PNNL-16303

Pacific Northwest
National Laboratory
Operated by Battelle for the
U.S. Department of Energy

Borehole Summary Report for Core Hole C4998 – Waste Treatment Plant Seismic Boreholes Project

D. B. Barnett
B. J. Garcia

December 2006

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

DISCLAIMER

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

**Available to DOE and DOE contractors from the
Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831;
prices available from (615) 576-8401.**

**Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161**

PNNL-16303

Borehole Summary Report for Core Hole C4998 – Waste Treatment Plant Seismic Boreholes Project

D. B. Barnett
B. J. Garcia

December 2006

Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

Seismic borehole C4998 was cored through the upper portion of the Columbia River Basalt Group and Ellensburg Formation to provide detailed lithologic information and intact rock samples that represent the geology at the Waste Treatment Plant. This report describes the drilling of borehole C4998 and documents the geologic data collected during the drilling of the cored portion of the borehole.

Drilling of borehole C4998 began in June 2006 with the drilling of an entry hole to the top of basalt using a cable-tool drill. After the entry hole was drilled approximately 401.5 ft through the sediments into basalt, a coring diamond drill was positioned over the borehole to continue to the total depth of 1400 ft. A wireline diamond drill with a depth capability of 1500 ft was used with HQ-sized bit and rods to produce borehole and core diameters of 3-4/5 in. and 2-1/2 in., respectively. The hole was enlarged to approximately 4 in. by a reaming shell above the bit. Total depth was reached on September 14.

Overall recovery of core from 401.5 ft to 1400 ft below ground surface (bgs) was 99%, with a total of 12 ft of core lost in the Cold Creek and Mabton sedimentary interbeds combined. Recovery of basalt was 100%, including relatively fragile flow-top materials.

Sampling in borehole C4998 consisted of collecting core and rock cuttings from the entry hole and retrieving 2-1/2-in. core during the core hole drilling. Grab samples of specific mineralogical features and representative samples of basalt flows (top, interior, and bottom) also were collected from the core for physical and chemical analyses. In addition, numerous photographs and photomicrographs were taken to document the appearance of the core as it emerged from the borehole and to compare with the various types of samples taken. All core was examined and logged immediately after it was removed from the core barrel and placed on the core tray.

The overall stratigraphy consists of basalt flows of the Miocene Saddle Mountains Basalt and Wanapum Basalt of the Columbia River Basalt Group, alternating with sedimentary interbeds of the Ellensburg Formation. Five basalt flows were penetrated, and a sixth was partially penetrated. Four sedimentary interbeds were entirely penetrated. Comparison of actual unit depths and thicknesses with those predicted indicate close agreement, with only a few exceptions.

Immediately following the completion of the borehole to total depth, natural gamma and density logging was performed from September 15 through 18. Inspection of the log indicates that density and natural gamma functions corroborate accurately the features observed visually in the core.

Abbreviations

ASTM	American Society for Testing and Materials (now known as ASTM International)
bgs	below ground surface
BNI	Bechtel National, Inc.
DOE	U.S. Department of Energy
HLW	high-level waste
HQ	standard designation for wireline drill bits and drill rods of nominally 3.782 in. and 3.5 in., respectively
HWT	standard designation for flush-joint casing of nominally 4.0-in. and 4.5-in. inside and outside diameters, respectively
PC-3	Performance Category 3
PNNL	Pacific Northwest National Laboratory
RQD	Rock Quality Designation
SBP	Seismic Boreholes Project
Vp	compressional wave velocity
Vs	shear wave velocity
WTP	Waste Treatment Plant
XRD	x-ray diffraction
XRF	x-ray fluorescence

Contents

Figures

Tables

1.0 Introduction

During the period of June through October 2006, four deep boreholes were drilled beneath the site of the Waste Treatment Plant (WTP) at the U.S. Department of Energy (DOE) Hanford Site near Richland, Washington. The boreholes were drilled to provide information on ground-motion attenuation in the basalt and interbedded sediments underlying the WTP site. One of these boreholes, C4998, was cored through several basalt flows and interbeds to provide detailed lithologic information and intact rock samples for testing in support of the Seismic Boreholes Project, defined below. This report describes the drilling of the basalt and sedimentary interbeds in borehole C4998 and provides all resulting data sets available as of December 2006.

1.1 Waste Treatment Plant and the Seismic Boreholes Project

The seismic design basis for the WTP was reevaluated in 2005, resulting in an increase by up to 40% in the seismic design basis. The original seismic design basis for the WTP was established in 1999 based on a probabilistic seismic hazard analysis completed in 1996. The 2005 analysis was performed to address questions raised by the Defense Nuclear Facilities Safety Board about the assumptions used in developing the original seismic criteria and adequacy of the site geotechnical surveys. The updated seismic response analysis used existing and newly acquired seismic velocity data, statistical analysis, expert elicitation, and ground-motion simulation to develop interim design ground-motion response spectra that enveloped the remaining uncertainties. The uncertainties in these response spectra were enveloped at approximately the 84th percentile to produce conservative design spectra, which contributed significantly to the increase in the seismic design basis.

A key uncertainty identified in the 2005 analysis was the velocity contrasts between the basalt flows and the sedimentary interbeds beneath the WTP. The velocity structure of the upper four basalt flows (Saddle Mountains Basalt) and that of the interlayered sedimentary interbeds (Ellensburg Formation) produce strong reductions in modeled earthquake ground motions propagating through them. Uncertainty in the strength of velocity contrasts between these basalts and interbeds resulted primarily from an absence of measured shear wave velocities (Vs) in the interbeds. For the 2005 analysis, Vs in the interbeds was estimated from older, limited compressional wave (Vp) data using estimated ranges for the ratio of the two velocities (Vp/Vs) based on analogues in similar materials. A range of possible Vs for the interbeds and basalts was used and produced additional uncertainty in the resulting response spectra.

Because of the sensitivity of the calculated response spectra to the velocity contrasts between the basalts and interbedded sediments, DOE initiated the Seismic Boreholes Project (SBP) to emplace additional boreholes at the WTP site and obtain direct Vs measurements and other physical property measurements in these layers. One corehole and three boreholes were installed at the WTP site to a maximum depth of 1500 ft below ground surface. The three boreholes are within 500 ft of and surround the high-level waste vitrification and pretreatment facilities of the WTP, the Performance Category 3 (PC-3) structures affected by the interim design spectra. The corehole is co-located with the borehole closest to the two PC-3 structures. The new measurements from the seismic boreholes are expected to reduce the uncertainty in the modeled site response caused by the lack of direct knowledge of the Vs contrasts within these layers.

1.2 Organization and Responsibility

Work described in this report was conducted by Pacific Northwest National Laboratory (PNNL) and subcontractors for the U.S. Department of Energy. Bechtel National, Inc. (BNI) is responsible for WTP construction and all WTP site control. Drilling was subcontracted by PNNL, and drill site supervisory and logistical services were provided by Energy Solutions, Inc. (formerly Duratek Federal Services) and subcontractors. Additional site personnel were provided by Fluor Hanford, Inc. Drilling of the entry hole for borehole C4998 was performed by Blue Star Enterprises NorthWest, Inc., of Richland, Washington. The cored portion (basalt and interbeds) of the borehole was drilled by Layne Christensen Company of Salt Lake City, Utah.

1.3 Procedure Requirements and Quality Assurance

PNNL has primary responsibility for quality assurance and quality control, with recognition of BNI requirements for NQA-1 standards. The *Sampling and Analysis Plan* (PNNL 2006) and *Quality Assurance Project Plan* (QAPjP 2006) were used to guide the procedure development and data collection activities needed to support borehole drilling, geophysical measurements, and sampling. The *Sampling and Analysis Plan* identifies standards (e.g., American Society for Testing and Materials [ASTM]), Hanford Site procedures, and other guidance documents for data collection activities. For lithologic logging, sampling, and handling of core, combinations of standards were used, as appropriate, to achieve the desired level of detail required by the project (ASTM 1999, 2002, 2003, 2006; Groundwater Remediation Project 2004; USACE 2001; PNNL 2006).

1.4 Report Scope

This report provides and describes the data collected during the drilling of the cored portion of borehole C4998. Drilling and lithologic information for the upper, suprabasalt portion of the borehole is summarized here only for completeness. Drilling and lithologic descriptions for the upper 400 ft of borehole C4998 are documented in full by Horner (2006).

In this report, the drilling site is described in Section 2. Section 3 provides a history of the drilling activities for borehole C4998. In Section 4, the procedures used in collecting and logging core samples and preparing them for various analyses are described. Section 5 contains the characterization of stratigraphic units encountered during the drilling and summarizes the results of geophysical logging in the borehole. References cited in the text are listed in Section 6. The appendixes provide the complete list of the sample inventory (A), photographs and photomicrographs of core samples and drilling activities (B), copies of the lithologic logs (C), and a copy of the geophysical log (D).

2.0 Site Description

The WTP is located on the Hanford Site in Washington State, just east of the 200 East Area (Figure 2.1). The boreholes drilled at the WTP are located in the central and eastern portion of the facility (Figure 2.2). Borehole C4998 was drilled near the northeast corner of the high-level waste vitrification facility currently under construction and is only approximately 90 ft north of borehole C4997. This proximity was intentional so that detailed information from the core can be compared with cuttings collected from rotary boreholes C4993, C4996, and C4997. Table 2.1 lists surveyed coordinates for all four boreholes drilled during the project.

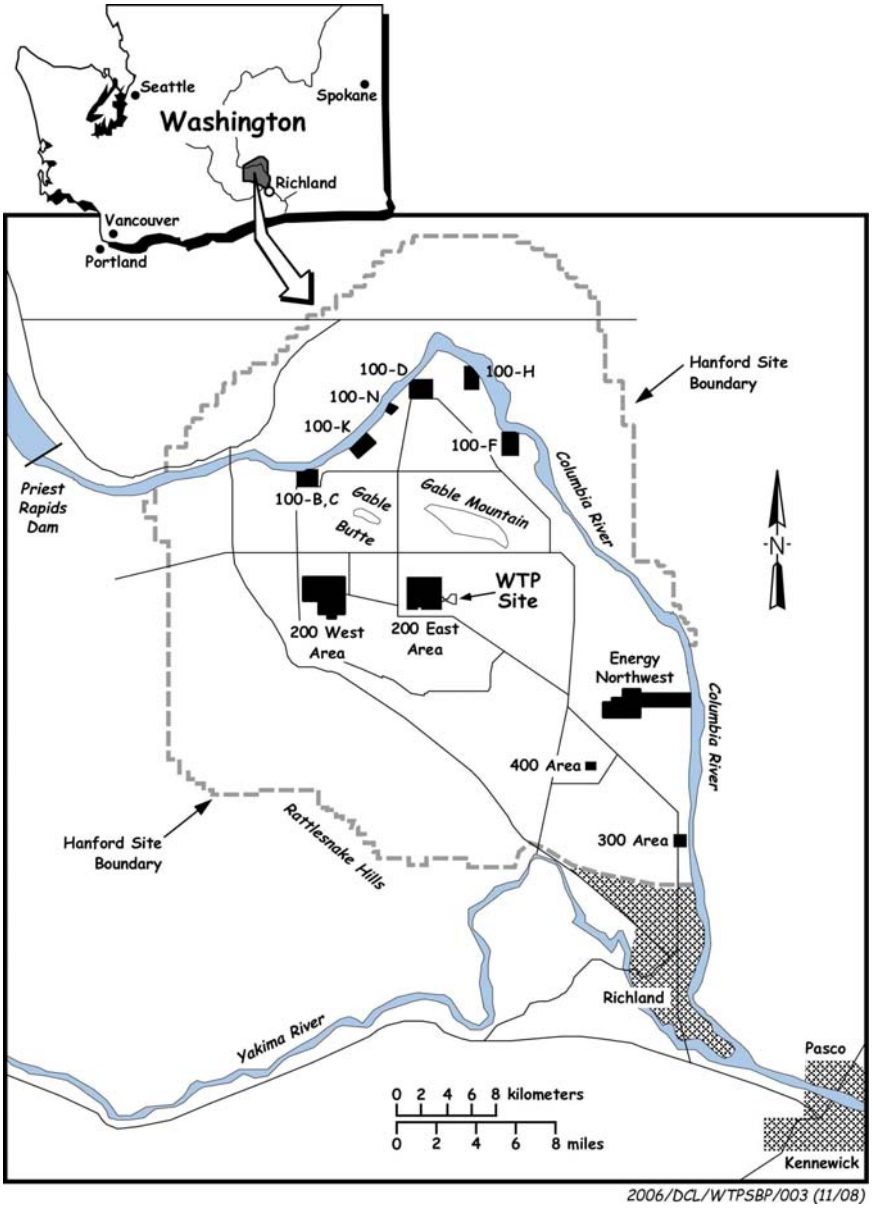


Figure 2.1. Waste Treatment Plant on the Hanford Site

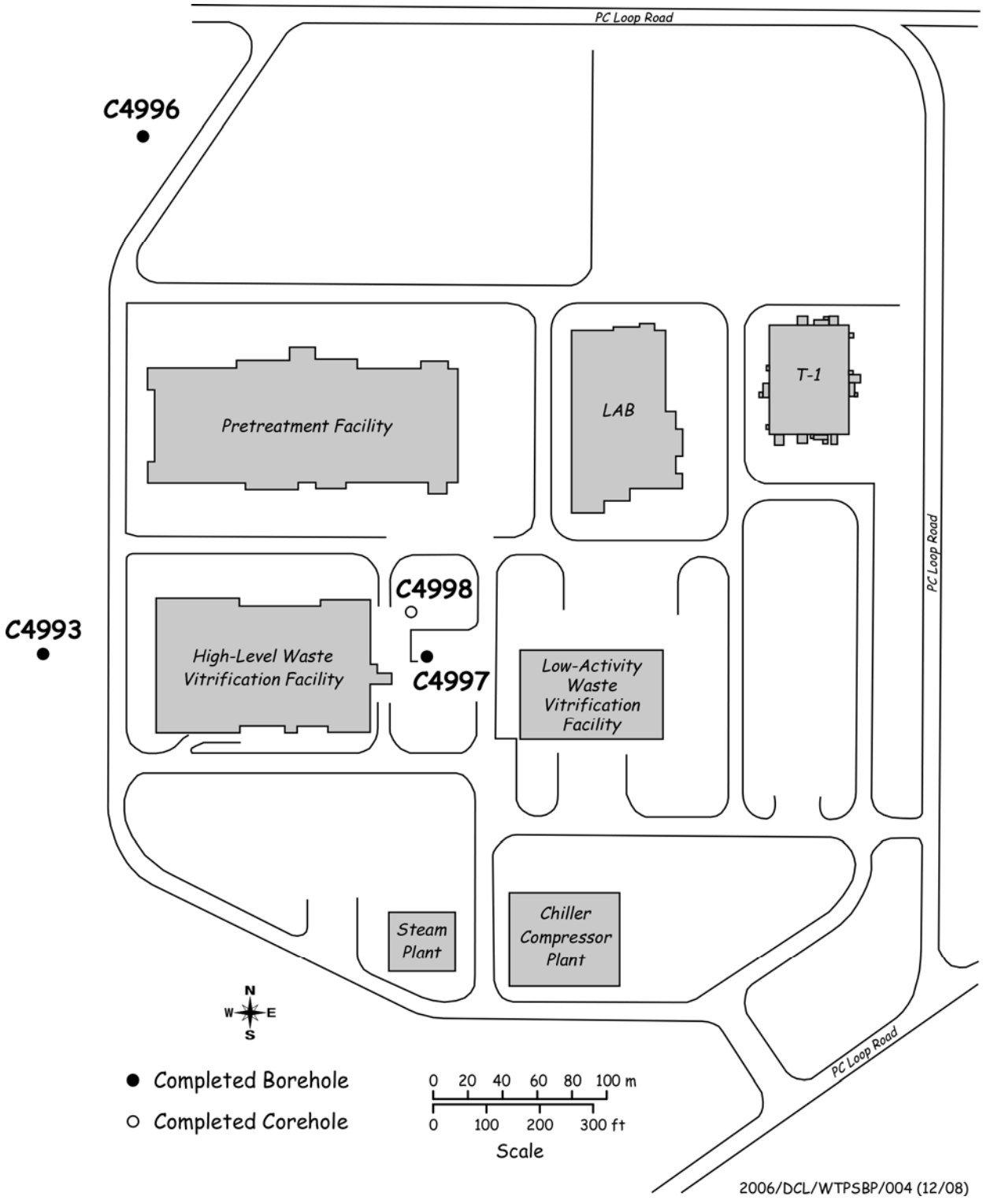


Figure 2.2. Seismic Test Holes Drilled in 2006 at the Waste Treatment Plant

Table 2.1. Surveyed Horizontal Locations of Seismic Boreholes

Hanford Borehole ID	WTP Seismic Location	Surveyed WTP Coordinates (ft)		Converted – NAD83 State Plane Coordinates (m)		Elevation (ft) at Ground Surface
C4997	Center of Site	E 10,375.480	N 3,836.210	E 576,309.433	N 135,755.318	676.87
C4998	Center of Site	E 10,345.400	N 3,920.390	E 576,300.266	N 135,780.973	676.87
C4993	SW of Site	E 9,647.070	N 3,840.600	E 576,087.439	N 135,756.656	658.24
C4996	NW of Site	E 9,836.490	N 4,816.880	E 576,145.168	N 136,054.191	670.06

3.0 Drilling and Related Activities

Drilling of borehole C4998 began in June 2006 with a cable-tool drill. After the entry hole was drilled approximately 401.5 ft through the sediments into basalt, a coring diamond drill was positioned over the borehole to continue to a total depth of 1400 ft. This section describes the drilling process and equipment as they relate to understanding the constraints of data collection with these drilling methods.

3.1 Entry Hole Drilling

The drilling of this portion of the borehole is described in detail by Horner (2006). Hence, only a brief summary of the entry hole drilling is presented here. The entry hole, which penetrates the sediments overlying the basalt, was drilled with the cable-tool drill shown in Figure 3.1.

The entry hole for C4998 was spudded on June 12, 2006, and reached the first basalt flow (Elephant Mountain Member) at a depth of 382 ft below ground surface (bgs) on July 10, 2006. The cable-tool drill was used to drill approximately 19 ft into the basalt (to 401.5 ft bgs) before the borehole was cemented near the bottom and prepared to receive the core drill. Surface casing with an outside diameter (OD) of 13-3/8 in. was emplaced to a depth of 200 ft bgs. At 200 ft bgs, the casing size was reduced to 9-5/8 in. OD, which was installed to total depth of the entry hole at 401.5 ft bgs. A 4-1/2-in. final conductor casing (HWT) was cemented in place to accommodate the core drilling system. To ensure borehole straightness, tests were conducted every 100 ft during the entry hole drilling using a 20-ft × 10-in. dummy casing and a downhole gyroscope.

Figure 3.1. Cable-Tool Drill Used to Drill Entry Hole at Borehole C4998. The 13-3/8-in. threaded casing is seen in the foreground in front of the drive barrel (arrow), which is used to remove cuttings from the borehole as the casing is advanced.

3.2 Core Hole Drilling

Core hole drilling of basalt began on July 19, 2006, after about 55 ft of cement were drilled out. The cement was tremmied into place by the crew of the cable-tool drill to support the 4-1/2-in.-OD HWT casing (see Section 3.1). Core drilling required nearly two months; the total depth of 1400 ft was reached on September 14, 2006.

3.2.1 Diamond Drill and Drilling Operations

Core hole C4998 was drilled using HQ-sized bit and rods with a Christensen Boyles Corporation CS-1000 wireline drill with a depth capability of 1500 ft. The hole and core diameters were 3.8 in. and 2.5 in., respectively. A reaming attachment immediately above the drill bit enlarges the hole slightly to allow better circulation of drilling fluid within the borehole (Figure 3.2). The bit and reamer are attached to the lowermost reinforced drill rod, called a collar. A 5-ft core barrel fits inside the collar immediately above the bit. The core barrel, in turn, encloses a split-tube or inner tube (Figure 3.3). Core moves up into the inner tube as the hole progresses. When the inner tube is filled with core or withdrawal is otherwise desired, an overshot device is lowered via wireline through the drill rods and connects with a male receiver attached to the core barrel. This also releases the core barrel from a locking device in the lowermost drill rod and allows the core barrel to be brought to the surface with the wireline. Once brought to the surface, the end of the core barrel is removed and the inner tube containing the core is slid out of the core barrel. The core is then removed from the inner tube and placed on the core tray for examination (Figure 3.3). This process of retrieval of a nominally 5-ft length of core is called a run.

Figure 3.2. Layout of Core Drill and Accessories; Configuration of Diamond Drill Bit (left inset) and 2.5-in. Core Produced (right inset)

Figure 3.3. Opening Inner Tube Halves and Exposing Core After Removal from Core Barrel. Inset: sliding inner tube out of core barrel.

Following the extraction of the core, the inner tube halves are placed back in the core barrel and the core barrel is placed in the drill rods and allowed to free-fall to the depth of the bit where it engages the locking device. Drilling then resumes.

Drilling fluid (also known as mud—combinations of bentonite, polymers, and water) was cleaned of cuttings and recirculated into the borehole using a mud pump and portable mud plant with a sand screen (Figure 3.2). A mud pump injects fluid into the hole inside the drill rods, through the face of the diamond bit, and returns to the surface, carrying rock cuttings and heat dissipated at the bit face. The fluid is then pumped into the mud plant for cleaning and is returned to the mud pump. In this manner, excessive spillage and settling pits are avoided. Drilling fluid was occasionally replenished to make up for downhole losses in permeable portions of the borehole.

Figure 3.4. Overshot and Wireline Assembly Used To Retrieve Core Barrel. Inset is detail of overshot receiver attached to core barrel.

3.2.2 History of Core Drilling at Borehole C4998

This section summarizes the sequence of significant events during the drilling of the core hole in borehole C4998. Figure 3.5 illustrates the important features of the construction of the borehole, significant dates associated with these features, and generalized stratigraphy corresponding to the construction.

Overall recovery of core from 401.5 ft to 1400 ft bgs was 99%, with a total of 12 ft of core lost in the Cold Creek and Mabton interbeds combined. Most of the loss occurred in unconsolidated and flowing sand layers in these interbeds (see Section 5.1). Recovery of basalt was nearly 100%, including relatively fragile flow-top materials.

Cable-tool drilling of the surficial sediments began on June 12 and ended on July 11 at a depth of 401.5 ft bgs. Following the emplacement and cementing of the 4-1/2-in. casing from this depth to surface, the diamond drill was situated over the hole on July 17. Cement was tagged at 346 ft bgs inside the 4-1/2-in. casing on July 19, and this was drilled out to 401 ft bgs with a drag bit. Later the same day, the drill rods were tripped out, the drag bit was replaced with a coring bit, and coring of basalt began.

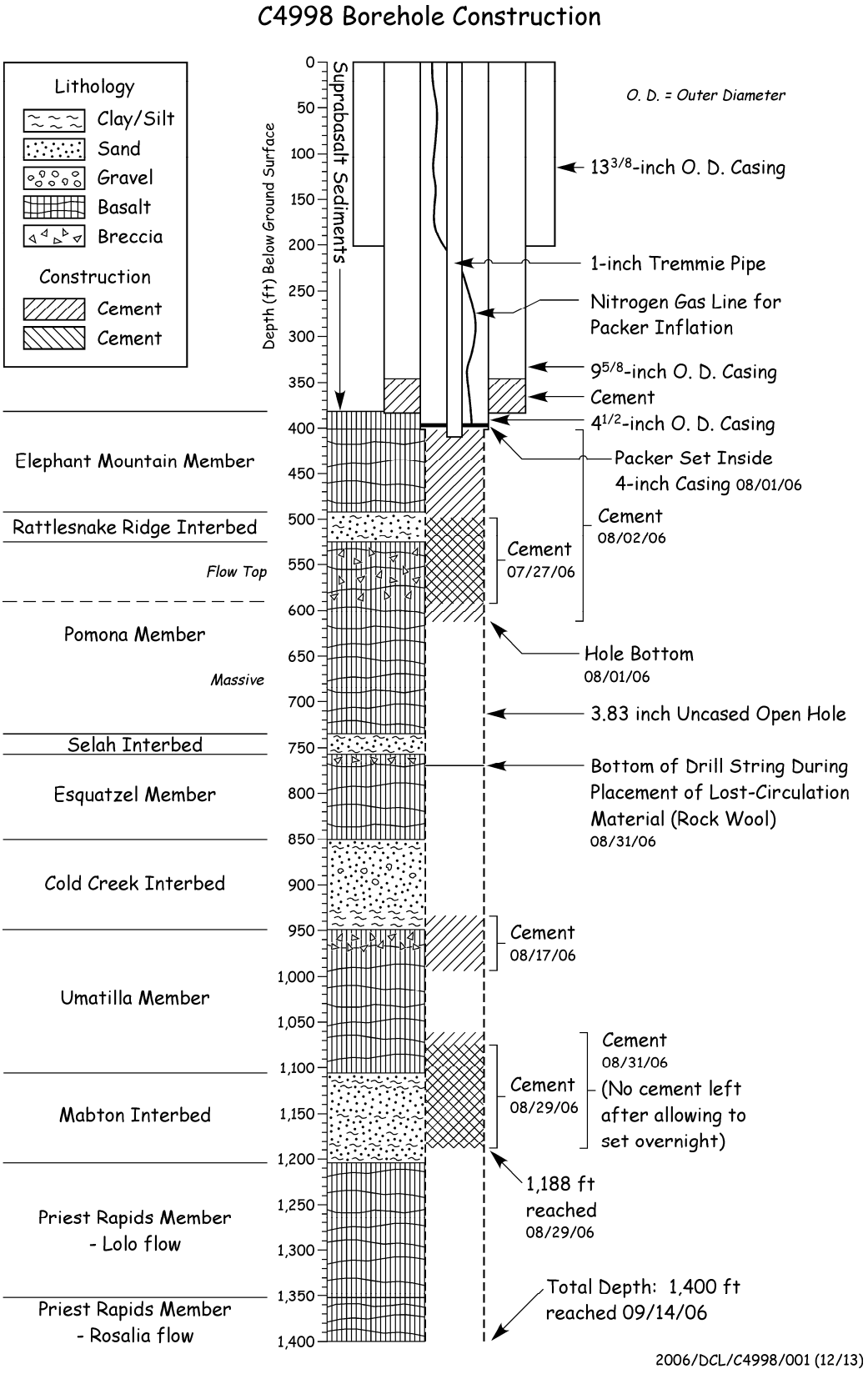


Figure 3.5. Borehole Construction Details for C4998 at Total Depth

By July 27, the flow top of the Pomona Member had been penetrated and, in conjunction with unstable materials in the overlying Rattlesnake Ridge Interbed, caused significant loss of drilling fluid circulation and sticking of the drill string. This portion of the hole, from the hole bottom (595.5 ft bgs) up to 492 ft bgs, was cemented and allowed to cure overnight. Drilling resumed on July 28 after the cement plug was drilled out, but significant loss of circulation continued, and the hole was advanced only another 12.5 ft (to 608 ft bgs) before the drill string again became stuck. After the drill was freed from the formation, the interval was re-cemented using pressure-grouting techniques. This method required the use of a packer and tremmie combination, with the packer being set near the bottom of the 4-1/2-in. casing (see Figure 3.5). On August 1, the entire cored portion of the hole from bottom (608 ft bgs) to 400 ft bgs was cemented and allowed to cure overnight. Drilling of this cement plug began on August 2 but reached only 507 ft bgs when the mud plant suffered a mechanical failure.

Following the repair of the mud plant, drilling of the remaining cement, and preparation of new drilling fluid, coring of basalt resumed on August 7. Drilling continued without incident until the flow top of the Umatilla Member basalt was encountered on August 16; at that time, problems with formation caving and loss of drilling fluid occurred again. The interval from 934 ft to 994 ft bgs was cemented on August 17 and drilled out on August 18. Drilling of Umatilla Member resumed late on August 18, and the Mabton Interbed was reached on August 22.

Penetration of the 98-ft-thick Mabton Interbed proved the most challenging portion of the borehole from a drilling standpoint. The depth of the borehole (~1188 ft bgs) and the unconsolidated nature of the Mabton sediments combined to nearly cause the abandonment of the targeted depth and the end of the drilling of borehole C4998. Flowing (upwelling) unconsolidated coarse sand caused serious sticking of the drill rods and accumulations of sand in the core barrel, preventing operation. The period of August 24 through September 5 was spent emplacing two cement plugs across the trouble zone in the Mabton Interbed sands. Neither of these cement plugs set up, as only cement-colored water was encountered throughout the borehole the morning following each job. Upon pulling back the drill rods after the second cement job, the drillers injected a pill (a small volume) of lost circulation material at the level of the Selah Interbed to preempt any unrecognized problems from that horizon. Finally, the decision was made on September 6 to condition the hole as carefully as possible with a new batch of drilling fluid, and the borehole began to stabilize. From this point on, only minor sticking was experienced, and the borehole was completed to target depth on September 14.

Special expertise was required to prepare and maintain drilling fluid integrity throughout the core drilling and hole-conditioning processes. Suspended solids had to be minimized at all times to avoid *mud rings*—accumulations of drilling solids inside the drill rods that prevent operation of the wireline retrieval system. This required on-site tailoring of the drilling fluid to exact specifications of viscosity, pH, and other factors (Figure 3.6). Following each of the five cementing jobs, the drilling fluid had to be disposed of and a new batch mixed. Expertise in drilling fluid mixing and testing was provided by Baroid Fluid Services.

Figure 3.6. Drilling Fluid Properties Evaluation by Onsite Mud Laboratory

4.0 Geologic Sampling and Logging

Sampling in borehole C4998 consisted of collecting core and rock cuttings from the entry hole and retrieving 2.5-in. core during the core hole drilling. Grab samples of specific mineralogical features and representative samples of basalt flows (top, middle, and bottom) also were also collected from the core for physical and chemical analyses. Numerous photographs and photomicrographs were taken to document the appearance of the core as it emerged from the borehole and to compare with the various types of samples taken. Sampling techniques and analysis of samples taken during entry hole drilling are described by Horner (2006) and are not presented here.

4.1 Core Sampling

After a 5-ft interval of core was drilled, the core barrel was retrieved from its locked-in position inside the drill string behind the bit. Setting the 5-ft-long core barrel horizontally on a stand, a split spoon inner tube was extracted from one end of the core barrel and placed in the core tray, which consisted of two lengths of plastic pipe sliced lengthwise into two halves and secured onto a table side-by-side (Figures 3.3 and 3.4). The split spoons of the inner tube were removed from around the core as gently as possible; the core was then cleaned to remove drilling mud and loose debris not derived from the core interval. Occasionally, extraction of the split spoon tube from the core barrel proved difficult due to wedging of the core inside the end of the core barrel. In the event that the split spoon tube could not be removed from the core barrel by the usual method, more forceful methods such as hammering were needed to loosen the core. This procedure sometimes induced fracturing of the core from incipient fractures that would otherwise have remained intact.

Each run normally consisted of a 5-ft interval, which completely filled the inner tube. However, mechanical and geological circumstances sometimes prevented a full 5 ft of core from being drilled. Lost fluid circulation and caving formation material sometimes required early retrieval of the core. Rarely, the incompetent nature of the materials, such as loose sand in sedimentary interbeds, resulted in less than 100% recovery of the cored interval. In such cases, the lost, disaggregated material was washed out by the drilling fluid ahead of the bit and carried to the mud plant with the other cuttings.

Upon removal of washed core from the inner tube, photographs were immediately taken of the entire run (see Appendix B). Starting at the top of the depth interval, the first photograph contains a placard identifying the footage of the drilled interval (footage) to the nearest 0.1 ft, run number, date, and a scale bar. After the core was laid on the tray table for examination, a determination of percentage recovery was made and recorded on the Borehole Log. Percentage recovery is simply the length of the core recovered divided by the length of the run (drilled interval length) multiplied by 100.

Next, a Rock Quality Designation (RQD) measurement was obtained and recorded in the Borehole Log (see Section 4.2 and Table 4.1). RQD is a rough estimate of rock competence and is calculated by dividing the total length of the retrieved core (e.g., run length) into the sum length of the pieces of core 4 in. long or longer multiplied by 100 (to obtain percent). For example, if a 5-ft run (60 in.) has a total of 48 in. of rock in pieces equal to or longer than 4 in., then the RQD value would be 80% (ASTM 1999, 2006). Table 4.1 lists all runs from the core hole with corresponding recoveries and RQD values.

