4 Main results from Phase I-a

In this Chapter the results from the respective disciplines of geology (Section 4.1), hydrogeology (Section 4.2), hydrochemistry (Section 4.3) and rock mechanics (Section 4.4) are presented. Sections 4.5 and 4.6 present techniques and equipment and modeling predictions, respectively.

4.1 Geological investigations

4.1.1 Overview

4.1.1.1 Objectives

The objectives of geological investigations were established to meet the overall goals of the MIU Project and its Phases, as follows [7].

① Data acquisition and analysis of the geology and the geological structures from surface to deep underground at the Shobasama Site

② Construction of the geological model by analysis and integration of the data and assessing its accuracy

③ Developing methodology for systematic investigation and analysis of geology and geological structures

4.1.1.2 Overview of the investigations

In Phase I-a, as the first step to achieve these objectives, it was necessary to investigate the geology and the geological structures in the Shobasama Site and from this knowledge to construct the geological model. The data collection and analysis are described below. As stated previously, the geological models are constructed for two areas. The larger area, (about 4 km×about 6 km) was established for the performance of and to improve the accuracy of groundwater flow simulations. The other, within the larger area, is the Shobasama Site. The knowledge obtained through the geological investigations forms the basis of the models for hydrology, hydrochemistry and rock mechanics. Accuracy in the geological model will carry forward to the other models and result in more robust site models.

Two models were constructed for each area, so that an assessment of (a) the amount of data that can or should be acquired, i.e., the data requirements for the investigations and the investigations to be performed in terms of the type, detail and scope are related to (b) the quality and accuracy of the results needed for analysis and modeling. The first model was constructed using only the data from literature surveys and the earlier geoscientific research, excluding the new research for the MIU Project. The data predates the reporting period of this report. The second model is constructed using the data obtained from Phase I-a, the MIU Project data for this reporting period, in addition to the data used for the first model.

4.1.1.3 Construction of geological models

As stated above, the geological model will form the basis of the models for the other disciplines. Therefore, in addition to the importance of accuracy in the geological model, the methodologies for constructing the other models and their data requirements should be taken into consideration when constructing the geological model.

For example, there are two approaches to developing hydrogeological models of groundwater flow; a continuum model, postulating the rock mass as a porous and homogeneous continuous medium and a discrete fracture model, characterized by the inclusion of fractures in the rock mass. For the groundwater flow simulation in Phase I-a the continuum model was adopted largely due to lack of information on distribution of fractures and their permeability, as well as constraints on time required for analyzing the several kilometre square rock mass as a fractured rock mass. Assuming that the hydrogeological model was to be constructed as a continuum model, construction of geological model requires the following conditions.

① Division of the sedimentary rocks into geological units on the assumption that physical properties are uniform, that is, homogeneous in the same sedimentary formation.
② Specify the location, continuity and width of and structural discontinuities such as faults that extend throughout the entire model area.
③ Divide crystalline rocks into geological/structural domains which have statistically significant differences in fracture density or preferred orientations and that can be treated as homogeneous in terms of hydraulic conductivity and transmissivity.

Geological model was constructed in the following order.
① Definition of the geological units based on the known geology
② Define the boundaries between geological units and their characteristics
③ Construct the model using 3-D visualization software, Section 4.1.1.4 below.

4.1.1.4 Visualization of geological model

The geological model forms the basis of the models for hydrogeology, hydrochemistry and rock mechanics. The 3-D visualization of the geological model through computer graphics can make it easy to share and to integrate the necessary information for constructing the above models.

EarthVision, 3-D visualization software produced by Dynamic Graphics Inc., was used for visualization of the geological model. The software forms a 3-D geological model of the rock mass, including capability to show estimated shapes of discontinuity planes such as the boundaries between geological formations and large faults, and combining these discontinuities, taking relationships such as position in space and development process into consideration [16,17].

This software is used to construct models in other major projects for geological disposal, such as at

Sellafield (Nirex), Wellengerg (Nagra), Äspö HRL (SKB) and Yucca Mountain (USGS, USDOE) [18].

Minimum tension theory based on spline interpolation is one of the functions of EarthVision. It is applied to estimate the ground surface, geological boundaries and fault planes. This method interpolates between adjacent data with the smoothest curved surface by an n-dimensional polynomial formula based on the input data of positions and directions [19].

4.1.2 Geological results – JNC's geoscientific research prior to Phase I-a of the MIU Project

The geology and geological structures in and around the Shobasama Site were investigated prior to the MIU Project in what is termed in this report "other geoscience research". This research includes surveys on the Tsukiyoshi uranium deposits [20,21], the RHS Project [15], the Shaft Excavation Effect Experiment [22], investigations in the Tono Mine and historic geological knowledge available from literature surveys. Following is an overview on the other geoscience research.

4.1.2.1 Lineament definition, analysis and interpretation [15]

It is generally accepted that a lineament refers to a linear topographic feature (sometimes a geophysical linear) possibly related to an underlying structure such as a fault, fracture zone or lithologic contact. Generally, a linear topographic feature is visible on aerial photographs or satellite imagery such as Landsat or SPOT [23]. Structures such as faults and fracture zones often, though not always, have a linear topographic expression. Therefore, lineament analyses may provide a rapid method to develop knowledge of the location of individual structures and also, from a statistical analysis of lengths and trends, can provide a basis for conceptualization of structural patterns and a preliminary indication of regional deformation.

In the RHS Project, TGC used Landsat Thematic Mapper multi-spectral imagery with a ground level resolution of 30 m (1:200,000 scale) covering an area of 50 km square. As shown in Figure 4.1(1), 1,276 lineaments were identified, including ones coincident with known active faults [14] such as the Adera Fault, Ako Fault, Hanadate Fault, Shirakawa Fault, Byobusan Fault, Kasahara Fault, Enasan Fault and Sanageyama-Kita Fault.

These faults form a grid-like pattern and are interpreted to form the boundaries of several large blocks. The trends of lineaments in each fault-bounded block, the intra-block, were compared statistically. It was clear that, as is shown in Figure 4.1(1), there are differences in the distribution patterns of lineament trends among the blocks. This may suggest that, if we assume the lineament is a reflection of discontinuities such as faults, there are regional differences in tectonic patterns related to variations in stress conditions and deformation in the blocks. The reasons for the inter-block variations are not clear: they could be due to stress redistribution during tectonic events resulting in different deformation patterns or due to the underlying geology. Nevertheless, from conceptualization of geological models and a predictive perspective, the lineaments are useful. In addition, whether related to stress redistribution or internal geological fabrics, each block can be assumed to have had a slightly different evolution of the geological