 – Verchne-Itatsky (7); 2 - Eniseysky

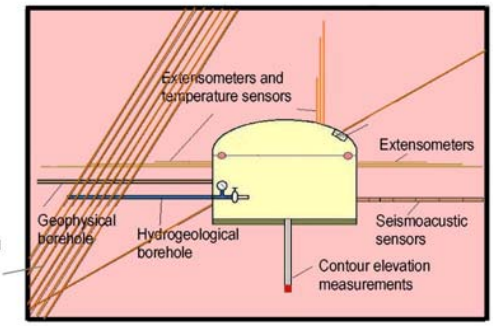
RW AND SNF UNDERGROUND ISOLATION OPTION



SCHEME OF EXPERIMENTAL WORKS IN UNDERGROUND LABORATORY



COMPOSITION OF ROCK MASSIF INSTRUMENT CONTROL POINT



FACILITY PURPOSE – underground isolation of solidified RW and SNF.

Fig. 2. Nizhnekansky granitoid massif and proposed underground facilities

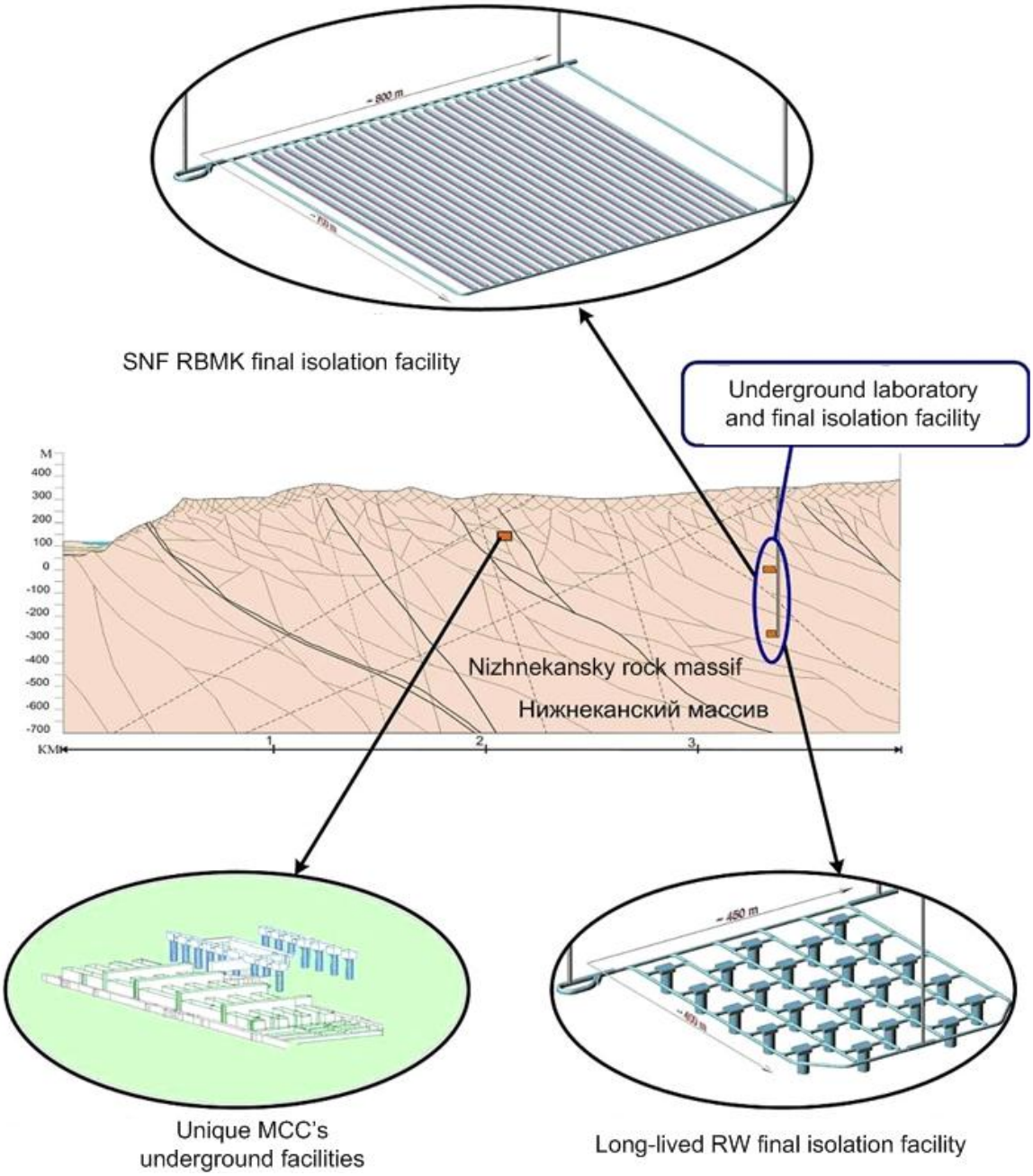


Fig. 3. Schematic of the underground laboratory and final isolation facilities in the Nizhenkansky rock massif

The VNIPIPT models of comparative assessment of appropriateness of the two sites proposed for ultimate RW isolation facilities are based on safety calculations of a multi-barrier underground isolation system. Results of many years of studies of changes in geomechanical, hydrogeological, and geochemical processes under temperature impacts are used as input data.

The development and testing of computer models of the studied processes were done based on

monitoring results of the underground objects at the MCC K-26 site, e.g., gneiss rock heated up for a period of 40 years. The last operating reactor at the MCC K-26 site is scheduled to be shut down in 2007. This will provide another unique opportunity to monitor, collect data, and model the rock massif as the gneiss rock cools once the reactor is shut down and the large heat source is removed. Preliminary modeling of the rock cool-down responses has been initiated as part of this ISTC Partner Project.

CONCLUSIONS

- As a result of the vast amount of work completed, the geographical position for construction of the underground laboratory was determined within the Nizhnekansky granitoid rock massif.
- Proceeding from the results obtained by comprehensive analysis, the two most appropriate sites within the Nizhnekansky granitoid rock massif were determined by expert evaluation.
- A plan for construction of the geologic isolation facility was prepared and substantiated.
- Preliminary characterizations of climate, hydrography, geological, hydrogeological, and seismic conditions of the area for the construction site were prepared.
- Key factors to be used as a basis for the choice of the best site for further research and subsequent construction of the underground laboratory were determined.

Joint financing will make it possible to further advance the work plan for creation of the underground isolation facility in the Nizhnekansky massif. The merged financing will allow obtaining unique data to demonstrate the safety of the ultimate geologic isolation of RW in this facility. The expenses for the underground research are deemed sufficiently justified for a project with such international importance.

The implementation of the underground laboratory project will corroborate the correct choice of site for the RW emplacement and the appropriateness of the concept accepted in terms of the isolation and reliability of engineering solutions. It is extremely important that all validation, substantiation, and calculation activities be based on a large scope of measurements made at the same site where the wastes will be subsequently placed, rather than on hypothetical input data only.

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