Table 4.1. Recovery and Rock Quality Designation (RQD) for Core in Borehole C4998

Run Number(s)	Interval (ft bgs)	Core Recovery (%)	RQD (%)	Material	Comments
1	401–403	100	65	Basalt	Top of Elephant Mountain Member
2	403–408	100	48	Basalt	Much fracturing with clay fill
3	408–413	100	40	Basalt	Much fracturing with clay fill
4	413–418	100	24	Basalt	Much fracturing with clay fill
5	418–423	100	100	Basalt	
6	423–428	100	86	Basalt	
7	428–433	100	100	Basalt	
8	433–438	100	93	Basalt	
9	438–443	100	94	Basalt	
10	443–448	100	95	Basalt	
11	448–453	100	99	Basalt	
12–14	453–468	100	95	Basalt	Very competent interval
15	468–473	100	91	Basalt	
16	473–478	100	100	Basalt	
17	478–483	100	96	Basalt	
18	483–488	100	100	Basalt	
19	488–492	100	98	Basalt	
20	492–493	100	44	Clay	Top of Rattlesnake Ridge Interbed
21	493–496	100	38	Clay	
22	496–498	100	85	Silt/sand	
23	498–503	100	84	Silt/sand/clay	
24	503–505	90	100	Sand	
25	505–510	100	74	Silt/sand, minor clay	
26	510–513	100	75	Coarse sand/sandst	
27	513–515	100	68	Sand	
28	515–520	85	86	Sand	
29	520–523	100	82	Sand	
30	523–526	100	100	Sand/sandst	
31	526–531	100	70	Flowtop breccia (clay + basalt)	Top of Pomona member
32	531–536	100	70	Flowtop breccia (clay + basalt)	
33	536–541	100	91	Flowtop breccia (clay + basalt)	
34	541–546	100	20	Flowtop breccia (clay + basalt)	
35	546–551	70	30	Flowtop breccia (clay + basalt)	
36	551–553	100	83	Flowtop breccia (clay + basalt)	
37	553–556.5	100	32	Flowtop breccia (clay + basalt)	
38	556.5–561.5	100	60	Brecciated/ fractured basalt	Fault zone
39	561.5–565.5	100	0	Brecciated/fractured basalt	Fault zone

Table 4.1. (contd)

Run Number(s)	Interval (ft bgs)	Core Recovery (%)	RQD (%)	Material	Comments
40	565.5–570.5	100	94	Basalt	
41	570.5–575.5	100	0	Flowtop breccia (clay + basalt)	
42	575.5–580.5	100	36	Flowtop breccia (clay + basalt)	
43	580.5–585.5	100	36	Flowtop breccia (clay + basalt)	
44	585.5–590.5	100	0	Flowtop breccia (clay + basalt)	
45	595.5–599	100	96	Basalt	
46	599–603	100	65	Basalt	
47–48	603–613	100	100	Basalt	
50	613–616	100	90	Basalt	
51	616–621	100	88	Basalt	
52	621–623	100	100	Basalt	
53	623–628	100	77	Basalt	
54	628–633	100	67	Basalt	
55	633–638	100	91	Basalt	
56	638–643	100	74	Basalt	
57	643–648	100	68	Basalt	
58	648–653	100	88	Basalt	
59	653–658	100	84	Basalt	
60	658–663	100	47	Basalt	
61	663–668	100	100	Basalt	
62	668–673	100	60	Basalt	
63	673–678	100	82	Basalt	
64	678–683	100	90	Basalt	
65–66	683–693	100	100	Basalt	
67	693–698	100	88	Basalt	
68–69	698–708	100	100	Basalt	
70	708–713	100	93	Basalt	
71	713–718	100	74	Basalt	
72	718–723	100	80	Basalt	
73	723–728	100	92	Basalt	
74	728–733	100	64	Basalt	
75	733–734.7	100	45	Basalt breccia	
76	734.7–736	100	44	Clay	Top of Selah Interbed
77	736–737	100	50	Clay	
78	737–742	100	10	Clay	
79	742–747	100	84	Sand/sandst	
80	747–752.3	100	70	Sand/sandst	
81	752.3–755	75	59	Clay and basalt frag	
82	755–760	100	100	Clay and basalt breccia	Top of Esquatzel Member
83	760–765	100	80	Clay and basalt breccia	

Table 4.1. (contd)

Run Number(s)	Interval (ft bgs)	Core Recovery (%)	RQD (%)	Material	Comments
84	765–770	100	58	Vesicular basalt	
85	770–775	100	90	Basalt	
86	775–780	100	94	Basalt	
87	780–785	100	73	Basalt	
88	785–790	100	95	Basalt	
89	790–793	100	80	Basalt	
90	793–798	100	100	Basalt	
91	798–803	100	81	Basalt	
92	803–808	100	85	Basalt	
93	808–813	100	93	Basalt	
94	813–818	100	66	Fractured basalt	
95	818–823	100	79	Fractured basalt	
96	823–828	100	96	Basalt	
97	828–833	100	97	Basalt	
98	833–838	100	93	Basalt	
99	838–843	100	93	Basalt	
100	843–848	100	100	Basalt	
101	848–853	100	90	Basalt	
102	853–858	60	83	Sand	Top of Cold Creek Interbed–loss of core
103	858–859	100	83	Clay/sand	
104	859–862	100	75	Sand/clay	
105	862–867	100	52	Sand/clay	
106	867–872	40	100[(a)]	Sand	Loss of core
107	872–877	100	0	Very friable sand	
108	877–882	90	100[(a)]	Sand/sandst	Loss of core
109	882–887	100	93[(a)]	Sand/sandst	
110	887–892	100	80[(a)]	Sand/sandst	
111	892–897	100	100[(a)]	Sand/sandst	
112	897–902	100	100[(a)]	Sand/sandst	
113	902–907	100	0	Sand	
114	907–909	100	69	Clay/sand/gravel	
115–116	909–919	100	100	Sand/gravel/silt	
117	919–924	100	95	Sand/sandst	
118	924–929	70	NA[(a)]	Sand/silt	Loss of core
119	929–932	77	66	Sand/clay	
120–122	932–947	100	NA[(a)]	Clay/claystone	
123	947–951	100	0	Clay and basalt breccia	Top of Umatilla Member
124	951–953	100	0	Clay and basalt breccia	
125	953–958	100	28	Basalt	
126	958–963	100	57	Basalt	
127	963–968	100	70	Basalt	

NA= Not Applicable.
(a) Material is semi-consolidated or friable; RQD may not apply.

Table 4.1. (contd)

Run Number(s)	Interval (ft bgs)	Core Recovery (%)	RQD (%)	Material	Comments
128–129	968–978	100	100	Basalt	
130	978–983	100	97	Basalt	
131	983-988	100	68	Basalt	
132	988-993	100	90	Basalt	
133	993-994	100	70	Basalt	
134	994-998	100	91	Basalt	
135	998-1003	100	100	Basalt	
136	1003-1008	100	90	Basalt	
137	1008-1013	100	83	Basalt	
138	1013-1018	100	43	Basalt	
139	1018-1022	100	50	Basalt, vesicular	
140	1022-1027	100	13	Fractured basalt	
141	1027-1032	100	75	Basalt	
142	1032-1033	100	80	Basalt	
143	1033-1037	100	47	Basalt, vesicular	
144	1037-1040	100	52	Basalt, vesicular	
145	1040-1043	88	98	Basalt breccia	
146	1043-1047	100	0	Basalt breccia	
147	1047-1052	100	0	Basalt breccia	
148	1052-1053	100	0	Basalt breccia	
149	1053-1057	100	42	Basalt	
150	1057-1062	100	99	Basalt	
151	1062-1067	100	94	Basalt	
152	1067-1072	100	88	Basalt	
153	1072-1077	100	62	Basalt	
154	1077-1082	100	100	Basalt	
155	1082-1087	100	85	Basalt	
156	1087-1092	100	84	Basalt	
157	1092-1097	100	95	Basalt	
158	1097-1102	100	93	Basalt	
159	1102-1105.5	100	100	Basalt	
160	1105.5-1109	100	89	Sand	Top of Mabton Interbed
161	1109-1112	100	39[(a)]	Clay	
162	1112-1113	0	NA		Loss of core
163	1113-1118	100	72	Sand/clay	
164	1118-1123	100	92	Clay/sand	
165	1123-1125	100	87	Sand	
166	1125-1130	60	100	Sand	Loss of core
167	1130-1135	100	100	Sand/clay	
168	1135-1140	100	82	Sand, cross-bedded	
169	1140-1145	100	100	Sand, cross-bedded	
170	1145-1150	96	84	Sand, cross-bedded	Loss of core
171	1150-1153	17	0	Sand	Loss of core

NA= Not Applicable.
(a) Material is semi-consolidated or friable; RQD may not apply.

Table 4.1. (contd)

Run Number(s)	Interval (ft bgs)	Core Recovery (%)	RQD (%)	Material	Comments
172-173	1153-1163	100	100	Sand/clay	
174	1163-1168	36	75	Sand	Loss of core
175	1168-1170	100	20	Clay	
176	1170-1174	100	48	Clay/sand	
177	1174-1179	40	NA[(a)]	Sand	Friable, no structural integrity
178	1179-1184	80	NA[(a)]	Sand	Friable, no structural integrity
179	1184-1188	50	19	Sand/clay	Loss of core
180	1188-1189	100	0	Clay	
181	1189-1193	100	85	Clay/silt	
182	1193-1196	100	100	Clay/silt	
183	1196-1198	100	72	Clay	
184	1198-1203	100	100	Clay	
185	1203-1208	92	98	Clay/basalt	Top of Priest Rapids Member Lolo flow
186	1208-1210	100	85	Basalt, vesicular	
187	1210-1215	100	92	Basalt, vesicular	
188-189	1215-1225	100	100	Basalt, vesicular	
190	1225-1230	100	62	Basalt, vesicular	Fracturing
191	1230-1235	100	100	Basalt, vesicular	
192	1235-1238	100	100	Basalt	
193	1238-1243	100	90	Basalt, vesicular	
194	1243-1248	100	100	Basalt	Large void--vesicle
195	1248-1253	100	100	Basalt	Micropegmatite
196	1253-1258	100	95	Basalt	
197-200	1258-1278	100	100	Basalt	
201	1278-1283	90	100	Basalt	
202-209	1283-1321	100	100	Basalt	
210	1321-1326	100	94	Basalt	
211-217	1326-1358	100	100	Basalt	
218	1358-1363	100	86	Basalt, vesicular	Some brecciation
219	1363-1365.5	100	100	Basalt, vesicular	
220	1365.5-1370.5	100	60	Basalt, vesicular	Top of Rosalia flow
221-223	1370.5-1383	100	100	Basalt, vesicular	
224	1383-1387	100	76	Basalt, vesicular	
225-227	1387-1400	100	100	Basalt	Total depth of borehole = 1400 ft

NA= Not Applicable.

(a) Material is semi-consolidated or friable; RQD may not apply.

*Footages and material descriptions are approximate.

After the RQD value was calculated, the core was placed into core boxes and an arrow pointing in the "up" direction was drawn on the uppermost cohesive section of the core. The core was placed in the box "book" fashion, starting with the up-hole end of the core in the upper left and proceeding left to right and downward until all five rows of the box were filled (Figure 4.1). Some boxes were filled only partially to accommodate natural separations in the core (i.e., along fractures) and avoid excessive breaking of the core for fitting into boxes. To distinguish between separate runs within a single box, wooden blocks were labeled with the run number, footage of the drilled interval, borehole designation (C4998), and the date obtained. Each core box was labeled with project name (WTP Seismic), company name (Battelle), corehole designation (C4998), box number, and the footages of the interval contained within the box.

Figure 4.1. Typical Box of Basalt Core from Borehole C4998. The arrow on the first row of core indicates the up-hole direction (the highest stratigraphic position is in the upper left corner of the box, and proceeds "book" fashion to the lowermost depth at the lower right end of the box). Each box row is 2 ft long.

4.2 Core Logging

Information included in the Borehole Log includes an initial lithologic description of the core, a graphic representation of the rock type and important features, RQD values, the percentage of the run recovered from at depth, descriptions of any secondary minerals present, other notable geologic features such as fracturing and vesiculation, and notes on drilling-related activities or occurrences (see Appendix C). Photograph numbers also were noted on the Borehole Log for some photographed features.

In particularly complex intervals, such as fault zones, flow-top zones, or some sedimentary interbed sequences, additional detail was recorded on a Supplemental Drill Log (Appendix C.2). Samples collected from the core also were recorded on the Supplemental Drill Log.

Procedures for lithologic descriptions and symbols are based on widely accepted standards in the industry and are found in several specific documents discussed in Section 1.3 of this report. Symbols are shown in Figure 5.4 and Appendix C.

4.3 Samples for X-Ray Diffraction and X-Ray Fluorescence

Mineral samples were collected from fracture-filling material and vesicle- or cavity-filling/encrusting material found in the basalts and occasionally in interbed sediments. These samples were submitted for x-ray diffraction (XRD) analysis at PNNL for identification. When an unidentifiable fracture- or vesicle-filling material was observed, a small (~0.1- to 0.5-g) sample was removed from the core, packaged in foil, and labeled (see Appendix A). These were prepared and analyzed with a ScintagPAD V diffractometer. Specific methods for sample preparation and analytical procedures are described by Crum and Riley (2006).

Several samples of each basalt member were taken for supplemental information for confirmation of flow identities. Samples of fresh, unaltered basalt were collected from selected stratigraphic positions within each flow. Samples (40–50g) were chipped from the core at the desired locations, cleaned of any altered material (e.g., fracture fill clays), and packaged in canvas sample bags. These samples were sent to Washington State University for x-ray fluorescence (XRF) analysis to determine major and minor element concentrations.

Both XRD and XRF analyses were performed to provide supplemental qualitative characterization information on basalt samples from beneath the WTP. The analytical data have been determined to be non-quality-affecting. Hence, PNNL standard laboratory practices and procedures were used. Results for both the XRD and XRF analyses, and their relevance to the Seismic Borehole Project, will be presented in a separate report.

4.4 Samples for Mechanical and Dynamic Testing

All core samples of the sedimentary interbeds were covered in foil and/or wrapped in plastic wrap to minimize moisture loss while in the field. Certain representative core segments of the sedimentary interbeds, selected based upon their cohesiveness and ability to remain solid despite handling, were taken off-site and covered with foil, then sealed in wax to preserve moisture content for future testing (Figure 4.2). Several interbed cores were released to the U.S. Army Corps of Engineers for testing. Basalt samples were removed from seven intervals for resonant column-torsional shear (RC/TS) testing at the University of Texas–Austin. Another 28 samples were selected for free-free resonant column testing at a future date. Chain-of-custody documentation was prepared and accompanies all samples (XRD, XRF, mechanical/dynamic, and waxing) removed from the core boxes after initial placement of the core in the boxes. Chain-of-custody records are maintained in PNNL project files.

4.5 Photography

Additional photographs, apart from runs and core boxes, were taken of notable features of the core as warranted. These included primary sedimentary structures and replacement/secondary features in interbeds, and brecciation, replacements, veins, shear surfaces, and vesicles in basalts. Photomicrographs of these and other features were taken of notable fine-scale structures or minerals. These were taken at the drill site with a digital camera temporarily affixed to an ocular of a reflected-light microscope. All photographs/microphotographs are listed in the photograph log of Appendix B.

Figure 4.2. Examples of Waxed Interbed Sediment Cores from Borehole C4998

5.0 Stratigraphy and Geologic Observations

All core was examined and logged immediately after it was removed from the core barrel and placed on the core tray (see Section 3.2). The Borehole Log (Appendix C.1) represents the initial descriptions of the core lithologies and any corresponding activities with the drilling that may have a bearing on the interpretation of subsurface conditions. When additional detail was desired, the Supplemental Drill Log (Appendix C.2) was used.

5.1 Stratigraphic Units Encountered

Figures 5.1 and 5.2 show the general stratigraphy of the Hanford Site and more specific nomenclature for the Saddle Mountains Basalt, respectively. Figure 5.3 illustrates the stratigraphy and contact depths of major units in the C4998 borehole, as predicted by nearby preexisting boreholes (left side) and the actual depths and thicknesses (right side) encountered during the coring. The primary source for the predicted depths and thicknesses is found in Reidel and Fecht (1981). The borehole log of Figure 5.4 provides

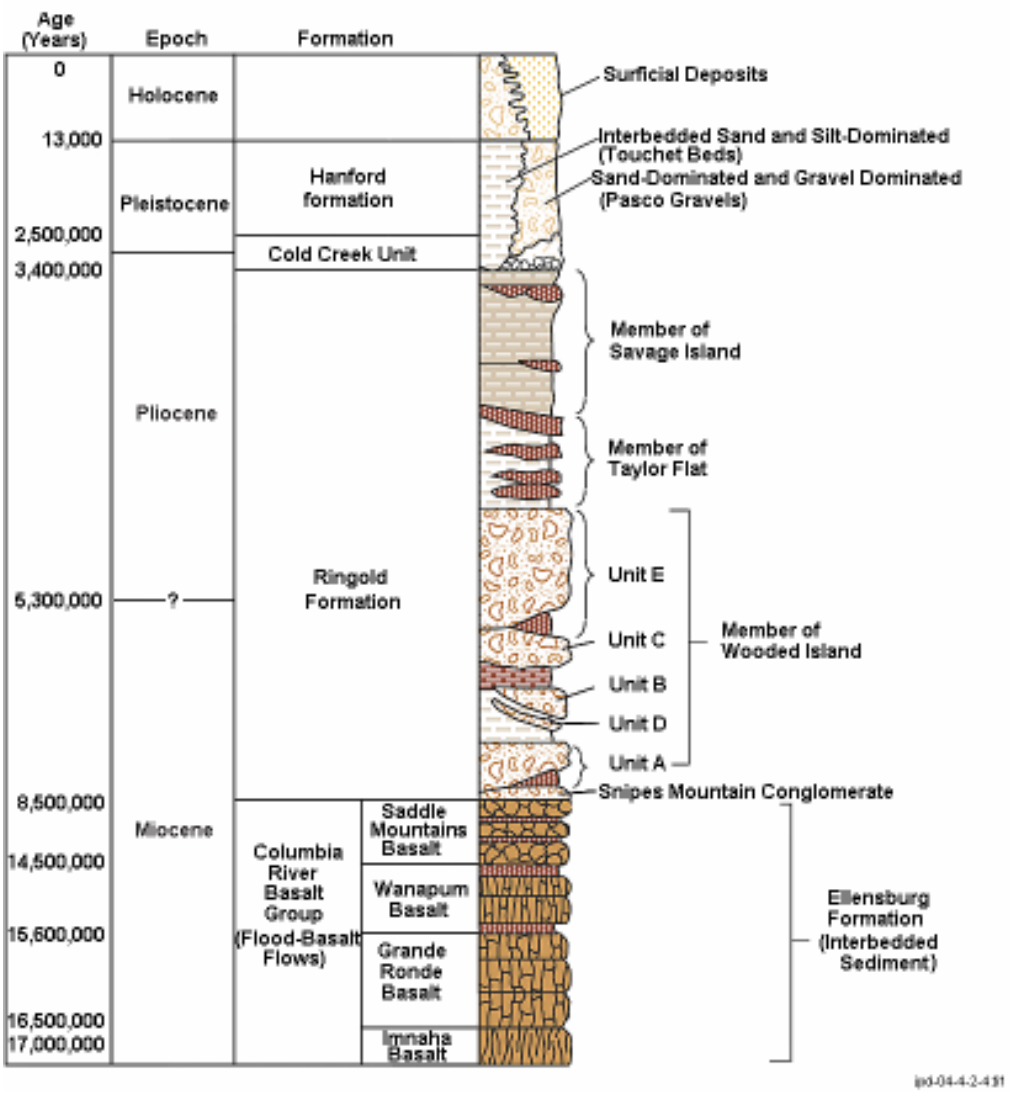


Figure 5.1. General Stratigraphy of the Hanford Site

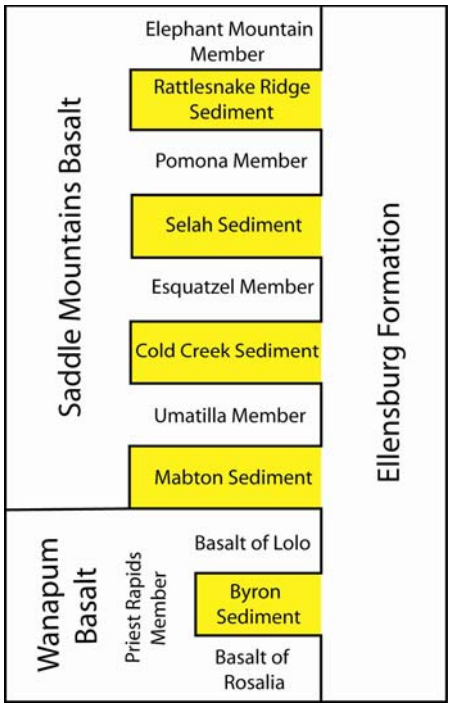


Figure 5.2. Basalt Members and Interbeds (Ellensburg Formation) of the Saddle Mountains Basalt Beneath the Hanford Site

detail on lithologies and structures observed in the core. These are discussed below in the order in which they were encountered during drilling, from stratigraphically highest to lowest. The overall stratigraphy consists of lava flows of the Miocene Saddle Mountains Basalt and Wanapum Basalt, alternating with sedimentary interbeds of the Ellensburg Formation (see Reidel et al. 1994). Discussion of the suprabasalt sediments of the Hanford formation and Ringold Formation is deferred to Horner (2006).

Comparison of actual unit depths and thicknesses with those predicted (Figure 5.3) indicates close agreement, with a few exceptions. The Rattlesnake Ridge Interbed is significantly thinner than predicted (only 33.6 ft as compared to 60 ± 8 ft), while the underlying Pomona Member is approximately 20 ft thicker than predicted. The Mabton Interbed is also thinner than predicted by about 10 to 20 ft. During the drilling of seismic borehole C4996 (see Figure 2.2), which preceded the core drilling, a 5-ft sedimentary sequence was encountered between the Lolo and Rosalia flows of the Priest Rapids Member. This stratum, called the Byron Interbed (Figure 5.2), is described as occurring sporadically throughout the Pasco Basin. In the core hole, this interbed was completely absent, with only a 1-in. clay horizon separating the Lolo and Rosalia flows.

5.1.1 Saddle Mountains Basalt – Elephant Mountain Member

Immediately underlying the Ringold Formation sediments is the Elephant Mountain Member of the Saddle Mountains Basalt. This flow is 110 ft thick at C4998 and is black to medium gray. It is also characterized by a uniform distribution of small (~1–2 mm) plagioclase phenocrysts and vesiculation, which affects coloration, depending on the density of these features. Vesicles are found mostly near the top and bottom thirds of the flow. The flow interior is dense with little fracturing. The flow top of this unit is missing because of erosion.

5.1.2 Ellensburg Formation – Rattlesnake Ridge Interbed

The first sedimentary interbed encountered between basalt flows was the Rattlesnake Ridge Interbed of the Ellensburg Formation. This unit is 33.6 ft thick and occurs from 492 to 525.6 ft bgs. The unit is dominated by silt and claystone in about the upper 18 ft and sand/sandstone in approximately the lower 16 ft.

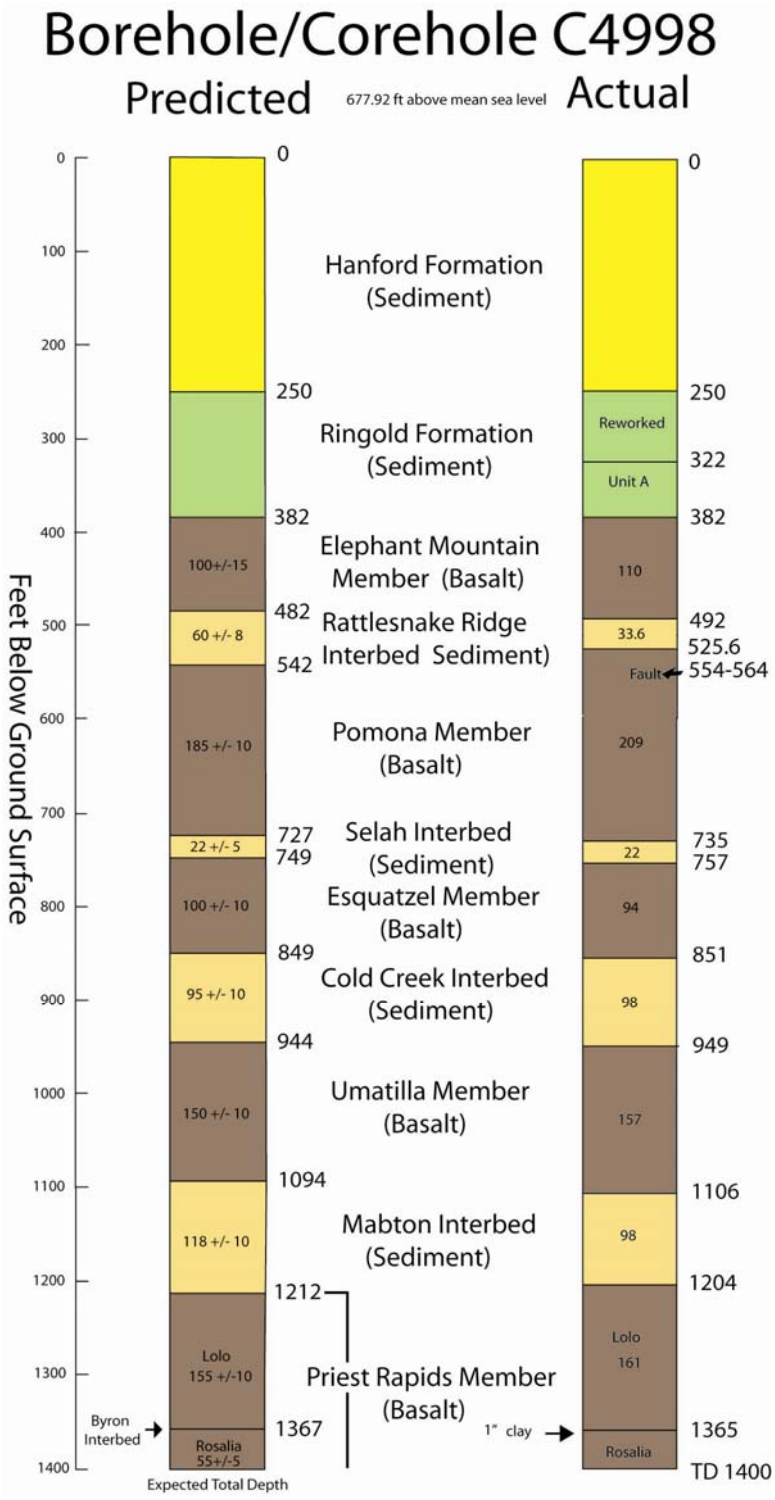


Figure 5.3. Predicted and Actual Depths of Stratigraphic Units Encountered in Borehole C4998. Thicknesses in feet, both predicted (left) and actual (right), are shown inside the columns.

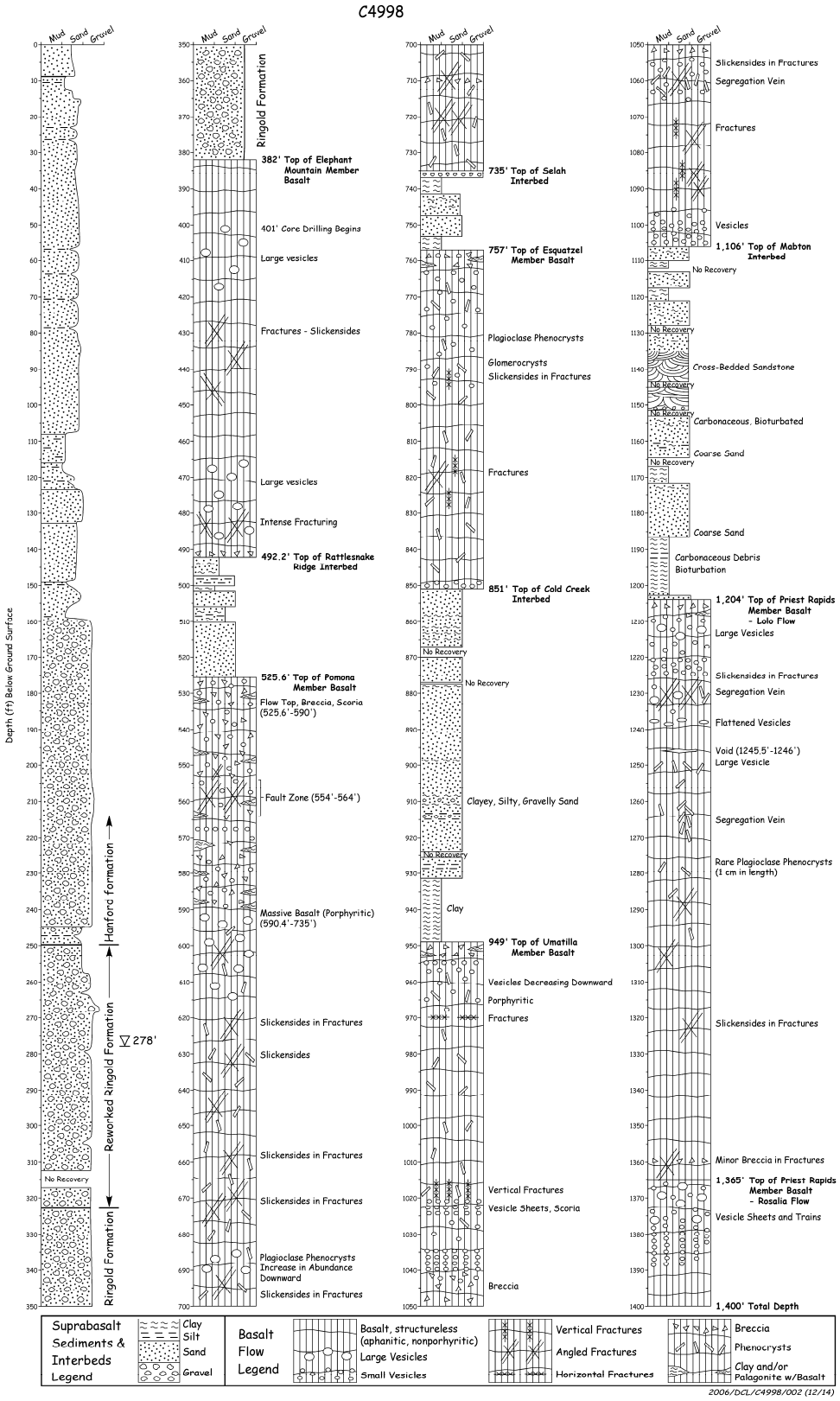


Figure 5.4. Lithologic Log for Borehole C4998 at the Waste Treatment Plant. Suprabasalt geology is derived from Horner (2006).

5.1.3 Saddle Mountains Basalt – Pomona Member

Immediately underlying the Rattlesnake Ridge sediments is the flow top of the Pomona Member basalt flow. At roughly 209 ft thick, this is the thickest basalt flow encountered during the drilling of borehole C4998. The flow begins at 525.6 ft bgs, with a very thick (~65-ft) flow-top breccia and scoria layer, and extends down to 735 ft bgs. Approximately midway through the flow (554 ft to ~564 ft bgs), features indicative of a fault zone are encountered. These include intense fracturing and brecciation that appear distinct from primary flow brecciation. Another suspect feature is a large fracture filling or replacement consisting of chalcedony. This feature suggests the presence of a significant conduit for circulation of groundwater in the geologic past sometime after the emplacement of the basalt (Figure 5.5). Elsewhere in the borehole, fracture fillings in basalt consist mostly of soft (common) opal, clays, siderite, and minor quartz and calcite. Offset of fractures is observed in some sections of this zone, accompanied by slickensides, indicating both normal and reverse movements (Figure 5.6).

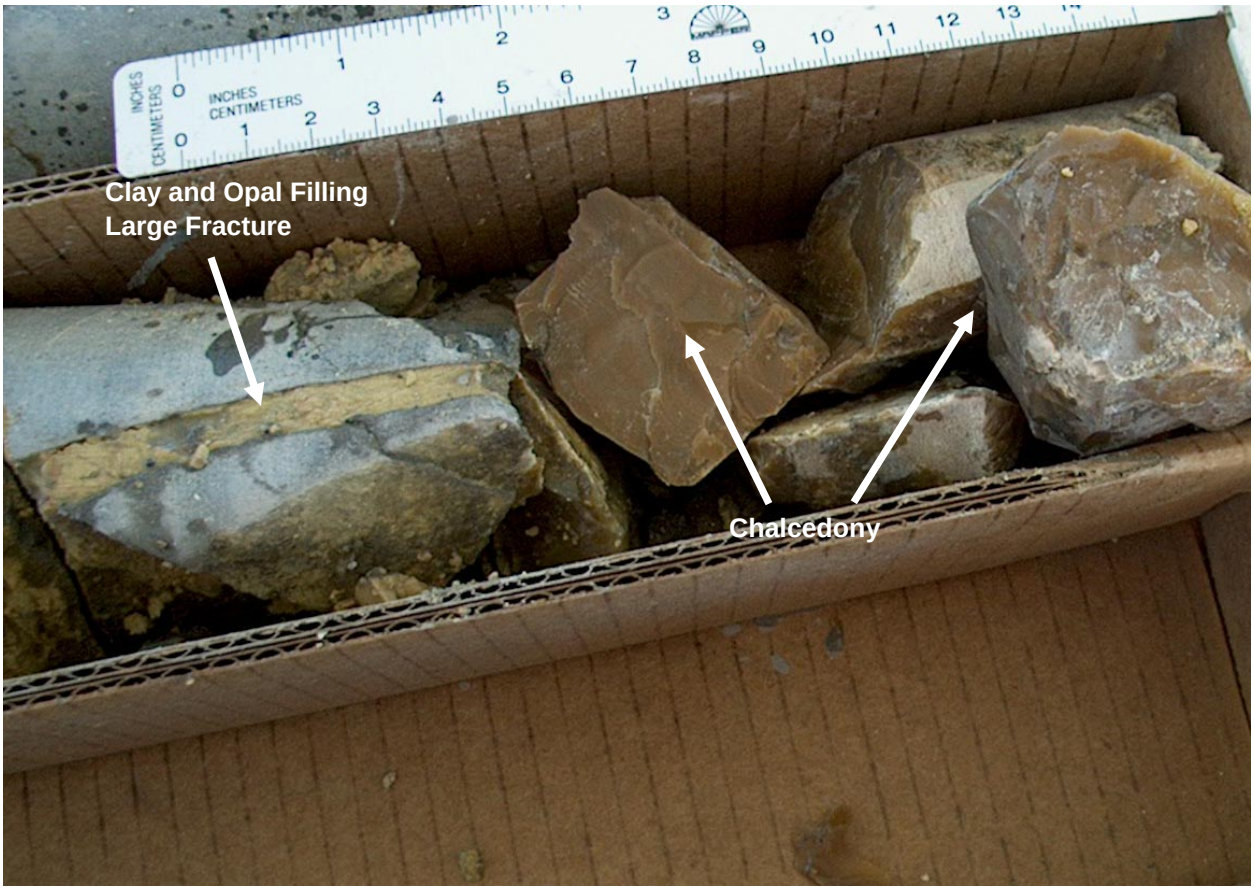


Figure 5.5. Chalcedony and Clay/Opal Veins in Suspected Fault Zone in Pomona Member

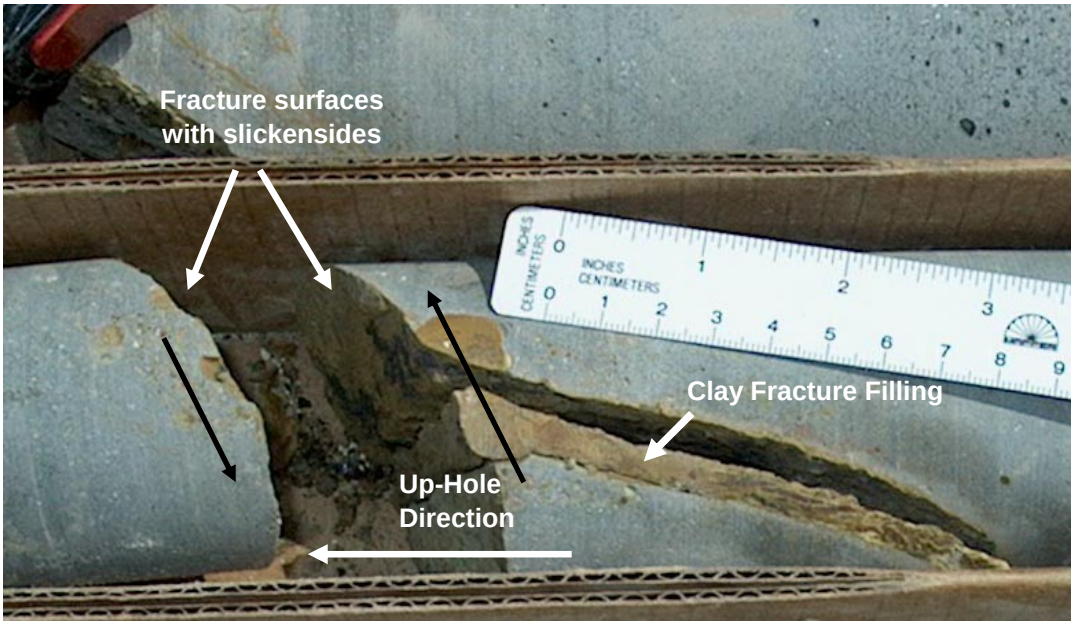


Figure 5.6. High-Angle, Clay-Filled Fracture Offset by a Low-Angle Fracture in the Pomona Member. Black arrows indicate relative motion of opposing blocks.

5.1.4 Ellensburg Formation – Selah Interbed

The Selah Interbed is the thinnest of the four interbeds encountered. Occurring immediately beneath the Pomona Member (from 735 ft to 757 ft bgs), it is only 22 ft thick. The dominant lithology is clayey sand, which occupies the middle two-thirds of the interbed. This layer is bounded above and below relatively thin clay layers.

