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Basalt Waste Isolation Project Quarterly Report

April 1, 1981 through June 30, 1981

R.A. Deju
Director, Basalt Waste Isolation Project

Prepared for the United States Department of Energy Under Contract DE-AC06-77RL01030

Rockwell International

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ABSTRACT

This document reports progress made in the Basalt Waste Isolation Project during the third quarter of fiscal year 1981. Efforts are described for the following programs of the project work breakdown structure:

- Systems
- Waste Package
- Site
- Repository
- Regulatory and Institutional
- Test Facilities
- In Situ Test Facilities.

This project is being conducted for the U.S. Department of Energy under Contract DE-AC06-77RL01030.

SUMMARY

This report addresses the technical progress for the Basalt Waste Isolation Project (BWIP) for the third quarter of fiscal year (FY) 1981. The organization of the report follows the work breakdown structure for the technical areas of the project. The major highlights for the quarter are provided below.

SYSTEMS

During this quarter, work in the Systems program progressed in the Program Baseline, Systems Analysis, and Performance Assessment activities. The Regulatory and Institutional End Function Technical Plan was developed and approved by the BWIP Director. The BWIP Principal Criteria Document (PCD) was revised to include U.S. Department of Energy (DOE) and Office of National Waste Terminal Storage Integration (ONI) comments, and the draft of the BWIP Missions Document was completed and submitted to DOE and ONI. In the Systems Analysis activity, a statement of work for an engineering service agreement subcontract covering the general subject of Systems Engineering and its application to the BWIP was prepared and delivered to Rockwell Materials for subcontractor acquisition. An updated draft of a report on the interim reference repository conditions for a nuclear waste repository in basalt (NWRB) was prepared for transmittal to the Reference Repository Conditions Interface Working Group (RRC-IWG) chairman and members. In support of the BWIP Performance Assessment, a 3-day workshop meeting was held to define the status of site suitability and performance assessment.

WASTE PACKAGE

The BWIP Program Plan for developing waste packages was presented to the National Academy of Science Panel on the Waste Isolation System Study and to the Waste Package Overview Committee. The Program Plan was well received by both groups. Hydrothermal experimentation continued at Arizona State University and Temple University with the initiation of work to assess the interaction among supercalcine/basalt/groundwater and borosilicate glass/basalt/groundwater respectively. Preparation continued at Atomics International for the initiation of hot cell shake-down testing early in FY 1982. Continuing sorption studies conducted at 23° and 60°C showed that selenium sorption on Hanford basalts was little affected by temperature and groundwater composition. Sorption was low and essentially the same under both oxidizing and reducing conditions for Umtanum and Flow E basalts, while for Pomona basalt it was two to three times greater under both conditions. This may have been due to a possible greater concentration of sulfidic minerals in the Pomona basalt. Thermal modeling showed that for a waste package containing 10-yr-old pressurized water reactor (PWR) spent fuel emplaced in basalt, the peak temperatures reached and time to maximum were 269°C (4 yr), 264°C (5 yr), and 191°C (7 yr) for

the waste package centerline, canister wall, overpack wall, and emplacement hole surface respectively. The effect of spent fuel age on emplacement hole temperature was also calculated.

SITE

The major effort in the Geologic Characterization activity during this quarter was the documentation of the subsurface geology of the Cold Creek syncline. Stratigraphic, lithologic, and structural interpretations of the area are presented. Structural analysis of selected localities within the Yakima fold system reveal that the synclinal troughs observed do not display pervasive tectonic jointing or small-scale faulting related to folding. The completion of six reference repository boreholes resulted in data to revise the surface of basalt map in the A-H site as well the production of a more detailed suprabasalt stratigraphy.

A study to evaluate the current and potential value of mineral, fossil fuel, and geothermal resources within 100 km of the proposed repository site showed that the per-unit-of-area value is less than one-half that of the remainder of the Columbia Plateau.

During the third quarter in the Hydrologic Characterization activity, seven flow tops were hydrologically tested within the Grande Ronde Basalt. The transmissivities determined ranged between 10^{-4} and 10^{-7} m^2/s. When these data are combined with existing data files they suggest that the hydraulic conductivities of typical flow tops within the Grande Ronde Basalt are one to two orders of magnitude lower than flow tops in the Saddle Mountains and Wanapum Basalts. Numerical modeling results for the very near field conservatively give a resaturation period of 300 yr for the repository. Hydrothermal simulations under saturated conditions indicate a peak temperature of about 190°C in the adjacent rock mass 4 yr following canister emplacement. Near-field modeling results show groundwater travel times to the near-field boundary of 12,000 to 16,000 yr under isothermal conditions and 18,000 to 30,000 yr for the nonisothermal case. These simulations showed that the pathlines are controlled by flow top and are confined to the Grande Ronde Basalt. Far-field modeling has shown that water particles travel in a southeasterly direction from the repository to the edge of the model boundary. This is a distance of ~64.5-km with a travel time in excess of 100,000 yr.

REPOSITORY

Nuclear waste repository in basalt conceptual design work by Kaiser Engineers/Parsons Brinckerhoff Quade and Douglas, Inc. continued during this quarter with effort directed toward completion of draft conceptual system design description and draft conceptual design reports by September 30, 1981.

In Repository Data Base Development, the analysis of the full-scale heater test thermal data was completed. The rock mass conductivity was calculated from the heater test data by parameter estimation methods. Verified extensometer data for the first 270 days of the heater test is now ready for analysis. Cancellation pressure in Block Test #1, Step 1 was determined and the pressure cycles up to 7.5 MPa were completed.

REGULATORY AND INSTITUTIONAL

The major emphasis of the Regulatory and Institutional program during this quarter was the planning and initiation of writing for the Site Characterization Report (SCR) and its supporting Environmental Assessment (EA). As a direct result of agreements made at the National Waste Terminal Storage (NWTS) workshop held in Seattle, Washington in early June, the SCR Annotated Outline was prepared based on the format and content proposed in U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide GS-027-4 (draft). Preparation of the SCR began on June 15, 1981.

TEST FACILITIES

During this quarter, the full-scale heater tests continued in accordance with the Test Plan. No net power changes were programmed or required. Diagnostics and analyses were continued on rock instrumentation to the end of generic improvements for continuing Phase I and for Phase II applications.

Block Test #1, Step 1 test equipment was installed and operations initiated. Preparations for Step 2 continued including major progress in development and procurement of optically sensed borehole deformation instrumentation.

Substantial modifications were made to the data acquisition systems to extend their usefulness consonant with developing test requirements and experience.

In the NSTF Phase II end function, facility construction continued at a high level. All government furnished equipment was installed by the end of the quarter, the electrical system testing was completed and the system energized.

Contract surveillance in the procurement of rock instrumentation and initiation of procurement for the nuclear instrumentation were the principal efforts continued under Test Implementation. This included coordinate improvements in instruments as an outgrowth of Phase I tests. The interface activities of Test Implementation were extensive in support of the design Phase II engineered test equipment.

Test Operations activities for Phase II were accelerated in the third quarter in the development of the support procedures and in the support of readiness review and startup documentation.

IN SITU TEST FACILITIES

The preparation of a test plan for an Exploratory Shaft Test Facility continued following a Rockwell Hanford Operations design review in April 1981. The test plan has been restructured with Phase I of the project limited to in situ site characterization.

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INTRODUCTION

The Basalt Waste Isolation Project (BWIP) was initiated in May 1976 to investigate the feasibility of using Columbia Plateau basalt formations as a repository site for deep geologic disposal of high-level radioactive waste. Rockwell Hanford Operations (Rockwell) was selected by the U.S. Department of Energy (DOE) to serve as the prime contractor for performance of the required site exploration and repository design studies. The BWIP is administered by the DOE - Richland Operations Office (DOE-RL).

The BWIP is part of the National Waste Terminal Storage (NWTS) program, which is the comprehensive DOE program to assess alternate sites and host media for geologic disposal and to evaluate other viable modes for permanent disposal of radioactive waste. The NWTS is managed for the DOE by the Office of National Waste Terminal Storage Integration (ONI).

Several key projects within the NWTS, including the BWIP, have been organized to share common Work Breakdown Structure (WBS) elements. This approach facilitates communication and coordination of activities between equivalent functional groups at the various organizations participating in the NWTS.

Formal Interface Coordination Groups (ICGs), including representatives of the major waste disposal projects, were established for:

- Systems
- Waste Package
- Site
- Repository
- Regulatory and Institutional
- Test Facilities.

The ICG activities are coordinated and controlled by the Isolation-Interface Control Board (I-ICB). Participation in these panels is an essential element of Rockwell's BWIP management effort.

Technical progress in BWIP for the third quarter of fiscal year (FY) 1981 is reported in this document for the programs listed in Figure 1 except for "Land Acquisition," which is not relevant to the BWIP, and "Program Management," which is a nontechnical function. Note that some WBS elements below the program level either have not started or are not applicable to the BWIP and are, therefore, not reported.

PROGRAM	END FUNCTION	ACTIVITY	SUBACTIVITY	WBS NO
SYSTEMS	SYSTEMS	PROGRAM BASELINE	DATA MANAGEMENT	L111
			CONFIGURATION MANAGEMENT	L112
			TECHNICAL BASELINE	L113
		SYSTEMS ANALYSIS	SYSTEMS DEVELOPMENT	L121
			TECHNICAL SERVICES	L122
		SOCIOECONOMIC ASSESSMENT	SOCIOECONOMIC ASSESSMENT	L131
		ALTERNATE DISPOSAL CONCEPTS	ALTERNATE DISPOSAL CONCEPTS	L141
		PERFORMANCE ASSESSMENT	PERFORMANCE ASSESSMENT	L151
WASTE PACKAGE	WASTE PACKAGE	WASTE PACKAGE BASELINE	WASTE PACKAGE BASELINE	L211
		WASTE FORM	INTEGRATION OF WASTE FORM DATA	L221
		BARRIER MATERIALS		L231
			WASTE/BARRIER/ROCK INTERACTIONS	L232
			SORPTION CHEMISTRY	L233
			CANISTER/OVERPACK MATERIALS	L234
			BACKFILL/BUFFER MATERIALS	L235
		DESIGN & DEVELOPMENT	BARRIER SYSTEM DESIGN REQUIREMENTS	L241
		PERFORMANCE EVALUATION	NEAR FIELD RADIONUCLIDE BEHAVIOR	L251
			ENGINEERING EVALUATION	L252
			FIELD AND IN-SITU TESTING	L253
SITE	SITE	SITE BASELINE	SITE BASELINE	L311
		EARTH SCIENCES	EARTH SCIENCES	L321
		GEOLOGIC CHARACTERIZATION	SURFACE GEOLOGY	L331
			RESOURCE POTENTIAL	L332
			VOLCANIC ACTIVITY	L333
			TECTONIC SETTING	L334
			STRUCTURAL GEOLOGIC SETTING	L335
			HOST ROCK GEOMETRY	L336
			HOST ROCK LITHOLOGY	L337
			HOST ROCK STRATIGRAPHIC SETTING	L338
			INTEGRATION OF GEOLOGIC DATA	L339
		HYDROLOGIC CHARACTERIZATION	HYDROLOGIC PROPERTIES	L341
			HYDROLOGIC CONCEPTUAL MODEL	L342
			HYDROLOGIC NUMERICAL MODEL	L343
			GROUNDWATER MONITORING	L344
			INTEGRATION OF HYDROLOGIC DATA	L345
		ENVIRONMENTAL CHARACTERIZATION	ENVIRONMENTAL CONDITIONS	L351
			ENVIRONMENTAL IMPACTS	L352
		SOCIOECONOMIC EVALUATION	SOCIOPOLITICAL CONSIDERATIONS	L361
			ECONOMIC CONSIDERATIONS	L362
		PERFORMANCE EVALUATION	HYDROLOGIC MODEL PREDICTIONS	L371
			GROUNDWATER ASSESSMENT	L372
			ENVIRONMENTAL SYSTEMS ASSESSMENT	L373
REPOSITORY	REPOSITORY	REPOSITORY BASELINE	REPOSITORY BASELINE	L411
		REPOSITORY DATA BASE DEVELOPMENT	DATA BASE ANALYSIS	L421
			MODEL DEVELOPMENT	L422
			LABORATORY TESTS	L423
			FIELD TESTS	L424
		EQUIPMENT DEVELOPMENT	SHAFT SINKING	L431
			MINING EXCAVATION	L432
			WASTE HANDLING	L433
			MINE SERVICE SYSTEMS	L434
			REPOSITORY SEALING EQUIPMENT	L435
		INSTRUMENTATION DEVELOPMENT	IN-SITU TEST INSTRUMENTATION	L441
			REPOSITORY INSTRUMENTATION	L442
		REPOSITORY SEAL DEVELOPMENT	MATERIAL DEVELOPMENT	L451
			SEAL DESIGN	L452
			TESTING	L453
			SYSTEM ANALYSIS	L454
		GENERIC REPOSITORY ENGINEERING	GENERIC REPOSITORY ENGINEERING	L461
		REPOSITORY CONCEPTUAL DESIGN	TECHNICAL DIRECTION	L471
			PRECONCEPTUAL DESIGN	L472
			AE SELECTION	L473
			CONCEPTUAL DESIGN	L474
			UPDATED CONCEPTUAL DESIGN	L475
			ENGINEERING STUDIES	L476
		REPOSITORY DESIGN AND INSPECTION	TITLE I PRELIMINARY DESIGN	L4U1
			TITLE II FINAL DESIGN	L4U2
			TITLE III INSPECTION SERVICES	L4U3
		REPOSITORY LONG LEAD PROCUREMENT	PROCUREMENT SERVICES	L4V1
			SURFACE FACILITIES PROCUREMENTS	L4V2
			ACESS SHAFTS PROCUREMENTS	L4V3
			SUBSURFACE FACILITIES PROCUREMENTS	L4V4
			WASTE HANDLING SYSTEMS PROCUREMENTS	L4V5
			SERVICE SYSTEMS PROCUREMENTS	L4V6
		REPOSITORY CONSTRUCTION	CM SELECTION	L4W1
			CONSTRUCTION MANAGEMENT	L4W2
			SURFACE FACILITIES CONSTRUCTION	L4W3
			ACCESS SHAFTS CONSTRUCTION	L4W4
			SUBSURFACE FACILITIES CONSTRUCTION	L4W5
			WASTE HANDLING SYSTEMS CONSTRUCTION	L4W6
			SERVICE SYSTEMS CONSTRUCTION	L4W7
		REPOSITORY OPERATION	REPOSITORY OPERATION	L4X1
		REPOSITORY DECOMMISSIONING	REPOSITORY DECOMMISSIONING	L4Y1
		REPOSITORY MONITORING	REPOSITORY MONITORING	L4Z1
		PERFORMANCE EVALUATION	MODEL DEVELOPMENT	L481
			MODEL APPLICATION	L482
REGULATORY AND INSTITUTIONAL	REGULATORY AND INSTITUTIONAL	REGULATORY BASELINE	REGULATORY BASELINE	L511
		LICENSING APLLICATIONS	SITE RELATED DOCUMENTS	L521
			CONSTRUCTION AUTHORIZATION	L522
			OPERATING LICENSE	L523
			DECOMMISSIONING LICENSE	L524
		NEPA DOCUMENTS	ENVIRONMENTAL EVALUATION	L531
			ENVIRONMENTAL ASSESSMENT	L532
			ENVIRONMENTAL IMPACT STATEMENT	L533
			ENVIRONMENTAL REPORT	L534
		COMMUNICATION & INSTITUTIONAL LIAISON	DOE/NWTS LICENSING COMMUNICATIONS	L541
			STATE AND LOCAL GOVERNMENT LIAISON	L542
			INFORMATION SERVICES	L543

FIGURE 1. Basalt Waste Isolation Project Work Breakdown Structure (Sheet 1 of 2).

PROGRAM	END FUNCTION	ACTIVITY	SUBACTIVITY	WBS NO
TEST FACILITIES (NSTF)	NSTF PHASE I	PHASE I TEST FACILITY BASELINE	PHASE I TEST FACILITY BASELINE	
		DESIGN	ENGINEERING STUDY & CONCEPTUAL DESIGN	LB21
			GEOLOGIC SURVEILLANCE	LB22
			DESIGN TITLE I (VITRO)	LB23
			DESIGN TITLE I (ROCKWELL)	LB24
			DESIGN TITLE II (VITRO)	LB25
			DESIGN TITLE II (ROCKWELL)	LB26
			DESIGN SUPPORT	LB27
			DESIGN MANAGEMENT	LB28
		CONSTRUCTION	PROCUREMENT	LB31
			TUNNELS & EXCAVATION	LB32
			TEST & INSTRUMENT HOLES	LB33
			ELECTRIC DISTRIBUTION LINE (J A. JONES)	LB34
			ELECTRIC DISTRIBUTION LINE (ROCKWELL)	LB35
			FACILITY REQUIREMENTS & SITE WORK	LB36
			WATERLINE	LB37
			TITLE III	LB38
			CONSTRUCTION MANAGEMENT	LB39
		SAFETY AND ENVIRONMENTAL ANALYSIS	ENVIRONMENTAL REVIEW	LB41
			SAFETY REVIEW	LB42
		TEST IMPLEMENTATION	FULL SCALE TEST NO 1	LB51
			FULL SCALE TEST NO 2	LB52
			BLOCK TEST NO 1	LB53
			BLOCK TEST NO 2	LB54
			ENGINEERING SUPPORT	LB56
			OPERATIONS	LB57
	NSTF PHASE II	PHASE II TEST FACILITY BASELINE	PHASE II TEST FACILITY BASELINE	LC11
		DESIGN	ENGINEERING STUDY & CONCEPTUAL DESIGN	LC21
			GEOLOGIC SURVEILLANCE	LC22
			DESIGN TITLE I (VITRO)	LC23
			DESIGN TITLE I (ROCKWELL)	LC24
			DESIGN TITLE II (VITRO)	LC25
			DESIGN TITLE II (ROCKWELL)	LC26
			DESIGN SUPPORT	LC27
			DESIGN MANAGEMENT	LC28
		CONSTRUCTION	PROCUREMENT	LC31
			TUNNELS & EXCAVATION	LC32
			TEST & INSTRUMENT HOLES	LC33
			FACILITY REQUIREMENTS & SITE WORK	LC34
			BOTTOM LOADING TRANSPORTER (ROCKWELL)	LC35
			BOTTOM LOADING TRANSPORTER (CONTRACT)	LC36
			CONSTRUCTION MANAGEMENT	LC37
			TITLE III	LC38
		SAFETY AND ENVIRONMENTAL ANALYSIS	ENVIRONMENTAL REVIEW	LC41
			SAFETY REVIEW	LC42
		TEST IMPLEMENTATION	ENGINEERING SUPPORT	LC54
			OPERATIONS	LC55
			3 CANISTER NUCLEAR WASTE TEST	LC56
	SUPPORT FACILITIES	SUPPORT FACILITIES	SUPPORT FACILITIES	LD11
	DECOMMISSIONING	DECOMMISSIONING	DECOMMISSIONING	LE11
IN SITU TEST FACILITIES (IN SITU)	EXPLORATORY SHAFT PHASE I (ES 1)	ESTF PHASE I BASELINE	ESTF PHASE I BASELINE	LF11
		CONFIRMATORY BOREHOLE	CONFIRMATORY BOREHOLE	LF21
		DESIGN & INSPECTION	DESIGN MANAGEMENT	LF31
			CONCEPTUAL DESIGN	LF32
			TITLE I DESIGN	LF33
			TITLE II DESIGN	LF34
			TITLE III INSPECTION SERVICES	LF35
		LONG LEAD PROCUREMENT	LONG LEAD PROCUREMENT	LF41
		CONSTRUCTION	CONSTRUCTION MANAGEMENT	LF51
			SITE IMPROVEMENTS	LF52
			SURFACE FACILITIES CONSTRUCTION	LF53
			SHAFT CONSTRUCTION	LF54
		IN SITU SITE CHARACTERIZATION	OPERATIONS	LF61
			TEST EQUIPMENT	LF62
			IN SITU TESTING	LF63
		PERFORMANCE EVALUATION	ENVIRONMENTAL REVIEW	LF71
			SAFETY REVIEW	LF72
			READINESS REVIEWS	LF73
	ES PHASE II	TBD	TBD	LG
	TEST & EVALUATION FACILITY (TEF)	TEF BASELINE	TEF BASELINE	LH11
		CONFIRMATORY BOREHOLE	CONFIRMATORY BOREHOLE	LH21
		DESIGN & INSPECTION	DESIGN MANAGEMENT	LH31
			CONCEPTUAL DESIGN	LH32
			TITLE I DESIGN	LH33
			TITLE II DESIGN	LH34
			TITLE III INSPECTION SERVICES	LH35
		LONG LEAD PROCUREMENT	LONG LEAD PROCUREMENT	LH4
		CONSTRUCTION	TBD	LH5
		OPERATION	TBD	LH6
LAND ACQUISITION	LAND ACQUISITION	LAND ACQUISITION	LAND ACQUISITION	L711
PROGRAM MANAGEMENT	PROGRAM MANAGEMENT	PROJECT MANAGEMENT	PROJECT MANAGEMENT	L811
		PROJECT CONTROL	PROJECT CONTROL	L821
		INTERFACE ACTIVITIES	INTERFACE ACTIVITIES	L831
		QUALITY ASSURANCE	QUALITY ASSURANCE	L841
		SPECIAL SUPPORT	SPECIAL SUPPORT	L851

FIGURE 1. Basalt Waste Isolation Project Work Breakdown Structure (Sheet 2 of 2).

SYSTEMS

The objective of the Systems program is to integrate the BWIP technology development activities leading to the selection and characterization of a site and to the design and licensing of a repository for nuclear waste within the basalt underlying the Hanford Site. Systems assures that the BWIP work is aimed at resolving key issues as required to meet programmatic criteria.

The Systems program consists of one end function, Systems, which is divided into five activities:

- Program Baseline
- Systems Analysis
- Socioeconomic Assessment
- Alternate Disposal Concepts
- Performance Assessment.

During the third quarter of FY 1981, efforts were conducted in the Program Baseline, Systems Analysis, and Performance Assessment activities.

PROGRAM BASELINE

The objective of the Program Baseline activity is to integrate and control the Technical Baseline for the BWIP. The Program Baseline activity provides technical direction to the BWIP staff by identifying, preparing, implementing, and maintaining the BWIP Technical Baseline. In addition, this activity identifies and evaluates all external and internal criteria and requirements which form the basis for the BWIP baseline. The Program Baseline activity includes Data Management and Configuration Management services for the BWIP through a matrix relationship between the BWIP and the Engineering Management Systems Department in the Research and Engineering function of Rockwell.

The Program Baseline activity is divided into three subactivities:

- Data Management
- Configuration Management
- Technical Baseline.

During the third quarter of FY 1981, work has progressed in all three subactivities.

Data Management

The objectives of the Engineering Data Management subactivity are to ensure that: (1) BWIP design documents are released and controlled by an automated data system and that a current file is maintained of all released items; (2) BWIP records are recorded, filed, and tracked in an automated data system, and placed in a Records Holding Area available for retrieval; (3) all BWIP reference material is located in a central library, cataloged, filed, and tracked by an automated data system; and (4) all borehole core samples are indexed, photographed, cataloged, stored, and controlled by an automated data system.

During the third quarter of FY 1981, progress included the following:

- The Configuration Summary Reports were converted from a manual system to production on the Engineering Release System automated tracking system, by Configuration End Item (CEI).
- The Design Document Release and Control System processed 14,396 design documents.
- Core and chip samples were relocated in the Core Sample Storage Facility to provide sufficient storage space for FY 1981 cores. The computer tracking system was modified to reflect this large move.
- The original copies of the NWTS Data Collection Tapes and Reports are being tracked via the Records Retention System Data Base. These tapes are maintained and controlled in measured humidity conditions.
- A review of BWIP Data Storage problems was conducted and recommendations submitted.
- Engineering Data Management personnel participated as part of the BWIP Document Control System Task Force.

Configuration Management

The objectives of the Configuration Management subactivity are to ensure that the system design is effectively recorded, communicated, and controlled by project and functional managers, and implementation of changes is controlled. During the third quarter of FY 1981, progress included the following:

- Revised the Configuration Management Plan to incorporate the establishment of the Change Evaluation Board
- Changed the Configuration Summary Reports from a manual to an automated system

- Participated as part of the BWIP Document Control System Task Force

- Formally established the Project Correspondence Control for the BWIP.

During the third quarter of FY 1981, a total of eleven Engineering Change Proposals were processed through the change control system. The changes were approved by the Change Control Board (CCB) and implemented into the program.

Technical Baseline

The objective of the Technical Baseline activity is to identify, prepare, and integrate essential BWIP documents and baseline them into the overall program. Progress on this subactivity during the third quarter of FY 1981 is described below.

NSTF Phase II Safety Analysis Report (SAR). Basalt Waste Isolation Project Systems personnel, in conjunction with Vitro Engineering Corporation, prepared Chapter 5, "Facility Design," for the referenced report.

Technical Plans. During this quarter, the Regulatory and Institutional End Function Technical Plan was completed and approved by the BWIP Director.

Effort continued on final draft preparation of the other BWIP end function technical plans:

- Waste Package

- Site

- Repository

- Exploratory Shaft Test Facility

- Test Facilities.

These end function technical plans will ultimately be used to prepare the BWIP Technical Plan.

Principal Criteria Document (PCD). The PCD was given to DOE and ONI for review and comment. These comments were received and incorporated to ensure meeting the completion date of September 1, 1981 of the first revision of the PCD.

BWIP Missions Document. The draft of the BWIP Missions Document was completed and submitted to DOE and ONI on June 25, 1981.

Basalt Waste Isolation Traceability System (BITS). During the third quarter of FY 1981, a Rockwell Supporting Document, which discusses the proposed basalt waste isolation project index and traceability system was reviewed by BWIP management. The BITS scheduling was revised to reflect new budgetary constraints and to include a brief discussion of the NWTS Activity Information Data System (AIDS).

SYSTEMS ANALYSIS

The purpose of the Systems Analysis activity is to assess the relationships of interacting BWIP elements and to identify studies and work necessary to achieve specific program objectives. Progress within this activity during the third quarter of FY 1981 proceeded in several different areas.

A statement of work for an engineering service agreement subcontract covering the general subject of Systems Engineering and its application to the BWIP was prepared and delivered to Rockwell Materials for subcontractor acquisition. Particular emphasis was placed on the evaluation of current and planned functional analyses, trade studies, modeling, technical baselines, and performance assessment efforts at various project development phases. The subcontract will include periodic seminars/presentations to be given to BWIP Engineering and Planning personnel covering findings, recommendations, and the tailoring of systems engineering methodology to provide guidelines for effective and efficient project conduct.

Several NWTS Program document reviews were conducted during this reporting period. For example, BWIP comments on the following documents were compiled and transmitted to DOE-RL:

- NWTS-11, "NWTS Rock Mechanics Plan"
- NWTS-33(4), "Waste Package Performance Criteria".

The BWIP review comments on NWTS-147(1), "Position Paper on Technical Conservatism," were compiled and transmitted to the Chairman of the I-ICB.

An in-depth review of the BWIP Documentation Control System was initiated, and a detailed plan of action for defining/correcting BWIP documentation inconsistencies through modified control was submitted to DOE-RL. The plan of action is currently being implemented.

An updated draft of a report on the interim reference repository conditions for a nuclear waste repository in basalt (NWRB) was prepared for transmittal to the Reference Repository Conditions Interface Working Group (RRC-IWG) chairman and members. Technical changes included the addition of recent thermal properties data for Umtanum basalt and modification of predicted oxygen fugacities and Eh conditions at the repository horizon. Format changes were also made to maintain consistency with recent drafts of reference repository conditions reports for other geologic media. Numerous wording changes were made in response to RRC-IWG member comment on specific topics for which the basalt report differs from those for other geologic media.

PERFORMANCE ASSESSMENT

A 3-day workshop meeting was held to determine the status of site suitability and performance assessment issues. Individual contributors from the Site Department made presentations on all aspects of the site characterization and selection activities to BWIP management, a select audience of Systems Department personnel, and all end function managers. In preparation for the workshop, the Systems Department prepared a set of correlation tables relating the criteria/subcriteria factors on typical site suitability considerations as found in NWTS-4, "The National Plan for Siting High-Level Radioactive Waste Repositories and Environmental Assessment," (September 19, 1981) to the PCD criteria on siting. The individual contributors, as well as other workshop participants, used work sheets developed by the Systems Department to identify areas where: (1) there is a major technical and/or perceptional issue relative to the status and state of knowledge of a particular siting activity; (2) no major issues are apparent, but additional work, either in the field, in the form of documentation, or related to the verification process is needed; and (3) means to satisfy the criteria have already been determined and, therefore, the issues were closed.

This material has been summarized in tabular form by the Site Department staff and is presently undergoing integration and analysis by the Systems Department staff. When complete, this study will provide the BWIP management with an initial definition of technical issues relative to siting an NWRB.

WASTE PACKAGE

The objective of the Waste Package program is to define site-specific waste package requirements and monitor NWTS waste package design to ensure that a waste package emplaced in a repository constructed in basalt meets required regulatory criteria.

The Waste Package program consists of one end function, Waste Package, which is divided into five major activities:

- Waste Package Baseline
- Waste Form
- Barrier Materials
- Design and Development
- Performance Evaluation.

During the third quarter of FY 1981, work has progressed in all but the Design and Development activity.

WASTE PACKAGE BASELINE

This activity provides project control for the Waste Package end function and includes the preparation, implementation, and control of project plans, schedules, and budgets; the overall direction of technical work; and integration of BWIP waste package studies with the NWTS.

During this reporting period, presentations covering the BWIP Waste Package Program Plan were made to the National Academy of Science Panel on the Waste Isolation System Study. In addition, a Waste Package Overview Committee was established consisting of six members of national reputation with expertise relevant to waste package studies. A 3-day session was held during which BWIP Waste Package Studies' staff members presented the detailed program plan for developing waste packages for basalt isolation to the committee. On the third day, the committee work session concluded with a review of the committee members' assessment of the program and suggestions for improvement; they were fully supportive of the program plan.

