Status Report on Studies to Assess the Feasibility of Storing Nuclear Waste in Columbia Plateau Basalts

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STATUS REPORT ON STUDIES TO ASSESS THE
FEASIBILITY OF STORING NUCLEAR WASTE
IN COLUMBIA PLATEAU BASALTS

Raul A. Deju
Basalt Waste Isolation Program

July 2-6, 1979

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A B S T R A C T

In February 1976, the U. S. Energy Research and Development Administration (currently the U. S. Department of Energy) expanded the commercial radioactive waste management programs and established the National Waste Terminal Storage Program. Its mission was to provide multiple facilities in various deep geologic formations within the United States. The Office of Waste Isolation was established within the Union Carbide Corporation-Nuclear Division to provide program management of the National Waste Terminal Storage Program. The overall program consisted of investigating a number of geologic rock types to determine their suitability for terminal storage of radioactive waste. Basalts, such as the Columbia Plateau basalts, which underlie a large portion of the Pacific Northwest and the Hanford Site, were selected for initial geologic reconnaissance. Atlantic Richfield Hanford Company was asked in May 1976, by the Office of Waste Isolation, to plan and execute a basalt feasibility study. Geologic exploration of Columbia Plateau basalts was needed to determine the feasibility of utilizing those formations as a site for terminal storage of commercial nuclear waste.

In September 1977, the National Waste Terminal Storage Program was restructured. While emphasis was still on a salt repository, additional funds were given to support investigations of two U. S. Department of Energy sites-Hanford and Nevada. The Hanford program is presently the responsibility of the U. S. Department of Energy-Richland Operations Office. Rockwell Hanford Operations (successor to Atlantic Richfield Hanford Company) is the prime contractor responsible for this work. The Basalt Waste Isolation Program within Rockwell Hanford Operations has been chartered with the responsibility of conducting these investigations. This program is divided into systems integration, geology, hydrology, engineered barriers studies, engineering testing, and the construction of a near-surface test facility.

SYSTEMS INTEGRATION

The systems integration program involves the definition of studies required as part of the qualification of basalt as a repository medium for nuclear waste storage. These studies include the planning of demonstration facilities, as well as the specifying of scientific studies to be undertaken during and for the licensing process. In addition, the systems integration program is responsible for utilizing the results of ongoing research and development insofar as needed to select repository sites in basalt and assess the feasibility of nuclear waste storage in basalt. Thus, the systems integration program is responsible for integrating all our research and development studies and preparing the information needed for licensing a basalt nuclear waste repository.

During fiscal year 1978:

1. Research and development tasks needed for licensing a basalt repository were identified;
2. Siting criteria for a geologic repository were outlined;
3. A demonstration program for the in situ definition of heat and heat plus radiation effects on the basalt was designed;
4. Information required for the license application was proposed and a detailed format and content of the license application for the basalt repository was drafted;
5. The proposed contents of the environmental report were outlined;
6. Work was initiated to examine the types of facilities required as part of the repository, model these facilities, and establish guidelines to be used in the preconceptual design phase.

The systems integration program placed special emphasis on planning a demonstration program to provide information on the response of in situ basalt under heat loads similar to those which would be developed in a repository. In addition, the demonstration program will examine the in situ effect of heat and radiation resulting from the actual emplacement of spent fuel canisters. Test plans for these demonstrations were prepared. Results from the heater tests will provide data on borehole decrepitation, thermal stability, structural integrity, temperature, and displacement fields, and the influence of fractures and joints upon in situ basalt properties. These

studies will provide the basis for the design of key repository elements such as canister storage, borehole criteria, borehole liner performance, acceptable waste canister power levels, storage borehole array criteria, and repository step-loading evaluation. An equally important aspect of the in situ testing program is the development and verification of design models simulating the performance of a repository. The plan for testing the behavior of a basalt repository where an array of spent fuel canisters is emplaced was drafted.

GEOLOGY

The geologic studies are aimed at gathering the data required for selection and evaluation of potential repository sites in basalt. These studies will lead to identifying repository target areas, if any, that potentially provide geologic barriers adequate to prevent release of radiocontaminants to the biosphere. When a repository site is selected, geologic studies will thoroughly characterize the area to determine the extensiveness of individual basalt flows, the stability of the region, and the presence or absence of potentially hazardous geologic structures. After a site is selected, geologic studies will thoroughly characterize that site and continue to evaluate existing risks and provide adequate information for any safety assessment of the site selected.