5.1.5 Saddle Mountains Basalt – Esquatzel Member

Flow-top breccia of the Esquatzel Member was first encountered at 757 ft bgs. The 94-ft-thick flow is vesicular in about the upper 30 ft and contains conspicuous plagioclase phenocrysts and glomerocrysts throughout. The flow top is approximately 10 ft thick with numerous amygdules and red, oxidized basalt fragments (breccia). The bottom few feet of the flow are also moderately vesicular, with the vesicles displaying a horizontally elongate geometry.

5.1.6 Ellensburg Formation – Cold Creek Interbed

The top of the Cold Creek Interbed begins immediately below the flow bottom of the Esquatzel Member at 851 ft bgs. The Cold Creek Interbed is 98 ft thick and mostly semiconsolidated to unconsolidated sand with admixtures of clay and silt. This sand contains some gravel from roughly 908 to 916 ft. The bottom 18 ft of this interbed is clay. Three thin intervals at 867, 877, and 924 ft bgs were not recovered due to the highly friable nature of the sediments in these areas.

5.1.7 Saddle Mountains Formation Basalt – Umatilla Member

The Umatilla Member is 157 ft thick in borehole C4998, spanning the interval from 949 ft to 1106 ft bgs, and typically consists of two flows (Reidel and Fecht 1981). The top of the Umatilla Member is a relatively thin (~5-ft) flow breccia, but another breccia-and-scoria zone occurs from approximately 1020 to 1065 ft bgs. This interval is marked by dense vesiculation, scoria, and brecciated basalt mixed with palagonite. The base of this zone (~1060 ft bgs) hosts pegmatitic segregation veins, also known as micropegmatites. These features are concordant (sub-horizontal) to discordant (~vertical veins) with a coarser texture of plagioclase and pyroxenes and sharp contacts with the enclosing basalt (Figure 5.7). These features are mostly recognized in the older Priest Rapids Member (see Section 5.1.10). The origins of these features are discussed by Puffer and Horter (1993). The Umatilla Member is weakly porphyritic with plagioclase in this borehole, with the exception of approximately the bottom 50 ft of the flow.

Figure 5.7. Possible Pegmatitic Segregation Vein in Umatilla Basalt. Note stretched vesicles near upper contact at left.

5.1.8 Ellensburg Formation – Mabton Interbed

The 98-ft-thick (1106–1204 ft bgs) Mabton Interbed consists of alternating layers of sand and clay/silt, with sand dominating in abundance. A total of 7 ft of core were not recovered from this interbed due to the extremely friable nature of the (mostly) sand intervals. That only 7 ft were lost is a tribute to the skill of the driller in penetrating these loose, unstable sand intervals. The Mabton Interbed contains much coarser sand than found in the other interbeds higher in the borehole. Sand from 1135 ft to 1150 ft bgs displays striking festoon crossbedding.

5.1.9 Wanapum Basalt – Priest Rapids Member

The Priest Rapids Member consists of two distinct basalt flows in this area; the Lolo flow overlies the Rosalia flow. The Lolo (uppermost) flow is the only one of the two flows to be completely penetrated

here and is 161 ft thick (1204–1365 ft bgs). The flow top of the Lolo flow is marked by brecciation near the top and very pronounced vesicle sheets down to approximately 1245 ft bgs. Vesicles are so large in this region of the flow that the boundaries of at least one vesicle (1245.5 ft bgs) fell entirely outside the perimeter of the borehole, appearing as a void in the core. Pegmatitic segregation veins and chambers appear at around 1230 ft and 1265 ft bgs in the Lolo flow (Figures 5.8 and 5.9). The flow is weakly porphyritic with large (up to 1-cm-long) phenocrysts of plagioclase from approximately 1250–1300 ft bgs. Minor brecciation, apparently primary flow-derived, occurs near the bottom of the flow at around 1360 ft bgs.

Figure 5.8. Possible Pegmatitic Segregation Veins and Chambers in Lolo Basalt Flow at 1230 ft bgs

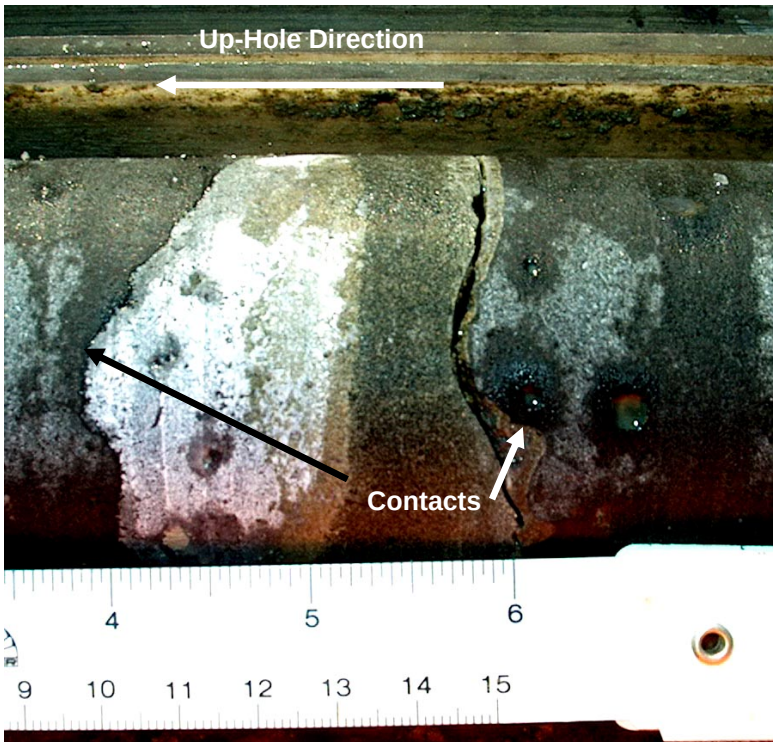


Figure 5.9. Pegmatitic Segregation Vein in Lolo Basalt Flow at 1231 ft bgs

The Lolo and Rosalia basalt flows are separated by a barely perceptible approximately 1-in. clay layer. This clay corresponds to the stratigraphic position of the Byron Interbed, a sedimentary layer that is sometimes present between these two flows. Immediately below this layer, at 1365 ft bgs, is the vesicular flow top of the Rosalia flow of the Priest Rapid member. The flow is otherwise distinguished by ubiquitous black specks consisting of altered glass, pyroxene glomerocrysts, and/or in-filled vesicles (~1–2 mm diameter) and plagioclase phenocrysts up to 3 mm long. Drilling of the borehole stopped in this unit at the total depth of 1400 ft bgs.

5.2 Geophysical Logs

Immediately following the completion of the borehole to total depth, natural gamma and density logging was performed by Colog from September 15 through 18. Results of this logging are shown in Appendix D. The functions provided on the tools include short- and long-spaced density, compensated density, natural gamma, and caliper. The logged intervals were 1 ft bgs to 1393 ft bgs for the natural gamma tool and from 2 ft bgs to 1396 ft bgs for the density and caliper tool. Three separate runs are indicated in Appendix D—the top log was performed in an open hole from 1170 ft to 400 ft bgs; the middle log was performed inside the HQ drill rods from 1215 ft to 1100 ft bgs, and the lower log is a repetition of approximately the bottom 50 ft of the borehole.

Inspection of the logs indicates that density and natural gamma functions corroborate accurately the observed features in the core. Particularly apparent are the locations of the sedimentary interbeds, the erratic vertical density variations in the basalt flow tops, and the relatively featureless density signature of the dense flow interiors. Although more subdued, the responses in density and natural gamma from the cased (HQ) run also reveal contacts and features observed in the core. Significant washouts are seen in the caliper and density responses in the Selah and Cold Creek interbeds at around 750 and 865 ft bgs, respectively, and throughout the Mabton Interbed.

Additional (seismic) logging is currently planned for the entry portion in borehole C4998.

6.0 References

ASTM. 1999. *Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation.* Standard D 2113-99, American Society for Testing and Materials, West Conshohocken, Pennsylvania.

ASTM. 2002. *Standard Practices for Preserving and Transporting Rock Core Samples.* Standard D 5079-02, American Society for Testing and Materials, West Conshohocken, Pennsylvania.

ASTM. 2003. *Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock.* Standard D 5434-03, American Society for Testing and Materials, West Conshohocken, Pennsylvania.

ASTM. 2006. *Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core*. Standard D 6032-02, American Society for Testing and Materials, West Conshohocken, Pennsylvania.

Crum JV and BJ Riley. 2006. *Mineral Identification of Geologic Samples from Borehole C4998.* PNNL-16297, Pacific Northwest National Laboratory, Richland, Washington.

Groundwater Remediation Project. 2004. *Geologic Logging Procedure*. GRP-EE-01-7.0, Fluor Hanford, Inc., Richland, Washington.

Horner JA. 2006. *Entry Boreholes Summary Report for the Waste Treatment Plant Seismic Boreholes Project*. WMP-32119, Fluor Hanford Inc., Richland, Washington.

PNNL. 2006. *Sampling and Analysis Plan – Waste Treatment Plant Seismic Boreholes Project*. PNNL-15848 Revision 2, Pacific Northwest National Laboratory, Richland, Washington.

Puffer JH and DL Horter. 1993. "Origin of pegmatitic segregation veins within flood basalts." *Geological Society of America Bulletin* 105:738–748.

QAPjP. 2006. *Waste Treatment Plant (WTP) Seismic Borehole Project Quality Assurance Project Plan*. Rev. 0, March 2006, Pacific Northwest National Laboratory, Richland, Washington.

Reidel SP and KR Fecht. 1981. "Wanapum and Saddle Mountains Basalts of the Cold Creek Syncline Area." In *Subsurface Geology of the Cold Creek Syncline*, pp. 3-1 through 3-43, CW Myers and SM Price (eds.). RHO-BWI-ST-14, Rockwell Hanford Operations, Richland, Washington.

Reidel SP, NP Campbell, KR Fecht, and KA Lindsey. 1994. "Late Cenozoic Structure and Stratigraphy of South-Central Washington." In *Regional Geology of Washington State*, Bulletin 80, pp. 159–180. Washington State Department of Natural Resources, Division of Geology and Earth Resources, Olympia, Washington.

USACE. 2001. *Geotechnical Investigations*. EM-1110-1-1804, Section 5, U.S. Army Corps of Engineers, Washington, D.C.

Appendix A

Sample Inventory

Table A.1. X-Ray Diffraction Samples from Core Hole C4998

Sample No.	Depth (feet bgs)	Date	Description	Page No. of Supplemental Log	Comments
518.0-A-C4998	518	9/1/2006	fracture fill	5	slickensides, RR sandstone
518.0-B-C4998	518	9/1/2006	fracture fill	5	slickensides, RR sandstone
559.5-A-C4998	559.5	9/1/2006	fracture fill	7	photo 5172-high angle fracture
559.5-B-C4998	559.5	9/1/2006	fracture fill	7	photo 5172-high angle fracture
631.5-C4998	631.5	9/1/2006	fracture fill	10	Green, "micaceous" clay; slickensides
642-C4998	642	9/1/2006	fracture fill	10	
653.3-C4998	653.3	9/1/2006	fracture fill	11	slickensides
673-A-C4998	673	9/1/2006	fracture fill	11	"paired bands of black and green clay"; slickensides
673-B-C4998	673	9/1/2006	fracture fill	11	"paired bands of black and green clay"; slickensides
714.2-C4998	714.2	9/1/2006	fracture fill	13	"clay", slickensides
778.6-C4998	778.6	9/1/2006	fracture fill	16	"black"
815-C4998	815	9/1/2006	fracture fill	17	"black"
954.4-A-C4998	954.4	9/1/2006	vesicle fill	23	vesicle filler (carbonate?)
954.4-B-C4998	954.4	9/1/2006	fracture fill	23	sulfice mineral
964-C4998	964	9/1/2006	fracture fill	23	fracture fill
992-C4998	992	9/1/2006	fracture fill	24	black fracture fill
1020-A-C4998	1020	9/1/2006	fracture fill	25	clear, encrusting crystals
1020-B-C4998	1020	9/1/2006	fracture fill	25	green clay
1060.6-C4998	1060.6	9/1/2006	fracture fill	27	fracture fill from low angle fracture
1090.3-A-C4998	1090.3	9/1/2006	fracture fill	28	clear crystals from black fracture fill
1090.3-B-C4998	1090.3	9/1/2006	fracture fill	28	black, botryoidal mineral
1043.8-C4998	1043.8	9/1/2006	fracture fill	26	bx (breccia) matrix
XRD sample C4998 @1208.6 ft bgs	1208.6	9/7/2006	vug coating	33	vug coating
XRD sample C4998 @ 1213.5 ft bgs	1213.5	9/7/2006	cavity-lining mineral	33	brown-green cavity-lining mineral
XRD sample C4998 @ 1219 ft bgs	1219	9/7/2006	fracture fill	33	speckled green-brown fracture fill
XRD sample C4998 @ 1231.5	1231.5	9/8/2006	crystals	34	green crystals from top edge of cumulate chamber
XRD sample C4998 @ 1231.6	1231.6	9/8/2006	vesicle fill	34	vesicle-filling clay
XRD sample C4998 @ 1233.8	1233.8	9/8/2006	fracture fill	34	green fracture fill
XRD sample C4998 @ 1241.5	1241.5	9/8/2006	fracture fill	34	white fracture fill
XRD sample C4998 @ 1266.2	1266.2	9/8/2006	fracture fill	35	grenn fracture fill
XRD sample C4998 @ 1267	1267	9/8/2006	fracture fill	35	green/brown fracture fill
XRD sample C4998 @ 1269 ft	1269	9/8/2006	fracture fill	35	brown fracture fill
XRD sample C4998 @ 1277.5	1277.5	9/14/2006	fracture fill	36	fracture fill
XRD sample C4998 @ 1360.7	1360.7	9/14/2006	fracture fill	39	very dark green fracture fill
XRD sample C4998 @ 1375.5 ft	1375.5	9/14/2006	vesicle fill	40	black, botryoidal vescle fill

Table A.2. X-Ray Fluorescence Samples from Core Hole C4998

X-RAY Fluorescence

Sample No.	Depth (feet bgs)	Date	Type/Description	Page No. of Supplemental Log	Comments
C4998-E1	433.5	8/31/2006	rock/basalt	2	Elephant Mt basalt
C4998-E2	473	8/31/2006	rock/basalt	3	lower Elephant Mt basalt
C4998-P1	612.7	8/31/2006	rock/basalt	9	upper Pomona basalt
C4998-P2	672.8	8/31/2006	rock/basalt	11	middle Pomona basalt
C4998-P3	713.2	8/31/2006	rock/basalt	13	lower Pomona basalt
C4998-ESQ1	773	8/31/2006	rock/basalt	15	upper Esquatzel basalt
C4998-ESQ2	808	8/31/2006	rock/basalt	17	upper Esquatzel basalt
C4998-ESQ3	839.7	8/31/2006	rock/basalt	18	lower Esquatzel basalt
C4998-957	957	8/31/2006	rock/basalt	23	upper Umatilla basalt
C4998-968	968	8/31/2006	rock/basalt	23	upper Umatilla basalt
C4998-978	978	8/31/2006	rock/basalt	24	upper Umatilla basalt
C4998-989	989	8/31/2006	rock/basalt	24	upper Umatilla basalt
C4998-998	998	8/31/2006	rock/basalt	24	upper Umatilla basalt
C4998-1013	1013	8/31/2006	rock/basalt	25	middle Umatilla basalt
C4998-1018	1018	8/31/2006	rock/basalt	25	middle Umatilla basalt
C4998-1031	1031	8/31/2006	rock/basalt	26	middle Umatilla basalt
C4998-1039	1039	8/31/2006	rock/basalt	26	middle Umatilla basalt
C4998-1038	1038	8/31/2006	rock/basalt	26	middle Umatilla basalt
C4998-1061	1061	8/31/2006	rock/basalt	27	lower Umatilla basalt
C4998-1071	1071	8/31/2006	rock/basalt	27	lower Umatilla basalt
C4998-1077	1077	8/31/2006	rock/basalt	28	lower Umatilla basalt
C4998-1087	1087	8/31/2006	rock/basalt	28	lower Umatilla basalt
C4998-1097	1097	8/31/2006	rock/basalt	28	lower Umatilla basalt
C4998-1104	1104	8/31/2006	rock/basalt	29	lower Umatilla basalt
XRF sample C4998 @ 1278 ft	1278	9/11/2006	rock/basalt	36	massive basalt; Lolo flow
XRF sample C4998 @ 1213.9 ft	1213.9	9/12/2006	rock/basalt	33	Priest Rapids basalt
XRF-C4998-1357.2	1357.2	9/15/2006	rock/basalt	39	Lolo flow
XRF-C4998-1392	1392	9/15/2006	rock/basalt	40	Rosalia flow

Table A.3. Waxed Core Segments from Interbeds in Core Hole C4998

Preserved Intervals (Interbed Sediments)

Interval (feet bgs)	Date	Interbed/Description	Page No. of Supp. Log	Comments
503.6- 504.2		RR/sand	5	marked for USACE, not waxed as of 10/27/06
505.3- 507		RR/sand	5	sent to USACE for analysis
515- 516.2		RR/sand	5	sent to USACE for analysis
753.1- 754.2		S	15	sent to USACE for analysis
740.3- 741		S	14	sent to USACE for analysis
897.4- 897.9		CC	20	sent to USACE for analysis
925.7- 926.3		CC	22	sent to USACE for analysis
933.8- 934.5		CC	22	sent to USACE for analysis
941.0- 942.1		CC	22	sent to USACE for analysis
944.5- 945.4		CC	22	sent to USACE for analysis
1121.3- 1122.0		M	29	sent to USACE for analysis
1127' 11"- 1128' 9"		M	30	sent to USACE for analysis
1110.6- 1111.7		M	29	prepared for USACE for analysis, not taken as of 10/27/06
1176.0- 1176.4		M	32	sent to USACE for analysis

RR = Rattlesnake Ridge Interbed
S = Selah Interbed
CC = Cold Creek Interbed
M = Mabton Interbed

Appendix B

Photographs Log for Core Hole C4998

Appendix B

Photographs Log for Core Hole C4998

Photographs for core hole C4998 are contained on compact disk (CD) that is provided with the hardcopy version of this report (inside back cover).

Date	Photo Number	Subject
7/13/06	4958-4960	Drill equipment
7/17/06	4960B-4992	Drill equipment and setup activities
7/18/06	4993	View of fitting at hole collar showing mud exit
7/18/06	4994	Drilling platform area
7/19/06	4995-4996	Deleted
7/19/06	4997	View from NW of drilling area
7/19/06	4998	Mud plant tailings area-trailer covered with plastic sheeting to collect tailings
7/19/06	4999	View of transfer mud pit while operating (drilling cement)
7/19/06	5000	View of site from NW core table set up
7/19/06	5001	Close-up of core table
7/19/06	5005	Set up showing bucket to catch drilling mud when breaking rods
7/19/06	5006	Set up showing bucket to catch drilling mud when breaking rods
7/19/06	5009	Core barrel being opened to remove core
7/19/06	5010	Pump hose connected to core barrel to apply pressure to remove inner tube
7/19/06	5011	First run of core from borehole C4998; 401-402 ft bgs
7/19/06	5012	First run of core from borehole C4998; 401-402 ft bgs
7/20/06	5014	Box no. 1 core
7/20/06	5015	Core in box 1 (repeat)
7/20/06	5016	RCT surveying core barrel
7/20/06	5017	Down-hole end of core barrel
7/20/06	5018	Down-hole end of core barrel
7/20/06	5019	RCT surveying core barrel
7/20/06	5020	Spoil trailer at end of mud plant
7/20/06	5021	Spoil trailer at end of mud plant
7/20/06	5022	View of drill from NE showing overshot
7/20/06	5023	Pulling inner tube from core barrel
7/20/06	5024	Removing core from inner tube to tray
7/20/06	5025	Core in box 2
7/20/06	5026	Core in box 2 (retake)

Date	Photo Number	Subject
7/20/06	5027	Healed fracts that opened during storage activities
7/20/06	5028	Fracture surface with whitish-green-gray mineral
7/20/06	5029	Fracture material with mullion-like surface at ~426
7/20/06	5030	Fracture material with mullion-like surface at ~426
7/20/06	5031	Box 4
7/20/06	5032	Repeat of core box 4
7/20/06	5033	Core box 3
7/21/06	5034	Pyrite in fracture at 453.5 ft.
7/21/06	5035-5038	Isolated vesicle with partial geopedal filling
7/21/06	5039	High-angle fractures at ~470 ft
7/21/06	5040	Core in Box 10
7/21/06	5041	Dark horizontal bands (glass?) at ~487 ft
7/21/06	5042	Core in box 11
7/21/06	5043-5050	Chilled/altered/brecciated zone at 491.5-492
7/24/06	5051	New bit with face discharge ports
7/24/06	5052	Clay-filled fractures in basalt at ~492.3 ft
7/24/06	5053	Deleted
7/24/06	5054-5055	Tan-colored stringer in claystone-Rattlesnake Rdg Interbed (RRI)
7/24/06	5056	Fresh surface of siltstone (RRI)
7/24/06	5057	Sandstone (RRI)
7/24/06	5058-5059	Concretion in sandstone
7/24/06	5060	Core in box 12
7/24/06	5061-5062	Light yellow-brown mottling in sandstone
7/24/06	5063	Core in box 13
7/24/06	5064-5065	Thin lenses of silt (clay?) in sandstone
7/24/06	5066	Concentric markings on core due to spindling in core barrel
7/24/06	5067	Mottling in sandstone (penecontemporaneous deformation?)
7/24/06	5068-5070	Deleted
7/25/06	5071-5074	Structures in sandstone (RRI) 512-515 ft bgs
7/25/06	5075-5076	Core in box 14 (RRI)
7/26/06	5077-5078	White mineral (opal?) laminae in sandstone at 519.1 ft bgs
7/26/06	5079-5081	Replaced debris in sandstone
7/26/06	5082-5083	Solution cavities(?) in tephra-like laminae at ~519 ft bgs
7/26/06	5084-5086	Rip-up clasts of clay in sandstone at ~519.5 ft bgs
7/26/06	5087	Core in Box 15
7/26/06	5088	Contact of RRI sandstone with underlying invasive basalt (prob. Pomona) at 525.6 ft bgs

Date	Photo Number	Subject
7/26/06	5089-92	Views of mast, swivel, and mud hose going into swivel
7/26/06	5093-5095	Invasive basalt features: highly vesiculated basalt fragments in palagonite or other clay/baked seds around 530 ft bgs
7/26/06	5096	Core in box 16
7/26/06	5097	Scoriaceous basalt w/palagonite (note bedding laminae in sandstone in row above)
7/26/06	5098-5099	Basalt breccia in palagonite(?) matrix supported ~535 ft bgs
7/26/06	5100	Edge of pillow-like structure at 535.0 ft bgs
7/26/06	5101	Core in box 17
7/26/06	5102	Core in box 18
7/26/06	5103	Competent (dense) non-vesiculated basalt interval surrounded by heavy vesiculation and palagonite
7/26/06	5104	Detail of above near upper end of interval
7/26/06	5105	Brecciated basalt with high angle fractures w/clay fillings around 556 ft bgs
7/26/06	5106-5107	High-angle, fractures with thick clay fillings and chalcedony interval (opal) around 561 ft bgs
7/26/06	5108	Core in box 19
7/26/06	510-5113	Cuttings from C4996 at 326-355.5 ft bgs
7/26/06	5114-5115	Clay fracture fillings in high and low-angle fracts around 558-560 ft bgs
7/26/06	5116	Another shot of chalcedony-opaline material at 561 ft bgs
7/26/06	5117-5119	High-angle fracture with basalt breccia
7/26/06	5120	Large vug at ~569 in basalt
7/26/06	5121	Core in box 20
7/26/06	5122	Core in box 21
7/27/06	5123	Core in box 22
7/27/06	5124-5125	Core in box 23 (note zonation at ~589.5 ft, lower left, 4th row from top)
7/27/06	5126	Cement plant
7/27/06	5127	Core in box 24
7/27/06	5128	Cement plant
7/28/06	5129-5133	Bx filling high-angle fractures at 563.8 ft bgs
7/28/06	5134	Cement cored out of hole around 570 ft bgs
7/28/06	5135	“Stalactites” in vesicle
7/28/06	5136	Core in box 25
7/28/06	5137	View of rig area
8/1/06	5138,5141	Inflatable packer used to pressure grout
8/1/06	5140, 5142	Drag bit used to drill out cement on 8/2/06
8/2/06	5143	Core in box 26

Date	Photo Number	Subject
8/2/06	5144-5151	Deleted
8/2/06	5152	Breccia zone at base of EM basalt at 391.5 ft
8/2/06	5153-5155	Photomicro of contact zone between EM and RRI
8/3/06	5156-5157	Deleted
8/3/06	5158-5161	Photomicrograph of 0.5 cm breccia zone infilled with white secondary mineral at base of Elephant Mt Mbr
8/3/06	5162-5163	Photomicrograph of contact zone between base of Elephant mountain basalt and RRI, showing basalt (?) fragments within matrix of opaline secondary filling. Plag pheno
8/3/06	5164-5165	Deleted
8/3/06	5166	45^{o} fracture surface at 558.5 ft bgs with slickensides indicating normal faulting
8/3/06	5167-5168	75^{o} fracture showing offset by 45^{o} fracture and widening at juncture
8/3/06	5169	Photomicrograph of altered basalt fragments (hard) (bx) in clay fracture fill about 0.5 cm wide at 558.5 ft bgs
8/3/06	5170-5173	Photomicrograph of breccia zone @ 559.5 ft bgs clay hosting secondary black mineral with needle-like habit
8/3/06	5174-5175	Hand specimen and photomicrograph of breccia in fragment at 560.5 ft bgs with clasts of altered basalt
8/3/06	5176-5177	Photomicro and hand specimen of fracture at 561.0 ft bgs with slickensides
8/4/06	5178-5187	Photomicrograph of slickensides on fracture filling from 75^{o} fracture on 45^{o} fault
8/4/06	5190	Drawing of relationships in fault zone at 558.5 ft bgs—steep fracture terminates against 45-degree fract
8/4/06	5191-5193	Slicks on fract surface at 561 ft bgs
8/4/06	5194-5196	Brecciated opal at 541 ft bgs
8/7/06	5197	Breccia w/clay + basalt clasts @ 554.3 ft bgs
8/7/06	5198-5199	Photomicrograph of bx w/basalt and clay clasts @ 545.7 + two types of basalt? (lt gray is softer than dk gray)
8/7/06	5200-5201	Clay clasts in basalt @ 542 ft bgs
8/7/06	5202	Core in box 27
8/7/06	5203	Pyrite in fracture 623.5 ft bgs
8/7/06	5204	Deleted
8/7/06	5205	Core in box 28
8/7/06	5206	Core in box 29
8/7/06	5207	Core in box 30
8/8/06	5208	Core in box 31
8/8/06	5209	Core in box 32
8/8/06	5210	Core in box 33
8/8/06	5211-5212	Core in box 34

Date	Photo Number	Subject
8/8/06	5213	Core in box 35
8/8/06	5214	Photo of fracture filling sample box
8/8/06	5215	Core in box 36
8/8/06	5216	Deleted
8/8/06	5217	Core in box 37
8/8/06	5218	Deleted
8/8/06	5219	Photomicrograph of fined grained sand, very friable orange red @ 498.8 ft bgs
8/8/06	5220	Photomicrograph of silt w/clay @ 500.5
	5221-5223	Deleted
8/8/06	5224	Photomicrograph of fine grained sand @ 513.7
8/8/06	5225	Photomicrograph of fine sand @ 515.6
8/8/06	5226	Photomicrograph of sandy silt @ 518.0
8/8/06	5227	Deleted
8/8/06	5228	Core in box 38
8/8/06	5229	Photomicrograph of fine-grained sand @ 518.7
8/8/06	5230	Photomicrograph of medium-fine-grained sand @ 521.7
8/8/06	5231	Photomicrograph of fine-to-coarse sand @ 527.8
8/8/06	5232	Box 39
8/9/06	5233	Brown alteration halo around fract @ 671 ft bgs
8/9/06	5234	Core in box 40
8/9/06	5235	Core in box 41
8/9/06	5236	Deleted
8/10/06	5237	View of core rig
8/10/06	5238	Core box
8/10/06	5239-5242	View of core rig
8/10/06	5243	Deleted
8/10/06	5244	Core table activity
8/10/06	5245	Run 78, 741-742
8/10/06	5246	Core in box 42
8/10/06	P1010002	Preparing core barrel for core extraction
8/10/06	P1010003-6	Run 80
8/10/06	P1010007	Removing core from core tray
8/10/06	P1010008	Oblique view of core in box 43
8/10/06	5247	Mud trailer
8/10/06	5248-5250	Oblique view of core in box 44
8/10/06	4251	View of core rig

Date	Photo Number	Subject
8/10/06	5252-5255	Run 84, 765-770 (runs 79-83 and 85-87 not photographed separately—see box photos)
8/10/06	5256-5260	Run 88, 785-790
8/10/06	5261-5263	Run 89, 790-793
8/10/06	5264	Box 42
8/10/06	5265	Close up of bx in box 42
8/10/06	5266	Box 43 (Cold Cr interbed)
8/10/06	5267	Close up of Selah seds in box 43
8/10/06	5268	Box 44
8/10/06	5269	Closeup of light banding in box 44
8/10/06	5270	Box 45
8/10/06	5271	Closeup of flowtop bx in box 45
8/10/06	5272	Box 46
8/10/06	5273	Box 47
8/10/06	5274	Box 48
8/10/06	5275-5276	Slickensides and fracture at ~792.5
8/10/06	5277-5284	Run 90, 793-798
8/10/06	5285-5289	Run 91, 798-803
8/10/06	5290-5294	Run 92 (**no label**) 803-808
8/10/06	5295-5298	Run 93 (**no label**) 808-813 (no. 5296 deleted)
8/10/06	5299-5303	Run 94 (**no label**) 813-818
8/11/06	5304-5308	Run 96 (**no label**) 818-823 (no photo of run 95)
8/11/06	5309-5312	Run 97 (**no label**) 823-828
8/11/06	5313-5317	Run 98 (**no label**) 828-833
8/11/06	5318-5321	Run 99 (**no label**) 833-838
8/11/06	5322-5323	Fracture surface at **?**
8/11/06	5324	Box 53
8/11/06	5325	Box 52
8/11/06	5326	Box 51
8/11/06	5327	Box 50
8/11/06	5328	Box 49
8/11/06	5329	Box 48
8/11/06	5330	Box 47
8/11/06	5331	Box 46
8/11/06	5332	Box 45
8/11/06	5333	Box 44
8/11/06	5334	Box 43 (Selah interbed)

Date	Photo Number	Subject
8/11/06	5335	Box 42
8/11/06	5336-5339	Run 100 (no label)
8/11/06	5340	Box 54
8/11/06	5341	Box 55
8/14/06	5342-5346	Run 101 848.4-853.4 (placard erroneously shows 748.4-753.4) Photos 5342 through 5356 have erroneous date stamp—should be 8/14/2006
8/14/06	5347-5350	Run 102, 853.4-855.1 and Run 103, 855.1-859.4 (The placard erroneously shows an interval of 853.4 to 859.4—the run blocks in the box are correct)
8/14/06	5351-5353	Run 104, 859.4-862.4
8/14/06	5354-5356	Run 105, 862.4-867.4
8/14/06	5357	Run 106, 867.4-872.4 (60% lost)
8/14/06	5358-5361	Run 107, 872.4-877.4 (placard erroneously shows interval ending at 875.4—block in box is correct)
8/14/06	5362-5365	Run 108, 877.4-882.4
8/14/06	5366-5369	Run 109, 882.4-887.4
8/14/06	5370-5372	Run 110, 887.4-892.4
8/14/06	5373-5376	Run 111, 892.4-897.4
8/14/06	5377-5381	Run 112, 897.4-902.4
8/14/06	5382	Box 60
8/14/06	5383	Box 59
8/14/06	5384	Box 58
8/14/06	5385	Box 57
8/14/06	5386	Box 56
8/15/06	5387-5389	Run 113 902.4-907.4
8/15/06	5390	Box 61
8/15/06	5391-5392	Run 114 , 907.4-909.4
8/15/06	5393-5396	Run 115, 909.4-914.4
8/15/06	5397-5398	Close up of core in run 115
8/15/06	5399-5402	Run 116, 914.4-919.4
8/15/06	5403	Close up of core in run 116
8/15/06	5404-5406	Run 117, 919.4-924.4
8/15/06	5407-5408	Run 118, 924.4-929.4 (only 70% recovery)
8/15/06	5409-5410	Run 119, 929.4-932.4 (placard erroneously indicates run ends at 931.4-931.4 to 932.4 was lost)
8/15/06	5411-5414	Run 120, 932.4-937.4 (placard erroneously shows 931.4 as start of run)
8/15/06	5415-5419	Run 121, 937.4-942.4
8/15/06	5420-5421	Run 123, 947.4-951.4
8/15/06	5422	Box 62

Date	Photo Number	Subject
8/15/06	5423	Box 63
8/15/06	5424	Box 64
8/15/06	5425	Box 65
8/15/06	5426	Box 66
	5427-5432	Deleted
8/16/06	5433-5436	Run 126, 958.4-963.4
8/16/06	5437	Box 67
8/16/06	5438-5440	Run 127, 963.4-968.4
8/16/06	5441	Box 68
8/16/06	5442-5445	Run 128, 968.4-973.4 (placard erroneously shows run ends at 972.4)
8/16/06	5446-5447	Box 69
8/16/06	5448-5451	Run 129, 973.4-978.4
8/16/06	5452	Box 70
8/16/06	5453-5456	Run 130, 978.4-983.4
8/16/06	5457-5460	Run 131, 983.4-988.4
8/16/06	5461	Box 71
8/16/06	5462-5465	Run 132, 988.4-993.4
8/16/06	5466	Run 133, 993.4-994
8/18/06	5467-5469	Run 134, 994-998
8/18/06	5470-5473	Run 135, 998-1003
8/18/06	5474	Box 73
8/18/06	5475-5478	Run 136, 1003-1008
8/18/06	5479-5482	Run 137, 1008-1013
8/18/06	5483-5486	Run 138, 1013-1018
8/18/06	5487-5489	Run 139, 1018-1022
8/18/06	5490	Close up of fracturing in run 139
8/18/06	5491-5494	Run 140, 1022-1027
8/18/06	5495	Closeup of vesiculation and fracturing in run 140
8/18/06	5496-5499	Run 141, 1027-1032
8/18/06	5500	Box 77
8/18/06	5501	Box 72
8/18/06	5502	Box 76
8/18/06	5503	Box 75
8/18/06	5504	Box 74
8/18/06	5505	Box 71
8/21/06	5506	Run 142, 1032-1033
8/21/06	5507-5509	Run 143; 1033-1037

