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Richland, Washington 99352

ARH-SA-281

**FEASIBILITY OF STORING RADIOACTIVE WASTES IN
COLUMBIA RIVER BASALTS**

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December 7, 1976

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PREPARED FOR THE U.S. ENERGY RESEARCH AND DEVELOPMENT
ADMINISTRATION UNDER CONTRACT E (45-1) 2130

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54-6000-085 (8-75)

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FEASIBILITY OF STORING RADIOACTIVE WASTES IN
COLUMBIA RIVER BASALTS

(A speech by Raul A. Deju, Atlantic Richfield
Hanford Company, 1976)

In 1968, the Atlantic Richfield Hanford Company, a contractor of the Energy Research and Development Administration, started a study to assess the feasibility of final geologic storage of Hanford defense, radioactive waste in deep caverns constructed in the Columbia River flood basalts. The project included:

geologic studies to characterize these basalts and to understand their relative stratigraphic position;

hydrologic tests into the basalts and interbeds to assure waste isolation;

heat flow analysis to evaluate the heat release resulting from emplacement of radioactive waste in a deep cavern;

compatibility studies to determine the interaction between solidified waste and the host basaltic rock; and

tectonic studies to assess the seismic stability of the Columbia River Basin.

The entire project was suspended in 1972 before completion of interpretative work.

In early 1976, the Office of Waste Isolation, Union Carbide Corporation, requested Atlantic Richfield Hanford Company to complete the interpretation and documentation of the early studies, inasmuch as such studies may be valuable in qualifying the Columbia River flood basalts as a viable medium for final geologic storage of commercial radioactive waste. A recent report, ARH-ST-137, available through the National Technical Information Service, is the result of that request. This report summarizes existing information and identifies key issues that require resolution to qualify basalt as a viable final geologic storage medium. Prior to issuing the report, its contents were reviewed by a select Committee of scientists and engineers from across the United States representing a diversity of points of view. Overall the Committee agreed with the results of the investigations to date. Dr. Aaron Waters, a senior member of the Committee and world-renowned authority on basalt geology, summarized the Committee's findings as follows:

To be presented at:

Office of Waste Isolation Public Meeting
Oak Ridge, Tennessee
December 7, 1976

"The general conclusion among the conferees is that certain stratigraphic units of basalt rock do possess chemical and physical properties which make them strong candidates among earth materials presently being considered as suitable for long-term storage of atomic wastes."

In the next few minutes, I will attempt to summarize the findings to-date resulting from this most exciting project. At the end, I will try to give you a glimpse of what we propose to do in the near future.

Geologic studies have been aimed at developing a picture of the regional stratigraphic framework and identifying individual basalt flows. This information is fundamental to the selection of those flow units suitable for waste storage. These studies have included surface as well as subsurface geology and the development of geochemical, geophysical, mineralogical, and petrographic techniques for identifying individual basalt flows.

The Columbia River Basalts of Miocene-Pliocene age in south central Washington represent one of the largest accumulations of continental basaltic rock in the world. The Hanford Reservation is located in the Pasco Basin near the center of the Columbia River Plateau flood basalt province where the accumulation of the layered basalts is thickest, exceeding 3,000 meters in thickness. These basalts appear to have developed as a layered sequence of lavas that intermittently filled a gradually down-warpage basin that, in later stages, began to fold into an undulation of anticlines and synclines. The most prominent land forms of the region surrounding the Pasco Basin are the east-west trending anticlinal ridges that began to rise more than 10 million years ago.

Most of the basalt within the Pasco Basin is tholeiitic basalt. Although many of the basalts are highly jointed, field and core hole evidence suggests that some of the basalt flows may be highly impervious to water. This appears to be the case with many flow units underlying the Hanford Reservation at depths in excess of 300 meters. Inspection of basalt joints and fractures shows that secondary minerals, predominantly clays, fill the joints and cracks effectively sealing them. The stratigraphy of the Pasco Basin has been developed from information obtained by drilling deep core holes and mapping and sampling sections exposed in river gorges.

Methods of chemical and petrographic analyses of basalts were applied to the identification, characterization, and correlation of individual flows and groups of flows of the Yakima Basalts. Basalt samples were analyzed for major element content by atomic absorption spectroscopy, for naturally occurring radioisotopes by gamma energy spectroscopy and for minor elements by emission spectrometry and neutron activation analysis. A truck-mounted energy-dispersive X-ray fluorescence unit was used for field studies and core hole stratigraphic control. Basalt mineralogy was studied by electron microprobe and X-ray diffraction techniques. Some samples were dated by potassium-argon methods.

Formally named flows and members were sampled at the type locality and chemically and petrographically analyzed. The results from the type localities were then compared with chemical and petrographic analyses of basalt from core holes and field sections. This comparison showed that some individual flows and groups of flows can be identified and correlated by chemical and petrographic properties. Geophysical logs supported the identification.