Studies to date have been broken up into two categories: reconnaissance regional studies; and local studies of a more intensive nature within the Pasco Basin. As part of the regional studies, a survey of published and unpublished documents concerning the geology of the Columbia Plateau was completed. Over 1,500 references were cataloged and listed.^[1] In addition, mapping of the basalt within the Columbia Plateau^[1] (Figure 1-A) and the overlying late Cenozoic sediments have been conducted (Figure 1-B). The stratigraphic nomenclature of the Columbia River Basalt Group has been revised by the U. S. Geological Survey and is presently being compiled.

The Pasco Basin studies during fiscal year 1978 have included a definition of the local stratigraphy of the basalt^[2] and an assessment of the viability of using chemical properties,^[3] and magnetic characteristics for stratigraphic definition.^[4,5] In addition, extensive mapping (Figure 2) has been conducted and continues to be conducted in structurally significant areas of the basin. Preliminary results of the mapping have been reported.^[6] The geologic mapping effort has been supplemented by geophysical studies to examine the structural characteristics of subsurface strata.

FIGURE 1-A

REGIONAL COLUMBIA RIVER BASALT MAPPING

FIGURE 1-B

REGIONAL COLUMBIA RIVER BASALT MAPPING
LATE CENOZOIC MAP QUADRANTS MAPPED, WASHINGTON STATE

V7810-3.4

1. SURFACE GEOLOGIC MAPPING
AND RELATED FIELD STUDIES
(REPORTS ON INDIVIDUAL AREAS
HAVE BEEN PREPARED)

- (A) SADDLE MOUNTAINS AREA
- (B) UMTANUM RIDGE AREA
- (C) GABLE MOUNTAIN-GABLE BUTTE AREA
- (D) SOUTHWEST PASCO BASIN AREA
- (E) NINE CANYON AREA
- (F) INTRAFLOW STRUCTURES STUDY,
GRANDE RONDE BASALT,
SENTINEL GAP
- (G) PALEOMAGNETIC MEASUREMENTS,
GRANDE RONDE BASALT,
UMTANUM RIDGE

3. TECTONIC STABILITY STUDIES

- GEOLOGIC MAPPING LATE
CENOZOIC SEDIMENTS,
WESTERN PASCO BASIN
(DASHED PATTERN)
- SURFACE GEOLOGIC MAPPING
(1A TO 1E) ALSO INCLUDES TECTONIC
STABILITY STUDIES

2. BOREHOLE GEOLOGIC STUDIES

	DC-2	DC-4/5	DC-6	DC-7/8	DDH-3	DH-5
LITHOLOGIC AND GEOMECHANICAL LOGGING AND CORE PHOTOGRAPHY		•	•	•		
MAJOR AND TRACE ELEMENT ANALYSES	•		•	•		
PALEOMAGNETIC MEASUREMENTS	•				•	•

NOTE: ALL DATA ON FILE IN THE BASALT WASTE ISOLATION PROGRAM LIBRARY
NO PASCO BASIN GEOLOGIC STUDIES WERE CONDUCTED IN DH-4
OR RSH-1 DURING FY-78.

FIGURE 2
THE PASCO BASIN

HYDROLOGIC STUDIES

The hydrologic program provides hydrologic criteria and evaluation techniques by which potential repository sites can be selected and evaluated. The studies of the ground water regimes underlying the Columbia Plateau are important, since the ground water pathway probably affords the fastest avenue of contact between the repository and the biosphere. Thus, our hydrologic studies have emphasized the gathering of data to characterize the ground water systems underlying the plateau and the modeling of such data so as to evaluate radiocontaminant transport potential to the biosphere. The hydrologic studies include reconnaissance regional studies within the Columbia Plateau and intensive local studies within the Pasco Basin where the Hanford Site is located. The Pasco Basin was selected for detailed study because of its unique structural significance in the region; i.e., the greatest accumulation of basalt rock appears to occur within the Pasco Basin.

