Current Status and Next Five-year Plan of R&D Activities of Mizunami Underground Research Laboratory

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The Mizunami Underground Research Laboratory (MIU) project has proceeded in three overlapping phases, "Phase I: Surface-based investigation", "Phase II: Construction" and "Phase III: Operation". The construction of research galleries in the MIU has been completed to the GL-500 m depth in 2014. The research activities in Phase III have been conducted in the underground since 2010. Current R&D activities include a gallery closure test on the -500 m level to study recovery processes in the geological environment around a gallery after it has been backfilled and to develop long-term monitoring technology, a post-excavation grouting experiment to demonstrate the feasibility of impermeable grouting technology, and a mass transport experiment. This report introduces the next five-year R&D plan and its current status.

1 Introduction

One of the features of the geological disposal policy in Japan is the establishment of multiple URLs. The URLs must be distinct from an actual disposal facility, the latter to be selected by the Nuclear Waste Management Organization of Japan (NUMO). URLs in the JAEA projects are classified as purpose-built generic URLs as described in the OECD/NEA report[1)], and are distinct from on-site (site-specific) URLs to be constructed at potential waste disposal sites. JAEA's URL projects are directed towards improving the reliability of geological disposal technologies and developing advanced safety assessment methodologies. In order to cover the general range of geological environments in Japan, two generic URLs have been built, one is the Mizunami Underground Research Laboratory (MIU) for crystalline rock, and the other is the Horonobe Underground Research Laboratory for sedimentary rock[2)] (Fig.1). The MIU project has proceeded in three overlapping phases, "Phase I: Surface-based investigation", "Phase II: Construction" and "Phase III: Operation". The construction of research galleries in the MIU has been completed to -500 m depth in 2014[3)] (Fig.2). Research activities in Phase III have been conducted in the underground since 2010. Current R&D activities include a gallery closure test at the GL-500 m level to study recovery processes in the geological environment around a gallery after it has been backfilled, the development of long-term monitoring technology, a post-excavation grouting experiment to demonstrate the feasibility of impermeable grouting technology and a mass transport experiment.

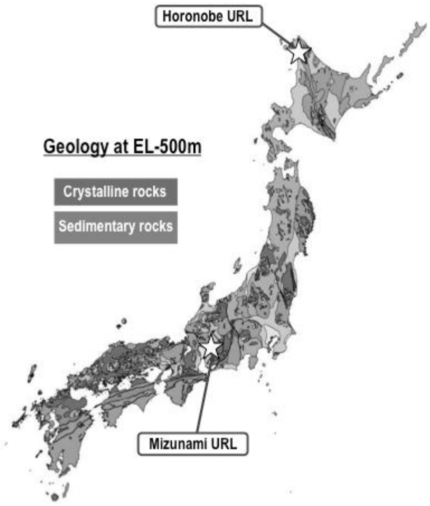

Fig. 1 Predicted geology at EL-500m in JAPAN and location of JAEA's URLs [2)]

2 Next five-year plan of R&D activities

JAEA's R&D activities should contribute to establishing the scientific basis for geological disposal in Japan[4] (Fig.3). MIU reached GL-500 m, there was relatively low fractured area in MIU. The next five-year plan of R&D activities will focus on development of the methodologies for detailed site investigations for a repository in Japan. The following points have been considered in defining the future activities:

- Check and review of the second mid-term plan;
- Consider the present progress of geological disposal in Japan;
- Consider the specific features that might affect a geological disposal system in Japan (eg. natural phenomena in an active mobile belt, complex geological structure and deformation of fractures due to location in a tectonic region[5] (Fig.4), large groundwater recharge); and
- Optimization of the project at the MIU.

In keeping with the above policy, three major R&D items[5] were identified as shown in Fig. 5.

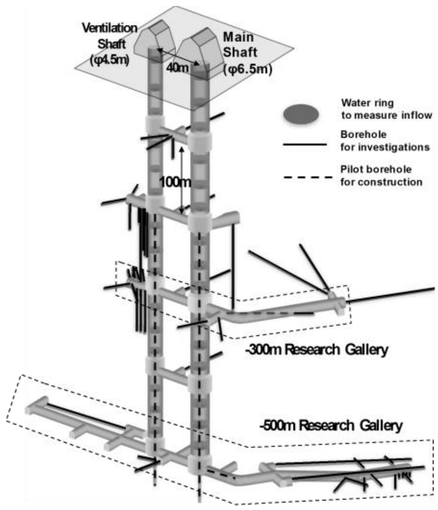

Fig.2 Schematic layout for investigation and drift in MIU [3]

