DOE/NV/11718-162
UC-703

Bechtel Nevada

PROCESSING AND GEOLOGIC ANALYSIS OF CONVENTIONAL CORES FROM WELL ER-20-6#1, NEVADA TEST SITE

September 1997

Prepared for the
U.S. Department of Energy, Nevada Operations Office
Under Contract No. DE-AC08-96NV11718

DISCLAIMER

Available to DOE and DOE contractors from:

Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831

For prices call (423) 575-8401

Available to the public from:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Rd.
Springfield, VA 22161
Telephone (703) 487-4650

DISCLAIMER

DOE/NV/11718-162
UC-703

Bechtel Nevada

PROCESSING AND GEOLOGIC ANALYSIS OF CONVENTIONAL CORES FROM WELL ER-20-6#1, NEVADA TEST SITE

by

Lance B. Prothro, Margaret J. Townsend,
Sigmund L. Drellack, Jr., and Jose L. Gonzales

Geology/Hydrology Group
Geotechnical Services
Bechtel Nevada

September 1997

This page intentionally left blank.

Table of Contents

List of Figures

Number	Title	Page

List of Tables

List of Acronyms and Abbreviations

BHI	Baker Hughes INTEQ
BHTV	Borehole Televiewer Log
BN	Bechtel Nevada
cm	Centimeter(s)
DOE	U.S. Department of Energy
ft	Foot (feet)
in.	Inch(es)
IT	IT Corporation
LFA	Lava-flow aquifer
m	Meter(s)
mm	Millimeter(s)
NTS	Nevada Test Site
TCU	Tuff confining unit
TD	Total depth
USGS	U.S. Geological Survey

1.0 Introduction

In 1996, Well Cluster ER-20-6 was drilled on Pahute Mesa in Area 20, in the northwestern corner of the Nevada Test Site (NTS) (Figure 1-1). The three wells of the cluster are located from 166 to 296 meters (m) (544 to 971 feet [ft]) southwest of the site of the underground nuclear test code-named BULLION, conducted in 1990 in Emplacement Hole U-20bd (Figure 1-2). The well cluster was planned to be the site of a forced-gradient experiment designed to investigate radionuclide transport in groundwater (IT, 1997; IT, 1996). To obtain additional information on the occurrence of radionuclides, nature of fractures, and lithology, a portion of Well ER-20-6#1, the hole closest to the explosion cavity, was cored for later analysis.

Bechtel Nevada (BN) geologists originally prepared the geologic interpretation of the Well Cluster ER-20-6 site and documented the geology of each well in the cluster (DOE, 1996). However, the cores from Well ER-20-6#1 were not accessible at the time of that work. As the forced-gradient experiment and other radionuclide migration studies associated with the well cluster progressed, it was deemed appropriate to open the cores, describe the geology, and re-package the core for long-term air-tight storage. This report documents and describes the processing, geologic analysis, and preservation of the conventional cores from Well ER-20-6#1.

1.1 Objectives

The objectives of the Well ER-20-6#1 core processing and analysis included the following:

- Describe the lithology of the cores (which had been left unexamined in their original sleeves) to verify that the lithology is consistent with original descriptions based on drill cuttings and geophysical logs (DOE, 1996).
- Perform a fracture analysis, recording critical parameters such as fracture density, aperture, orientation, and secondary mineral coatings.
- Repackage the cores in an air-tight material for long-term storage.
- Document in a report the methods used and results obtained during core processing and analysis.

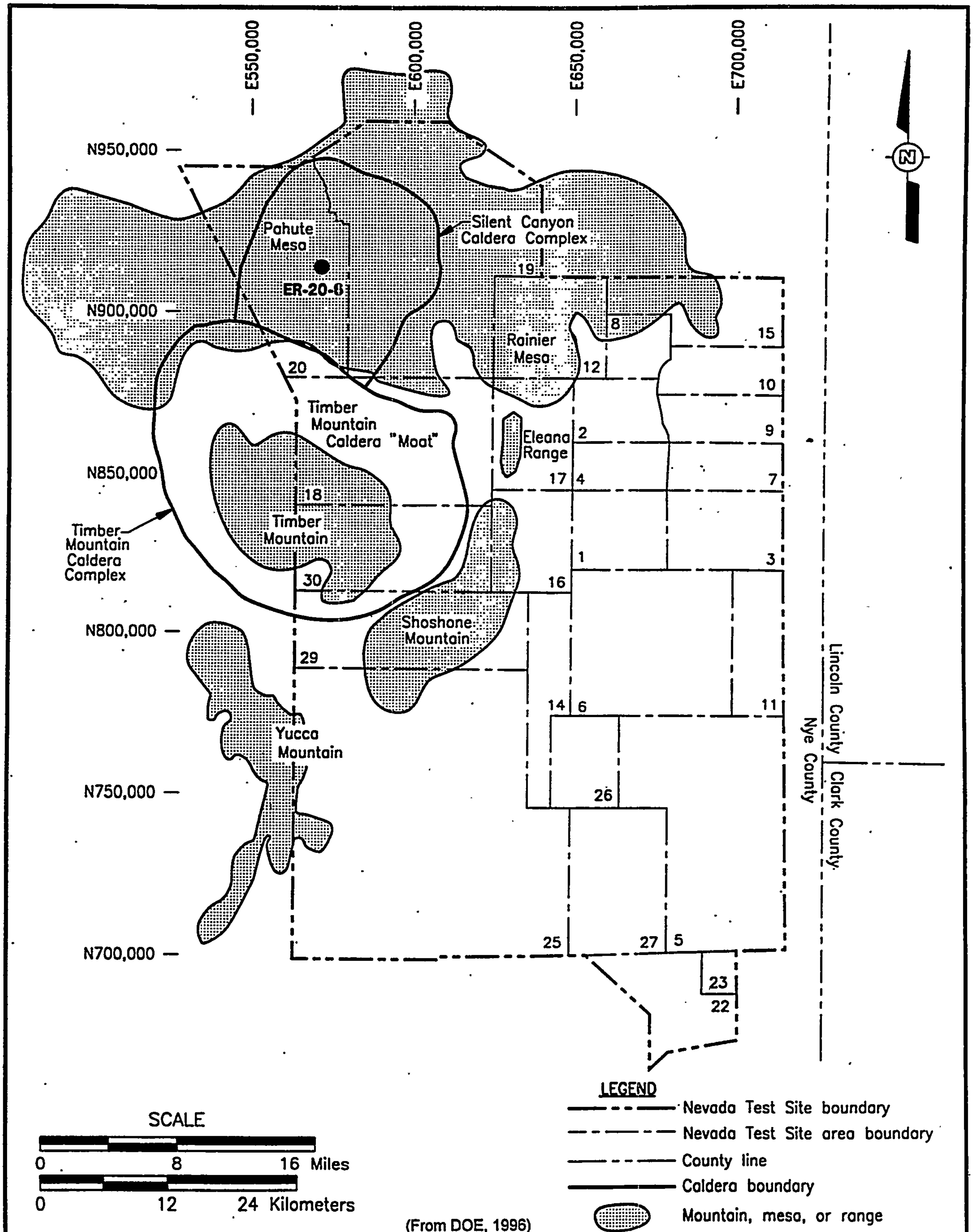


Figure 1-1
Location of Well Cluster ER-20-6

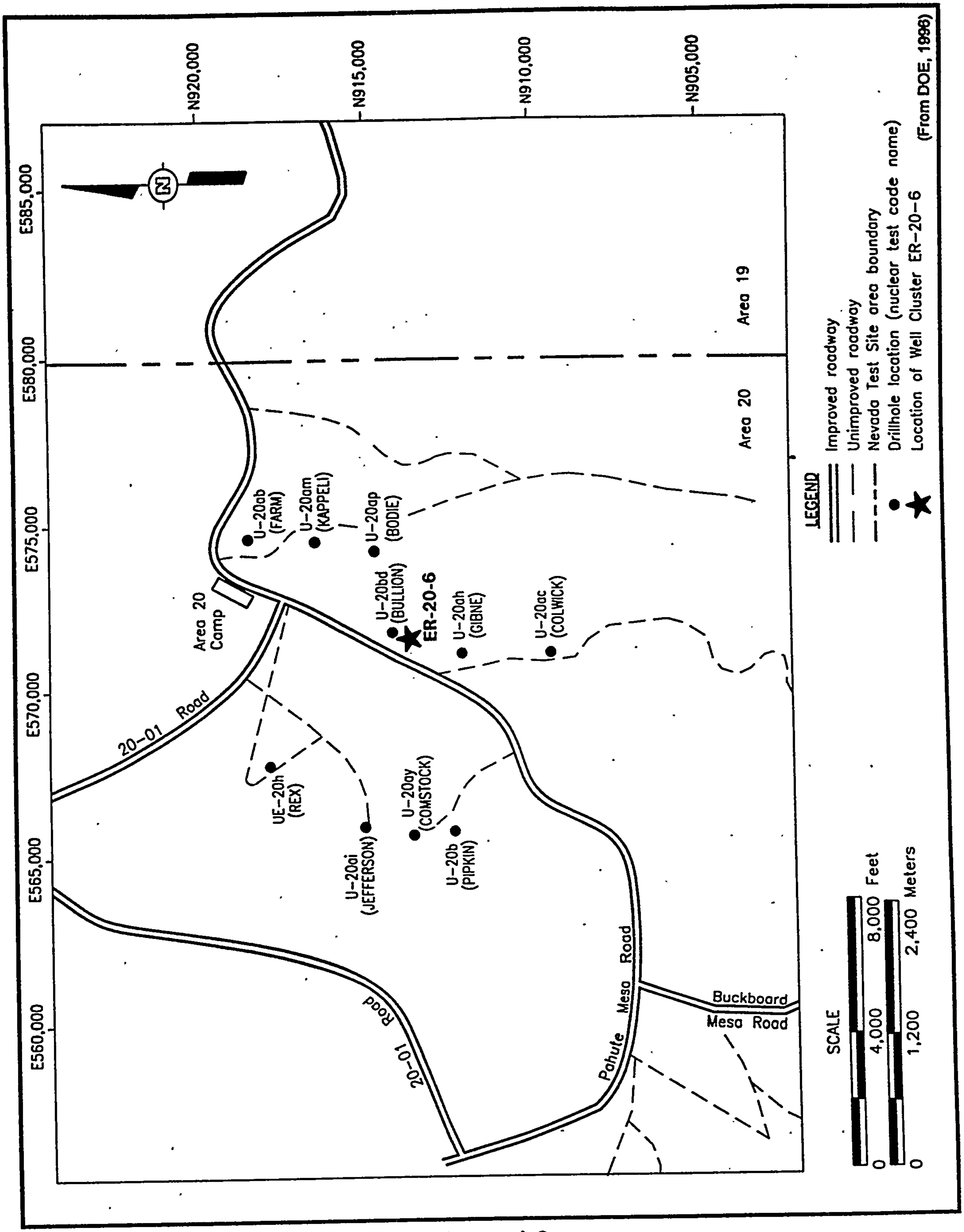


Figure 1-2
Area Map for Well Cluster ER-20-6,
Area 20, Nevada Test Site

1.2 Methodology

This section describes the methods and procedures used to process, analyze, and package the core from Well ER-20-6#1. Because one of the main objectives was to preserve the core for air-tight long-term storage, a detailed discussion of the core preservation method is presented in Section 4.0.

Core processing and analysis were conducted at the U.S. Geological Survey (USGS) Geologic Data Center and Core Library in Mercury, Nevada, where the cores had been maintained under controlled conditions. Prior to core processing and analysis, radiochemists from Lawrence Livermore National Laboratory and Los Alamos National Laboratory were consulted on their needs for special handling or analysis of these cores because of the interest in near-field radionuclide migration, and concurrent radiochemical studies of the drill cuttings and sidewall cores from Well Cluster ER-20-6.