During fiscal year 1978 as part of the regional studies, a bibliographic search of information on the regional hydrology of the Columbia Plateau was completed.^[7] This bibliography includes over 640 references. In addition, analysis of the regional data was initiated and work is well under way in adapting and checking out the three-dimensional ground water flow code to be used in ground water modeling of the Columbia Plateau. A model of uni-dimensional diffusion was completed to examine transport through a dry repository layer by diffusion. This model provides the diffusion time for contaminants to reach a permeable interbed and will be used as a base line for modeling other scenarios.^[8]

The Pasco Basin studies were scoped to determine, in key areas, specific parameters that would allow modeling of this basin. The Pasco Basin appears to possess the smallest quantity of ground water compared to other basins within the Columbia Plateau. The basin has numerous thin beds of clay-rich sediment and saprolite which were deposited between the outpourings of Columbia River Basalt. This material has since plugged pore and fracture spaces causing slow ground water movement. This sealing has also reduced the ability of the rock to store water.

As part of the Pasco Basin hydrology studies, a geohydrologic annotated bibliography of the Pasco Basin was completed.^[9] This bibliography contains over 225 annotated references. The Pasco Basin hydrology studies required the drilling of several holes. As-builts and core hole histories of individual holes were prepared and reported after completion of each hole.^[10-14] All drilling activities to date indicate that the basalts are present in a predictable pattern beneath the Hanford Site. Formation depths and thicknesses are consistent with previous estimates based on earlier data.

The newly drilled holes and existing holes were used to conduct various hydrologic tests. Rockwell Hanford Operations interpreted drill stem tests from Well RSH-1 in the Rattlesnake Hills. This analysis shows hydraulic conductivity values between 10^{-7} and 10^{-9} cm/sec within the dense basalt flows themselves. Science Applications, Inc. conducted more sensitive tests and found hydraulic conductivities ranging from 10^{-7} to 10^{-13} cm/sec in the zones tested. Lawrence Berkeley Laboratory completed multiple static pressure tests and fluid level measurements in various holes. They also obtained water samples from selected horizons. Their results appear to indicate a downward hydraulic gradient in several of the wells tested. Their results also appear to substantiate that some basalt flows act as barriers to vertical ground water flow. An apparent regional flow barrier (the Umtanum Ridge-Gable Mountain anticline) was also postulated from the preliminary field results.

In subsequent years, the regional and Pasco Basin hydrologic studies will use the data being gathered in the field and through bibliographic studies to model the subsurface hydrologic systems and calculate transport times from a potential repository site to the biosphere under various conditions.

ENGINEERED BARRIERS

The emplacement of nuclear waste in a geologic repository may cause physicochemical perturbations to the surrounding environment. The engineered barriers program attempts to identify from a physicochemical standpoint, the features of various barriers to transport of radioactive contaminants. The program looks at four potential barriers: the waste; the rock; the container; and the overpack. In addition, a borehole plugging system is analyzed as a final barrier once the repository is sealed and abandoned. To assess the effectiveness of such a multiple barrier system, one examines chemical changes which could lead to chemical reactions, both at the canister (phase transformations, dissolution) and outside the repository (dissolution/precipitation, and sorption/desorption).

During the past fiscal year, work in this program was aimed at:

1. Defining the characteristics of various nuclear waste forms insofar as these are important to the long-term isolation of the waste in basalt;^[15]
2. Defining the geochemical environment expected near a basalt repository, and the effect of the waste form on the environment;

3. Identifying the chemical characteristics and past history of the basalts and associated secondary minerals with emphasis on assessing the conditions that existed during and after their formation or emplacement;^[16]
4. Simulating the reactions that take place when nuclear waste is emplaced in a basalt environment under repository conditions and identifying the resulting reaction products;^[17-19]
5. Thermodynamically modeling reactions in a basalt repository with emphasis on those cases where reaction rates are slow and needed experiments require long times to observe a significant alteration; and
6. Planning a borehole plugging program to demonstrate the applicability of plugging technology in a basalt environment.

Considerable progress has been made toward characterizing basalt and the alteration products found in basalt. Petrographic studies, electronmicroprobe studies, X-ray diffraction studies, and scanning electronmicroscopy studies have been made on core samples taken from various depths. In addition, preliminary computer simulations of the chemical environment in a basalt repository have been made from these findings.