WASTE FORM

Integration of Waste Form Data

The number and types of components required for the design of effective waste packages will be dependent on the chemical and physical properties of the waste form. Consequently, the objectives of this subactivity are to integrate currently available data on the properties of candidate waste forms and to provide this data base and simulated and radioactive waste forms to the Waste/Barrier/Rock Interaction subactivity for testing.

A draft of a report on the fabrication and characterization of a simulated spent fuel was received from the Hanford Engineering Development Laboratory (HEDL), Richland, Washington for review. This report provides details of the fabrication procedure and characterization of a 1-kg quantity of simulated light water reactor (LWR) spent fuel prepared for the BWIP. This simulant is being used in continuing waste/barrier/rock interaction studies.

BARRIER MATERIALS

Waste/Barrier/Rock Interactions

The objective of BWIP hydrothermal chemistry studies is to assess the performance of candidate waste forms and waste package component materials under conditions expected in a repository constructed in basalt at the Hanford Site.

The advance hydrothermal testing was continued this period. Emphasis is being placed on the accurate determination of steady-state test solution compositions. These experiments differ from the screening tests conducted earlier in that more sophisticated equipment and experimental techniques are being used. For example, Dickson-type autoclaves, which allow on-line sampling of the test solution, are being used to minimize the disturbance created by interrupting the test for solution sampling, required when using less sophisticated equipment.

A set of experiments at 200°C and 300 bars pressure was initiated in the system's supercalcine/groundwater and supercalcine/basalt groundwater at Arizona State University (ASU). These experiments are to be of long duration due to the decrease in reaction rates at the lower temperature. In addition, a set of experiments have been initiated in the system's borosilicate glass (PNL 76-68)/basalt groundwater at ASU. The experiments are being conducted at 300°C and 300 bars pressure. The experiments, using Umtanum basalt and groundwater, will provide data on the change in solution composition and the solid alteration products formed as the basalt is altered. In addition, the effects of basalt alteration on the Eh of the groundwater will be measured to determine the rate and capacity of basalt to impose reducing conditions within the repository.

Work continued at Atomics International (AI), Canoga Park, California, to prepare for the initiation of nonradioactive shakedown hydrothermal testing to begin in early FY 1982. Toward this end, AI designed the roller rack mechanism for the agitation of the autoclaves and other fixtures for the remote handling of the autoclaves. Arizona State University completed the construction of the advanced autoclave for use in the hot cells and tested the autoclave to 500 bars pressure at 400°C. Some initial problems with sealing the vessel were overcome and work is continuing to improve the design. The design of the autoclave has been given to AI for technical evaluation in terms of remote handling.

Sorption Chemistry

The objective of the sorption chemistry studies is to obtain distribution coefficients for the key radionuclides under conditions which simulate the groundwater flow path from a repository constructed in basalt to the biosphere. The distribution coefficient (K_d) is defined as the ratio of the activity sorbed onto the solid phase to the activity in the aqueous phase. These K_ds, along with other relevant chemical and physical data, will be used to evaluate the ability of the geohydrologic system and the candidate engineered barriers materials to prevent the transport of radionuclides to the biosphere.

Radionuclide K_ds between representative Hanford Site geologic materials and simulated Hanford groundwaters were determined using an equilibrium batch technique, as a function of solution composition, solid composition, radionuclide species, pH, temperature, and pressure. The geologic materials included Umtanum, Flow E, and Pomona basalt. The groundwater formulations used in the sorption experiments were presented previously (RHO-BWI-80-100 4Q).

The need for data on radionuclide sorption under the strongly reducing Eh and high pH conditions expected for a repository constructed in basalt prompted the investigation of several Eh-pH control systems. Basalt repository conditions are expected to vary in pH from approximately 6 to 10 and in Eh from approximately -0.4 V (10^{-68} atm O_2) to +0.5 V ($10^{-0.7}$ atm O_2). Experiments have shown that a 0.1M hydrazine solution can poise the basalt system at about -0.44 V at 25°C. In addition, the hydrazine appears to act as a pH buffer. The hydrazine buffers the basalt system at a pH of about 10. However, it is somewhat less efficient at buffering the secondary mineralization. This is probably due to the greater reactive surface area of the secondary mineralization. The results of the hydrazine buffered, low Eh sorption experiments for selenium at 23° and 60°C are given in Tables 1 and 2, respectively, for the basalts. Because the repository conditions will be oxidizing during the operating period and immediately after closure, it is also important to investigate radionuclide sorption under oxidizing conditions. Results of the high Eh sorption experiments for selenium at 23° and 60°C are given in Tables 3 and 4, respectively. These data indicate that temperature and groundwater composition do not significantly affect selenium K_d values.

TABLE 1. Selenium Sorption Data at 23°C Reducing Conditions.

Solid media	Initial selenium (M)	Final selenium (M)	Solids loading (moles Se/g)	Kd' (mL/g)	Average final pH (23°C)	Average final Eh (mV at 23°C)
Synthetic Groundwater (GR-1)						
Umtanum basalt	1.000×10^{-5}	6.911×10^{-6}	3.089×10^{-8}	4.5 ± 0.1	9.50	-400
	1.000×10^{-8}	7.775×10^{-9}	2.225×10^{-11}	2.9 ± 0.3	9.60	-395
	1.018×10^{-11}	7.376×10^{-12}	2.624×10^{-14}	3.6 ± 0.3	9.65	-390
	1.844×10^{-13}	1.358×10^{-13}	4.858×10^{-16}	3.6 ± 0.4	9.65	-370
Flow E basalt	1.000×10^{-5}	6.927×10^{-6}	3.073×10^{-8}	4.4 ± 0.3	9.45	-395
	1.000×10^{-8}	7.546×10^{-9}	2.454×10^{-11}	3.3 ± 0.6	9.50	-390
	1.018×10^{-11}	7.088×10^{-12}	2.912×10^{-14}	4.1 ± 0.2	9.60	-385
	1.844×10^{-13}	1.229×10^{-13}	5.444×10^{-16}	4.2 ± 0.4	9.60	-390
Pomona basalt	1.000×10^{-5}	4.840×10^{-6}	5.160×10^{-8}	10.7 ± 0.6	9.40	-395
	1.000×10^{-8}	4.774×10^{-9}	5.226×10^{-11}	11.1 ± 2.2	9.50	-390
	1.018×10^{-11}	3.969×10^{-12}	6.031×10^{-14}	15.2 ± 0.5	9.50	-390
	1.844×10^{-13}	7.424×10^{-14}	1.101×10^{-15}	14.9 ± 1.9	9.60	-395
Synthetic Groundwater (GR-2)						
Umtanum basalt	1.000×10^{-5}	6.845×10^{-6}	3.155×10^{-8}	4.6 ± 0.4	9.80	-410
	1.000×10^{-8}	7.080×10^{-9}	2.920×10^{-11}	4.1 ± 0.2	9.85	-405
	1.020×10^{-11}	7.370×10^{-12}	2.631×10^{-14}	3.6 ± 0.8	9.90	-410
	1.980×10^{-13}	1.464×10^{-13}	5.156×10^{-16}	3.5 ± 0.5	9.80	-410
Flow E basalt	1.000×10^{-5}	6.421×10^{-6}	3.579×10^{-8}	5.6 ± 1.1	9.75	-400
	1.000×10^{-8}	6.768×10^{-9}	3.233×10^{-11}	4.8 ± 0.2	9.80	-400
	1.020×10^{-11}	6.583×10^{-12}	3.416×10^{-14}	5.2 ± 0.1	9.80	-405
	1.980×10^{-13}	1.327×10^{-13}	6.529×10^{-16}	4.9 ± 0.2	9.70	-410
Pomona basalt	1.000×10^{-5}	3.860×10^{-6}	6.140×10^{-8}	15.9 ± 0.8	9.70	-400
	1.000×10^{-8}	3.589×10^{-9}	6.411×10^{-11}	17.9 ± 0.7	9.75	-400
	1.020×10^{-11}	3.490×10^{-12}	6.510×10^{-14}	18.7 ± 0.8	9.70	-405
	1.980×10^{-13}	7.032×10^{-14}	1.277×10^{-15}	18.2 ± 0.6	9.60	-405

NOTE: The solid weight to solution volume was 1 g/10 mL with 30 d of contact.

TABLE 2. Selenium Sorption Data at 60°C Reducing Conditions.

Solid media	Initial selenium (M)	Final selenium (M)	Solids loading (moles Se/g)	Kd' (mL/g)	Average final pH (60°C)	Average final Eh (mV at 60°C)
Synthetic Groundwater (GR-1)						
Umtanum basalt	1.000×10^{-5}	2.001×10^{-6}	7.999×10^{-8}	40.1 ± 2.3	9.15	-210
	1.000×10^{-8}	5.987×10^{-9}	4.013×10^{-11}	6.7 ± 0.3	9.20	-280
	1.018×10^{-11}	6.037×10^{-12}	3.963×10^{-14}	6.6 ± 0.8	9.10	-260
	1.844×10^{-13}	1.117×10^{-13}	7.270×10^{-16}	6.6 ± 1.3	9.15	-280
Flow E basalt	1.000×10^{-5}	2.236×10^{-6}	7.764×10^{-8}	35.0 ± 4.3	9.00	-245
	1.000×10^{-8}	6.673×10^{-9}	3.327×10^{-11}	3.1 ± 0.7	8.90	-260
	1.018×10^{-11}	6.449×10^{-12}	3.551×10^{-14}	5.6 ± 1.4	9.00	-270
	1.844×10^{-13}	1.206×10^{-13}	6.376×10^{-16}	5.3 ± 0.9	9.00	-270
Pomona basalt	1.000×10^{-5}	1.894×10^{-6}	8.106×10^{-8}	42.8 ± 0.1	9.05	-275
	1.000×10^{-8}	3.837×10^{-9}	6.163×10^{-11}	16.1 ± 1.5	9.00	-270
	1.018×10^{-11}	3.448×10^{-12}	6.552×10^{-14}	19.2 ± 3.1	9.10	-280
	1.844×10^{-13}	7.035×10^{-14}	1.140×10^{-15}	16.3 ± 2.2	9.10	-285
Synthetic Groundwater (GR-2)						
Umtanum basalt	1.000×10^{-5}	1.899×10^{-6}	8.101×10^{-8}	42.7 ± 1.1	9.30	-240
	1.000×10^{-8}	6.027×10^{-9}	3.973×10^{-11}	6.6 ± 0.7	9.30	-285
	1.018×10^{-11}	6.139×10^{-12}	3.861×10^{-14}	6.4 ± 1.6	9.30	-300
	1.844×10^{-13}	1.175×10^{-13}	8.045×10^{-16}	7.2 ± 3.0	9.30	-305
Flow E basalt	1.000×10^{-5}	1.620×10^{-6}	8.380×10^{-8}	51.7 ± 1.1	9.00	-250
	1.000×10^{-8}	7.129×10^{-9}	2.871×10^{-11}	4.1 ± 0.8	9.00	-275
	1.018×10^{-11}	7.153×10^{-12}	2.847×10^{-14}	4.0 ± 0.2	9.20	-295
	1.844×10^{-13}	1.350×10^{-13}	6.304×10^{-16}	4.7 ± 0.2	9.20	-290
Pomona basalt	1.000×10^{-5}	1.893×10^{-6}	8.107×10^{-8}	42.9 ± 2.3	9.10	-260
	1.000×10^{-8}	3.800×10^{-9}	6.200×10^{-11}	16.4 ± 1.1	9.10	-275
	1.018×10^{-11}	5.523×10^{-12}	4.477×10^{-14}	18.5 ± 2.4	9.20	-295
	1.844×10^{-13}	7.602×10^{-14}	1.228×10^{-15}	16.1 ± 0.2	9.20	-295

TABLE 3. Selenium Sorption Data at 23°C Oxidizing Conditions.

Solid media	Initial selenium (M)	Equilibrium selenium (C) (M)	Moles Se/g basalt (S)	Kd' (mL/g)	Average final pH (23°C)	Average initial pH (23°C)
Synthetic Groundwater (GR-1)						
Umtanum basalt	1.000×10^{-5}	6.512×10^{-6}	3.488×10^{-8}	5 ± 0.1	7.62	7.80
	1.000×10^{-8}	7.901×10^{-9}	2.099×10^{-11}	3 ± 0.9	7.70	7.95
	1.011×10^{-11}	7.508×10^{-12}	2.492×10^{-14}	3 ± 1.0	7.75	8.00
	1.090×10^{-13}	8.154×10^{-14}	2.756×10^{-16}	4 ± 1.2	7.70	7.92
Flow E basalt	1.000×10^{-5}	7.958×10^{-6}	2.024×10^{-8}	3 ± 0.4	7.95	
	1.000×10^{-8}	8.922×10^{-9}	1.078×10^{-11}	1 ± 0.1	7.75	
	1.011×10^{-11}	8.612×10^{-12}	1.388×10^{-14}	2 ± 0.2	7.70	
	1.090×10^{-13}	9.732×10^{-14}	1.178×10^{-16}	1 ± 0.4	8.00	
Pomona basalt	1.000×10^{-5}	8.133×10^{-6}	1.867×10^{-8}	2 ± 0.3	8.00	
	1.000×10^{-8}	8.846×10^{-9}	1.154×10^{-11}	1 ± 0.2	7.95	
	1.011×10^{-11}	8.792×10^{-12}	1.208×10^{-14}	1 ± 0.2	8.00	
	1.090×10^{-13}	9.520×10^{-14}	1.390×10^{-16}	2 ± 0.2	7.79	
Synthetic Groundwater (GR-2)						
Umtanum basalt	1.000×10^{-5}	7.764×10^{-6}	2.236×10^{-8}	3 ± 0.9	8.69	7.82
	1.000×10^{-8}	7.492×10^{-9}	2.508×10^{-11}	3 ± 0.9	8.75	8.65
	1.022×10^{-11}	7.994×10^{-12}	2.006×10^{-14}	3 ± 0.3	8.80	8.70
	2.163×10^{-13}	1.548×10^{-13}	6.150×10^{-16}	4 ± 1.0	8.75	8.79
Flow E basalt	1.000×10^{-5}	5.848×10^{-6}	4.152×10^{-8}	7 ± 0.4	8.79	
	1.000×10^{-8}	5.379×10^{-9}	4.621×10^{-11}	9 ± 0.9	8.80	
	1.022×10^{-11}	5.439×10^{-12}	4.561×10^{-14}	8 ± 0.4	8.75	
	2.163×10^{-13}	1.303×10^{-13}	8.600×10^{-16}	7 ± 0.3	8.75	
Pomona basalt	1.000×10^{-5}	9.232×10^{-6}	7.685×10^{-9}	1 ± 0.2	8.69	
	1.000×10^{-8}	7.956×10^{-9}	2.044×10^{-11}	3 ± 0.3	8.69	
	1.022×10^{-11}	8.208×10^{-12}	1.792×10^{-14}	2 ± 1.0	8.70	
	2.163×10^{-13}	1.141×10^{-13}	1.022×10^{-16}	9 ± 0.3	8.65	

NOTE: The solution-basalt contact was for 60 d at a solid weight to solution volume ratio of 1 g/10 mL.

TABLE 4. Selenium Sorption Data at 60°C Oxidizing Conditions.

Solid media	Initial selenium (M)	Equilibrium selenium (C) (M)	Moles Se/g basalt (S)	Kd' (mL/g)	Average final pH (60°C)	Average initial pH (60°C)
Synthetic Groundwater (GR-1)						
Umtanum basalt	1.000×10^{-5}	6.932×10^{-6}	3.068×10^{-8}	4 ± 0.5	8.22	7.80
	1.000×10^{-8}	8.662×10^{-9}	1.338×10^{-11}	2 ± 0.3	8.25	7.95
	1.011×10^{-11}	7.691×10^{-12}	2.309×10^{-14}	3 ± 0.7	8.25	8.00
	1.091×10^{-13}	1.091×10^{-13}	2.320×10^{-16}	3 ± 0.5	8.20	7.92
Flow E basalt	1.000×10^{-5}	6.502×10^{-6}	3.498×10^{-8}	5 ± 1.2	8.19	
	1.000×10^{-8}	8.172×10^{-9}	1.828×10^{-11}	2 ± 0.4	8.15	
	1.011×10^{-11}	7.804×10^{-12}	2.196×10^{-14}	3 ± 0.3	8.15	
	1.091×10^{-13}	9.355×10^{-14}	1.555×10^{-16}	2 ± 0.2	8.15	
Pomona basalt	1.000×10^{-5}	6.678×10^{-6}	3.322×10^{-8}	5 ± 1.4	8.25	
	1.000×10^{-8}	7.414×10^{-9}	2.586×10^{-11}	4 ± 0.3	8.22	
	1.011×10^{-11}	7.309×10^{-12}	2.691×10^{-14}	4 ± 0.4	8.25	
	1.091×10^{-13}	9.416×10^{-14}	1.494×10^{-16}	2 ± 0.3	8.25	
Synthetic Groundwater (GR-2)						
Umtanum basalt	1.000×10^{-5}	8.332×10^{-6}	1.668×10^{-8}	2 ± 0.1	8.67	7.82
	1.000×10^{-8}	8.445×10^{-9}	1.555×10^{-11}	2 ± 1.7	8.69	8.65
	1.022×10^{-11}	8.302×10^{-12}	1.698×10^{-14}	2 ± 0.8	8.69	8.70
	2.163×10^{-13}	1.786×10^{-13}	3.771×10^{-16}	2 ± 0.9	8.65	8.79
Flow E basalt	1.000×10^{-5}	8.084×10^{-6}	1.916×10^{-8}	2 ± 0.6	8.67	
	1.000×10^{-8}	7.516×10^{-9}	2.484×10^{-11}	3 ± 0.8	8.69	
	1.022×10^{-11}	6.884×10^{-12}	3.116×10^{-14}	5 ± 0.3	8.70	
	2.163×10^{-13}	1.661×10^{-13}	5.020×10^{-16}	3 ± 0.4	8.65	
Pomona basalt	1.000×10^{-5}	7.242×10^{-6}	2.758×10^{-9}	4 ± 0.9	8.69	
	1.000×10^{-8}	6.107×10^{-9}	3.893×10^{-11}	6 ± 0.1	8.59	
	1.022×10^{-11}	5.894×10^{-12}	4.106×10^{-14}	7 ± 0.4	8.70	
	2.163×10^{-13}	1.128×10^{-13}	1.035×10^{-15}	9 ± 0.3	8.60	

NOTE: The solution-basalt contact was for 60 d at a solid weight to solution volume ratio of 1 g/10 mL.

There is little significant difference in the sorption of selenium under oxidizing and reducing conditions for the Umtanum and Flow E basalts; sorption is low under both conditions. The predominant selenium species expected under this range of experimental conditions are shown in Figure 2. Under oxidizing conditions the predominant species are SeO_4^{2-} and SeO_3^{2-}. Being anionic, these species are poorly sorbed by geologic materials. Under reducing conditions, the predominant specie is the metal, Se^0, and its behavior will be predominately controlled by its solubility. Therefore, unless the solubility limit of Se^0 is exceeded, the K_d for selenium would not be expected to increase significantly with decreasing Eh. Selenium metal should be essentially insoluble in the low Eh, alkaline groundwater and should be almost completely removed from solution. However, the low K_d values at low Eh suggest that the reduction of selenium by hydrogen at high pH (10) to the metal is a very slow reaction.

The order of magnitude increases in the selenium K_d values at an initial selenium concentration of 10^{-5}<u>M</u> at 60°C and under reducing conditions (Table 2) is the only indication that selenium has been reduced to the metal and has precipitated.

Sorption of selenium onto the Pomona basalt is generally two to three times greater than selenium sorption on the Umtanum and Flow E basalts. This may be the result of the sources of the various basalts. Both the Umtanum and Flow E basalts were collected from surface outcrops whereas the Pomona basalt was collected at depth during the excavation of the Near-Surface Test Facility (NSTF) at Gable Mountain. It is possible that the unweathered Pomona basalt has a somewhat greater proportion of sulfidic minerals than the slightly weathered Umtanum and Flow E basalts. Selenium has been shown to sorb on some of the sulfide minerals.

Radionuclide K_d values have been shown to be sensitive to changes in the initial concentration of radionuclides present. The concentrations of the radionuclides in groundwater can be expected to vary with time because of changes in the thermal and physiochemical conditions in and near the repository.

Sorption isotherms describe dependence of radionuclide sorption on the radionuclide concentration. Selenium sorption, over the concentration range investigated, can be described by the Freundlich isotherm equation:

$$S = KC^N$$

where:

S = amount of solute sorbed by the basalt

K = "affinity" constant

C = equilibrium solute concentration

N = constant related to energy of sorption.

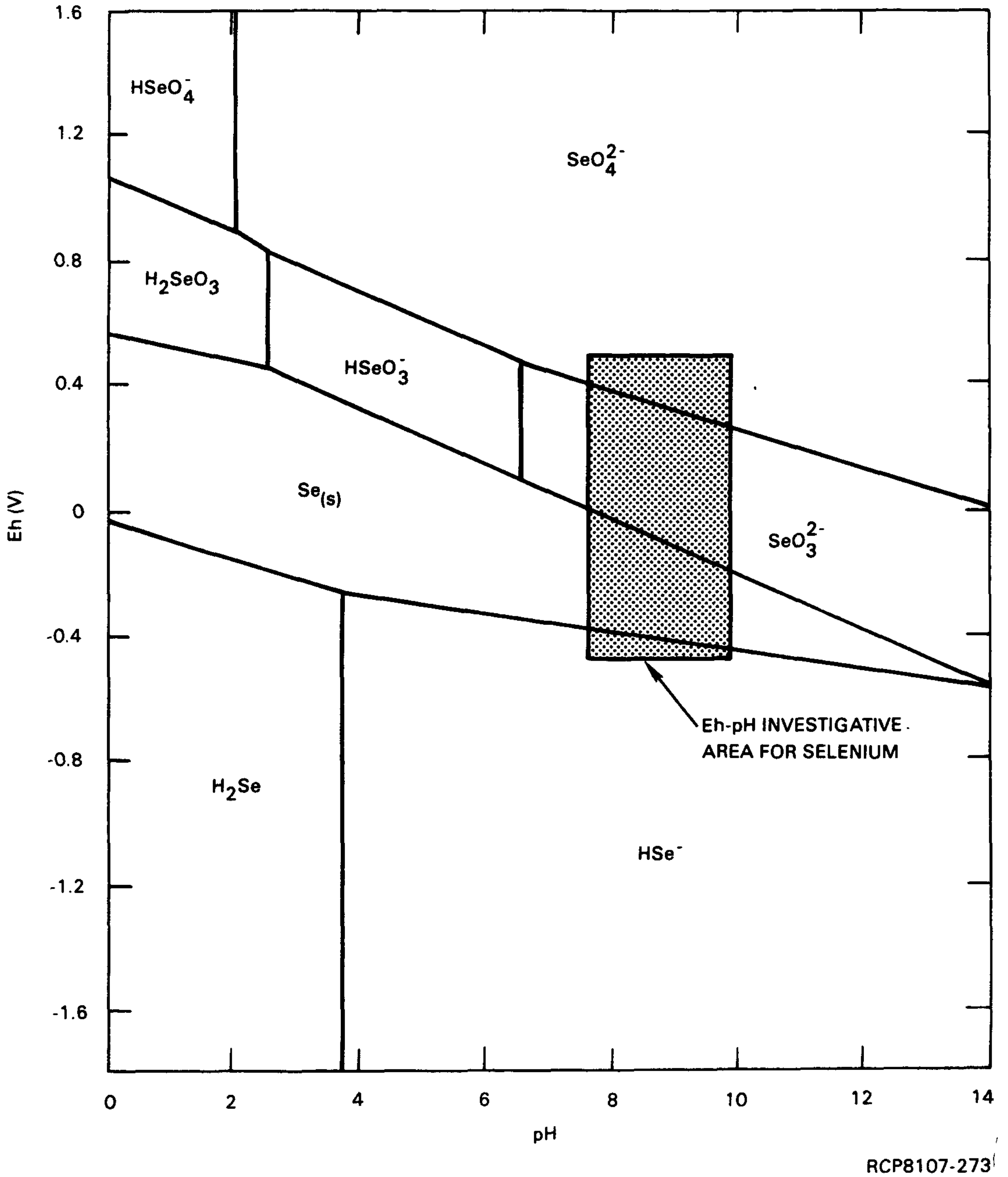

FIGURE 2. Eh-pH Predominance Diagram for Selenium-Water at 25°C and Selenium Concentration of 3 x 10^{-12}M.

The Freundlich isotherm is followed under both reducing and oxidizing conditions. Figure 3 shows the Freundlich isotherm describing selenium sorption onto the Umtanum basalt. Tables 5 and 6 give the Freundlich constants and correlation coefficients for the regression for selenium sorption under reducing and oxidizing conditions, respectively. These isotherm equations are used in calculating radionuclide retardation factors, a term used in modeling radionuclide transport.

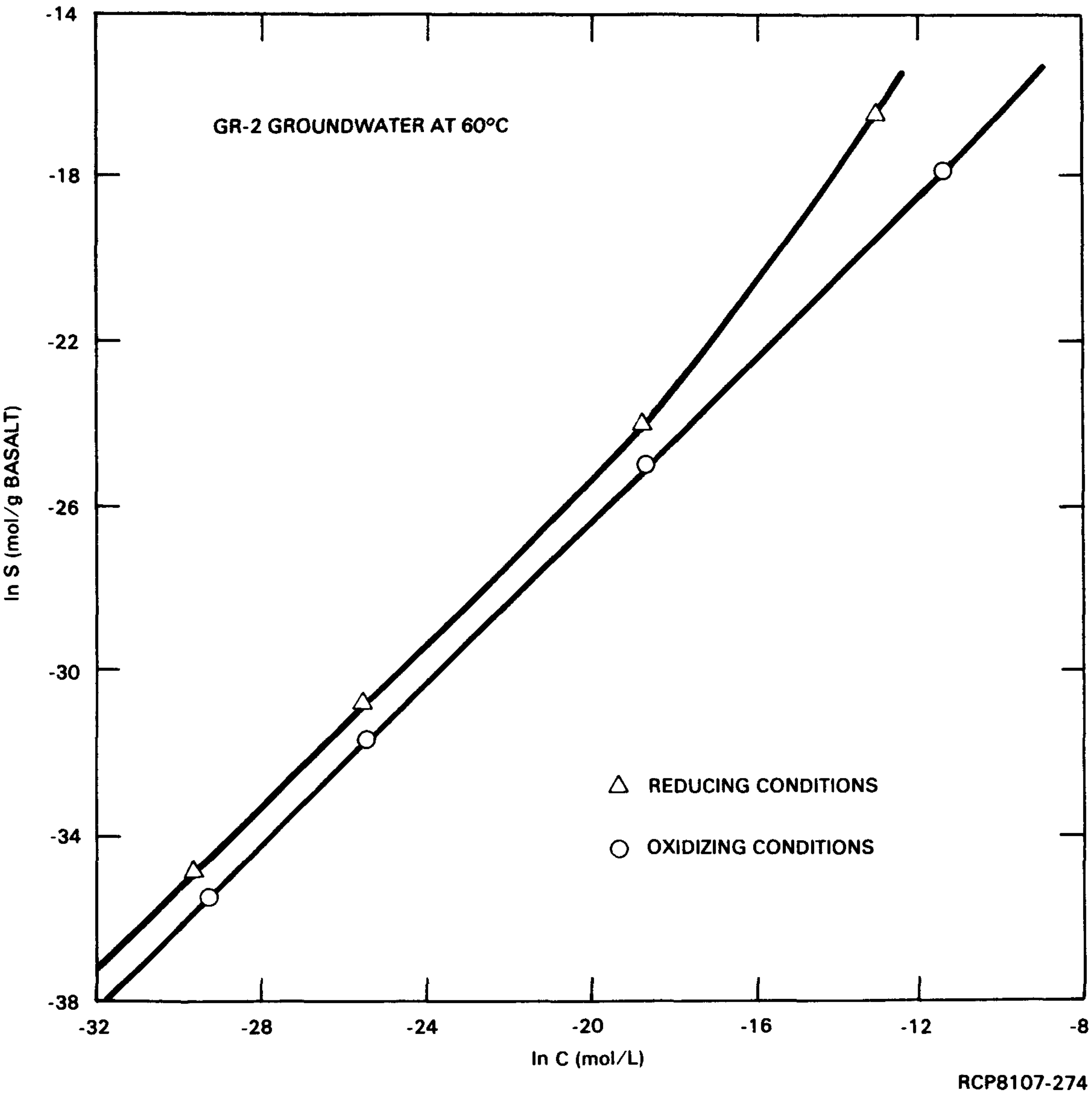

FIGURE 3. Freundlich Isotherm, Selenium Sorption on Umtanum Basalt.

TABLE 5. Freundlich Constants for Selenium Sorption on Three Basalts at Low Eh Values. The equation was ln S = ln K + N ln C.

Solid media	K	N	r*
23°C			
Synthetic Groundwater (GR-1)			
Umtanum basalt	0.004267	1.00829	+0.9998
Flow E basalt	0.003934	0.99957	+0.9998
Pomona basalt	0.007845	0.97794	+0.9999
Synthetic Groundwater (GR-2)			
Umtanum basalt	0.005565	1.016188	+0.9999
Flow E basalt	0.005667	1.004835	+0.9999
Pomona basalt	0.014823	0.992207	+0.9999
60°C			
Synthetic Groundwater (GR-1) (lower three experimental points only)			
Umtanum basalt	0.008348	1.00869	+0.9999
Flow E basalt	0.004493	0.99368	+0.9999
Pomona basalt	0.015588	0.99649	+0.9999
Synthetic Groundwater (GR-2) (lower three experimental points only)			
Umtanum basalt	0.006199	0.99765	+0.9999
Flow E basalt	0.003135	0.98802	+0.9999
Pomona basalt	0.016396	1.00958	+0.9974

*r = regression correlation coefficient.

