JNC TN5510 2003-001

Horonobe Underground Research Laboratory Project
Plan of the Investigation Program
for the 2003 Fiscal Year (2003/2004)

August, 2003

Japan Nuclear Cycle Development Institute
Horonobe Underground Research Center

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(Translated Document[1])

Junichi Goto* and Katsuhiro Hama*

Abstract

The Horonobe Underground Research Laboratory Project is an investigation project which is planned over 20 years. The investigations are conducted in the three phases, investigations from surface (Phase 1), investigations during construction of the underground facility (Phase 2) and investigations using the facility (Phase 3). The 2003 fiscal year is the fourth year of the Phase 1 surface-based investigations.

In the development of techniques to investigate the geological environment, geophysical, geological, surface hydrogeological and borehole investigations are carried out. Geoscientific models are constructed and revised, and analyzed based on the acquired data. In the development of monitoring techniques of the geological environment, long-term monitoring of groundwater pressure is continued in the previously equipped borehole. The long-term monitoring systems are also installed in the remaining boreholes, and measurement is subsequently started. Development of the remotely operated monitoring system (ACROSS) is continued. In the study on long-term stability of the geological environment, monitoring with seismographs, GPS and electromagnetic survey equipment is carried out. In the development of basis for engineering techniques in deep underground, basic design of the underground facility is defined.

In the research and development on geological disposal, laboratory tests are continued on the transportation and emplacement equipment of engineered barrier, and on the reinforcement material to make detailed plans of the Phase 2 and 3 investigations. In the improvement of reliability on safety assessment methods, suitability of safety assessment methods is examined using the field and laboratory data.

Design of the facility on the ground is defined, and development of the construction site is started. In the environmental survey, environmental monitoring is continued. Cooperation with domestic and overseas research institutes is proceeded.

* Horonobe Underground Research Center Co-ordination Group

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1 This document is an English translation of Technical Document JNC TN1410 2002-002 (in Japanese).

JNC TN5510 2003-001
2003 年 8 月

幌延深地層研究計画　平成 15 年度調査研究計画

(翻訳資料[2])

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要旨

幌延深地層研究計画は、調査研究の開始から終了まで 20 年程度の研究であり、「地上からの調査研究段階（第 1 段階)」、「坑道掘削（地下施設建設）時の調査研究段階（第 2 段階)」、「地下施設での調査研究段階（第 3 段階)」の 3 つの段階に分けて実施する。平成 15 年度は、地上からの調査研究段階（第 1 段階）の 4 年目にあたる。

地質環境調査技術の開発では、物理探査、地質調査、表層水理調査、試錐調査を実施し、地質環境モデルの構築・更新および解析を行う。地質環境モニタリング技術を開発では、既存の試錐孔における水圧観測を継続するとともに、試錐孔に長期モニタリング機器を設置し、水圧の観測を行う。また、遠隔監視システム(ACROSS)の開発を継続する。地質環境の長期安定性に関する研究では、地震計、GPS および電磁探査機器による観測を実施する。深地層における工学的技術の基礎を開発では、地下施設の基本設計を行う。

地層処分研究開発では、第 2 段階以降の試験計画を具体化するために、搬送定置装置や覆工材料に関する室内試験、および人工バリアの試設計を実施する。安全評価手法の高度化では、これまでの調査で取得したデータに基づき安全評価手法の適用性に関する検討を行う。

地上部の施設建設に関しては、地上施設の設計を行い、地下施設建設用地の造成を開始する。環境調査では、モニタリング調査を継続する。国内・海外の研究機関との連携も継続・発展させる。

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[2] 本資料は核燃料サイクル技術資料「JNC TN1410 2002-002 幌延深地層研究計画 平成 15 年度調査研究計画」を英訳したものである。

Contents

1. Introduction

Japan Nuclear Cycle Development Institute (JNC) Horonobe Underground Research Center is proceeding the Horonobe Underground Research Laboratory Project (Horonobe URL project) to carry out research and development on geological disposal techniques of high-level radioactive waste.

The Horonobe URL is one of the underground research laboratories stated in the "Long-term Program on Research, Development and Utilization of Nuclear Energy (LTP)" (Atomic Energy Commission of Japan (AEC), 1994), and aims to study the deep geological environment in sedimentary rocks. The importance of the underground research laboratories is stated in the revised LTP (AEC, 2000) that the laboratories provide the sites for research and development to confirm techniques of the geological disposal and to establish methods of the safety assessment, also provide the places for the people who wish to know about the geological disposal.

The role of JNC is defined in the " Security of Basic Technology on Atomic Energy" (Atomic Energy Subcommittee in the Comprehensive Energy Resources Research Committee, 2001) that JNC should proceed steadily its research and development, *i.e.* scientific study of the deep geological environment, improvement of reliability on the geological disposal techniques and advancement of safety assessment methods, through accumulation of actual data and subsequent modeling using the planned underground facilities, and laboratory test facilities such as the Geological Disposal Radiochemical Research Facility. The above "scientific study of the deep geological environment" and "improvement of reliability on the geological disposal techniques and advancement of safety assessment methods" correspond to the "Geoscientific Research" and "Research and Development on Geological Disposal" in the Horonobe URL project.

