GEOHYDROLOGIC CHARACTERIZATION AND QUALIFICATION OF A HIGH-LEVEL WASTE SITE IN BASALTS

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ABSTRACT

Geohydrologic studies are under way on the Hanford Site, Washington, to characterize the Columbia River basalt as a possible geologic medium for disposal of nuclear wastes. Findings indicate that deformation of the Pasco Basin and reference repository location has occurred slowly (averaging < 0.1 mm/yr) and is expected to continue at a slow rate along existing geologic structures. Most groundwater in the deep basalts moves laterally through portions of basalt flow tops under low ($\sim 10^{-4}$ m/m) hydraulic gradients. These flow tops are separated by basalt flow interiors having hydraulic conductivities in the range of 10^{-11} to 10^{-13} m/s. Using site-specific characterization data, performance assessment modeling indicates that groundwater traveltimes to the accessible environment are > 10,000 yr. Because of the limiting solubilities of major radionuclides and the sorptive capacity of basalt, most radionuclides are effectively immobilized in the basalt medium.

INTRODUCTION

The Basalt Waste Isolation Project (BWIP) is chartered to assess the possible usage of the Columbia River basalts beneath the Hanford Site as a geologic medium for disposal of nuclear waste (Fig. 1). This project is administered by Rockwell Hanford Operations (Rockwell) under auspices of the U.S. Department of Energy's National Waste Terminal Storage Program. Within the BWIP, geohydrologic studies are focusing on repository site identification and characterization, particularly on those aspects possibly influencing groundwater transport of radionuclides.

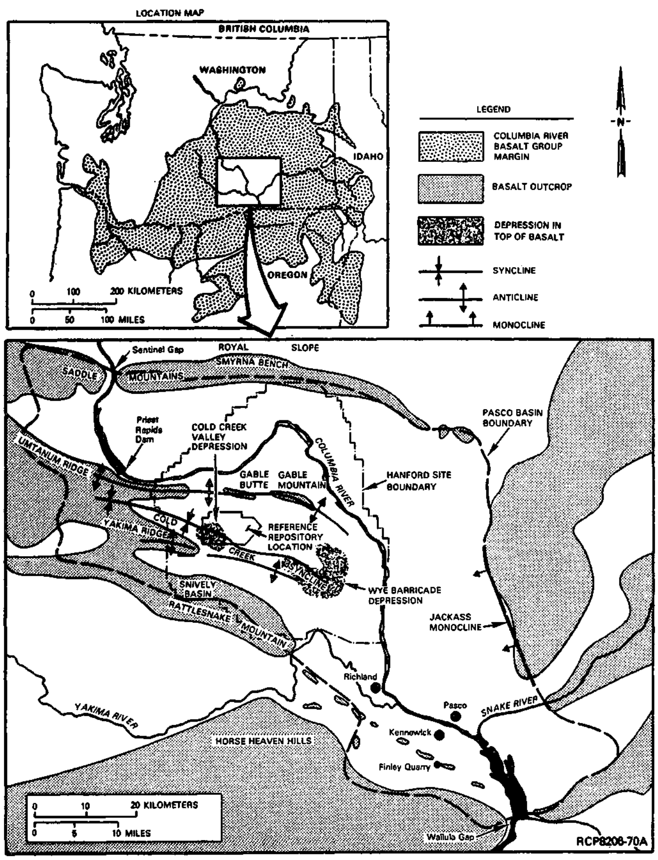

Fig. 1. Extent of the Columbia River Basalt Group, Pasco Basin, and Reference Repository Location.

This paper provides an overview of the geohydrology beneath the Hanford Site and geohydrologic issues involved in siting a high-level waste repository. Emphasis is given to several hydrologic findings being incorporated in a conceptual model of the groundwater system. Much of the data available on the geohydrologic environment are summarized in overview reports.[1-4]

Within the Hanford Site, a preferred and alternate repository location have been identified using a screening process to reduce the Hanford area to candidate sites, while a ranking process has been used to discriminate between sites.[5-7] The highest ranked candidate site was designated the reference repository location (Fig. 1).

In addition, preliminary screening of individual basalt flows, based on flow thickness, groundwater, and radionuclide traveltimes, has identified the Cohassett, McCoy Canyon, and Umtanum flows of the Grande Ronde Basalt as candidate repository horizons within the reference repository location (Fig. 2). Studies are under way for identification of a preferred repository horizon for an exploratory shaft breakout.