Date	Photo Number	Subject
8/21/06	5510	Box 78
8/21/06	5511	Box 78, 1034.4 feature – elongated vesicles
8/21/06	5512-5514	Run 144; 1037-1040
8/21/06	5515-5518	Run 145; 1040-1043
8/21/06	5519-5522	Run 146; 1043-1047
8/21/06	5523	Box 79
8/21/06	5524-5529	Run 147; 1047-1052
8/21/06	5530-5532	Run 148; 1052-1053 (no photo for run 149)
8/21/06	5533-5536	Run 150 1057-1062
8/21/06	5537	Box 81
8/21/06	5538	Box 80
8/22/06	5539	Micropegmatite at 1059.6
8/22/06	5540-5543	Run 151; 1062-1067
8/22/06	5544	Box 82
8/22/06	5545-5548	Run 152, 1067-1072
8/22/06	5549-5552	Run 153; 1072-1077
8/22/06	5554	Box 83
8/22/06	5555-5558	Run 154; 1077-1082
8/22/06	5559	Box 84
8/22/06	5560-5563	Run 155, 1082-1087
8/22/06	5564	Deleted
8/22/06	5565-5566	Photomicrograph of dark grn mineral with stepped (en eschelon) texture in fracture at ~1086
8/22/06	5567-5570	Run 156
8/22/06	5571	Box 85
8/22/06	5572-5574	Photomicro of green botryoidal mineral and clear cubic habit mineral on open space fract filling at ~1090.3
8/22/06	5575-5578	Run 157; 1088-1097
8/22/06	5579	Core in box 86
8/22/06	5580-5583	Run 158, 1097-1102
8/22/06	5584-5586	Run 159, 1102-1105.5
8/22/06	5587	Box 87
8/23/06	5588-5590	Run 160, 1105.5-1109
8/23/06	5591	Run 161, 1109-1112
8/23/06	5592-5595	Run 163, 1113-1118
8/23/06	5596	Core in box 88
8/23/06	5597-5600	Run 164, 1118-1123

Date	Photo Number	Subject
8/23/06	5601-5602	Run 165, 1123-1125
8/23/06	5603-5604	Run 166, 1125-1130
8/23/06	5605-5606	Box 89
8/23/06	5607	Box 87 (see also photo no. 5587)
8/23/06	5608-5611	Run 167, 1130-1135
8/23/06	5612	Box 90
8/24/06	5613-5616	Run 168, 1135-1140
8/24/06	5617	Box 91
8/24/06	5618	Deleted
8/24/06	5619-5621	Run 169
8/24/06	5622-5625	Deleted
8/24/06	5626-5629	Run 170
8/24/06	5630	Deleted
8/24/06	5631	Box 92
8/24/06	5632	Run 171
8/24/06	5633-5636	Run 172
8/24/06	5637,5639-5640	Run 173 (5638 bad file)
8/24/06	5641	Run 174 (Note that although plackard says 3.2 ft are missing, actually only 2.2 ft were not recovered
8/24/06	5642	Box 93
8/24/06	5643	Run 175
8/24/06	5644-5646	Run 176, 1170-1174
9/24/06	5647	Box 94
8/24/06	5648-5650	Run 177, 1174-1179
8/24/06	5651	Deleted
8/24/06	5652-5653	Run 179, 1184-1188 (for run 178 see photo for box 96)
8/24/06	5654	Box 95
8/31/06	5655-5657	Deleted
8/31/06	5658-5662	Py and marcasite in fract surface @ 473.2
8/31/06	5663	Py @ 473.2
8/31/06	5664	Zoned py and marcasite or chalcopy @ 473.2
8/31/06	5665-5666	Siderite xtals (?) at 954.4 in vug (vesicle)
8/31/06	5667-5668	Marcasite or py on siderite at 954.4
9/1/06	5669-5670	Botryoidal mineral at 1090 ft bgs
9/1/06	5671-5672	Plagioclase xtal on basalt frag from C4996 from depth of Roza from C4996
9/1/06	5673	Marcasite octahedron at 1035.5 ft bgs

Date	Photo Number	Subject
9/1/06	5674	Marcasite and py or chalcopy at 1035.5 ft bgs
9/1/06	5675	Mud man (Halliburton) doing viscosity measurements
9/6/06	5676-5682	Views of Geovision probe and accessories at C4997 (5679 and 5680 deleted)
9/6/06	5683	Run 180, 1188-1189 ft.
9/6/06	5684-5687	Run 181, 1189-1193 ft
9/6/06	5688	Box 96
9/6/06	5689	Coalified wood from Run 180
9/6/06	5690-5691	Run 182, 1193-1196
9/6/06	5692-5693	Run 183, 1196-1198
9/6/06	5694	Petrified wood @ ~1193 ft
9/6/06	5695	Box 97
9/6/06	5696-5700	Run 184, 1198-1203 ft
9/6/06	5701-5704	Run 185, 1203-1208 ft
9/6/06	5705	Deleted
9/6/06	5706	Box 98
9/7/06	5707	Run 186, 1208-1210 ft
9/7/06	5708-5711	Run 187, 1210-1215 ft
9/7/06	5712	Box 99
9/7/06	5713-5716	Run 188, 1215-1220 ft
9/7/06	5717-5720	Run 189, 1220-1225 ft
9/7/06	5721	Box 100
9/7/06	5722-5726	Run 190, 1225-1230
9/7/06	5727-5728	Vesicles containing “cumulate” of unknown mineral
9/7/06	5729	Box 101
9/7/06	5730-5734	Run 191, 1230-1235 ft
9/7/06	5735-5736	“Mineral chamber” at 1231.5 ft
9/7/06	5737-5739	Quartz xtals in vug @ 1234 ft
9/7/06	5740	Box 102
9/8/06	5741-5744	Photomicrograph of quartz xtals in vug at 1234 ft
9/8/06	5745-5749	Cumulate chamber at 1231.5 ft
9/8/06	5750-5751	Green fracture coating and white mineral spheres at 1234 ft, dry and wet, respectively
9/8/06	5752-5753	Run 192, 1235-1238 ft
9/8/06	5754-5757	Run 193, 1238-1243 ft
9/8/06	5758	Box 103
9/8/06	5759	Deleted

Date	Photo Number	Subject
9/8/06	5760-5763	Run 194, 1243-1248 (5763 is start of run)
9/8/06	5764-5766	Run 195, 1248-1253
9/8/06	5767	Box 104
9/8/06	5768-5770	Run 196, 1253-1258
9/8/06	5771	Box 105
9/8/06	5772-5775	Run 197, 1258-1263
9/8/06	5776-5778	Run 198, 1263-1268
9/8/06	5779	Box 106
9/8/06	5780-5783	Run 199, 1268-1273
9/8/06	5784	Box 107
9/8/06	5785-5788	Run 200, 1273-1278
9/11/06	5789-5791	Run 201, 1278-1283
9/11/06	5792	Box 108
9/11/06	5793-5795	Run 202
9/11/06	5796	Run 202—unbroken
9/11/06	5797	Box 109
9/11/06	5798-5801	Run 203
9/11/06	5802-5804	Run 204
9/11/06	5805	Box 110
9/11/06	5806-5807	Large plagioclase xtal @ 1297 ft bgs
9/11/06	5808-5811	Run 205
9/11/06	5812-5814	Run 206
9/11/06	5815	Box 111
9/11/06	5816-5817	Photomicrograph of Priest Rapids basalt @ ~1298 ft bgs
9/11/06	5818-5821	Photomicrograph of Pyritic vein (fracture lining) @ ~1298 ft bgs
9/11/06	5822-5825	Run 207, 1308-1313
9/11/06	5826	Box 112
9/12/06	5827-5828	Run 208, 1313-1316 ft
9/12/06	5829-5831	Run 209, 1316-1321 ft
9/12/06	5832	Box 113
9/12/06	5833-5835	Run 210, 1321-1326 ft
9/12/06	5836-5338	Run 211, 1326-1331 ft
9/12/06	5839	Box 114
9/12/06	5840-5842	Run 212, 1331-1336 ft
9/12/06	5843	Box 115
9/12/06	5844-5846	Run 213, 1336-1341 ft
9/12/06	5847-5850	Run 214, 1341-1346 ft

Date	Photo Number	Subject
9/12/06	5851	Box 116
9/12/06	5852-5854	Run 215, 1346-1351 ft
9/13/06	5855-5856	Plagioclase in Lolo P.R. basalt (micro)
9/13/06	5857	Run 216, 1351-1353 ft
9/13/06	5858	Box 117
9/13/06	5859-5862	Run 217, 1353-1358 ft
9/13/06	5863-5866	Run 218, 1358-1363 ft
9/13/06	5867	Clay fracture fill material at 1360.5 ft
9/13/06	5868	Box 118
9/13/06	5869	Run 219, 1363-1365.5 ft
9/13/06	5870-5872	Run 220, 1365.5-1370.5 ft
9/13/06	5873	Box 119
9/13/06	5874-5876	Run 221, 1370.5-1375.5 ft
9/13/06	5877	Box 120
9/13/06	5878-5880	Run 222, 1375.5-1380.5 ft
9/13/06	5881	Run 223, 1380.5-1383 ft
9/13/06	5882	Box 121
9/14/06	5883-5885	Run 224, 1383-1387 ft
9/14/06	5886-5888	Run 225, 1387-1392 ft
9/14/06	5889	Box 122
9/14/06	5890-5892	Run 226, 1392-1397 ft
9/14/06	5893	Box 123
9/14/06	5894	Run 227, 1397-1400 ft **TOTAL DEPTH**
9/14/06	5895	Deleted
9/14/06	5896	Box 124
9/14/06	5897	View of core rig at TD
11/15/06	6165	Core in box 5
11/15/06	6166	Core in box 6
11/15/06	6167	Core in box 7
11/15/06	6168	Core in box 8
11/15/06	6169	Core in box 9

Appendix C

Lithologic Logs

Appendix C

Lithologic Logs

Lithologic symbols used in the field during the drilling and in this report are shown in Figures C.1 and C.2.

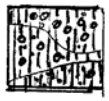
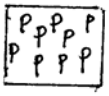
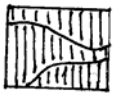
Symbol	Description
	**Basalt (with vesicles, large/small)**
	**Basalt with horizontal fractures**
	**Basalt with vertical fractures**
	**Basalt with angled fractures**
	**Basalt with phenocrysts**
	**Basalt pillows (with or without palagonite)**
	**Palagonite without basalt**
	**Basalt: Flowtop, flowtop breccia, aa, or pahoehoe**
	**Basalt, structureless (aphanitic, nonporphyritic)**

Figure C.1. Lithologic Symbols for Basalt and Basalt-Related Features

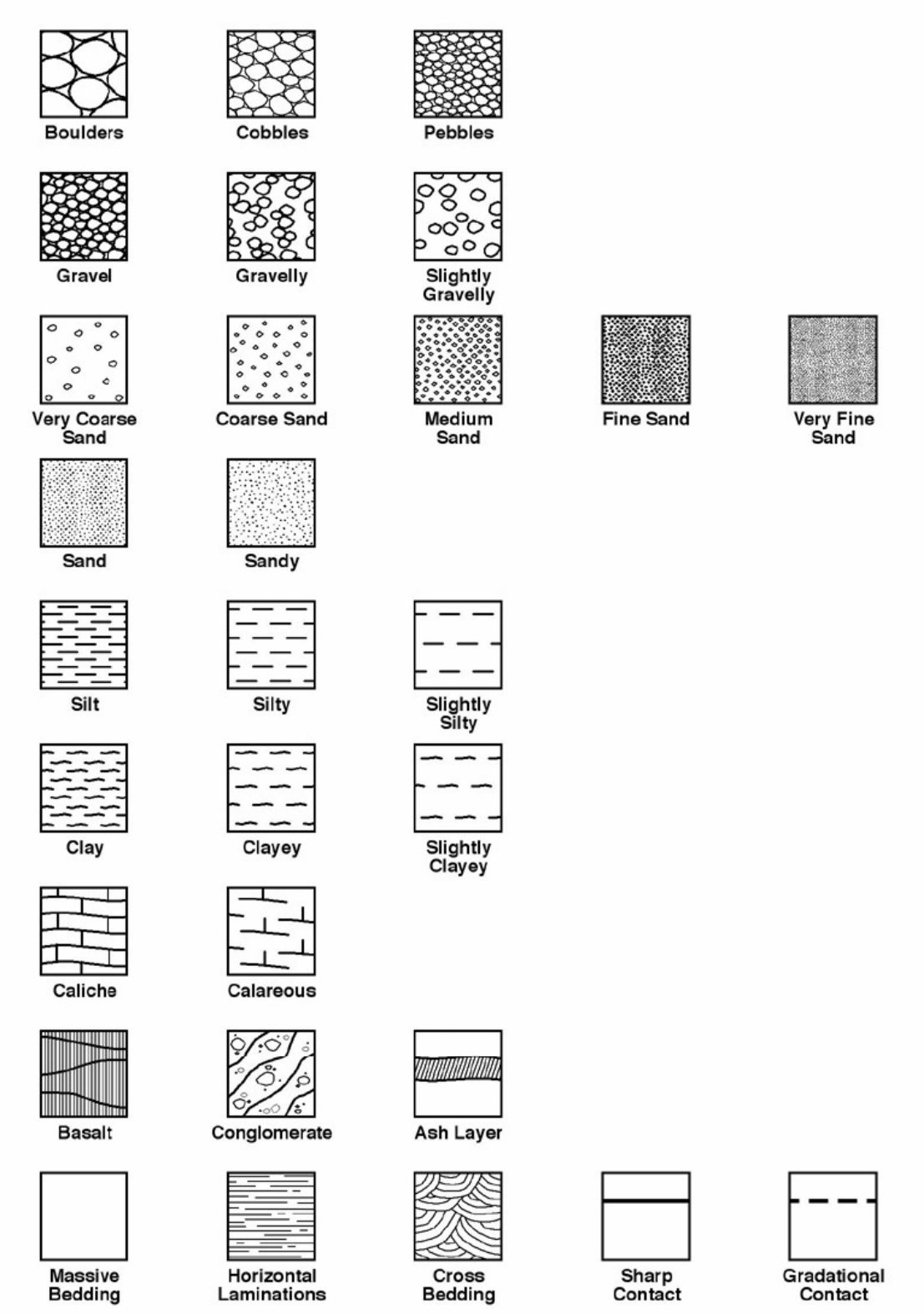


Figure C.2. Lithologic Symbols for Surficial Sediments and Sedimentary Interbeds

C.1 Borehole Logs

49647/T5.2.1
Log-06-148

BOREHOLE LOG

Page 1 of 46
Date: 7/17/06

Well ID: C4998 | Well Name: Corehole | Location: WTP DBB 8/28/06
Project: WTP SEISMIC | ~~Reference Measuring Point: Elev.~~ Reference DBB 7/19/06 = ~~690 ft. MSL~~ See p. 11

Depth (Ft.)	~~Box Run Type~~ Sample No.	~~DBB 7/14/06 Blows~~ Recovery %	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
				Set-up diamond drill →	
				06:30 - ~~16:30~~ DBB 7/17/06 16:30	(Photos taken) - MAST going up - deck
				DBB 7/17/06	09:00 - Driller had to leave site to get more supplies from town. Helper Ken took 2 Aspirin from First Aid kit to treat bee stings he received over the weekend.
				DBB 7/17/06	11:20 Electrician (American Electric) finished grounding rod install for mud plant.
					10:00 - digging hole for small mud tank. The drill is a CS-1000 (Christensen Boyles Corp.) "Constant" drill rod above ground = 5 ft. Rig No. is 723.
					~800 - visited by T. Browns, Lou Miller & intern. ~13:15 driller returned ~13:45 Bryan Raeder, RCT, visited. ~13:45 Rick G. visits.
					14:35 - drillers began tripping into hole w/ new rods and drag bit (will be used to drill out cement). Mike Wolkup arr @ ~14:20
					15:30 Nathan Pakish arr to clear photos
					16:00 Drillers knock off work.

Reported By: D.B. Barnett | Reviewed By: S.P. Reidel
Title: Geologist | Title: Staff Geologist
Signature: D. B. Barnett | Date: 7/17/06 | Signature: S.P. Reidel | Date: 10/18/06

SEE REVERSE SIDE
DBB 8/23/06

A-6003-642 (03/03)

Reverse side to page 1 of Borehole Log
C4998 – Core hole DBB 8/23/06

Procedures used throughout this Log:*

ASTM: D6032-02, Determing Rock Quality Designation of Rock Core.
D5434-03, Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock.

Fluor Hanford:
GRP-EE-01-7.0. Geologic Logging Procedure.
~~DS~~ DBB 8/24/06

PNNL:
PNNL-15848 Rev. 2. Sampling and Analysis Plan, Waste Treatment Plant Seismic Boreholes Project (sections 2.42, 2.5, Appendix)
ICN-PNNL-15848-2.1 (Interim change Notice)

ASTM (cont.):
- D5079-02, Standard Practices for Preserving and Transporting Rock Core samples.
- D2113-99, Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation.

U.S. Army Corps of Engineers. Geotechnical Investigations
EM 1110-1-1804, Section 5.

* Combinations of these procedures will be used, where appropriate, to achieve the level of detail necessary to meet project needs as they arise or change.

BOREHOLE LOG

Page 2 of 46
Date: 7/18/06

Well ID: C4998 | Well Name: Core Hole | Location: (Approximate) N3901 E10381 DBB 8/28/06
Project: WTP SEISMIC | ~~Reference Measuring Point~~ DBB 7/18/01 Approx. elev = 640 ft. msl See p. 11

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Comments Sample Description DBB 7/18/06 — Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments — Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
				0600 P.O.D mtg. - drillers need to cover ground beneath rig, mud plant/pump to handle any spillage.	
				06:30 - 09:30 - Drillers placing plastic fabric under mud mixing/handling areas.	
				09:30 - Walkup informs drillers of info needed for daily reports. 09:35 began fueling drill	
				10:10 - Drillers began lowering additional rods into hole (some were removed yesterday eve so would not be on bottom) Working on swivel & mud pump - circulating into hole.	
				11:26 - Drill shut off - Paul off to get water (~11:10). Drillers discovered that fittings on pump hose were too large, hence not sealing (swivel problem). Pasco is nearest supply house. Decision was made ~ 12:05 to shut down for the day by driller.	
				We discussed tomorrows P.O.D., secured the site & left @ ~2:30	

NA DBB 7/18/06

7/18/06 DBB

Reported By: D.B. Barnett | Reviewed By: S.P. Reidel
Title: Geologist | Title: Staff Geologist
Signature: DBBarnett | Date: 7/18/06 | Signature: SP Reidel | Date: 10/19/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 3 of 46

Date: 7/19/06

Well ID: C4998 | Well Name: Core Hole | Location: (Approx): N3901, E10381 DBB 8/20/06 see p. 11

Project: WTP SEISMIC | ~~Reference Measuring Point:~~ PBB 7/19/06 Approx. elev. 690 ft MSL

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
345				6:40 – After plan of day, began setting up with new hose fittings 7:20 began drilling out cement @~346 ft bgs.	Drillers report cement is soft – most washing out of hole instead of drilling (07:45) Top of cement is ~346 ft. BGS ~0.5 ft/min = penetration rate w/ drag bit (photo)
350				Cement grout 346ft± Top	
355					
360					
365				DBB 8/23/06	DBB 8/23/06
370					
375					
380					

Reported By: D.B. Barnett | Reviewed By: S.P. Reidel

Title: Geologist | Title: Staff Geologist

Signature: D B Barnett | Date: 7/19/06 | Signature: S P Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 4 of 46
Date: 7/19/06

Well ID: C4998 | Well Name: Core Hole | Location: (Approx): N3901, E10381 DBB 8/28/06

Project: WTP SEISMIC | ~~Reference Measuring Point:~~ Approx. elev. ~~690 ft~~. MSL see p. 11 DBB 7/19/06

Depth (Ft.)	Sample ~~Type~~ Box/Run No.	Sample ~~Blows~~ Recovery c/o	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
390				cement to 401 ft. Bgs	09:10 - hit basalt @ 401 ft. Bgs & began tripping out of hole to change bits.
395	NA (using drag bit)	NA (using drag bit)			~ 11:00 to 14:00 rinse out cement drilling mud, prepare new mud (BAROID rep), trip into hole with diamond bit
400					→ Driller reports a void (water w/o cement from 400 to 401 ft bgs. After consultation with Energy Solutions (Gardner) Site rep (Walkup) determine seal is ok and can proceed with coring
401	1/1	100		401 — Basalt, blk to dk green/blue; vesicular from ~ 402.2 to ~ 402.8, vesicles <1mm to ~1cm in longest dimension. Contains uniformly distrib of plag. pheno ~ 1-2 mm in length. Moch fracturing high-angle fracts @ 401 to 402.5	14:18 - Began (7/19/06) coring basalt
403					
405	1/2	100			
408					
410	2/3	100		Fractures filled w/clay, chlorophaeite. Thick fracture at 401 - 402.5 ~ 0.5 cm thk.	NOTE: The convention used for arrangement of core in Core Boxes is "Book" Standard, i.e., with the box label on left and uppermost sample beginning in the upper left-hand corner, proceeding from left to right
415	2/4	100		Vesicles most numerous: 403 - 403.5, 406-408.	
	3/4			~ 416.4 ft — vesicles are filled w/ white mineral H ≅ 3-4. (Not all vesicles in this region are filled)	DBB 7/19/06
420	3/5	100		extremely fractured 417 - 417.7	ALL core markers in FEET
				very competent from 417.7 - had to break up the two cores to fit in Box - tap w/hammer and the whole section from 421 to 423 broke into 4 pieces along fractures (healed fracts) - see photo log # 5027 DBB 7/20/06	Began on 7/20/06 @ 403.0
425	4/6	100			
	(See P. 5)				

Reported By: D.B. Barnett | Reviewed By: S.P. Reidel

Title: Geologist | Title: Staff Geologist

Signature: D.B. Barnett | Date: 7/19/06 | Signature: S.P. Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 5 of 46
Date: 7/20/06

Well ID: C4998 | Well Name: Core hole | Location: (approx) N3901, E10381 DBB 8/28/06 See P. 11
Project: WTP Seismic | ~~Reference Measuring Point:~~ DBB 7/20/06 Approx. elev. ~~690 ft~~ msl

Depth (Ft.)	Sample Box Type Run No.	Sample ~~Blows~~ Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
425	(see p.4)	0/0		Relatively large vesicles 423.6 and 425.11 0.5 to 1.5 cm dia. occur isolated in otherwise featureless basalt. High angle fracts filled w/ ~3 mm wide veins of chlorophaeite and white mineral @ 426.0 – 427.8 Strongly magnetic fracture surfaces have striations that resemble mullion (photo no. ~~5029~~ this date DBB 7/20/06 5029 and 5030)	Driller reports Run 6 was harder rock. Drillers drop the 429–433 run in mud tank at end of deck – otherwise would have likely be one solid stick.
430	4/7	100			
	5/7				
435	5/8	100		High angle fractures (~75°) occur intermittently ~439– Lower-angled fracts (~30°) are more common, but in general rock is very competent	
	5/9				
440	6/9	100		Small (~1mm) vesicles distributed evenly and numerously 448–453 with isolated larger elongated vesicles @ ~448.7 ft	
445	6/10	100		Core very competent – requires breaking to store – some (most) breakage occurs along incipient fracts	
	7/10				
450	7/11	100			~3 in left in hole from run 11
				Shift ended with Run 11 @ 453 ft 16:00	Started Run 12 on 7/21/06 @ ~07:20
455	7/12	100		4 ft of run 12 is almost entirely fracture and feature – free – only small vesicles evenly throughout as above. 4 ft section in one solid piece.	
	8/12				
460	8/13	100		Upon breaking to fit in box a fracture opened at ~453.5 revealing pyrite on fract. wall. (Photo #5034 this date – 7/21/06) Pk grn to blk clay or serpent. min in fract @ ~~462 ft~~ 462.9 has greasy feel DBB 7/21/06	
	(see p.6)				

Reported By: D.B. Barnett | Reviewed By: S.P. Reidel
Title: Geologist | Title: Staff Geologist
Signature: [signature] Date: 4/20/06 | Signature: [signature] Date: 10/18/06

A-6003-642 (03/03)

ALL VALUES in feet unless otherwise indicated

BOREHOLE LOG

Page 6 of 46
Date: 7/21/06

Well ID: C4998 | Well Name: Core Hole | Location: (approx) N3901 E10381
Project: WTP Seismic | ~~Reference Measuring Point:~~ approx. elev. = ~~690~~ ft msl (see p.11)

DBB 7/20/06 DBB 8/28/06

Depth (Ft.)	Sample ~~Type~~ No.	Sample ~~Blows~~ Recovery %	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
BOX / Run					
460	(see previous sheet)				
DBB 7/21/06 465	8/14	100		AT ~ 469 ft began observing large, isolated vesicles with some dark mineraloid accumulations on downhole (bottom) of vesicles — still mostly open space. More high-angle fracts appearing in Run 15. Photo of isolated vesicle w/mineraloid @ ~ 471.4 ft. (Photo #s 5035-5038) Photo of high-angle tracts at ~ 470.0 (#5039) Rock otherwise still v. competent @ these depths.	Began having trouble with "mud rings" — centrifuging mud on walls of drill pipe (inside) thus hindering retrieval of core barrel — This started around run 13.
	9/14				
470	9/15	100			
	10/16				Drillers and mud man put in ~ 2 lbs ~~bicarbonate~~ bicarbonate to flocculate cuttings & help reduce mud rings. (~ 09:30) DBB 7/21/06
475	10/16	100		473.4 and 474.4 — more py in fracts — exposed during breakage to fit box. Microcrysts are too small to be visible — appears much more glassy in ground mass (sounds glassy on striking) 482.6 — intensely fractured 481.5 — flattened vesicles (1.5 cm x 2 mm max) filled, in some case w/zeolite(?) (483 ft bgs = 101 ft of Elephant mountain mbr. basalt) Fracture fillings of zeolite (?) w/MnO2 coatings occasionally. Dark bands (glass?) ~ 1 to 3 cm long, horizontal (photo 5041)	
	10/17				(Box 10 #5040)
480	11/17	100			
	11/18				
485		100			Drilling shut in @ ~ 492 — could be interbed — 4 ft. run ~ 13:15 — after pulling core it was still in basalt — driller thinks bit is worn out and is tripping out to change bit. End day @ 392. ft
	12/19				
490		100		491.8 — Basalt appears altered and brecciated to 492.0. Appears to be a chill zone (?) with two distinct bands of brecciated/sheared basalt (glass?) ~ 0.5 cm wide each, in-filled w/zeolite ok other light-colored material (photos 5044-5050 this date)	
495	(See p. 7)				

DBB 7/21/06

Reported By: D.B. Barnett | Reviewed By: S.P. Reidel
Title: Geologist | Title: Staff Geologist
Signature: [signature] Date: 7/21/06 | Signature: [signature] Date: 9/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 7 of 46
Date: 7/24/06

Well ID: C4998 | Well Name: Core Hole | Location: (Approx) N 3901 E 10381 DBB 8/28/06
Project: WTP Seismic | Reference Measuring Point: DBB [redacted] Approx. elev. ~~690 ft~~ msl

see p. 11

Depth (Ft.) Box/Run	Sample Type No.	Sample Blows Recovery %	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
490	(see p. 6)			492 (cont.) Basalt has two clay-filled fracts - largest is ~1 cm wide, low-angle (~horiz) (see photo 5052) Fracts bifurcate, clay is dk grn to DBB 7/24/06 492 blk. clay begins to slake in air, crumbles - has greasy feel and appearance	3'4" run 21
	12/20	100			will try to preserve core seds. by keeping wet
495	12/21	~~80~~ 100 DBB 7/24/06		492.2 - 496.0 Clay - most gray - grn. w/ 1 cm - wide tan - grn clay stringer crossing core @ ~ 30° from horizontal Mod. hard, possibly baked (?) (photo # 5054) some silt, minor mica @ ~ 495.5 (photo # 5056) 496.0 - 497.7 silt, coarsening ↓ to fine/med sand/sandstone - contains ~ 30% felds sp. (?) 40% qtz, 90% matrix Some matrix - looking grains may be organic frags - sand - coated casts of replacement bodies (fossil/tr. fossil) (see photo 5059)	Drillers make short runs when necessary to preserve core
	13/22	100			also fine sand (poor sorting) 493° - 496°
500	13/23	100			(photo # 5060 = Box 12)
505	13/24	90			core is turning slightly in barrel - hence lost 10% recovery
	14/25	100		497.7 - 499.9 med. sand/sandst: tan to dk brn. (salt/pepper appearance)	core appears to break at bedding changes
510	14/26	100		499.9 - 501.9: silt/clay, lt. brn, compact, but can be carved w/ knife 501.9 - 505.5 fine/v fine Sand/sandst: lt gray-grn, lam/cycl - brn mottling 504.3 - 504.5 (photo 5062), 505.5 silt/siltstone w/ v. fine sand and minor clay/claystone → to med. grn-grn w/ lenses up to 0.5 cm of lt. brn silt/clay (photo # 5065) @ 509.0 ft (IG) (lt. gry-grn @ 508.5 - ~~510.0~~ DBB 7/24/06 510.1 - 525.6 med/coarse sand/sandst. poorly sorted, lt-med gry-grn to med brn w/ clay frags & mottling (bio turb.?) @ 511.0 to ~512.3 and with more pronounced structure w/ depth - may be penecontemp. deform. struct. (eg. ball & pillow) (photos ~~5070~~ 5071 - 74) micaceous and organic debris - carbonaceous in portions of interval, lighter, irreg leases are fine sand, silt, clay in the coarse sand host. (Photos 5075 - 5076 = Box 14) Possibly bx of semi-consol. seds.	(photo # 5063 = Box 13)
	15/27	100			(photo # 5066 = concentric markings on core due to spindling)
515					509.5
520				DBB 7/25/06	11:20 - driller's helper received serious thumb injury - activity ceased - Wally takes helper (Paul Chaney) to first aid
525	(see p. 8 for continuation)				11:43 - all systems off - stand down on project left site @ 14:30

Reported By: D.B. Barnett | Title: Geologist | Signature: [signature] | Date: 7/25/06

Reviewed By: S.P. Reidel | Title: Staff Geologist | Signature: [signature] | Date: 10/19/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 8 of 46

Date: 7/[illegible]/06

Well ID: C4998 | Well Name: core Hole | Location: (Approx) N3901 E10381

Project: WTP Seismic | ~~Reference Measuring Point:~~ Approx. elev. 690 ft (msl) DBB 8/28/06 see p. 11

Depth (Ft.)	Sample Box/Run ~~Type~~ No.	Sample ~~Blows~~ Recovery	DBB 7/25/06 Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
515	(see p. 7)				Began drilling 7/25/06 @ 515 ft
	15/18	7/25/06 DBB 70 85		(Two fracture mineral samples taken @ ~518°) intercalated tuffaceous (?) laminae, esp. at 519.1 to 519.6 (Photo # 5077-78) Debris fragments replaced by Calc. or other @ ~518.0 (photos 5079-81) - soft sed. deform.	New mud man from Halliburton Buck Hammond. ~8:17 swivel and hose locked up [illegible] hose — "bird-egged" the main hoist cable. New parts needed - shut down.
520	15/29 16/29	100		(Stopped here on 7/25/06 (520 ft bgs) features involving the white tephra laminae Replacement features/texture prominent w/ rings @ ~519.° (Photo # 5083) Sand becomes massive w/ a few rip-up clasts of clay/silt @ 519.5 (photos 5084-5086) ; salt/pepper appearance	This repair took [illegible] 15:35 Will pull barrel tomorrow. END @ 16:00
525	16/30	100		Sand coarsening downward [illegible] @ 524.2 525.6	7/26/06 0640 — drillstring is stuck in hole — WA1 left 17ft off bottom, but still bound up.
	16/31	100		→ Contact 525 [illegible] (Photo # 5088)	
530	[illegible] 32			525.6 to 546° - Breccia (flowtop?) - vesicular basalt clasts, angular to rounded from < 1mm to > 10 cm in dia. matrix-supported by a reddish-brn (dark) clay (palagonite ?) (photos # 5093-5095) (5097). Scoriaceous basalt w/ clay (same as above, but more vesicular, rubbly)	(Photo 5087 = Box 15) photos 5089-92 swivel, hose & mast
535		100		at 535.[illegible] rubbly zone appears to be the edge of a pillow (Photo # 5100) This may be invasive portion of a flow.	(Photo 5096 = Box 16) (Photo 5101 = Box 17, 5102 = Box 18.)
	18/33	100			
540	18/34	100			
545	19/34				Driller reports lost circulation @ 547°
	1/35	70		546° to 547.6 - very vesiculated, but otherwise competent basalt. Based on rel. rare plag phenos ~ 1-3 mm, could be Pomona mbr. Invasive flow. Also 551.5 - 552.5 and 553-554 Large vesicle (~ 3x2 cm) @ 553.2 (Photo # 5104)	
550					
	(See p. 9)				

Reported By: D.B. Barnett | Title: Geologist | Signature: [signature] | Date: 7/26/06

Reviewed By: S.P. Reidel | Title: Sr. Geologist | Signature: [signature] | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Date: 7/26/06

Well ID: C4998 | Well Name: Core Hole | Location: See p. 1 | DBB 9/28/06 see p. 11

Project: WTP Seismic | ~~Reference Measuring Point:~~ DBB 7/25/06 | Approx elev. ~~C98ft~~ msl

Depth (Ft.) Box/Run	Sample ~~Type~~ No.	~~Blows~~ Recovery %	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
550	(see p. 8)			554.0 - 556.2 - Brecciated basalt w/ matrix of lt. brn. clay. Clasts of (photos 5103, 5105) basalt are not very vesiculated. Vesicles do occur in rel. narrow bands within competent basalt intervals as noted above (photo 5104) Also this interval high-angle to low angle fracts w/ grn-tan clay fillings 0.5 to 0.75 cm wide (photos 5114-5115) Chalcedony (prob. opaline) layer from ~ 561.3 to 561.5 which has apparently been itself refract. and healed w/ silica (photo 5116) and clay min. High-angle fract w/ BX @ ~ 563.7 (photos 5117-19)	11:20 Shut down to fuel drill - began fueling @ 11:26 finished ~ 11:37
	19/36	100			
	19/37	100			(Photos 5109-13 are Cuttings from C4996)
555	20/37				14:45 last run due to loss of mud
556.5	20/38	100			Driller retracted rods to 400 ft bgs to prevent sticking
560	20/39	100			(559.5 - two mineral samples from fracture)
	21/39			565.3 - 570.3 Basalt dk gry vesicle sheets @ ~ 566, intermit thereafter Aphyric/aphanitic some vesicles coated w/ glossy mineraloid or botryoidal blu grn mineral - Numerous plag phenos @ ~ 570' and in massive portions of basalt in this interval.	
565	21/40	100			
				570.3 Basalt BX and clay - Scoria and palagopite (clay) 570.3 to 590.4 with red cinder - basalt contains sparse phenocrysts of plag. ~ 1-3 mm length	Stopped at 570.5 on 7/26/06 ~~started~~ 08:20 on 7/27/06
570	22/41	100			Lost 35% of mud during first run on 7/27/06 - Last more at 577.0
575	22/42	100			(Photo 5123 = Box 22) 5124 = Box 23
580	23/42				DBB 7/28/06
	23/43	100			DBB 7/28/06
585	see p. 10 DBB 7/28/06				

Reported By: D.B. Barnett | Title: Geologist | Signature: [signature] | Date: 7/27/06

Reviewed By: S.P. Reidel | Title: Staff Geologist | Signature: S.P. Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 10 of 46
Date: 7/27/06

Well ID: C4998 | Well Name: Core Hole | Location: (approx) N3901, E10381
Project: WTP Seismic | ~~Reference Measuring Point:~~ DBB 7/31/06 (see p. 11)