The Horonobe URL project is planned over 20 years. The investigations are conducted in the three phases, investigations from surface (Phase 1), investigations during construction of the underground facility (Phase 2) and investigations using the facility (Phase 3). This report summarizes the investigation program in the 2003 fiscal year (2003/2004), the fourth year of the Phase 1.

2. Outline of investigation program in 2003/2004

In 2003/2004, investigations are focused on the Hokushin area, which was selected as the laboratory construction area in July 2002[1]. Geophysical, geological and borehole investigations are carried out to acquire geoscientific data to develop techniques to investigate the geological environment. The acquired data together with the previous data are used to construct and revise models of the geological environment. Monitoring of groundwater pressure using the long-term monitoring systems is continued in a borehole since the last fiscal year, and is to be started in the remaining boreholes to develop techniques to monitor the geological environment. Measurement is started on the borehole seismograph, GPS and electromagnetic survey systems, which were installed in 2002/2003 for the study on long-term stability of the geological environment. Seismographs are also set on the ground and measurement is to be started.

Basic design of the underground facility is started to develop basis of engineering techniques in deep underground.

Laboratory tests regarding deposition of engineered barrier and low alkaline concrete material are conducted to define the plan of research and development on geological disposal in the Phase 2 and Phase 3. Geoscientific data and phenomena which are relevant to safety assessment, and issues on quantity and accuracy of data are examined.

Basic and detailed designs of the facilities on the ground are defined. Development of the construction site is started.

Items in the environmental survey are reconsidered after the survey in spring, and subsequently surveys with the new items are carried out.

Interaction with wide range of specialists in domestic and overseas research institutes is continued.

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[1] The construction site of the laboratory was determined later.

3. Geoscientific research

3.1 Development of techniques to investigate the geological environment

3.1.1 Acquisition of geoscientific data

In 2003/2004, ground geophysical survey, geological investigations and borehole investigations are carried out to acquire data on geological structure, stratigraphy, hydraulic property, groundwater chemistry, and rock mechanical property. A meteorological monitoring system is employed for the surface hydrogeological investigation, and chemical analyses of river water and precipitation is planned. Applications for the ground geophysical survey, geological investigations and borehole investigations in 2004/2005 are also made. Details are described in the following sections.

(1) Geophysical investigations

Geophysical survey (AMT method) is carried out with several hundreds of meters measurement interval on two lines across the estimated geological structures such as the Omagari fault in the laboratory construction area (Fig. 1). Location and geometry of the Omagari fault and other geological structures are comprehensively interpreted from data of this survey and those of previous geophysical surveys, geological investigations and borehole investigations.

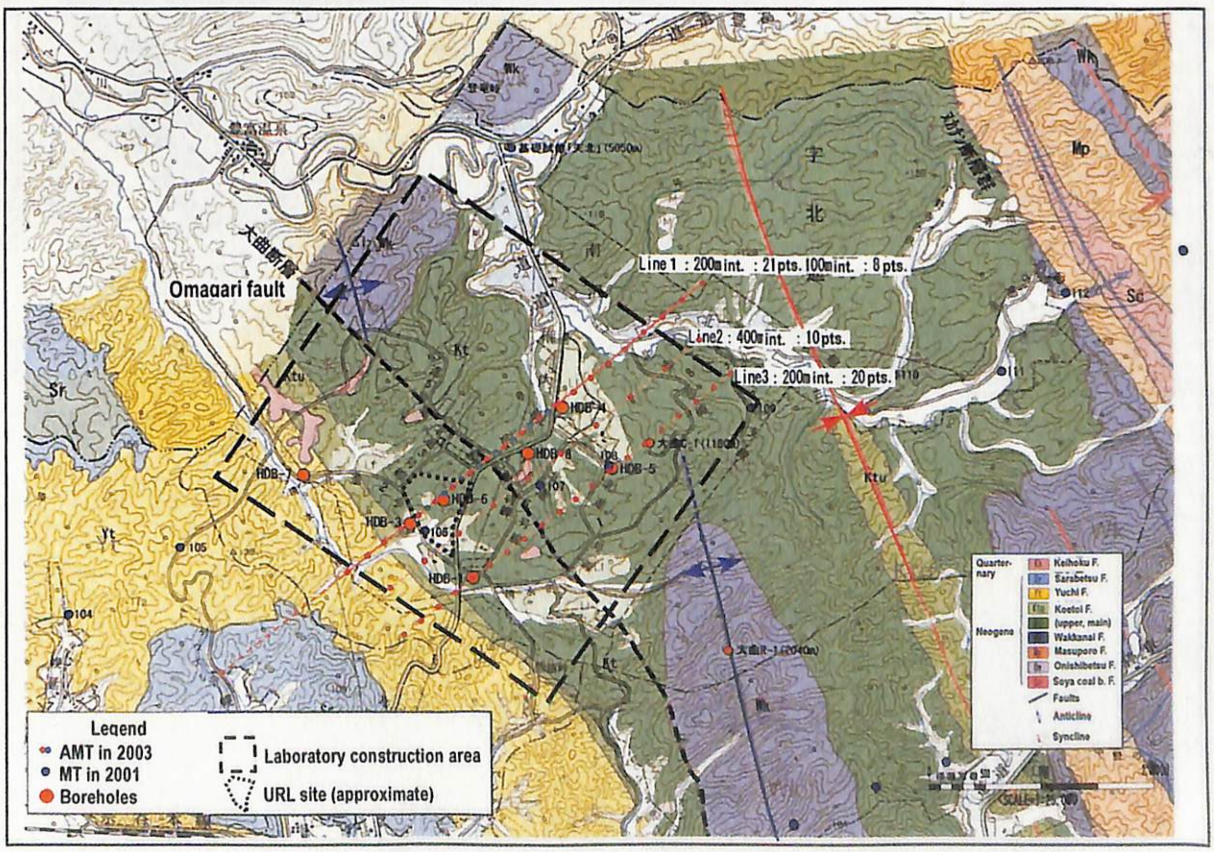

Fig. 1 Location of the ground geophysical survey.