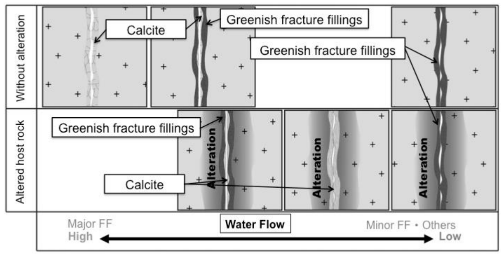

Fig.4 Conceptual model for fractures observed in MIU [5]

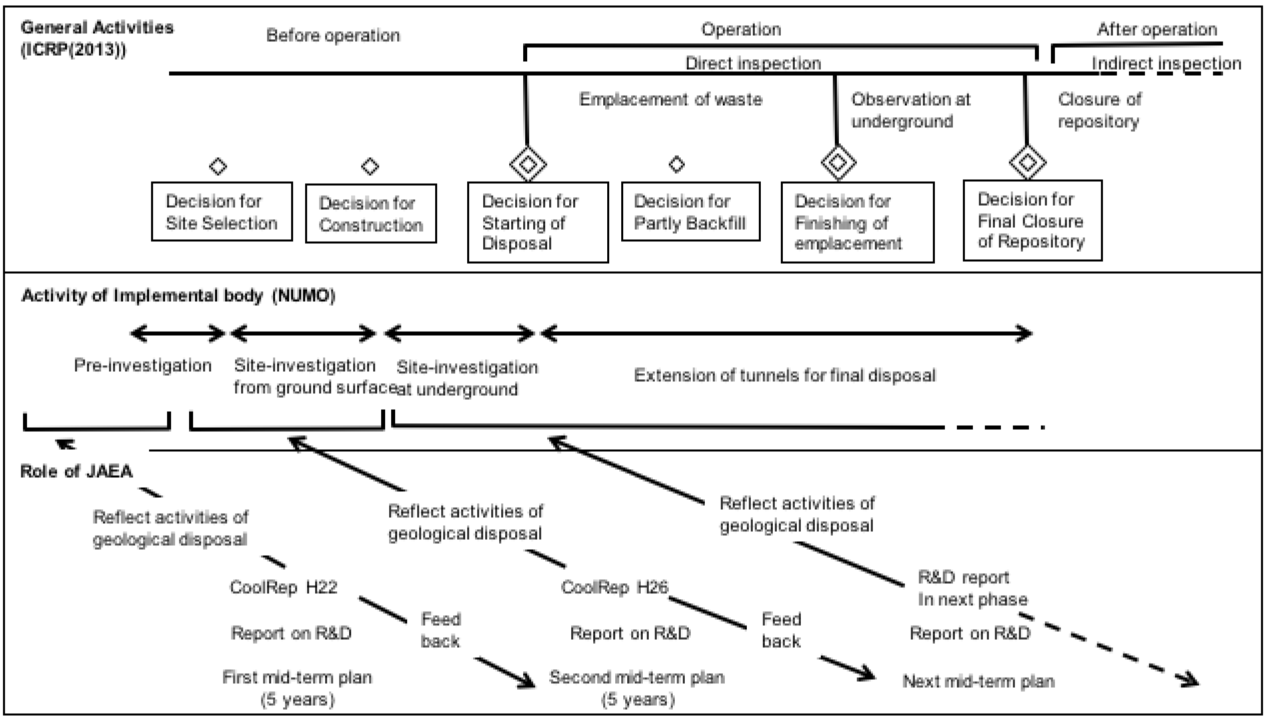

Fig.3 The interrelationship between the progress of geological disposal, and the activities of the implemental body (NUMO) and JAEA R&D activity [4]