GEOHYDROLOGIC ISSUES

Geohydrologic investigations are directed toward evaluating the long-term suitability of basalt to contain nuclear waste safely. To this end, specific regulatory and program criteria have been proposed against which repository performance is compared.[4] The emphasis of geologic and hydrologic criteria is upon assessing stability; i.e.,

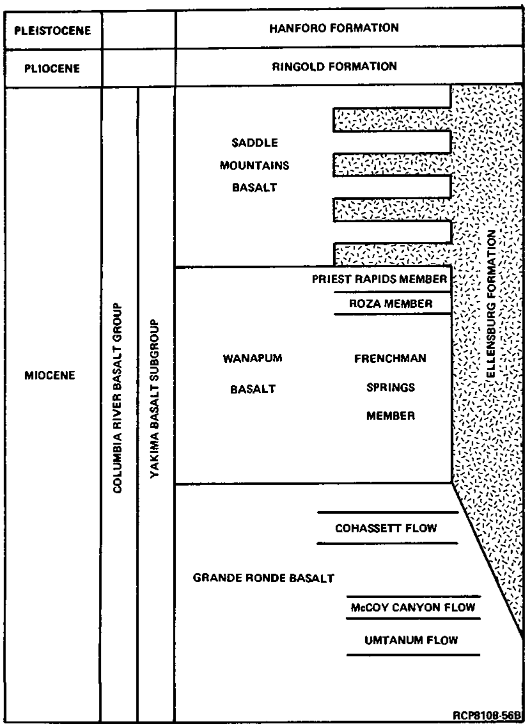

Fig. 2. Stratigraphy of the Columbia River Basalt Group and Intercalated Sediments within the Pasco Basin.

- Determination of past ($\sim$ 3 million years before present), present, and future (10,000 yr from present) geohydrologic processes and rates. (This is a site characterization activity.)

- Evaluation of the consequence of present and projected geohydrologic processes on waste isolation. (This is a performance assessment activity.)

The above characterization activity encompasses stratigraphy, structure, tectonics, and groundwater flow system evaluation. Basalt stratigraphy and structure form dominant controls to groundwater occurrence and flow. These characteristics of the candidate repository horizons and surrounding strata can significantly influence radionuclide migration to the accessible environment. Projected groundwater traveltimes also requires evaluation of the location and characteristics of existing structures along with the potential for future tectonic activity generating new geologic structures or affecting existing ones.

Following the repository's thermal-loading period, groundwater movement should prevail for the life of the repository, providing no significant disruptions take place. Therefore, an understanding of the present groundwater system and the potential impact of future geologic changes is needed to model long-term groundwater movement. Since groundwater affords the most likely means for radionuclides to reach the accessible environment, hydrology is a prime site characterization issue.

The quantification of basalt's waste isolation capability is a performance assessment activity involving numerical modeling. Evaluating basalt's compliance with U.S. Nuclear Regulatory Commission and U.S. Environmental Protection Agency proposed regulations requires detailed risk assessment, probabilities of waste release and concentrations, plus conservatively bound uncertainty analyses.[8,9] The principal geohydrologic issues for performance assessment are:

- Are the pre-waste-emplacement groundwater traveltimes from the repository to the accessible environment > 1,000 yr?

- What are the fractional radionculide release rates for the engineered system and are these $< 10^{-5}$ yr?

- What is the total activity of radionuclides potentially released to the accessible environment in a 10,000-yr period and is this amount less than suggested limits?

The ultimate objectives of performance assessment are to develop a technical consensus of basalt's waste isolation capability and to achieve a final engineered design balancing cost and risk.

GENERAL GEOHYDROLOGIC SETTING

The reference repository location is sited within the west-central portion of the Cold Creek syncline (Fig. 1). This syncline is a subdivision of the Pasco Basin, one of several structural and topographic basins located within a structural subprovince of the Columbia Plateau termed the Yakima Fold Belt. The Pasco Basin is underlain by flows of the Miocene Columbia River Basalt Group (Fig. 2). Though lava flows of this group were erupted 17.5 to 6 million years ago, more than 99% of the basalt erupted during a short 2- to 3-million-year interval centered about 15 million years before present.[10] Because of low viscosity and large volume, these lavas spread considerable distances from linear vents in the east and southeast portions of the plateau.

Within the Columbia Plateau, individual basalt flows range from a few tens of centimeters (rarely) to more than 100 m thick, averaging 30 to 40 m.[11] Individual basalt flows generally consist of an upper vesicular flow top overlying a jointed flow interior. Groundwater movement principally occurs within permeable flow tops or sedimentary interbeds. Recharge is from precipitation on basalt outcrops surrounding the Pasco Basin, river flow infiltration, and interbasin groundwater movement. Groundwaters are under confined conditions between low-permeability aquitards of dense basalt flow interiors.