TABLE 6. Freundlich Constants for Selenium Sorption on Three Basalts at High Eh Values. The equation was ln S = ln K + N ln C.

Solid media	K	N	r*
23°C			
Synthetic Groundwater (GR-1)			
Umtanum basalt	0.005470	1.019966	+0.9995
Flow E basalt	0.003108	1.031922	+0.9996
Pomona basalt	0.002535	1.022485	+0.9997
Synthetic Groundwater (GR-2)			
Umtanum basalt	0.002585	0.991048	+0.9997
Flow E basalt	0.007972	1.002086	+0.9999
Pomona basalt	0.005745	1.051497	+0.9993
60°C			
Synthetic Groundwater (GR-1) (lower three experimental points only)			
Umtanum basalt	0.003709	1.014660	+0.9987
Flow E basalt	0.008600	1.053132	+0.9995
Pomona basalt	0.009772	1.052136	+0.9995
Synthetic Groundwater (GR-2) (lower three experimental points only)			
Umtanum basalt	0.001830	0.995871	+0.9999
Flow E basalt	0.002057	0.979094	+0.9996
Pomona basalt	0.002394	0.955387	+0.9999

*r = regression correlation coefficient.

PERFORMANCE EVALUATION

Engineering Evaluation

Temperature estimates for the waste package and the very near-field rock resulting from the storage of spent fuel element (SFE) in basalt were determined. The reference waste package conceptual design for a repository in basalt was modeled using the heat transfer computer code, HEATING5. This code uses the Crank-Nicolson finite difference method to evaluate transient temperature behavior. Transient heat transfer analysis is necessary because the heat generated by spent-fuel varies with the radioactive decay of fission products.

Using the finite difference method, the temperature of the emplacement hole surface as a function of time over a 10,000-yr period was first determined. Assuming a quasi-steady-state equilibrium condition between the emplacement hole surface and the waste package, calculations were then made to determine temperature histories of various components of the waste package. These are shown in Figure 4 together with the time required to reach the maximum temperatures.

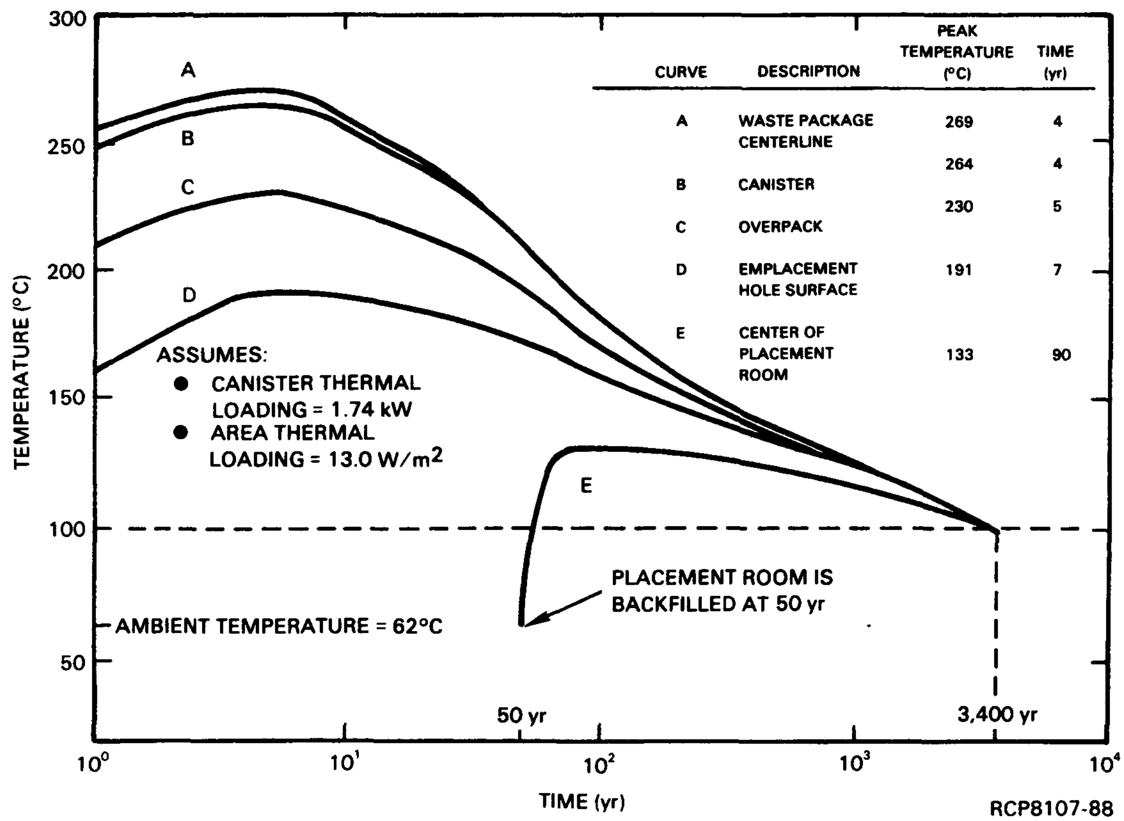

FIGURE 4. Temperature Estimates for a Spent Fuel Waste Package in Basalt.

The waste package conceptual design developed jointly by the BWIP and Kaiser Engineers/Parsons Brinckerhoff Quade and Douglas, Inc. (KE/PB) were used for the analysis. Waste packages, each containing three 10-yr-old pressurized water reactor (PWR) disassembled spent fuel assemblies, were assumed to be stored vertically in a single row in long, parallel rooms separated by pillars. The individual waste packages in a row were emplaced with a center-to-center pitch of 4 m. The distance between room centers or rows was 37 m. For the model, the fuel was contained in a carbon steel canister surrounded by a layer of bentonite (buffer) and then placed inside a titanium overpack. The canister/ overpack assemblage was then emplaced in the repository surrounded by a backfill composed of a bentonite clay/crushed basalt mixture. The analysis was also based on the additional assumptions:

- Simultaneous emplacement of waste packages each containing 10-yr-old unreprocessed spent fuel
- Air in rooms above package is stagnant and radiation heat transfer is neglected during retrieval period (first 50 yr)
- Ambient temperature = 61.5°C at the repository level
- Semi-infinite basalt media
- Dry basalt media
- The waste package contents are in quasi-steady-state equilibrium with the basalt
- Backfilled regions remain unsaturated throughout the analysis.

Each of these assumptions tended to overestimate the temperature; thus, the results were conservative.

A major influence on the waste package temperatures is the conductivity of the backfilled region which, in turn, is influenced by the moisture content and the amount of crushed basalt added to the mixture. The resulting effect on temperature is illustrated in Figure 5. Also shown is the effect of the temperature-sensitive basalt conductivity on waste package peak temperatures. The effect of spent fuel age on the emplacement hole temperature is shown in Figure 6. This analysis permits the comparision of very near-field thermal behavior of 20- and 40-yr-old spent fuel with 10-yr-old fuel. The comparison can be used to assess the economic incentives for aging the spent fuel for longer time periods prior to disposal. Also included for comparison are two waste loadings for a commercial high-level reprocessed waste form.

The computer model "BARIER," developed by Science Applications, Inc. (SAI), La Jolla, California, for the NWTS has been added to the BWIP computer file. "BARIER" was developed as a basic structure that would easily accommodate major additions and enhancement and is being considered for use by the BWIP for waste package degradation modeling.

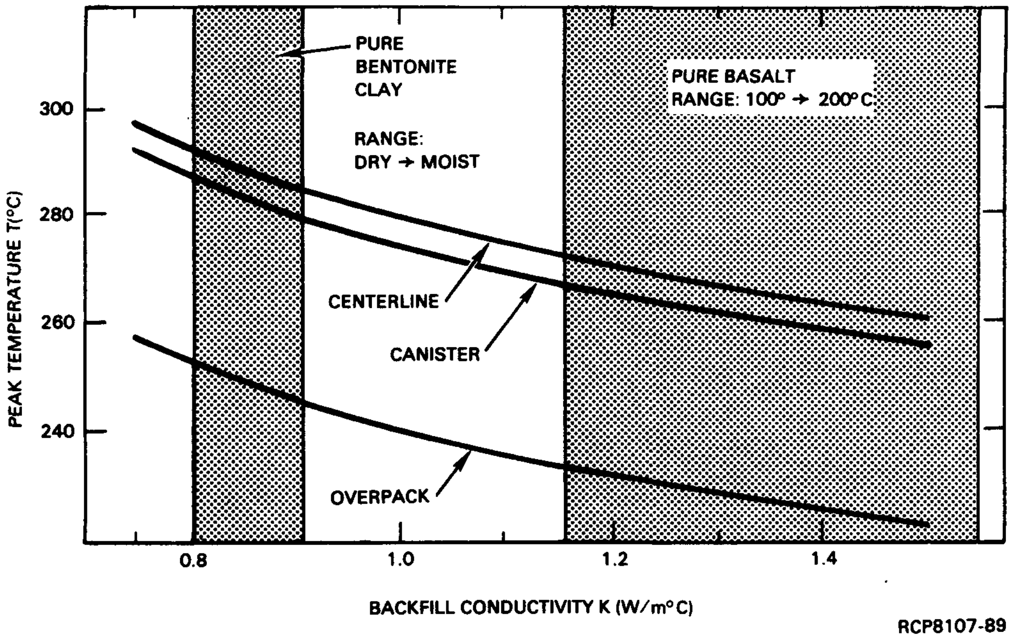

FIGURE 5. Waste Package Peak Temperatures Versus Backfill Conductivity.

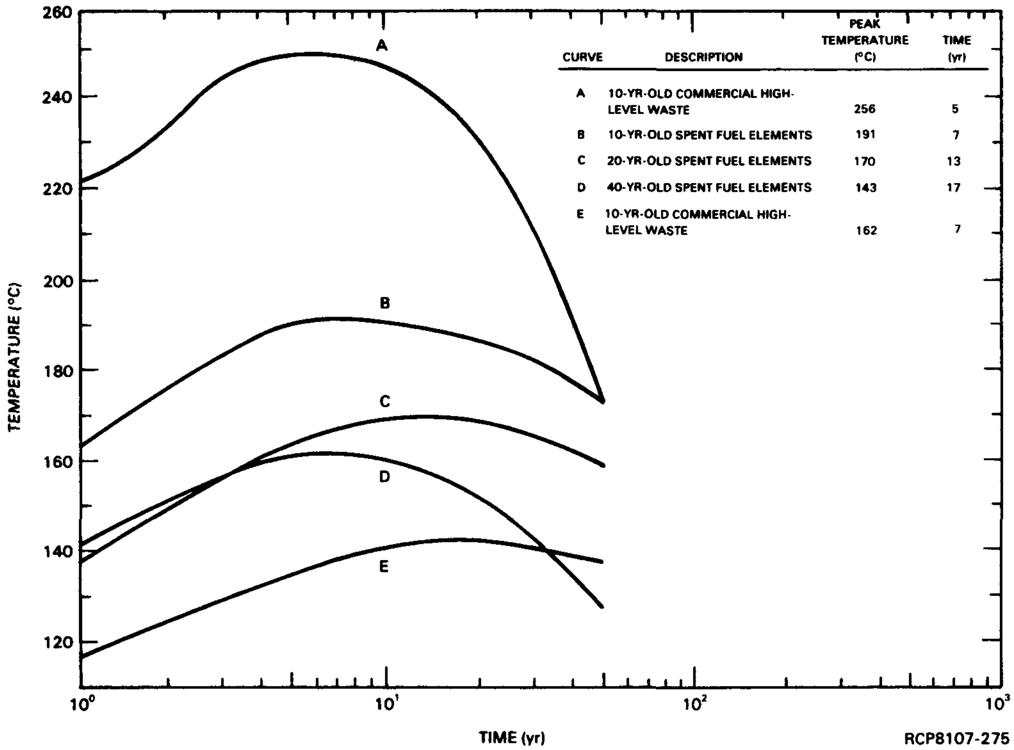

FIGURE 6. Emplacement Hole Temperature Estimates for Selected Waste Forms.

SITE

The Site program includes the activities required to identify and characterize a suitable site for a repository of nuclear wastes in basalt rock underlying the Hanford Site.

The Site program consists of one end function, Site, which consists of seven activities:

- Site Baseline
- Earth Sciences
- Geologic Characterization
- Hydrologic Characterization
- Environmental Characterization
- Socioeconomic Evaluation
- Performance Evaluation.

Efforts during this quarter focused on the Geologic Characterization and Hydrologic Characterization activities.

GEOLOGIC CHARACTERIZATION

The Geologic Characterization activity provides geologic data and interpretations significant to the evaluation of candidate repository sites in the basalt beneath the Hanford Site. Geologic investigations include reconnaissance studies of the Columbia Plateau and detailed studies within the Pasco Basin where the Hanford Site is located (Figure 7). The major effort during this quarter was the documentation of the subsurface geology of the Cold Creek syncline. This report summarizes the results of geologic investigations within the Cold Creek syncline and presents stratigraphic, lithologic, and structural interpretations.

The Geologic Characterization activity is subdivided into the following nine subactivities:

- Surface Geology
- Resource Potential
- Volcanic Activity
- Tectonic Setting
- Structural Geologic Setting

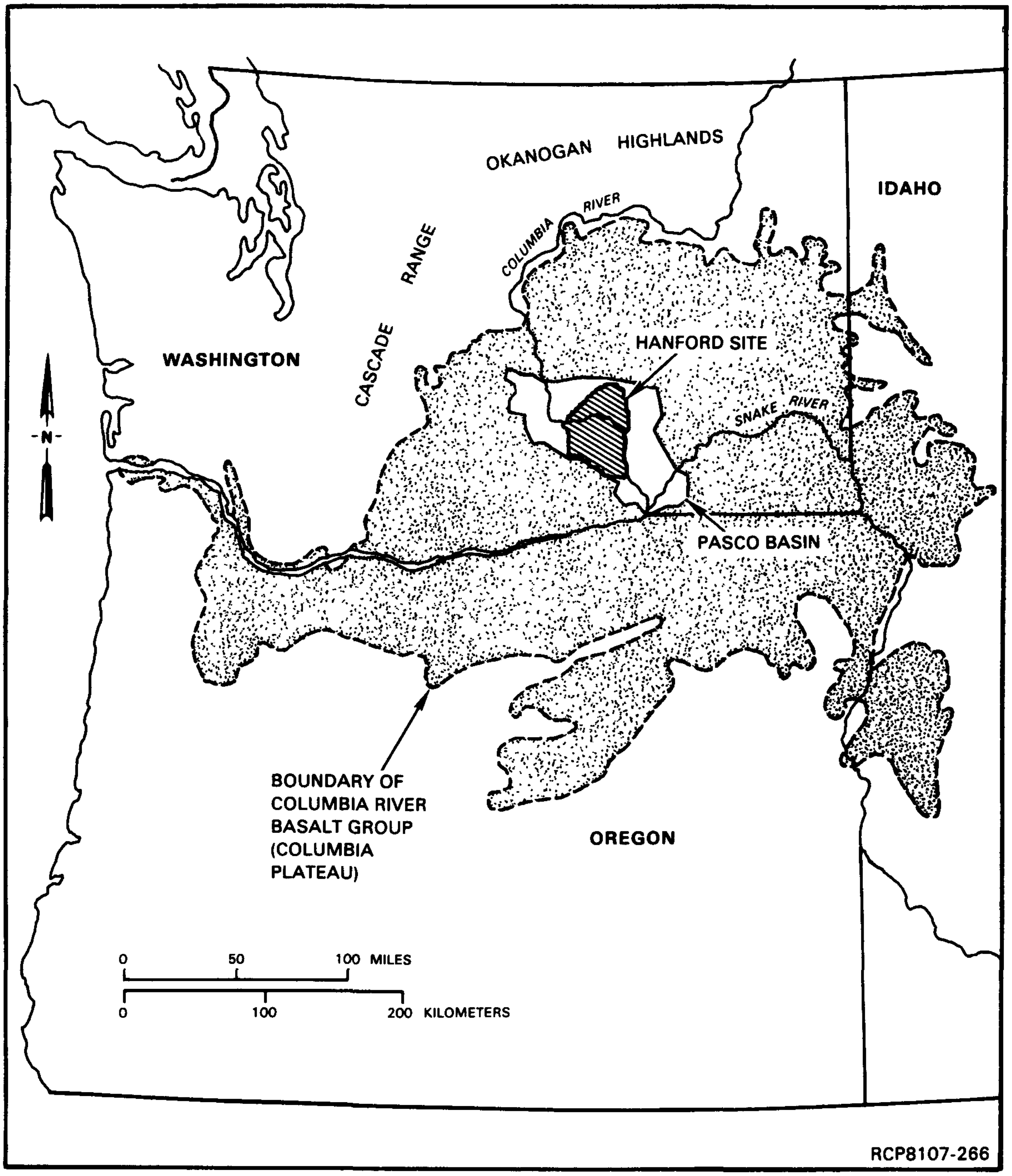

FIGURE 7. Columbia Plateau, Pasco Basin, and Hanford Site.

- Host Rock Geometry
- Host Rock Lithology
- Host Rock Stratigraphic Setting
- Integration of Geologic Data.

A discussion of work conducted under each of these subactivities during the third quarter follows.

Surface Geology

The objective of the Surface Geology subactivity is to: (1) collect and interpret surface geologic data (surface geologic mapping) as needed for input to tectonic setting and structural geologic setting subactivities, (2) determine the net effect of surficial processes at or near the repository site to aid in the long-term repository stability, and (3) collect and interpret data on the Miocene to present suprabasalt sediments of the Cold Creek syncline to refine the sedimentary stratigraphy of the area.

During this quarter the six reference repository location (RRL) boreholes were completed and a fence diagram of the suprabasalt sediments in the RRL was finished using data from these and previously existing borehole data (Figures 8 and 9). The four textural facies of the Miocene-Pliocene Ringold Formation are present except where the upper facies is eroded. The Ringold Formation is overlain by Pleistocene flood deposits, the Hanford formation. Coring began on a series of DH sediment core holes to aid in a more detailed interpretation of the sediments of the RRL.

Three representative stratigraphic section types are used to describe the lateral variation of the Ringold Formation throughout the Pasco Basin. The central portion of the Cold Creek syncline, and much of the central Pasco Basin, is representative of Section Type I, the basal, lower, middle and upper Ringold facies[a] (Figure 10). Section Type II is found north and east of Gable Mountain and is composed predominantly of sand and silt. Section Type III, the fanglomerate facies, occurs on the flanks of anticlinal ridges.

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[a]Myers, C. W./S. M. Price, J. A. Caggiano, M. P. Cochran, W. J. Czimer, N. J. Davidson, R. C. Edwards, K. R. Fecht, G. E. Holmes, M. G. Jones, J. R. Kunk, R. D. Landon, R. K. Ledgerwood, J. T. Lillie, P. E. Long, T. H. Mitchell, E. H. Price, S. P. Reidel, and A. M. Tallman, 1979, Geologic Studies of the Columbia Plateau, a Status Report, RHO-BWI-ST-4, Rockwell Hanford Operations, Richland, Washington.

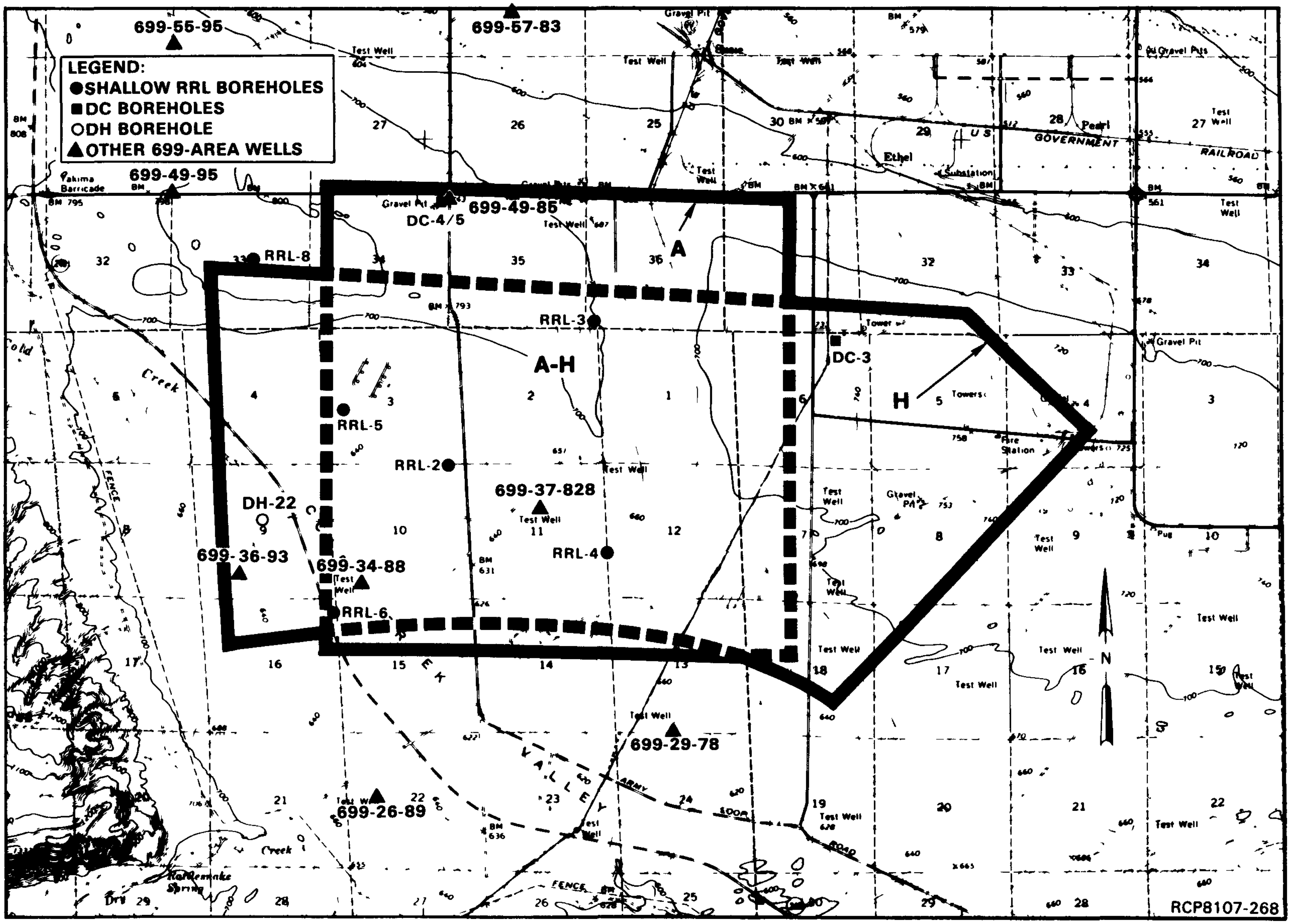

FIGURE 8. Borehole Location Map.

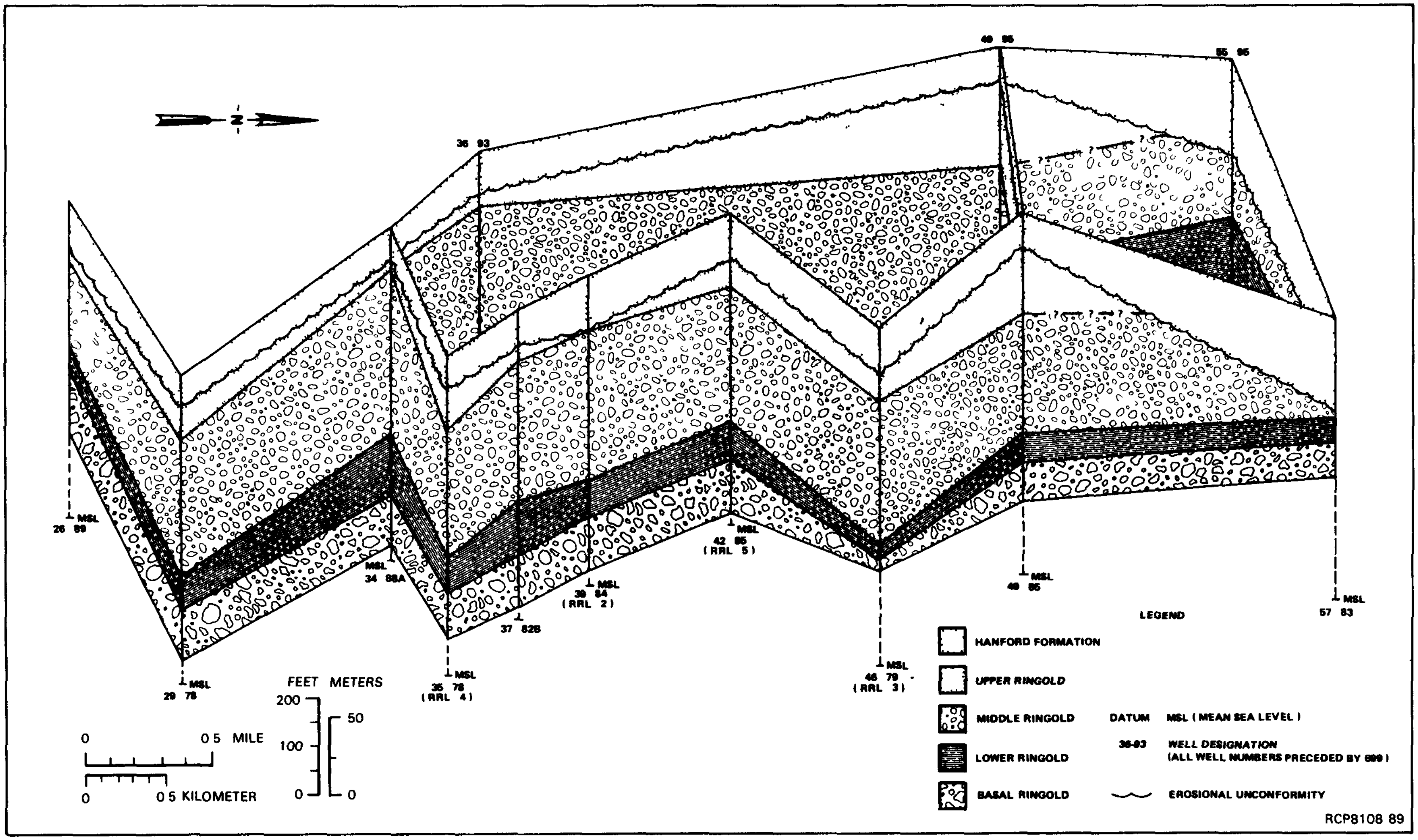

FIGURE 9. Suprabasalt Sediment Correlation.

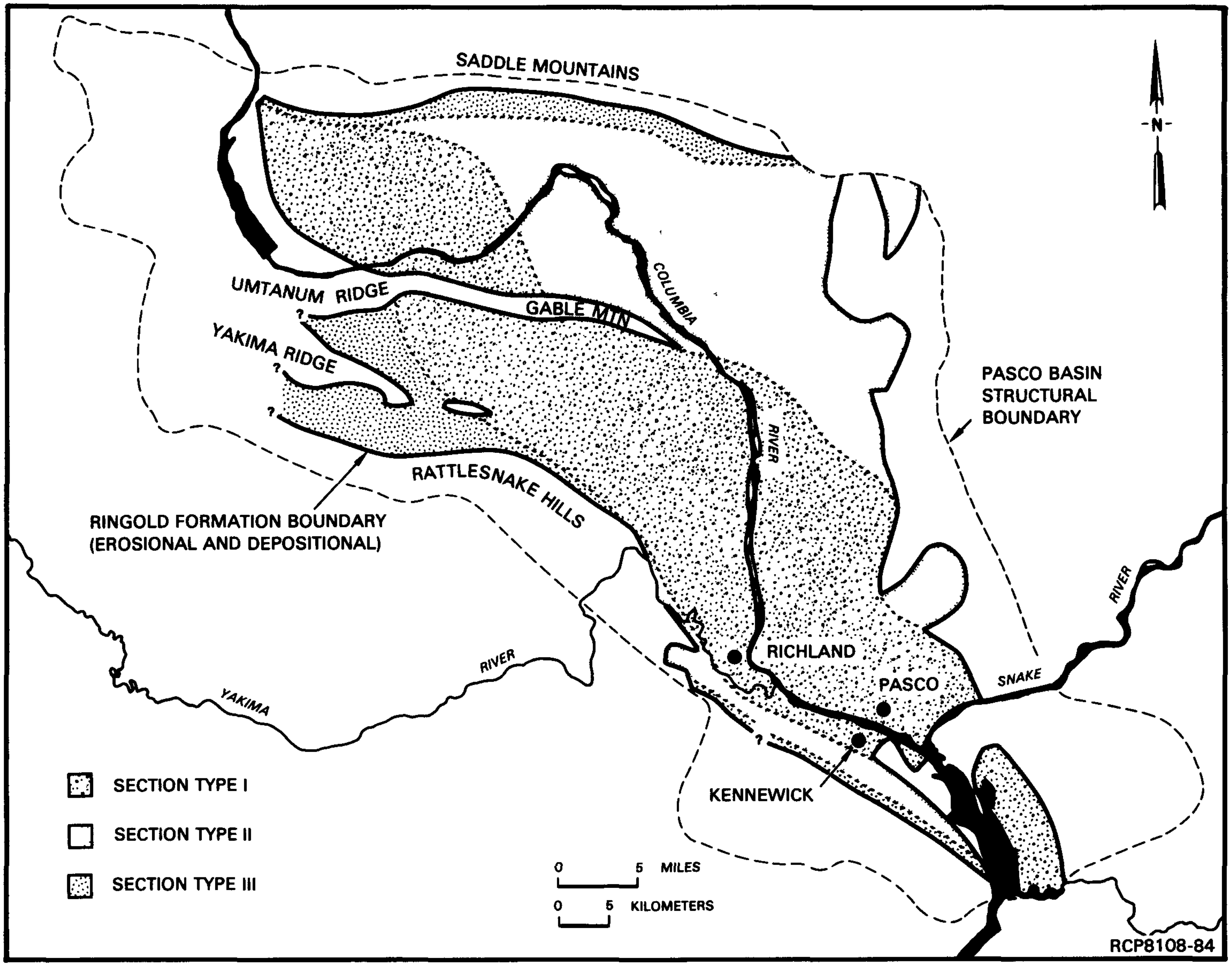

FIGURE 10. Distribution of Ringold Sediment Types.