(2) Geological investigations

Topograhical and lineament analyses of saterite and aerial photos, geological mapping, shallow borehole coring and laboratory analysis of rock samples are carried out to confirm stratigraphy, lithology and geological structures. The laboratory analysis comprises of petrological/mineralogical and microfossile analyses. The investigations are carried out around the laboratory construction area and to the south along the estimated geological structures such as the Omagari fault (Fig. 2).

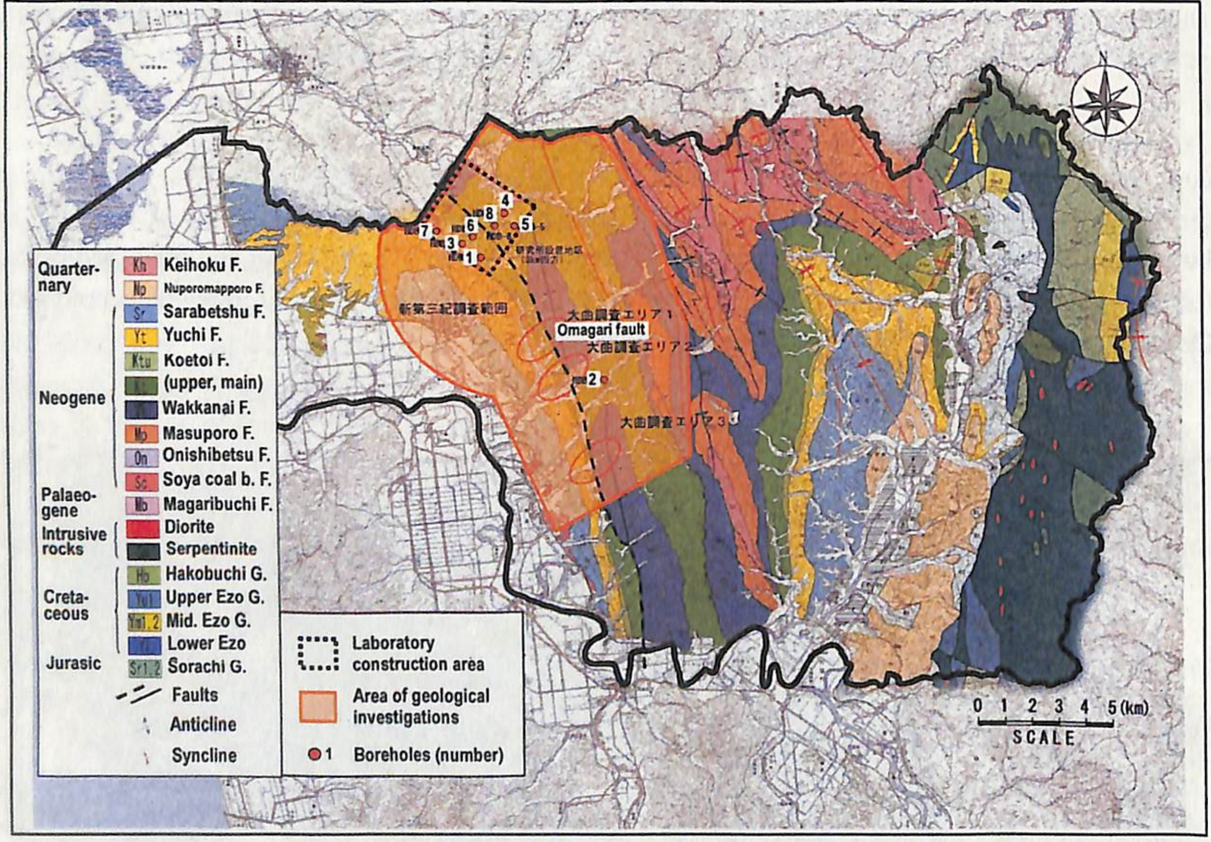

Fig. 2 Location of the geological investigations.

(3) Surface hydrological investigations

Measurement of river flux is continued since 2002/2003. Measurement of meteorological data such as precipitation, temperature, humidity, wind velocity and direction, evapotranspiration rate are started with the newly installed monitoring systems in the laboratory construction area and several points in the Horonobe town (Fig. 3). Chemical analysis of river water and precipitation is also carried out. These data are used to estimate recharge rate and to interpret flow of water near surface.