Depth (Ft.) / Box/Run	Sample ~~Type~~ No.	Sample ~~Blows~~ Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
585	See p. 9	d/o			Driller reports losing up to 95% of fluid in runs 43 & 44
	23/45	DBB 7/27/06 100			
	24/44				
590	24/45	100		590.4 ± to Basalt, vesicular, but much less so than previous intervals - rock overall much harder/more competent signif clay-filled (yel-tan) fracts (high-angle) @ ~591.3. Plag. phenos up to 5mm, but otherwise aphyric. Becoming less vesic. w/depth. Small "stalactites" in Mango vesic. @ 598.8 (photo 5135	Stopped drilling @ 10:00 to prepare for cement job - started mixing @ 11:15 - started pumping 11:25 Finished w/ 11:35 then began tripping out of hole
595	25/46	100		Vesicles becoming larger @ 596.3, but fewer. Numerous high-angle fracts. 599 - 602.5 (photo 5136 = Box 25)	No additives to cement - drillers do not want it too hard as it could divert the bit in soft formation (photo 5125 = Box 24)
600	25/47	100			
605	26/48	100		COMMENTS	Finished tripping @ 12:02 Began moving items to new storage areas
				608' Stopped here on 7/28/06 15:00. Tripped out to 500 ft bgs. Tom Bradfield (RCT mgr.) came out to trailer @ ~2:30 to explain reason for continuous RCT coverage.	Rig Shut off @ 12:15
610					
615				7/31/06 - began @ 608' ft bgs encountered sludge (cement + drilling mud + natural clay ?) @ 30 ft from bottom. Could not get core barrel any lower than this - driller reasons that fm. was depressuring after last week's drilling May need a squeeze job Drillers began tripping out of hole @ 08:00	Drillers left site @ 14:05 on 7/27/06
620	(See p. 11 for continuation)	DBB 7/31/06			Started 7/28/06 with cement tagged @ 500ft Kiensay this is enough. Drilled out cement w/ diamond bit until finished @ 13:45 Rods stuck at 11:30 due to stop for RCT

Reported By: D.B. Barnett | Title: Geologist | Signature: [signature] | Date: 7/31/06

Reviewed By: S.P Reidel | Title: Sr. Geologist | Signature: [signature] | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 11 of 46

Date: 8/3/06

Well ID: C4998 | Well Name: core hole | Location: (approx) N 3901, E 1038

Project: UTP Seismic | ~~Reference Measuring Point~~ DBB 7/31/06 Approx. Elev. 676.78 ft msl

Depth (Ft.)	~~Sample~~ Type No.	~~Sample~~ ~~Rec~~ Blows Recovery	Graphic Log	~~Sample Description~~ Comments DBB 8/2/06 Group Name, ~~Grain Size Distribution~~, Soil Classification, Color, Moisture Content, Sorting, ~~Angularity~~, Mineralogy, Max Particle Size, Reaction to HCl	Comments Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
Box/Run →		%			
605	(see p. 10)			Comments: Driller & tool pusher have been discussing the best way to proceed with hole caving - Driller (Ken Lowes) wants to pressure grout (as do geologist, site mgr.) Tool pusher (Willie Franklin) would rather try to continue.	This elevation provided by Steve Reidel 7/29/06
610	26/49	100		8/1/06: Prepared for packer insertion and pressure grouting. Static Water Level = 172 ft bgs @ ~ 07:30 (photos of packer assem. 5138, 5141) Finished grouting @ ~ 13:00 — Hole would only take 100% pore volume. Pulled out tremmie & tripped back into hole to 300 ft Finished for the day @ 14:50	7/31/06: 09:40 – At the instruction of the tool pusher, the driller decided to go ahead and drill another 5 ft to see how much fluid would be lost — Lost about 1400 gal 10:30 - driller reports losing another ~500 gal. during iron 49. Drill pipe stuck after retrieving core barrel. 11:07 drillers finished tripping up to casing. Mixing new batch of mud @ 11:30
615	29/49				
620	CONT. ON P. 12				
625				8/2/06: Began drilling out cement with drag bit (see photos 5139-40) Cement tagged @ 480 ± ft bgs (see photos 5146-48) (photo 5143 = Box 26 core) ~ 10:30 - Drill is stuck @ ~ 500-507 ft bgs ~ 11:45 – Generator on mud plant blew up - caught fire & was put out w/ extinguisher (photos of generator 5156, 57) 14:10 – finally got the drill loose & began tripping out of hole ~ 14:45 - received visit from Don Alexander and John Orchard (sp?) of DOE. Stayed ~ 30 min. Asked questions about "the fault" & showed them core. Depart site @ ~ 15:45	12:45 - Rods stuck in hole until 13:40 — Walkupasks driller to pull out & wait decision. 14:15 Ken talked to W. Ille & has him convinced of the risks of proceeding w/o grouting. Left site ~~3:45 pm~~ DBB 7/31/06 16:00
630					
635					
640					

DBB 8/2/06

DBB 8/3/06

Reported By: D.B. Barnett | Reviewed By: S.P. Reidel

Title: Geologist | Title: Stop Geologist

Signature: [signature] | Date: 8/2/06 | Signature: [signature] | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Date: 8/3/06

Well ID: C4998 | Well Name: Corehole | Location: (see p. 1)

Project: WTP Seismic | Reference Measuring Point: (see entry p. 11) DBB 8/9/06

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	~~Sample Description~~ Cements DBB 8/3/06 ~~Group Name~~, Grain Size Distribution, Soil Classification, Color, Moisture Content, ~~Sorting~~, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
				8/3/06 07:45 – SWL in hole is 112.5 ft ~~-~~ (This is probably water/mud resting on cement below) - to TOC - 1ft = 111.5 ft bgs. 08:20 – Bill Linzau (DNFSB) visited and was given a briefing by DBB on the "fault zone" and other features in core. Repairs underway for mud plant generator, mud pump, and cleaning mud plant, disposing of old mud/cement slurry. Hydraulics on ram were repaired ~06:30. Ended day @ 15:35	
				8/4/06 06:45 – Began drilling cement @ 513 ft bgs. Bob ____ DNFSB visited ~08:40 – showed core in fault zone, scope, slickensides. Adding detail to brecciated zone on supplemental log/photos. 11:40 – cement is very hard but becoming crumbly, softer @ 560–570. ~13:20 – finished drilling out cement to 618' ft bgs. Circulate & clean hole 15:35 – left site.	← see sample from ~ 540 ft bgs

DBB 8/4/06

DBB 8/4/06

DBB 8/7/06

Reported By: D.B. Barnett | Reviewed By: S.P. Reidel

Title: Geologist | Title: Stgy Geologist

Signature: DBBarnett | Date: 8/7/06 | Signature: S P Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 13 of 46
Date: 8/7/06

Well ID: C4998 | Well Name: Core Hole | Location: (see p. 1)

Project: WTP seismic | ~~Reference Measuring Point~~ (elev collar) 677.92 msl

Box/Run	Depth (Ft.)	Sample Type	Sample No.	Blows	Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
	610	DBB		0/0			8/7/06	
			(See p. 11)				07:00 – SWL = 203 ft bgs – (rods in down ft ~400 ft.)	
							~~548° fracture sample~~ DBB 8/8/06	09:45 – began drilling run 50 – having trouble with small mud pump return to plant
DBB 8/7/06	615		27/50		100		611 – 623 plag phenos more abundant	(Photo 5204 = core in box 27)
			27/51		100		620.5 – 621° slickensides on clay fracture	
							622 – 623 high angle fracts v. few vesicles	
	620		28/51				~611 – 643 and elsewhere – two populations of plagioclase 1 fine groundmass 2.) phenos. (more abundant @ ~645°	(Photo 5205 = core in Box 28)
			28/52		100		Pyrite in fracture @ 623.5 (photo # 5203)	(5206 = core in Box 29)
			28/53		100		643.5 – 645, ± 650 fracturing more intense – slicks @ 650.	(photo 5207 = core in box 30)
	625		~~28/53~~					
			29/54		100		631° – 632.2 – intense fracturing (comparatively) vertical & subordinate fract – otherwise very solid, dense basalt.	
			~~29/55~~				Glomerocrysts @ ~632.5 (plag.)	
	635		30/55		100		~634° High angle fract. w/ blue grn filling w/ slicks ~3 mm thick.	
	640		30/56		100		DBB 8/23/06	
	645		31/57		100			
			See p. 14				DBB 8/8/06	

Reported By: D.B. Barnett | Title: Geologist | Signature: [signature] | Date: 8/9/06

Reviewed By: SP Reidel | Title: Staff Geologist | Signature: SP Reidel | Date: 10/28/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 14 of 46
Date: 8/8/06

Well ID: C4998 | Well Name: Core hole | Location: (see p. 1)
Project: WTP Seismic | Reference Measuring Point: (see p. 11)

Depth (Ft.)	Sample Type No.	Sample Blows, Recovery %	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
Box/Run				8/8/06 →	SWL = 81.5 ft bgs @ 06:48 inside rods. Driller reports rods are stuck..
645	(see p. 13)				81.5 (5.0) DBB 8/9/06
					- 3.5 stick up
					~~78.0~~ ft bgs
					~~76.5~~ DBB 8/9/06
650	31/58 – 27/58	100			
655	32/59	100		657.5 High angle fracts w/ slicks.	This value is prob. not representative of SWL.
660	33/60	100		+678 ~662-663 light gry banding in basalt (micro pegmatite?) 667.5 slickensides in fract. and @ ~663 Slickensides @ 667.5-668 indicate left-lateral displacement and are nearly horizontal	
665	33/61	100		685-688 – Few large vesicles widely separated ~ 1-1.5 cm dia. (see p. 15)	
	34/61				
670	34/62	100		670.3 – 671.5 fracture system w high angle fracts (45°-60°) with brown alteration halo either side of some fracts (photo 5233) 673°-~0.75 cm fract. fill (clay) (DK-brn) w/ slicks showing right lateral movement.	
675	35/63	100			
680	35/64 – 36/64 DBB 8/8/06	100		DBB 8/23/06	
	see p. 15				

Reported By: D.B. Barnett | Title: Geologist | Signature: | Date: 8/8/06
Reviewed By: S.P. Reidel | Title: Staff Geologist | Signature: S P Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 15 of 46
Date: 8/8/06

Well ID: C4998 | Well Name: Core hole | Location: (See p. 1)
Project: WTP Seismic | Reference Measuring Point: (See p. 11)

Depth (Ft.)	Sample Type / No.	Sample Blows / Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
Box/Run		%			
680		DBB 8/8/06 See p. 14			
				693.5 – 50°-60° fract fill 0.5 cm wide w/ slicks	
				696° – 697° – v. long fract @ DBB 8/9/06 vertical slicks indicate reverse dip slip and left lateral strk-slip displacements	
685	36/65	100			
	36/66				
690		100			
	37/66				
695	37/67	100			
	37/68			Plag phenos becoming more abund. downward then less abundant (to 773.5') Then increasing again	
700	38/68	100		707 – 708.5 – thick clay fract fill w/ basalt clasts	
	38/69				
705		100		701° → 713° Dark bands w 2-3 mm wide – looks like glass (?)	
DBB 8/8/06 710	38/70				
	39/70			714° slicks indicate reverse dip slip and right lateral strike slip mvmt.	
710		100			
715	39/71	100		DBB 8/23/06	
	40/71				
	(See p. 16)	DBB 8/9/06			

Reported By: DB Barnett, Colleen Rust | Reviewed By: S P. Reidel
Title: Geologists | Title: Staff Geologist
Signature: [signature] | Date: 8/8/06 | Signature: S P Reidel | Date: 10/18/06

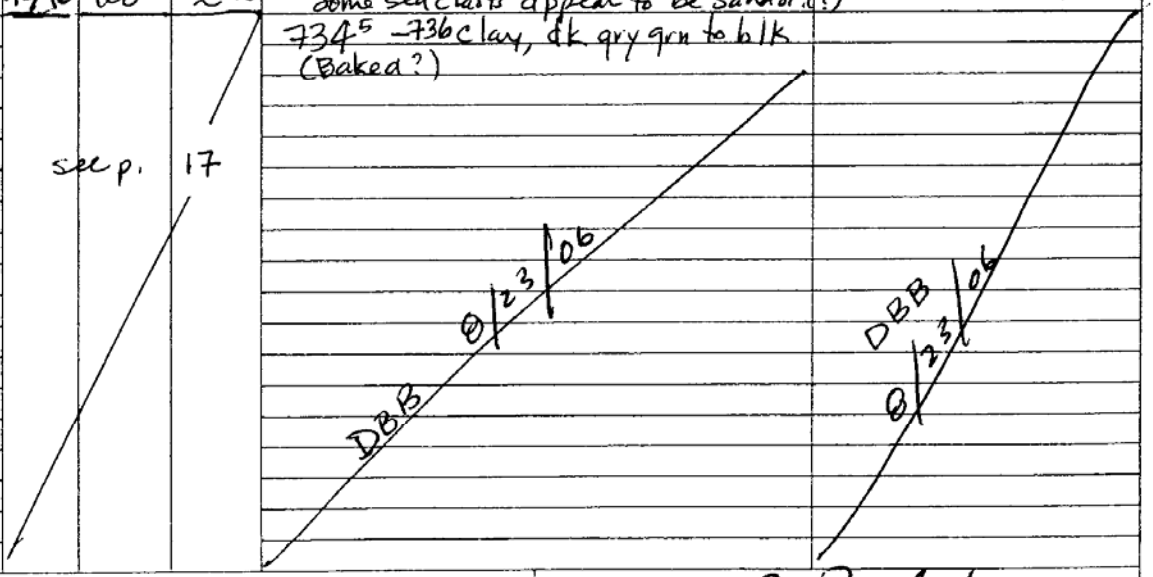
A-6003-642 (03/03)

BOREHOLE LOG

Page 16 of 46
Date: 8/8/06

Well ID: C4998 | Well Name: Core Hole | Location: (see p. 1)
Project: WTP Seismic | Reference Measuring Point: (see p. 11)

Depth (Ft.) Box/Run	Sample Type No.	Sample DBB 8/8/06 Blows Recovery %	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
715	(see p. 15)		DBB 8/8/06		
720	40/72	100		720-722': Heavily fractured basalt. Fracts are healed, mostly high-angle	
				Stopped @ 723' on 8/8/06	
					8/9/06 - 06:30 to ~09:00 mix mud condition hole.
725	40/73				@ 355 - SWL = 106.5 (includes subtract of stickup)
	41/73	100			
730	41/74	100			8/9/06 - 12:00 - Drillers only able to get short runs - bit is plugging and needs change - Replacing bit w/ jet-discharge config.
	42/75	100		733'-734.5' Breccia - Basalt and sediment clasts w/ clay matrix	
735	42/76	100		some sed clasts appear to be sandst. (?)	
				734.5 - 736 clay, dk gry grn to blk (Baked?)	
740	see p. 17				
745					
750					



Reported By: D.B. Barnett | Reviewed By: S.P. Reidel
Title: Geologist | Title: Staff Geologist
Signature: DBBarnett | Date: 8/9/06 | Signature: SP Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 17 of 46
Date: 8-10-06

Well ID: C4998 | Well Name: Corehole | Location: N3901, E10381 | DBR 8/28/06 | see p. 11
Project: WTP Seismic | Reference Measuring Point: approx. elev. 690 m.s.l.

B.G. 8-10-06

Depth (Ft.)	Sample Type No.	Sample Run Blows Recovery (%)	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
735	see p. 16	100		brecciated basalt w/ green fracture-filling mineral (clay) and dark grey clay filling of fractures and voids, rock appears baked	depth to water: 181 ft. 7-20-06
736	42/77	100			core rod: 5 ft.
	42/78	100			new mud mix for run 77
740				737-738.6 B.G. 8-10-06	run 79 core fell out of barrel (spoons)
	43/78	100		737-738.6, brecciated basalt w/ (chlorite?) clay and dark grey clay matrix, clay fraction increases until basalt "dissappears" at approx 738.6, clay (dk grey) becomes slightly harder until ~741.5	
	43/79	100			60% mud loss down through sediment interbed
745				741.5 - clay grades to v. fine sand, sand is orange-to-light-tan in color moderately well-sorted, micaceous (ind. flakes ≤ 1mm wide)	
	43/80	100			
750	44/80	100		742 - v. fn. sand in mud matrix, light tan micaceous sand and dk brown mud 744 - slight coarsening of sand, also becomes greenish-tan and slightly less well sorted	752³-753 = lost sample in the hole
	44/81	75			
755	44/82	100		745-749 - tan, fine sand w/ occasional pockets of dark-brown mud, sand is in a clay matrix, 747-749 - reddish fn-med sand, shot through w/ orange streaks, also	
760	45/82			B.G. 8-28-06 mica, back to tan micaceous sand at 749', 749-752³ - med-gr, moderately-poorly sorted sand, takes on greenish color through to end of Run 80	
				B.G. 8-10-06	
765				752³-755 = green clay with basalt fragments (scoriaceous), 2-15 cm diam. 753-755 = hard, green claystone w/ basalt (scoriaceous) fragments, fragments show orange-brown oxidation rinds 755-757 = laminated, hard green claystone 757-760 = brecciated, fractured basalt w/ green clay-filled fractures and cavities, basalt is scoriaceous and suspended in green clay matrix w/ clasts of dk. green (clay) clasts, smaller red-orange clasts;	

Reported By: Ben Garcia | Title: geologist | Signature: B. J. Garcia | Date: 8-10-06
Reviewed By: S.P. Reidel | Title: Staff Geologist | Signature: S P Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 18 of 46
Date: 8-10-06

Well ID: C4998 | Well Name: Corehole | Location: N 3901, E 10381 see p. 11 DBB 8/28/06
Project: WTP Seismic | ~~Reference Measuring Point:~~ approx. elev. 670 msl

B.G. 8-10-06 B.G. 8-10-06

Depth (Ft.)	Box/Run Sample Type No.	~~Blows~~ Recovery %	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
760	45/83	100		scoriaceous basalt breccia in a green clay matrix w/ smaller red brown and tan xclasts, majority of basalt fragments have red oxidized rinds	
				761 = massive, fractured basalt; highly vesicular, with cavities/fractures filled w/ green clay and red oxidized bas. breccia. 762 = massive, vesicular, amygdaloidal basalt, fractured with greenish-blue and brown mineral fill; chalcedony present in some vesicles; vesicles are smaller and more abundant @ 765'.	
765	45/84	100			
	46/84	(100)		766 - black-dk. green fracture fill in nearly horizontal fractures	
				768 - black, massive basalt, vesicular (small) with ~~fracture~~ B.G. 8/1906 high angle fractures filled with black (greenish) fill; phenocrysts present, also glomerocrysts	
770	46/85	100			8-10-06: from 760' - last circulation; ~60% mud loss to sediment above this stretch of basalt
				basalt; grey to dk grey, massive, mildly vesicular, phenocrysts, glomerocrysts present 1cm-spaced vesicle sheets (shear surfaces?); all angles of fractures, most filled with black, glassy (clay?) material, often lines insides of vesicles	
775	46/86				
	47/86	100			
780	47/87	100		785-790 = same as above, except little or no vesicles	
				790 = black, glassy fracture filling material also found with light green clay	
785	48/88	100		791-793 = 70°-90° fractures filled w/ black, glassy material; slickensides present	
				793 = basalt, diktytaxitic, phenocrysts and glomerocrysts present; medium angle cracks (unbroken) - 45°-60° (at 797')	
790	48/89	100		794 = pyrite on fracture surface, also black glassy material, when powdered, black material is translucent, greenish, shows possible xtal faces	
	49/90	100			
795		100% RQD		NOTE: for RQD values in Runs 1-89 see Supplemental Log pages 1-16 DBB 12/6/06	
		DBB 8/30/06		see p. 19	

Reported By: Ben Garcia | Reviewed By: S.P. Reidel
Title: geologist | Title: Staff Geologist
Signature: B.J. Garcia | Date: 8-10-06 | Signature: S P Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 19 of 46
Date: 8-16-06

Well ID: C4998 | Well Name: Corehole | Location: N3901 E10381 see p. 11 DBR 8/28/06 B.G. 8-8-06
Project: WTP Seismic | ~~Reference Measuring Point~~: approx. elev. 690 msl

B.G. 8-8-06

Depth (Ft.)	Sample box/run Type No.	Sample Blows Recovery (%)	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
795	(see pg 18) B.G. 8-11-06			798 = generally ~~aphanitic~~ B.G. 8-11-06 non vesicular phenocrysts and glomerocrysts; mildly-to-heavily fractured w/ near vertical tracks filled w/ black glassy material	
798	49/91	100 RQD=81		805 = same as above; pyrite found as radial sheets in fractures	
800	50/91			basalt B.G. 8-11-06	
	50/92	100 RQD=85		809 = ~~moist~~ [massive, not as fractured; pyrite and black glassy material as fracture fill; light green clay lines some fractures and vesicles; phenocrysts and glomerocrysts present]	
805				813.5-814.5 = 70° fractures	
				816 = vertical fracture	
				822 = vertical fracture	
	50/93	100 RQD=93		826 = 80° fracture	
810	51/93	100		830 = thin, micro-vesicle sheets become more apparent (shear planes?)	
	51/94	RQD=66 100			
815					
	52/95	RQD=79 100			
820					
	52/96	RQD=96			
825	53/96	100			
	53/97	100 RQD=97			
830					

B.G. 8/23/06

Reported By: Ben Garcia | Reviewed By: S. P. Reidel
Title: geologist | Title: Staff Geologist
Signature: B.J. Garcia | Date: 8-11-06 | Signature: S P Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 20 of 46
Date: 8-11-06

Well ID: C4998 | Well Name: Corehole | Location: N3901, E10381 ~~Datum~~ ~~Measuring Point~~: approx. elev. 6[illegible] msl | Project: WTP Seismic

B.G. 8-11-06

Depth (Ft.)	Sample Box Run / Type No.	Sample Blows / Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
830	(see pg 19)	%			
	53/98	100		basalt, poorly vesiculated, black fractured; phenocrysts and glomerocrysts present; pyrite and glassy black material filling fractures	
835	54/98	RQD=73		847 - aphanitic basalt	
	54/99	100		850 = vesicular basalt;	
840		RQD=93		850.5 - 851 = veside sheet	
	55/99			851 = basalt is non-vesicular, contains spidery, often unconnected network of fractures filled with either white mineral or blue-green clay (larger cracks) - may be cooling features; phenocrysts present	
	55/100	100			
845		RQD=100		854 - ½" with clay layer; moca @ 854.25, 854.5; aphanitic basalt, blue-green-filled fractures	8-14-06 @ 7:11am water level at 282', (-5' for core rod) =262' bgs.
	55/101	100			
850	56/101	RQD=90		853.4 - 855.4 = fractured aphanitic basalt with mud filling some large cracks	
	56/102	60		855.4 = bottom of basalt top of sediment; brown, fine-grained sand w/ white silt stringers; slightly welded	washover @ Run 103; initial recovery of 60% Run 103 includes the rest of run 102 plus an extra foot
RQD=93	PBB 8/30/06				
	103	100			
B.G. 8-24-06	57/103				
860	57/104	100 RQD=75		858.5 = greyish-brown muddy sandstone interval ends at grey muddy sandstone (859'); 859.4 — 860.8 = intercalated resistant sand-and-mud-stone and clay layers; sand-and-mud-stone consists of greenish, fine-sandst. breccia in dark-green muddy sandstone matrix; brecciation decreases between 859.4 - 860.8	
	(see pg 21)	B.G. 8-24-06		860.8 - 862.4 = resistant sandstone/mudstone is massively brecciated and clay (greenish-grey) fills gaps	

Reported By: Ben Garcia | Reviewed By: S.P. Reidel
Title: geologist | Title: Staff Geologist
Signature: B J. Garcia | Date: 8-14-06 | Signature: S P Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 21 of 46
Date: 8-14-06

Well ID: C4998 | Well Name: Corehole | Location: N3901, E10381 | DBB 8/29/06 see p. 11
Project: WTP Seismic | Reference Measuring Point: BG 8-24-06 | approx. elev. 610 msl

Depth (Ft.)	Sample Box Run Type No.	Blows Recovery (%)	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
860	54/104	see pg 20	see pg 20	862' – 867' = intercalated sandstone and clay; sandstone is light green, fine-grained, well-sorted, resistant; sandstone contains horizontal stringers of dark-green mudstone w/ light-green s.s. clasts; clay layers are green and contain clasts of light-green s.s. and dark green mudstone	BG 8-24-06
865	54/105	100 RQD=52		865' = sandstone is laminated, also contains large (2-3 in) mudstone clasts and white-grey sandstone clasts	One foot left off log from previous page should begin here (p. 21) @ 862.4 DBB 8/30/06
870	58/106	40 RQD=100	not recovered	867' = very fine green sandstone w/ darker green sandstone bands	
875	58/107	100 RQD=0		872 = green sandstone, very friable, med-coarse-grained, (-872') micaceous, moderately-well sorted, dark sand-sized grains [biotite & muscovite; ≤ 2mm diam]	
				878 = sharp contact between coarse sand and med-grained sandstone	See notes on reverse side DBB 8/23/06
				879 = fine-grained layer 1" thick	
880	57/108	90 RQD=100	not recovered		
885	59/109	100 RQD=29			
	60/109				
890	60/110	80 RQD=100			
895	60/110.111	100 RQD=100			
	61 80/111				
	BG 8-24-06				

BG 8-14-06

B.G. 8-14-06

Reported By: Ben Garcia | Title: ~~geologist~~ geologist | Signature: B.J. Garcia | Date: 8-14-06

Reviewed By: SP Reidel | Title: Staff Geologist | Signature: S P Reidel | Date: 10/18/06

(See reverse side of sheet)

A-6003-642 (03/03)

Additional Notes for Borehole log C4998- corehole page 21. Beginning 8/14/06, all runs are photographed before removal from tray. Plackard showing Depth interval & date is placed @ top of hole for first in a series (from 1-4 photos) taken of each Run. Subsequent shots are taken in a progressively down-hole direction. DBB 8/23/06

BOREHOLE LOG

Page 22 of 46
Date: 8-14-06

Well ID: C4998 | Well Name: Corehole | Location: N 3901, E 10381 | 8/28/06 | see p. 11
Project: WTP Seismic | Reference Measuring Point: approx. elev. 690 msl | BG 8-14-06

BG 4-14-06

Depth (Ft.)	Box/Run Sample Type No.	Blows Recovery (%)	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
895	See pg 21.			898 = coarse, white sandstone band approx. 2" thick	
BG 5-24-06	G1/60	100		899 = green, coarse muddy sandstone w/ black and dark green laminations, 6" thick	
900	G1/112	RQD=100		901-902 = coarse green sandstone becomes less consolidated until at 902' green sandstone is nearly completely unconsolidated; large (≤2 mm) muscovite flakes, poorly rounded to rounded lithic grains, basaltic sand-sized grains, moderately-well sorted, no mud or matrix of any kind. Note: on RQD, med-coarse green sand that began around 897.2' is v.v. friable, most fractures as seen in pictures or in corebox are a product of handling; most of the sand is not a rigid mass, so RQDs may or may not be useful.	
905	G1/113	100		904.4-908' = cohesive, brown mud	
	G2/113	RQD=0		908' - hardened mud (or pebble?) clasts in a zone of completely unconsolidated coarse green sand (≤1.5" diam.)	
	G2/114	100 RQD=69		908.6 = slightly-more-consolidated med-coarse green sand	
910	G2/115	100		909-910.2 = green muddy sandstone w/ dark green streaks; mud/clay clasts (shades of green) are rare; clasts mixed in w/ different layers of various degree of sorting	
	G2/115	RQD=100		910.2-914.4 = green mud/clay clasts are very abundant, as are white, hard clasts (pebbles?) and smaller dark red clasts; most clasts are ≤.25" in diam.; poorly sorted clast-rich zones intercalated w/ fine sand-rich laminar zones; clast-rich areas are often grain-supported	
915	G3/116	100 RQD=100		915.5 = poorly-sorted clast-rich zones shrink while med-fine grained muddy sand becomes more abundant; coarser zones show higher degree of lamination	
920	G3/117	100		919.8 - last major coarse, poorly-sorted zone; muddy fine-grained sand dominates after; repeating sequence of light green fading to dark green, then sharp change back to light green	
	G4/117	RQD=95		921 = med-fine grained micaceous sand w/ green mud cement; cm-scale laminations of lighter and darker green sands	
925	G4/118	90 RQD=NA		← 931.4 to 932.4 WAS LOST	
930	G4-G5/119	100 RQD=66			

Reported By: Ben Garcia | Reviewed By: S.P. Reidel
Title: geologist | Title: Staff Geologist
Signature: B.J. Garcia | Date: 8-16-06 | Signature: S.P. Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

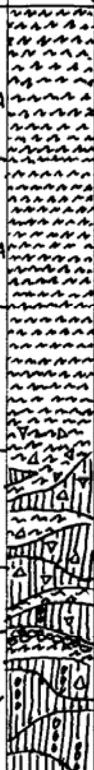
Date: 8-15-06

Well ID: C4998 | Well Name: Corehole | Location: N3901, E10381 ~~DBG~~ 8/20/06

Project: WTP Seismic | ~~Reference Measuring Point:~~ R.E. 8-15-06 approx. elev. 690 msl (see p. 11)

D.G. 8-15-06

Depth (Ft.)	Sample: ~~Type~~ box run No.	~~Blows~~ Recovery (%)	Graphic Log
930	(crossed out)	B.G. 8-15-06	
	65/120	100, RQD=NA	
935			
	65/121	100	
940	66/121	RQD=NA	
	66/122	100	
945		RQD=NA	
	67/123	100	
950		RQD=0	
	67/124	100, RQD=0	
	67/125	100	
955		RQD=28	
	68/125		
	~~68/126~~	~~100~~	
960		~~RQD=57~~	B.E. 8-16-06
965	see pg. 24		



Sample Description (Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl)

931'-932' = originally part of Run 119, this part of the core was not recovered

932'-937 = extremely brittle claystone; dark grey, low moisture content

937'-942' = dark grey claystone; still very brittle, however, much more cohesive than Run 120 (easier to get into box)

Note: RQD measurements on 932'-947' are not applicable ~~not~~; claystone here is very brittle and was never broken while inside the core barrel; handling always resulted in break up to some degree; lower in the section proved slightly more resistant than higher

947' = dark grey clay containing small (0.5cm) basaltic fragments and much larger fragments of blue clay-like hard material w/ green clay filling small cracks (blue mass is probably altered basalt?)