Resource Potential

The objective of the Resource Potential subactivity is to determine the risk for disruption of an NWRB as a result of potential geologic resource exploration and development. This subactivity includes determination of whether there has been conventional or in situ subsurface mining or drilling for resources, whether there are resources economically exploitable by current technology with present market conditions, and whether resources within a 100-km radius of a potential repository have greater gross or net value than the average for other areas of similar size in the Columbia Plateau.

Progress continued toward evaluation of current and potential attractiveness of the Pasco Basin for geologic resource exploitation within and above the Columbia River basalt. Work to evaluate current and potential gross and net value, and net present value of mineral, fossil fuel, and geothermal resources within 100 km of the proposed site was completed by George Leaming Associates, Marana, Arizona. In addition, a comparison of these values was made with the remainder of the Columbia Plateau on an equal area, employment, per capita income, and tax revenue basis.

The report concludes that the projected value of geologic resources over the next 25 yr is $33.3 million in terms of 1980 dollars in the 10-county study area, within a radius of 100 km of the proposed site. On a per-unit-of-area basis, this value is less than half of resource values for the remainder of the Columbia Plateau, and on a per-inhabitant basis, it is less than two-thirds of the value for the remainder of the plateau. In both areas, the portion of the Columbia Plateau in the vicinity of the proposed site and the remainder of the Columbia Plateau, per-square-kilometer and per-inhabitant resource values are only one-thirtieth of the comparable values for a relatively mineral-rich state such as New Mexico.

Results of eight vitrinite reflectance analyses and three methane gas hydrogen isotope analyses conducted for Rockwell by the U.S. Geological Survey (USGS), Denver, Colorado were reported. Such analyses are being conducted to help evaluate the potential for occurrence of significant natural gas and petroleum resources within the Pasco Basin, particularly those resources that might occur within the Columbia River Basalt Group. Results of the analyses, interpreted in the context of earlier carbon isotope analyses (Figure 11), indicate that methane gas from the Wanapum formation penetrated in drill hole DC-15 is of biogenic origin and is derived from terrestrial, rather than from marine, sediments.

Recent petroleum exploration lease sales by the state of Washington resulted in lease bids of up to $200 per acre for lands within the Columbia Plateau. Shell Oil Company completed its deep petroleum exploration well on Umtanum Ridge north of Yakima, Washington at a depth in excess of 4,800 m, but has not announced the results. Permits are being sought by Shell Oil Company to drill two additional wells north and west of the Hanford Site.

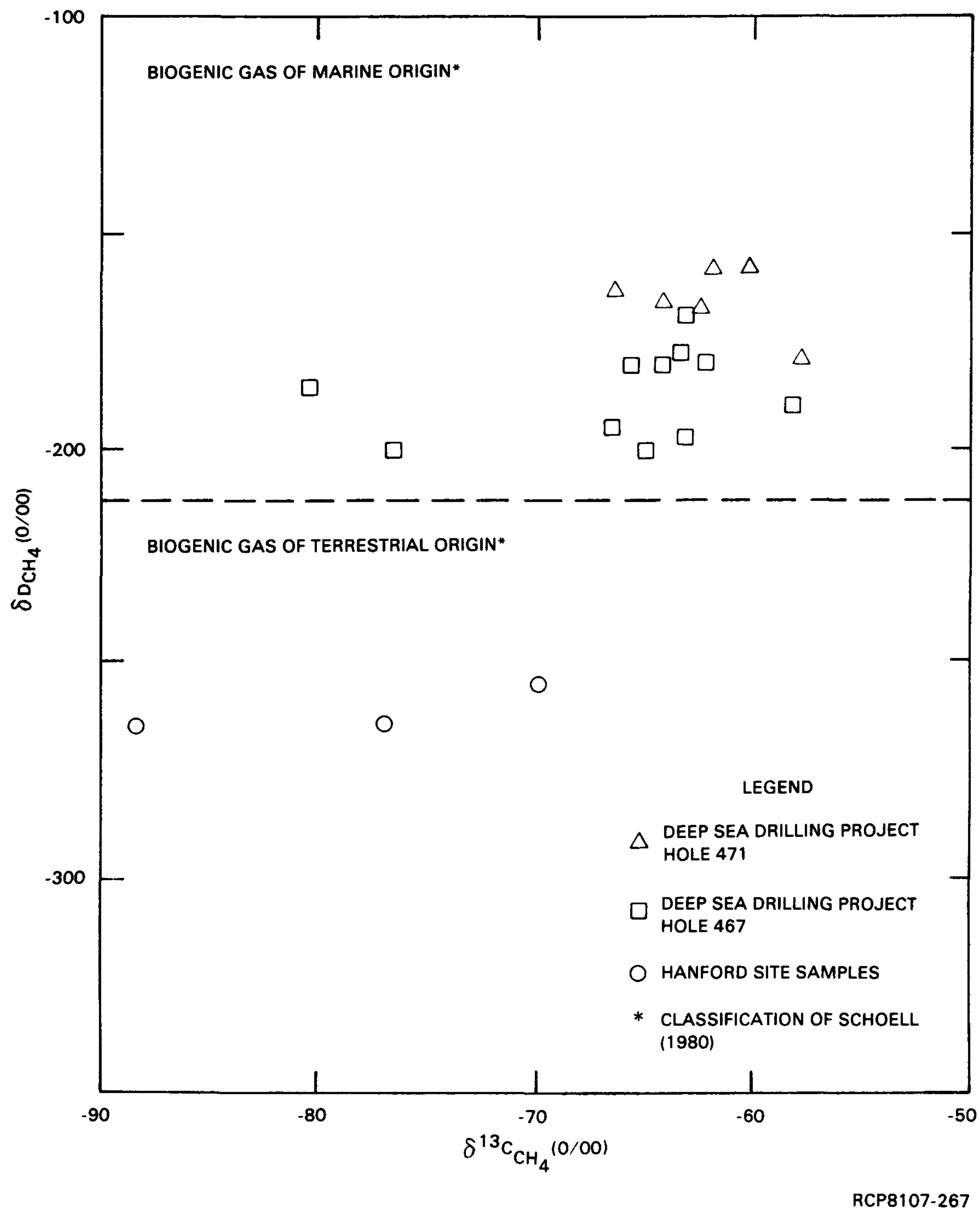

FIGURE 11. Plot of Carbon and Hydrogen Isotope Analyses of Methane Gas from Well DC-15 as Compared to Isotopic Compositions of Biogenic Gases of Marine Origin. Isotopic compositions of thermogenic gases, that is, gases derived from naturally occurring pyrolysis processes, would plot to the right of the graph.

*Schoell, M., 1980, "The Hydrogen and Carbon Isotopic Composition of Methane from Natural Gases of Various Origins," Geochimica et Cosmochimica Acta 44 649-661.

Volcanic Activity

The objective of this subactivity is to assess the potential for renewed igneous activity within the Columbia Plateau and vicinity, with emphasis on the Pasco Basin. A second objective of this subactivity is to provide data which can be used to conduct an assessment of geothermal energy resource potential.

ERTEC (formerly Fugro) of Long Beach, California was placed under subcontract with Rockwell's Geosciences Group to update and refine the Group's evaluation of geothermal resource potential within the Pasco Basin and to refine its event network/risk consequence analysis of the potential for occurrence of renewed igneous activity potentially disruptive to a terminal waste repository within the Pasco Basin. Work currently is proceeding toward completion of the subcontract in accordance with the terms of the agreement.

Tectonic Setting

The objective of this subactivity is to characterize the tectonic setting of a repository site in the Cold Creek syncline area. Work during this quarter included: regional seismic monitoring, site-specific seismic monitoring, and geodetic surveys.

During this quarter, the eastern Washington regional seismic monitoring network operated by the University of Washington, Seattle, Washington located two events of interest in the southeastern Cascade Range: (1) a magnitude 5 earthquake on May 28, 1981 and a series of aftershocks in the Goat Rocks Wilderness area north of Mt. Adams and (2) a magnitude 3.2 earthquake near Goldendale, Washington on June 19, 1981. The southern Washington Cascade Range region experienced a higher rate of seismic activity during the last two quarters, which may be related to a change in regional stress indirectly caused by the eruption of Mt. St. Helens. Local events of note this quarter include several minor earthquake swarms that have occurred in the Saddle Mountains and a magnitude 1.6 event beneath Wooded Island.

The site-specific seismic monitoring effort has continued during this quarter, with progress in the following areas:

- An order has been placed for a digital seismic recording system with the Digital Equipment Corporation, Spokane, Washington. Delivery is expected in late September 1981. Modifications to the Tannadore Building's seismic laboratory for electrical circuits and air conditioning were completed.

- Magnetic tape recordings of numerous blasts at Ice Harbor Dam (U.S. Army Corps of Engineers) and at the original Northwest Energy Services Company (NESCO) site southeast of Gable Mountain (Weston Geophysical, Weston, Massachusetts) were obtained, and transmitted to Woodward-Clyde Consultants, San Francisco, California. These tapes will be used to study attenuation of seismic waves in support of the Washington Public Power Supply System (WPPSS) Richland, Washington, licensing effort. Arrival times of the waves from the Weston Geophysical blasts have been transmitted to them for inclusion in their refraction studies. In addition, recordings were made of the low-frequency signals of a nuclear explosion at the Nevada Test Site to evaluate instrumentation requirements for deep structural studies by Woodward-Clyde Consultants for WPPSS.

- An agreement between the BWIP, DOE, and WPPSS was made to jointly purchase and install nine additional short-period vertical seismometers on the Hanford Site.

- The portable three-component network has been used to temporarily test three new sites east of Wooded Island. Landowners' permissions were obtained to use the site. Another new site is now operating near Coyote Rapids, north of Gable Butte. The permanent stations in the Cold Creek network continue to monitor the RRL area. No events in this area have been detected this quarter.

- The new borehole seismometer was received by the University of Washington and tested. This instrument will be installed deep in borehole DC-3 when hydrologic testing is completed.

An interagency agreement was reached between the DOE and the Office of Earthquake Studies, USGS, Menlo Park, California for the performance of geodetic surveys. A single-color-laser distance survey will be used of the USGS's 19-station Hanford trilateration network and networks newly established by Rockwell in the Snively Basin area of the Hanford Site (9 stations) and at the bend in the Horse Heaven Hills structure near Prosser (3 stations). The purpose of the laser survey is to attempt, over a period of years, to detect and monitor potential aseismic movement across known structures in the Pasco Basin and vicinity, through relative changes in survey line lengths.

Structural Geologic Setting

The objective of this subactivity is to characterize the structural setting of the Cold Creek syncline and surrounding area. A structural analysis of the Yakima fold system and the completion of six RRL holes were the major input during this quarter.

Structural analysis of selected localities within the Yakima fold system was completed. The analyses show that relatively little deformation, other than tectonic jointing, has taken place in the anticlinal crests and that little-to-no deformation has occurred in the synclinal troughs. The gently dipping limbs of the anticlines contain widely disseminated shear along small conjugate faults, whereas the steeply inclined flow layers contain the most extensive faulting and brecciation.

The overall consistency of these strain features between the areas studied suggests a similar strain distribution should be found within the Cold Creek syncline subsurface. Anticlinal crests should show little deformation other than steeply inclined tectonic jointing. Individual fractures of such jointing would cross flow contacts and represent possible vertical groundwater flowpaths. Because the folds are asymmetric, more extensive shearing and large reverse faults may underlie the crestal areas at depth. Within the gently dipping limbs of the anticlines, discrete shear zones or faults a few centimeters to a meter wide should be present. A recent examination of small breccia zones (see RHO-BWI-81-100 2Q) in core from boreholes within the Cold Creek syncline basalts suggests that several of these small faults have been penetrated. Such small faults can crosscut flow contacts and, on occasion, have been observed with groundwater flowing from them on Umtanum Ridge. Based on surface observations, these faults should be considered possible vertical groundwater flowpaths.

The synclinal trough areas exhibit the least strain of any part of the fold structures. The synclinal troughs observed do not display pervasive tectonic jointing or small-scale faulting related to folding.

The shallow RRL holes were completed in June 1981. Their locations are shown in Figure 8. All RRL boreholes penetrated the Hanford and Ringold Formations. All holes, except RRL-8, penetrated the Elephant Mountain flow (Table 7); RRL-8 terminated at the top of basalt (TOB) because the final objective was to install a seismometer near the basalt contact. The other RRL boreholes were drilled completely through the Elephant Mountain flow with the option of deepening through the Rattlesnake Ridge interbed and into the top of the underlying Pomona flow. Drilling to the contact between the Elephant Mountain and Rattlesnake Ridge, and possibly as deep as the contact between the Rattlesnake Ridge and the Pomona, was judged as necessary to avoid misinterpretation of erosional relief on top of the Elephant Mountain flow as structural dip.

Data from the RRL boreholes confirmed that the TOB in the western part of the Cold Creek syncline, particularly in the Cold Creek depression, has an overall dip of less than 1^o across an area of at least 18 mi^2. Data from the RRL boreholes in the western half of the A-H site also supports current interpretations, although untested, that the same low dip on the TOB exists at the level of the Umtanum flow and that the trough of the Cold Creek syncline at the TOB coincides with the trough at the Umtanum level. The average dip of the TOB in the western part of the A-H site is 0.7^o based on the RRL borehole data. Elevations of the top of the Umtanum flow, from two boreholes on the edge of the A-H site were used to project a suggested dip of 1.1^o on the Umtanum flow in the Cold Creek Valley depression. The trough of the syncline is interpreted to be the area within the A-H site that has the highest likelihood of containing undeformed, intact rock at the lowest dip.

TABLE 7. Predicted Versus Observed Stratigraphy for the RRL Boreholes. Measurements are in feet (1 ft = 0.3048 m)

Borehole	Elevation ground surface	Predicted (Observed)				
		Thickness sediment	Elevation of sediment/ basalt contact	Elephant Mountain thickness	Elevation of Elephant Mountain/ Rattlesnake Ridge contact	Completed depth
RRL-2	638	618 (603)	20 (35)	75 (83)	-55 (-48)	(1,530)
RRL-3	680	540 (509)	140 (171)	75 (117)	65 (54)	(730)
RRL-4	651	601 (582)	50 (69)	95 (60)	-45 (9)	(644)
RRL-5	645	585 (624)	60 (21)	60 (77)	0 (-56)	(701)
RRL-6	642	642 (657)	0 (-15)	75 (85)	-75 (-100)	(a)
RRL-8	805	655 (742)	150 (63)	(a)	(a)	(755)
DC-16[b]	625	614 (607)	11 (18)	90 (a)	-79 (a)	(a)

[a]Data not available.
[b]Data point replaces drilling RRL-1.

Host Rock Geometry

The objective of the Host Rock Geometry subactivity is to determine the variations in thickness and attitudes of the interior of the Umtanum flow in the Cold Creek syncline area. This is to ensure that the volume of relatively impermeable rock in the flow is adequate for siting and construction of a repository. During this quarter, a revised isopach map of the Umtanum flow was constructed (Figure 12) based on data from three new boreholes reported last quarter. This isopach also includes the addition of three stratigraphic sections in the vicinity of Priest Rapids Dam. This new data has had little impact on previous estimates of total flow thickness or thickness of flow interior in the Cold Creek syncline area.

An important part of the Host Rock Geometry subactivity is to determine variations that are likely to occur in the thickness of the flow-top breccia of the Umtanum flow. Photographs were taken of the Umtanum flow exposed along ∿300 m at Umtanum Ridge. Enlargements of these photographs have revealed that the flow-top breccia has greater thickness directly above arrays of fanning columns in the entablature. Thickness of the dense interior of the flow available to isolate the waste from the Umtanum flow top and overlying layers could thus be reduced if such features occurred in the RRL. At Umtanum Ridge these fan features have spacings which range from a few meters to ∿100 m apart. Consequently, it may be possible to avoid such features with appropriate repository layouts. Moreover, the exposure at Umtanum Ridge has an anomously thick flow top which is not the case in the RRL. The association between thickening of the flow-top breccia and fanning columns in the entablature may not be as prominent in the RRL. Nonetheless, the existence of such features cannot be ruled out and, hence, they should be explored and hydrologically tested for in an exploratory shaft test facility (ESTF).

Host Rock Lithology

The objective of the Host Rock Lithology subactivity is to characterize Grande Ronde Basalt with emphasis on the Umtanum flow. Characterization includes determining the petrography, phase chemistry and internal structures (fracture patterns) of these flows. Understanding these features of the host rock is important in assessing isolation of waste from hydrologic flow systems and in predicting long-term behavior of waste-rock interactions.

During this quarter, work continued on developing image analysis techniques to relate fracture abundance to petrographic textures of the Umtanum flow. At present, efforts are aimed at obtaining accurate petrographic data by image analysis. It is now recognized that accurate modal abundance data for glass and plagioclase are probably best obtained by point counts. Obtaining this data for the Umtanum flow is under way but will require 6 mo to 1 yr at current staffing levels. Image analysis does, however, show great promise in determining textural features of the flows, particularly for titaniferous magnetite and pyroxenes. Textural features and modal abundance, together, will provide the basis for relating fracture abundance to the petrography of the Umtanum flow.

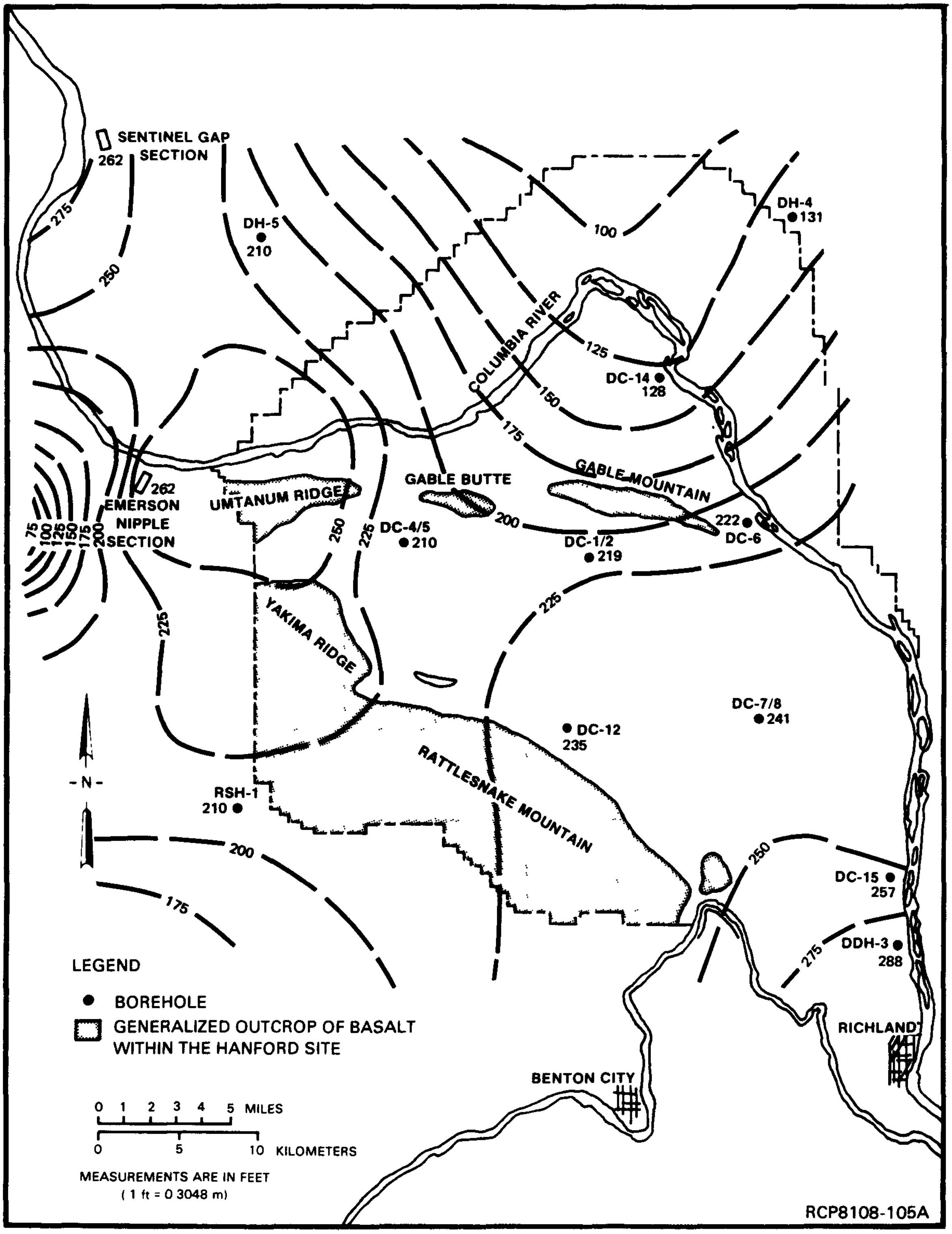

FIGURE 12. Isopach of Umtanum Flow.

Limited use of the electron microprobe facility continues due mainly to poor performance of one spectrometer. This problem is currently being given high priority by the manufacturer. Use of the energy dispersive analysis system has, however, allowed preliminary microprobe studies of the mineral constituents of the Umtanum flow. These studies have revealed that a significant proportion of the pyroxenes grains are pigeonite. The occurrence of pigeonite (low-Ca pyroxene) in Grande Ronde Basalt, and specifically in the Umtanum basalt has been previously noted[a,b], but its volumetric abundance has not been well established. These results show that up to one-third (by volume) of the pyroxenes in colonnade samples are pigeonite whereas in entablature samples, the abundance is much lower, approximately 5 to 10% of the total amount of pyroxene present. Analyses also demonstrate that pigeonite in the colonnade have more iron-rich rims than those of the coexisting augite grains. It is not yet known if these chemical characteristics of the basalt mineralogy will have a significant impact on the interactions with nuclear waste, but it is baseline data which will be important in interpreting hydrothermal waste-rock interaction experiments.

Efforts to characterize secondary minerals and alteration of basalt along fractures have also been focused on the Umtanum flow. Petrographic examination of these features shows that alteration halos around fractures are principally alteration of the glass. This indicates that the glassy mesostasis of the basalts will be the first phase to alter under thermal condition of the repository. We suggest that the clays and zeolites filling the fractures are locally derived from the glass alteration processes; further alteration in a repository is likely to produce more of these minerals which are highly sorptive. Clays and zeolites also tend to fill void space as they are formed because they represent a volume expansion relative to the glass from which they likely form.

Volume abundance of fracture-filling secondary minerals was estimated using fracture logs. These data for three Grande Ronde flows are shown in Figure 13. The significance of these data is the extremely low volume percent of secondary minerals present. This suggests that any adverse conditions that might arise from local dehydration of these minerals during or after the thermal phase of the repository will be minimal.

Host Rock Stratigraphic Setting

The objective of the Host Rock Stratigraphic Setting subactivity is to determine the stratigraphy of individual flows and sequences of flows above and below the Umtanum flow in the RRL. During this quarter, work continued on magnetostratigraphic and trace element correlations of

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[a]Price, S. M., 1977, An Evaluation of Dike-Flow Correlations Indicated by Geochemistry, Chief Joseph Swarm, Columbia River Basalt, Ph.D. Dissertation, University of Idaho, Moscow, Idaho.

[b]Noonan, A. F., K. Fredricksson, and J. Nelen, 1979, Phase Chemistry of the Umtanum Basalt, a Reference Repository Host in the Columbia Plateau, RHO-BWI-SA-77, Rockwell Hanford Operations, Richland, Washington.

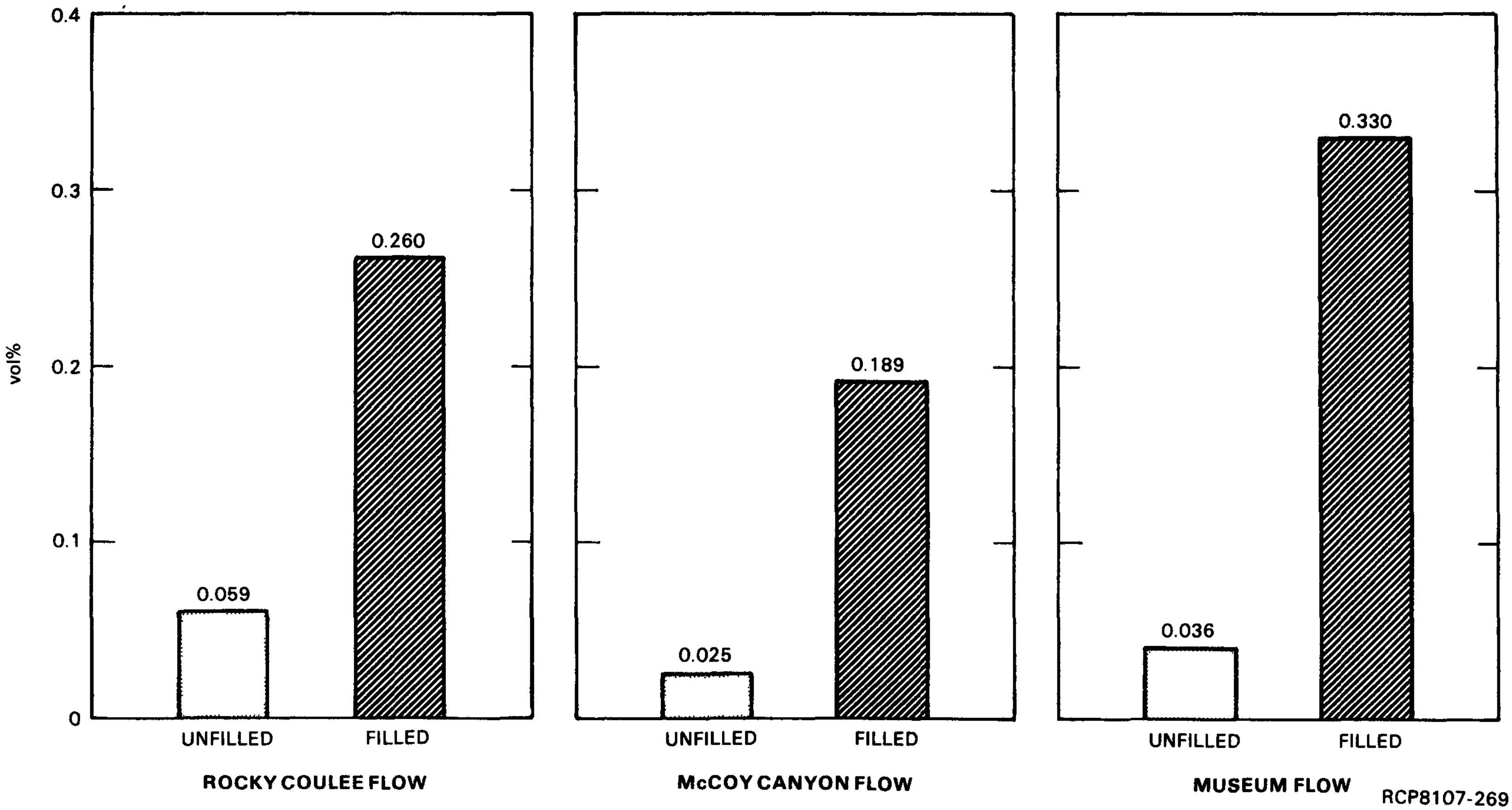

FIGURE 13. Volume Percent of Filled and Unfilled Fractures in the Rocky Coulee, McCoy Canyon, and Museum Flows. Values presented are calculated by summing fracture widths and dividing by total length of core over which the fractures occur. From these examples it appears that the maximum fracture volume (filled and unfilled) is less than 0.4 vol%.

flows. Data available to date have shown that it is possible to correlate individual flows across wide areas of the Pasco Basin. Results are shown in Figure 14, a diagram which illustrates the Grande Ronde Basalt section. It confirms the correlations presented in RHO-BWI-ST-4[a] wherein thick, laterally continuous flows are interspersed with thin commonly discontinuous flows. If the thick flows are considered to be the major hydrologic barriers, then hydrologic modeling of the Grande Ronde Basalt will require at least six layers.

Stratigraphy presented in Figure 14 is modified slightly from previous work[a,b] based on re-analysis of well cuttings from RSH-1 and data from new core holes DC-12 and -15 (Figure 12). In particular, the very high magnesium flow underlying the Umtanum flow has a more restricted distribution than previously thought; it forms a tongue-shaped lobe that was apparently emplaced from the east or southeast. Two later flows which underlie the Umtanum flow were partially impounded by the very high magnesium flow. The hydrologic significance here is that the vesicular flow edges of these flows are all in close proximity directly beneath the Umtanum flow and so may create vertical permeability greater than would normally occur across continuous basalt layers. In addition, slight topography created by these flows could have affected the intraflow structures of the Umtanum flow itself. A core hole currently being drilled will intersect the predicted location of these flow edges and so will provide a test of their location and perhaps their hydrologic properties.

Integration of Geologic Data

During this quarter, a draft of a report on the subsurface geology of the Cold Creek syncline was completed. The specific purpose of this report is to review current knowledge of stratigraphic, lithologic, and structural factors that directly relate to the suitability of the Umtanum flow within the Cold Creek syncline for use as a nuclear waste repository host rock. Major emphasis is on the structure and stratigraphy of the basalt bedrock. Chapter 1 of the report is devoted to a brief summary of the geologic setting of the Cold Creek syncline and of the status of the repository siting effort. Chapters 2 through 5 contain discussions of the stratigraphic setting of the Cold Creek syncline and lithologic properties of the Umtanum flow. The remaining three chapters, 6, 7, and 8, contain discussions of the bedrock structure of the study area. Borehole data and geophysical data pertinent to these discussions are contained in five appendices.