STRATIGRAPHY

The Hanford Site is underlain by at least 50 basalt flows with a cumulative thickness > 3,000 m.[12] The majority of these flows are units of the Grande Ronde Basalt. The candidate repository horizons, Cohassett, McCoy Canyon, and Umtanum, are three Grande Ronde Basalt flows that lie $\sim$ 900, 1,060, and 1,100 m below ground surface, respectively (Fig. 2). These flows are continuous throughout the Pasco Basin and have average thicknesses within the Cold Creek syncline of > 40 m.

Within the reference repository location, the Grande Ronde Basalt is overlain by up to 20 additional flows of the Wanapum and Saddle Mountains Basalts. These upper two basalt formations have a cumulative thickness of 700 m and are interbedded with clastic sediments of the Ellensburg Formation. The Saddle

Mountains Basalt is overlain by Miocene-Pliocene fluvial and lacustrine sediments of the Ringold Formation and Pleistocene flood deposits.

Rocks lying beneath the Grande Ronde Basalt within the Pasco Basin have not been penetrated by boreholes. However, based on available magntotelluric data, the basalt sequence is interpreted to range between 1,200 and 5,000 m in total thickness.[13]

STRUCTURAL AND TECTONIC SETTING

East-west-trending anticlinal ridges of the Yakima Fold Belt bound the Pasco Basin on the north and south and plunge into the basin from the west (Fig. 1). More subtle folds, subparallel to the principal folds, are present as well as northwest-trending folds. East-west faults within the basin are associated with anticlinal folds and probably developed at the same time as the folding.[14] Northwest-trending faults of limited strike-slip displacement may also be present. Faults of major displacement are not anticipated in shallow-dipping strata, such as in the Cold Creek syncline, although faults of small displacement may be present.

The Cold Creek syncline lies between the Umtanum Ridge-Gable Mountain anticline on the north and the Yakima Ridge and Rattlesnake Mountain anticlines to the south. Two subtle, subsurface depressions in the top of basalt are present along the troughline of the syncline: (1) the Cold Creek Valley depression, located within the area of the reference repository location; and (2) the Wye Barricade depression, located ∿ 25 km to the east (Fig. 1). The central and eastern parts of the Cold Creek Valley depression appear to be free of major bedrock structures relative to other parts of the Cold Creek syncline and Hanford Site. Within these areas, the structure of the Saddle Mountains Basalt, as well as deeper basalt horizons, is interpreted as nearly flat lying (< 5°) across areas in excess of tens of square kilometers. Magnetotelluric data collected within the Pasco Basin suggest significant relief on the geoelectric layers below the basalt, indicating that prebasalt structures may be present.

The tectonic stability of the Pasco Basin and reference repository location is being assessed using geologic, geophysical, geodetic, and seismologic data.[15] These data suggest that the Pasco Basin was deforming at a low rate of strain in the Miocene and this rate has continued into the late Cenozoic. The basis for this conclusion is:

- Average uplift rates (vertical strain rates) for the Pasco Basin were ∿ 40 to 80 m/million years on anticlinal folds from 14.5 to 10.5 million years ago.[16] Once initiated, deformation appears to have continued along the same anticlinal structures formed in the Miocene.

- Quaternary sediments overlying faults associated with Yakima fold belt anticlines generally do not appear offset. A fault on the Hanford Site exhibiting Quaternary offset at Gable Mountain (sited ∿ 8 km northeast of the reference repository location) indicates decreasing displacement in younger strata. An average displacement of < 0.01 mm/yr (horizontal strain rate) was calculated for this fault.[17]

- Historically, few earthquakes have been felt in the Pasco Basin, and most of these occurred beyond the margins of the basin.[18,19]

- Six trilateration surveys across the Pasco Basin indicate that nonuniform compression at a rate of < 0.1 mm/km/yr (near the limit of detection) is occurring along northeast and northwest axes, respectively.[20]

- Instrumental earthquake data for eastern Washington[21] indicate minor stress release as microearthquakes. The frequency, areal distribution, and mechanisms suggest that stress is not relieved as earthquakes along geologically mapped or unmapped faults. The east-west to northwest trend of folds and faults and the north-south trend of dikes in the basalt suggest north-south compression; such compression agrees with the stress field determined from focal mechanism solutions.[15]

In summary, both "geologic" and "contemporary" data indicate deformation of the Pasco Basin and reference repository location has occurred slowly (averaging < 0.1 mm/yr) and may be expected to continue at a relatively slow rate for a projected 10,000-yr period.[15]

GROUNDWATER OCCURRENCE

Groundwater within basalt moves laterally through zones of high hydraulic conductivity (interbeds and flow tops) and vertically through fractured basalt interiors (the degree of vertical movement depends on the flow's vertical transmissivity). In nonstructurally deformed areas, minimal groundwater quantities are thought to move across flow interiors separating more permeable zones. Because of the greater-than-normal occurrence and length of fracturing in structurally disturbed areas (e.g., Umtanum Ridge-Gable Mountain anticline), water is considered to seep vertically through such structures to a larger extent than in nondisturbed areas. As opposed to anticlines, synclines are broad, open features having undergone little structural disturbance. Thus synclines should contain less secondary fracturing and less vertical groundwater leakage compared to anticlines.