947⁴ = greenish black basaltic breccia; heavily altered to green and/or blue clay in some zones; cracks filled with coarse sand at top of Run 123

950 = basaltic breccia partially altered to green and/or blue clay; decreasing presence of green clay/mudstone as filling in cracks and gaps

950' = CONTACT; bottom of sediment, top of basalt

951' = highly fractured basalt, most of which is only partially altered; large cracks and voids are filled with green clay and pebble-sized basalt fragments

953⁴-953⁷ = layer of unconsolidated gravel-sized basalt pebbles, rounded as from abrasion; overlying a thin (1") zone of green (laminated?) claystone

953⁷ = fractured, vesicular basalt with some fractures filled w/ green clay; botrioydal (sp?) chalcedony found at 953⁷-955; vesicles are ≤3 cm in diam. and horizontal, some filled w/ black glass; phenocrysts present

Comments (Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level)

8-16-06 = drillers mix new mud; start of 12-hr shift (6am-6pm), @ 951', started drilling at 7:55am

Reported By: Ben Garcia | Reviewed By: S P Reidel

Title: geologist | Title: Staff Geologist

Signature: B.J. Garcia | Date: 8-16-06 | Signature: S. Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Date: 8-16-06

Well ID: C4998 | Well Name: Corehole | Location: N3901, E10381 ~~DG 8-16-06~~ ~~DBB 8/23/06~~ see P.11

Project: WTP Seismic | ~~Reference Measuring Point~~: approx. elev. ~~640~~ 1431'

Depth (Ft.)	Sample box/run Type No.	Sample Blows Recovery %	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
955	(see pg. 23.)			~~X~~ basalt, fractured heavily, vesicular, porphyritic, fractures filled w/ black glassy material and pyrite, chalcedony	During Run 126, driller lost 100% of fluid; LCM added, drilling continued (see 961 note)
960	68/126	100 RQD=57		962.6 = basalt turns brownish in color until 963', vesicles in brown zone filled w/ black glassy material; 961 = 0.5-7.0"-wide cavity in core, connected to vertical fractures	
965	69/127	100 RQD=70		963' = basalt, mildly ~~fractured~~, vesicular, porphyritic, fractures filled with black glassy material and pyrite, blue-ish clay fills some fractures, green clay fills some vesicles; 968' = basalt, mildly fractured, porphyritic, vesicles are rare, horizontal fractures (filled) throughout Run 128, 60° fractures @ ~~207~~ 970' and 971'; DG 8-16-06	During Run 128, driller lost circulation, lost 100% of mud
970	69/128 70/128	100 RQD=100		blue-green clay-filled horiz. layer @ 973' forming natural core break	
975	70/129 71/129	100 RQD=100		973' = basalt, porphyritic, fractured (filled); fractures are filled with black glassy material, as are the few vesicles that are present; most fractures from 973-983 have a darkened, 1-2 cm wide halo (of darker-grey against the lighter-grey basalt)	
980	71/130	100 RQD=97		983 = basalt, porphyritic, fractured	From Run 128 until Run 132 (end of shift on 8-16-06), constant loss of mud and circulation; mud tank is emptied between runs
985	72/131	100 RQD=68		DBB 8/23/06	DBB 8/23/06
990	see pg. 25				

Reported By: Ben Garcia | Reviewed By: S.P. Reidel

Title: geologist | Title: Staff Geologist

Signature: B.J. Garcia | Date: 8-16-06 | Signature: S P Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 25 of 46
Date: 8-16-06

Well ID: C4998 | Well Name: Corehole | Location: N 3901, E 10381 B.G. 8-16-06 | ~~Reference Measuring Point:~~ approx. elev. ~~690~~ msl DBB 8/28/06
Project: WTP Seismic

Depth (Ft.)	Sample Box Run Type	Sample No.	Blows/ ~~Recovery~~ Recovery %	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
985			see pg. 24 B.G. 8-18-06		988 = (-994) large, hyperbolic-appearing fractures filled with black, glassy material; larger nearly-horizontal cracks join w/ smaller sub-vertical cracks; fractures have dark halos (as mentioned at 973')	Problem encountered at the beginning of Run 132; rods aborted; drillers tripped out of hole at 4:45 pm (
990	77/132		100 RQD=90			8-17-06: water level at 265' bgs.; drillers to cement hole up to depth of 950' - No drilling for this date (major source of fluid loss at 961') [8-17]
995	77/134		100 RQD=91		8-18-06: ~60' of cement to be cored out of the hole today; driller's helper to leave in the early afternoon and to be replaced	
1000	77/135		100 RQD=100		Cement tapped at ~934', ~~found to still not cured~~ B.G. 8-17-06 not yet cured fully; partially-set cement was drilled out and 994' reached at 11:47 am; coring continued	After drillers tripped in completely, water level in the hole was 176'. (12:22 pm)
1005	77/136		100 RQD=90		994 = included at the beginning of Run 134 (in the corebox) is the end of the cement and ~2" of cave-in material, however these are not considered in the RQD and Recovery values ↓	extremely hard drilling;
1010	77/136 137 B.G. 8-18-06		100 RQD=83		dark-grey, black basalt, porphyritic, glassy, fractured; fractures filled w/ black glassy material	
1015	74/138		100 RQD=43		998-1003 = same as above, except ~~less~~ less fractured; those fractures that are present are horiz. 1010 = 80° fracture; no obvious signs of movement	B.G. 8-18-06
1020	B.G. 8-18-06 see pg. 26				1016'-1018 = zone of intense vertical fracturing; basalt changes color to a lighter grey; fractures above this zone possess lighter-grey halos	

Reported By: Ben Garcia | Reviewed By: S.P. Reidel
Title: geologist | Title: Staff Geologist
Signature: B.J. Garcia | Date: 8-18-06 | Signature: S.P. Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 26 of 46
Date: 8-18-06

Well ID: C4998 | Well Name: Corehole | Location: N 3901, E 10381 ~~see pg. 11 DBB 8/29/06~~
Project: WTP Seismic | ~~Reference Measuring Point:~~ ~~D.B. 8-18-06~~ approx. elev. ~~690 msl~~

Depth (Ft.)	Sample box ~~Run~~ Type No.	Sample ~~D.B. 8-18-06~~ Blows Recovery (%)	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
1015		B.G. 8-18-06 see pg. 25			
	76/139	100 RQD=50		1020² = scoriaceous basalt w/ very slight, pinkish tint, large vertical fractures and some vesicles contain green and black glassy (but friable) material and pyrite xtal clusters	
1020	77/135			1020² - 1024 = most heavily fractured/altered/vesiculated zone, contains red splotches in the basalt (oxidation); after 1024, vesiculation density and size decrease by 60-70%; still fractured, but more cohesive	
B.G. 8-18-06	~~77/139~~	~~100~~			
1025	77/140	100 RQD=13			
	77/141	100 RQD=75		1027 - 1027⁹ = usual dark-grey basalt; low degree of vesiculation and fracturing, porphyritic 1027⁹ - 1028⁶ = heavily fractured and slightly pink zone, porphyritic 1028⁶ = dark grey, porphyritic, low degree of vesiculation; larger vesicles filled w/ black glassy material or chalcedony, smaller vesicles define a diktytaxitic texture	
1030	78/141				
	78/142	80 RQD=		1032 - 1033 - RQD = 78%	
	78/143	100 RQD=47		dark-grey porphyritic basalt, vesicles rare	8-21-06 = depth at start of shift is 1032'. 1st Run (142) is short b/c driller wanted to open out core stick-up; drilling halted to clean remnant cement out of mud tank; coring resumed @ 10:40 am
1035	79/144	100 RQD=52		1034' = extremely vesicular (though not scoriaceous) basalt, vesicles parallel to angular, x-cutting feature (lineament) at 1034'4"; extremely large vesicles (1.5") directly below lineament; some fractures and vesicles filled in (small %) with green clay and/or pyrite	
1040		D.B. 8-21-06		*1036⁴ - 1036¹⁰ = scoria-vesicular zone made of aphanitic basalt w/ large cavities filled w/ friable, black, glassy (micro-) botryoidal material; slickensides present here	*problems w/ sump pump on mud mixer
1045				1037 - 1037⁶ = mixed zone of aphanitic, vesicular basalt and black glassy material; vesicular basalt from 1037⁶ and on	
1050		see pg. 27		[Basalt sample for chem analysis (XRF) taken @ 1039 ft bgs 8/23/06 DBB]	DBB 8/23/06

Reported By: Ben Garcia | Reviewed By: S. P. Reidel
Title: geologist | Title: Staff Geologist
Signature: B.J. Garcia | Date: 8-21-06 | Signature: S P Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 27 of 46
Date: 8-21-06

Well ID: C4998 | Well Name: Corehole | Location: N 1901, E 10381 per d/28/06 see p. 11
Project: WTP Seismic | ~~Reference Measuring Point~~: approx. elev. ~~690~~ msl
B.G. 8-21-06

Depth (Ft.)	Sample ~~Type~~ No.	Sample ~~Blows~~ Recovery (%)	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
1040	79/145	88 RQD=98		1040 - 1043 = brecciated and weathered basalt fragments in a matrix of green and black clay; color of basalt breccia range from light green to faint pink to dk grey; most fragments are vesiculated, though not to any great extent. all vesicles are filled in by green, black or yellow clay and/or chalcedony; appears to be two different types of basalt fragments (1) dark grey, less weathered and (2) lt.-grey/pinkish, extremely weathered; dk-grey fragments have a greenish tint when wet	B.G. 8-21-06
	79/146	100 RQD=0			
1045	80/146				
	80/147	100 RQD=0		1043 - 1047 = (see above) *from 1043-1047 interval, it is observed that from larger fragments that all fragments are probably the same, except for differences (gradational) in color due to differing oxidation state of rock	
1050					
	81/148	100		1047 - 1049.6 = (See 1040 - 1043 description)	
	81/149	100 RQD=NA		1049.6 - 1052 = brecciated fragments become more angular, less altered (though still multi-colored); core sample is composed less of clay matrix and more of brecciated fragments which fit together and are themselves fractured Run 148 = RQD is NA	
1055	81/150	100 RQD=99			
1060	81/150			1052 - 1053 = angular brecciated fragments; sample appears to be pervasively fractured basalt which has been oxidized by fracture-born processes; in this interval, a larger fracture is filled w/ smaller, angular fragments; though no prima facie evidence for shearing has been observed this texture is indicative of faulting, however, no evidence of movement along these fractures has been observed in the field	
1065				1053 = basalt, massive, mildly vesicular, porphyritic, several high-angle fractures filled w/ black glassy material	Run 149: could not be retrieved from core barrel as a solid core
1070				1056 = basalt (massive or fragments?) overlies hard, green fine-grained stone with dark green rounded clasts and black/dk grey angular clasts (mm-sized)	
1075				1057 - 1062 = massive basalt, dk grey, porphyritic, vesicular, minor fractures, @ 1060', 5-in. cavity is filled w/ green, hard clay; green clay contains xtals (plag.?), green layered clasts, and vesicles (rare).	

B.G. 8-22-06
see pg. 28

Reported By: Ben Garcia | Reviewed By: S.P. Reidel
Title: geologist | Title: Staff Geologist
Signature: B.J. Garcia | Date: 8-22-06 | Signature: S.P. Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 28 of 46
Date: 8-22-06

Well ID: C4998 | Well Name: Corehole | Location: N3901, E10381 see p. 11.
Project: WTP Seismic | ~~Reference Measuring Point:~~ DG 8-22-06 | approx. elev. 690 msl

D.G. 8-22-06

Depth (Ft.)	Sample Box Type / No.	Sample DBB 8/22/06 ~~Blows~~ Recovery / RQD %	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments DBB 8/23/06: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
1060	DBB 8/22/06 See p. 27			1060.8 – high angle (~75°) is offset or terminates against low angle fract. (~30°) Although much of run 150 is intact core, numerous healed fractures – some with offset indicators are noted throughout run interval. Sample of fract. fill material collected @ 1060.6 ft bgs. Feature @ 1059.8 appears to be micropegmatite (photo #5539) and contains plag. phenos. Slicks @ 1059.4 indicate reverse dip-slip motion. Numerous healed fractures @ 1063.4 ~ 1063.9, 1078 – 1079 @ various angles	Began drilling @ 07:55 on 8/22/06
1065	82/151	100/94			Drilling rate ~ 8 ft/hr.
1070	83/152	DBB 8/22/06 100/88		Basalt sample for chem (XRF) analyses taken @ 1061 ft. bgs 8/23/06 DBB 8/23/06	~ 12:40 began mixing more mud due to progressive losses during day thus far. – much difficulty in removing core from core barrel all or most runs
1075	83/153 84/153	100/62			
1080	84/154	100/100			
1085	85/155	100/85		Healed, anastomosing fractures centered on 1085.2 ± grn fracture fill w/ en echelon fract surface texture (photos 565-66) @ 1086.0	Last ~0.5 ft of run 155 broken up by removal from barrel
1090	85/156 86/156	100/84		~1090 – 92: Healed fracts numerous @ various angles. ~1090.3 fracture fill of grn botryoidal translucent mineral w/ patina of MnO_2 (?) – open space fillings – vugs (photos 5572-74) PP in high-angle fract 1094.7	Run 157 was drilled in 5-min less time than preceding run.
1095	86/157	100/95		DBB 8/23/06	DBB 8/23/06
	See p. 29	DBB 8/22/06			

Reported By: Dan Garcia / D.B. Barnett | Reviewed By: S.P. Reidel
Title: geologist | Title: Staff Geologist
Signature: DBBarnett | Date: 8/22/06 | Signature: S P Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Date: 8/22/03

Well ID: CA998 | Well Name: corehole | Location: see p. 11

Project: INTP Seismic | Reference Measuring Point: ~~DBB 8/23/06~~ Approx. Elevation: see p. 11

Depth (Ft.) Box/Run	Sample Type No.	Sample Blows Recovery	Graphic Log RQD(%)	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
1095	DBB 8/22/06			See p. 28 DBB 8/22/06	D.B. 8-23-06
	87/158	100/93		v. small vesicles increasing downward in run 158	
1100				1105^6 = contact between overlying basalt and underlying altered sediment; and 1105^6-1105^2 = green, fine-grained, clay-rich rock containing white phenocrysts and clasts of black clay	
	~~DBB 8/24/06~~ 159	100/100		1105^2-1105^H = black, shiny, clay-rich rock w/ blue clay on fracture surfaces (and pyrite xtals) 1106^3- to	** Run 159: 1100-1113' $1102'$-1104^6 = Box 87 1104^6-1106 = Box 88 B.G. 8-24-06
1105	88/160	100/100 DBB 8/23/06		~~1106~~ - 1106^9 = dark grey, fine-grained, clay-rich rock containing layered/altered clasts green, black, and orange in color;	
1110	88/161	100/39		1106^7 = green, layered (oolitic?) clasts in grey matrix predominate ~~Prob vesicles filled w/ calc. replace~~ DBB 8/23/06 - spherical/spheroidal	
	88/162	0/NA	not recovered	concretions containing alt. layers of replacement/chem. deposition and(?) sediment (fine sand/silt) These are	drilled to 1113' then press went up on mud pump - pulled core barrel - no core - blocked off. 10:00
	88/163	100/72		N 1cm max dia. - most smaller	
1115	89/164	100/92		1108^2 = grey (fine-) sandy matrix contains larger and larger green clay clasts until green clay becomes matrix	1112-1113 NOT recovered
	90/165			⑧ ~1109^2 ft., green matrix clay supports dk grey-black, angular clay fragments for duration of Run 161 (wet description)	
	90/166	100/87			
1120				*See supplemental logs for description of Run 161 D.B. 8-23-06	
				1113-1118 = fine-grained, sandy clay, alternating dk green and lighter-green intervals, micaceous, darker zones are generally enriched in clay. At 1116' contact between fine sandst. above and clay/silt below.	
1125				1121^4 - gradational contact between clayey silt above and clayey sand (fn-med grained) below, sediment here is uniformly green and micaceous	
	DB 8-22-06	see pg 30			
1130					

Reported By: D.B. Barnett / Ben Garcia | Reviewed By: S.P. Reidel

Title: Geologist | Title: Staff Geologist

Signature: [signature] | Date: 8/23/06 | Signature: S P Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 30 of 46
Date: 8-23-06

Well ID: C4998 | Well Name: Corehole | Location: ~~N 3401, E 1031~~ DBB 8/23/06
Project: WTP Seismic | ~~Reference Measuring Point:~~ approx. elev. ~~690 MSL~~ D.B. 8-23-06

Depth (Ft.)	Sample Type / No.	Sample Blows / Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
1125				1123^{3} = sand coarsens slightly (medium-grained), mica flakes (muscovite) increase in size, sand is poorly-sorted, all stages of rounding	
	90/160	60/100	not recovered	1123^{2} = noticeable loss of most of coarsens through Run 165	clay fraction, sand
1130	90/167	100/100		1125 - 1125^{2} = med-coarse green sand, large muscovite flakes, poorly sorted, very little cement	13:00: Driller reports that bit is worn out - will try one more run (to 1140) then change bit. 13:30 - could not drill further - tripping out to change bit
	91/167			1125^{2}-1128 = sand turns slightly less coarse, contains rip-up clasts of green mudstone, small increase in clay fraction	
1135	91/168	100/82		1130 - 1130^{5} = med-grained, micaceous, poorly-sorted green sand	STOPPED drilling @ ~~1035~~ 1135 ft bgs on 8/23/06 DBB
	92/168			1130 - gradational increase in clay fraction and decrease in sand size and fraction, variation in core thickness due to wearing out of drill bit	8/23/06
1140	92/168 169 DBB 8/24/06	100/100	not recovered	1135 - 1140 = med-grained micaceous, poorly sorted green sand, x-bedded, (moderately poorly sorted) small clay fraction	8-24-06 = drilling start (1st core) @ 9:00 am and 1135'
1145	92/169	96/84		1140 - 1145 = (see above description for 1135-1140) x-beds defined by light/dark bands	1008 cm: Run 169 - driller senses cavity or low density material for last 2'
	93/180				
1150	93/171	17/0	not recovered	1143^{6} = sand coarsens slightly and is not competent - last 1.4' of Run 168 washes out of hole	Run 169 takes 6 min. to core
BG. 8-24-06 1155		DBB 8/25/06		1145 - 1145^{6} = med-coarse-grained green sand, micaceous, very poorly-sorted, gradational transition to med-grained by 1146' 1146'-1150' = med-grained green sand, no mud; x-bedded w/ dark green, light green, and finer dk grey (placer deposits?) bands	DBB 8/25/06
1160				1150 - 1150^{4} = same as above, very slightly gravelly	

Reported By: D.B. Barnett / Ben Garcia | Reviewed By: S.P. Reidel
Title: Geologist | Title: Staff Geologist
Signature: DB Barnett | Date: 8-24-06 | Signature: SP Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 31 of 46
Date: 8-24-06

Well ID: C4998 | Well Name: Corehole | Location: See p. 11
Project: | ~~Reference Measuring Point~~ DBB 8/24/06 Elevation (see p. 11

Box/Run	Depth (Ft.)	Sample Type/No.	Sample Blows/Recovery %	Graphic Log	Sample Description (Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl)	Comments (Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level)
	1160		TRR 0%		1150.4 – 1153.5 ; Med to v. coarse sand/ sandst.	
			B.G. 8-24-06			
			see pg 30			
		93/172	100/100		1153.5 – 1153.8 ; clayey sand w/ indications of organic debris/bioturb – med. gray-brn w/ dark clasts or replace. of opal (dk brn-grn)	
	1155				1158.2 – 1158.8 ; med ss w/ v. large mica + very abundant (up to 0.5 cm. long flakes)	
		93/173	100/100		DBB 1158.88 – 1160.5 clayey silt & fine sand w/ clay (poorly sorted) med-to-lt. grg-brn	DBB 8/24/06
	1160	94/173			1160.2 – 1160.8 Med-coarse sand, dk gray v. large + abund mica. soft, poorly consolid.)	
					1160.8 – 1162 1162.3 – clayey silt, lt.-med. gray/brn DBB 8/24/06	1153.5 – 1158.5 Med. sand/sandst. clayey, silty locally, lt. gray-brn, gry-grn
		94/174	36/75	NOT Recovered	1162.31 – 1164.3 Sand, med to v. coarse, dk grn (wet), large, abund mica	
	1165				1164.8 – 1171.6 Clay, dk grn, well consolid. contains rip ups or intrusions of sand bodies ~ 1-2 cm long (?) DBB 8/24/06; photo taken for this run (174) shows 3.2 ft missing – on the Packard This is in error – actually only 2.2 ft are missing from the interval 1163-1168	
		94/175	100/20			
	1170	95/176	100/48			
					1171.6 – 1173 = gradational change from dk green clay to sandy clay to med-grained sand (w/ ent clay)	Give missing (lost) during interval 1174 – 1179 – exact location of loss unknown – DBB 12/4/06
	1175	95/177	40/80*		1173 – 1174 = med-grained sand changes grades into coarse-grained sand, Cs-grained sand is moderately-poorly-sorted subangular, 2% lithics, 91% white/light-green, qtz, 7% mica (muscovite) + most of this core is incompetent and lacks cement, majority of lithic fraction is fine-grained (relative to qtz), green clay grades, coarse green sand ends at 1186.5	
	1180	96/178	80/			
			B.G. 8-25-06			
			see pg. 32		B.G. 8-24-06	

Reported By: D.B. Barnett / Ben Garcia | Reviewed By: S.P. Reidel
Title: Geologist | Title: Staff ~~Site~~ Geologist
Signature: [signature] | Date: 8/24/06 | Signature: S P Reidel | Date: 10/18/06

* Although intact to 80%, this material is highly fragile – consistency of gel.

A-6003-642 (03/03)

BOREHOLE LOG

Date: 8-24-06

Well ID: C4998	Well Name: Corehole	Location: see pg. 11
Project: WTP Seismic	~~Reference Measuring Point~~ D.G. 8-24-06: elevation (see pg 11)	

B.G. 8-24-06

Depth (Ft.)	box ~~Type~~ No.	~~Blows~~ Recovery % RQD	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
1180		B.G. 8-24-06 see pg 31		1186? – 1188 = smaller (thin) green clay layer followed by brown, fissile clay bed; brown clay is highly fissile, has shiny fracture surfaces, and @ closer inspection using a	End @ 1188' bgs on 8/24/06
1185	96 / 179	50 / 19 — based on reinspection of core 12/6/06 DBB		macroscope possesses a chaotic, cross-hatched pattern of lighter and darker brown, elongate shapes. Carbon content appears to be high (possibly lignite.) Core lost in interval 1184-1188 DBB 12/6/06 ~2 ft	Did not drill on 8/25/06 due to illness in drillers family
1190				Comments (8/28/06) Driller had rods 100 ft from bottom last Thursday when activity stopped for the day (8/24/06). Upon extracting rods, however, the bottom 30 ft was packed with coarse sand from the interbed – similar to that encountered @ 1184 ft bgs. and higher in the Mabton Interbed.	8/28/06 Drillers began tripping into hole @ ~6:45 Bit began plugging as bottom of hole was reached – had to trip out to unplug (see notes for 8/29/06 - DBB 8/29/06)
1195					
1200	Cont. p. 33			Driller needed to "double-line" the main hoist cable to be able to accommodate additional weight/depth of hole requirements. This work was performed after tripping out of hole. Will cement tomorrow.	
	DBB 8/29/06			DBB 8/29/06	DBB 8/29/06

Reported By: Ben Garcia / D. D. Barnett	Reviewed By: SP Reidel
Title: geologist	Title: Staff Geologist
Signature: [signature] Date: 8/28/06	Signature: SP Reidel Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Date: 8/29/06

Well ID: C4998 | Well Name: Core hole | Location: See p. 11

Project: WTP Seismic | ~~Reference Measuring Point~~: Elevation (see p. 11)

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	~~Sample Description~~ Comments ~~Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Cohesion/Angularity, Mineralogy, Max Particle Size, Reaction to HCl~~	Comments Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
				06:50 – 8/29/06: SWL in corehole @ ~331 ft bgs. This is 775 ft above the top of the Mabton Interbed. Driller reports that he reached ~1086' bgs before the bit began plugging. As it turned out, the bottom ~30 ft of rods was full of sand. He believes that this happened on 8/24/06 when he pulled back at end of day to ~600 ft bgs, having sucked the sand up in the rods as he was pulling back. However it is possible that this occurred on 8/28/06 as he was washing back down to T.D. (1188 ft bgs). As of 8/29/06 a.m. the driller plans to emplace ~100 ft of cement from bottom up.	
				At 13:30 Driller reported that he had to redrill out the hole from ~948 ft bgs to bottom. Cementing was completed by ~14:50, and began retracting rods.	
				Water level was measured at 13:30 @ 265 ft bgs but falling @ > 1 ft./min.	
				Drillers finished @ 16:00 – left site. ~100 ft of sed. cement was emplaced; rods pulled back to 600 ft.	

DBB 8/29/06

DBB 8/29/06

DBB 8/29/06

Reported By: D. B. Barnett | Reviewed By: S. P. Reidel

Title: Geologist | Title: Staff Geologist

Signature: [signature] | Date: 8/29/06 | Signature: [signature] | Date: 10/19/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 34 of 46
Date: 8/30/06

Well ID: C4998 | Well Name: Corehole | Location: see p. 11
Project: WTP Seismic | ~~Reference Measuring Point:~~ Elevation - see p. 11

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	~~Sample Description~~ DBB 8/30/06 Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, ~~Sorting~~, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
				COMMENTS 8/30/06 was spent working down to the cement emplaced yesterday and drilling this out of the hole. It was determined that the cement job (from ~1188 (T.D.) to ~1088) did not fix the caving/flowing problem. (The fact that yesterday's a.m. SWL reading was almost the same as today (331 ft bgs and 334 ft bgs respectively) is an indication of upward pressure sustaining this level in spite of the cement job. Obstruction or slough was encountered from 740' off bottom to bottom. It was decided to place another 100 ft of cement in the Mahton, the come up the hole and place a plug across (cement) the Selah Interbed. The plug will consist of a fibrous lost-circulation material. Driller left site ~ 15:30.	8/30/06 : 0735 – SWL = 334 ft bgs ≅ 343 ft. msl.

DBB 8/30/06

DBB 8/31/06

Reported By: D.B. Barnett | Reviewed By: S.P. Reidel
Title: Geologist | Title: Staff Geologist
Signature: DBBarnett | Date: 8/31/06 | Signature: SP Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Date: 8/31/06

Well ID: C4998 | Well Name: Core Hole | Location: see p. 11

Project: WTP Seismic | ~~Reference Measuring Point:~~ Elevation - see p. 11

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	~~Sample Description~~ Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Cementation, Mineralogy, Max Particle Size, Reaction to HCl	Comments Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
				DBB 8/31/06 static water level in core hole 8/31/06, 06:45 was ~~344 ft bgs~~ ≅ 333 ft. above msl.	
				P.O.D. – Drillers plan to wash down to bottom of hole, then pump cement from bottom (1188 ft bgs) to ~1070 ft. bgs. Then they will retract/rinse rods up to Selah Interbed (757 – 735 ft bgs) and emplace lost circulation material. Driller believes that the hole is disrupted and caving near the bottom where the heaving sand of Mabton Interbed was encountered.	
				8/31/06, 14:00 – cementing is in place and drillers preparing to emplace LCM around Selah. 14:25 – LCM is in place.	
				DBB 8/31/06	
				DBB 9/1/06	

Reported By: D.B. Barnett | Reviewed By: SP Reidel

Title: Geologist | Title: staff Geologist

Signature: DBB | Date: 9/1/06 | Signature: SP Reidel | Date: 10/18/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 36 of 46
Date: 9/1/06

Well ID: C4-998 | Well Name: Core Hole | Location: See p. 11
Project: WTP Seismic | ~~Reference Measuring Point:~~ DBB 9/1/06 Elevation - see p. 11

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	~~Sample Description~~ Comments DBB 9/1/06 Group Name, ~~Grain Size~~ Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
				0640 (9/1/06): SWL 337 ft bgs = ~340 ft msl.	
				Drillers went to bottom (near bottom) to try to tag cement poured on 8/31/06, but did not encounter any solid material — only cement-colored water. Cement emplaced yesterday had been washed out (placed ~1060 ft bgs). Cement/water encounted first at ~990 ft. bgs. The plan is to continue drilling on 9/5/06 with mud — adding fluid as necessary. Drillers left @ 12:30. See p. 37 for illustration.	

DBB 9/1/06

DBB 9/1/06

Reported By: D. Barnett
Title: Geologist
Signature: DB Barnett Date: 9/1/06

Reviewed By: SP Reidel
Title: Staff Geologist
Signature: SP Reidel Date: 10/18/06

A-6003-642 (03/03)

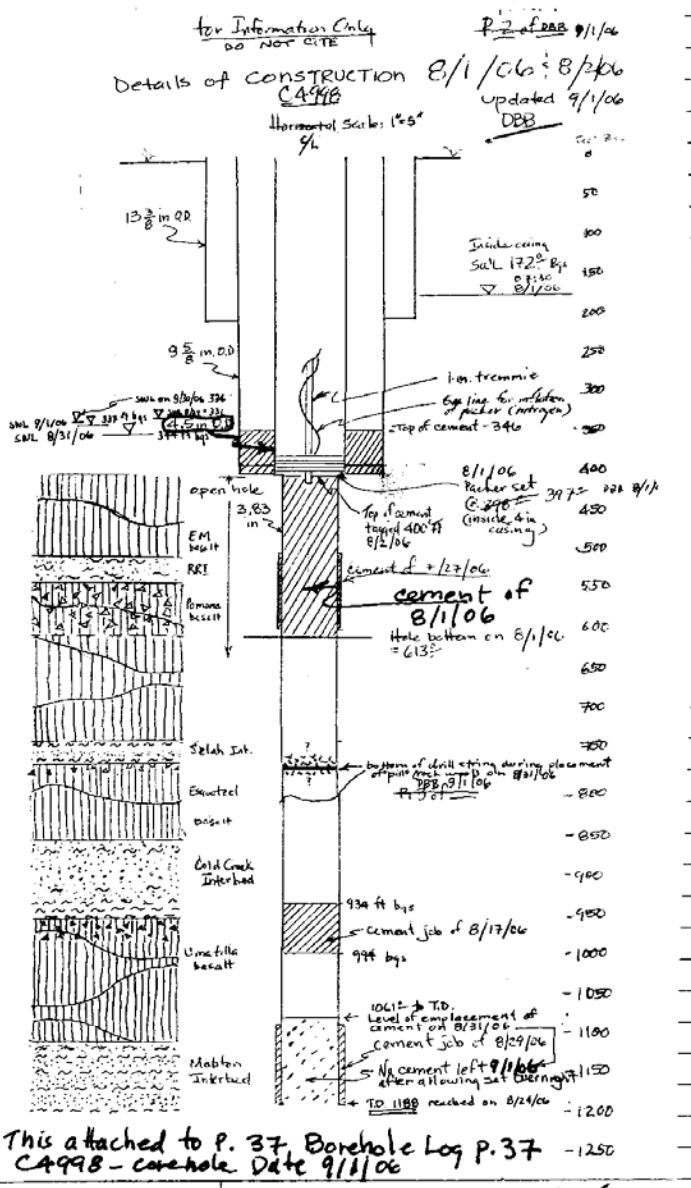
BOREHOLE LOG

Page 37 of 46
Date: 9/1/06

Well ID: C4998 | Well Name: Core Hole | Location: See p. 11

Project: WTP Seismic | ~~Reference Measuring Point:~~ DBB 9/1/06 Elevation – see p. 11

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	~~Sample Description~~ Group ~~Name~~, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
				Construction and cementing details as of 9/1/06	



Reported By: D.B. Barnett		Reviewed By: SP Reidel	
Title: Geologist		Title: Staff Geologist	
Signature: DB Barnett	Date: 9/1/06	Signature: SP Reidel	Date: 10/19/06

A-6003-642 (03/03)

This is original SPR 9/27/06 ~~FOR~~ COPY

BOREHOLE LOG

Date: 9/5/06

Well ID: C4998 | Well Name: Core Hole | Location: See p. 11

Project: WTP | ~~Reference Measuring Point:~~ Elevation - see p. 11 DBB 9/5/06

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
1185		DBB 9/5/06		DBB 9/5/06	06:35 - 9/5/06 SWL = 345 ft bgs ≈ 332 ft msl. Drill @ 580 ft bgs. Drillers work back into hole bottom (actually ~ 4' off bottom) until ~12:30. At this point the over-shot was inserted to retrieve core barrel but could not get down past ~ 30 ft bgs due to mud ringing. Had to pull rods back to ~980 ft bgs. Spent remainder of day pulling rods and disposing of contaminated mud. Driller believes the reason for ringing is the cement residue in the mud and Bicarbonate. Will continue Drilling tomorrow @ ~1188 ft bgs w/ new target of ~1400 ft bgs (see insert, left).
		See p. 32			

Instructions from S P. Reidel and A.C. Rohay on final target depth for C4998

Page 1 of 1

Barnett, D B (Brent)

From: Rohay, Alan C **Sent:** Tue 9/5/2006 1:46 PM
To: Reidel, Stephen P; Reynolds, Kent D
Cc: Barnett, D B (Brent); Brouns, Thomas M; Rohay, Alan C
Subject: RE: Final depth for corehole C4998
Attachments:

When I add these up, I get 215 feet to go assuming the Rosalia flow top is 30' thick.
25 (Mabton) + 155 + 5 + 30.
That would make the C4998 corehole TD 1182 + 215 approximately 1400

I think that the deep borehole C4997should extend an additional 30' to make room for the suspension tool to fully cover the Rosalia flow top.

Alan

From: Reidel, Stephen P
Sent: Tuesday, September 05, 2006 1:26 PM
To: Reynolds, Kent D
Cc: Barnett, D B (Brent); Brouns, Thomas M; Reidel, Stephen P; Rohay, Alan C
Subject: Final depth for corehole C4998

Kent

Alan Rohay wants to have core through the Byron Interbed and the flow top of the underlying basalt of Rosalia, Priest Rapids Member. I estimate, in round numbers, final depth to be approximately 1390 ft BGS, leaving about 210 ft left to drill.

The logic behind that depth is as follows:

The present depth is 1182 ft BGS and they are in the Mabton Interbed. The Mabton is 100 ft thick in C4996. This should leave about 24 ft of Mabton left for C4998. The basalt of Lolo, Priest Rapids Member is 155 ft thick, the Byron interbed is about 5 ft thick and the basalt of Rosalia, Priest Rapids Member is 60 feet thick. The flow top of the basalt of Rosalia is about 25-30 feet thick in the local area. If you have them drill into the massive part of the Rosalia, then that would make the final depth at approximately 1390 giving about 210 ft left to drill.

Brent Barnett will watch the core; work with him on the decision to stop drilling C4998.

Steve

Stephen Reidel PhD
Pacific Northwest National Laboratory
and Battelle-Pacific Northwest Division
MS K6-75; PO Box 999
Richland, WA 99352
sp.reidel@pnl.gov
(509) 376-9932
http://www.pnl.gov
Street Address: 3110 Port of Benton Blvd.

