



by Hitoshi Koide

Geologic problems of radioactive waste disposal in Japan

The long-term stability of the geologic environment is of primary importance for repositories that are to be considered for the geologic disposal of high-level radioactive waste. Research in Japan emphasizes both the generic validation of geologic disposal and a general survey of the geologic environment of the Japanese islands. Intensive hydrogeologic, geochemical, and geotechnical investigations are being conducted in the Tono mine of southeastern Honshu, among others, because the Tono uranium deposit within Tertiary sediments is a natural analog of nuclide migration through geologic mediums. The long-term geologic predictions of tectonic disturbances and water-rock interactions are key issues for the assessment of the performance of high-level waste disposal.

Introduction

Japan generates nearly 10 percent of the world's nuclear electricity by using 39 nuclear reactors that have a total capacity of 31 gigawatts (GW). By the year 2000, nuclear power generation in Japan is expected to reach 50 GW, equivalent to 35 percent of its total electricity supply. One of the current projects to achieve independence for Japan's energy supply is the construction of major nuclear fuel cycle facilities, such as the reprocessing plant, uranium enrichment plant, and land burial facility for low-level radioactive waste (LLW) at Rokkasho-mura, Aomori Prefecture, in northeastern Japan. By the end of March 1989, the volume of LLW had reached the equivalent of 760,000 drums of 200-liter capacity.

Japan's energy policy includes the reprocessing of spent nuclear fuel and the utilization of the plutonium and recovered uranium in atomic power plants. High-level radioactive waste (HLW) in liquid form, produced at reprocessing plants, is to be vitrified into a stable form, stored for 30 to 50 years for cooling, and disposed of finally in geologic formations that are deeper than several hundred meters. By the year 2030, the volume of vitrified HLW will be equivalent to 36,000 canisters of 110-liter capacity.

Research and development for radioactive waste disposal in Japan

The research and development for the safe disposal and storage of radioactive waste are carried out by the Power Reactor and Nuclear

Fuel Development Corporation (PNC), Japan Atomic Energy Research Institute (JAERI), Radioactive Waste Management Center (RWMC), Geological Survey of Japan (GSJ), Central Research Institute of Electric Power Industry (CRIEPI), and other organizations under the total planning and supervision of the Atomic Energy Commission (AEC), Nuclear Safety Commission (NSC), Science and Technology Agency (STA), and Agency of Natural Resources and Energy (ANRE) of the Ministry of International Trade and Industry (MITI).

The geologic disposal of HLW in Japan is planned for four stages. The first stage is the selection of an effective geologic formation. Next, a candidate disposal site will be chosen. Demonstration of the disposal technology at the candidate site will be the third stage. The fourth and final stage involves the construction, operation, and closure of the selected disposal facilities. The study in the first stage ended in 1984, but the conclusion was that the selection of a particular rock type should be postponed. Instead, the investigation of geologic properties and engineered barriers is continuing for a wide variety of formations, excluding obviously inadequate formations, such as unconsolidated rocks. Crystalline rocks like granite and sedimentary rocks like shale and tuff are being investigated today as possible host rocks for waste disposal.

Although the final purpose of the second stage of HLW disposal is the selection of the candidate disposal site, Japan's research emphasizes the generic validation of geologic disposal in the Japanese islands, analysis of multibarrier systems, disposal technology, a general survey of Japan's geologic environment, and techniques for forthcoming site characterization.

Geoscience study for radioactive waste disposal

Understanding the geologic setting of a site is essential to the assessment of long-term safety of radioactive waste disposal. Constant efforts are made to collect relevant data from the Japanese islands. Although intensive surveys of the mineral resources and geothermal energy have been conducted in many regions of Japan, data are barely suitable for the investigation of waste disposal. The geologic environment at depths of several hundreds and some 1,000 meters should be clarified in order to predict the behavior of buried radioactive waste.

The PNC has plans to construct proper underground research laboratories for the development of HLW disposal technology, and it is trying to get the approval of nearby residents and local governments for construction of the facilities. The PNC and JAERI participate actively in international research programs such as the Stripa Project in Sweden and the Alligator Rivers Analogue Project in Australia. They also conduct joint research with the USA, Canada, Sweden, Australia, Germany, Belgium, and Switzerland.

The Tono mine of southeastern Honshu (fig. 1) is located in the largest uranium deposit in Japan. The Tono deposit formed when