1.2.1 Core Processing

The entire process of extracting, documenting, analyzing, and packaging the cores from Well ER-20-6#1 had to be performed quickly to minimize exposure of the cores to the atmosphere (i.e., to prevent drying). To accomplish this, the work was planned so that up to three geologists could perform the various tasks concurrently as each 0.6 m (2 ft) core segment was passed through a series of "work-stations." For example, as one core segment was being packaged, the next segment was being extracted from the casing to begin the documentation process.

One core segment at a time was extracted from the aluminum casing into a plastic-lined cardboard core box for processing, then reassembled, measured, and marked. Depths were marked at one-foot intervals, and an arrow which points down-hole was drawn on each of the largest pieces. All measurements were made in field units (English system), and recorded to the nearest tenth foot. A photograph was then taken of the entire 0.6 m (2 ft) length of each core segment, with a color chart to aid in color corrections and a graphic scale. Close-up photos were taken of a few features. Core pieces selected for preservation were measured and recorded as the core was being sketched and described, and a fracture analysis performed. Upon completion of the descriptions and analyses, the cores were packaged and returned to their original cardboard core boxes (see Section 4). All core material now resides in order of hole depth in 37 heavy-duty cardboard boxes at the USGS Geologic Data Center and Core Library in Mercury, Nevada.

1.2.2 Geologic Analysis

Typically, the core samples were examined megascopically; however, a 10x- to 40x-zoom binocular microscope was used for more detailed examination. Geologic information was recorded on prepared, customized data sheets to assure consistency and completeness. Each sheet (one per two-foot core segment) contained prompts for notes on core condition, lithology, packaging, and photographs taken. Each sheet also contained a generic core outline on which fractures and other features, such as bedding, vesicles, and flow banding, were sketched. Lithologic descriptions followed BN department procedure NTS-GEO-003.

A fracture analysis was also performed on the core samples. For consistency, this analysis generally followed that outlined in Drellack *et al.* (1997), a comprehensive analysis of volcanic cores from other Pahute Mesa core holes. Table 1-1, abstracted from Drellack *et al.* (1997), provides definitions of terms used in the Well ER-20-6#1 core fracture analysis.

A total of 190 natural fractures were described during the analysis. Because only natural fractures were described, it was necessary to differentiate between natural fractures and breaks induced during coring or handling. The presence of secondary mineral coatings on fracture surfaces is generally indicative of a natural fracture; therefore, all breaks in the cores were carefully examined for the presence of secondary minerals. In addition, natural fractures are usually more planar and have smoother surfaces that commonly appear weathered or stained. Faults (as indicated by the presence of slickensides, gouge, or apparent relative displacement) and cooling joints are defined as fractures in this data set.

Fractures resulting from a nearby nuclear test(s) are almost impossible to recognize for certain in core. Testing-induced fractures are likely to appear fresh and be difficult to distinguish from coring- and handling-induced breaks. Indications of possible test-induced fractures include anomalous high numbers of fresh-looking fractures and highly broken core having a shattered appearance. Although no test-induced fractures were definitively identified in the Well ER-20-6#1 core, there were some indications that nuclear testing in the area may have resulted in fractures (see Section 3.2).

Both open and closed natural fractures were examined during the analysis, and the information was recorded on data sheets. The location of each fracture was typically recorded to the next whole foot. Fracture characteristics recorded included surface texture, the type of secondary mineral coating(s) present, an estimate of the percent of the fracture

Table 1-1
Definitions of Terms Used in the Core Fracture Analysis
(From Drellack *et al.*, 1997)

Term	Definition Used in Study
Fracture	A break or crack in a rock core.
Natural Fracture	A fracture resulting from natural geologic processes, including faults and cooling joints. Natural fractures are usually coated or filled with secondary minerals. They are usually high- to medium-angle (but seldom vertical and running down the center of the core), relatively smooth and planar, and have a weathered or stained appearance.
Coring and Handling-Induced Fracture	A fracture resulting from stresses created during coring or handling. Coring and handling-induced fractures will not have secondary mineral coatings and usually have rough textures, curved to irregular shapes, and "fresh" appearances.
Open Fracture	A natural fracture that has open space between the sides of the fracture.
Closed Fracture	A natural fracture that is completely filled with secondary minerals and, thus, has no open space along the fracture trace in the core.
Depth of Fracture	The bottom of the one-foot interval in which the fracture occurs (i.e., the depth of the fracture recorded to the next whole foot depth).
Fracture Density	The number of fractures per vertical foot of core.
Fracture Orientation	The dip of the fracture (i.e., the acute angle formed by the fracture and a horizontal plane normal to the long axis of the core).
High-angle	A fracture with a dip greater than 60 degrees and less than or equal to 90 degrees.
Medium-angle	A fracture with a dip greater than 30 degrees and less than or equal to 60 degrees.
Low-angle	A fracture with a dip greater than or equal to 0 degrees and less than or equal to 30 degrees.
Aperture	A representative open distance in millimeters between the sides of the fracture, visually estimated as representative for the portion of the fracture exposed in the core.
Percent Open	The estimated percent of the open space (i.e. aperture) along the entire visible portion of the fracture. When only a single fracture surface was available for examination, estimate of percent open was based on the abundance, distribution, and crystal size of the minerals observed on the surface.
Secondary Mineral Coatings	Naturally occurring minerals that coat the surface of a fracture. Secondary mineralization occurs after the formation of natural fractures, and, therefore, is indicative of natural fractures.
Percent Coated	The estimated percent of the fracture surface that is coated with secondary minerals.
Texture	The feel and appearance of the sides (i.e., surfaces) of a fracture. Texture was described as either very smooth, smooth, intermediate, or rough.
Very Smooth	A fracture surface that is polished. The surface feels slick and appears glossy and shiny.
Smooth	A fracture surface that has a very minor coarse feel and appearance.
Intermediate	A fracture surface that has a coarse and somewhat jagged feel and appearance.
Rough	A fracture surface that has a very coarse and jagged feel and appearance.
Fracture Shape	The general shape of the fracture plane. Fracture shape was described as either planar, curved, or irregular.

surfaces coated with secondary minerals, the measured dip of the fracture, an estimate of the representative aperture, an estimate of the percent of the fracture open, and any additional characteristics such as cross-cutting relationships and fracture shape.

This page intentionally left blank.

2.0 Well ER-20-6#1 Hole Summary

2.1 Hole History

The collar of Well ER-20-6#1 is located 166 m (544 ft) southwest of the BULLION surface ground zero. The well was drilled to a depth of 975.4 m (3,200 ft) during February and early March, 1996, and completions were installed in two intervals for later hydrologic testing in the lava-flow aquifer that is believed to communicate with the BULLION explosion cavity. The static, open-hole fluid level prior to completion installation was measured at 618.1 m (2,028 ft) on March 7, 1996. See the completion report for Well Cluster ER-20-6 for more information on this drilling project, including construction data, background information on the BULLION test, other geologic data collected, and well-construction data (DOE, 1996). Abridged drill hole statistics for Well ER-20-6#1 are presented in Table 2-1.

Six 12.7 centimeter (cm) (5 inch [in.]) diameter conventional cores (a total of 39.5 m [129.5 ft] recovered) were cut in Well ER-20-6#1 between the depths of 673.3 and 869.3 m (2,209 - 2,852 ft) (Table 2-2). The target aquifer, a rhyolite lava flow within the Calico Hills Formation, was encountered between 765.0 and 897.6 m (2,510 - 2,945 ft) and sampled by cores #4, #5, and #6. No contamination was noted in the core samples, though the highest tritium values encountered during drilling were noted in the fluid returns from the 797.7 to 802.2 m (2,617 - 2,632 ft) interval just below core #4, and a slight indication of an enhanced gamma signature was noted at 687.3 m (2,255 ft) just below core #2.

At its closest approach to the explosion point, at the depth of approximately 670.6 m (2,200 ft), the borehole is estimated to be approximately 1.5 cavity radii from the edge of the collapse chimney. A hydrologic cross section showing all three holes in the cluster in relation to U-20bd (BULLION), the geologic and hydrogeologic units encountered at the site, and the position of the cored intervals in Well ER-20-6#1 is presented in Figure 2-1.

2.2 Coring Activities

Baker Hughes INTEQ (BHI) cut six cores using a 12¼-in. by 5¼-in. core bit and 9.1 m (30 ft) aluminum inner barrels. Each recovered core was sawed (still inside the inner barrel) into 0.6 m (2 ft) sections and the ends were capped at the drill site. Only the exposed ends of

Table 2-1
Abridged Drill Hole Statistics for Well ER-20-6#1

LOCATION DATA: Coordinates:
Central Nevada State Planar: N913,790.5 E571,558.5 ft
Universal Transverse Mercator: N4,123,691.8 E551,362.8 m

Ground Elevation: 1,973.5 m (6,474.8 ft)

DRILLING DATA:

Spud Date:	02/19/96
Total Depth (TD):	975.4 m (3,200 ft)
Date TD Reached:	03/06/96
Date Well Completed:	03/15/96
Hole Diameter:	101.6 cm (40 in.) from surface to 11.6 m (38 ft); 44.5 cm (17.5 in.) to 243.8 m (800 ft); 31.1 cm (12.25 in.) to 975.4 m (3,200 ft).
Drilling Techniques:	Dry-auger drilling to 11.6 m (38 ft). Rotary drilling with mud (and lost circulation material as needed), using a 17½-in. bit to 243.8 m (800 ft). Rotary drilling using a 12¼-in. bit and air-foam in conventional circulation to the TD, except for a total of 39.9 m (131 ft) cored conventionally in six intermittent intervals between 673.3 and 869.3 m (2,209-2,852 ft).

CASING DATA: 30-in. conductor casing from the surface to 11.6 m (38 ft). 13⅜-in. surface casing set at 242.7 m (796.2 ft).

WELL COMPLETION DATA:
The pump string is installed within slotted 14.0-cm (5½-in.) outside-diameter (od) casing. The 5½-in. casing consists of fiberglass from the surface to 763.8 m (2,506 ft) and stainless steel from 763.8 to 891.2 m (2,506-2,924 ft). A Moyno® pump stator was installed at the bottom of 7.3-cm (2⅞-in.) od stainless-steel tubing, with No-Turn Tools® above and below the stator. The pump rotor was removed from the well on April 8, 1996. A slotted access string consisting of 7.3-cm (2⅞-in.) od fiberglass tubing was landed off at 893.1 m (2,930 ft).

	Completion String	Access String
Total Depth:	891.2 m (2,924 ft)	893.1 m (2,930 ft)
Depth of Screened Sections:	764.1-835.8 m (2,507-2,742 ft) 863.2-881.5 m (2,832-2,892 ft)	776.6-839.1 m (2,548-2,753 ft) 865.9-892.8 m (2,841-2,929 ft)
Depth of Sand Pack:	742.8-756.8 m (2,437-2,483 ft) 843.4-858.0 m (2,767-2,815 ft)	Same as for completion string
Depth of Gravel Pack:	756.8-843.4 m (2,483-2,767 ft) 858.0-898.2 m (2,815-2,947 ft)	Same as for completion string
Depth of Moyno® Pump:	755.0-761.6 m (2,477.1-2,498.8 ft)	Not applicable
Fluid Depth[a]:	618.1 m (2,028 ft)	

DRILLING CONTRACTOR: Welch & Howell Drilling

GEOPHYSICAL LOGS BY: Atlas Wireline Services, Baker Hughes INTEQ, Barbour Well Surveying, Desert Research Institute, Geophysical Engineering Group of the Joint Test Organization, Schlumberger

SURVEYING CONTRACTOR Bechtel Nevada Corporation

a Fluid level in the open borehole as of March 7, 1996.