D.B. Barnett DBBarnett

Logged by D.B. Barnett DBBarnett 9/5/06

DBB 9/5/06

P. 38 of Borehole Log for C4998 Core HOLE
DBB 9/5/06

reviewed by: SP Reidel
Staff Geologist
SP Reidel Date 10/18/06

https://webmail.pnl.go...:%20Final%20depth%20for%20corehole%20C4998.EML?Cmd=ope 9/5/2006

A-6003-642 (03/03)

This is the Original SBR 9/6/06 ~~COPY~~

BOREHOLE LOG

DBB 9/6/06

Date: 9/6/06

Well ID: C4998 | Well Name: ~~C4~~ core Hole | Location: See p. 11

Project: WTP Seismic | ~~Reference Measuring Point:~~ DBB 9/6/06 Elevation – see p. 11

Depth (Ft.) Box/Run	Sample ~~Type~~ No.	~~Blows~~ Recovery RQD % DBB 9/6/06	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
1185		See p. 32		Slickensides @ 1184.3 indicate reverse dip-slip movement. This surface is between sandstone & clay/claystone.	07:00 9/6/06 – SWL = 327 ft bgs = ~ 350 ft msl.
1188	95/180	100/0		clay is gry-grn to med. to dark (wet) w/ carbonaceous (blk) debris frags	Worked back into hole from ~ 600 ft. bgs. change mud & go to T.D. at
1190	96/181	100/85		Driller says run 180 is probably cave material (?)	1188 ft bgs – reached T.D. by ~ 12:00
	97/181			1189.6 – 1191.6 Claystone/clay mod. hard (coarses w/ knife) med. gry-gra (wet) Clay with clasts (rip up?) of clay or bioturbo features, silty-clayey sand at 1191.6	with drew core barrel and put other core barrel in – went down w/ overshot to confirm that barrel went to bottom.
1195	97/182	100/100		w/ occas. horizontal stringers of opal and opalized (H=5½) wood frags @ 1194 – 1196 Also unreplaced wood frags or replaced by black, soft opal (caverstolite) (See photo 5686)	Began drilling new hole @ 11:45. First core up @ 12:10 (1 ft run).
	97/183	100/22		1191.6 – 1199.5 Claystone, med-dk gry-grn hard light grn-yel opaline replacement bodies or concretions up to 4 cm dia.	
1200	98/184	100/100		large opalized wood frag 1193.5	
	98/185	97/98		1199.5 – 1202.3 – Claystone, dk gry to black (wet) – carbonaceous with plant casts and replacements (coalified debris?) softer, more friable than previous	(Slickensider on fracts) throughout 1199.5 – 1202.3 interval.
1205	99/185			1202.3 – 1204.5 Sandstone, lt reddish brn to gray, poorly sorted w/ sign. f clay/silt	16:00 – Driller is stuck at or near
		See p. 40		1204.5 – 1206.8 – Breccia, clay + basalt frags – hyaloclastic texture.	hole bottom – is able to free up pipe with difficulty (this occurred
1210				1206.8 – 1221' Basalt, DK gray, somewhat vesicular, but mostly massive, numerous fractures.	during Run 185)
					slickens @ 1203.7 on vert. fract surface
1215				DBB 9/7/06	DBB 9/7/06
1220					

Reported By: D.B. Barnett | Reviewed By: SP Reidel

Title: Geologist | Title: Staff Geologist

Signature: DB Barnett | Date: 9/6/06 | Signature: SP Reidel | Date: 10/18/06

A-6003-642 (03/03)

This is original SPR 9/27/06 ~~COPY~~

BOREHOLE LOG

Page ~~40~~ 46 of 46
Date: 9/7/06

Well ID: C4998 | Well Name: Core Hole | Location: See p. 11
Project: WTP Seismic | ~~Reference Measuring Point~~ DBB 9/7/06 | Elevation-see p. 11

Depth (Ft.) Box/Run	Sample ~~Type~~ No.	Sample DBB 9/7/06 ~~Blows~~ % Recovery	Graphic Log % RQD	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
1205	See p. 39			Large vesicles penetrating horizontally through core ~ 2.5 cm dia. This is filled w/ lining + "stalactites" of green translucent mineral (sample no. C4998-9-7-06 Vug coating @ 1208.6 ft bgs) Large vugs continue down to 1215.5 Basalt is aphyric with Plag phenos ~ 1-2 mm long – not readily visible except on fresh surface (~ 1215 ft bgs) Smaller vesicles at this level (~ 1215) are filled w/ blu-grn clay min. Plag microcrysts become more visible w/ depth, esp. @ ~ 1217 ft bgs. Vesicles becoming (XRD sample @ 1219) more numerous (mostly) (see supplemental log) filled @ ~ 1221, then larger and still more numerous (open more often) @ ~ 1223. Run 189 came out of core barrel as one solid piece. (photos 5717-5720 = Run 189, 5721 = Box 100) (photos 5722-5726 = Run 190) Vesicles connected w/ narrow channels and containing clasts or xtals of unknown mineral in clay matrix (photos 5727-5728) @ ~ 1226.5 ft bgs. Bx and slickensides in fracture complex @ 1227.5 (photo 5729 = Box 101) More "mineral chambers" from 1231.5 Qtz xtals in vug @ 1234° up to 0.6 cm long. Fract @ 1233.7 is coated w/ translue. green mineral (color of epidote) and vesicles filled w/ glassy (but soft) translue. brn mineral w/ conchoidal fracts. (photos 5730-5734 = Run 191) (photos 5735-5736 = "mineral chamber" @ 1231.5') (photos 5737-5739 = Qtz xtals in vug @ 1234') (photo 5740 = Box 102)	0600 – P.O.D. Mtg – 9/7/06: Kent Reynolds, Steve Reidel met w/ USUAL crew to discuss options on stabilizing hole and continuing to core. Ken Jones, driller notes that it is risky to continue but can get more core. 06:30 BWL = 342.4 bgs = 335 ft msl. Drillers and mud man mixed up a combo of additives (Quick Gel, N-seal, Quick Trol) to better develop a filter cake to hold walls up in Mahon Interbed. To this mixture was also added Aqua Clear (PFD) to help reduce viscosity. Began drilling run 186 @ ~ 11:50 DBB 9/7/06 (Run 186 photo 5787) Lost drill fluid @, begin run 187 (~ 1210 ft) @ 12:35. There was ~ 3 ft of cake material @ top of Run 186 (1st run) Looks like clay from ~ 1190. (photos 5708-5711 = Run 187) (photo 5712 = Box 99) (photos 5713-5716 = Run 188) Stopped drilling @ ~ 16:45 tripped out to 580 ft bgs
1210	99/187	100/92			
1215	100/188	100/100			
1220	101/189	100/100			
1225	101/190	100/62			
1230	102/191	100/100			
1235	See p. 41		9/8/06		

DBB 9/8/06

Reported By: D.B. Barnett / Ben Garcia | Reviewed By: SP Reidel
Title: Geologists | Title: Staff Geologist
Signature: DBBarnett | Date: 9/7/06 | Signature: SP Reidel | Date: 10/18/06

A-6003-642 (03/03)

This is the original SPR 9/27/06 COPY

BOREHOLE LOG

Date: 9/8/06

Well ID: C4998 | Well Name: Core Hole | Location: See p. 11

Project: WTP Seismic | ~~Reference Measuring Point~~ DBB 9/8/06 | Elevation – see p. 11

Depth (Ft.)	Sample Type / Run No.	Sample Blows / Recovery % / RQD %	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
Box x / Run No.					06:30, 9/8/06: SWL = 341 ft bgs = 336 ft msl. Began coring again @ ~0950 after tripping back in from 580' bgs while cleaning hole near bottom – no problems except ~80% loss of drill fluid. First core out @ ~11:05.
1235	See p. 40				
	103/192	100/100		Noted @ 1235.3 and downward: Basalt is light gray due to dense groundmass of plag xtals 1-2 mm length (is similar to that noted @ ~1217')	
1238				Vesicles numerous 1237.8 to 1290.5. Some opts ~ 3 cm long and horizontally elongated. Vesicle filling of qtz and clay w/ some forming vugs of qtz xtals. Large fract ~5° @ ~1241.5	
1240	103/193	100/90			
1243					
	104/194	100/100			
1245		98/100		← VOID (probably large vesicle) 1245.7 – 1246.2 (Driller reported that the rods dropped ~0.5 ft.	Photos 5752-5753 Run 192 (5754-5757) Run 193 (Photo 5758 = Box 103) (5759-5762 = Run 194) (Photos 5760-62 and 5763) Run 195 came out of core barrel as one solid piece – broken during retraction from barrel (Photos 5764-5766 = Run 195) (5767 = Box 104) (Run 196 = 5768-5770) (5771 = Box 105) (5772-5775 = Run 197) (5776-5778 = Run 198) (5779 = Box 106) (5780-5783 = Run 199) (5784 = Box 107) (5785-5788 = Run 200)
	104/195	100/100		Micropegmatite 1250 1251 (-1251.2 – plag phenos up to 4 mm long. Possible matic mineral (pyrox?) altered to clay (dark grn-blk) as phenos also ~0.5 cm long (Also @ 1257.7)	
1250	105/195				
	105/196	100/95		1255' – 3 cm-wide vesicular zone/glassy zone w/ vesicles filled w/ grn clay or opal. In Run 196 occur very sparse plag. phenos up to 1 cm long	
1255				Fract. @ 1258° = 75°; 2-cm-thk micropeg @ ~1260°. Run 197 came out as one solid pc. The micropegmatite @ 1258 contains plag phenos 8 mm long. The adjoining basalt has a dense weave of plag xtals ~1-2 mm, with v. sparse widely scattered xtals of up to 1 cm in length. Two populations recognized.	
	106/197	100/100			
1260					
	106/198	100/100		Signif. Fractures: 1263°, 1264.7 (high angle fract (~75°) truncated or terminates into horizontal fract), 1266.2 and 1266.8 (high angle)	Finished tripping back to 580 Ft bgs. @ 16:00
1265	107/199			1266.2 – 1268' micropegmatite follows vert. fracture	
	107/199				
	107/199				
1270	108/199	100/100			
	See p. 42				

DBB 9/8/06

DBB 9/8/06

Reported By: D.B. Barnett / Ben Garcia		Reviewed By: SP Reidel	
Title: Geologists		Title: Staff Geologists	
Signature:	Date: 9/8/06	Signature: SP Reidel	Date: 10/18/06

A-6003-642 (03/03)

This is the original SPR 9/[illegible]/06 COPY

BOREHOLE LOG [redacted]

Page 42 of 46
Date: 9/8/06

Well ID: C4998 | Well Name: Core Hole | Location: See p. 11 and 9/11/06
Project: WTP Seismic | ~~Reference Measuring Point:~~ DBB 9/8/06 Elevation: See p. 11

Depth (Ft.) Box/Run	Sample Type No.	Sample Blows Recovery % RQD	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
1270		DBB 9/8/06 See p. 41			photos 5789-91 = Run 201 (1278-1283 ft) photo 5792 = Box 108) Photos 5793-5795 = Run 202 Photo 5796 = Sheet of Run 202 held; Photo 5797 = Box 109 Photos 5798-5801 = Run 203 Photos 5802-5804 = Run 204 Photo 5805 = Box 110 Photos 5806-5807 = lg. Plag @ 1297' ← end @ 1600, depth = 1278 ft bgs on 9/8/06.
1275	108/200	100/100			
1280	108/201	90/100		fract @ 1279.8 = 75°	
	109/201				9/11/06: SWL = 335 ft bgs = 342 ft msl @ ~6:30 – tripped down to bottom, (mixed mud) and began drilling 1278 ft @ ~10:15 on 9/11/06, Run 201 lost ~0.5 ft of core due to grinding Run 202 = one piece Run 203 = one piece
1285	109/202	100/100		Basalt still light-med gray (drg) but w/ more abundant pyroxenes(?) or other dark mineral beginning @ 1289.5 becoming less conspicuous and with transition @ ~ 1309.	
1290	110/203	100/100		Many thin, healed fractures at different angles 1288.5 to 1305.6 and 1309 to 1312.5	
				205 DBB 9/11/06	Photos 5808-5811 = Run 205, – 5812-5814 = Run 206; 5815 = Box 111
1295	110/204	100/100*		*RQD: several incipient (healed) fracts were opened during extraction from core barrel. ← Very infrequent, isolated and large (up to 1 cm) plag. xtals. These first appeared ~ 1290 ft bgs. DBB 9/11/06	Drillers say they lost 2 fractions worth of mud during 9/11/06
	111/204				
1300	111/205	100/100		1301 – sticks on 20° fract surface indicate reverse dip slip motion. Also right lateral component	
					Stopped drilling @ ~ 15:45 – out of mud, Stopped @ 1313 ft bgs. DBB 9/11/06
1305	111/206	100/100		mostly healed fracts, but abundant, spider-web like network (~ 1304) DBB 9/11/06	
1308		See p. 43 DBB 9/11/06			

Reported By: D.B. Barnett | Title: Geologist | Signature: [signature] | Date: 9/11/06
Reviewed By: SP Reidel | Title: Staff Geologist | Signature: [signature] | Date: 10/18/06

A-6003-642 (03/03)

This is the original SP Ridgley COPY

BOREHOLE LOG

Page 43 of 46

Date: 9/11/06 - 9/12/06

Well ID: C4998 | Well Name: Core Hole | Location: see p. 11

Project: WTP Seismic | ~~Reference Measuring Point:~~ Elevation - see p. 11

Depth (Ft.) Box/Run	Sample Type No.	Sample Blows Recovery % RQD	Graphic Log	Sample Description	Comments
1305				DBB 9/11/06 see p. 42	Photos 5822-5825 = Run 207 (1308-1313) 5826 = Box 112
1310	112/207	100/100		Fracture (@ 65°) with thick (0.3 cm) filled w/ dark grn/blk clay - at ~1310 and ~1311 (~80°)	Photos 5816-5817 f.R. basalt @ ~ 1298 ft bgs Photos 5818-5821 - pyritic fracture fill/vein @ ~ 1298 ft bgs.
1315	113/208	100/100		1313.4 - 1315: Network of thin, healed fractures - some indicating offset or termination. Also @ 1318.5 - 1314.1, 1326 - 1330.	9/12/06 - start @ 1313 ft. bgs. SWL = 339 ft bgs @ 06:45 = 338 ft msl. Trip into hole & start first run @ ~ 0915
1320	113/209	100/100		Large (1 cm) plag. x tals at long intervals still present as above. Fracture angles = 55°, 30°, 45°, 75° appear most common. Box 113.	Photos 5827-5828 = Run 208 Driller reports that drill would not go down due to rock lodged in shoe (-); pulled core barrel; recovered 0.2 ft piece (part of run 208) and went back in - OK this time (10:30)
1325	114/210	100/94		1321° - 1329° DBB 9/12/06 1326° - 1329°: Network of thin, mostly healed fracts. Fracture (75°) w/ slicks indicating normal, left-lateral movement @ 1321.5'. At ~ 1323.5', basalt becomes light gray (dry) apparently due to reduction in grain size of both felsic and matic components (less matics?) Large (1 cm) plag phenos still present at long intervals (about one x tal per foot). Color change of rock is gradual, however.	Runs 208, 209 extracted as one piece each. Photos 5829-5831 = Run 209. Photo 5832 = Box 113
1330	114/211 115/211	100/100			~12:30 Bonneton drill chuck came loose and was repaired. Photos 5833-5835 = Run 210. Photos 5836-5838 = Run 211. Photo 5839 = Box 114 Photos 5840-5842 = Run 212 Photo 5843 = Box 115. Photos 5844-5846 = Run 213.
1335	115/212	100/100		DBB 9/12/06	DBB 9/12/06
1340	116/213	100/100		See p. 44 DBB 9/12/06	

Reported By: D. B. Barnett / Ben Garcia | Reviewed By: SP Ridgley

Title: Geologist | Title: Staff Geologist

Signature: D B Barnett | Date: 9/12/06 | Signature: SP Ridgley | Date: 10/10/06

A-6003-642 (03/03)

This is the original SPR 9/12/06 ~~COPY~~

BOREHOLE LOG

Date: 9/12/06 and 9/13/06

Well ID: C4998 | Well Name: Core Hole | Location: See p. 11 | Reference Measuring Point: DBB 9/12/06 | Elevation: See p. 11

Project: WTP Seismic

Depth (Ft.)	Sample Type / No. / Blows / Recovery / RQD	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
Box/Run				
1340	See p. 43	DBB 9/12/06	DBB 9/13/06	2 photos 5847 - 5850 = Run 214
				Photo 5851 = Box 116
				Photos 5852-5854 = Run 215
	116/214 100/100			
	117/215			Started @ 1351 ft on 9/13/06 - no SWL measurement today
1345			Plagioclase phenocryst more infrequent than higher intervals - gradational.	photos 5855-5856 = micro of Ldo basalt @ 1316 ft. bgs showing plag.
	117/215 100/100		Imbricate structure of fracture fill (dk grn - blk) suggests NORMAL dip slip movement @ 1351'.	Began drilling @ ~~09:00~~ ~09:45 on 9/13/06. DBB 9/13/06
1350				
	117/216 100/100			Photo 5857 = Run 216; Photo 5858 = Box 117; Photos 5859 - 5862 = Run 217, Photos 5863-5866 = Run 218. Photo 5867 = fracture fill material @ 1360.5'
			larger, but still sparse plag. phenos up to 1.6 cm long (see 1354.5').	
1355	118/217 100/100			12:05 - Driller is only able to make 2.5 ft run to 1365.5' - drill noticeably ~~feet~~ fell more rapidly @ ~ 1365.
			heavy fracturing @ 1358.7' and ~ 1360.5' with thick fracture fill of brittle, dk grn to black mineral. V. minor breccia in fracture @ 1358.7' Sample taken of dk grn mineral from ~ 1360.5' V. small (~2mm max) vesicles appearing @ 1361.5' Dense network of fractures (healed) from 1364.5' to 1365.4' offset of low angle fract (~5°) by high angle fract (75°) indicates reverse dip slip movement. Increasing pyrox and plag (megascopic) in separate and ophitic textures beginning ~ 1360. Plag esp. visible (~2mm long) @ 1364 downward.	
	118/218 100/86			Photo 5868 = Box 118
	DBB 9/13/06			Photo 5869 = Run 219
1360	119/219 100/100			Drilling faster beginning @ ~ 1365. Photos 5870-5872 = Run 220 photo 5873 = Box 119; photos 5874-5876 = Run 221; 5877 = Box 120
	119/220 100/60			
	120/220			
1370	DBB 9/13/06		Very thin (~0.1 ft) clay/altered vesicular basalt. Clay is hard, but carvable w/ knife V. sharp contact w/ overlying basalt at 1365.4'	
120	119/221 100/100		1365.5 - 1283 Vesicular basalt, blk to med. gray, glassy from 1365.5' to 1366.2' w/ some tiny plag xtals (~1-2 mm) then becoming lt to med gray w/ abundant plag (1-2 mm) in dense weave. Also bands of higher concentrations of plag. Py in fracts 1371.5' and others in vicinity. White soft mineral in vesicle @ 1373 (~~sample taken~~) D.F. 9-14-06	DBB 9/13/06
1375	120/221			
	DBB 9/13/06			
	See p. 45			

Reported By: D.B. Barnett / Ben Garcia | Title: Geologist | Signature: DBBarnett | Date: 9/13/06

Reviewed By: SP Reidel | Title: Staff Geologist | Signature: SP Reidel | Date: 10/18/06

A-6003-642 (03/03)

This is the original 9/27/06 COPY

BOREHOLE LOG

Date: 9/13/06

Well ID: C4998 | Well Name: Core Hole | Location: See p. 11

Project: WTP Seismic | ~~Reference Measuring Point:~~ Elevation - see p. 11

Depth (Ft.) Box/Run	Sample ~~Type~~ ~~BB~~ 9/13/06 No.	Recovery % RQD %	~~Blows~~	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
1375	See p. 44				Dark gray-grn to blk mineral w botryoidal habit in vesicles @ 1375'. Vesicles from 1365' are >3 cm dia. (longer than core is wide) in some places (e.g. ~1374.5') Also smaller vesicles in sheets/trains @ 1374-1375. Alternate light/dark banding appears to be due to varying proportions of plag and mafics or glass or opaques (?)	14:40 9/13/06 - weather clouding up, wind rising ← sample taken @ 1375' of this mineral
1380	121/222	100/100				photos 5878-5880 = Run 222. 5881 = Run 223
1383	121/223	100/100			slickensides in fracture @ 1377.8' indicate right-lateral displacement. Very rare, large plag phenos around 1380 and vicinity. Up to 0.5 cm long. S.G. 9-14-06	STOPPED Run the day @, 15:45 @, 1383 ft bgs on 9/13/06.
	122/223					
1385	122/224	100/76			1383-1388 1387' = fractured basalt, vesicular, 65°-70° fracture @ ~1384', fracture surface covered by green-blue-grey mineral, vesicles and smaller fractures filled w/ black, botryoidal, soft mineral (clay?), some vesicles surrounded by uneven blob (2-3 cm) of darker, aphanitic basalt; character of basalt here is speckled dk grey and black, w/ optically-visible matrix plag (grey) and darker (glass?) portions	
1390	122/225	100/100				0700 9/14/06 - ~60°, partly cloudy static water level @ 319 ft. bgs., start drilling @ 1383 ft.
	123/225					
1395	123/226	100/100			plagioclase (See 1365' description) 1389' = 75° fracture coated w/ green mineral 1387-1392 = basalt is only lightly fractured and vesicular, only near top of run (Run 225), vesicles are filled w/ either black or green (clay) mineral, Large phenocrysts apparent (2-3 mm long) [plagioclase], aphanitic (dk-gr.), vesicular bands occur every 1' or so, ~~#~~ layer's vesicles are filled in w/ black mineral, ~~matrix plag is much smaller~~ B.G. 9-14-06 band contains higher proportion of dark material (glass?)	0840 = encountered sand in the hole at ~1200 ft., possibly flowing sand from Mabton Interbed
1400	see p. 45 & 46 DBB 9/19/06					*photos 5883-5885 = Run 224
						*photos 5886-5888 = Run 225
1405						photo 5887 = Box 122
						photo 5890-5892 = Run 226
						photo 5893 = Box 123

Reported By: D.B. Barnett, Ben Garcia | Reviewed By: S P Reidel

Title: Geologist | Title: Staff Geologist

Signature: D.B. Barnett / B.J. Garcia | Date: 9-14-06 | Signature: S P Reidel | Date: 10/18/06

A-6003-642 (03/03)

This is the original SPR 9/27/06 ~~COPY~~

BOREHOLE LOG

Date: 9-14-06

Well ID: C4998 | Well Name: Corehole | Location: see p. 11

Project: WTP Seismic | ~~Reference Measuring Point~~ B.G. 9-14-06 elev.; see p. 11

Depth (Ft.)	Sample ~~B.G. 9-14-06~~ ~~Type~~ ~~No.~~ Box/Run	Blows Recovery RQD% 9-14-06	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
1395	B.G.	see p. 45		1392'-1397' = (see p. 45) largely unfractured, vesiculation occurs only in discreet discrete layers (see previous run's description), plag phenocrysts present in speckled dk grey/black basalt	
	124/227	100/100			Total depth of 1400 reached @ 1330
1400				1397'-~~1400~~ 1400' = (see previous run's description), @ 1399', appearance of basalt changes, not as speckled, proportion of dark fraction decreases, matrix plagioclase xtals not as ~~distinguished~~ distingishable B.G. 9-14-06	photo 5894 = Run 227 photo 5896 = Box 124
1405					
	B.G. 9-14-06				

Reported By: Ben Garcia | Reviewed By: SP Reidel

Title: geologist | Title: Staff Geologist

Signature: B.J. Garcia | Date: 9-14-06 | Signature: SP Reidel | Date: 10/18/06

A-6003-642 (03/03)

44647/T5.2.2 Log-06-149

SUPPLEMENTAL
DRILL LOG

NOTE: This log begins @ 401.0 ft bgs, where diamond drilling began.

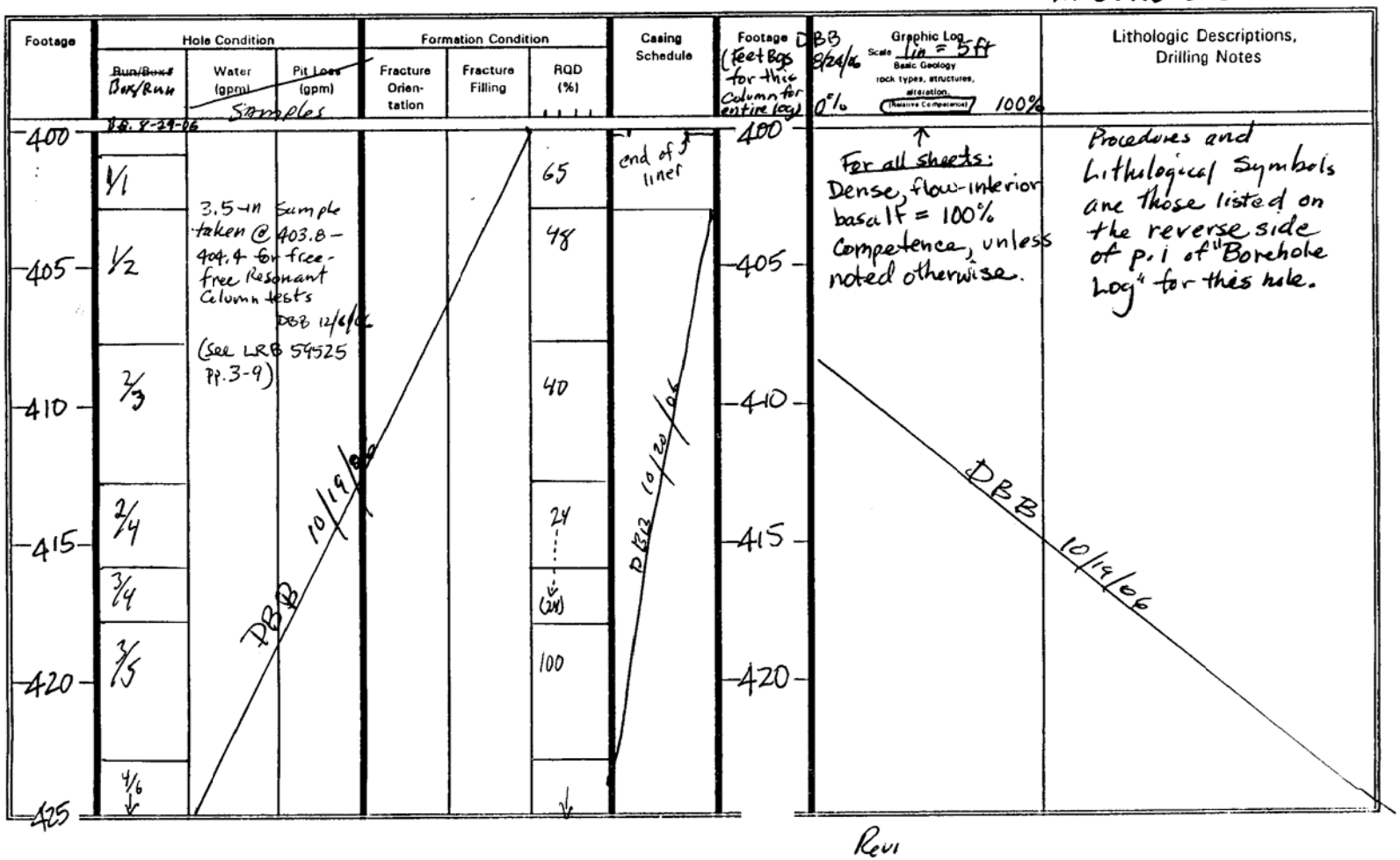
Page 1 of 40

676,78 ~~FT~~ DBB 8/24/06

HOLE NO. C4998-corehole

PROJECT WTP Seismic
CONTRACTOR Layne / Christensen
DATE STARTED 7/19/06 COMPLETED 9/14/06
LOGGED BY D.B. Barnett / Ben Garcia / Colleen Rust

TOTAL DEPTH 1400 ft LAND SURFACE ELEV. ~690 msl
INCLINATION Vert. BEARING NA
COORDINATES T NA R NA S NA OTHER N3901, E10381
SURVEY REFERENCES NA — see p. 11 of "Borehole Log" for C4998-Corehole



Rev1

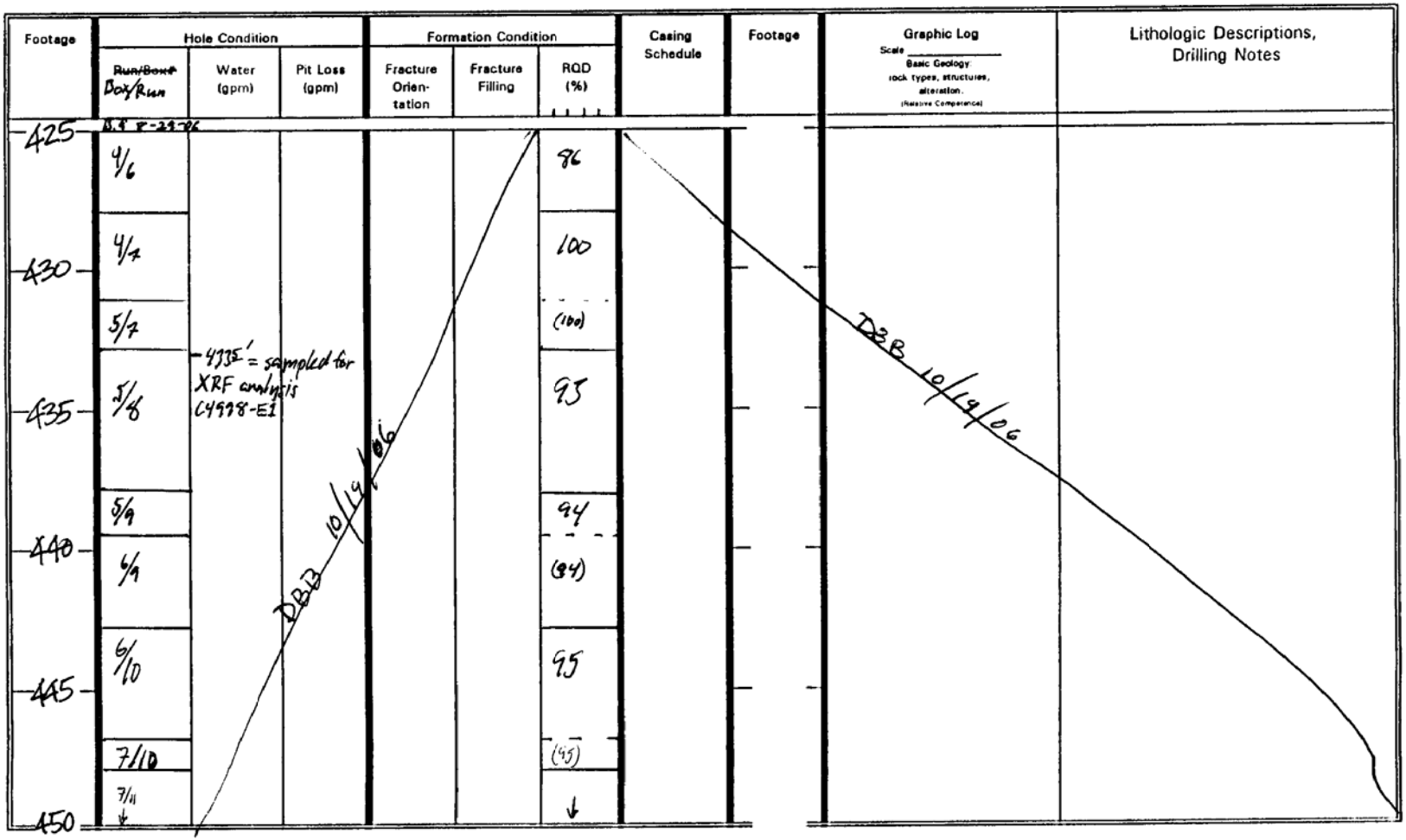
SUPPLEMENTAL

DRILL LOG

HOLE NO. C4998 - corehole

DBB 8/22/06

PROJECT _____ } See p. 1 { TOTAL DEPTH _____ LAND SURFACE ELEV. _____
CONTRACTOR _____ } { INCLINATION _____ BEARING _____
DATE STARTED _____ COMPLETED _____ } { COORDINATES T ___ R ___ S _____ OTHER _____
LOGGED BY _____ } { SURVEY REFERENCES _____



SUPPLEMENTAL

DRILL LOG

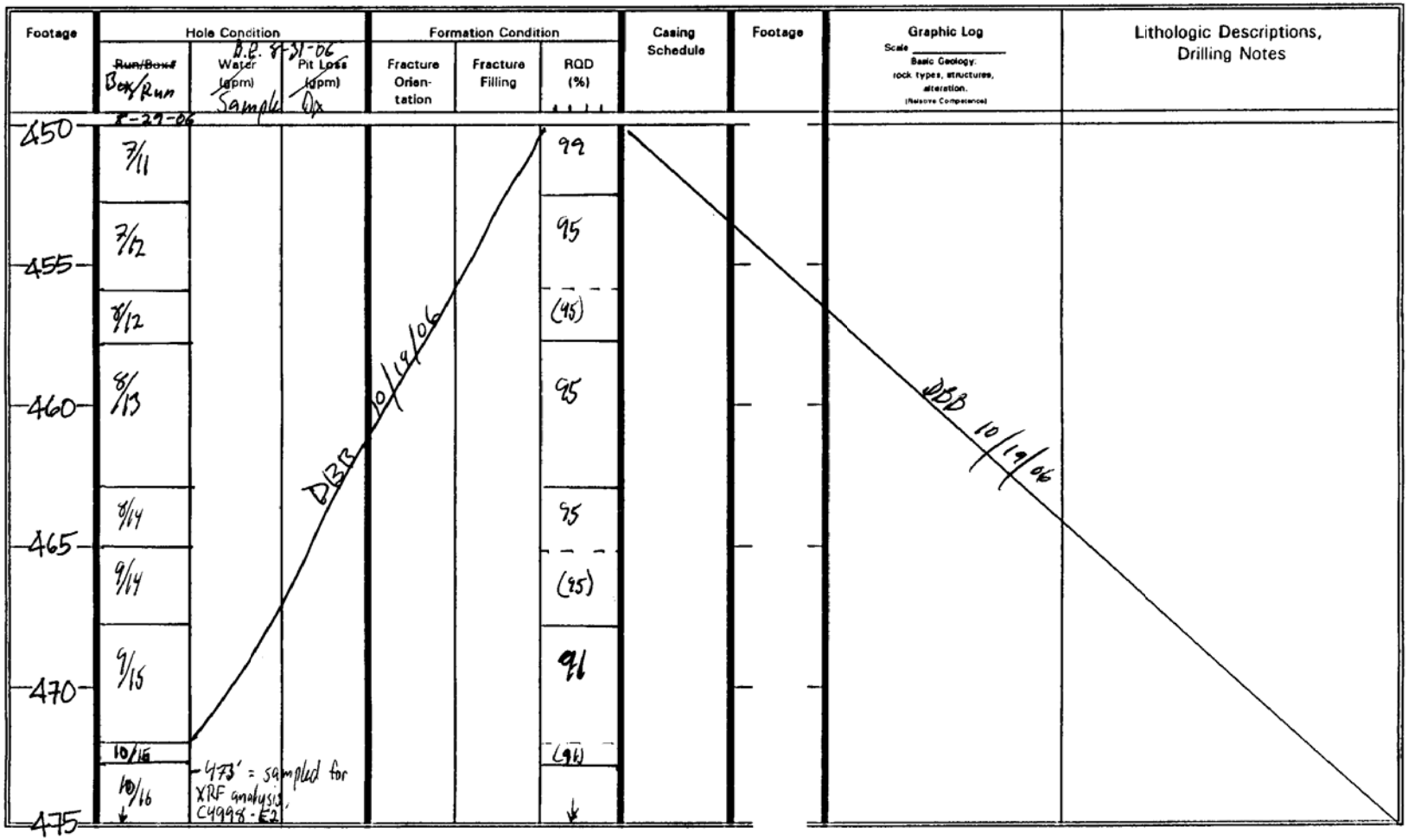
DBB 8/2/06

HOLE NO. C4998 - corehole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY Ben Garcia

See p. 1

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



SUPPLEMENTAL

DRILL LOG

HOLE NO. C4998-corehole

DBB 8/22/06

PROJECT WTP seismic

CONTRACTOR LAYNE/C

DATE STARTED 7/19/06 COMPLETED _____

LOGGED BY D.B. Barnett

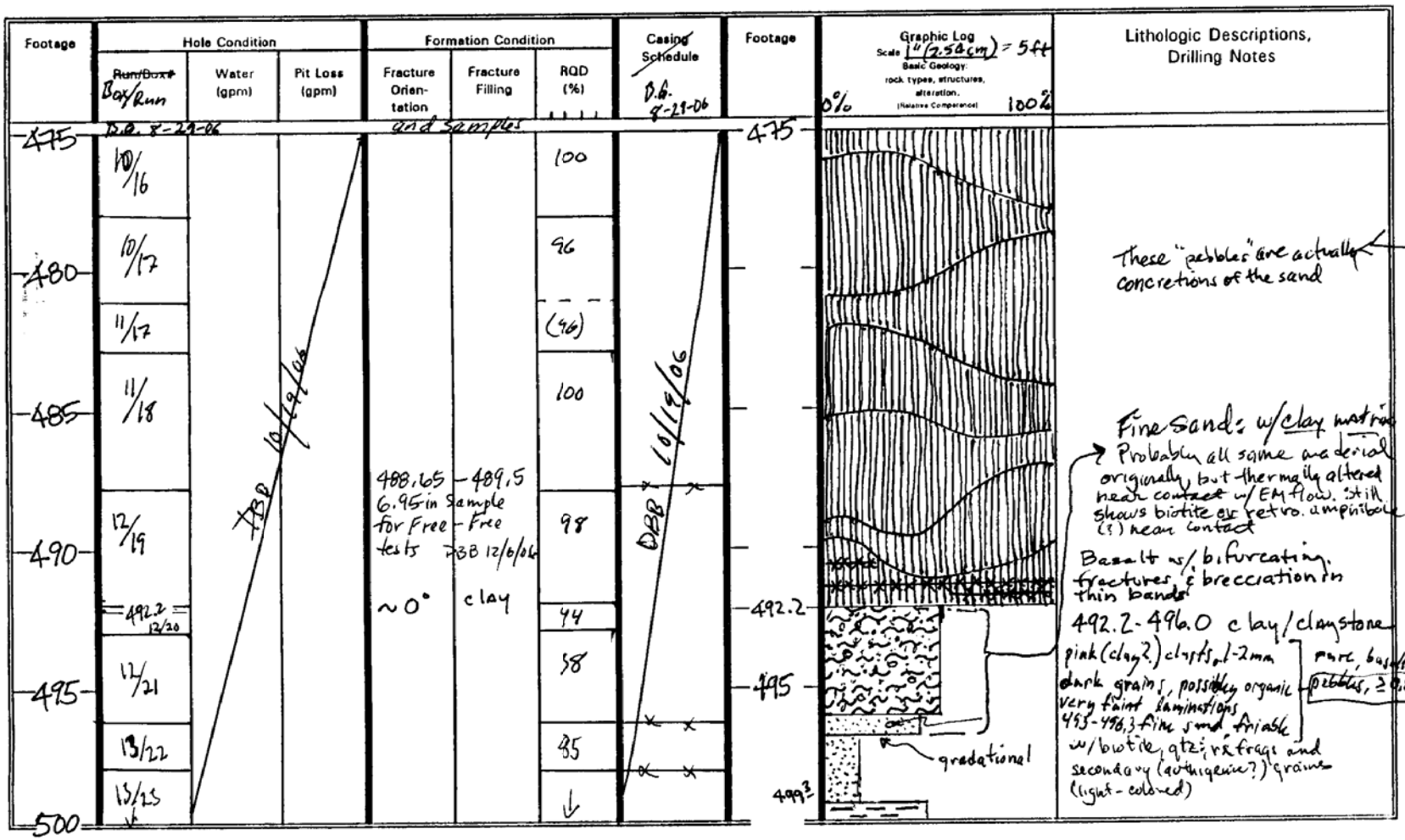
see p. 1

TOTAL DEPTH _____ LAND SURFACE ELEV. _____

INCLINATION _____ BEARING _____

COORDINATES T ___ R ___ S _____ OTHER _____

SURVEY REFERENCES _____



SUPPLEMENTAL

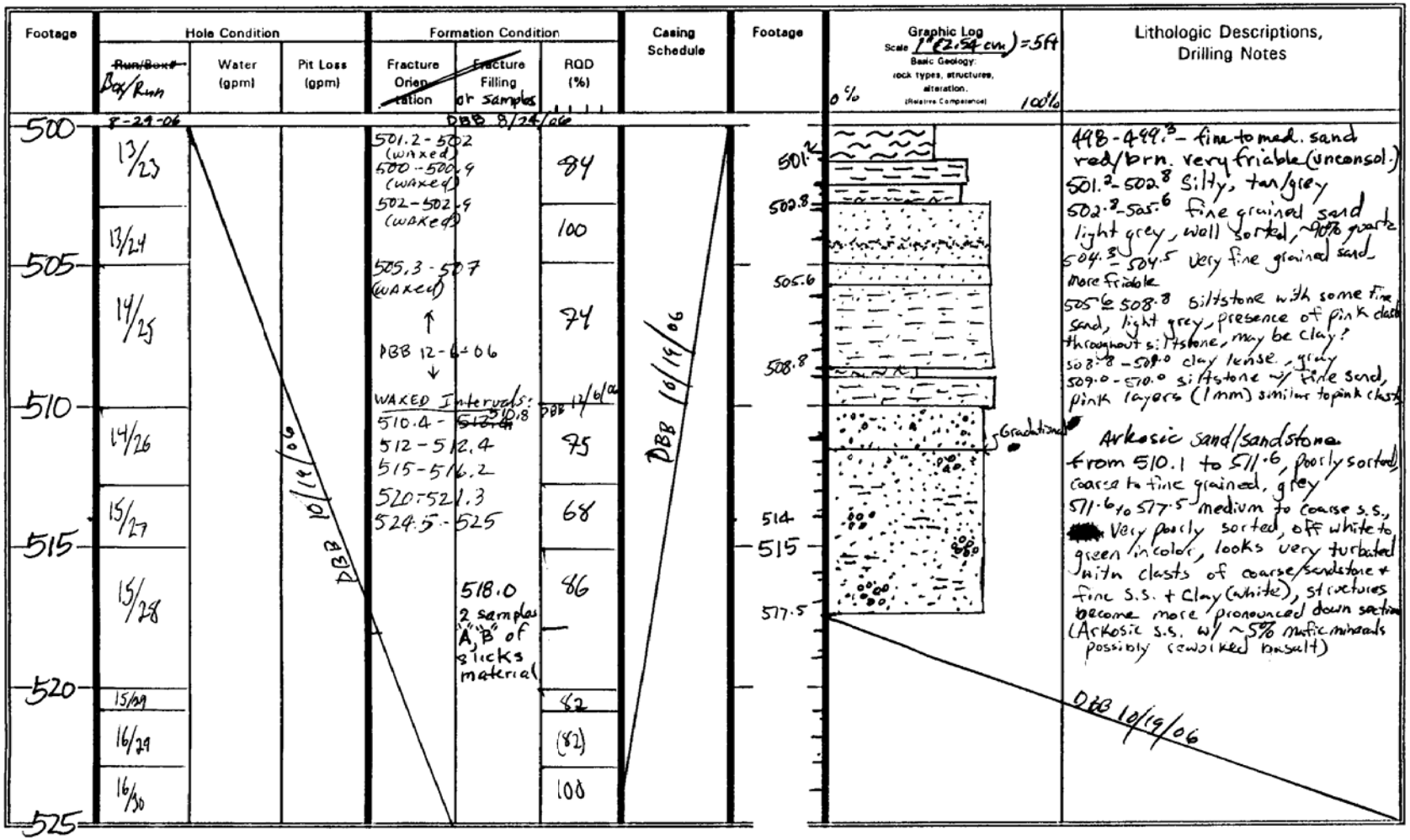
DRILL LOG

HOLE NO. CA998-corehole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY Colleen Rust