Overall, groundwater moves from areas of recharge to discharge. Local recharge areas for shallow basalts are the basalt outcrops surrounding the Pasco Basin. Regional recharge of deeper basalts is thought to be from interbasin groundwater movement. Discharge is to the major rivers, though the exact location(s) remain debated. Along these groundwater flow paths, water is under artesian conditions. Areas of flowing artesian wells exist within the Cold Creek Valley (west of the reference repository location) and along the Columbia River where low land elevations exist.

ASPECTS OF THE GEOHYDROLOGIC CONCEPTUAL MODEL

In developing a conceptual model for groundwater flow, a number of findings are being addressed. In the following text, five of these are briefly evaluated.

Lack of Structural Control of the Columbia River

A study was completed recently that examines the concept that deep groundwaters, possibly derived from sediments underlying the basalt sequence, were upwelling beneath the Columbia River along the eastern border of the Hanford Site. Such groundwater movement was thought to take place along previously undetected structures, such as faults or dikes.[22] The course of the Columbia River adjacent to Hanford was attributed to the same structures.

Geohydrologic studies determined there existed no field evidence to support the hypothesis of localized fold or fault control of the Columbia River or deep groundwater discharge along such structures. Gravity data along with structural and stratigraphic maps revealed no evidence for fault control of the Columbia River.[1] Also, dike control is unlikely because the youngest basalt flow in the area is 8.5 million years old, yet the Columbia River flows on thick sediment < 6 million years old.

The present course of the Columbia River developed over the last 15 to 16 million years.[23] Within the Pasco Basin, the river's course is a product of several events, including the westward-tilting paleoslope, a subsiding Pasco Basin from the Miocene on, growth of the Yakima folds, sediment transport into the basin, control of surface drainage by numerous basalt flows, and extensive flooding during the Pleistocene. This is not an analogous geologic setting to high plateau, deep canyon terrains where local structures can be responsible for topography which in turn control surface drainage.

If extensive groundwater upwelling was occurring beneath the Columbia River, then hydrochemical analyses should identify the resultant groundwater mixing. However, available data support the existence of hydrochemical continuity across the Columbia River for equivalent stratigraphic units. In addition, hydrochemical data from boreholes DC-14 and -15, located adjacent to the Columbia River (Fig. 3),

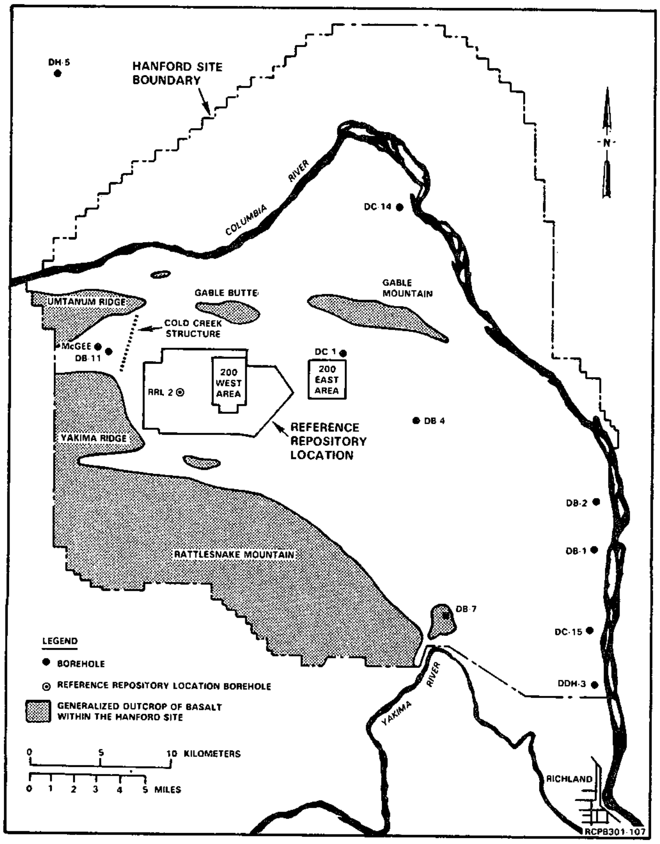

Fig. 3. Location Map for Selected Boreholes used in Basalt Waste Isolation Project Studies.