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[a]Myers, C. W./S. M. Price, J. A. Caggiano, M. P. Cochran, W. J. Czimer, N. J. Davidson, R. C. Edwards, K. R. Fecht, G. E. Holmes, M. G. Jones, J. R. Kunk, R. D. Landon, R. K. Ledgerwood, J. T. Lillie, P. E. Long, T. H. Mitchell, E. H. Price, S. P. Reidel, and A. M. Tallman, 1979, Geologic Studies of the Columbia Plateau, a Status Report, RHO-BWI-ST-4, Rockwell Hanford Operations, Richland, Washington.

[b]Long, P. E., R. K. Ledgerwood, C. W. Myers, S. P. Reidel, R. D. Landon, 1980, Chemical Stratigraphy of Grande Ronde Basalt, Pasco Basin, South-Central Washington, RHO-BWI-SA-32, Rockwell Hanford Operations, Richland, Washington.

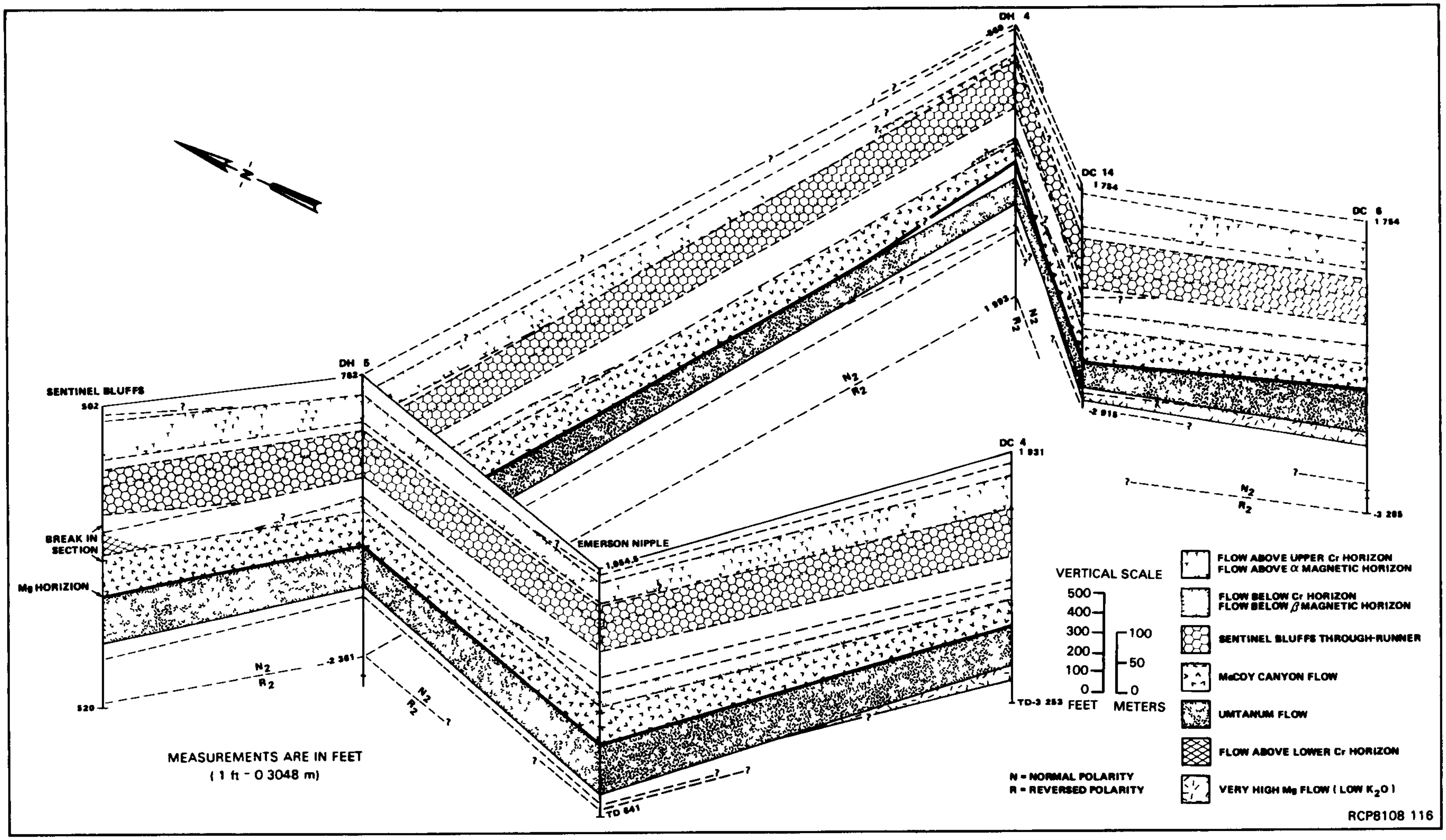

FIGURE 14. Grande Ronde Correlation.

Key interpretive maps which accompany this report include isopach maps for (1) the Wanapum and Saddle Mountains Basalts and each of the members present in the Cold Creek syncline, (2) the major sedimentary interbed units, and (3) selected flows and portions of flows, including the Umtanum of the Grande Ronde Basalt. Structure contour maps for the tops of the Grande Ronde and Wanapum formations, the top of the Columbia River basalt, and the top of the Umtanum member are also included.

All chemical analyses from core samples have been incorporated into a data base for use with the computer statistical packages. Currently the discriminant analysis package of the Statistical Analysis System is being used to evaluate the reliability of using chemical analyses alone to identify and correlate flows. This technique allows a well-characterized data base to be used to characterize other samples with respect to that data base. Probabilities of sample membership in each group of the data base are calculated, thus providing a means of evaluating the correlations.

HYDROLOGIC CHARACTERIZATION

The Hydrologic Characterization activity provides criteria and evaluation techniques for hydrologic assessment of the rate and direction of groundwater movement to the biosphere from a potential repository site. Study of the groundwater regime within the Columbia River basalt is important, since the groundwater pathway affords the most likely avenue of contact between repository-stored wastes and the biosphere and is the basis for evaluating isolation potential. Hydrologic studies have emphasized the development of a data base to characterize the groundwater system and modeling of the flow system to evaluate the potential for radionuclide transport to the biosphere. The hydrologic studies include reconnaissance regional studies over the Columbia Plateau and intensive local studies within the Pasco Basin where the Hanford Site is located.

The Hydrologic Characterization activity is divided into five subactivities:

- Hydrologic Properties
- Hydrologic Conceptual Model
- Hydrologic Numerical Model
- Groundwater Monitoring
- Integration of Hydrologic Data.

Progress was made in the first four of these subactivities during this quarter.

Hydrologic Properties

During this quarter, emphasis was focused on acquiring new downhole hydrologic parameters and hydrochemical data for groundwater horizons within new and existing boreholes in the Hanford Site. Malfunctions of some of the leased hydrologic test equipment reduced the number of geologic intervals successfully tested during this quarter.

Stratigraphic intervals and transmissivity values determined during this quarter for selected interbed and interflow zones are listed in Table 8. Four geologic intervals were hydrologically tested in boreholes now under construction: DC-12 and -15 (see Figure 15 for locations). Three additional horizons were tested at existing boreholes DC-5, -6, and -7. Transmissivity values shown in Table 8 fall within the range previously reported for these types of intraflow structures.

TABLE 8. Transmissivity Values for Selected Interflow Zones and Sedimentary Interbeds Tested Between April 1, 1981 and June 30, 1981.

Borehole number	Stratigraphic formation	Test interval (m BGS)	Transmissivity (m^2/s)
DC-5	Grande Ronde	815.6 - 1,216.2	10^{-6} - 10^{-5}
DC-6	Grande Ronde	689.5 - 730.6	10^{-7} - 10^{-6}
DC-7	Grande Ronde	1,427.7 - 1,471.3	10^{-6}
DC-12	Grande Ronde	1,018.3 - 1,240.5	10^{-4} - 10^{-3}
	Grande Ronde	1,225.6 - 1,240.5	10^{-4} - 10^{-3}
DC-15	Grande Ronde	1,006.1 - 1,040.0	10^{-7} - 10^{-6}
	Grande Ronde	1,100.6 - 1,108.3	*

*Results not available. Test data currently being analyzed.

Hydrologic data obtained from individual boreholes at Hanford indicate that hydraulic conductivity values are lower overall in the Grande Ronde Basalt in comparison to test intervals in the overlying Saddle Mountains and Wanapum Basalts. Figure 16 shows the distribution of hydraulic conductivity values for sedimentary interbeds and interflow zones (flow top) within each of the formations of the Columbia River basalt. These data are a compilation of values from several boreholes. Seven of the Saddle Mountains values are for interflow zones; the remaining are interbeds. All values reported for the Wanapum and Grande Ronde Basalts are for interflow zones except two values (10^{-6} and 10^{-7} m/s) acquired across the Vantage interbed and an adjoining interflow.

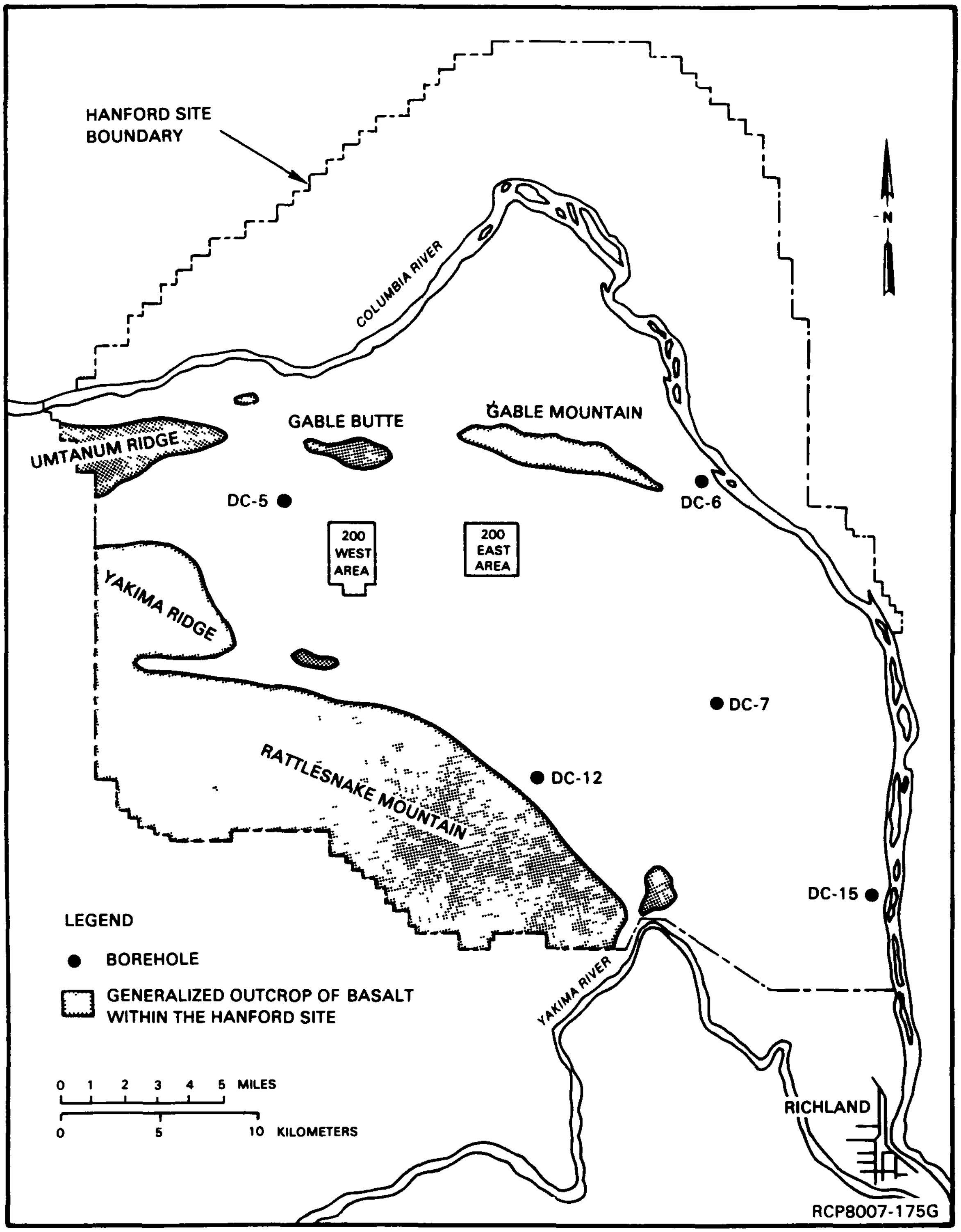

FIGURE 15. Location of Selected Boreholes on the Hanford Site.

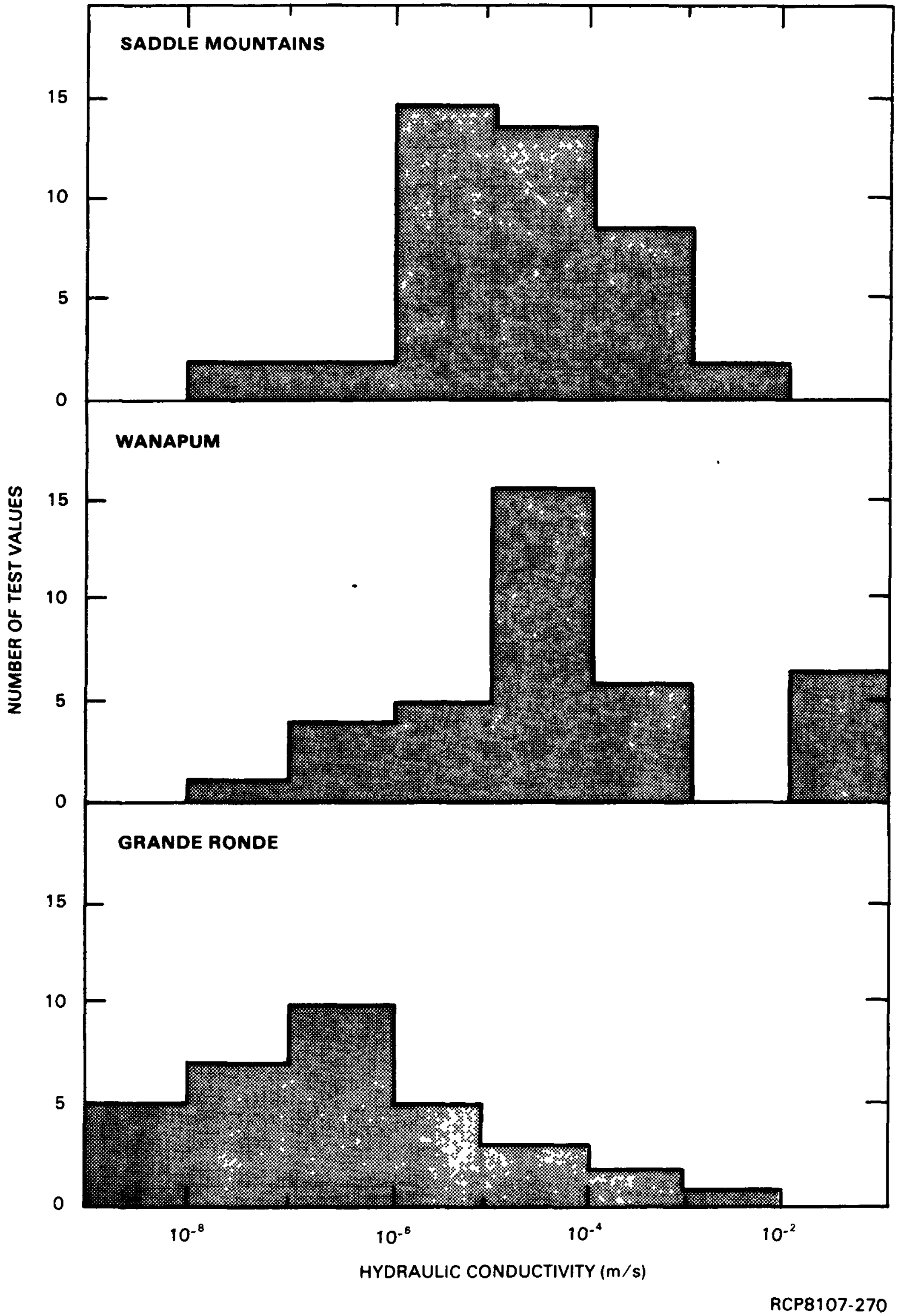

FIGURE 16. Comparison of Equivalent Hydraulic Conductivity Values.

Within the Saddle Mountains Basalt, most hydraulic conductivities range between 10^{-3} and 10^{-6} m/s with almost 70% of the values occurring between 10^{-4} and 10^{-6} m/s. Hydraulic conductivities for interflows within the Wanapum Basalt range between 10^{-1} and 10^{-7} m/s with 50% of the values reported as 10^{-4} to 10^{-5} m/s. Hydraulic conductivities for Grande Ronde interflows range between 10^{-2} and 10^{-9} m/s with two-thirds less than 10^{-6} m/s.

Evident from Figure 16 is a one-to-two order of magnitude drop in the median value of hydraulic conductivity in the Grande Ronde compared to the upper two basalt formations. This decrease is also evident when hydraulic conductivities are plotted as a function of depth at individual borehole sites. The reasons for this apparent decrease are not fully understood. Possible explanations include a decrease in fracture conductivities caused by increased secondary mineralization with depth and/or greater lithostatic pressures in zones where either higher or lower fracturing has occurred.

Hydrologic Conceptual Model

The Pasco Basin hydrometeorology study performed by the Pacific Northwest Laboratory (PNL), Richland, Washington for Rockwell in FY 1980 was revised using an interpolation routine which afforded a better data correlation than that given in the original draft. This higher level of precision was required for better areal estimation of recharge parameters. Pacific Northwest Laboratory also provided a photographic composite digital evaluation of irrigated agricultural land-use dynamics within the Columbia Plateau. This product combined digital data from classified LANDSAT scenes (for the years 1975 and 1979), terrain tapes, USGS Groundwater Site Inventory Data Base, and various maps in an effort to show the current extent, growth rate, and growth potential of irrigated agriculture within the region.

Other studies were initiated during the third quarter for the purpose of determining the magnitude and probability of flash flooding at the proposed repository site and for evaluating the economics of water resources within the Pasco Basin. The former study involves field surveys and computer simulations to evaluate the probable impacts of flooding on site operation and access. The latter study is being performed by George Leaming Associates, Marana, Arizona and is oriented toward an evaluation of factors contributing to human intrusion related to future groundwater exploitation.

Hydrologic Numerical Model

The hydrology modeling efforts currently under way are directed to studies of repository performance at three space scales: very near-field (canister to room scale), near-field (repository scale), and far-field (Pasco Basin scale). Computer modeling studies at each of these scales are being conducted to estimate pathlines, travel times, and potential nuclide migration rates. The work completed this quarter on these modeling studies is summarized below.

Very Near-Field Modeling. A computer modeling study of a typical repository room is under way and is focusing on the performance analysis of the Umtanum flow. In particular, the study is examining the mechanics of the groundwater ingress process after repository closure. Specific technical issues being addressed are:

- How long will it take for groundwater to fully saturate the room backfill?
- What is the relationship between the properties and extent of the disturbed rock zone (blast and construction damage zone) and the rate of groundwater ingress?
- Is the primary pathway through the backfill or through the disturbed rock zone?
- What are the potential nuclide release rates from the repository and how do they depend on canister longevity?

The analysis is being performed using numerical models which describe the coupled processes of stress-strain in the fractured rock mass, heat transfer through the water-rock system, and two-phase (air and water) flow in the room backfill.

Preliminary results of this study indicate that the air trapped in the pore spaces could significantly delay the groundwater ingress process. The model calculations for the isothermal case indicate that the air phase is compressed by the moisture front and then begins to dissolve in the water. For this case, the resaturation period is conservatively estimated to be ∿300 yr. Simulations for nonisothermal conditions (heat generation case) are expected to show the development of a moisture barrier as a result of higher air pressures in the pore space and high temperature gradients in the vicinity of the canister.

Hydrothermal simulations for the fully saturated case indicate a peak temperature of ∿190°C in the adjacent rock mass occurs at ∿4 yr after canister emplacement. These calculations are based on the assumption of 10-yr-old spent fuel with a power output of 1.5 W/canister; temperature contours for this case are shown in Figure 17.

Near-Field Modeling. The ongoing near-field modeling studies consist of two parallel efforts involving (1) verification and validation of the near-field numerical models and (2) parametric and sensitivity analysis for the reference repository site. In the first area, the near-field models MAGNUM and CHAINT (which are specifically applicable to flow and transport in fractured-porous media) are being tested using available theoretical models, i.e., boundary value solutions for code verification and published experimental data for model validation. Verification test cases completed to date indicate that the numerical models are capable of accurately solving the governing equations. Validation test cases for the flow model indicate that groundwater flow in discrete conduits can be

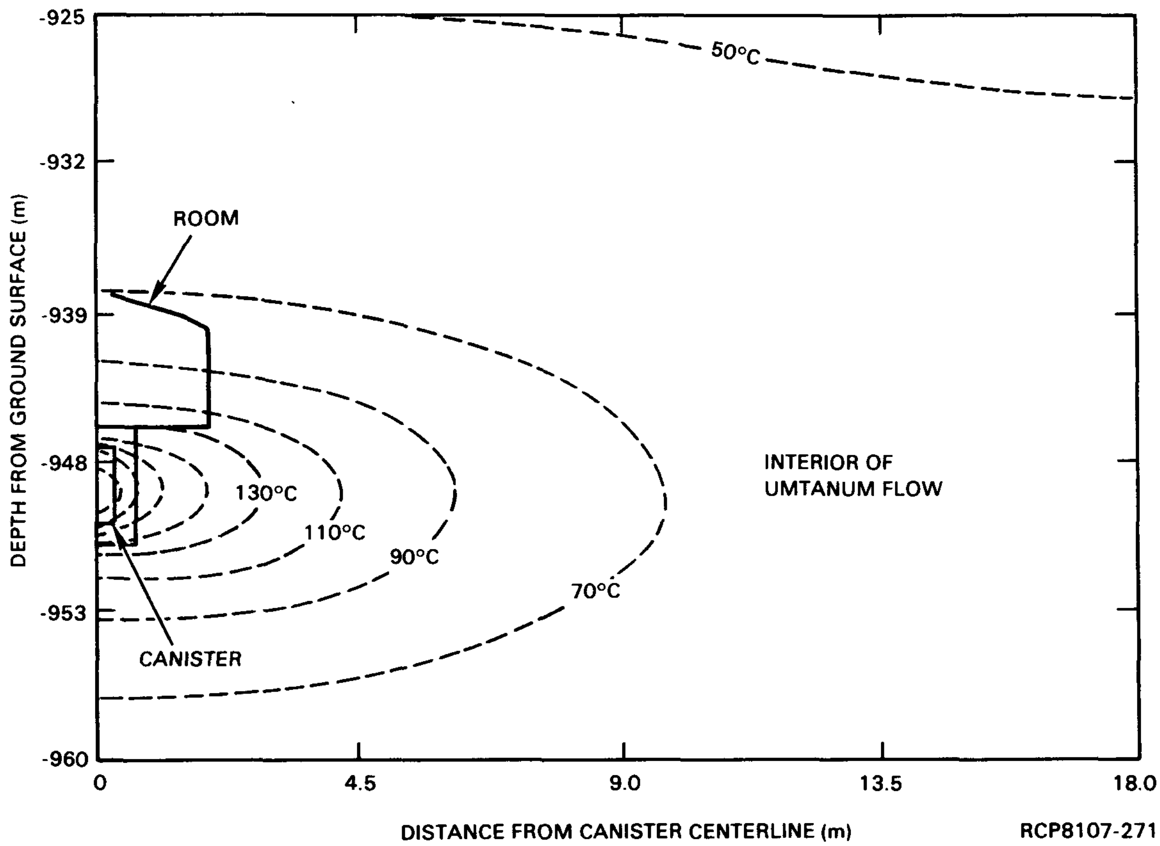

FIGURE 17. Room Scale Hydrothermal Calculations.

realistically simulated. The comparison shown in Figure 18 illustrates measured data with computer results; the results show good agreement with a maximum relative error at <3%. Validation tests are being performed using other published data for flow and transport in fractured rock; more complex tests involving coupled heat transfer and fluid flow are under way. The results of the verification and validation tests are being compiled for inclusion in a technical report which is expected to be issued this year.

Parametric and sensitivity modeling studies for the RRL (as defined by stratigraphic data for boreholes DC-4, -3, -2, and -8) are being performed to develop bounding estimates for groundwater pathlines and travel times. From simulation results compiled to date, the following observations are made with regard to sensitivity of model predictions:

- The pathline directions are most sensitive to the anisotropy ratio (ratio of vertical to horizontal permeability) and to hydraulic-head boundary conditions.

- Travel time calculations are strongly influenced by the assumed permeabilities and porosities of the interflow zones (flow tops).

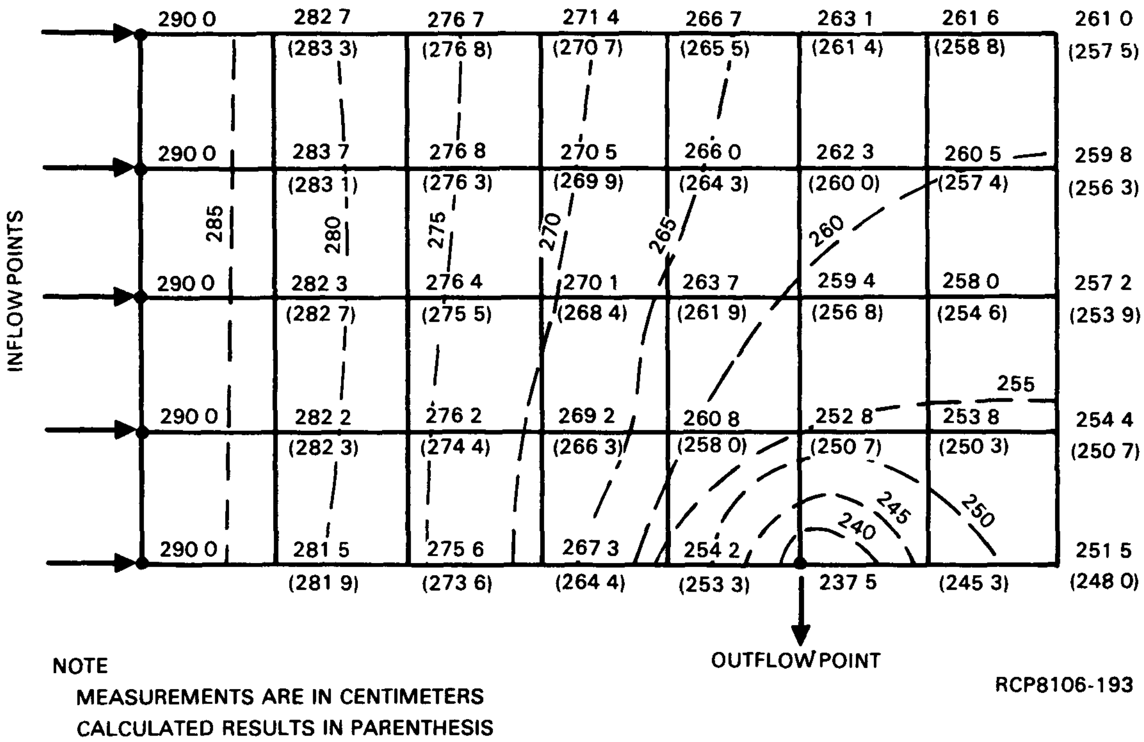

FIGURE 18. Comparison of Measured and Calculated Heads for Flow Through a Conduit Network.

Assuming representative hydraulic conductivities such as 10^{-6} m/s and 10^{-11} m/s for the flow tops and basalt layers, respectively (with the associated porosities of 0.01 and 0.001), the near-field simulations for the isothermal case indicate that pathlines are controlled by the interflows and exhibit a stair-step pattern through the near-field region; the travel times from the repository to the near-field boundary (∿5 km) range from ∿12,000 to 16,000 yr. In contrast, the simulation results for the nonisothermal case (heat generation by the waste form), the pathlines are deflected upwards through the basalts thus delaying the arrival at the system boundary; in this, the travel times range from 18,000 to 30,000 yr. Both of the cases ignore the travel time through the repository backfill which would significantly increase the travel time estimates. Sample results from these model simulations are shown in Figure 19. These results strongly suggest that the groundwater flow paths are confined to the Grande Ronde formation.

Pasco Basin Modeling (Far-Field). The Pasco Basin modeling studies consist of three efforts:

- Verification of the far-field numerical models
- Calibration of the flow model with existing borehole data
- Parametric and sensitivity analysis.