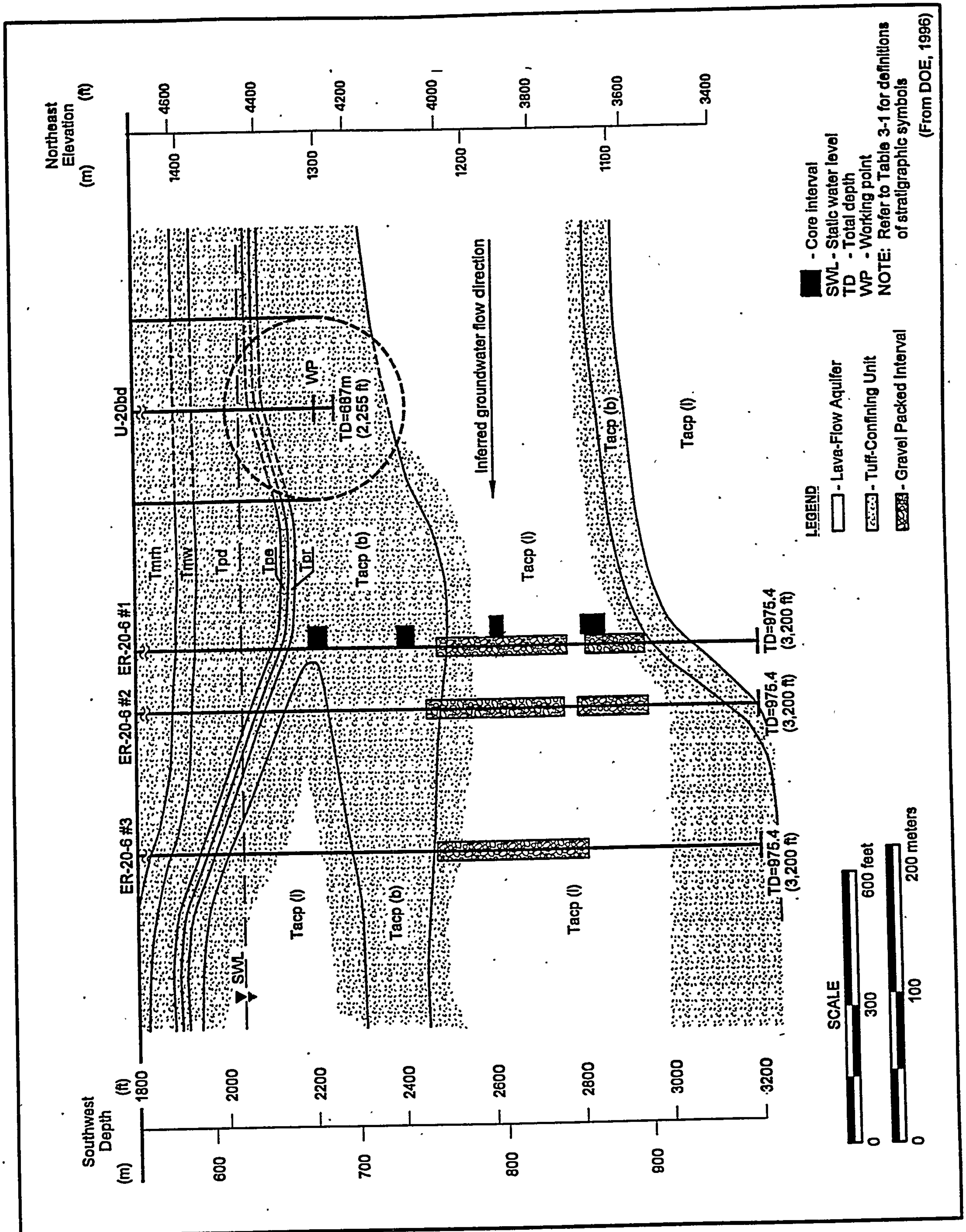


Figure 2-1
Hydrologic Cross Section Through Wells ER-20-6#3, #2, #1, and Emplacement Hole U-20bd (Southwest-Northeast)

the cores were examined at the drill site for lithologic information. The 65 core tubes were stored under secure conditions at the USGS Geologic Data Center and Core Library in Mercury, Nevada, pending geologic evaluation.

Core-recovery information is presented in Table 2-2. Additional information about the coring equipment and other data can be found in the BHI coring operations report (BHI, 1996).

Table 2-2
Conventional Cores Taken from Well ER-20-6#1

Core Number	**Cored Interval** meters (feet)	**Core Cut** meters (feet)	**Core Recovered** meters (feet)	**Stratigraphic Unit**	**Hydrogeologic Unit**[a]
1	673.3-678.8 (2,209-2,227)	5.5 (18)	5.0 (16.5)	Tacp[b]	TCU[c]
2	678.8-683.7 (2,227-2,243)	4.9 (16)	4.9 (16)	Tacp	TCU
3	731.5-740.7 (2,400-2,430)	9.1 (30)	9.1 (30)	Tacp	TCU
4	792.5-797.1 (2,600-2,615)	4.6 (15)	4.6 (15)	Tacp	LFA[d]
5	853.4-860.1 (2,800-2,822)	6.7 (22)	6.7 (22)	Tacp	LFA
6	860.1-869.3 (2,822-2,852)	9.1 (30)	9.1 (30)	Tacp	LFA

a Modified from Blankennagel and Weir (1973) and Laczniak *et al.* (1996).
b Calico Hills Formation, mafic-poor member. Stratigraphic nomenclature from Ferguson *et al.* (1994). See Table 3-2 for lithologic descriptions.
c Tuff confining unit.
d Lava-flow aquifer

3.0 Geology and Hydrogeology of Well ER-20-6#1 Cores

Well ER-20-6#1 is located within the Silent Canyon caldera complex (*Figure 1-1*), one of several calderas and caldera complexes within the southwestern Nevada volcanic field (Ferguson *et al.*, 1994). The volcanic rocks associated with the Silent Canyon caldera complex include bedded and nonwelded tuffs, welded ash-flow tuffs, and rhyolite lava flows. These rocks are cut by north- to north-northeast-trending, mostly down-to-the-west, high-angle normal faults related to Basin and Range extension (Byers *et al.*, 1976). Regional groundwater flow is generally to the south and southwest within aquifers formed by the fractured lava and welded ash-flow tuff units. Zeolitic nonwelded and bedded tuffs act as regional and local confining units (Blankennagel and Weir, 1973). Table 3-1 lists the stratigraphic, lithologic, and hydrogeologic units encountered at Well Cluster ER-20-6. For additional discussion of the local and regional geology and hydrology of Well Cluster ER-20-6, see the reports, *Completion Report for Well* ER-*20-6* (DOE, 1996) and *Drilling and Completion Criteria for Underground Test Area Operable Unit Well Cluster ER-20-6* (IT, 1995).

3.1 Stratigraphy and Lithology

The geologic units encountered in the Well ER-20-6 #1 cores belong to the mafic-poor member of the Calico Hills Formation. Rocks of the Calico Hills Formation were erupted from the Area 20 caldera, one of two known calderas of the Silent Canyon caldera complex. Beneath much of Areas 19 and 20, including the ER-20-6 site, this caldera-filling unit consists of a complex three-dimensional network of rhyolite lava flows and bedded and nonwelded tuffs (Drellack and Prothro, 1997).

The rocks sampled in the Well ER-20-6 #1 cores consist of several volcanic lithologies (Table 3-2), and are generally the same as those originally described using drill cuttings and geophysical logs (DOE, 1996). Bedded tuff was encountered in core #1 from 673.3 to 674.8 m (2209 - 2214 ft). Bedded tuff was also encountered in core #3 where it composes all of the core interval from 731.5 to 740.7 m (2400 - 2430 ft). Individual beds range in thickness from 3 to 30 cm (1 - 12 in.), and consist of various mixtures of zeolitic ash and coarser fragments of zeolitic pumice and nonwelded tuff. Angular fragments of devitrified welded tuff and lava up to 3 cm (1 in.) in size are common in many beds. Bedding contacts dip

Table 3-1
Stratigraphic, Lithologic, and Hydrogeologic Units Encountered at Well Cluster ER-20-6
(From DOE, 1996)

Stratigraphic Group	Stratigraphic[a] Unit	Symbol	Typical Lithology	Hydrogeologic[b] Unit
Quaternary/Tertiary Sediments				
Quaternary/Tertiary Sediments		QTa	Gravelly, sandy tuffaceous alluvium	Alluvial aquifer (unsaturated at this location)
Tertiary Volcanics				
Thirsty Canyon Group (Tt)	Trail Ridge Tuff	Ttt	Nonwelded to partially welded ash-flow tuff	Vitric-tuff aquifer (unsaturated at this location)
	Pahute Mesa Tuff	Ttp		
	Rocket Wash Tuff	Ttr	Nonwelded to moderately welded ash-flow tuff	
Volcanics of Fortymile Canyon (Tf)	Beatty Wash Formation	Tfb	Bedded tuffs, vitric	
	rhyolite of Chukar Canyon	Tfbr		
	rhyolite of Beatty Wash	Tfbw		
Timber Mountain Group (Tm)	Ammonia Tanks Tuff	Tma	Nonwelded to partially welded ash-flow tuff	
	mafic-poor Ammonia Tanks Tuff	Tmap		
	bedded Ammonia Tanks Tuff	Tmab	Bedded tuff, vitric	
	Rainier Mesa Tuff	Tmr	Nonwelded to densely welded ash-flow tuff	Welded-tuff and lava-flow aquifer (unsaturated at this location)
	mafic-rich Rainier Mesa Tuff	Tmrr		
	mafic-poor Rainier Mesa Tuff	Tmrp		
	rhyolite of Fluorspar Canyon	Tmrf	Bedded tuffs, zeolitized	Tuff confining unit (unsaturated at this location)
	tuff of Holmes Road	Tmrh		
	rhyolite of Windy Wash	Tmw		
Paintbrush Group (Tp)	rhyolite of Delirium Canyon	Tpd	Bedded tuff, zeolitized	Tuff confining unit (saturated)
	rhyolite of Echo Peak	Tpe		
	rhyolite of Silent Canyon	Tpr		
Volcanics of Area 20 (Ta)	mafic-poor Calico Hills Formation	Tacp(b)	Bedded tuff, zeolitized	
		Tacp(l)	Rhyolite lava flow	Welded-tuff and lava-flow aquifer (saturated)

a Ferguson *et al.*, 1994
b Modified from Blankennagel and Weir, 1973, and Laczniak *et al.*, 1996

Table 3-2
Detailed Lithologic Descriptions of Well ER-20-6 #1 Cores

Core No.	Depth Interval meters/(feet)	Lithology[a]	Stratigraphy
1	673.3 - 674.8 m (2209 - 2214 ft)	**Bedded Tuff:** Grayish-yellow (5Y 8/1); zeolitic; abundant pumice; rare felsic phenocrysts of feldspar and quartz; rare biotite; rare to common lithic fragments; dip of bedding ranges from 10 to 20 degrees.	mafic-poor Calico Hills Formation
1 / 2	674.8 - 683.7 m (2214 - 2243 ft)	**Nonwelded Tuff:** Grayish-yellow (5Y 8/4); zeolitic; rare to minor pumice; rare felsic phenocrysts of feldspar and quartz; rare biotite; rare to minor lithic fragments; subtle bedding in upper part.	mafic-poor Calico Hills Formation
3	731.5 - 740.7 m (2400 - 2430 ft)	**Bedded Tuff:** Mottled yellowish-gray (5Y 8/1) and moderate-orange-pink (10R 7/4) to 734.3 m (2409 ft), becoming mostly yellowish-gray (5Y 8/1) and conspicuously bedded below; zeolitic; rare to minor pumice; rare felsic phenocrysts of feldspar and quartz; rare biotite; mostly rare to minor lithic fragments, but containing abundant large lithic fragments up to 3 cm (1 in) in size from 737.0 to 737.6 m (2418 - 2420 ft); dip of bedding ranges from 10 to 20 degrees.	mafic-poor Calico Hills Formation
4	792.5 - 797.1 m (2600 - 2615 ft)	**Lava:** Light-brownish-gray (5YR 6/1); devitrified; rare felsic phenocrysts of feldspar and quartz; rare biotite; prominent, near vertical flow banding; minor vesicles less than 2 mm in size mostly aligned along fractures and flow banding.	mafic-poor Calico Hills Formation
5 / 6	853.4 - 866.9 m (2800 - 2844 ft)	**Lava:** Light-gray (N7) to medium-light-gray (N6), light-brownish-gray (5YR 6/1), and pale-red (10R 6/2); devitrified; rare felsic phenocrysts of feldspar and quartz; rare biotite; medium-angle (30 - 60 degrees) flow banding; conspicuous vesicles up to 2 cm (0.8 in.) in size, many aligned along fractures and flow banding, particularly prominent where flow banding is more contorted.	mafic-poor Calico Hills Formation
6	866.9 - 869.3 m (2844 - 2852 ft)	**Flow Breccia:** Mottled pale-red (10R 6/2), grayish-red (10R 4/2), and brownish-gray (5YR 4/1); devitrified; rare felsic phenocrysts of feldspar and quartz; rare biotite; clast-supported, with individual clasts of devitrified flow-banded lava up to 15 cm (6 in.) in size; conspicuous vesicles up to 5 cm (2 in.) in size, many aligned along fractures and flow banding, particularly prominent where flow banding is more contorted.	mafic-poor Calico Hills Formation

a Lithologic descriptions follow BN procedure NTS-GEO-003.

approximately 15 degrees. Zeolitic nonwelded tuff that has no distinct bedding was logged in core #2 from 674.8 to 683.7 m (2214 - 2243 ft).