support the existence of unique groundwater flow systems--a shallow sodium-bicarbonate, low total dissolved solids (300 to 500 mg/L) flow system overlying a deep sodium-chloride system having higher total dissolved solids (600 to 1,200 mg/L) and isotopically distinct groundwaters.[4] The chemical types of shallow versus deep groundwater near the Columbia River correlate well to basalt water sampled kilometers from the river. The direct comparison of shallow groundwaters on the east side of the Columbia River to deep groundwaters on the west side lead to the misconception that hydrochemical mixing occurs beneath the river. However, no hydrochemical anomaly exists near the Columbia River, which possibly correlates to a deep structural conduit for deep groundwater upwelling.

Cold Creek Valley Structure

An inferred buried structure exists between borehole DB-11 and the reference repository location (Fig. 3). Recent hydrologic interference tests position the structure about 0.8 km east of borehole DB-11. Aeromagnetic data also identify a possible bedrock structure trending northeast-southwest located 2.5 km east of DB-11. On the west side of this structure, head measurements in the McGee well across individual flow tops in the Wanapum Basalt are uniform with depth, averaging 277 to 278 m above mean sea level. East of the structure in borehole RRL-2, heads in the Wanapum and Grande Ronde Basalts are also uniform with depth, averaging 121 to 124 m above mean sea level. Thus, head elevations in the Cold Creek Valley west of the structure are some 150 m higher than just east on the Hanford Site. Because of this structure's proximity to the reference repository location, understanding its potential impact on the local geohydrologic model may be an important aspect to assessing the long-term isolation performance of the reference repository location.

Hydrochemical Breaks

Distinct groundwater chemical types exist in the Columbia River basalts. Changes from one type to another occur rapidly over short stratigraphic distances. Overall, Saddle Mountains, Wanapum, and Grande Ronde Basalt groundwaters are of sodium-bicarbonate, sodium-chloride-bicarbonate, and sodium-chloride chemical types, respectively. The specific stratigraphic boundaries separating these chemical types vary by small amounts, depending upon areal locations. Major isotopic shifts between shallow and deep basalts also take place (Fig. 4). Such hydrochemical and isotopic shifts (coupled with small vertical hydraulic head gradients) are believed to delineate flow system boundaries and suggest the lack of significant vertical mixing of groundwaters in structurally nondeformed areas. Studies are under way to examine the possibility of groundwater mixing along the Umtanum Ridge-Gable Mountain anticline and the Cold Creek Valley structure. Future geochemical modeling is also directed toward evaluating these concepts.

Hydraulic Head Changes

Based on available data, hydraulic head changes in the deep basalts beneath the Hanford Site appear to be slow and of small magnitude. This is concluded upon examining long-term head-monitoring records from boreholes DC-1, DDH-3, and DH-5 plus several shallower wells.

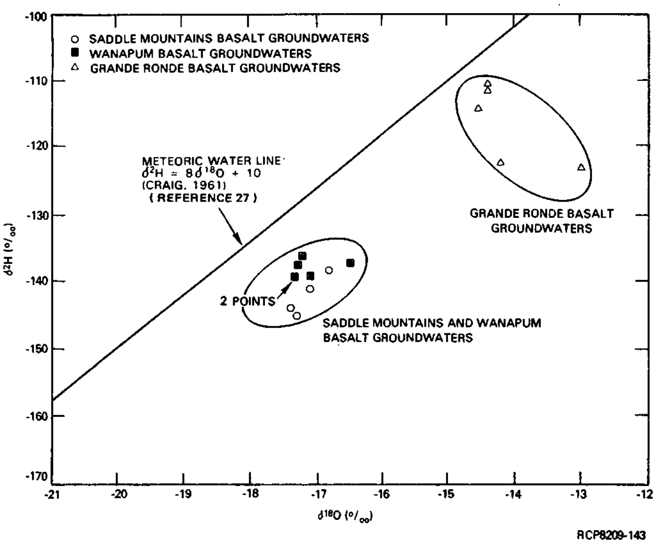

Fig. 4. Deuterium and Oxygen-18 Relationships for Groundwaters within the Columbia River Basalts at Borehole DC-15.

An examination of hydraulic heads from five piezometers in DC-1 indicates small head changes over the past decade in most piezometers following hole equilibration (Fig. 5). Piezometer 5 monitors a composite basalt interval between the depth of 372 to 642 m. The remaining piezometers monitor specific, narrow intervals between the depths of 888 and 1,478 m. With the exception of a long equilibration period for piezometer 4, maximum head variations in other piezometers over the last decade are within ±1 m.