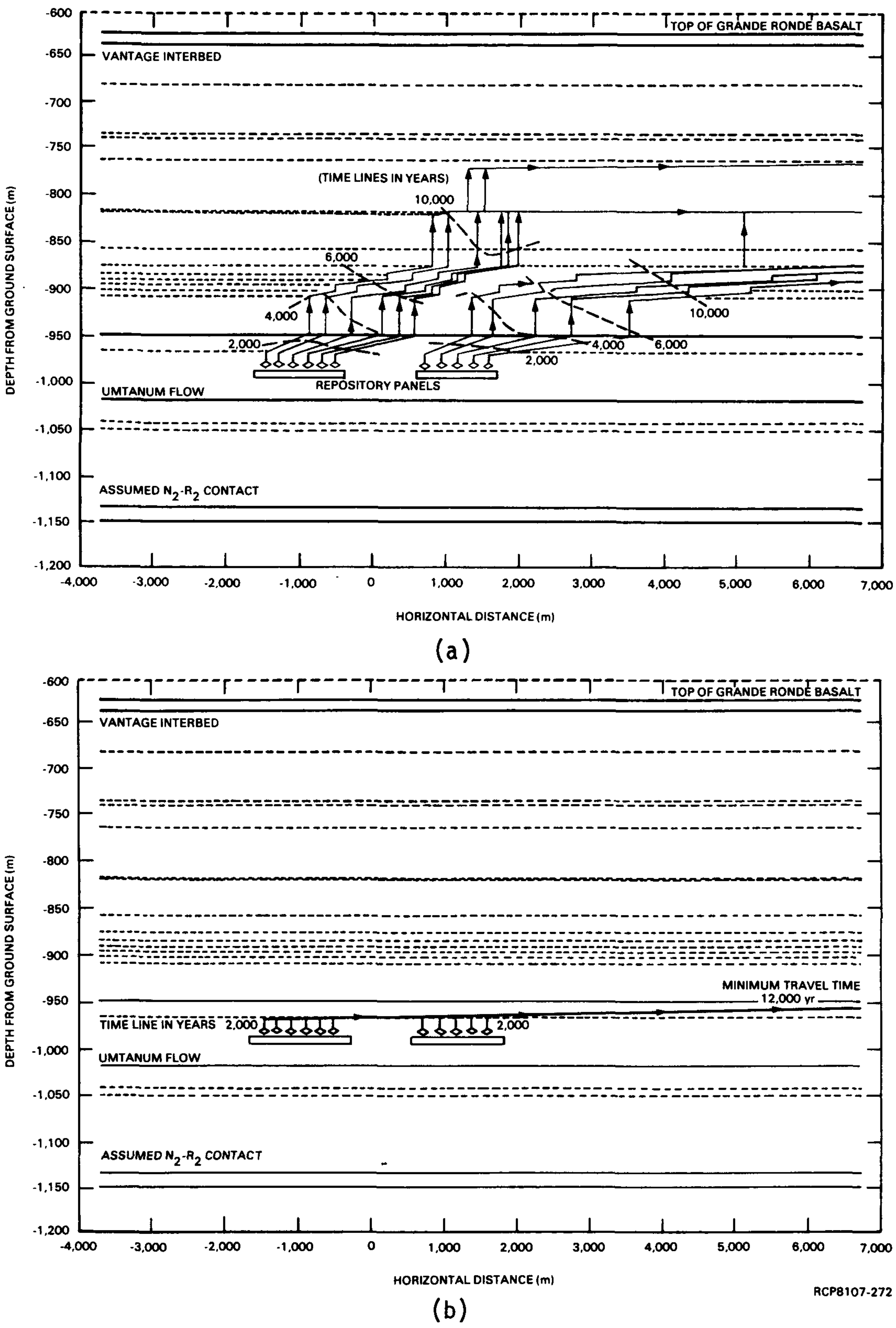

FIGURE 19. Pathline and Travel Time Calculations from Parametric and Sensitivity Modeling Studies: (a) Isothermal Conditions--Heat Generation and (b) Nonisothermal Conditions--Heat Generation.

The principal far-field groundwater flow model being used in the analysis is the MAGNUM-3D finite element model. This code is similar in structure and numerical procedures to the near-field MAGNUM model with the following exceptions:

- It is fully three-dimensional
- It is strictly porous media (single porosity)
- Only the groundwater flow equation is solved (no heat transport).

Because the MAGNUM-3D model is more traditional than the near-field models and simulates fewer physical phenomena, model verification is simpler and easier. Particular emphasis has been placed upon verification of the three-dimensional characteristics of the model. Closed form solutions to the groundwater flow equation were obtained for a series of simple one- and three-dimensional problems. The MAGNUM-3D model was used to obtain numerical solutions to these problems and the results compared to the closed form solutions. Less than 1% error was observed at every model node for the steady-state problems. When time-dependent comparisons were made, somewhat larger errors where noted at early times. This is a result of rather large time steps in the numerical model and contains the expectation that small time steps are needed at the beginning of a time dependent run.

Although the Pasco Basin modeling involves fewer physical phenomena, successful application must account for existing field measurements. The process of matching data is often called model "calibration." Emphasis during the past quarter was on model calibration. Steady-state model runs were conducted where the ratios of hydraulic conductivities were adjusted and the boundary conditions varied to reduce the difference between the model-calculated heads and heads measured in the field. The comparisons to date were performed visually using measured head data superimposed upon the model generated contour map at various horizons. The maximum difference between model calculated and field measured heads was $\sim$15 m and the average difference was $\sim$5 m. The direction of the model-calculated head gradients compared quite favorably to those indicated from the field, whereas the magnitude of the model-calculated head gradient was somewhat larger than indicated from available field measurements. Although the larger model-calculated head gradients are conservative from the standpoint of waste migration potential, improvement in the "fit" between model calculated and field-measured heads is expected as additional data become available and the level of conceptual understanding of the hydrologic system increases.

The near vertical head profiles in recently tested deep wells indicated similar vertical head profiles in the boundary conditions along the periphery of the basin. The boundary conditions are the key parameters in the head matching process (but only one of several parameters important in calculating travel times).

Streamlines and travel times have been calculated under a variety of conditions. For example, the travel time from the near field to the biosphere or model boundary was calculated by assuming that the hypothetical particle moved entirely in interflow zones. During movement along the path length the hypothetical particle stayed within the Grande Ronde Basalt. The calculated travel time along the particles' south-easterly path to the edge of the model boundary (∿64.5-km distance) exceeded 100,000 yr. In this analysis, the material properties (hydraulic conductivity and porosity) were assumed uniform for each horizontal layer and values were used which are most representative of the Cold Creek syncline.

A full sensitivity analysis of the Pasco Basin model is being initiated to estimate the consequences of uncertainty in the boundary conditions and material properties.

Hydrology modeling reports and articles issued the third quarter include:

- "Parametric and Sensitivity Analysis of Waste Isolation in a Basalt Medium," RHO-BWI-C-94
- "Analysis of Fracture Flow and Transport in the Near-Field of a Nuclear Waste Repository," RHO-BWI-SA-81
- "Numerical Modeling of Flow and Transport Processes in a Fractured-Porous Rock System," RHO-BWI-SA-113.

Groundwater Monitoring

A groundwater monitoring network and record-keeping file was initiated during the third quarter. The network consists of about 15 basalt wells within the Hanford Site. These data are expected to provide a portion of the shallow hydrologic baseline required by the U.S. Nuclear Regulatory Commission (NRC). The report on the survey of selected offsite wells, which was completed by Converse, Ward, Davis, and Dixon, Seattle, Washington, is being used as a basis for selecting possible wells outside of the Hanford Site to be used in areally expanding the baseline monitoring network.

The monitoring strategy subcontract with Brown and Caldwell Consulting Engineers, Seattle, Washington, was terminated by mutual agreement. The reason for the termination was related to the subcontractor's inability to provide a useful groundwater monitoring strategy document within the existing time frame and budget. The BWIP has, therefore, undertaken the lead in preparing the document relying also on the assistance of its currently contracted hydrology consultants.

REPOSITORY

The objectives of the Repository program are to develop the technology required for the design, construction, operation, and decommissioning of an NWRB underlying the Hanford Site and to complete the conceptual design of an NWRB.

The Repository program consists of one end function, Repository, which is divided into the following activities:

- Repository Baseline
- Repository Data Base Development
- Equipment Development
- Instrumentation Development
- Repository Seal Development
- Generic Repository Engineering
- Repository Conceptual Design
- Repository Design and Inspection
- Repository Long-Lead Procurement
- Repository Construction
- Repository Operation
- Repository Decommissioning
- Repository Monitoring
- Performance Evaluation.

During the third quarter of FY 1981, work progressed in six of these activities: Repository Baseline, Repository Data Base Development, Equipment Development, Instrumentation Development, Repository Seal Development, and Repository Conceptual Design.

REPOSITORY BASELINE

The repository baseline activity is responsible for the management of the Repository end function, specifically, the preparation and control of plans and schedules, preparation of budgets and work packages, control of program costs, and overall direction of the technical activities.

REPOSITORY DATA BASE DEVELOPMENT

Data Base Analysis

Rock Mechanics Integration Report. Preparation of the integration report continued during this quarter. In addition to the three volumes that were in preparation during the second quarter, a new fourth volume on calibration and performance of full-scale heater test instrumentation was added to the integration report series. The following are the volumes under preparation: (1) laboratory and rock mass characterization, (2) mining technology development, (3) rock mechanic modeling and analysis, and (4) calibration and performance of full-scale heater test instrumentation. Volume 1 is expected to be ready for editorial review during the next quarter. Rough drafts of Volume 2 have been completed and are now undergoing internal review. Volumes 3 and 4 are currently in preparation.

Full-Scale Heater Tests #1 and #2 Analysis. Thermal data from the first 90 d of operation of Full-Scale Heater Test #2 (FS2) were analyzed by Dames & Moore's Advanced Technology Group, Burlington, Massachusetts to evaluate the in situ thermal conductivity of basalt.

The methodology used in this analysis relies upon the similarities between conductive heat flow in a solid and the flow of fluid in a porous medium. The general equation of heat conduction can be written as:

$$\nabla \cdot (k \nabla T) = \rho c \frac{\partial T}{\partial t} + Q$$

where

k = thermal conductivity

T = the temperature

ρc = heat capacity

t = time

Q = the strength of sink (+) or source (-).

The equation for flow in a porous medium can be written as:

$$\nabla \cdot (k \nabla \phi) = S_s \frac{\partial \phi}{\partial t} + Q$$

where

k = hydraulic conductivity

S_s = specific storage

ϕ = the piezometric head

t = time

Q = the strength of sink (+) or source (-).

Using this approach, there is a direct similarity between thermal conductivity and hydraulic conductivity and between heat capacity and specific storage calculations. Methods developed in groundwater hydrology to determine hydraulic parameters were applied to determine the thermal parameters. In particular, the methodology developed for analyzing single well pump tests was applied to the analysis of the test data.

The following three methods of parameter estimation were applied to arrive at the data from the test:

- Type-curve matching method
- Jacob straight-line method
- Gauss-Newton technique.

Jacob's method was shown to be unsuitable because of the relatively short (90 d) duration of the first phase of the test. Both the type-curve matching and the Gauss-Newton method produced reliable results. The Gauss-Newton method was chosen for the final analysis because it removes the subjectivity present in the type-curve matching procedures. The average value of rock mass conductivity was calculated as $K = 1.48 \times 10^5 J/m \cdot d \cdot {}^oC$ with a standard deviation of $0.86 \times 10^5 J/m \cdot d \cdot {}^oC$. An example of best fit produced by Gauss-Newton optimization for a thermocouple response in FS2 is shown in Figure 20.

The results were compared with earlier laboratory investigations of thermal conductivity, by Foundation Sciences, Inc. (FSI)[a] and Erickson and Krupka[b]. The results of the present analysis lie between those of FSI and Erickson and Krupka. It is concluded that the results of the in situ thermal conductivity analysis from the FS2 agree well with laboratory results and give values representative of basalt in the temperature range of 15^o to 160^oC.

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[a]Foundation Sciences, Inc., 1980, Thermal Mechanical Properties of Pomona Member Basalt--Full Scale Heater Test #1 (Area I), RHO-BWI-C-77, Rockwell Hanford Operations, Richland, Washington.

[b]Erickson, R. L. and K. M. Krupka, 1980, Thermal Property Measurements of Pomona Basalt from Core Holes D-85 and DB-15, Hanford Site, Southeastern Washington, RHO-BWI-C-76, Rockwell Hanford Operations, Richland, Washington.

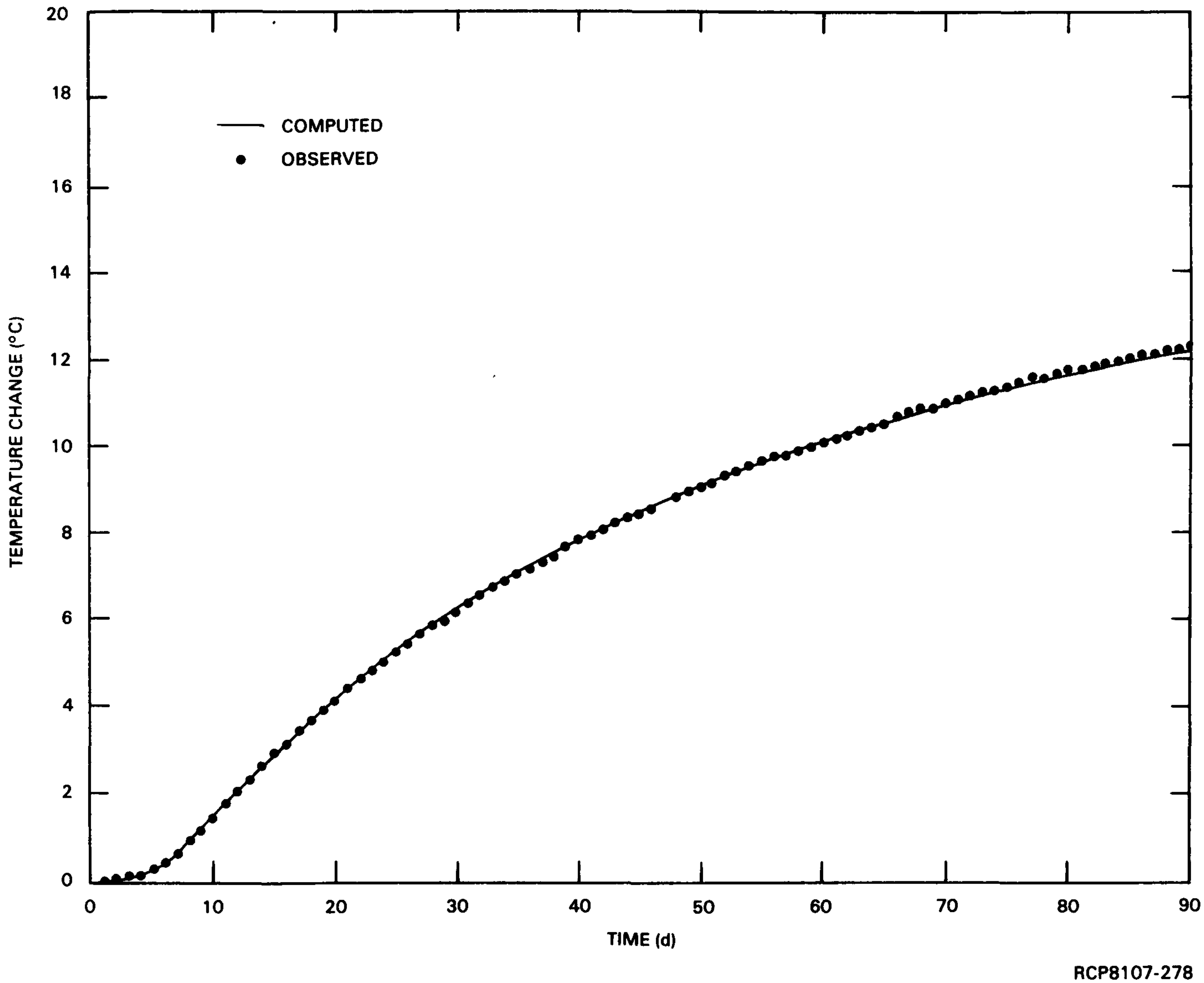

FIGURE 20. Best Fit Produced by Gauss-Newton Optimization for Thermocouple 2T06T03.

Model Development

The Rock Mechanics and Mining Technology (RMMT) Group is currently in the process of analyzing the test data from Full-Scale Heater Test #1 (FS1) and FS2. Table 9 presents typical thermal data from the full-scale electric heater test and several predicted temperatures.

TABLE 9. Actual and Predicted Basalt Temperatures at Selected Locations 83 d into Full-Scale Heater Test #2.

Location*	Temperatures (°C)			
		Predicted		
	Actual	DAMSWELL (original data)	HEATING5 (updated data)	HEATING5 (original data)
1. 1.5 m above the center plane of the heater	49.8	48.2	41.2	45.8
2. At the center plane of the heater	70.0	78.6	68.7	80.6
3. 1.5 m below the center plane of the heater	40.2	43.1	37.9	42.9

*All points are 0.4 m from the centerline of the heater in a radial direction.

The original predicted data was provided by the Dames & Moore's Advanced Technology Group[a] and was modeled using DAMSWELL[b], a finite element code. Rockwell has conducted additional analyses since test startup, using the finite difference code, HEATING5. The Rockwell analysis has used updated values of the specific heat, the thermal conductivity, and the heat transfer coefficient from basalt to air, which were not available at the time of the original modeling. In addition, some specific changes were made in the model configuration to correct for actual test conditions. The original model, for example, included an air gap between the bottom of the heater and the bottom of the borehole. The Rockwell model provides for direct heater/rock contact and vertical heat conduction at the heater base.

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[a]Hocking, G., J. R. Williams, P. Boonlualohr, I. Mathews, and G. Mustoe, 1981, Numerical Prediction of Basalt Response for NSTF Heater Tests #1 and #2, RHO-BWI-C-86, Rockwell Hanford Operations, Richland Washington.

[b]Boonlualohr, P., G. Mustoe, and J. Williams, 1980, Program DAMSWELL Programming Manual, Code Verification, Program Listing, RHO-BWI-C-74, Rockwell Hanford Operations, Richland, Washington.

A modeling run, using the Rockwell model and the original thermal property data was made and is also shown in Table 9. Model runs using the original model and the updated parameters are currently being performed.

The results presented in this modeling analysis are preliminary and will be reported in final form during the next quarter. This preliminary analysis indicates that it is possible to get agreement between actual and predicted basalt temperatures through numerical modeling. It also highlights the need for accurate determination of site specific basalt properties as input to the modeling process.

Laboratory Tests

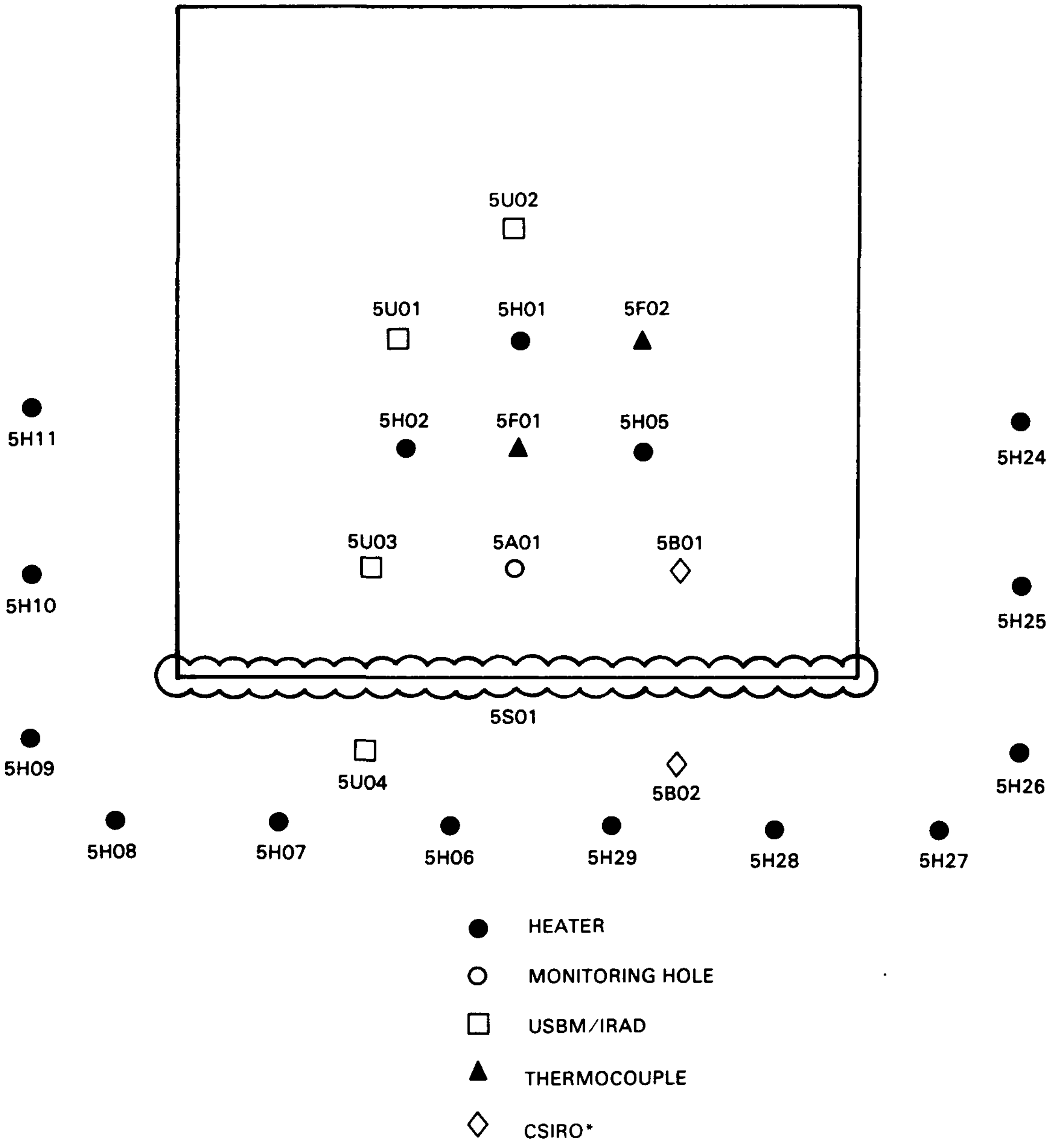
The testing program to characterize core from the Jointed Block Test #1 (BT1) area was completed, and comparisons with the present data base were completed. Preliminary results from the analysis indicate that wave velocities, rock strengths, bulk density, grain density, and thermal conductivity values are less than average values observed to date. An apparent porosity that is four times higher than average also adds to the general conclusion that the core, and thus the rock mass in the BT1 area is more fractured than in the previous areas.

The preparations for the Rock Mechanics Laboratory facility are nearing completion with only minor checklist items remaining to be completed. Negotiations with MTS Systems Corporation of Minneapolis, Minnesota are in progress for the compression testing machine. An award is expected in July 1981. Remaining equipment is being ordered, and a tentative laboratory startup date for full operations has been set for April 1, 1982.

Field Tests

Modified Goodman Jack Tests. These tests are designed to measure the in situ deformation modulus and the in situ stress state. The tests were originally performed near the FS2. The results were unsatisfactory. Additional tests were conducted in the following Phase II boreholes at depths to 7 m: 10M02, 10M04, 10M01, 10E03, 10E04. Tests were also performed at depths to 10 m in 10E03 and 10E04 and to 6 m in 8M04, 8M02, and 8M03. Test locations were selected after rock core examination and visual inspection of the borehole walls with a borescope.

Block Test. Block Test #1 consists of a cube of basalt (∿2 m on a side and 4.5 m deep) located in a tunnel wall. It will be heated by electric heaters and confined by hydraulic flat jacks that will simulate the pressures of a deep underground repository environment. Testing will be conducted in two steps: In the first step, only one of the four slots surrounding the test cube is excavated. Heaters, rock instruments, and flat jacks are installed in the configuration shown in Figure 21 for Step 1. A series of temperature and pressurization cycles will be conducted to determine the rock response to uniaxial pressures up to 7.5 MPa and temperatures up to 100°C.



*COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

NOTE: EACH INSTRUMENT AND HEATER SHOWN CONTAINS A THERMOCOUPLE RCP8105-159

FIGURE 21. Step 1--Slot and Instrument Locations.

Step 2 commences with the completion of the remaining three slots and installation of the flat jacks and rock instruments. Pressure cycles up to 20 MPa and temperature cycles up to 200°C will be conducted to determine biaxial rock deformation, thermal conductivity, thermal expansion coefficient, and stress distribution and magnitude.

During this quarter, stress relaxation measurements were made on the block after the initial lower slot was drilled. The flat jacks were then installed in the slot, and the remaining support equipment for Step 1 tests was activated.

The cancellation pressure in Step 1 of the test was established as 2.2 MPa. Following the cancellation measurement, the block was subjected to two pressure cycles, 5 and 7.5 MPa. After completing the initial pressure cycles at ambient temperature, the heaters were started for thermal conductivity measurements and subsequent pressurization tests.

Data Verification (FS1 and FS2)

Validation and verification of data received from the full-scale heater tests continued in accordance with the Data Verification Plan. This effort includes evaluation of instrument performance and conversion algorithms and compilation of data for test analyses. During this reporting period, a test data package from heater startup through March 29, 1981 was assembled and transmitted to Dames & Moore for analysis. Preparation of a comprehensive report describing the performance, calibration, and operation of the rock instrumentation was initiated.

Temperature Measurements. The maximum scheduled heater power levels, achieved on February 12, 1981, have been maintained throughout the quarter. The next scheduled change is a reduction in peripheral heater power level (FS1) on August 25, 1981. The basalt rock surrounding the heaters continues to increase in temperature at a constant rate. A temperature rise of 50°C (FS1) and 20°C (FS2) at 0.5 m into the rock was observed during this reporting period.

Temperatures along the horizontal midplane on June 15, 1981 are presented for FS1 and FS2 in Figures 22 and 23. The midplane in each case is ∿4.25 m below the test room floor. Due to the presence of the peripheral heaters, a larger volume of rock is being heated to higher temperatures in FS1 than in FS2.

Temperature histories of three thermocouple locations in FS1 and FS2 are presented in Figures 24 and 25, respectively. The horizontal midplane temperatures for the heater liner, 0.5 m and 1.5 m into the rock, are shown. In Figure 24 the thermocouple located at 1.5 m from the heater centerline shows a decrease in temperature due to moisture effects. A thermal analysis of data from both tests from startup through March 29, 1981 (270 d) is in progress.

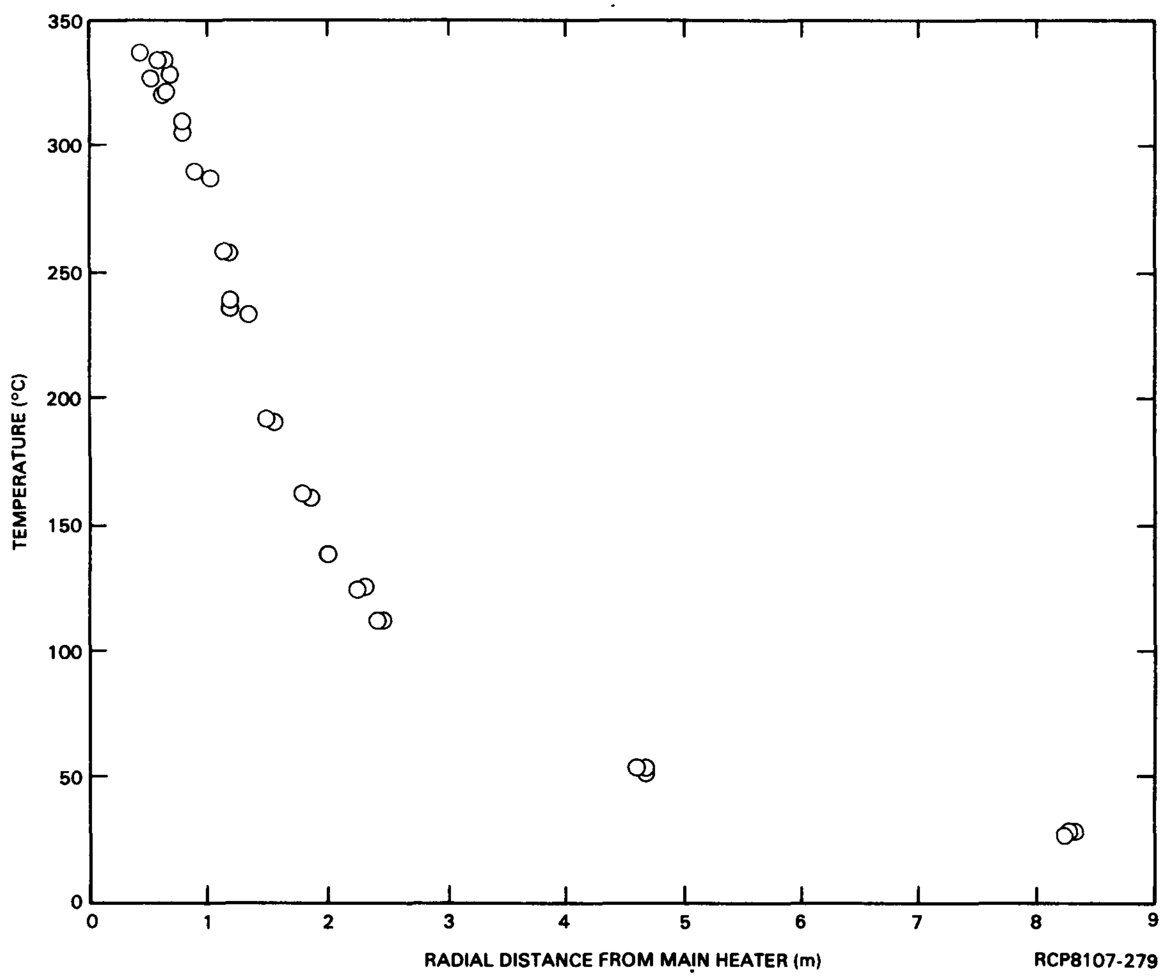


FIGURE 22. Full-Scale Heater Test #1 Horizontal Midplane Temperature Profile, June 15, 1981.

Investigations on the 100°C or steaming phenomenon continued during the quarter. The output of the thermocouples subject to steaming is lowered by the presence of moisture. As the heater power levels are raised and the thermal field increased in magnitude, water migrates away from the heat source and fewer thermocouples are affected by moisture. During this reporting period the number of thermocouples showing moisture effects was reduced from five to one in FS1 and from four to three in FS2. All of the remaining thermocouples (156 in FS1 and 208 in FS2) are producing valid data indicative of rock temperature.