Cores #4, #5, and the upper 6.7 m (22 ft) of #6 consist of devitrified rhyolite lava. This lava is typically flow banded and contains vesicles up to 2 cm (0.8 in.) in size. In many places the vesicles are elongated and aligned with fractures and flow-band contacts. Vesicles tend to be more abundant where flow banding is more pronounced, particularly below 861.4 m (2,826 ft). The lava appears to be somewhat frothy and less dense in places, with some apparent interstitial porosity and permeability.

Rhyolite lava in core #6 grades into flow breccia at approximately 866.9 m (2,844 ft). The flow breccia is completely clast-supported, consisting of angular clasts of devitrified, flow-banded rhyolite lava up to 15 cm (6 in.) in size. Vesicles are common, and are up to 5 cm (2 in.) in size. Like the overlying lava, the flow breccia appears to be somewhat frothy and less dense in places with some interstitial porosity and permeability.

3.2 Fractures

Fractures were observed in all lithologies, but as expected, most were recorded within the denser and more brittle rhyolite lava and flow breccia (Figure 3-1). The density of fractures observed in nonwelded and bedded tuff averages 0.8 fractures per vertical meter of core (0.3 fractures per vertical foot of core), but ranges from 0 to 4 fractures per vertical meter of core (0 to 3 fractures per vertical foot of core). This compares relatively well with an average of 1.3 fractures per vertical meter of core (0.4 fractures per vertical foot of core) observed in zeolitic bedded and nonwelded tuff from other core holes on Pahute Mesa (Drellack *et al.*, 1997).

Very little aperture was observed associated with fractures within the bedded and nonwelded tuffs in the Well ER-20-6 #1 cores, most fractures being completely closed or healed by zeolitic material. Where aperture was present, it was generally less than 0.1 millimeters (mm) in width and accounted for less than 50 percent of the fracture volume, the rest being closed or sealed by zeolitic material. These fracture attributes also compare well with observations from similar rocks from other cores holes on Pahute Mesa (Drellack *et al.*, 1997).

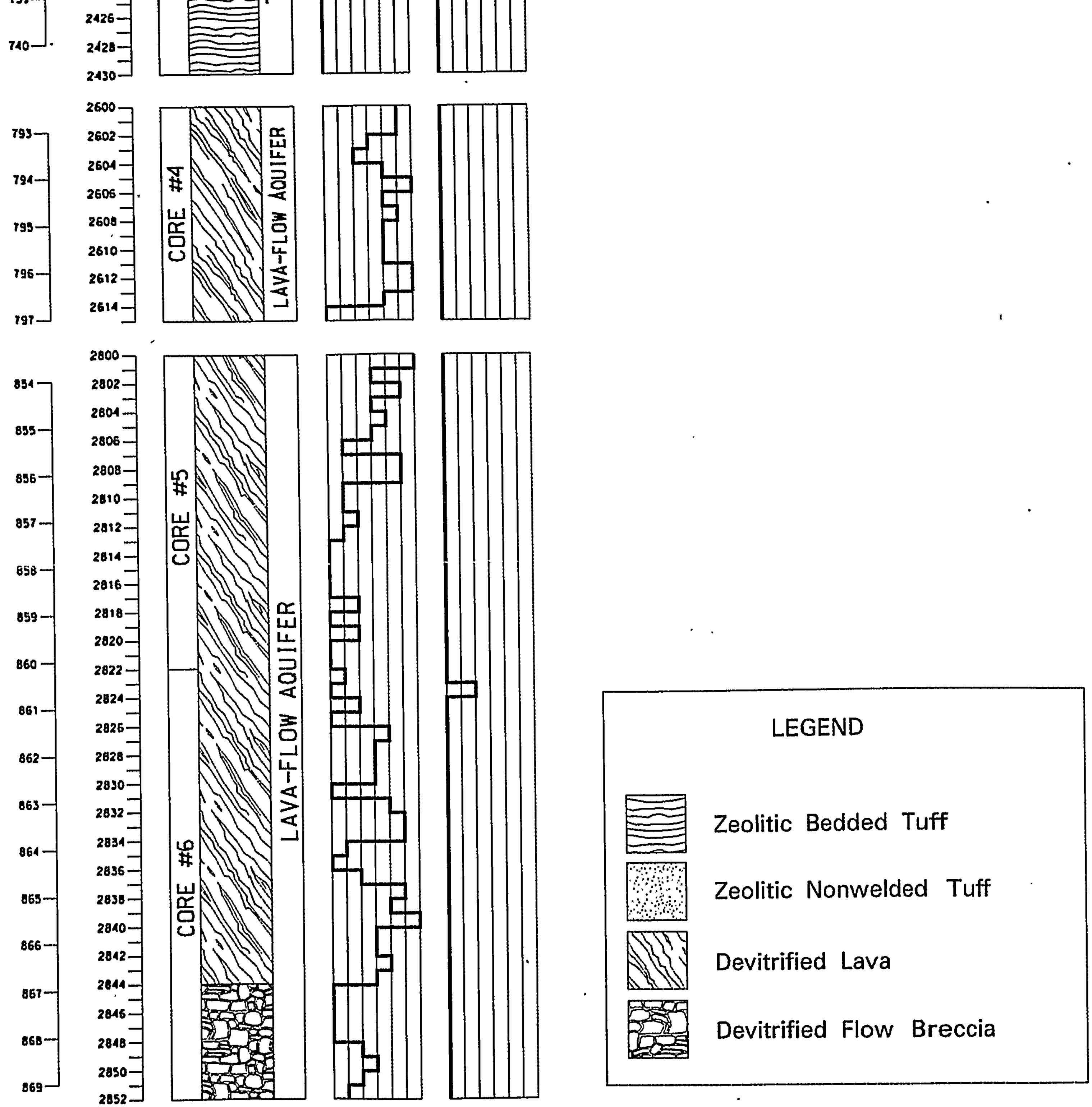
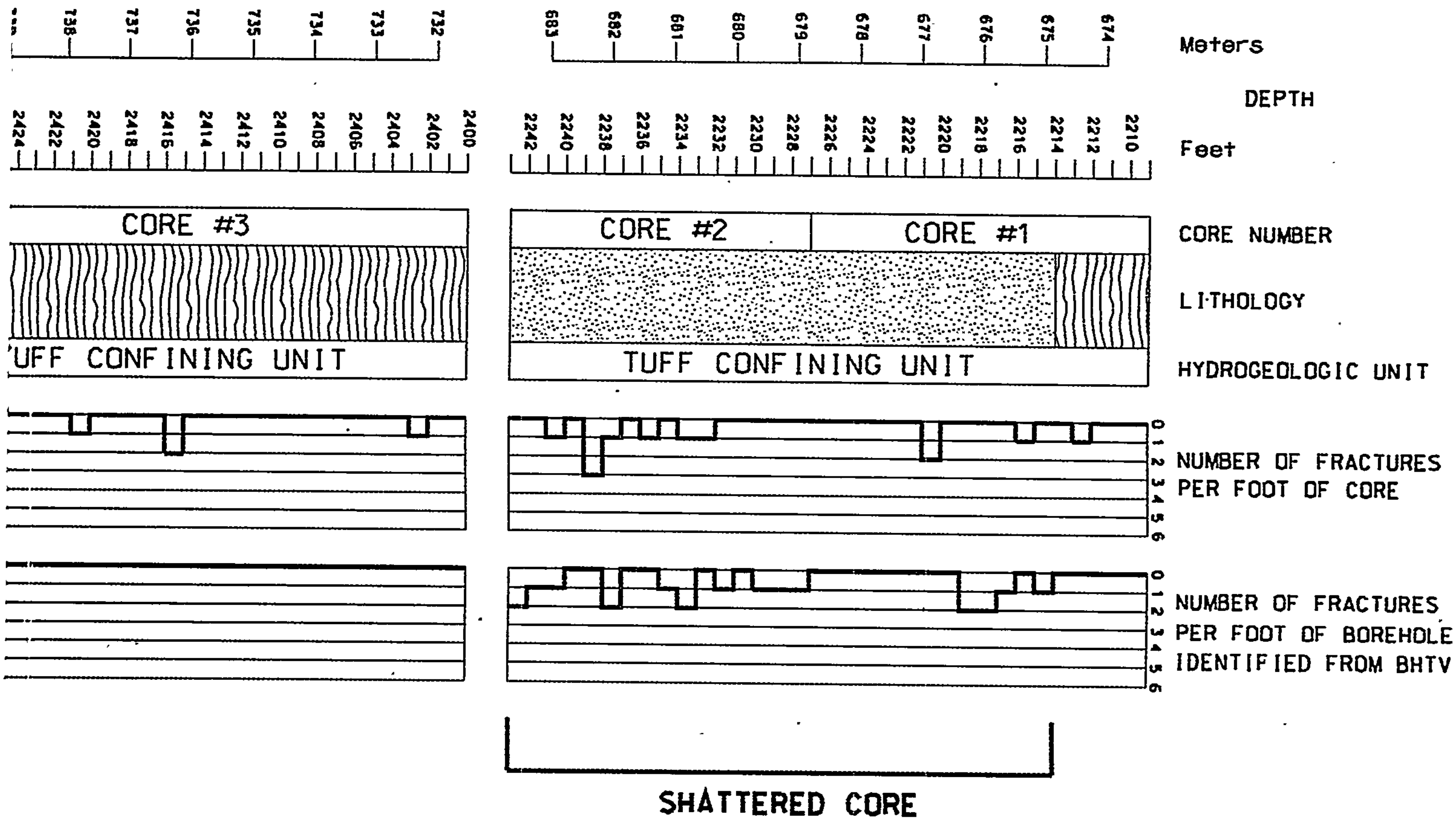


Figure 3-1

Fracture Log for
Well ER-20-6#1 Cores



Meters
DEPTH
Feet
CORE NUMBER
LITHOLOGY
HYDROGEOLOGIC UNIT
NUMBER OF FRACTURES PER FOOT OF CORE
NUMBER OF FRACTURES PER FOOT OF BOREHOLE IDENTIFIED FROM BHTV
CORE #1
CORE #2
CORE #3
TUFF CONFINING UNIT
'UFF CONFINING UNIT
SHATTERED CORE

Most of the fractures observed in the zeolitic rocks of cores #1, #2, and #3 were found within the interval of nonwelded tuff from 674.8 - 683.7 m (2214 - 2243 ft) sampled by cores #1 and #2. The core in this interval is also highly broken, having a shattered appearance that makes the recognition of natural fractures difficult. This shattering and fracture development is believed to be the result of the nearby BULLION explosion at U-20bd. This interval is very near the closest point in the borehole to the BULLION working point.