Borehole DDH-3 has a single piezometer open across two flow contacts in the Frenchman Springs Member of the Wanapum Basalt at a depth of 601 to 626 m below ground surface. Heads have been periodically monitored in DDH-3 since 1970. These measurements give head elevations of 117 to 118 m (plus minus a few tenths of a meter) above mean sea level. Such small changes monitored over a 12-yr period suggest that the overall head elevation has changed little in that portion of the Wanapum Basalt. Thus, groundwater withdrawals or water applications in the Columbia Basin Irrigation Project, located east of the Hanford Site and the Columbia River, do not appear to have had any significant influence on head measurements in the lower Wanapum Basalt at DDH-3.

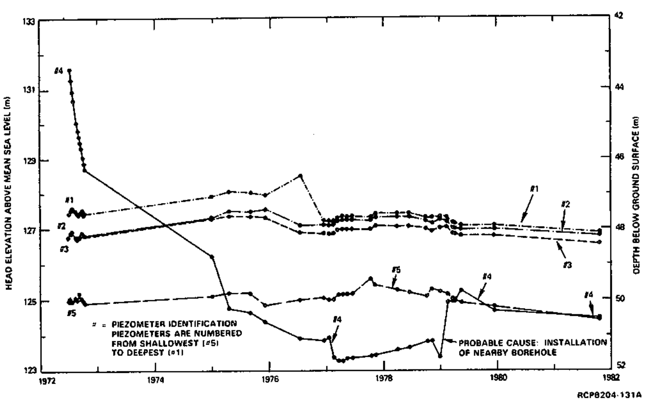

Fig. 5. Hydrograph of the Water Levels in the DC-1 Piezometers from 1972 Through 1981.

Borehole DH-5 is located on Wahluke Slope just north of the Hanford Site. In the early 1970's, DH-5 was cored to a depth of 1,525 m. A single, sealed piezometer tube was opened from depths of 1,479 to 1,525 m. (The top of this open interval is 619 m below the bottom of the Umtanum flow.) Water-level measurements were recorded from August 1972 to July 1976. Later measurements were not possible because of an in-hole obstruction. The water levels during this 4-yr period varied less than ±0.5 m.

An active borehole-monitoring program is also maintained in a series of shallow DB boreholes completed in either the lower Saddle Mountains or upper Wanapum Basalts. These holes are located adjacent to the Columbia River, within the Cold Creek syncline, and in the Cold Creek Valley where heavy groundwater withdrawals are taking place (Fig. 3). A summary of these data indicate that over the period from which monitoring records are available (∿ 4 yr), heads in boreholes DB-1 and -2, sited near the Columbia River, have undergone a slow, cyclic response with a maximum head variation of ± 1 m, having a periodicity of > 1 yr. Very minor head variations (±0.2 m) have taken place in DB-4, located centrally within the Cold Creek syncline, and in DB-7 (±0.4 m), located in the southern Cold Creek syncline. In the Cold Creek Valley west of the Cold Creek structural barrier mentioned earlier, water levels in DB-11 have declined 7.5 m since 1978. This change resulted from nearby agricultural water withdrawals.

The above monitoring data indicated that hydraulic heads in the deep basalts beneath Hanford change slowly and by small amounts. Heads in shallow basalts, east of the Cold Creek structural barrier, vary by slightly larger amounts. It is thus suggested that hydraulic heads, carefully measured over a period of months in different basalt horizons as a hole is drilled, can be directly compared. These reconnaissance data are then used to construct vertical head gradients and potentiometric maps.

Such hydraulic head data collected from within the reference repository location are being integrated with Hanford-wide information to develop a more complete understanding of the groundwater system. Within the Saddle Mountains Basalt beneath the reference repository location, head elevations decrease with depth from 137 to 127 m. Lower heads with depth are characteristic of groundwater recharge areas such as found in the shallow basalts along the western Hanford Site. Head elevations are rather uniform within the Wanapum and Grande Ronde Basalts in the reference repository location, averaging 123 ±1.5 m above mean sea level. These generally uniform head distributions are common in the Cold Creek syncline and are interpreted as indicating an area of lateral groundwater movement--that portion of the groundwater system not undergoing major recharge or discharge. The average areal head gradient in the deep basalts is 10^{-4} m/m. Groundwater from the reference repository location appears to move southeasterly.

Comparison of Hydraulic Conductivity Values

Ranges of hydraulic conductivity values for basalt flow tops and flow interiors are shown in Fig. 6 compared to values reported for a wide variety of crystalline and argillaceous rock types.[24] Basalt flow-top conductivities plot along values commonly sited for other rock types. Basalt flow interiors (colonnade and entablature zones), such as those considered as repository horizons, possess conductivities (∿ 10^{-11} to 10^{-13} m/s) in the lower range for other rock types.