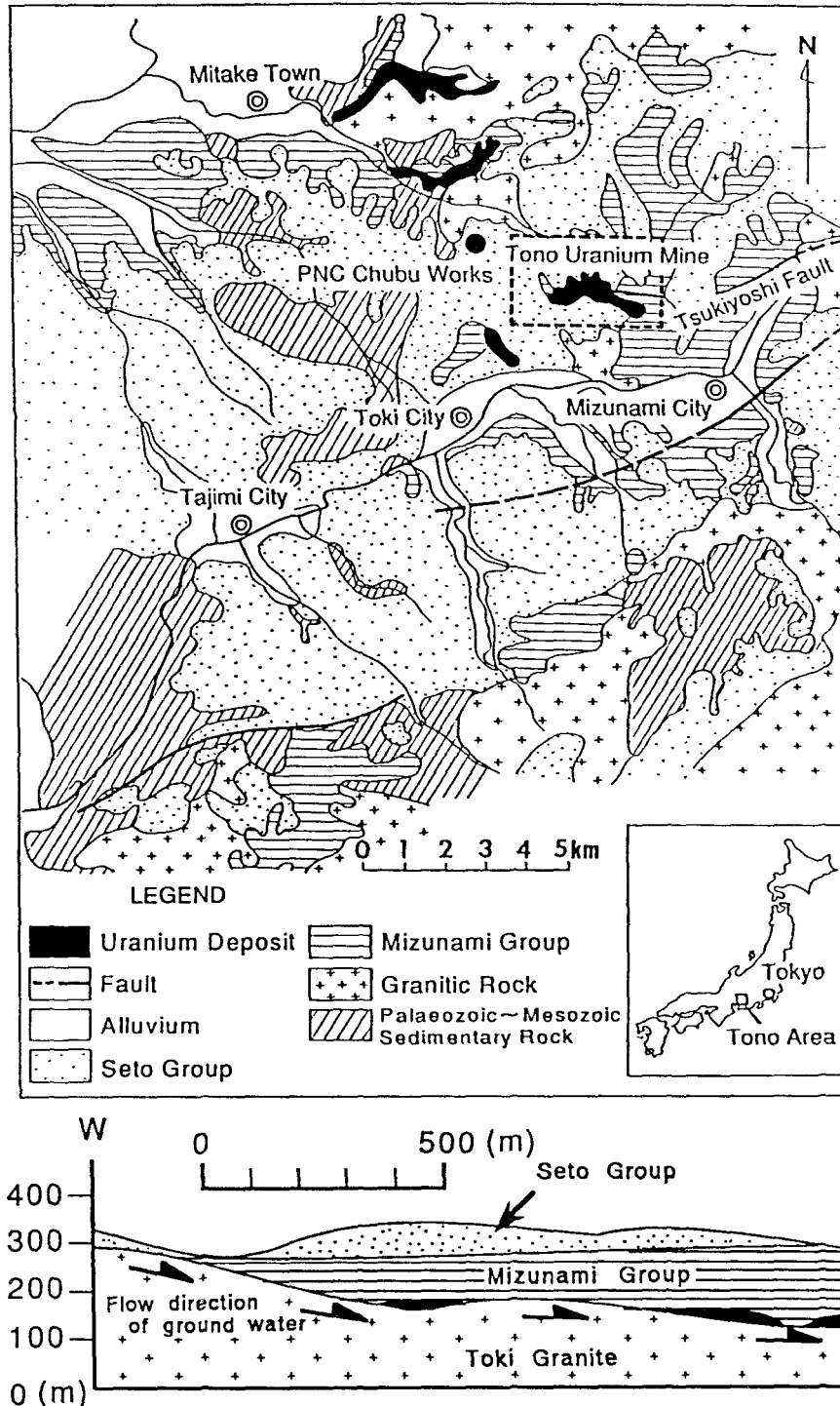


Figure 1.—Geology of the Tono area in southeastern Honshu (taken from Kawamura, 1991).

uranium precipitated from ground water into coarse sediments of Miocene age that were in paleochannels just over granitic basement rocks (Sakamaki, 1985; Doi and Hirono, 1990). The PNC and GSJ are conducting a cooperative study on the migration and fixation mechanisms of uranium and other related elements in the Tono area as a natural analog of nuclide migration through geologic mediums.

The PNC operates intensive hydrogeologic, geochemical, and geotechnical experiments in the sedimentary formations and basement granite of the Tono mine, as well as in granitic rocks of the Kamaishi mine in Iwate Prefecture, northeastern Japan. The “shaft excavation effect” (SEE) experiment (PNC, 1991) is being conducted in the Tono mine in order to understand the excavation effect, verify

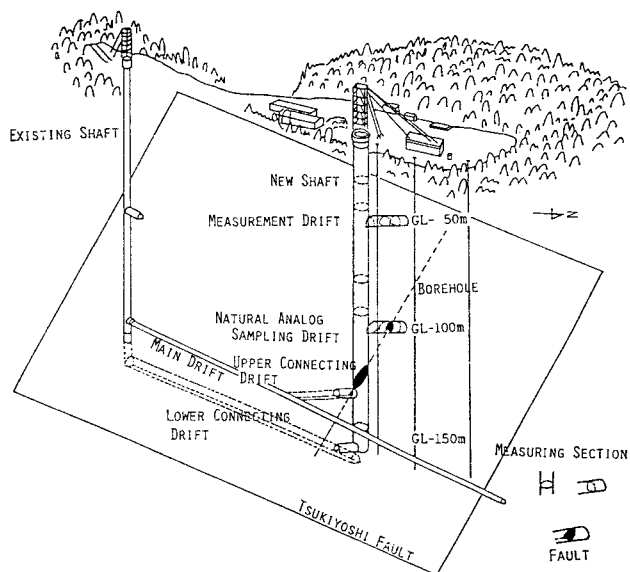


Figure 2.—Schematic diagram of “shaft excavation effect” experiment in the Tono mine (taken from Kawamura, 1991). GL indicates the depth from ground level. Three vertical lines near the new shaft are boreholes for testing.

regional hydrological models, obtain changes in geochemical properties due to the shaft excavation, and develop hydrogeologic and rock mechanical models that can estimate excavation effects (fig. 2).