As expected, most fractures observed were in the lava and flow breccia (*Figure 3-1*). The density of fractures within the lava and flow breccia averages 8.5 fractures per vertical meter of core (2.6 fractures per vertical foot of core). This is a much higher average fracture density than determined for similar rocks in other core holes at Pahute Mesa, where average fracture density was determined to be 2.2 fractures per vertical meter of core (0.7 fractures per vertical foot of core) (Drellack *et al.*, 1997). The high density of fractures in the lava and flow breccia in the Well ER-20-6 #1 cores is reflective of the normal lithologic and fracture variability of rhyolite lava flows. In other words, it is probably the result of the small interval cored, much of which included the basal portion of an individual flow where fracturing is usually more pronounced (Warren, 1994).

Most of the fractures within the lava and flow breccia are short, irregular, discontinuous, and hairline in character. Fracture aperture is generally less than 0.5 mm in width. However, a wide range of aperture widths was observed, including up to 2 cm (0.8 in.). This is due to the alignment of vesicles with some fractures. The largest apertures (i.e., vesicles) were observed below 861.4 m (2,826 ft). Fractures are less than 50 percent open, with the most open fractures also occurring below 861.4 m (2,826 ft). Fracture aperture and openness compare relatively well with those observed in similar rocks from other core holes on Pahute Mesa (Drellack *et al.*, 1997). Although difficult to determine by visual observation, the vesicles did not appear to be well interconnected. Thin coatings of what appeared to be manganese-oxide were the only secondary mineralization observed associated with fractures in the lava and flow breccia, and are most common in core #4 (792.5 - 797.1 m [2,600 - 2,615 ft]). Some fractures were observed to offset flow banding, but no slickensides were observed along fracture surfaces.

A Borehole Televiewer log (BHTV) was run in Well ER-20-6#1 to determine fracture orientations. Preliminary field analysis of the log showed fractures that generally strike N35°E above about 667.5 m (2,190 ft) depth and N75°W below (DOE, 1996). Based on observations in nearby holes, N35°E was the expected structural strike, while the N75°W strike seems anomalous. The origin of the anomalous fracture strike is currently unknown, but a similar change in fracture orientations was observed in Well ER-20-5#1 (Drellack, *et al.*, 1997). The BHTV shows most fractures within the Well ER-20-6#1 core intervals dipping greater than 30 degrees. This is consistent with fracture dips measured in the cores.

The distribution of fractures within nonwelded and bedded tuff determined from the BHTV compares relatively well with that observed in the ER-20-6 #1 core (*Figure 3-1*). However, the BHTV showed several fractures that were not observed in the core. This is probably because these fractures are within the highly broken portions of cores #1 and #2 where the recognition of natural fractures in the cores is much more difficult.

The BHTV for Well ER-20-6 #1 showed only two fractures within the lava and flow breccia. This is probably due to the discontinuous and hairline nature of many of the fractures. Such fractures probably do not result in continuous planar borehole irregularities (breakouts) that the BHTV acoustic signal can detect.

3.3 Hydrogeology

The zeolitic bedded and nonwelded tuffs encountered in cores #1, #2, and #3 form typical tuff confining units. These relatively low density rocks usually support very few fractures, and thus tuff confining units usually have low transmissivity values.

The lava flow and flow breccia lithologies seen in cores #4, #5, and #6 form lava-flow aquifers. Lava-flow aquifers are believed to be major conduits for groundwater flow beneath Pahute Mesa (Blankennagel and Weir, 1973). Due to the dense, brittle nature of lava and flow breccia, lava-flow aquifers are usually fractured and therefore transmissive. However, in the Well ER-20-6 #1 cores, many of the fractures observed in lava and flow breccia are irregular and discontinuous, with little aperture and openness. However, the rocks contain vesicles and appear to have some interstitial porosity and permeability. Therefore, with respect to the Well ER-20-6 #1 core only, groundwater flow within these lava-flow aquifers is probably through a complex network of fractures, vesicles, and interstitial permeability.

Hydrostratigraphically, all the cores were taken within the upper portion of the Calico Hills Zeolitic Composite Unit (Drellack and Prothro, 1997). This hydrostratigraphic unit, established for the Pahute Mesa modeling effort, consists of a complex three-dimensional network of intercalated lava-flow aquifers and tuff confining units. The Calico Hills Zeolitic Composite Unit is present beneath most of eastern and central Area 20. It is estimated to be 1,300 m (4,300 ft) thick at Well Cluster ER-20-6 (Drellack and Prothro, 1997).

This page intentionally left blank.

4.0 Preservation of Well ER-20-6#1 Cores

The cores recovered from Well ER-20-6#1 are a valuable resource, and if handled properly will be able to provide many investigators with material for measurement and testing of rock properties and pore water characteristics. To make the cores more accessible and easier to handle, and to help preserve their natural moisture, it was decided to seal the cores in a proven core preservation material after they were examined and documented.

4.1 As-Received Core Condition

The cores were recovered in 9.1 m (30 ft) aluminum casings, then cut at the drill site into 0.6 m (2 ft) lengths. The ends of the casing segments were capped with heavy black rubber caps sealed onto casings with metal hose clamps. Depth intervals were marked on the outside of the casings. The casings were stored in heavy-duty 76.2 cm (30 in.) cardboard boxes, two to a box. Each two-foot casing segment with core weighed approximately 20 to 23 kilograms (45 to 50 pounds). Most of the cores appeared damp when their sleeves were opened, and free water dripped from some. Some of the cores were slipped from the casings in one or two pieces, while others were fractured and were removed only after much jarring and rapping on the casing with a hammer.

4.2 Core Preservation Method

The choice of core-preservation method was greatly influenced by the size and weight of the cores. The standard NTS method, in which samples are preserved in several layers of aluminum foil and beeswax, was considered inappropriate because the wax coating would be easily damaged by the weight of the core. ProtecCore®, a laminate of aluminum, nylon, and plastic, was selected as the preservation material because it is an industry standard for rock preservation and is relatively easy to use (see Appendix A for the manufacturer's information about ProtecCore®).

ProtecCore® laminate is sold as a flattened tube (sealed on the sides) 28 centimeters (11 in.) wide on 61-m (200-ft) long rolls. After a core segment was selected for preservation and measured, the appropriate length of ProtecCore® was cut from the roll and sealed at one end using a heat-sealer. The bag thus formed was labeled with the hole name, depth interval (in feet), date, and initials of the packager. When photography and descriptions of a segment of core was completed, the core was covered in at least three wraps of plastic film ("food film"), and the ends were taped. The wrapped core was then inserted into the bag and the other end of the ProtecCore® bag was heat-sealed, leaving a small hole for insertion of a tube connected to a small vacuum pump. As much air as possible was evacuated from the package before the remaining opening was sealed.

After about half the core had been processed, it was found that abrasion along sharp corners on the cores and some loose particles had caused small "pin holes" to form in some of the ProtecCore® bags. This problem was confined to the longer core segments, and was due to their greater weight. Where observed, the holes were repaired with tape. However, due to time constraints and the lack of enough laminate to re-package these cores and preserve the remaining cores, no attempt was made to re-seal the cores. From that point the core segments were wrapped in a layer of 3-mm-thick closed-cell foam (in addition to the plastic film) before they were inserted into the laminate bags and sealed. Thick paper padding was then added to all the core boxes to further protect the laminate. Foam padding was also taped to the outside of some of the laminate bags as added protection from sharp core edges. The addition of the foam and paper padding provided the needed protection of the laminate to preserve the seal on the longer, heavier core segments.

Small core fragments were not preserved with ProtecCore®. These smaller pieces were placed in labeled plastic bags and taped shut. The original plan was to preserve all core pieces greater than approximately 0.1 m (0.4 ft), and transfer other material into plastic bags. However, after processing approximately 75 percent of the core, it was determined that there might not be enough ProtecCore® to preserve all desired pieces. When the laminate began to run low, a few of the longer pieces in the last few meters of core #6 were wrapped in several layers of plastic film and covered with a layer of closed-cell foam.

After the cores were packaged, they were returned to their original cardboard boxes. The box labels were updated if necessary to reflect the correct depth interval of cores stored within. The preserved and unpreserved cores were placed together in the appropriately labeled box, with adequate padding to protect the ProtecCore® packages from abrasion. Due to the weight of the core, the boxes are currently stacked only one deep to prevent damage to the core packages.

4.3 Results and Lessons Learned

Eighty-two samples up to 0.6 m (2 ft) long were preserved in ProtecCore® packages. Eleven samples 0.2 to 0.6 m (0.7 to 2 ft) long were wrapped in plastic film with a layer of 3-mm-thick closed-cell foam around them for protection. The remainder of the core material, consisting of fragments less than 0.2 m (0.5 ft) in length, were sealed in plastic bags. Approximately 27.1 linear meters (89 ft) of core from Well ER-20-6#1 now reside in ProtecCore® envelopes. Approximately 12.2 m (40 ft) of core was left unpreserved. All core material was placed in order of hole depth in 37 padded heavy-duty cardboard boxes for long-term storage at the USGS Geologic Data Center and Core Library in Mercury, Nevada.

See Appendix B for a list of all core samples documented from Well ER-20-6#1. This list indicates for each sample the depth interval, packaging method (ProtecCore®, plastic bag, film and foam wrap), lithology, and hydrostratigraphic unit. Table 4-1 summarizes by lithology the total length of cores processed (preserved and unpreserved), listing the percentage of each lithology preserved. The number of individual preserved samples is also included.

Several lessons were learned from the core preservation process. ProtecCore® provides a reasonable alternative to the beeswax core preservation technique, and may be the only option when preserving large diameter core. The material is chemically inert, light-weight, versatile, and easy to work with. However, it is relatively expensive and cores sealed with ProtecCore® must be handled with care to avoid compromising the integrity of the material. Padding, both inside and out, may be necessary to help ensure air-tight preservation, particularly when preserving heavy core segments. These extra steps necessary to ensure the proper preservation of large diameter core can greatly increase time and manpower requirements.

Table 4-1
Well ER-20-6#1 Core Preservation Summary

Lithology [1], Depth Interval Meters (feet)	Packaging [2]	Length of Core Meters (feet)	Percent
Zeolitic, bedded tuff 673.30 - 674.83 (2,209 - 2,214)	ProtecCore® (6)	1.5 (4.8)	96.0
	Unpreserved	0.06 (0.2)	4.0
Zeolitic, nonwelded tuff 674.83 - 683.67 (2,214 - 2,243)	ProtecCore® (22)	5.0 (16.25)	59.1
	Unpreserved	3.4 (11.25)	40.9
Zeolitic, bedded tuff 731.52 - 740.66 (2,400 - 2,430)	ProtecCore® (21)	8.2 (26.8)	89.3
	Unpreserved	1.0 (3.2)	10.7
Devitrified lava 792.48 - 797.05 (2,600 - 2,615)	ProtecCore® (11)	3.1 (10.3)	70.1
	Unpreserved	1.3 (4.4)	29.9
Devitrified lava 853.44 - 866.85 (2,800 - 2,844)	ProtecCore® (19)	8.3 (27.2)	61.8
	Unpreserved	5.1 (16.8)	38.2
Devitrified flow breccia 866.85 - 869.50 (2,844 - 2,852.7)	ProtecCore® (3)	1.2 (4.1)	47.1
	Unpreserved	1.4 (4.6)	52.9

1 All samples are mafic-poor Calico Hills Formation.
2 The number in parentheses indicates the number of preserved samples in this lithologic interval.

5.0 Summary and Recommendations

Conventional cores from Well ER-20-6#1 were processed and analyzed to confirm previous lithologic descriptions, record fracture characteristics, and preserve the core for long-term air-tight storage. A total of 39.5 m (129.5 ft) of 12.7 cm (5 in.) core was processed and analyzed. Geologic analysis showed that the lithologic units sampled included zeolitic bedded and nonwelded tuff and devitrified rhyolite lava and flow breccia. These lithologic units are generally the same as those originally described for the well using drill cuttings and geophysical logs. Fracture characteristics observed in the cores are generally consistent with characteristics observed in other Pahute Mesa core holes. However, the fracture density observed in rhyolite lava in Well ER-20-6#1 cores is considerably higher than that observed in rhyolite lava from other Pahute Mesa core holes.