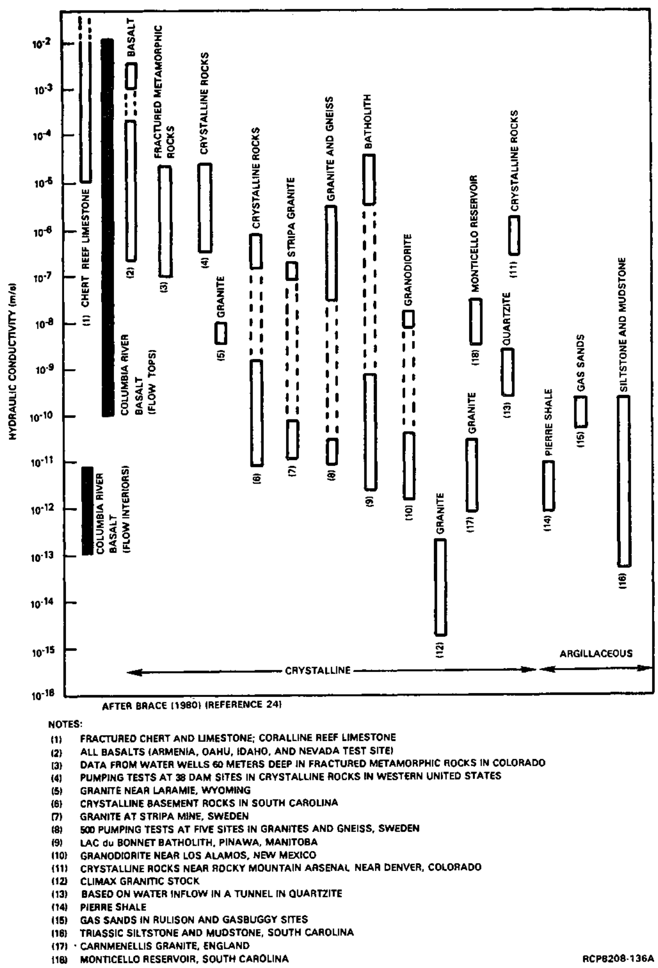

Fig. 6. Hydraulic Conductivity of Various Crystalline and Argillaceous Rocks.

The spread of flow-top conductivities is attributed to downhole hydrologic testing of discrete flow tops having a wide range of secondary mineralization, vesicularity, and brecciation. Some flow tops have a high conductivity, while others are hydraulically very tight. The narrower band for flow interior conductivities results from a lower detection limit for tests in hydraulically tight rocks and the limited number, 8, of available flow interior tests.

Ongoing studies are now directed toward evaluating vertical hydraulic conductivities within flow interiors, continuing definition of horizontal conductivities across flow interiors and flow tops, and understanding the areal continuity of hydrologic properties for individual stratigraphic horizons.

PERFORMANCE ASSESSMENT

The BWIP performance assessment methodology is based on the conjunctive use of a suite of numerical models. These models are designed to describe the coupled processes of rock stress-strain, heat transfer, groundwater flow, and radionuclide transport.[4] The suite of models are grouped into three categories: very near field (canister to room scale), near field (repository scale), and far field (groundwater basin scale). The very near-field models use a mathematical approach that considers both the fractured and porous features of the basalt medium. The near-field and far-field models use the concept of an "equivalent porous continuum" to represent the major basalt flows and confined aquifers.

For the very near-field zone, the performance models are used to compute the fractional radionuclide release rates at the boundary of the engineered barriers and candidate repository horizon. Output from near-field predictions are the concentrations of key radionuclides in the groundwater and the time-integrated activity crossing the 10-km-controlled zone boundary. Flow paths and traveltimes in the far-field zone (i.e., from the control zone boundary to points in the accessible environment) are determined as functions of the recharge/discharge characteristics, hydrologic properties and boundary conditions, and major structural features of the geologic system.

Very near-field analyses indicate that the fractional release rates for key radionuclides are a function of the release rate at the waste package, hydraulic properties of the emplacement horizon, and the magnitude of the thermally induced driving forces. For those radionuclides with even a nominal amount of sorption (i.e., k_d >0.5 mL/g), the retardation effects are sufficient to reduce the release rates from the repository horizon to levels well below the 10^{-5}/yr proposed regulatory criterion during the first 10,000 yr.[25] The very low-solubility properties of major radionuclides (technetium, uranium, plutonium, americium) in the reducing (anoxic) environment of the deep basalt play an even greater role than sorption in maintaining release rates below the proposed release criterion.