Long-term stability of geologic environment

Japan is composed of a combination of arcuate islands along the boundaries among four major plates: the Eurasia, North America, Pacific, and Philippine Sea plates. Interaction of the plates forms complex geologic structures. Frequent earthquakes and numerous active faults clearly indicate severe deformation of the Earth's crust. Volcanic eruptions and abundant hot springs suggest intensive underground geothermal activity in some regions.

The long-term stability of the geologic environment is of primary importance in the disposal of radioactive waste in Japan. The speed of ordinary geologic processes, however, is much slower than the speed of human activities. Tectonic movements greater than 1 mm a year occur in restricted regions near plate boundaries, volcanic fronts, or major active faults, such as the Median Tectonic Line. Catastrophic events, such as major earthquakes and gigantic volcanic eruptions, are extremely rare in many regions. Even most active faults move less than several meters after being locked for periods that can last as long as several thousand years.

Any underground repository should be designed by using reliable knowledge of the maximum possible rate of tectonic movement, the probability of catastrophic events, and the consequences of geologic events and processes. The high durability of underground facilities against earthquakes was demonstrated in the epicentral region during the 1976 Tang-shan earthquake in China (Wang, 1985). The

Tang-shan earthquake brought great disaster to Tang-shan city, but it resulted in relatively little damage to the underground Tang-shan coal mine at a depth of 640 m below the ground surface. In the mine, minimal damage occurred, in spite of the presence of the earthquake-generating fault across the mine. Apparently, the probability that magma will intrude directly through the repository is extremely low. Careful investigations are in progress in order to evaluate the indirect effects of geologic events, such as a change in a ground-water path as a result of big earthquakes.

Rock properties slowly evolve as consolidation, diagenesis, weathering, and hydrothermal alteration take place. Hydrothermal processes, which are the indirect results of geothermal and igneous activity, are widespread in Japan. Low-temperature hydrothermal processes are studied as analogs of water-rock and water-waste interaction following burial of radioactive waste. Altered clay materials and vein-filling precipitates from hydrothermal fluids often effectively prevent the migration of ground water and nuclides through faults and fractures in rocks.

The densities of active faults and volcanoes show drastic regional variation. Volcanic activity is absent in regions between the volcanic front and the subduction zone (Sugimura and Uyeda, 1973). Kinugasa (1990) has proposed “active fault fronts” similar to the volcanic front in Japan (fig. 3). Active faults are rare on the oceanic side of active fault fronts. The great regional variation in the geologic environment will be important in forthcoming investigations for the site selection of safe radioactive waste disposal.

Geologic prediction

Scenarios for the long-term performance assessment of HLW disposal have been developed with special reference to the geologic setting of Japan. The long-term predictions of tectonic disturbances and water-rock interactions are key issues for performance assessment, especially in the Japanese islands (Koide, 1991). The methods of geologic prediction for radioactive waste disposal are classified as follows (Koide, 1990): (1) Prediction by extrapolation, the most fundamental method of geologic prediction. This method is effective especially in steady, slow processes such as tectonic movement, but it also is applicable to periodic phenomena. Research on Quaternary geology is needed in order to build a data base for this type of prediction. (2) Prediction by analogy. Most earthquake prediction methods can be classified as belonging to this category. Natural analogs (Chapman and McKinley, 1987) are the only reliable means of validating models for long-term prediction. (3) Prediction by probability. Statistical research may be indispensable to the risk assessment of some catastrophic events. Most geologic events, however, are not random in the strict sense. (4) Prediction by experiment. Laboratory experiments and in-place experiments are essential to an exact understanding of processes, as long-range experiments lasting hundreds or thousands of years are impractical. (5) Prediction by conceptual model. The plate tectonic model is useful for the prediction of tectonic movements. (6) Prediction by numerical simulation model. Great efforts have been made to develop reliable simulation models of ground-water flow around a repository. (7) Prediction by safety assessment model. The safety assessment of complex disposal systems requires the development of synthetic models, scenario analyses, and consequence analyses.

Long-term geologic prediction for radioactive waste disposal should be performed and cross-checked by using several of these different methods. Furthermore, the thorough cooperation of many organizations is essential in order to establish a safe disposal method for radioactive waste in Japan.

Figure 3.—Seismotectonic provinces in Japan (modified from Kinugasa, 1990). Short solid lines denote active faults, small dotted lines denote boundaries of provinces, and large dotted lines denote active fault fronts.



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