Approximately 27.1 m (89 ft) of core from Well ER-20-6#1 was preserved in ProtecCore®, a laminate of aluminum, nylon, and plastic, designed to provide air-tight storage of core samples. The remaining core, mostly fragments and pieces less than 0.2 m (0.5 ft) in length, were sealed in plastic bags. All core material was placed in order of hole depth in 37 padded, heavy-duty cardboard boxes for long-term storage at the USGS Geologic Data Center and Core Library in Mercury, Nevada.

The weight of large-diameter core (i.e., > 7.6 cm [3 in.]) makes handling of the core difficult and time consuming, particularly when attempting to provide air-tight long-term preservation. Therefore, it is recommended that if air-tight preservation is required, cores no larger than 7.6 cm (3 in.) in diameter be taken. If larger cores are necessary, extra care should be taken in handling preserved core segments. This includes the use of extra padding to help ensure that the preservation material is adequately protected.

This page intentionally left blank.

6.0 References

Baker Hughes INTEQ, 1996. *Air Coring Completion Report for ERD-DOE ER-20-6#1 Nevada Test Site*, Bakersfield, CA.

Bechtel Nevada, 1995. *Description of Rock Samples*, Geology/Hydrology Procedure NTS-GEO-003, Rev. 1, Mercury, NV.

BHI, see Baker Hughes INTEQ.

Blankennagle, R.K., and J.E. Weir, 1973. *Geohydrology of the Eastern Part of Pahute Mesa, Nevada Test Site, Nye County, Nevada*, U.S. Geological Survey Professional Paper 712-B.

BN, See Bechtel Nevada.

Byers, Jr., F.M., W.J. Carr, P.P. Orkild, W.D. Quinlivan, and K.A. Sargent, 1976. *Volcanic Suites and Related Cauldrons of Timber Mountain-Oasis Valley Caldera Complex, Southern Nevada,* U.S. Geological Survey Professional Paper 919.

DOE, see U.S. Department of Energy.

Drellack, Jr., and L.B. Prothro, 1997. *Descriptive Narrative for the Hydrogeologic Model of Western and Central Pahute Mesa Corrective Actions Units.* Interim documentation report for the UGTA project, submitted in support of the FY 1997 Pahute Mesa hydrogeological modeling effort, Bechtel Nevada, Las Vegas, NV.

Drellack, Jr., S.L., L.B. Prothro, K.E. Roberson, B.A. Schier, and E.H. Price, 1997. *Analysis of Fractures in Volcanic Cores From Pahute Mesa, Nevada Test Site.* Report No. DOE/NV/11718-160.

Ferguson, J.F., A.H. Cogbill, and R.G. Warren, 1994. "A Geophysical-Geological Transect of the Silent Canyon Caldera Compels, Pahute Mesa, Nevada.

IT, see IT Corp.

IT Corp., 1995. *Drilling and Completion Criteria for Underground Test Area Operable Unit Well Cluster ER-20-6,* DOE/NV/10972-129. Las Vegas, NV.

IT Corp., 1996. *Criteria for the Forced-Gradient Experiment at the BULLION Event Location.* Las Vegas, NV.

IT Corp., 1997. *BULLION Forced Gradient Experiment Implementation Plan.* Report No. ITLV/10972-195. Las Vegas, NV.

Laczniak, R.J., J.C. Cole, D.A. Sawyer, and D.A. Trudeau, 1996. *Hydrogeologic Controls on Groundwater Flow at the Nevada Test Site, Nye County, Nevada.* U.S. Geological Survey Water-Resources Investigation Report 96-4109.

U.S. Department of Energy, 1996. Draft, *Completion Report for Well ER-20-6.* Las Vegas, NV.

Warren, R.G., 1994. *Structural Elements and Hydrogeologic Units of the Southwestern Nevada Volcanic Field.* Informal Los Alamos National Laboratory technical report prepared for the Underground Test Area project, January, 1994.

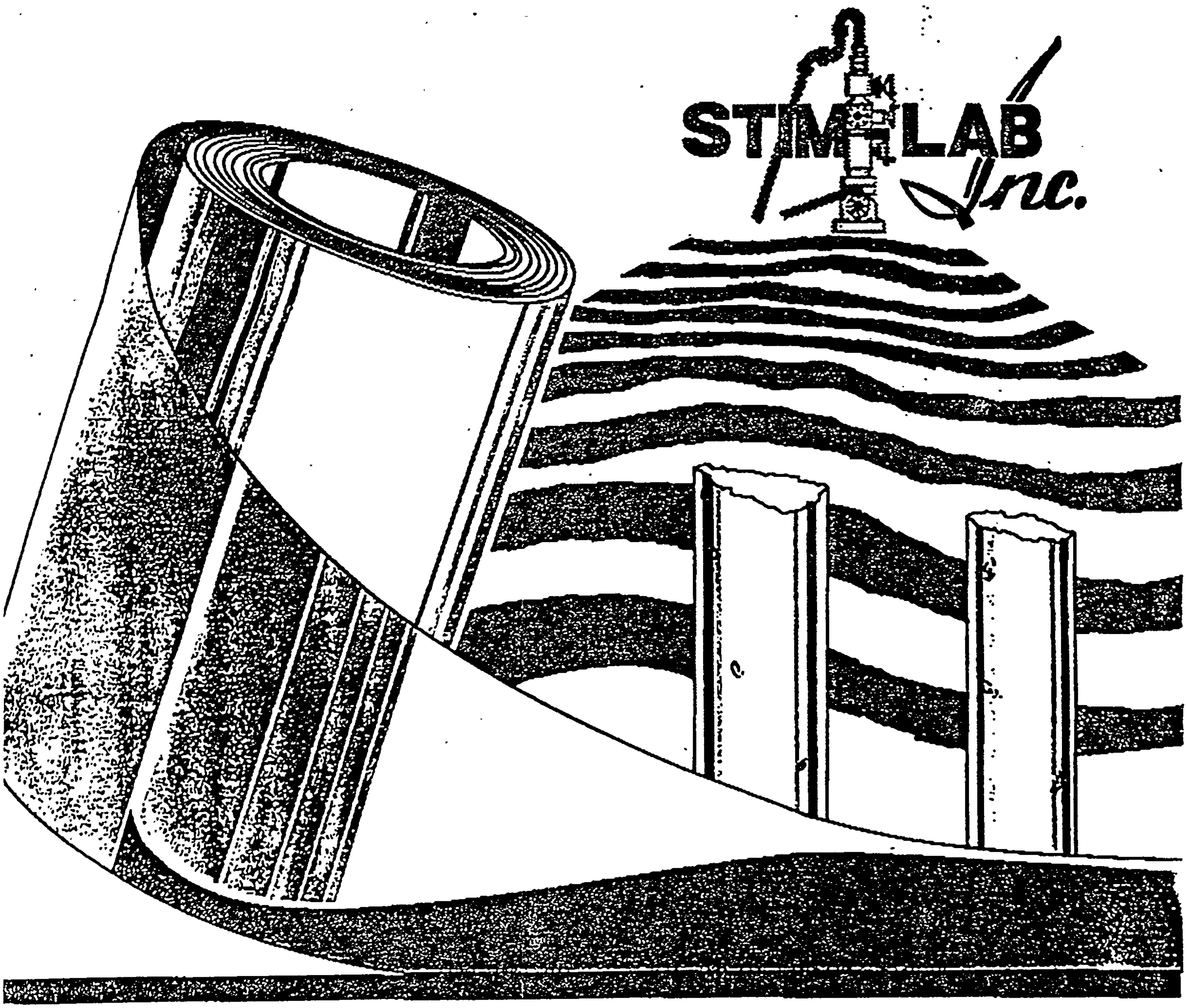
Appendix A

Manufacturer's Information for ProtecCore®

Stronger than ever!

ProtecCore–

with the new and improved strengthening process...biaxial nylon.



Stronger than ever.
Chemically inert. Economical. And very easy to use.

Now you can protect your costly core samples with ProtecCore, a patented, high performance core preservation method that far outperforms other packaging methods, allowing you to transfer samples from wellsite to laboratory with a minimum alteration of core properties. It's easy to use and you can even write on it, recording important data for later analysis of your preserved core. And it's available in compact, easy to handle rolls.

Why protect cores?

An unprotected core can undergo significant changes in saturation and fluid chemistry during shipping, handling, and storage. These changes can drastically affect the accuracy of laboratory analyis results. By preserving the sample, the laboratory data will more closely reflect actual reservoir conditions for an extended period of time. And that makes the most of your investment in time and money spent retrieving the sample.

How ProtecCore works

ProtecCore consists of six layers of different materials, each designed to add a measure of strength, durability, fluid containment or chemical inertness to the final package. The innermost layer, which contacts the core, is Barex® film – a chemically resistant material. Next is a layer of biaxial nylon, a material renowned for its strength and flexibility in a variety of packaged products. Next is a layer of aluminum foil, two layers of low-density polyethylene and a layer of polyester – to give ProtecCore even more strength.

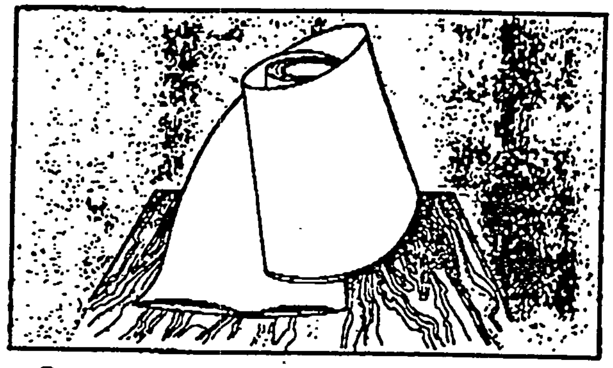
By surrounding and sealing your core sample with ProtecCore, you have a package with high oxygen and water vapor barrier properties that is resistant to chemical attack by fluids in the core such as brine, crude oil and drilling mud. Furthermore, the manner in which ProtecCore is sealed (see "How to preserve with ProtecCore") prevents oxygen and water vapor transmission at package edges.

Field and lab tests

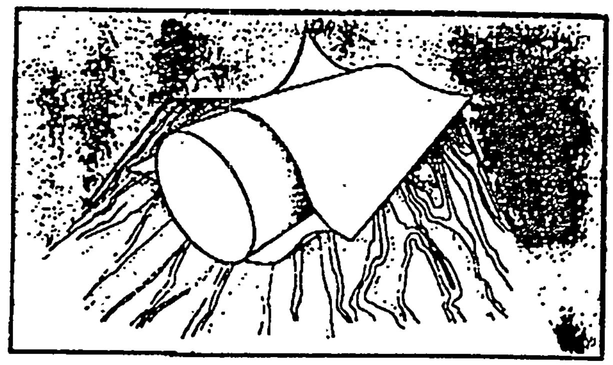
To evaluate ProtecCore's superiority over other core preservation and protection methods, look at the results of extensive laboratory and field tests.

In both tests, ProtecCore was compared to two widely used methods for protecting core samples. One was a package made up of plastic wrap + aluminum foil + two B-60 seal peel coat. (Saran Wrap® was used in the lab test and Reynolds 904® in the field.) The other utilized an all-purpose plastic wrap + aluminum foil + one B-60 seal peel coat. The foil layers of both packages were carefully sealed by crimping before dipping into the seal peel to ensure the best possible protection characteristics these methods can offer.