Near-field simulation results from the candidate repository horizons indicate that relatively few radionuclides are of concern within a 10,000-yr waste isolation period. Most actinide elements and long-lived fission products are of little importance because of their retardation characteristics and apparently very low solubilities.[26] Carbon-14 appears to be a key radionuclide in the spent fuel inventory because of its mobility (i.e., nonsorbing characteristic and relatively long half-live). For the flow paths predicted from the canister repository horizons, the ^{14}C concentrations are predicted to be well below the conservative maximum permissible concentration levels at the accessible environment. The cumulative releases of ^{14}C to the accessible environment are estimated to be much smaller than the U.S. Environmental Protection Agency limit.

Far-field modeling studies have focused on the problem of determining natural groundwater flow patterns in the deep basalts. Using a three-dimensional representation of the Saddle Mountains, Wanapum, and Grande Ronde Basalts, large-scale flow patterns have been calculated. Flow path predictions indicate a predominantly horizontal groundwater movement along basalt flow tops. The minimum traveltime from the reference repository location to a 10-km boundary is estimated to be about 30,000 yr; the total traveltime to the Columbia River has been predicted to be in excess of 100,000 yr (Fig. 7).

These flow paths and traveltime estimates differ from those of previous hydrologic modeling studies conducted by the BWIP and other independent organizations.[4] For example, previous studies have suggested flow paths with greater vertical movement and traveltimes in the range of 13,000 to 100,000 yr. The primary reason for the differences is related to the various methods and assumptions used in estimating hydrologic boundary conditions, as well as differences in data bases. To refine the flow path and traveltime predictions for the pre-waste-

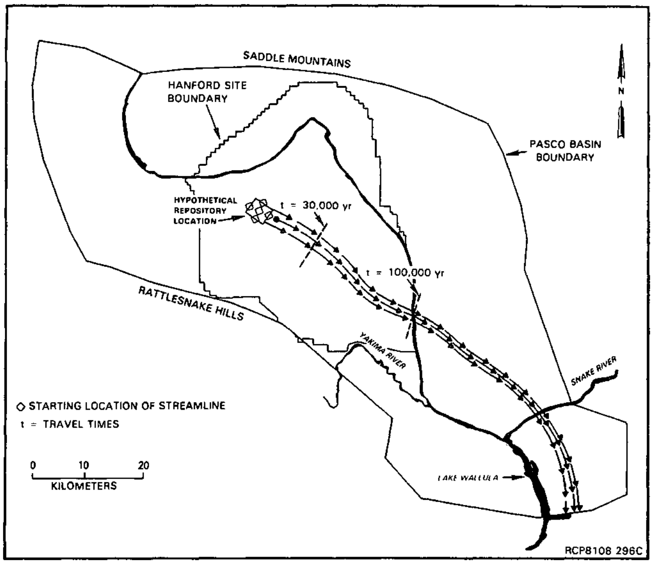

Fig. 7. Groundwater Flow Paths and Traveltimes in the Far-Field Zone.

emplacement period, a modeling task force, consisting of scientists from the U.S. Geological Survey, Pacific Northwest Laboratory, Lawrence Berkeley Laboratory, and Rockwell was recently formed to develop a technical consensus on boundary conditions and aspects of the geohydrologic data base. While work is needed to reduce uncertainty in these model predictions, all estimates (past and current) for pre-waste-emplacement traveltimes indicate compliance with the U.S. Nuclear Regulatory Commission's criterion of a 1,000-yr minimum transit time.

A preliminary analysis of post-waste-emplacement flow paths and traveltimes has also been performed. The analysis of groundwater flow patterns for the postclosure period indicates that the thermal environment (i.e., temperature field in the vicinity of the repository) will significantly influence the natural groundwater flow paths and traveltimes. Flow paths within the thermally influenced zone are predominantly upward where buoyancy driving forces are strong; whereas outside this zone the flow direction is controlled by the regional hydraulic gradient. The net effect is that the post-waste-emplacement traveltimes appear to be longer than those for pre-waste-emplacement conditions. This is because groundwater is driven vertically through several additional basalt flows of low interior permeability compared to pre-waste-emplacement flow paths which are along flow tops lower in the stratigraphic section.

FISCAL YEAR 1983 PLANS

During fiscal year 1983, additional geohydraulic data will be collected from within the reference repository location and will concentrate on the candidate horizons. Important activities in this site characterization work will be attempts at vertical hydraulic conductivity testing and extending age dating of basalt groundwaters beyond the existing limit of about 35,000 yr before present. Using the new data, performance assessment work will focus on evaluating potential groundwater and radionuclide flow paths under both existing and reasonable scenario conditions.

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