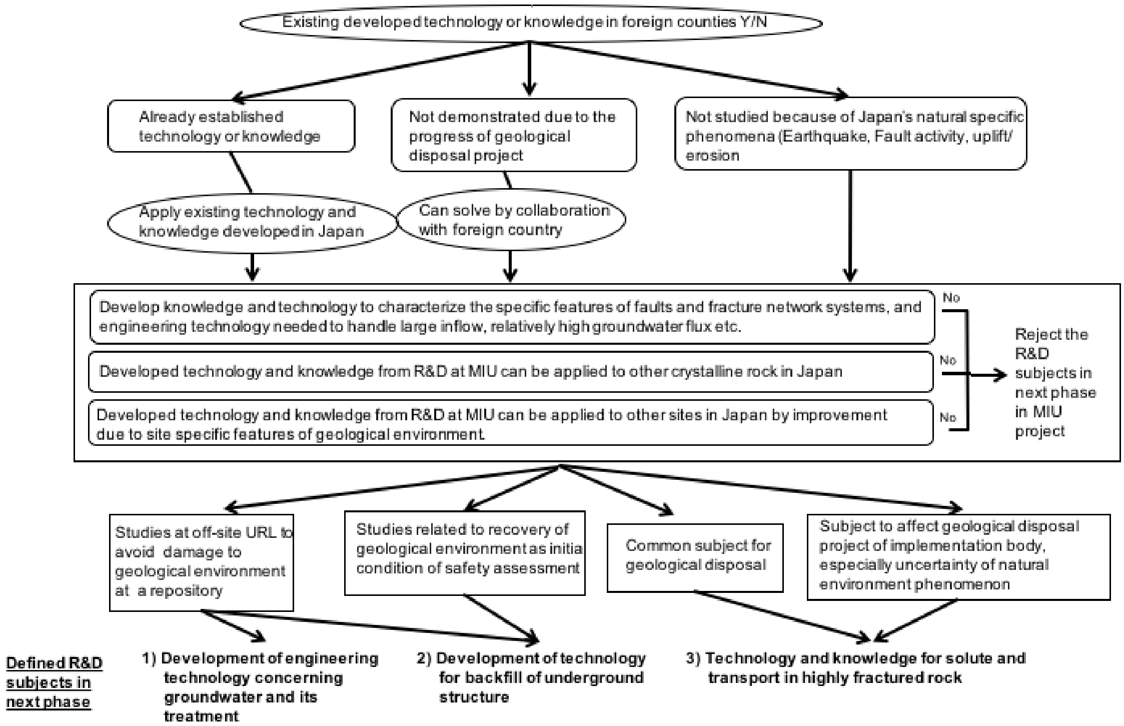

Fig.5 Extraction process of major R&D activities in MIU project in next five-year [5)]

2.1 Development of engineering technologies for preventing of groundwater inflow and its treatment

Generally, countermeasures are applied for construction of underground space because of need to avoid changes to the geological environment near surface, maintain condition of construction work and minimize operational cost for water treatment. In the view of geological disposal, the material used for countermeasures could possibly have a detrimental affect on barrier systems in geological disposal, such as the cement. Moreover, groundwater inflow into a gallery can directly affect the emplacement of buffer material like bentonite.

Therefore, it is essential to develop grouting technology to minimize any influence on the barrier systems.

With respect to these points, the following R&D activities are on-going:

(1) Development of grouting methodology that are a combination of pre- and post-excavation grouting; and
(2) Reasonable water treatment system for deep underground construction in Japan.

2.2 Development of technology for backfill of underground structure

In a geological disposal project, an excavated repository will be backfilled completely to avoid the rapid migration of radionuclides from emplaced high-level waste to the geosphere and to mitigate against human intrusion. On the other hand, safety assessment in postclosure is assumed to rely in part on re-establishment of the baseline conditions of the geological environment prior to repository construction. However, the recovery of geological environment is time dependent related to duration because of low permeable backfill material and coupling phenomenon of T-H-M-C around waste package. Therefore, it is important to develop the technology for backfilling and quantitative evaluation of disturbance of the geological environment in backfilled and of disturbed areas in a repository. The following R&D items are in progress:

(1) Groundwater recovery experiment;
(2) Development for monitoring system after backfilling of underground structures; and
(3) Backfill tests at drift scale.

2.3 Technology and knowledge concerning solute transport in highly fractured rock

Generally, fractures distributed in rock in Japan exhibit a high degree of thermal alteration in a complex fracture network system due to their location in an active tectonic environment and the influence of several major crustal plates. The alteration and sealing of fractures are specific features and processes that will affect the solute transport of radionuclides in crystalline rock. Therefore, it is important to understand their characteristics and long-term evolution by establishment of a site investigation methodology. Therefore, the following tasks have been selected for development:
(1) Development of mass transport models applicable in heterogeneous fracture network systems; and
(2) Development of methodology for quantitative estimation of geological evolution at a site.

3 Current status of MIU project

New five-year plan commenced from FY2015. Here, major topics are introduced as mentioned in previous section.

3.1 Development of grouting methodology - combined pre- and post-excavation grouting

This experiment was done in and around the 500 m Research Gallery south[6]. Pre- excavation grouting was performed to reduce groundwater inflow to below the design construction criterion of 300 L/min as a first step (Fig.6). It was successful with measured inflow of 200-220 L/min in the excavated drift after the pre- excavation grouting.