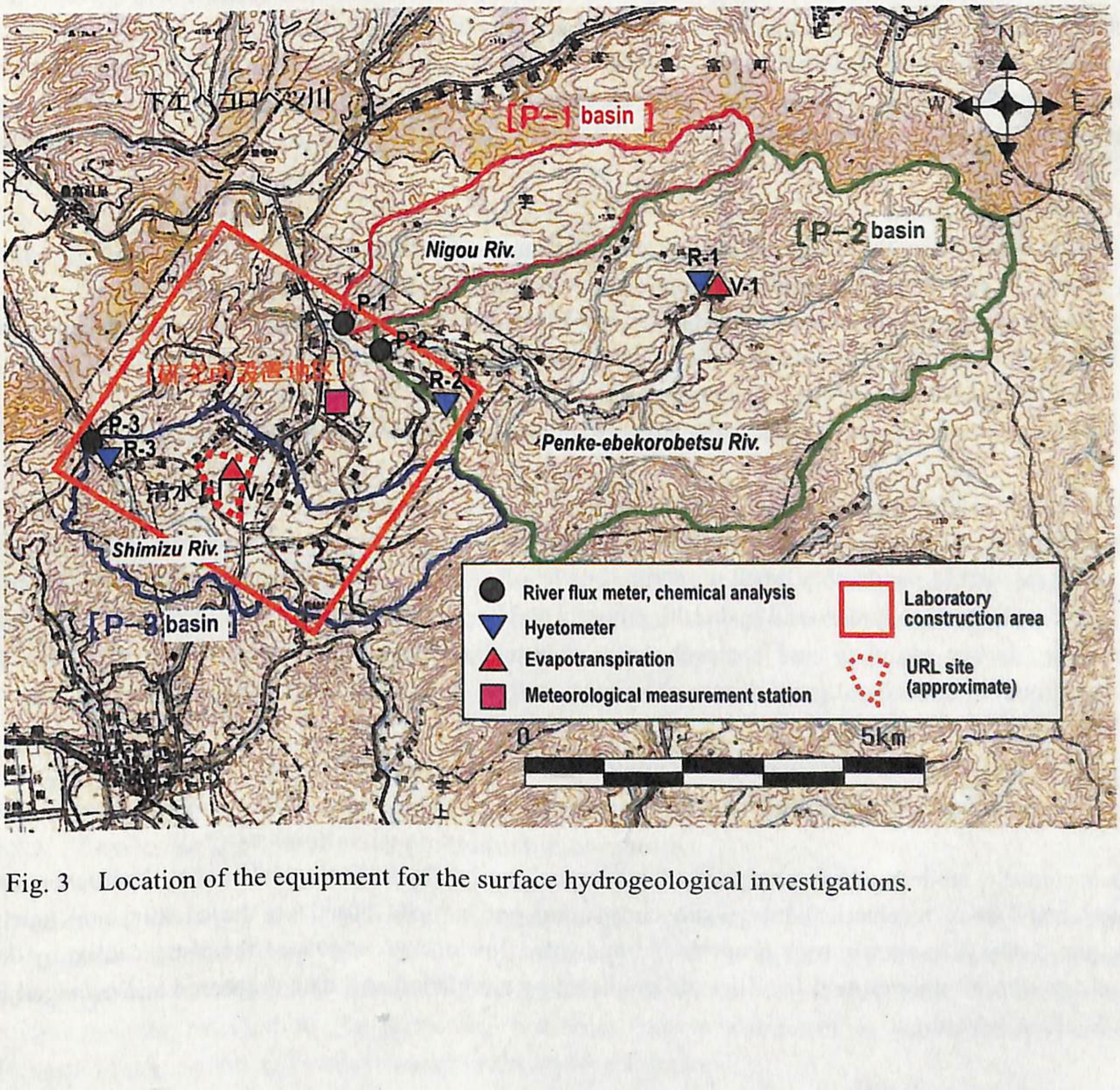

Fig. 3 Location of the equipment for the surface hydrogeological investigations.

(4) Borehole investigations

The borehole investigations are conducted in three sites in the laboratory construction area (HDB[2]-6, 7 and 8: Fig. 1 and 2). HDB-6 is a 620m deep vertical hole, located within the underground laboratory site. Its objectives are to acquire data for detailed designing of the facility and modeling of the site. HDB-7 is a 520m deep vertical hole, located to the west of the site near the border with Toyotomi town. Its objectives are to characterize the untested Yuchi formation which has not been well investigated yet. HDB-8 is a 470m deep vertical hole, located between HDB-4 and HDB-6. Its objectives are to increase geoscientific knowledge across the line perpendicular to the Omagari fault and improve the geoscientific models. All these boreholes have a role to monitor groundwater pressure and chemistry before, during and after the construction of the underground facility. General investigation items are described below.

a) Core investigations

- Core description (lithology, fractures, etc.), petrographical/mineralogical investigations, chemical analysis, age dating and microfossil analysis to understand geological characteristics.
- Physical property tests (porosity, density, resistivity, seismic wave velocity, etc.) and mechanical tests (uni/tri-axial compressive strength, tensile strength, etc.) to understand rock property.
- Hydraulic conductivity test in laboratory to understand hydraulic property.
- Porewater extraction and chemical analysis to understand groundwater chemistry.

b) Borehole investigations

- Geophysical logging (resistivity, density, neutron, temperature, sonic, caliper, etc.), stress measurement to understand rock property.
- Hydraulic tests to understand hydraulic property and head distribution.
- Groundwater sampling and comprehensive chemical analyses (major component, isotope, gas, microbe) to understand groundwater chemistry.