<u>Borehole Deformation Gauge (USBM)</u>. The performance status of the U.S. Bureau of Mines' (USBM) gauges in FS1 and FS2 is shown in Table 10. A comparison with the status reported in the RHO-BWI-81-100 2Q indicates a significant change in the number of suspect gauges. The zero offset measurements and calibration tests which were performed during this reporting period reduced the "suspect" category and increased the "acceptable" or "inoperative" categories. As shown in Table 10, the percentage of acceptable USBM gauges is currently 75% for FS1 and 38% for FS2.

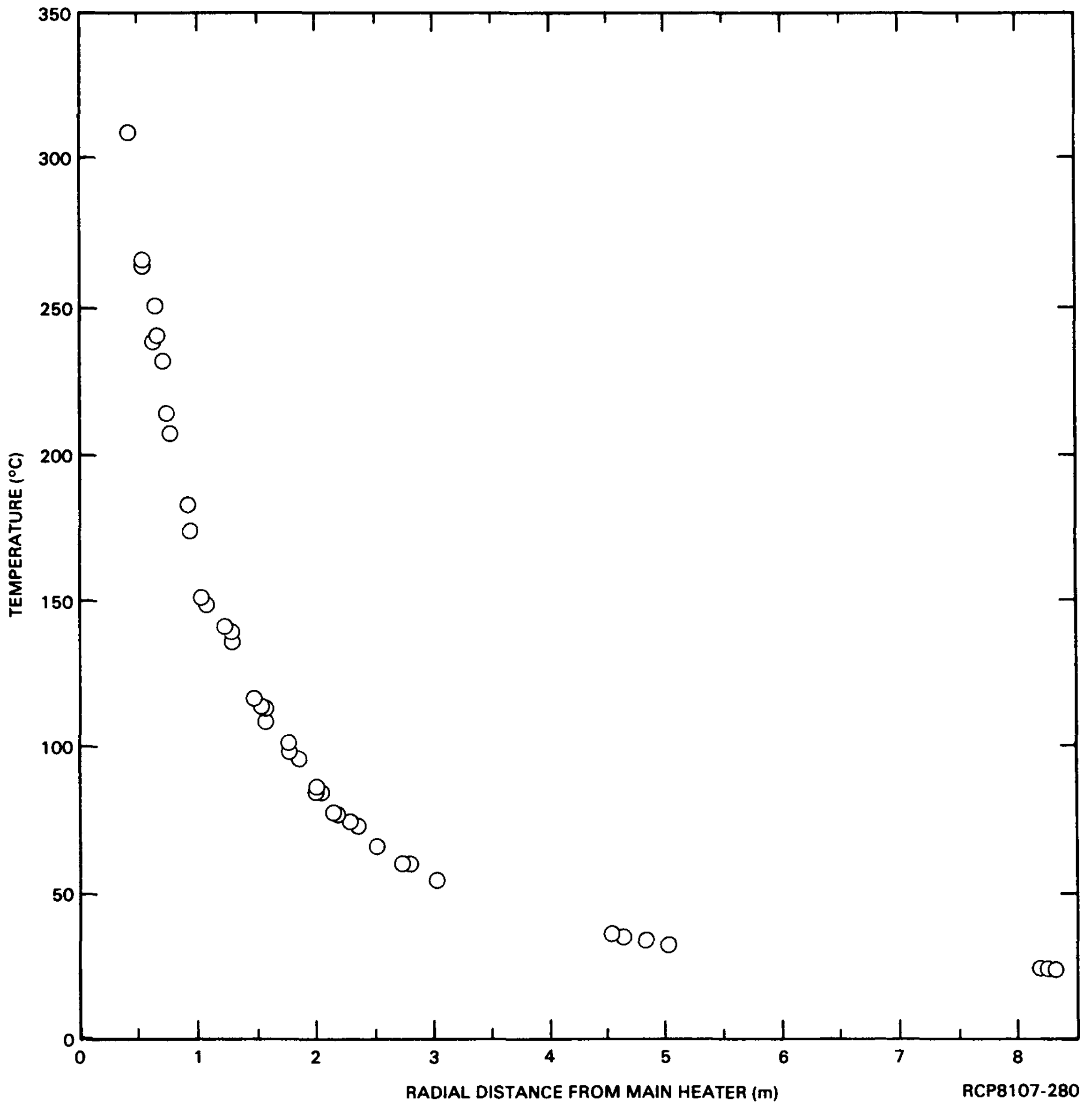


FIGURE 23. Full-Scale Heater Test #2 Horizontal Midplane Temperature Profile, June 15, 1981.

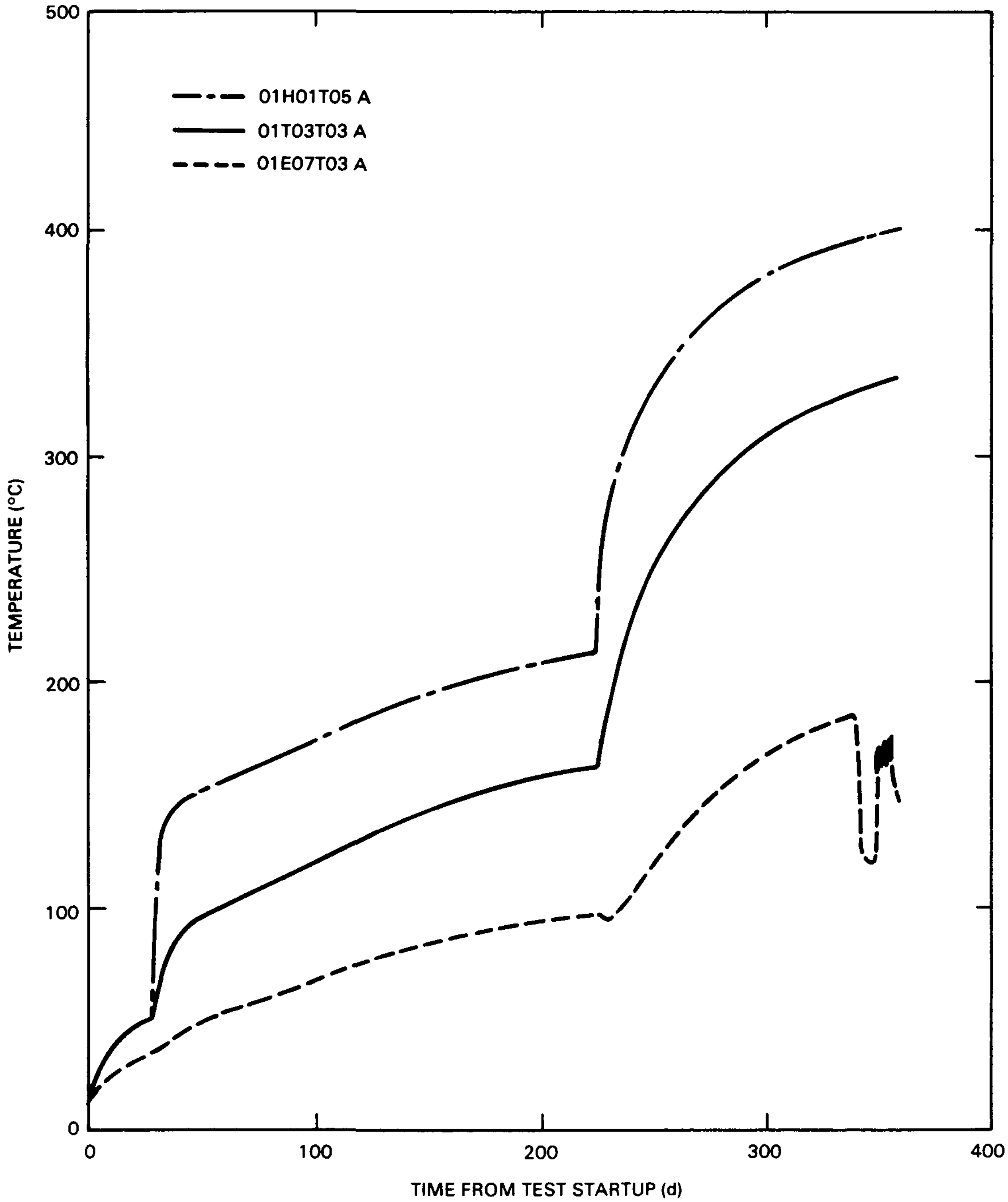


FIGURE 24. Full-Scale Heater Test #1 Selected Horizontal Midplane Temperature Histories.

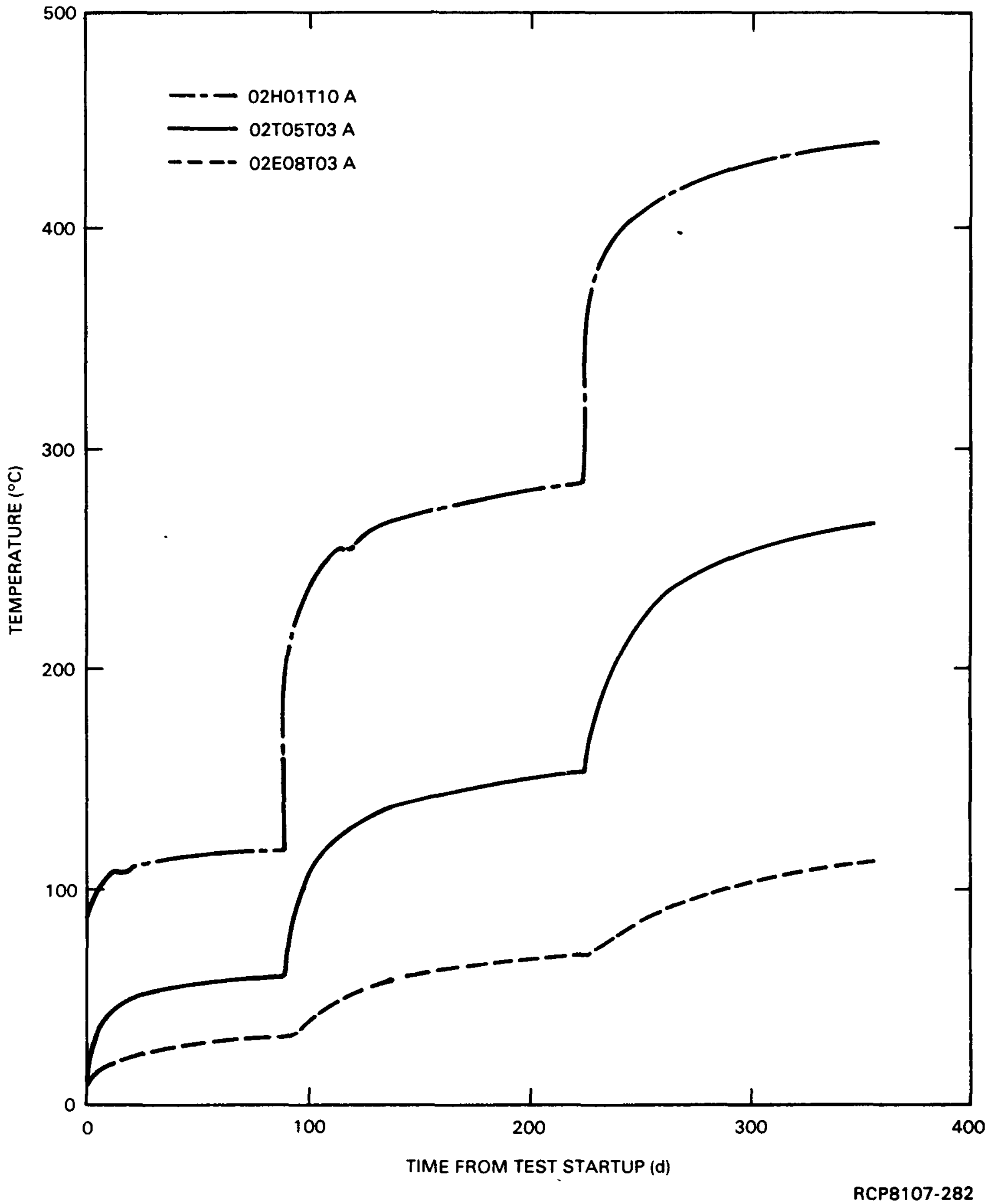


FIGURE 25. Full-Scale Heater Test #2 Selected Horizontal Midplane Temperature Histories.

TABLE 10. USBM Gauge Performance Status (June 1981).

Data status	Performance status	FS1		FS2		Combined	
		Number	Percent	Number	Percent	Number	Percent
Valid	Acceptable[a]	9	75	6	38	15	53
Question-able	Suspect[b]	0	0	5	31	5	18
Invalid	Replacement required[c]	3	25	5	31	8	29
Total		12	100	16	100	28	100

[a]Performing satisfactorily.
[b]Erratic behavior, large change in output, or trend reversal.
[c]Out-of-limits or extreme values, long-term erratic behavior.

One of the major factors affecting the output from USBM gauges in a high-temperature environment is the thermal expansion of the gauge body. The expansion of the gauge must be factored into the borehole deformation measurement to arrive at the true borehole deformation. Subsequently, the stress conversion algorithm must reflect this correction. During this reporting period, five USBM gauges were removed, allowed to cool to ambient temperature, and then reinstalled in the boreholes. During the short (3 to 4 hr) heatup period, no significant borehole deformation occurs; therefore, any change in gauge output can be attributed to gauge body expansion. Using the test temperatures, gauge body expansion was also calculated. The agreement between calculated and measured values for all gauges was $\sim$4%. The USBM displacement conversion algorithms were then revised and all test data recomputed. The results were significant. In many cases the correction exceeded the previously computed displacements, and trend reversals were noted. A revision to the stress conversion algorithm is in progress.

A performance analysis was completed during this quarter on a malfunctioning USBM gauge retrieved from the full-scale heater tests. Brewer Engineering Laboratories conducted a series of laboratory tests and made recommendations to improve gauge operability and to further characterize gauge response to the test environment. The results indicated that moisture infiltration was the main cause of failure. Long-term stability was found to be dependent on the amount of cantilever strain and is not necessarily characterizable. As a result of these studies, the USBM gauge calibration testing program has been revised. In the future, all gauges will be tested at ambient and elevated temperatures, and the new test design will incorporate corrections for thermal expansion of gauge body into the sensitivity factor.

Vibrating Wire Stressmeter (VWS) Performance (IRAD Gauge). A representative performance status of the stressmeters for FS1 and FS2 as of June 30, 1981 is shown in Table 11. The gauge performance has been categorized as follows:

- Gauges yielding valid data are producing consistent data trends.
- Gauges are considered to be producing questionable data when a wide range of readings are obtained over a short time frame, when 50% of the data are unobtainable, or when data logger scanner problems exist.
- Gauges which are producing no usable data at this time.

TABLE 11. VWS Gauge Performance Status (June 1981).

Data status	Performance status	FS1		FS2		Combined	
		Number	Percent	Number	Percent	Number	Percent
Valid	Acceptable	2	11	10	45	12	30
Questionable	Suspect	3	17	5	23	8	20
Invalid	Replacement required	13	72	7	32	20	50
Total		18	100	22	100	40	100

A calibration program has been instituted to further characterize the VWS (IRAD gauge) responses. A valid VWS conversion algorithm will not be available until the completion of the current calibration program.

Multiple-Position Borehole Extensometer (MPBX) Performance. The status of the MPBX instruments remains unchanged from the last quarter. All gauges are operating satisfactorily. The total of failed anchor systems remains at ~80% for FS1 and 30% for FS2. A test has been devised to check the holding ability of unpressurized anchors during the upcoming FS2 cool-down period. No anchor slippage has been detected to date. Stick-slip and manual measurement tests were conducted on these instruments during the quarter as part of the instrumentation verification program.

One characteristic associated with extensometer data is the "stick-slip" phenomenon; that is, restricted movement due to the frictional interference in the extensometer assembly or in the fractures and joints in the rock mass. Instrument-related problems can be detected and reduced by tapping the head with a mallet (dithering) to relieve the friction forces at the extensometer head. A test was conducted this quarter on selected gauges to determine if this problem exists. A statistical analysis of the test results was conducted.

As part of the instrument calibration and verification program, a series of manual measurements of anchor rod movement was conducted and compared with the electronic measurements of the rod movement. Differences between the manual and electronic readings were generally small and within the statistical error of the experiment although about one-third of the instruments showed some discrepancy in the data comparisons. These differences may be due to a change in sensitivity factors or to zero-offset drift. These measurements will be repeated on selected extensometers prior to the upcoming 30-d cool down on FS2. Instrument recalibration will be performed if necessary.

Data Evaluation. Measured extensometer displacements are a function of both movement of the anchor and movement of the rock mass at the borehole collar. Because of uncertainties as to the absolute movement of the extensometer heads at the test tunnel floor or into the extensometer room, vector analysis and precision survey methods were used for data evaluation.

Differential displacement vectors representing movements between two anchors for an FS1 vertical plane are shown in Figure 26. Reference anchors are located close to the heater centerline where movement along the borehole axis would theoretically be small relative to other anchors of a given extensometer. For comparison, three measured and predicted displacements were selected which would represent the three increased power-level stages of the test. Measured displacements compare favorably with predictions. Predicted displacements exceed measured displacements by ∿10%.

Figure 27 compares extensometer data with the results from the precision survey of the test tunnel floor. Multiple-Position Borehole Extensometer data are from an anchor located along the horizontal heater midplane. Relative displacements are movements measured between the anchor and the borehole collar. The precision survey target is located near the MPBX head. In general, comparisons between the extensometers and precision survey data are in reasonable agreement. These findings support the use of reference anchors located along the heater midplanes as indicators of tunnel floor movement. The test tunnel floor has moved ∿1 to 2 mm to date (after 1 yr of test operation); the extensometer room side wall has shown no significant displacement. Tape extensometer anchor points have been installed in the test pad to provide additional measurements of floor movement.

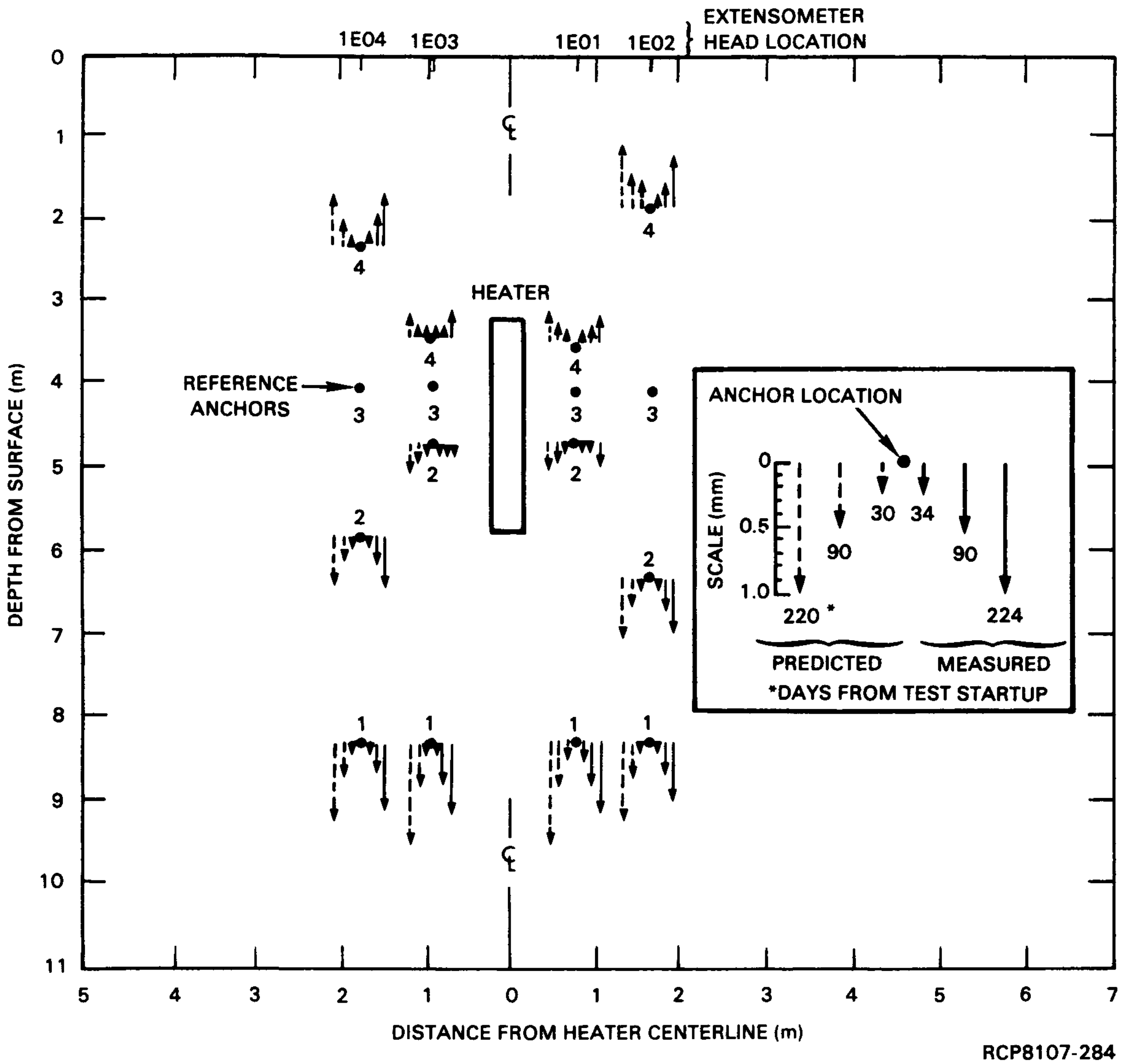


FIGURE 26. Full-Scale Heater Test #1 Extensometer Displacement Vectors Representing Movements Between Two Anchors in a Vertical Plane.

EQUIPMENT DEVELOPMENT

An excavation technology development plan is being prepared to evaluate available excavation technologies and developments necessary to construct a repository. This study will include shaft sinking, mining excavation, and mine service systems. A draft report on rock mechanics aspects of excavation technology development was completed by KE/PB. The technological needs identified in this report will be incorporated in the Equipment Development Plan.

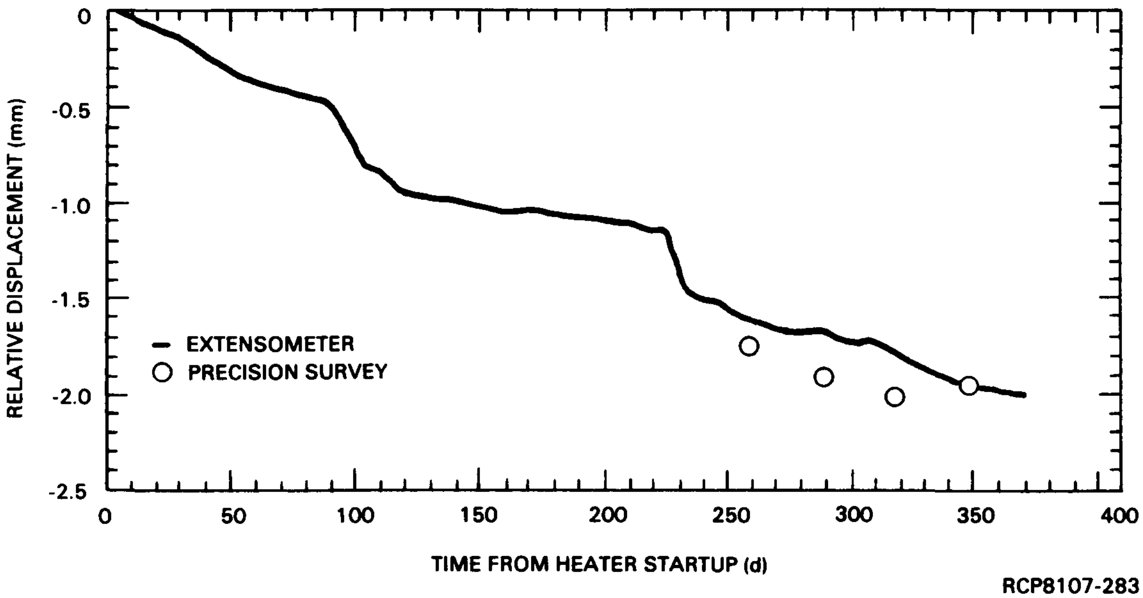


FIGURE 27. Comparison Between Extensometer Data and Precision Survey Results.

INSTRUMENTATION DEVELOPMENT

Work was initiated during the quarter to develop a rock instrumentation development plan. The development plan will address rock instrumentation for development design, construction, operation, and decommissioning phases of the repository. The plan will identify available instrumentation and technologies and associated improvement or development work (if needed) that will be necessary for repository use. A complete and detailed instrument calibration plan will be part of the development plan. The development plan will include all in situ test instruments and repository instruments.

As an addition to this effort, this instrumentation activity will also address the need of other BWIP activities requiring instrumentation. A plan of action for preparing a unified BWIP instrumentation development program plan has been prepared and is being implemented.

REPOSITORY SEAL DEVELOPMENT

The repository seal development objective is to develop seal systems for boreholes, shafts, tunnels, and room backfill. Several seal material types and configurations are being considered.

The Shallow Borehole Plugging Test (SBPT) Plan, completed last quarter and discussed in RHO-BWI-81-100 2Q, is being deferred to FY 1984 with a reassignment of seal design responsibilities from the BWIP to ONI. Certain site-specific SBPT objectives will be redeveloped subsequent to ONI issuing seal designs which require permeability and mechanical property verification. Testing will also be necessary to verify proposed emplacement machinery and techniques, and further to evaluate and develop plug in situ testing instrumentation.

Internal documents reporting silicate grout feasibility and host rock fracturing were completed. The silicate grout document focuses on calcium-silicate hydrate grouts that are insoluble at high pH and temperature. It states that one-shot grouting to produce calcium-silicate hydrates, if possible, would probably assure more complete grout penetration and result in more compositionally uniform products than two-shot grouting. The host rock fracturing document considers the scope of exploratory shaft construction recommendations. It concludes that machine boring, early support and post-grouting can most effectively limit disturbance, but quantification of the effects of these measures on permeability changes in the disturbed rock is required.

REPOSITORY CONCEPTUAL DESIGN

Repository conceptual design work by KE/PB continued during this quarter. Efforts were directed toward completion of conceptual design drawings and preparing narrative for the conceptual systems design description and the conceptual design reports. The conceptual design drawings are 98.6% complete.

REGULATORY AND INSTITUTIONAL

The objectives of the Regulatory and Institutional (R&I) program are to establish requirements for all BWIP work as needed to comply with the requirements identified in regulations and laws pertaining to all aspects of siting, construction, operation, and decommissioning of an NWRB; monitor the development of regulations that apply to the licensing of a nuclear waste repository; and coordinate the BWIP licensing documentation.

The R&I program is composed of one end function, R&I, which involves four areas:

- Regulatory Baseline
- Licensing Applications
- National Enviornmental Policy Act (NEPA) Documents
- Communications and Institutional Liaison.

During the third quarter of FY 1981, work progressed in all of these areas.

REGULATORY BASELINE

The Regulatory Baseline activity covers the development of the regulatory data and planning baseline and the constant updating required to ensure authenticity, traceability, and consistency of requirements, and to provide appropriate confidence that the BWIP meet all pertinent legal requirements for an NWRB. During this quarter, the NRC response to DOE proposed changes to 10 CFR 60 (Technical Rule) was reviewed. The NRC incorporated many of the DOE comments but retained the controversial 1,000-yr canister integrity requirement. Also, the R&I End Function Technical Plan was approved on May 9, 1981. The plan describes the logic by which the BWIP will support the DOE in the repository licensing process.

LICENSING APPLICATIONS

Licensing activities involve compliance with the permit and licensing procedures of the NRC and other agencies with jurisdiction over radioactive waste disposal. Activities during this quarter consisted of:

- The NWTS program workshop to discuss preparation of Site Characterization Reports (SCRs) was held in Seattle, Washington in early June 1981. A major conclusion of the workshop was that the format for preparing the SCR will be a modified version of the NRC Regulatory Guide GS-027-4 (draft).

- Preparation of the BWIP SCR was initiated in June 1981 after the SCR workshop in Seattle, Washington. Personnel assignments and preparation schedules have been completed and a management review team has been established for the SCR.

- The report on preliminary risk assessment results for a nuclear waste repository in basalt (draft) was received from Los Alamos Technical Associates (LATA). The document was reviewed by the BWIP and the review comments were incorporated by LATA. The BWIP is conducting a final editorial and technical review.

NEPA DOCUMENTS

This activity presents BWIP data and information related to compliance with the NEPA by documenting the decision-making process and the potential impacts of major program activities in the BWIP. During this quarter, an environmental evaluation to support drilling of borehole DC-21 was approved and transmitted to DOE-RL on May 26, 1981. In addition, the format and the schedule for an Environmental Assessment (EA) to support the SCR were prepared.

COMMUNICATIONS AND INSTITUTIONAL LIAISON

This activity encompasses the day-to-day coordination with the DOE/NWTS program on licensing matters, the planning and implementation of state and local government coordination plans, as well as day-to-day and periodic public-information services. On June 11-13, 1981, technical presentations were made to the Waste Isolation Systems Panel of the National Academy of Sciences (NAS) in Richland, Washington. The last day of the NAS visit was devoted to a tour of the NSTF and a geology field trip to Umtanum Ridge.

TEST FACILITIES

The objective of the Test Facilities program is to provide for the design, construction, and operation of test facilities in support of the technology development needs of the BWIP. The Test Facilities program is divided into four end functions:

- Near-Surface Test Facility Phase I
- Near-Surface Test Facility Phase II
- Support Facilities
- Decommissioning.

During the third quarter of FY 1981, work progressed in NSTF Phase I and NSTF Phase II.

NEAR-SURFACE TEST FACILITY PHASE I

The NSTF Phase I end function is divided into five activities:

- Phase I Test Facility Baseline
- Design
- Construction
- Safety and Environmental Analysis
- Test Implementation.

Design and construction activities for the Phase I test area tunnels and facilities were completed to the point of beneficial occupancy in January 1979. An environmental analysis was prepared prior to tunnel and facility construction. Continuing safety reviews are conducted to ensure the NSTF integrity.