These studies have led to the construction of the stratigraphic framework for the Pasco Basin. Our studies to-date have led to a division of the Yakima Basalts into four formations:

- the Saddle Mountain Basalt Formation consisting of six basalt members,
- the Wanapum Basalt Formation consisting of three basalt members,
- the Vantage Sandstone Formation consisting of a very thin layer of indurated and well sorted sandstone, and
- the Grande Ronde Basalt Formation consisting of at least two stratigraphic units on the basis of marked differences in chemistry.

The Umtanum Flow, a unit of the Grande Ronde Basalt Formation, appears especially promising from a waste isolation standpoint. Its geologic characteristics and setting are favorable and its thickness exceeds 60 meters within the Hanford Reservation.

Hydrologic tests in the deep basalts have been aimed at determining the extent of hydraulic isolation of these basalts and characterizing the overall flow regime. The hydraulic properties of the basalt flows and interbeds of the Grande Ronde Basalt Formation within the Hanford Reservation have been studied at one site, Well ARH-DC-1. The lithology of these beds has been studied using geophysical data. The hydraulic conductivity of all beds sampled below the Vantage Sandstone Formation is very small, especially for the dense basalts. The flows proper appear to act as barriers separating the various interbeds. The geochemistry of the waters in the interbeds appears to be controlled by the nature of the sedimentary interbeds and not the basalts themselves. Their composition appears to show an equilibrium with feldspars. Flow rates are very slow, thus supporting the low hydraulic conductivity values. Heads above and below the Umtanum Basalt Flow are quite different at well ARH-DC-1 thus showing favorable hydraulic isolation of this flow unit at this site.

Several computational techniques have been developed to study the effect of different variables on the maximum cavern temperature reached as a result of storage of radioactive waste. Computer programs were developed to allow the calculation of these temperatures under many conditions. These programs are based on an equation to calculate the temperature as a function of time from a line heat-generation source. Studies were made using these programs to calculate the effect on cavern temperature of various parameters.

Geochemical studies were also initiated to identify those factors that need to be considered in order to set criteria for a waste form that is acceptable for storage in a basalt cavern. These studies attempted to identify the factors needed to evaluate the stability of various waste forms, their solubility, and their compatibility with the basalt.

Tectonic studies were conducted to evaluate the regional tectonic stability and assess the earthquake hazard to a potential waste repository in basalt. These studies are preliminary in nature and have included:

- an evaluation of historic earthquakes in the Pacific Northwest,
- the establishment of a network of seven high-sensitivity seismometers to study microearthquakes at Hanford and vicinity,
- an analysis of a trilateration network across the Columbia River Plateau, and
- a field study of possible faults in the Columbia River Plateau.

The understanding thus far developed represents a preliminary base for initiating an assessment of the environmental suitability of basalts as a final storage medium for radioactive waste.

Although the regional geology of the Columbia River Plateau is relatively well understood, additional work will be conducted to assess the tectonic stability of the region and evaluate the extent of regional as well as local fracturing and folding.

The stratigraphic framework will be refined with emphasis on defining the hydrostratigraphic units in detail. The stratigraphic nomenclature will be standardized and made compatible with the work of other investigators in nearby areas.

The geochemical, petrographic, and geophysical identification techniques will be confirmed by applying them to additional field locations and core holes. This work will help assure the accuracy of the hydrostratigraphic model for the Columbia River Plateau and the Pasco Basin.

The hydrology of the Columbia River flood basalts will be studied through testing of five core holes. The significance of head relationships and concentrations of anions and cations in deep confined aquifers will be determined. Sources of recharge and discharge of these deep aquifers will be identified and quantitatively described. Such a hydrological program can then be used to provide data for mathematical models that can predict the behavior of the hydrologic regime under all probable stresses to assess the risk of contamination from a final radioactive storage site throughout the groundwater pathway. The extent of isolation afforded a deep cavern by the surrounding basalt is the critical hydrologic factor that needs to be determined.

Engineering studies will be carried out to assess the feasibility of constructing a terminal storage facility in the deep basalts. Design criteria must be developed and plans for implementation outlined. Engineering design will augment the environmental acceptability of the facility and will constitute the main thrust of the project in the final design stages should the basalts be proven environmentally acceptable for final radioactive waste storage. In addition, engineering studies are needed to assess heat dissipation and stored energy effects from the various waste forms to be stored in the cavern and to design contingency plans during any retrievable period.

Geochemical studies are fundamental to our understanding of the feasibility of long-term containment of radioactive waste and will require substantial additional research and development effort with emphasis on selection and characterization of the solidified waste form for storage and the compatibility of such a form with the basalt host rock. Chemical reactions in a wet as well as in a dry environment will be considered to allow for the possibility of eventual flooding of an underground cavern. The effect of radiation on each component, including the effect of stored energy on stability, solubility, and compatibility will be evaluated.

All this information will then be put together into a framework that allows a full assessment of the viability of basalt as a final storage medium for radioactive waste while assuring environmental safety, permanent isolation, and initial retrievability. To fully accomplish this task, in-situ information must be gathered in a prototype underground cavern to support the information obtained from surface and core hole studies. As part of the overall program, all release and transport mechanisms that might release radioactivity into the biosphere must be quantified.