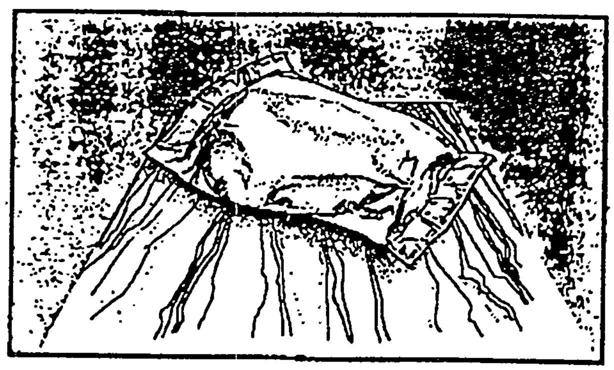
How to preserve with ProtecCore:



1. Prewrap core in a liberal amount of transparent Barex® film, then tape the ends. Slip prewrapped core sample into tubular laminate that is about 8" longer than the core.



2. Heat-seal both ends of the tube. (We recommend using an electric constant heat sealer, such as those made by the Clamco Corporation; although, a simple clothes iron can be used.) A 1" wide seal is recommended.



3. Your core is now preserved. To prevent mechanical damage to the preserved core during shipping, you should further wrap the core with plastic bubble wrap or other shock absorbing material.

Proven performance

Here are the results of those tests:

Table 1

LAB	Time in Storage		
	3 mos.	12 mos.	24 mos.
Saran Wrap® + aluminum foil + 2 seal peel coats	Saran Wrap® has become brittle.	Numerous holes in the Saran Wrap®.	Many holes in the Saran Wrap®, as well as some holes in the foil.
Generic wrap + aluminum foil + 1 seal peel coat	Many small holes in plastic wrap and a few small holes in the foil.	A few holes in the foil. Plastic wrap disintegrating.	Holes in foil. Plastic wrap disintegrating.
ProtecCore	No deterioration evident.	No deterioration evident.	No deterioration evident.
FIELD			
Reynold 904® + aluminum foil + 2 seal peel coats	One small puncture in the plastic wrap and foil.	Small rips and holes in plastic wrap. Foil badly degraded.	Plastic wrap is very brittle and punctured. Foil very badly degraded.
Generic wrap + aluminum foil + 1 seal peel coat	Very small holes in both foil and plastic wrap.	Small rips and holes in plastic wrap. Foil is badly degraded.	Plastic wrap is brittle and punctured. Foil is badly degraded.
ProtecCore	No deterioration evident.	No deterioration evident.	No deterioration evident.

Table 2

Preservation Method	Percent of original water lost during storage*		
	3 mos.	12 mos.	24 mos.
Saran Wrap® + aluminum foil + 2 seal peel coats	20	35	50
Generic wrap + aluminum foil + 1 seal peel coat	30	25	80
ProtecCore	2	5	2

* The influence of experimental error on this data is approximately ±5%.

Even cases involving short term storage saw some deterioration in packaging systems other than ProtecCore. And, as can be seen in Table 2, the measured water content changed considerably with time...except in samples preserved by ProtecCore.

For the field test, four-inch diameter cores were placed in ProtecCore and the two other packaging systems for storage. In the laboratory, homogeneous Berea sandstone samples were saturated with an oil-water mixture then halved. Initial water saturation measurements were made using one half, and the other half of each sample was preserved then placed in storage. After a period of time, samples representing each of the preservation methods were removed from storage, visually inspected, then analyzed for water saturation.

ProtecCore™

ProtecCore™ is a highly effective laminate material that preserves cores for laboratory analysis. Core samples are most valuable when they represent actual well conditions. ProtecCore™ helps prevent changes in the volume and chemistry of fluids and protects against contamination and desiccation of the core during shipping, handling and storage. By preserving the sample in ProtecCore™, laboratory data can closely reflect actual reservoir conditions for an extended period of time. And that makes the most of your investment in time and money spent retrieving the sample.

ProtecCore™ Stronger than ever with Biaxial Nylon!

ProtecCore™ consists of six layers of highly effective materials, each used to add strength, durability, fluid containment or chemical inertness to the final heat sealed package. The innermost layer, which contacts the core, is Barex® film (Acrylonitrile methyl acrylate copolymer), a chemically resistant material. Next is a layer of biaxial nylon, renowned for its strength, strong enough to package the military's "meals ready to eat". Next is a layer of nonporous and opaque aluminum foil, two layers of low-density polyethylene and a layer of polyester, to give ProtecCore™ even more strength. ProtecCore™ is tubular and is sold in rolls 11 inches wide and 200 feet in length.

By surrounding and sealing your core sample with ProtecCore™ you will take advantage of its high oxygen and water vapor barrier properties that are also resistant to chemical attack by fluids in the core such as brine, crude oil and drilling mud. Furthermore, ProtecCore™ is heat sealed, thus preventing oxygen and water vapor transmission at the package edges.

How well does ProtecCore work?

To evaluate ProtecCore's™ superiority as a core preservation and protection method, extensive tests have been documented.

Cores were logged and preserved as quickly as possible once removed from the borehole. The entire core was preserved. Intervals ranging from 50-100 cm were pre-wrapped in Barex®, secured at the ends with rubber bands, and slid into a length of ProtecCore™. ProtecCore™ is a multi-laminated tube of aluminum foil that is heat sealed. The packages ranged in weight from 500 to 1500 g. For the purpose of tracking changes over time, the sample weights were plotted for more than 650 days. Project success depended on the ability of ProtecCore™ to isolate the rock cores from atmospheric CO_2. ProtecCore™ preserved pore fluids successfully and was superior to other core preservation methods.[1]

Source: **Stim-Lab, Inc.,** 7406 N. 81 Highway, Duncan, OK 73534

1. Davidson, Gregg R. "Geochemical and isotopic investigation of the rate and pathway of fluid flow in partially-welded fractured unsaturated tuff." Ph.D. dissertation, Department of Hydrology and Water Resources, The University of Arizona, Tucson, Arizona (1995).

Appendix B

List of Well ER-20-6#1 Core Samples

Table B-1

Well ER-20-6#1 Core Samples Logged and Preserved (Page 1 of 9)

Box [1]	Sample Interval [2] Meters (Feet)	Package Type [3]	Lithology [4]	Hydrogeologic Unit
1	673.30 - 673.60 (2,209.0 - 2,210.0)	P*	Zeolitic bedded tuff	Tuff Confining Unit
	673.45 (2,209.5)	B frags		
	673.60 (2,210.0)	B frags		
	673.60 - 673.97 (2,210.0 - 2,211.2)	P*		
	673.97 - 674.22 (2,211.2 - 2,212.0)	P		
2	674.22 - 674.28 (2,212.0 - 2,212.2)	B frags		
	674.28 - 674.43 (2,212.2 - 2,212.7)	P		
	674.43 - 674.64 (2,212.7 - 2,213.4)	P		
	674.64 (2,213.4)	B frags		
	674.64 - 674.77 (2,213.4 - 2,213.8)	P*		
	674.77 - 674.83 (2,213.8 - 2,214.0)	B frags		
	674.83 - 674.86 (2,214.0 - 2,214.1)	B frags	Zeolitic nonwelded tuff	
	674.89 - 675.10 (2,214.2 - 2,214.9)	P		
	675.10 - 675.13 (2,214.9 - 2,215.0)	B frags		

See notes at end of table.

Table B-1
Well ER-20-6#1 Core Samples Logged and Preserved (page 2 of 9)

Box [1]	Sample Interval [2] Meters (Feet)	Package Type [3]	Lithology [4]	Hydrogeologic Unit
3	675.13 - 675.44 (2,215.0 - 2,216.0)	P	Zeolitic nonwelded tuff	Tuff Confining Unit
	675.44 - 675.47 (2,216.0 - 2,216.1)	B frags		
	675.47 - 675.86 (2,216.1 - 2,217.4)	P		
	675.86 (2,217.4)	B frags		
	675.86 - 676.05 (2,217.4 - 2,218.0)	P		
	676.05 - 676.20 (2,218.0 - 2,218.5)	P		
	676.20 - 676.35 (2,218.5 - 2,219.0)	B frags		
4	676.32 - 676.56 (2,218.9 - 2,219.7)	P*		
	676.56 - 676.66 (2,219.7 - 2,220.0)	BR (re-bagged)		
	676.66 - 676.80 (2,220.0 - 2,220.5)	P		
	676.75 - 677.27 (2,220.3 - 2,222.0)	B frags		
	676.75 - 676.96 (2,220.3 - 2,221.0)	B frags		
	677.05 - 677.27 (2,221.3 - 2,222.0)	B frags		
	677.27 - 677.45 (2,222.0 - 2,222.6)	B frags		
5	677.45 - 677.66 (2,222.6 - 2,223.3)	P		
	677.66 - 677.88 (2,223.3 - 2,224.0)	B frags		
	677.88 - 678.33 (2,224.0 - 2,225.5)	B frags (2 bags)		
	678.33 - 678.79 (2,225.5 - 2,227.0)	No core		

See notes at end of table.

Table B-1
Well ER-20-6#1 Core Samples Logged and Preserved (page 3 of 9)

Box [1]	Sample Interval [2] Meters (Feet)	Package Type [3]	Lithology [4]	Hydrogeologic Unit
6	678.79- 679.09 (2,227.0 - 2,228.0)	P	Zeolitic nonwelded tuff	Tuff Confining Unit
	679.09 - 679.34 (2,228.0 - 2,228.8)	P*		
	679.34 - 679.70 (2,228.8 - 2,230.0)	P		
	679.70 - 679.92 (2,230.0 - 2,230.7)	P		
7	679.92 - 680.07 (2,230.7 - 2,231.2)	B frags		
	680.07 - 680.19 (2,231.2 - 2,231.6)	B frags		
	680.19 - 680.13 (2,231.6 - 2,232.0)	P		
	680.13 - 680.44 (2,232.0 - 2,232.4)	P*		
	680.44 - 680.62 (2,232.4 - 2,233.0)	B frags		
	680.62 - 680.71 (2,233.0 - 2,233.3)	B frags		
	680.71 - 680.83 (2,233.3 - 2,233.7)	P		
	680.83 - 680.92 (2,233.7 - 2,234.0)	P		
8	680.92 - 681.26 (2,234.0- 2,235.1)	P(*?)		
	681.26 - 681.35 (2,235.1 - 2,235.4)	B frags		
	681.35 - 681.41 (2,235.4 - 2,235.6)	B frags		
	681.41 - 681.53 (2,235.6 - 2,236.0)	P		
	681.53 - 681.62 (2,236.0 - 2,236.3)	B/F		
	681.62 - 682.14 (2,236.3- 2,238.0)	P*		

See notes at end of table.

Table B-1
Well ER-20-6#1 Core Samples Logged and Preserved (page 4 of 9)

Box [1]	Sample Interval [2] Meters (Feet)	Package Type [3]	Lithology [4]	Hydrogeologic Unit
9	682.14 - 682.36 (2,238.0 - 2,238.7)	P	Zeolitic nonwelded tuff	Tuff Confining Unit
	682.36 - 682.63 (2,238.7 - 2,239.6)	B frags		
	682.63 - 682.75 (2,239.6 - 2,240.0)	B frags		
	682.75 - 682.84 (2,240.0 - 2,240.3)	B frags		
	682.84 - 682.97 (2,240.3 - 2,240.7)	P		
10	682.97 - 683.18 (2,240.7 - 2,241.4)	B frags		
	683.18 - 683.29 (2,241.4 - 2,241.75)	P		
	683.06 - 683.61 (2,241 - 2,242.8)	BR frags		
	683.45 - 683.67 (2,242.3 - 2,243.0)	BR frags (part of interval above)		
Interval not cored (683.67 - 731.52 m [2,243 - 2,400 ft])				
11	731.52 - 732.13 (2,400.0 - 2,402.0)	BR	Zeolitic bedded tuff	Tuff Confining Unit
	732.13 - 732.74 (2,402.0 - 2,404.0)	P*		
12	732.74 - 733.35 (2,404.0 - 2,406.0)	P*		
	733.35 - 733.96 (2,406.0 - 2,408.0)	P		
13	733.96 - 734.32 (2,408.0 - 2,409.2)	P*		
	734.32 - 734.57 (2,409.2- 2,410.0)	P*		
	734.57 - 735.18 (2,410.0 - 2,412.0)	P*		

See notes at end of table.