During the third quarter of FY 1981, work has progressed in two activities: Phase I Test Facility Baseline and Test Implementation.

Phase I Test Facility Baseline

This activity is responsible for the program management of the NSTF Phase I end function, specifically, the preparation and control of schedules, preparation of budgets and work packages, control of program costs, and overall guidance of technical activities.

Test Implementation

The Phase I Test Implementation activity includes six subactivities:

- Full-Scale Heater Test #1
- Full-Scale Heater Test #2
- Block Test #1
- Block Test #2
- Engineering Support
- Operations.

During the third quarter of FY 1981, work continued in all subactivities except BT2, which is not funded at this time.

Full-Scale Heater Tests #1 and #2. The full-scale heater tests, initiated on July 1, 1980, continued in operation throughout the quarter without incident. There were no net power changes programmed for either test during this period.

The program started last quarter and directed at problem analysis and correction for the FS1 and the FS2 instrument malfunctions was continued this quarter. All of the instrument improvement efforts are reported in the Phase II Test Implementation section of this report. The Repository section contains the results of the first micrometer measurements of the extensometer linear variable differential transformers.

Block Test #1. All engineered test equipment for Step 1 activities was installed. This included the two flat jacks fitted with deformeters, calibration and run-in of the hydraulic system, fifteen heaters and connection into the control system, final termination, and verification and acceptance testing of all instrumentation and equipment.

Cancellation pressure of 2.2 MPa of the basalt for the slot containing the two flat jacks was achieved without incident. The flat jacks and supporting equipment have operated up to 7.5 MPa and back to zero in accordance with the test plan.

One heater was activated for Step 1 tests to establish a thermal gradient for thermal conductivity measurements.

The original USBM deformation gauges, 5U03 and 5U04, installed prior to the slot drilling to monitor the basalt before, during, and following the drilling operation were replaced in accordance with the test plan by calibrated, characterized gauges after cancellation pressure was achieved.

A contract was awarded for the Basalt Deformation Measurement System (BDMS), an optical system for measuring displacements across BT1 to an accuracy never attempted previously in rock. The conceptual design was completed at the end of the quarter. This system is designed to measure a dynamic range of rock movement of ± 2 mm to an accuracy of 10 mμ. The distance between the measuring points is approximately 1.5 m. This measurement will be used to calculate the in situ rock-mass modulus and Poisson's ratio. The system detailed design is in progress and fabrication will commence early in next quarter.

The L slot demonstration of flat jack installation and operations techniques was terminated when the flat jack lost pressure at 15 MPa internal pressure. It is planned to remove the steel receiver and/or the flat jack. The pressure failure circumstances and background information suggest that a weld failed on the front edge of the flat jack. Visual inspection was attempted immediately following failure, but was inconclusive due to the distance from rock face (∿135 cm) and width of slot (>2.5 cm).

Engineering Support. This subactivity includes geologic characterization of the test areas and automatic data acquisition, data processing, and software maintenance.

Geologic characterization was accomplished by detailed geologic mapping, instrument borehole core logging, and borehole mapping of selected holes, and was reported on in previous quarterly reports.

Substantial general modifications and improvements have been made to the Phase I automatic data acquisition and processing systems. There are currently three different automated systems either being operated or developed to support the NSTF:

- The Data Acquisition System (DAS) is operational and supports Phase I of FS1 and FS2.
- The Data Collection and Retrieval System (DCARS) is operational and supports BT1.
- The Tests Automated Support System (TASS) is being designed and developed to support all Phase II tests and eventually to support all NSTF testing.

The two systems that support Phase I tests are discussed in the following paragraphs.

Data Acquisition System. The DAS is a fully operational system which records and processes NSTF test instrument responses and theoretical data. The system has been operational for 1 yr and has functioned in a very reliable and stable manner. The scan rate was reduced to 6/d rather than the earlier 12 and initial 48 scans/d.

The DAS has been fully described in previous quarterly and annual reports. The system has been modified to correct errors and to accommodate changing user and test requirements. To date, 115 system change requests have been written by system analysts and users. Fourteen of these changes have been made and incorporated into the system this quarter. To date, a total of 17 system change requests have been cancelled, 79 completed, and 19 remain open.

Data Collection and Retrieval System. The DCARS is the name of that set of computer software and hardware designed and configured to support BT1. It is the second generation system developed by the Basalt Technical Systems Unit (BTSU) to support the NSTF and consists of approximately 130 subroutines of FORTRAN code. To date, 43 system change requests have been written by analysts and users; 23 have been completed and included into the system this quarter.

Operations. Two sets of manual calibration checks were made on all FS1 and FS2 extensometers using a depth micrometer. Manual calibration readings were compared with existing electronic readings. Sixty percent of the manual calibration readings were in agreement with the electronic readings. Another set of manual calibration readings is expected to be obtained next quarter.

Step 1 of BT1 was started this quarter. Stress relaxation data measurements were acquired made on the BT1 basalt block after the initial lower slot was drilled. Flat jacks were installed after completion of these measurements and the remaining support equipment was readied for pressurization of the flat jacks.

The first phase of testing involved pressurization to cancel the relaxation which was measured after the initial lower slot was cut. The cancellation pressure was measured at 2.2 MPa. Upon completion of initial pressure cycles, the heaters were turned on in order to begin elevated temperature measurement. Completion of Step 1 of BT1 is planned for next quarter.

Fourteen USBM gauges were removed from FS1 and FS2 boreholes for zero offset checks during the third quarter. Two of the USBM gauges, 2U05 and 2U10, were decommissioned due to gauge failure and not reinstalled in the boreholes. The twelve remaining USBM gauges were reinstalled upon completion of the zero offset checks.

Zero offset checks were performed on two BT1 USBM gauges, 5U03 and 5U04, this quarter; 5U03 was not in calibration and was replaced with a new gauge. USBM gauge 5U04 was reinstalled as normal. A third USBM gauge, 5U01, could not be removed because a removal tool became wedged in the borehole. To avoid damage to other (VWS) gauge wires in the same borehole a decision was made to leave the USBM gauge undisturbed.

During the initial operations of the John Fluke Model 2240B data loggers, it was found that numerous problems resulted from mounting and cable failures. These malfunctions have been corrected by incorporating factory modifications.

A generic malfunction has been identified in the data logger analog-to-digital (D/A) conversion module. An exchange agreement has been established wherein the supplier will provide repaired D/A modules for a fixed fee on an exchange basis. Three such failures are currently being corrected using this agreement.

Borehole dewatering activities were continued during this quarter. Weekly pumping of water from borehole 3H01 has maintained the general area water levels at a relatively unchanged state from last quarter. Continued dewatering is expected through next quarter.

NEAR-SURFACE TEST FACILITY PHASE II

The NSTF Phase II end function is divided into five activities:

- Phase II Test Facility Baseline
- Design
- Construction
- Safety and Environmental Analysis
- Test Implementation.

Design activities covering the Phase II test area tunnels, facilities, and the Bottom Loading Transporter (BLT) were completed by August 1980. Construction of the test area tunnels were completed, and construction of the facilities and BLT are in progress.

During the third quarter of FY 1981, work progressed in four activities: Phase II Test Facility Baseline, Construction, Safety and Environmental Analysis, and Test Implementation.

Phase II Test Facility Baseline

This activity is responsible for program management of the NSTF Phase II end function--specifically, the preparation and control of schedules, preparation of budgets and work packages, control of program costs, and overall guidance of technical activities.

Construction

This activity is divided into eight subactivities:

- Procurement
- Tunnels and Excavation
- Test and Instrument Holes
- Facility Requirements and Site Work
- Bottom Loading Transporter (Rockwell)
- Bottom Loading Transporter (Contract)
- Construction Management
- Title III.

Tunnel and excavation work was completed in FY 1979, and test and instrument holes were completed in the first quarter of FY 1981. The contract work on the BLT was completed in FY 1979.

During the third quarter, work has progressed in five subactivities: Procurement, Facility Requirements and Site Work, Bottom Loading Transporter, Construction Management, and Title III.

Procurement. During this quarter the effort was concerned with expediting delivery of the equipment required to support construction. The exhaust system equipment, the security system equipment, and the distribution switch gear were received this quarter.

Facility Requirements and Site Work. The facility construction continued, and the major activities were as follows:

- The generator building structure was completed. The generator and electrical distribution equipment was installed.
- The instrument enclosure structure was completed. The air conditioning unit and the lighting and electrical distribution equipment were installed.
- The exhaust system comprised of filter setting, stack, and inlet manifolds was installed.
- The main service transformer was installed, tested, and energized.
- The main electrical distribution equipment was installed and the entire electrical system was energized.

- Framing for isolation doors #2 and #3 was completed and doors were installed.
- All concrete work in tunnel #2, the monitoring room, and the transfer room was completed.
- The base plates for the BLT rails were set and grouted.
- The closed circuit television (CCTV) system was installed.
- The fire alarm equipment was installed.
- Equipment for the facility functions monitoring system was installed.
- All equipment for the security system was installed except the remote alarm panel.

Bottom Loading Transporter. Fabrication of the BLT continued with the completion of the following subassemblies:

- Railcar assembly with drive units
- Cask
- Grapple Hoist
- Grapple Assembly
- Positioning Pins
- Railings and Ladders
- Canopy Assembly.

The major components and associated drive units were assembled to complete the basic structure; the electrical installation is proceeding as scheduled; and the plan for disassembly, moving, and reassembly was completed.

Construction Management. This is a continuous activity which is performed essentially as a level of effort. The effort is concerned with all activities under the Construction heading.

Title III. The Title III inspection effort is an ongoing activity. There has been a high level of activity this quarter as the construction work has been progressing rapidly in all areas.

Safety and Environmental Analysis

This activity is concerned with an ongoing effort in environment and safety analysis.

Environmental Review. The effort this quarter has been a continuation of the effort to establish the baseline for air and surface quality at the NSTF.

Safety Review. The principal effort in this area has been preparation of the Safety Analysis Report which was submitted for review and approval to the DOE-RL.

Test Implementation

Phase II Test Implementation includes five subactivities:

- Spent Fuel Test #1
- Spent Fuel Test #2
- Vitrified Waste Form Test
- Engineering Support
- Operations.

During the third quarter of FY 1981, work was performed in all subactivities.

Spent Fuel Tests #1 and #2 and the Vitrified Waste Form Test. The Spent Fuel Test #1 (SF1) test article is a canisterized PWR fuel element which was cycled out of a reactor 5 yr ago and is estimated to have a residual thermal output of about 0.7 kW.

The Spent Fuel Test #2 (SF2) test article is a second canisterized PWR fuel element, only 2 yr out of a reactor with an estimate thermal output at installation of 2.5 kW.

The third test article, the vitrified waste form (VWF) test, is canisterized nuclear waste generated during the processing of irradiated Point Beach Reactor fuel with a residual thermal output of $\sim$500 W.

The canister to be used for containment of the spent fuel and vitrified waste was designed by Westinghouse, Advanced Energy Systems Division. The total development program for the canister included the canister design, a final closure welding program, an evacuation and helium backfill demonstration, a drop test and seismic qualification, and a cask and canister thermal interference study.

The NLI 1/2 shipping cask for transporting the spent fuel and VWF was designed by the National Lead Company. The spent fuel assembly located at Turkey Point, Florida will be shipped to the Engine Maintenance Assembly and Disassembly (EMAD) Facility this fiscal year. Once the license amendment is approved by the NRC (now in progress), the VWF will be shipped to EMAD. Canisterization of the spent fuel and VWF will occur at EMAD in the first quarter of FY 1982. Shipment of all three test articles from EMAD to NSTF will occur in January and February of 1982, using a radiologically clean shipping cask.

Parallel and essentially identical work efforts were performed for each of the first three subactivities of Phase II Test Implementation, i.e., SF1, SF2, and VWF tests.

The instrumentation for each test is located in small-diameter boreholes surrounding each canister borehole. The layout (typical) for this instrumentation for each test is illustrated in Figure 28.

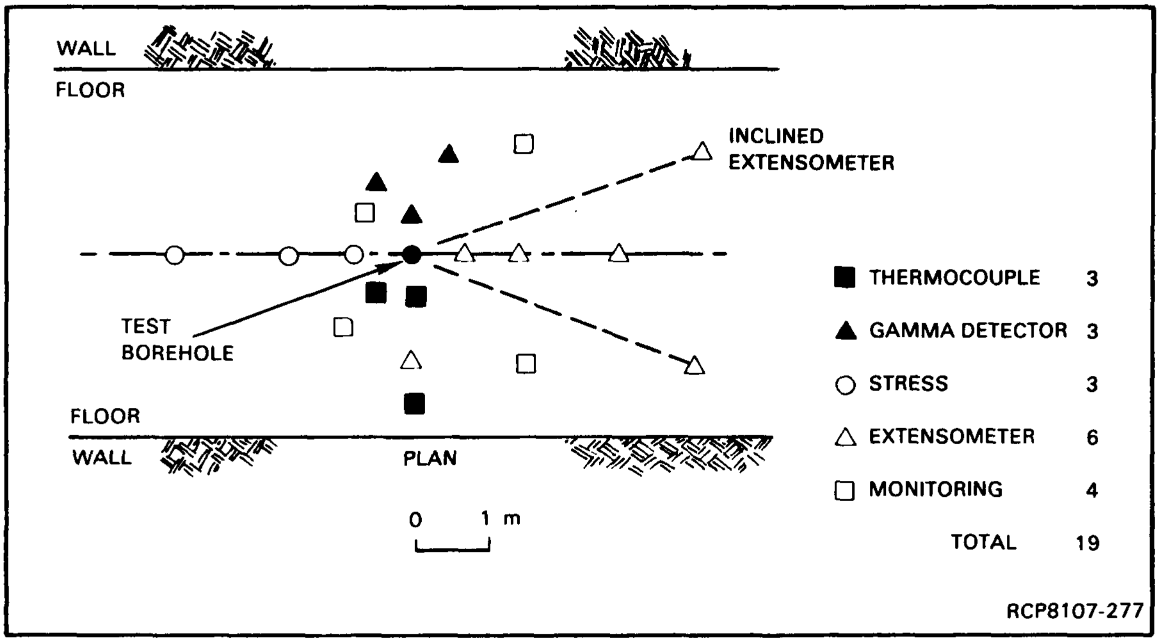


FIGURE 28. Instrumentation Layout Around Canister Test Borehole.

These instruments will measure the following parameters:

- Extensometers: rock mass displacement induced by thermal loading
- USBM borehole deformation and IRAD VWS gauges: rock mass stress and deformation induced by thermal loading

- Thermocouples: temperature
- Ionization chamber: levels of gamma radiation.

The Phase II rock instruments have been improved from the heater test rock instruments based on the problems observed in the Phase I instruments. A brief description of the improvements for each instrument type is given below.

The VWSs have been improved by seal-welding the cavity to prevent water intrusion, by plating the external surfaces to reduce surface corrosion and by increasing the sheathing thickness to reduce the probability of wire failure due to abrasion. An extensive testing program is also under way to uniquely identify the VWS high-temperature (200°C) response.

The borehole deformation gauges (BDG) have been improved by the following:

- Coating the strain gauges in the BDG with three moisture-resistant coatings. The first coating is the strain gauge adhesive (610), applied over the strain gauge and solder pad as well as the wires to the solder pad. The second coating is a Parylene D coating. This coating is used in the aerospace industry for protecting circuit boards. The third coating is 3145 RTV. Each of these coatings provides a moisture intrusion barrier for the BDG.
- Double piston "O" rings. Each of the six BDG pistons has an additional installed/grooved "O" ring. This will reduce the amount of moisture leakage through this, until now, major path for moisture intrusion.
- Beveling the holes in the BDG body through which the pistons travel. The original design did not have a bevel on the piston passages in the BDG body and risked "O" ring damage each time the pistons were inserted. This change improves the "O" ring seal.
- New wiring configuration of the strain gauges. The new configuration places the strain gauges on a given cantilever in the same arm of the Wheatstone bridge configuration. This approach improves the temperature compensation of the bridge circuit.
- Beveling the BDG body nose. The sharp edge of the nose piece of the BDG body was potentially damaging to the wires to the VWS gauges located downhole. The bevel minimizes this possibility.

- A lanyard attached to the BDG body. Removal of the BDG from a borehole containing VWS gauges has caused problems in the past due to interference of the BDG removal tool with (VWS) cables in the same borehole. The lanyard is attached to the body and is routed out of the borehole opening in a manner to allow removal of the BDG without using the removal tool.

- Changing the electrical grounding scheme of the BDG. The shield on the BDG cable is not electrically connected to the BDG body to avoid/prevent ground loop induced voltages. An additional lead wire is attached to the body to provide a circuit to check the strain gauge insulation resistance. This resistance measurement has been identified as a reliable indicator of strain gauge performance and should facilitate in-service identification of incipient failure.

- Change to the testing method and fixture. The BDG was typically and is currently calibrated using micrometers. The new fixture is a stepped cup which simulates the changes of a borehole. The cup is corrected for temperature and can be used in the field. The fixture is constructed to assure calibration repeatability.

The MPBX has been improved by:

- Changing from a hydraulic to a mechanical anchor. The heater test MPBXs have hydraulic anchors, some of which have failed through the hydraulic system. The spent fuel test MPBX has a snap-ring mechanical anchor to eliminate this potential source of error.

- Reducing the range of the DC linear variable differential transformer (DC-LVDT). The range of the DC-LVDT is being reduced based on the heater test results and to increase the accuracy when measuring small movements.

- Adding voltage regulators into the head of the MPBX. The addition of voltage regulators in the MPBX head area increases the reliability of controlling the small voltage fluctuations in the MPBX power supply and thereby reduces the necessary electrical signal corrections.

- Adding a step ability to the anchor coupling as a calibration check. Adding the bayonet step coupling at the end of the measuring rods allows the rod to be moved a set, known distance at the anchor and thereby provides a check on the DC-LVDT calibration. Present calibration practice involves moving the MPBX head; this step coupling allows us to move the rod end (as the rock will during the test) to verify the normal calibration.

Each canister borehole has three associated instrument boreholes for nuclear measurements. These vertical boreholes are located approximately 33, 53, and 69 cm from the canister borehole wall. The outer instrumentation hole will contain one ionization chamber with a resistance-type temperature detector (RTD). Each of the ionization chambers (and associated equipment) and RTD will be connected to the data acquisition hardware for radiation and temperature monitoring.

A portable ionization chamber (a fourth unit) with associated equipment will measure vertical radiation intensity profiles in all nuclear instrumentation boreholes (a total of nine) on a routine basis (TBD). The permanently stationed ionization chamber in the outermost radiation instrument borehole of each test will be temporarily displaced during the borehole profile measurement.

The design of the nuclear instrumentation system is completed and the hardware has been ordered. Installation and acceptance testing of the system will not be started until the canister liner installation is complete.

Each nuclear waste canister assembly will be placed in a 7.9-m-deep test hole equipped with a steel liner. A concrete shielding plug will provide a radiation barrier to the surface with a small tube through the plug to permit sampling of the test borehole. During liner installation, thermocouples and tubes for dewatering and desteaming of the test borehole will also be installed. The design for the liner installation and the associated equipment and instrumentation is essentially complete. Procurement of materials is in process with completion of installation scheduled for the fourth quarter of FY 1981.

The TASS is being developed as the third generation data collection system by the Basalt Technical Systems Unit (BTSU) in support of Phase II testing and combines the best features of both the DAS and the DCARS to include:

- Variable scan/scan on demand
- Access to all scans (on-line data files)
- Predicted data
- Interactive graphics
- Accept "N" frequency of "J" instrument types.

The system is depicted in Figure 29.

Engineering Support. This subactivity includes the geologic characterization of the structural and physical composition of the rock mass in which the Phase II tests will be conducted.

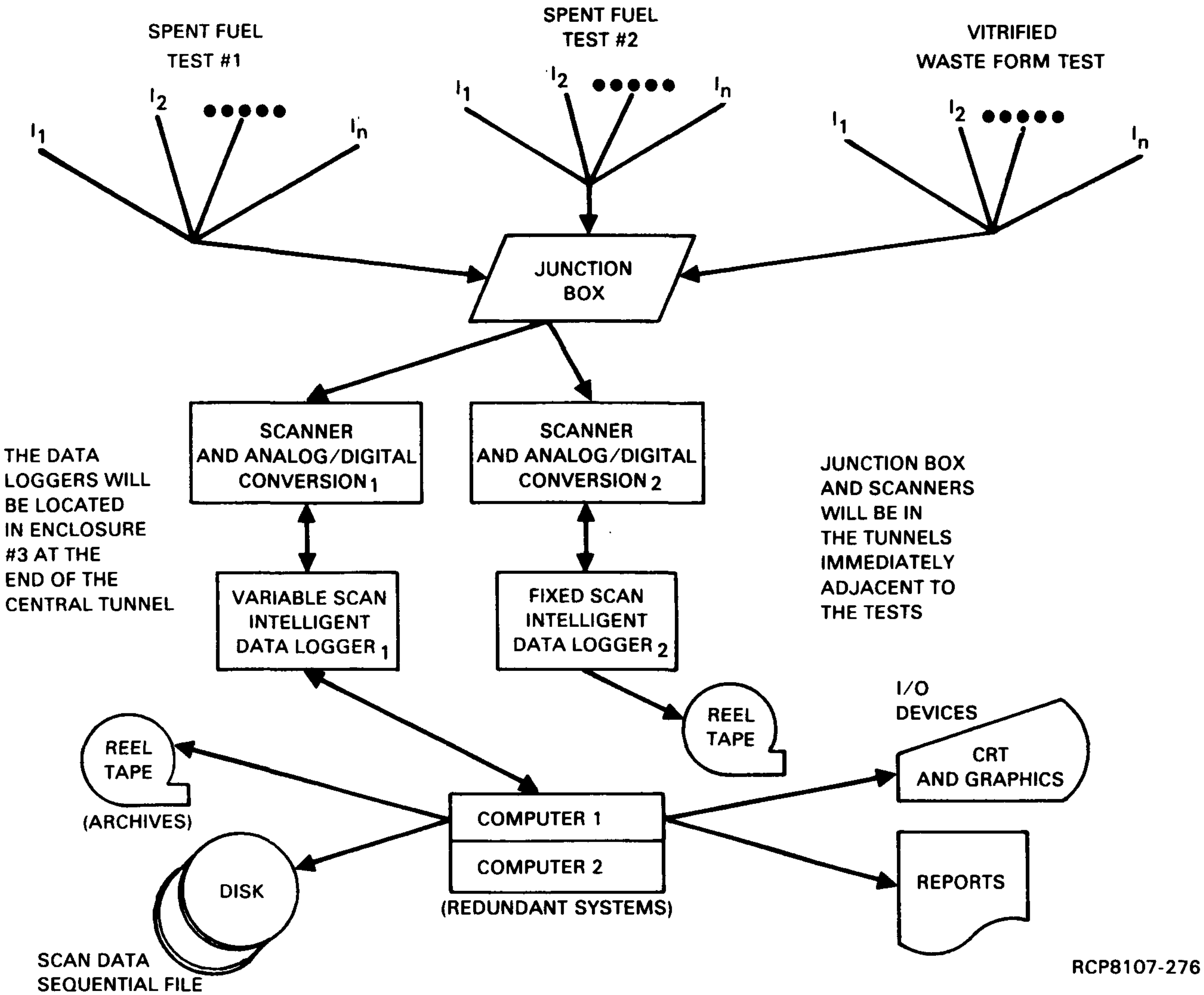


FIGURE 29. TASS Schematic.

Characterization provides baseline data so that changes resulting from testing can be identified and NSTF geologic conditions can be compared to those which prevail at a site selected for the repository. Characterization was accomplished by detail line map instrument borehole core logging and geologic mapping.

The Phase II tests (SF1, SF2, and VWF) are located in the Pomona flow of the Saddle Mountains Formation. The tests are located in a zone from ∿18 to 27 m below the top of the flow. This zone consists of entablature, colonnade, and a transition zone.

The entablature is characterized by 15- to 30-cm-dia columns which are continuous from 0.4 to 0.7 m. The columns are dissected by low-angle cross joints which are discontinuous between columns. The average joint frequency is 9.2 joints per meter and the average joint aperture is 0.3 mm.

The colonnade is characterized by 36- to 48-cm-dia columns which are also dissected by discontinuous cross joints. The length of the columns is probably 3 m or greater, which is consistent with observations of the colonnade in outcrop. The average joint frequency is 7.3 joints per meter and the average joint aperture is 0.4 mm.

The transition zone between the entablature and colonnade, which was determined by examining the instrument borehole core and petrographic analysis, is undulating and varies in thickness. For the purposes of the characterization report the middle of this zone was used as the break between entablature and colonnade.

All data to complete the Phase II characterization report has been collected and the report preparation is well under way. The report will be issued in the fourth quarter of FY 1981 and will contain a complete characterization of the Phase II test area.

Operations. The draft procedures for the BLT and the Near-Surface Emergency Plan have been completed and are in review cycle. Work on the master procedure for the test canister transfer operations is continuing.

Initial writing is in progress on a procedure for transport of the nuclear waste cask through NSTF Tunnel #1, including receipt of the cask and truck/tunnel transfer operations.

The Readiness Review Action Lists have been completed by the NSTF Phase II startup team.

IN SITU TEST FACILITIES

The objective of the In Situ Test Facilities program is to provide for the design, construction, and operation of test facilities in support of the technology development needs of the BWIP. The In Situ Test Facilities program is divided into three end functions:

- Exploratory Shaft Test Facility Phase I
- Exploratory Shaft Test Facility Phase II
- Test and Evaluation Facility.

During this quarter, work progressed in the Exploratory Shaft Test Facility (ESTF) Phase I end function.

EXPLORATORY SHAFT TEST FACILITY PHASE I

During this quarter, preparation of the test plan for an ESTF continued. A design review of the test plan was conducted on April 24, 1981. Based on comments from this design review and current NWTS program strategy, the test plan has been restructured so that Phase I of the project is limited to in situ site characterization. The objectives of Phase I are to:

- Confirm the suitability of the proposed location for an exploratory shaft at the RRL
- Demonstrate that an exploratory shaft can be sunk at the RRL and assess the construction method
- Verify that an exploratory shaft can successfully seal off the groundwater system and evaluate the effects of shaft construction on the surrounding rock at the RRL
- Measure the hydraulic properties (e.g., vertical hydraulic conductivity) of the reference horizon to provide input to a preliminary estimate of its isolation capability in the vicinity of the exploratory shaft
- Conduct geomechanic tests (e.g., in situ stress) and provide a preliminary characterization of the reference repository horizon.

The test plan will be issued during the fourth quarter of FY 1981.

A preliminary draft of the ESTF functional design criteria, based on the draft test plan which was reviewed in April 1981, was completed. The criteria are now being revised, based on the new test plan.

A work statement covering conceptual design of the ESTF was prepared. Conceptual design work to be performed by KE/PB is expected to begin by July 1981.

A work statement covering ESTF construction management was also prepared.

DOCUMENTS ISSUED
(DURING THE QUARTER)

RHO-BWI-81-100 1Q (unclassified), October 1, 1980 through December 31, 1980, R. A. Deju, "Basalt Waste Isolation Project Quarterly Report"

RHO-BWI-C-56 (unclassified), September 1979, Randall E. Brown, "A Review of Water-Well Data from the Unconfined Aquifer in the Eastern and Southern Parts of the Pasco Basin"

RHO-BWI-C-89 (unclassified), October 1980, F. S. Shuri, D. J. Dodds (FSI), and K. Kim, "Measurement of Rock-Mass Deformation Properties by the Borehole Jacking Method at the Near-Surface Test Facility"

RHO-BWI-C-91 (unclassified), December 1980, Foundation Sciences, Inc., "Thermal/Mechanical Properties of Pomona and Umtanum Basalts--Elevated Temperature Comparative Triaxial Test"

RHO-BWI-C-92 (unclassified), January 1981, Foundation Sciences, Inc., "Thermal/Mechanical Properties of Umtanum Basalt--Borehole DC-2"

RHO-BWI-C-94 (unclassified), February 1981, I. P. King, D. B. McLaughlin, W. R. Norton (Resource Managment Associates), R. G. Baca, and R. C. Arnett, "Parametric and Sensitivity Analysis of Waste Isolation in a Basalt Medium"

RHO-BWI-C-97 (unclassified), September 1980, H. P. Foote, S. C. Blair, W. E. Wukelic, and V. L. Coburn, "Evaluation of Growth in Irrigated Agriculture in the Columbia Plateau, 1975-1979"

RHO-BWI-LD-27 (unclassified), January 1981, F. A. Spane, Jr., "Hydrogeologic Properties and Hydrochemistry for the Levey Interbed at Well 699-S11-E12A, Hanford Site"

RHO-BWI-LD-29 (unclassified), September 1980, L. D. Diediker and R. K. Ledgerwood, "Drilling History of Core Hole DB-15"

RHO-BWI-LD-31 (unclassified), December 1980, J. T. Lillie, L. D. Diediker and R. K. Ledgerwood, "Drilling History of Core Holes DH-18 and DH-19"

RHO-BWI-LD-34 (unclassified), 1980, John B. Case, Alan D. Krug and John Williams, "Full-Scale Heater Tests #1 and #2 at the Near-Surface Test Facility: Preliminary Results"

RHO-BWI-LD-37 (unclassified), January 1981, T. S. Clawson, R. K. Ledgerwood and L. D. Diediker, "Drilling History of the Extension by Coring of Borehole DC-7"

RHO-BWI-SA-67 (unclassified), December 1980, P. E. Long, M. G. Snow, and N. J. Davidson, "Relationships Between Internal Structures and Petrographic Textures of Basalt Flows: Example from a Continental Flood Tholeiite Province"

RHO-BWI-SA-113 (unclassified), June 1981, R. G. Baca, R. C. Arnett, and I. P. King, "Numerical Modeling of Flow and Transport Processes in a Fractured-Porous Rock System"

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