3.1.2 Modeling of the geological environment and prediction of changes caused by construction of the underground facility

Geoscientific models which comprise of geological model, hydrogeological model, hydrochemical model and rock mechanical model are constructed and revised based on the existing and newly acquired data. Changes in rock property, groundwater flow and groundwater chemistry caused by the construction of underground facilities are predicted by simulation. All data are stored and managed in a database system.

(1) Geological model

The geological model of 2002/2003, which described distribution of sedimentary formations, faults and folds, is checked and revised by the newly acquired data of geophysical survey, geological investigations and borehole investigations in 2003/2004.

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[2] HDB stands for Horonobe Deep Borehole.

(2) Hydrogeological model

A hydrogeological model of the laboratory construction area and its periphery is constructed based on the existing model and data from the borehole investigations of 2002/2003. Amount of inflow and changes in groundwater pressure caused by construction of the underground facility are predicted by simulation using this model. In addition, flow of groundwater with different density (*e.g.* fresh water and saline water) and with dissolved gas is analyzed.

(3) Hydrochamical model

Evolution of groundwater chemistry is interpreted from chemical analysis of pumped groundwater samples from boreholes and of porewater samples, as well as from mineralogical and chemical analysis of core samples. According to the interpretation, the present model is revised to describe spatial distribution of chemical property.

(4) Rock mechanical model

The rock mechanical model which describes distribution of strength and stress of rock is revised based on the data from laboratory tests of core samples and measurements in boreholes. The model is required to evaluate stability of caverns. Changes in rock mechanical property (*e.g.* strain and stress of rock) caused by the construction of underground facilities is predicted by simulation using this model.

3.1.3 Development of investigation techniques and equipment

Drilling techniques which can minimize influence on the borehole investigations such as hydraulic tests are studied. Feasibility of borehole geophysics such as VSP survey is also studied. Suitability and specifications of the equipment are examined for *in-situ* measurement of pH-Eh, composition and amount of dissolved gas. A performance test of rock mechanical measurement equipment is carried out in a newly prepared 50m deep borehole, which has been developed for measurement of pressure, displacement and seismic wave velocity since 2001/2002.

3.2 Development of techniques for the long-term monitoring of the geological environment

3.2.1 Development of monitoring techniques in boreholes

Groundwater pressure and chemistry are continuously measured before, during and after the construction of the underground facility to monitor influences caused by the construction and investigations. In 2003/2004, monitoring is continued in the previously equipped borehole, and equipments are installed in the remaining boreholes and measurement is subsequently started. Methods of description and evaluation of results are also examined.

3.2.2 Development of remotely operated monitoring system

The ACROSS (Accurately Controlled Routinely Operated Signal System), a monitoring system using seismic and electromagnetic waves, is to be employed to monitor changes in the geological environment such as geological structures and rock property before, during and after the construction of the underground facility. In 2003/2004, the transmitter and receiver systems are prepared.

3.3 Development of basis for engineering techniques in deep underground

Basic design of the underground facility is defined in 2003/2004. It is taken into account that the facility should provide opportunity for ordinary people to experience the deep underground, as well as should prepare space for the geoscientific investigations. Safety of the facility has the highest priority, therefore evaluation of stability of caverns with various rock property and measures for hazard such as tunnel fire are fully considered in the designing.

3.4 Study on the long-term stability of the geological environment

3.4.1 Seismological study

Three seismographs are set on the ground following the one on the ground and at the bottom of a 141m borehole in 2002/2003. These establish a monitoring system to detect micro earthquakes in the laboratory construction area and its periphery (Fig. 4). Monitoring is started and distribution of hypocenter is analyzed together with the data from the existing seismographs of other research institutes such as universities.

3.4.2 Diastrophic study

A geological survey is carried out to understand topographical changes, deformation and weathering of geological formations. Tectonic history and climate changes around the Horonobe area are also surveyed. These data are compiled with the existing information, and tectonic evolution and climate changes around the Horonobe area are documented.

The amount of crustal movement and changes in the electromagnetic property in deep underground are analyzed by GPS and electromagnetic measurement.