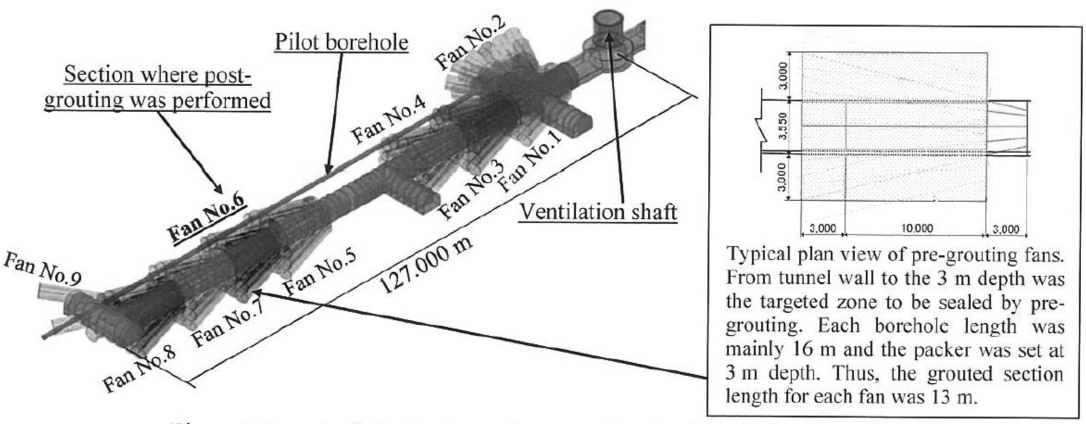

Fig. 6 Schematic layout of pre-excavation grouting fans [6]

Post-excavation grouting work included drilling six circular fan arrays in a 16 m section within the pre-excavation grouting area (Fig.7). Fundamentally, three design comparisons were set: “Material” (liquid-type colloidal silica (CSG) vs super fine cement), “Injection system” (complex dynamic injection vs ordinary static injection) and “Grouting concept” (Sealing outside of the pre-excavation grouting zone vs sealing only the exact grouted zone). The results of the experiment indicated that the application of “CSG”, “Complex dynamic injection” and “Sealing outside of the pre-excavation grouting zone” attained better results than the alternatives. The inflow after post-excavation grouting was reduced by 1/3 this is considered to meet the objectives of sufficiently decreased inflow.

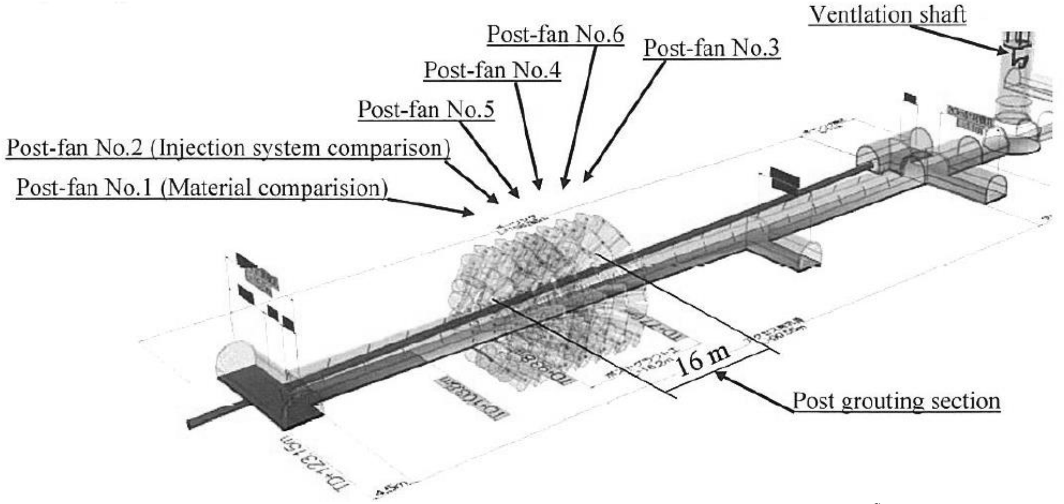

Fig.7 Schematic layout of post-excavation grouting fans [6)]

Then, the post-excavation grouting experiment was performed outside of the pre-excavation grouting zone with designs, applying colloidal silica grouting material and complex dynamic grouting. If pre- and post-excavation grouting were not performed, the groundwater inflow at this experiment section had been predicted to be 1,300 m^3/day. These applied grouting techniques were effective in reducing inflow to 15 m^3/day. These results indicate that the applied post-excavation grouting methodology is effective in reducing inflow and it can be applicable under high groundwater pressure conditions (4 MPa).