The results of work completed during this report period indicate that there is a pattern to the alteration of the Columbia River Basalt. Vertical zonation of secondary minerals occurs with smectite dominating the upper portion of the stratigraphic column and the zeolite clinoptilolite and silica dominating the lower portion. A similar zonation occurs within individual vesicles found in the Grande Ronde Formation. One or more layers of smectite line vesicle walls and are followed in sequence by silica and/or clinoptilolite and clay. Different vesicles sometimes contain different portions of the alteration pattern and sometimes include phases not generally observed, such as erionite, halloysite, mordenite, analcine, and illite. This loss of historical information is probably due to the vesicles isolation from moving fluid; i.e., the fluid pathway leading to or exiting from the vesicles becomes blocked and mass transport must take place by diffusion instead of advection.

Measurement of time-dependent K_d values for a number of radionuclides has continued. The radionuclides included ^{226}Ra , ^{75}Se , ^{125}I , ^{237}Pu , ^{60}Co , ^{85}Sr , ^{137}Cs , ^{95}mTc , and natural uranium. Sorption on Umtanum basalt, heulandite (a zeolite), and nontronite (a clay) were measured at 25 degrees centigrade and ambient pressure.

In all cases except uranium, sorption experiments showed that, on a unit surface area basis, basalt adsorbs larger quantities of radionuclides than the clays, heulandite, and nontronite. This is true of selenium, radium, iodine, and cobalt, as well.

Extensive progress has been made in isolating those interaction products resulting from waste-basalt-ground water reactions which are primary hosts for various cations and anions. Interaction experiments have been conducted with individual phases in the waste form and individual mineral constituents in the basalt to zero on more specific identification of reaction products.

During fiscal year 1978, a plan for assessing the feasibility of backfilling a basalt repository with a reliable plug was drafted. The plan included an overview analysis and a synthesis of work to date in this field.

ENGINEERING TESTING

The engineering testing program conducted those tests required to define those engineering characteristics of basalt needed for conceptual engineering design studies and qualification of basalt as a storage medium for a nuclear waste repository. Engineering testing began with a literature review of laboratory and field studies of the engineering properties of basaltic rocks.^[20] This study involved a search of published and unpublished data on the physical, thermal, and mechanical properties of basaltic rocks. After this literature search was completed, and existing literature tabulated, samples from several core holes from the Hanford Site were subjected to extensive thermal and mechanical tests.^[21] In addition, the testing program was designed to gain basic input data from numerical models, as well as to determine lateral and vertical variation of properties between individual basalt flows and within individual basalt flows.

In addition to laboratory studies, in situ demonstration programs will further examine the behavior of an entire basalt rock mass composed of rooms embedded in the central portion of a basalt flow. These data are aimed at examining the natural geologic material in situ. This is important because laboratory testing, among other things, fails to consider the presence of joints and joint filling.

These in situ tests, as noted in the systems integration section, include experiments with heaters, followed by experiments with nuclear materials, where the combined effect of heat and radiation will be examined.

Results from these tests will be integrated by the systems integration program as they become available and used in the qualification of basalt as a repository medium for nuclear waste.

THE NEAR-SURFACE TEST FACILITY DESIGN AND CONSTRUCTION

During the early phase of the Basalt Waste Isolation Program, the need for in situ thermal and mechanical testing of basalt was identified. This immediate need of engineering data, to qualify basalt as an acceptable repository medium and to provide the design basis for repository design, could be met by construction of an in situ test facility. Detailed planning was initiated in October 1977. Construction of the facility began in June 1978, and the first two tests are now scheduled for startup in early 1980.

A site selection committee was established and criteria were developed for the selection of the site. A preliminary review of areas within and around Hanford indicated that potential sites could be found within Hanford itself. The site selected as meeting all of the criteria was located on the north face of Gable Mountain within Hanford.

The Near-Surface Test Facility is located approximately 150 feet below the surface, and approximately 50 feet into the Pomona basalt. This allows a sufficient portion of basalt to remain undisturbed below the test room for the conduct of the test. The facility (Figure 3) will have a heater test area and a nuclear waste test area.

The heater test area will require the excavation of approximately 21,000 cubic yards of material from the 2 portal areas and the development of approximately 1,800 feet of underground workings. These will vary in size from an 8-foot diameter for the east access tunnel to 23-foot diameter for the time-scale test room. The nuclear waste test area will require the excavation of an additional 25,000 cubic yards of material from the portal area and another 1,200 feet of underground excavation.

FIGURE 3

NEAR-SURFACE TEST FACILITY
HANFORD SITE

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