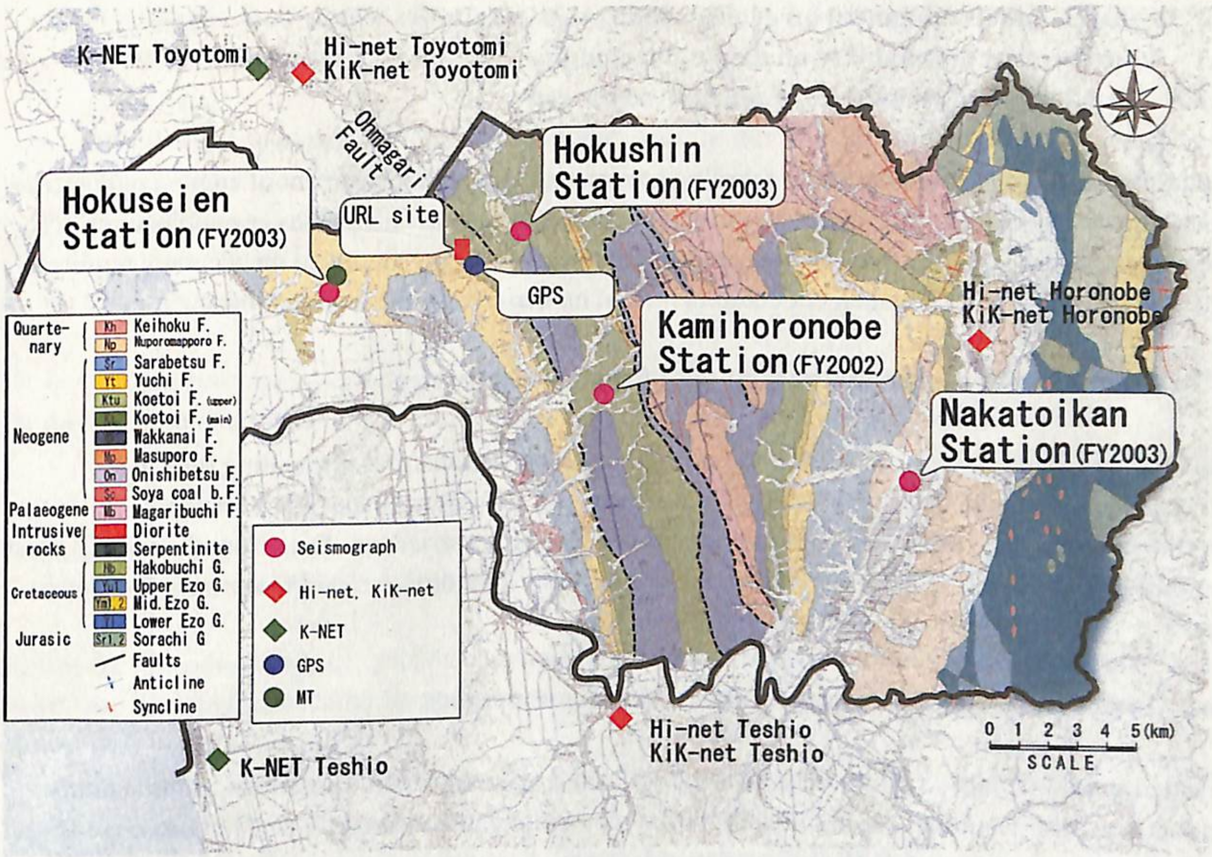

Fig. 4 Location of equipment for the seismological and diastrophic studies.

4. Research and development on geological disposal

4.1 Improvement of reliability on disposal techniques

4.1.1 Verification of techniques of engineered barrier

In the Phase 2 and 3, investigations regarding transportation and emplacement of engineered barrier, rock supporting and backfilling of tunnels are planned. To make detailed plans (*e.g.* objectives, test items, test layout, etc.) for these investigations, laboratory tests are continued on accuracy required for the transportation and emplacement equipment, and on material of the low-alkaline concrete.

4.1.2 Confirmation of designing methods of engineered barrier

In the Phase 2 and 3, long-term behavior of engineered barrier and the surrounding rock are investigated. To make detailed plans (*e.g.* objectives, test items, test layout, etc.) for these investigations, preliminary designing of engineered barrier is carried out. Data from the swelling test on buffer material in the laboratory using the groundwater of Horonobe, and those from the surface-based investigations are used in the designing.

4.2 Improvement of reliability on safety assessment methods

Scenarios and models of safety assessment are selected, parameters are chosen, and subsequently groundwater flow simulation, nuclide migration simulation, and uncertainty analysis are carried out. Data from the migration test of drill core samples in the laboratory, and those from the surface based investigations are used. Based on the results, geoscientific data and phenomena which are relevant to safety assessment, and issues to be solved to clarify the requirement on quantity and accuracy of data, are extracted.

5. Facility on the ground and environmental survey

5.1 Facility on the ground

Basic and detailed designs are defined for the facility on the ground such as research and administration offices, core storage, workshop, and exhibition hall. Development of the construction site is started. Basic and detailed designs are also defined for the dump of the excavation waste.

5.2 Environmental survey

Items to be surveyed are reconsidered after the environmental survey in spring 2003, and subsequently surveys with the new items (*e.g.* noise, vibration, water quality, etc.) are carried out.

6. Cooperation with other research institutes

Interaction with wide range of specialists in domestic and overseas research institutes is required in the Horonobe URL project because its research and development are highly interdisciplinary. Partners of cooperative studies at present are:

Hokkaido University for development of rock mechanical measurement equipment,
Saitama University for studies of groundwater flow modeling,
Central Research Institute of Electric Power Industry (CRIEPI) for studies of alteration of sedimentary rocks etc.,
Nagra (Switzerland) for development of hydrogeological borehole investigation technique, and
SNL (USA) for development of uncertainty analysis method.

In addition, our investigation field on surface and underground facility are open to the institutes such as **Horonobe Research Institute for the Subsurface Environment**[3].

[3] A research institute under Northern Advancement Center for Science and Technology (NOASTEC) established in 2003 in Horonobe town. Scientific researches related to the utilization of underground space are planned.

References

Atomic Energy Commission of Japan : "Long-term Program on Research, Development and Utilization of Nuclear Energy" (in Japanese), (1994).

Atomic Energy Commission of Japan : "Long-term Program on Research, Development and Utilization of Nuclear Energy" (in Japanese), (2000).

Atomic Energy Subcommittee in Comprehensive Energy Resources Research Committee : "Security of Basic Technology on Atomic Energy" (in Japanese), (2001).