3.2 Development of technology for backfill of underground structure

Groundwater recovery experiment mentioned in Section 2.2 is on-going. The experiment focuses on understanding the recovery processes linked to hydraulic pressure and hydrochemistry around underground galleries in fractured crystalline rock.

Fig.8 shows the experimental layout. The impervious plug was constructed before April, 2015 and preliminary testing was done to check the performance of the plug. However, there were defects in the plug due to construction defects and outflow occurred due to seal failure during the preliminary testing. After making the necessary repairs, preliminary testing restarted in January 2016.

The results show that the repaired plug complies with the design concept and meets the specified performance criteria. Water pressure recovery occurred instantly and was at about 75 % that of baseline, in situ water pressure conditions prior to excavation of the 500 m level galleries due to outflow around the plug (Fig.9). Additionally, it was confirmed that alkalization and reduction of isolated groundwater in closed gallery were happening with time.

Henceforth, the water pressure, water chemistry and displacement of rock mass around the drift filled with ground water will be monitored and continue the process to understanding of the recovery phenomenon around the drift.

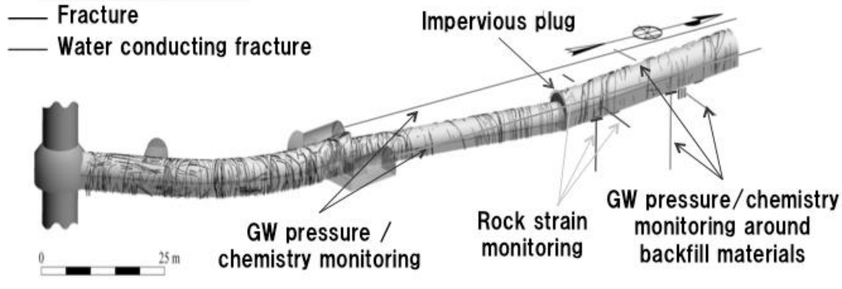

Fig.8 Fracture distribution and monitoring layout at groundwater recovery experiment site [3)]

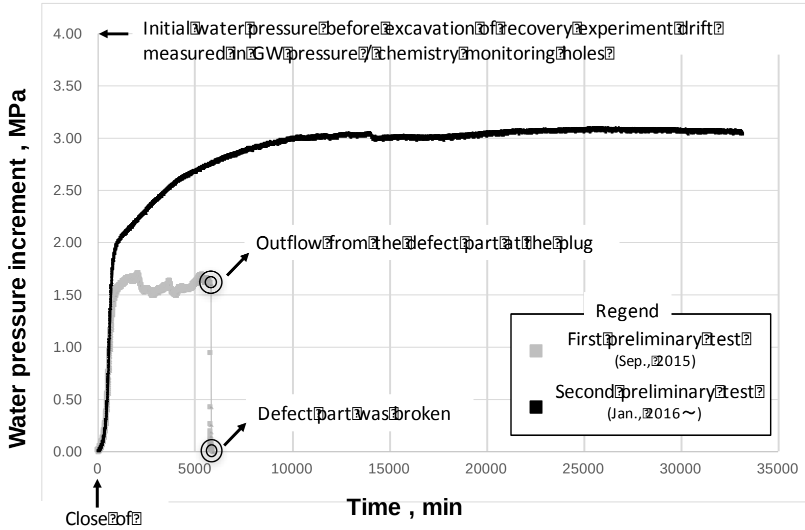

Fig.9 An example of the monitored water pressure recoveries in the groundwater recovery experiment drift during the preliminary tests

3.3 Technology and knowledge for solute transport in highly fractured rock

This R&D activity has been carried out as a collaborative study with CRIEPI funded by METI. In FY2015, several kinds of tracer experiments targeted the specific fractures as in fig.4 were performed at GL-300 m Gallery and several boreholes for the activity were drilled at end of south part of GL-500 m gallery for the investigation. Similar tracer experiments at GL-500 m level are planned for next year.

4 Future schedule of the MIU project

The three main R&D activities (Section 2) will be continued until FY2019 in the project. Also, collaboration with other institutions and organizations will be extended to develop a deeper understanding of the geological environment and for the development of new engineering technologies to enhance confidence in the safety of geological disposal.

5 Acknowledgements

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