Table B-1
Well ER-20-6#1 Core Samples Logged and Preserved (page 5 of 9)

Box [1]	Sample Interval [2] Meters (Feet)	Package Type [3]	Lithology [4]	Hydrogeologic Unit
14	735.18 - 735.39 (2,412.0 - 2,412.7)	P*	Zeolitic bedded tuff	Tuff Confining Unit
	735.39 (2,412.7)	B frags		
	735.39 - 735.79 (2,412.7 - 2,414.0)	P*		
	735.79 - 736.21 (2,414.0 - 2,415.4)	P*		
	736.21 - 736.40 (2,415.4 - 2,416.0)	P		
15	736.40 - 736.55 (2,416.0 - 2,416.5)	P		
	736.55 - 737.01 (2,416.5 - 2,418.0)	P (repaired)		
	737.01 - 737.25 (2,418.0 - 2,418.8)	P*		
	737.25 - 737.62 (2,418.8 - 2,420.0)	P*		
16	737.62 - 738.10 (2,420.0- 2,421.6)	P*		
	738.10 - 738.23 (2,421.6 - 2,422.0)	P*		
	738.23 - 738.84 (2,422.0 - 2,424.0)	P*		
17	738.84 - 739.38 (2,424.0 - 2,425.8)	P*		
	739.38 - 739.44 (2,425.8 - 2,426.0)	B frags		
	739.14 - 739.90 (2,425.0 - 2,427.5)	P*		
18	739.90 - 740.05 (2,427.5 - 2,428.0)	P		
	740.05 - 740.36 (2,428.0 - 2,429.0)	P		
	740.36 - 740.51 (2,429.0 - 2,429.5)	B frags		
	740.51 - 740.66 (2,429.5 - 2,430.0)	B frags		
Interval not cored (740.66 - 792.48 m [2,430 - 2,600 ft])				

See notes at end of table.

Table B-1
Well ER-20-6#1 Core Samples Logged and Preserved (page 6 of 9)

Box [1]	Sample Interval [2] Meters (Feet)	Package Type [3]	Lithology [4]	Hydrogeologic Unit
19	792.48-2 (2,600-2)	BR frags	Devitrified lava	Lava-Flow Aquifer
	792.48 - 792.57 (2,600.0 - 2,600.3)	B frags		
	792.57 - 793.06 (2,600.3 - 2,601.9)	P*		
	793.06 - 793.09 (2,601.9 - 2,602.0)	B frags		
20	793.09 - 793.70 (2,602.0 - 2,604.0)	P*		
	793.70 - 793.94 (2,604.0 - 2,604.8)	P		
	793.94 - 794.16 (2,604.8 - 2,605.5)	P (*?)		
20A	794.16 - 794.31 (2,605.5 - 2,606.0)	P		
	794.31 - 794.46 (2,606.0 - 2,606.5)	P		
	794.46 - 794.83 (2,606.5 - 2,607.7)	P*		
	794.83 - 794.92 (2,607.7 - 2,608.0)	No core		
	794.92 - 795.07 (2,608.0 - 2,608.5)	B frags		
21	795.07 - 795.22 (2,608.5 - 2,609.0)	B frags		
	795.22 - 795.38 (2,609.0 - 2,609.5)	B frags		
	795.38 - 795.53 2,609.5 - 2,610.0)	F frags		
	795.53 - 795.68 (2,610.0 - 2,610.5)	P		
	795.68 - 795.74 (2,610.5 - 2,610.7)	B frags		
	795.74 - 796.05 (2,610.7 - 2,611.7)	P*		

See notes at end of table.

Table B-1
Well ER-20-6#1 Core Samples Logged and Preserved (page 7 of 9)

Box [1]	Sample Interval [2] Meters (Feet)	Package Type [3]	Lithology [4]	Hydrogeologic Unit
22	796.05 - 796.14 (2,611.7 - 2,612.0)	B frags	Devitrified lava	Lava-Flow Aquifer
	796.14 - 796.26 (2,612.0 -2,612.4)	P		
	796.26 - 796.59 (2,612.4 - 2,613.5)	P*		
	796.59 - 796.75 (2613.5 - 2614.0)	B frags		
	796.75 - 797.05 (2,614.0 - 2,615.0)	BR frags		
Interval not cored (796.05 - 853.44 m [2,615 - 2,800 ft])				
23	853.44 - 853.74 (2,800.0- 2,801.0)	P*	Devitrified lava	Lava-Flow Aquifer
	853.74 - 853.96 (2,801.0 - 2,801.7)	P		
	853.96 - 854.35 (2,801.7 - 2,803.0)	P		
24	854.35 - 854.90 (2,803.0- 2,804.8)	P		
	854.90 - 854.96 (2,804.8 - 2,805.0)	B frags		
	854.96 - 855.54 (2,805.0 - 2,806.9)	F		
	855.54 - 855.57 (2,806.9 - 2;807.0)	B frags		
	855.57 - 855.88 (2,807.0 - 2,808.0)	P		
	855.88 - 856.18 (2,808.0 - 2,809.0)	B frags		
	856.18 - 856.79 (2,809.0 - 2,811.0)	P		
26	856.79 - 856.81 (2,811.0 - 2,811.05)	B		
	856.81 - 857.40 (2,811.05 - 2,813.0)	F		
	857.40 - 857.62 (2,813.0 - 2,813.7)	F		
	857.62 - 858.01 (2,813.7 - 2,815.0)	P		

See notes at end of table.

Table B-1
Well ER-20-6#1 Core Samples Logged and Preserved (page 8 of 9)

Box [1]	Sample Interval [2] Meters (Feet)	Package Type [3]	Lithology [4]	Hydrogeologic Unit
27	858.01 - 858.62 (2,815.0 - 2,817.0)	F	Devitrified lava	Lava-Flow Aquifer
	858.62 - 859.02 (2,817.0 - 2,818.3)	P*		
	859.02 - 859.23 (2,818.3 - 2,819.0)	F		
28	859.23 - 859.72 (2,819.0 - 2,820.6)	P		
	859.72 - 860.15 (2,820.6 - 2,822.0)	BR		
29	860.15 - 860.36 (2,822.0 - 2,822.7)	F		
	860.36 - 860.76 (2,822.7 - 2,824.0)	P		
	860.76 - 861.36 (2,824.0 - 2,826.0)	P*		
30	861.43 - 861.64 (2,826.2 - 2,826.9)	F		
	861.64 - 861.97 (2,826.9 - 2,828.0)	P		
	861.97 - 862.16 (2,828.0 - 2,828.6)	P		
	862.16 - 862.58 (2,828.6 - 2,830.0)	P*		
31	862.58 - 863.19 (2,830.0 - 2,832.0)	P		
	863.19 - 863.29 (2,832.0 - 2,832.3)	F		
	863.29 - 863.80 (2,832.3 - 2,834.0)	P		
32	863.80 - 864.41 (2,834.0 - 2,836.0)	F		
	864.41 - 865.02 (2,836.0 - 2,838.0)	P		

See notes at end of table.

Table B-1
Well ER-20-6#1 Core Samples Logged and Preserved (page 9 of 9)

Box [1]	Sample Interval [2] Meters (Feet)	Package Type [3]	Lithology [4]	Hydrogeologic Unit
33	865.02 - 865.51 (2,838.0 - 2,839.6)	F	Devitrified lava	Lava-Flow Aquifer
33	865.51 - 865.63 (2,839.6 - 2,840.0)	B frags	Devitrified lava	Lava-Flow Aquifer
33	865.63 - 865.78 (2;840.0 - 2,840.5)	B frags	Devitrified lava	Lava-Flow Aquifer
33	865.78 - 866.24 (2,840.5 - 2,842.0)	P	Devitrified lava	Lava-Flow Aquifer
34	866.24 - 866.36 (2,842.0 - 2,842.5)	B frags	Devitrified lava	Lava-Flow Aquifer
34	866.36 - 866.85 (2,842.4 - 2,844.0)	P	Devitrified lava	Lava-Flow Aquifer
34	866.85 - 867.46 (2,844.0 - 2,846.0)	F	Devitrified flow breccia	Lava-Flow Aquifer
35	867.46 - 868.07 (2,846.0 - 2,848.0)	P	Devitrified flow breccia	Lava-Flow Aquifer
35	868.07 - 868.13 (2,848.0 - 2,848.2)	F	Devitrified flow breccia	Lava-Flow Aquifer
35	868.13 - 868.59 (2,848.2 - 2,849.7)	P	Devitrified flow breccia	Lava-Flow Aquifer
35	868.59 - 868.68 (2,849.7 - 2,850.0)	F	Devitrified flow breccia	Lava-Flow Aquifer
36	868.68 - 868.86 (2,850.0 - 2,850.6)	P	Devitrified flow breccia	Lava-Flow Aquifer
36	868.86 - 869.08 (2,850.6 - 2,851.3)	F	Devitrified flow breccia	Lava-Flow Aquifer
36	869.08 - 869.23 (2,851.3 - 2,851.8)	F	Devitrified flow breccia	Lava-Flow Aquifer
36	869.23 - 869.50 (2,851.8 - 2,852.7)	BR frags	Devitrified flow breccia	Lava-Flow Aquifer
36	unlabeled fragments	BR	Devitrified flow breccia	Lava-Flow Aquifer

1 Box number refers to appropriately labeled cardboard core-storage boxes in the U.S. Geological Survey Core Library, Mercury, NV, where these cores can be found.

2 All depth measurements were made in English units (feet and tenths of feet), and the sample packages are labeled in feet. Metric equivalents are provided here for the convenience of the reader.

3 Sample-package symbols: P = sample sealed in ProtecCore®; P* = ProtecCore® sample which may no longer have an airtight seal; B = sample (usually several fragments) sealed in plastic bags immediately after removal from the core tube in the Core Library; BR = sample (usually fragments) placed in plastic bag at the drill rig; F = sample (usually one intact piece) wrapped in plastic wrap and foam immediately after removal from the core tube in the Core Library.

4 See Table 3-2 in main report for detailed lithologic descriptions.

This page intentionally left blank.

Distribution List

	Copies
DOE Office of Scientific and Technical Information, Oak Ridge, TN	2
DOE/NV Technical Information Resource Center, Las Vegas, NV	1
DOE/NV Public Reading Room, Las Vegas, NV	1
R. M. Bangerter, DOE/ERD. Las Vegas, NV	1
D. W. Duncan, DOE/ERD, Las Vegas, NV	1
P. D. Rowley, USGS, Las Vegas, NV	1
J. E. Magner, USGS Geologic Data Center, Mercury, NV	1
D. A. Trudeau, USGS/WRD, Las Vegas, NV	1
G. A. Pawloski, LLNL, Livermore, CA	1
D. K. Smith, LLNL, Livermore, CA	1
D. L. Finnegen, LANL, Los Alamos, NM	1
W. L. Hawkins, LANL, Los Alamos, NM	1
P. W. Reimus, LANL, Los Alamos, NM	1
R. G. Warren, LANL, Los Alamos, NM	1
A. V. Wolfsberg, LANL, Los Alamos, NM	1
Library, IT Corp., Las Vegas, NV	1
E. H. Price, HSI GeoTrans, Las Vegas, NV	1
K. R. Rehfeldt, HSI GeoTrans, Las Vegas, NV	1
R. K. Waddell, HSI GeoTrans, West Minster, CO	1
B. M. Allen, BN, Mercury, NV	1
H. S. Bensinger, BN, Las Vegas, NV	1
S. L. Drellack, BN, Las Vegas, NV	1
J. L. Gonzales, BN, Las Vegas, NV	1
P. K. Ortego, BN, Las Vegas, NV	1
L. B. Prothro, BN, Mercury, NV	1
M. J. Townsend, BN, Mercury, NV	1