Japan Nuclear Cycle Development Institute : "Horonobe Underground Research Laboratory Project Plan of the Investigation Program for the 2003 Fiscal Year (2003/2004) " (in Japanese), Technical Document JNC TN1410 2002-002, (2003).

APPENDIX

Overview of the surface-based investigations (Phase 1)

Items	Contents	Objectives	Application of results	2000FY (H12)	2001FY (H13)	2002FY (H14)	2003FY (H15)	2004FY (H16)	2005FY (H17)
					Surface-based investigations (Phase 1)	area selection			(Phase 2)
				Selection of area for the URL construction			Investigations in/around the selected area		
Geoscientific Research									
1. Development of techniques to investigate the geological environment									
1.1 Acquisition of geoscientific data									
(1) Airborn survey	Heliborn survey (magnetics, electromagnetics, natural gamma).	To estimate geology and geological structure to 150m deep.	Geological model. Planning and interpretation of other investigations. Arrangement of boreholes. Selection of construction area.						
(2) Ground geophysics	Electromagnetics.	To estimate geology and structure to 2000m deep. To estimate detailed geological formation and structure near the borehole in the selected area.	Geological model. Planning and interpretation of other investigations. Arrangement of boreholes. Selection of construction area. Construction design.	regional			detailed		
	Reflection seismics.	To estimate detailed geological formation and structure to 2000m deep in the selected area.	Geological model. Planning and interpretation of other investigations. Arrangement of boreholes. Construction design.						
	VSP surveys.	To estimate detailed geological formation and structure near the borehole in the selected area.	Geological model. Planning and interpretation of other investigations. Arrangement of boreholes. Construction design.			HDB-1, 3, 4, 5		HDB-6	
(3) Surface geology	Lineament interpretation and geological mapping.	To estimate distribution of geological structure. To confirm stratigraphy.	Geological model. Planning and interpretation of other investigations. Arrangement of boreholes. Selection of construction area. Construction design.	lineament, mapping		mapping	mapping	mapping	
	Laboratory tests (petrology, mineralogy, geochemistry, geochronology, micro fossils).	To characterize rocks and confirm stratigraphy.	Geological, hydrochemical and solute transport models. Planning and interpretation of other investigations. Arrangement of boreholes. Selection of construction area. Construction design.						
(4) Surface hydrogeology	Monitoring of weather (precipitation, temperature, humidity, sun exposure, evaporation), river flux, water table (wells, springs).	To estimate recharge rate.	Hydrogeological model. Planning and interpretation of other investigations. Arrangement of boreholes.	preparation (system, location)		installation, monitoring			
(5) Borehole investigations	Borehole investigations (geophysical logging, hydraulic tests, groundwater/gas chemical analysis, stress measurements).	To acquire physical, hydraulic, hydrochemical properties.	Geological, hydrogeological, hydrochemical and rock mechanical models. Planning and interpretation of other investigations. Arrangement of boreholes. Selection of construction are. Construction design.		HDB-1, 2 (700mx2) (for area selection)	HDB-3, 4, 5 (500mx3) (in/around the selected area)	HDB-6, 7, 8 (500mx3)	HDB-9, 10, 11, 12 (500mx4)	
	Core mapping, laboratory tests (petrology, mineralogy, geochemistry, geochronology, micro fossils, physical and rock mechanical property, stress, hydraulic conductivity, pore-water chemistry).	To characterize rocks and confirm stratigraphy.	Geological, hydrogeological, hydrochemical, solute transport and rock mechanical models. Planning and interpretation of other investigations. Arrangement of boreholes. Selection of construction area. Construction design.						
1.2 Modeling of the geological environment and prediction of changes caused by the construction of underground facilities									
(1) Geological model	Construction/revision of the model.	To understand spatial distribution of geology/structure. To provide basis for hydrogeological/hydrochemical/rock mechanical models. To understand degree of uncertainty with increasing amount of data.	Hydrogeological, hydrochemical and rock mechanical model. Planning and interpretation of other investigations. Arrangement of boreholes. Selection of construction area. Construction design. Development of comprehensive investigation/modeling methodology.		model construction/revision				
(2) Hydrogeological model	Construction/revision of the model. Groundwater flow simulation. Planning of fresh/saline water boundary study.	To understand groundwater flow, head distribution. To understand degree of uncertainty with increasing amount of data.	Planning and interpretation of other investigations. Arrangement of boreholes. Selection of construction area. Construction design. Development of comprehensive investigation/modeling methodology.	selection of methods		model construction/revision, groundwater flow simulation			
(3) Hydrochemical model	Construction/revision of the model.	To understand hydrochemical condition and its evolution. To understand degree of uncertainty with increasing amount of data.	Validation of hydrogeological model. Planning and interpretation of other investigations. Arrangement of boreholes. Selection of construction area. Construction design. Development of comprehensive investigation/modeling methodology.		model construction/revision				
(4) Rock mechanical model	Construction/revision of the model.	To understand spatial distribution of rock mechanical condition. To understand degree of uncertainty with increasing amount of data.	Planning and interpretation of other investigations. Arrangement of boreholes. Selection of construction area. Construction design. Development of comprehensive investigation/modeling methodology.		model construction/revision				
Prediction of changes related with construction	Prediction of distribution/condition of geological environment and its changes related with underground facility construction.	To understand distribution/condition of geological environment and its changes caused by underground facility construction. To prepare for evaluation of the prediction during/after the construction.	Construction design. Development of comprehensive investigation/modeling methodology.						
Database construction	Digitizing and management of all data.	To store data systematically and use effectively.	Planning and interpretation of investigations. Geological, hydrogeological, hydrochemical, rock mechanical and solute transport models. Construction design. Development of comprehensive investigation/modeling methodology.						
1.3 Development of investigation techniques and equipments									
Borehole drilling	Improvement and development of drilling techniques and equipments for soft sedimentary rocks (drilling mud, casing).	To provide good condition for core and borehole investigations and monitoring.	Core and borehole investigations and monitoring.	selection of techniques and equipments		improvement of equipment			
Borehole investigation	Improvement and development of techniques and equipments for hydraulic tests and groundwater sampling under the existence of oil/gas.	To acquire reliable data for hydrogeological/hydrochemical investigations.	Hydrogeological and hydrochemical investigations.	selection of techniques and equipments		improvement of equipment			

APPENDIX

Overview of the surface-based investigations (Phase 1)

Items	Contents	Objectives	Application of results	2000FY (H12) – 2005FY (H17): Surface-based investigations (Phase 1); area selection (2002FY); (Phase 2) (2005FY); Selection of area for the URL construction / Investigations in/around the selected area
2. Development of techniques for monitoring of the geological environment				
2.1 Development of monitoring techniques in boreholes				
	Development and improvement of equipment. Installation of equipment and start of monitoring.	To acquire reliable data on initial state condition before the construction, and their changes during/after the construction.	Monitoring techniques and methodology. Hydrogeological and hydrochemical models.	improvement of equipment → installation, monitoring
2.2 Development of remotely operated monitoring systems				
	Improvement of data transmission/detection system using seismic and electromagnetic waves (ACROSS). Installation of equipment and start of monitoring.	To acquire precise data on initial state of geologicla structures and rock property before the construction, and their changes during/after the construction.	Monitoring techriques and methodology.	improvement of system → installation, monitoring
3. Development of basis of engineering techniques in deep underground				
Designing of the underground facility	Planning of layout, construction schedule, engineering management (rock support and safety). Basic and detailed designing.	To proceed construction safely and steadily.	Construction design.	planning of layout, schedule, engineering management → basic and detailed designing → surface preparation for shaft excavation
Planning of investigations	Planning of investigations on detection and restoration of excavation damage.	To understand the possible excavation damage. To validate the restoration methods.	Construction design.	planning
4. Study on long-term stability of the geological environment				
4.1 Seismological study				
Seismological monitoring	Planning, installation and monitoring of seismographs.	To acquire and accumulate data. To understand aerial seismic activities and their relation to seismic faults. To evaluate effect of seismic activity on groundwater flow.	Assessment of long-term stability.	preparation of equipment → installation. monitoring
4.2 Diastrophic study				
Diastrophic monitoring	Planning, installation and monitoring of diastrophic monitoring equipment (electromagnetic survey meter and GPS).	To understand regional/local diastrophic activities. To understand diastrophic history (faults, terraces, basins, sea level).	Assessment of long-term stability.	preparationt of equipment, existing data analysis → installation, monitoring
Geological investigations	Trench survey on active faults.	To understand activity of the major faults (e.g. Omagari Fault)	Assessment of long-term stability.	
Research and development on geological disposal				
1. Improvement of reliability on desposal techniques				
1.1 Verification of techniques of engineered barrier				
Planning of investigations in the underground facility	Laboratory tests on effects of precision in deposition of the engineered barrier. Planning of investigations on deposition and backfilling/plugging.	To make and optimize plans for deposition and backfilling/plugging tests.	Verification of techniques for disposal	laboratory tests, basic designing → detailed planning
1.2 Confirmation of designing methods of engineered barrier				
Planning of investigations in the underground facility	Literature survey on the other underground laboratory. Laboratory tests (low alkaline cement, etc.). Planning of tests on engineered barrier, gas migration, effect of cement and saline	To make and optimize plans for tests on engineered barrier, gas migration, effect of cement and saline groundwater.	Development of methods for detailed designing of deep repository	laboratory tests, basic designing → detailed planning
1.3 Improvement of reliability on safety assessment methods				
Confirmation of performance assessment models	Application of the scenario construction method and performance assessment models (engineered barrier, natural barrier, biosphere) to the data from surface-based investigations.	To check and improve the applicability of models to the test in the underground facility.	Improvement of reliability in the performance assessment modeling	planning → application
Confirmation of requirements on geoscientific data	Sensitivity and uncertainty analysis.	To understand and confirm the items, quantity and accuracy of data required for the safety assessment.	Improvement of reliability on methods for safety assessment, planning of the geoscientific investigations	planning → analysis
Environmental research				
Environmental research	Literature, interview and field surveys on natural and living environment (e.g. rare animals/plants, wells). Environmental monitoring.	To understand natural and living environment, and to minimize impact on them caused by the construction.	Construction site selection, construction design	survey; monitoring, survey
Designing and construction of surface facilities				
Basic and detailed designing	Designing, ground survey.	To construct surface facilities.	Construction of surface facilities	designing of land preparation, research/administration office, core storage, workshop → desigining of exhibition and meeting facilities; ground survey
Construction	Land preparation. Construction of research/administration office, core storage and workshop.	To conduct research and administrative work.	Research and administrative work	