DBB 8/ See p.1

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



SUPPLEMENTAL

DRILL LOG

HOLE NO. C4998 - Corehole

PROJECT WTP seismic

CONTRACTOR _____

DATE STARTED _____ COMPLETED _____

LOGGED BY D.B. Barnett

DBB 8/22/06

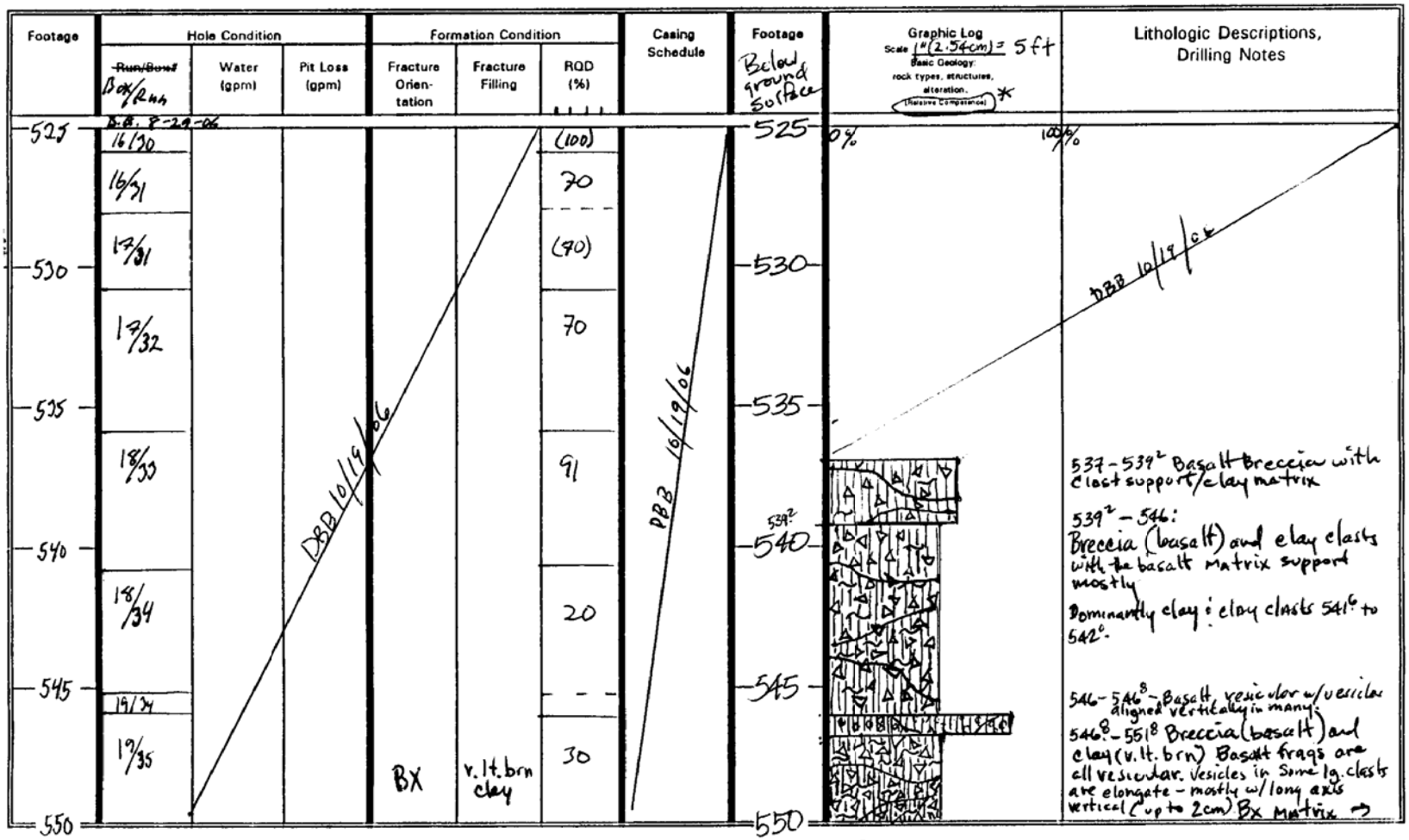
See p. i

TOTAL DEPTH _____ LAND SURFACE ELEV. _____

INCLINATION _____ BEARING _____

COORDINATES T ___ R ___ S _____ OTHER _____

SURVEY REFERENCES _____



* Dense flow interior basalt = 100% competent

SUPPLEMENTAL

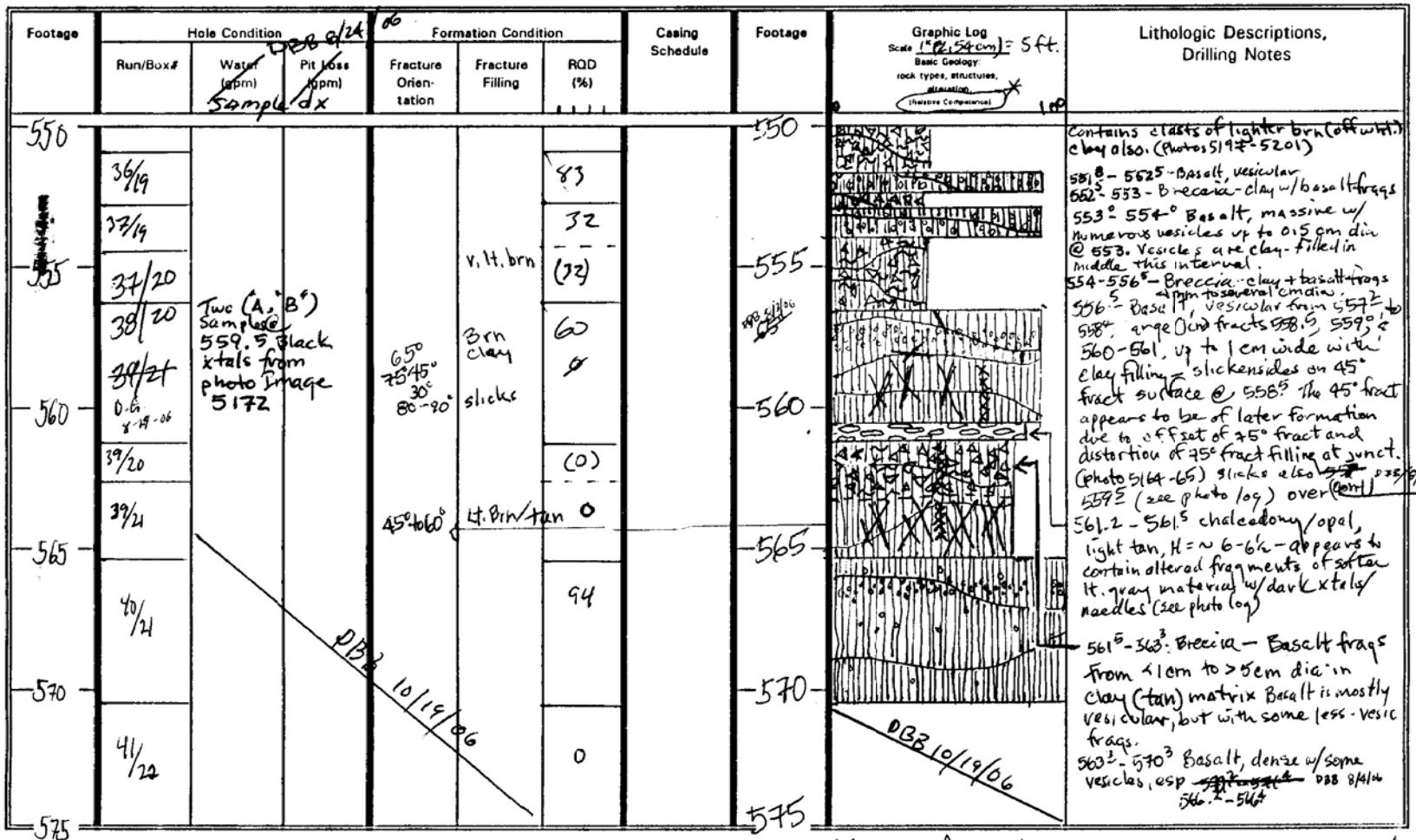
DRILL LOG

HOLE NO. c4998 - corehole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY D.B. Barnett

DBB 8/22/06 ← see p. 1 →

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



Contains clasts of lighter brn (off wht.) clay also. (Photos 5197-5201)

581.8 - 562.5 - Basalt, vesicular

562.5 - 553 - Breccia - clay w/ basalt frags

553 - 554' Basalt, massive w/ numerous vesicles up to 0.5 cm dia @ 553. Vesicles are clay-filled in middle this interval.

554-556.5 - Breccia: clay + basalt frags ~1 ppm to several cm in.

556.5 - Basalt, vesicular from 557.2 to 558.4, large (1cm) fracts 558.5, 559.1 & 560-561, up to 1 cm wide with clay filling + slickensides on 45° fract surface @ 558.5. The 45° fract appears to be of later formation due to offset of 75° fract and distortion of 75° fract filling at junct. (photo 5164-65) slicks also ~~559.2~~ 559.5 (see photo log) over (1cm) DBB 9/3/06

561.2 - 561.5 chalcedony/opal, light tan, H = ~ 6-6½ - appears to contain altered fragments of soft tan lt. gray material w/ dark xtals/ needles (see photo log)

561.5 - 563.3 Breccia - Basalt frags from <1 cm to >5 cm dia in clay (tan) matrix. Basalt is mostly vesicular, but with some less-vesic frags.

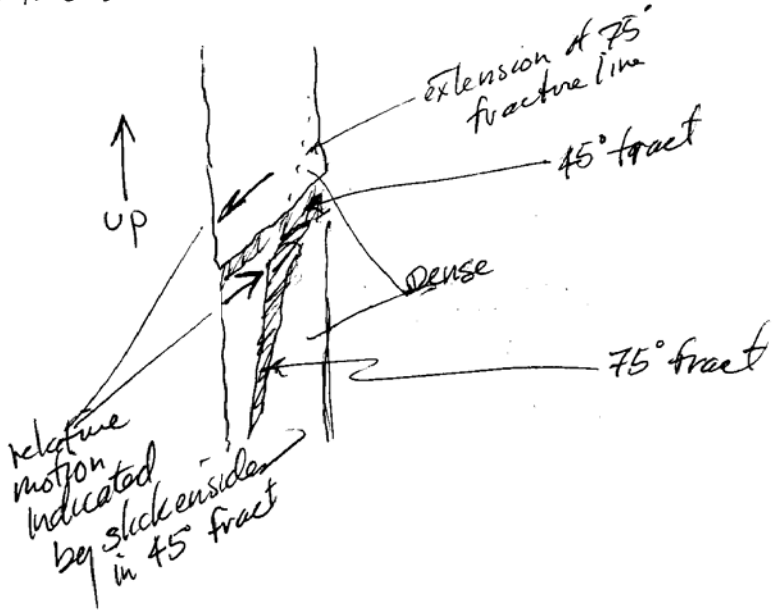
563.3 - 570.3 Basalt, dense w/ some vesicles, esp ~~570.3 - 569.4~~ 566.2 - 564 DBB 8/14/06

Information continued on reverse side

* Dense flow-interior basalt = 100% competent

(continued from reverse side)
of p. 7

558 ± ft bgs ~45° fracture appears to offset 75° fracture coming in from below — slickensides on 45° clay surface indicate NORMAL motion. Also abundant MnO_2 on fract surface next to wall rx.



SUPPLEMENTAL

DRILL LOG

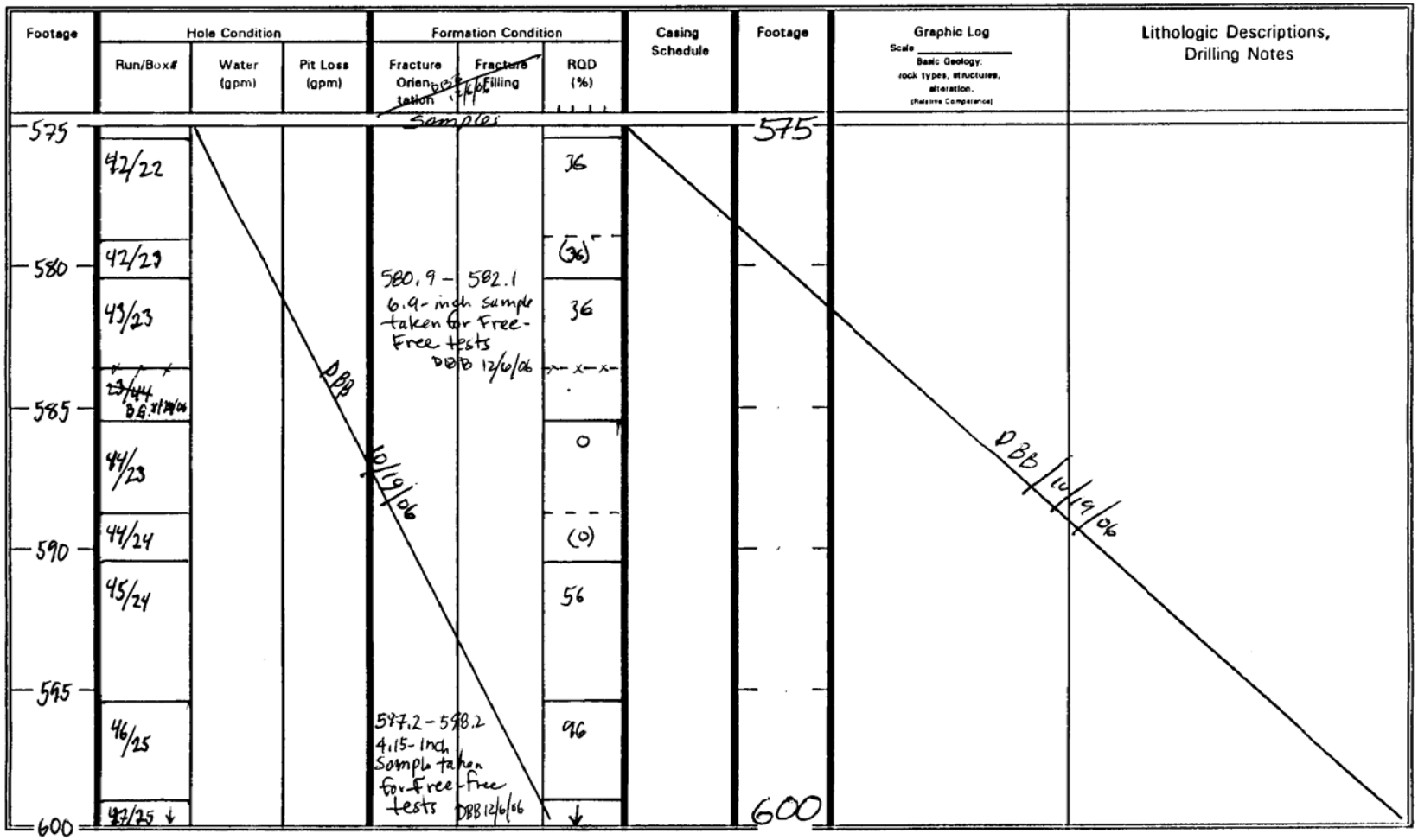
HOLE NO. C4998 - core hole

DBB 8/23/06

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY Ben Garcia

} see p. 1

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



SUPPLEMENTAL

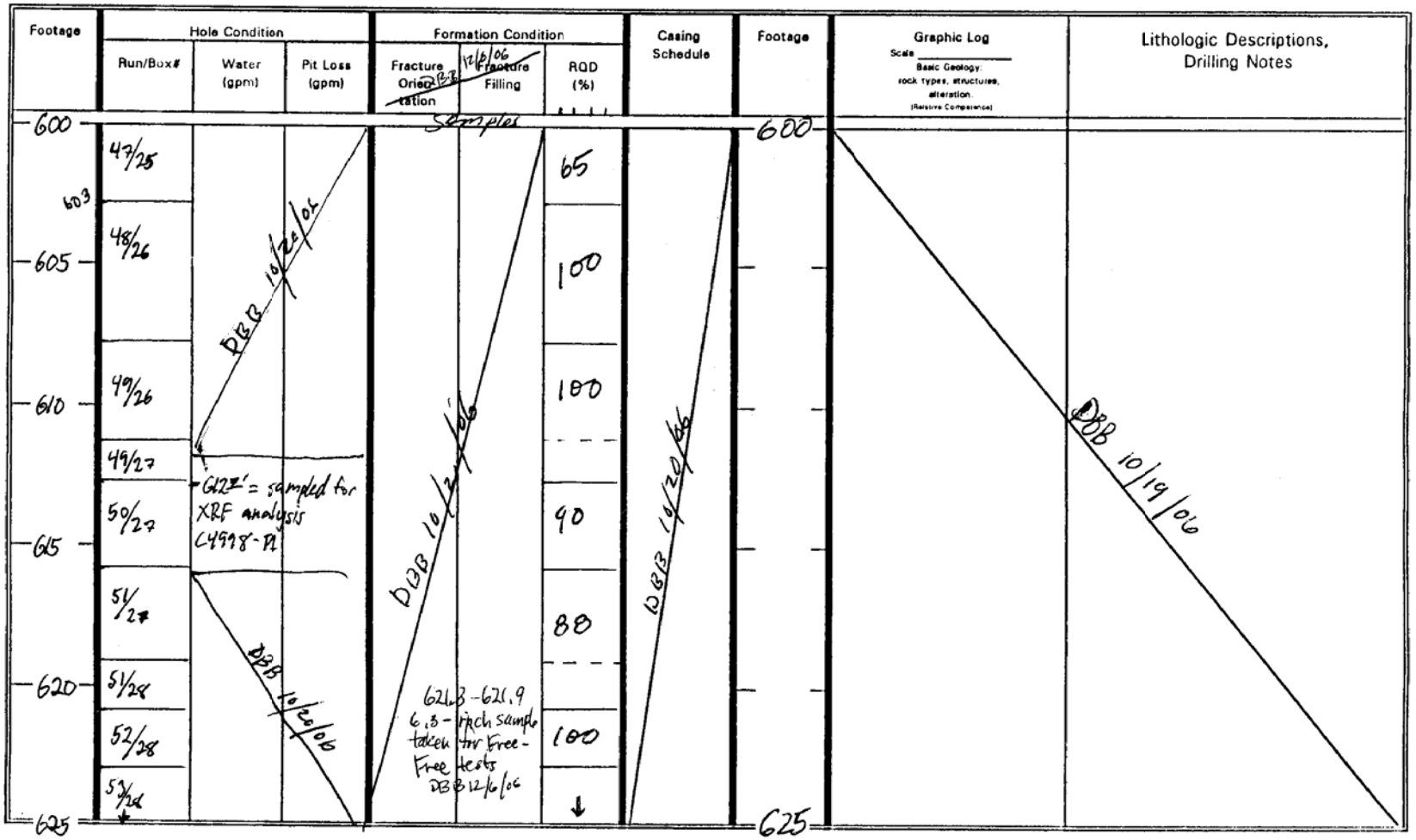
DRILL LOG

HOLE NO. C4998 - corehole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY Ben Garcia

See p. 1
DBB 8/23/06

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



SUPPLEMENTAL

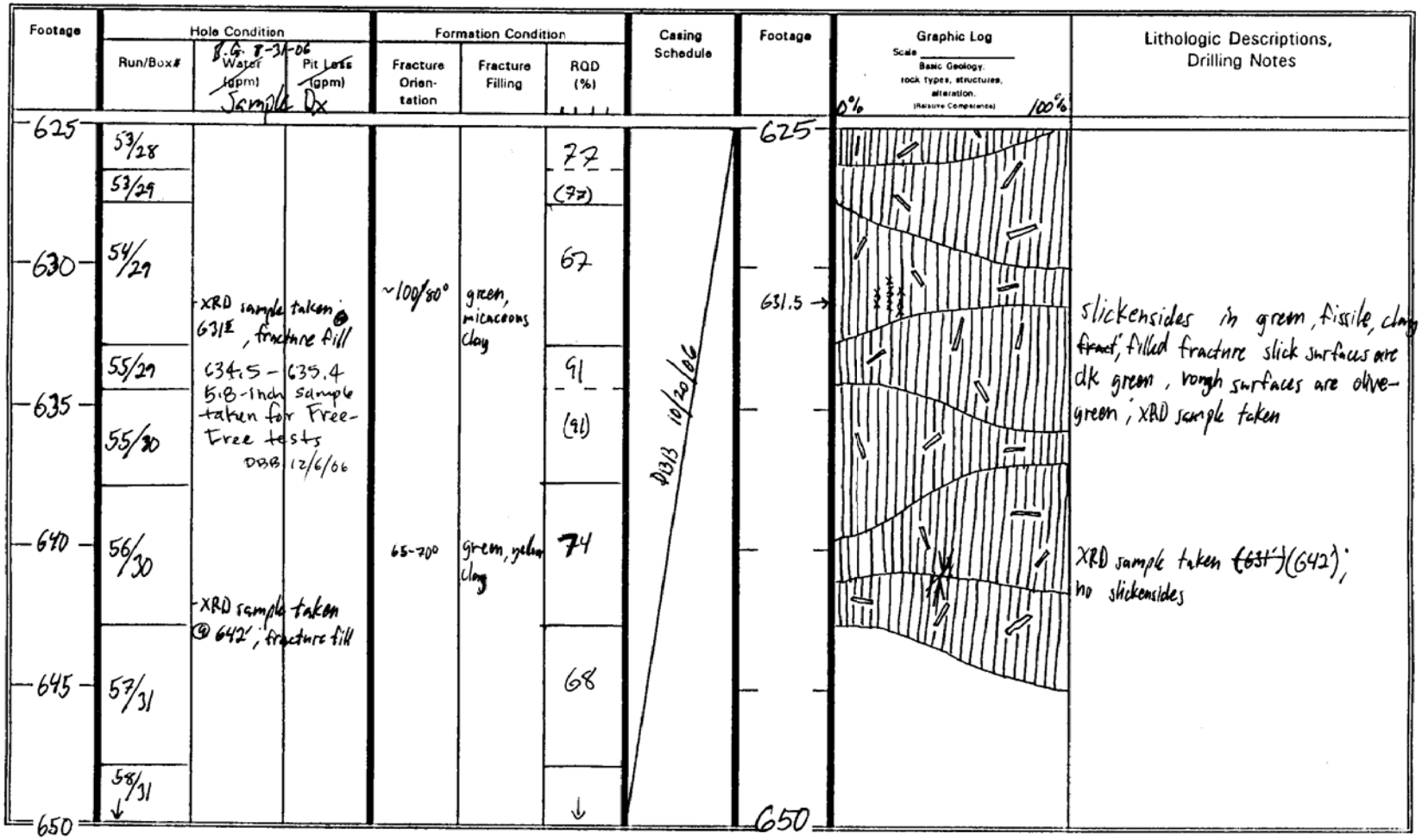
DRILL LOG

HOLE NO. C4998 - core hole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY Ben Garcia

See p.1
DBB
8/23/06

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



SUPPLEMENTAL

DRILL LOG

HOLE NO. C4998 - Corehole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY Ben Garcia

see p.1
8-27-06
BG.

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log (Scale ____; Basic Geology: rock types, structures, alteration, (Relative Competence); 0% – 100%)	Lithologic Descriptions, Drilling Notes
650	58/31					(82)		650		
	58/32					88				
655	59/32	XRD sample taken @ 653'; slickensides				84		655	653.5' slickenside	
660	60/33					47		660		
665	61/33					100		665		
	61/34					(100)				
670	62/34	673 = XRD samples; black fracture fill, green fracture fill		~70°	paired bands of black and green clay	60		670		673' - black and green clay bands w/ minor, fine-scale slickensides; bl. and green clay form distinct bands; XRD sample taken
	63/34	673' = sample for XRF analysis C4998'-P2				82				
675	63/35							675		

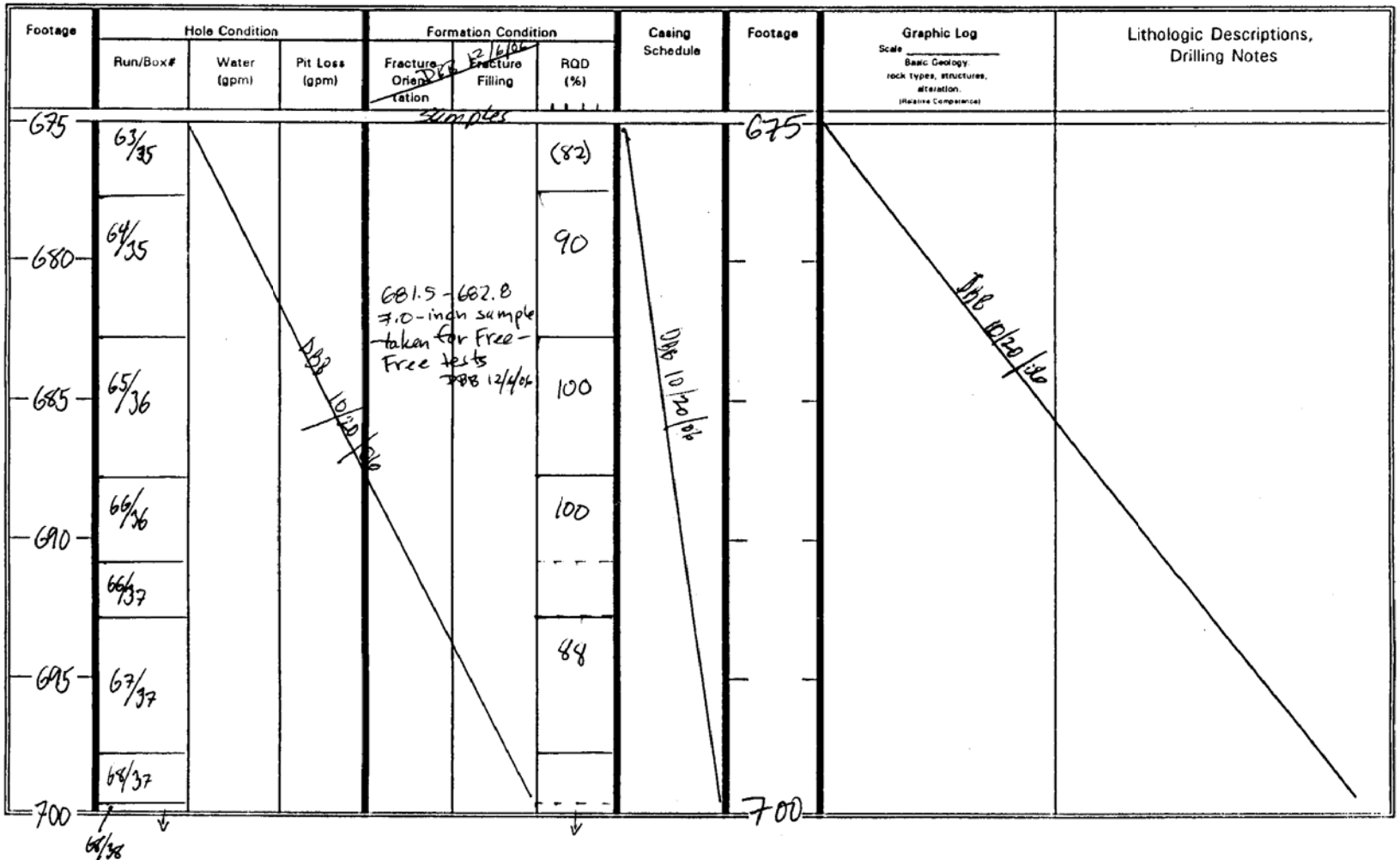
SUPPLEMENTAL
DRILL LOG

HOLE NO. C4998 - core hole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY Ben Garcia

See p.1
DBB
8/28/06

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



SUPPLEMENTAL

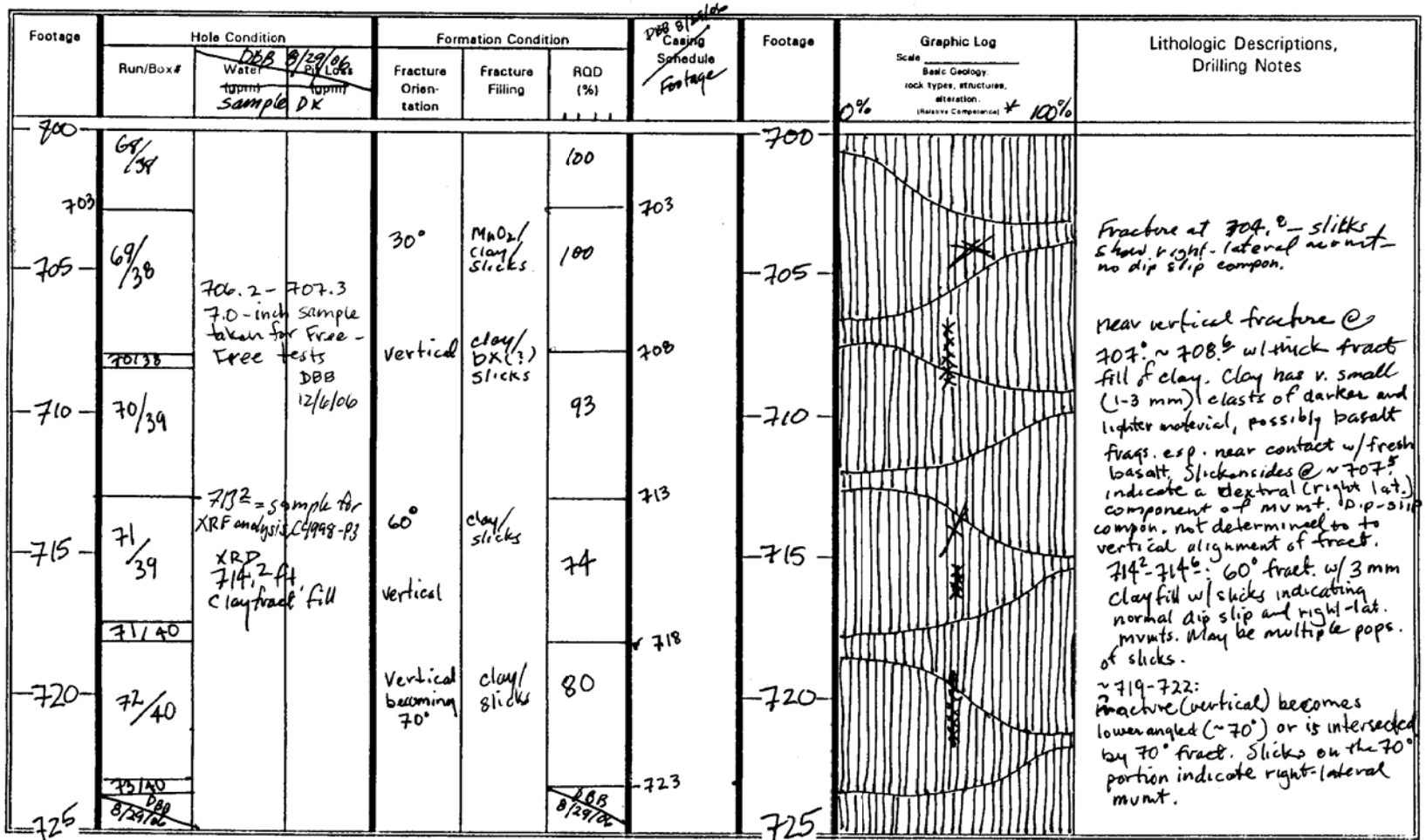
DRILL LOG

HOLE NO. C4998 - corehole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY Ben Garcia

See P.1 DBB 8/22/06

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



* solid, massive basalt = 100% relative competence

SUPPLEMENTAL

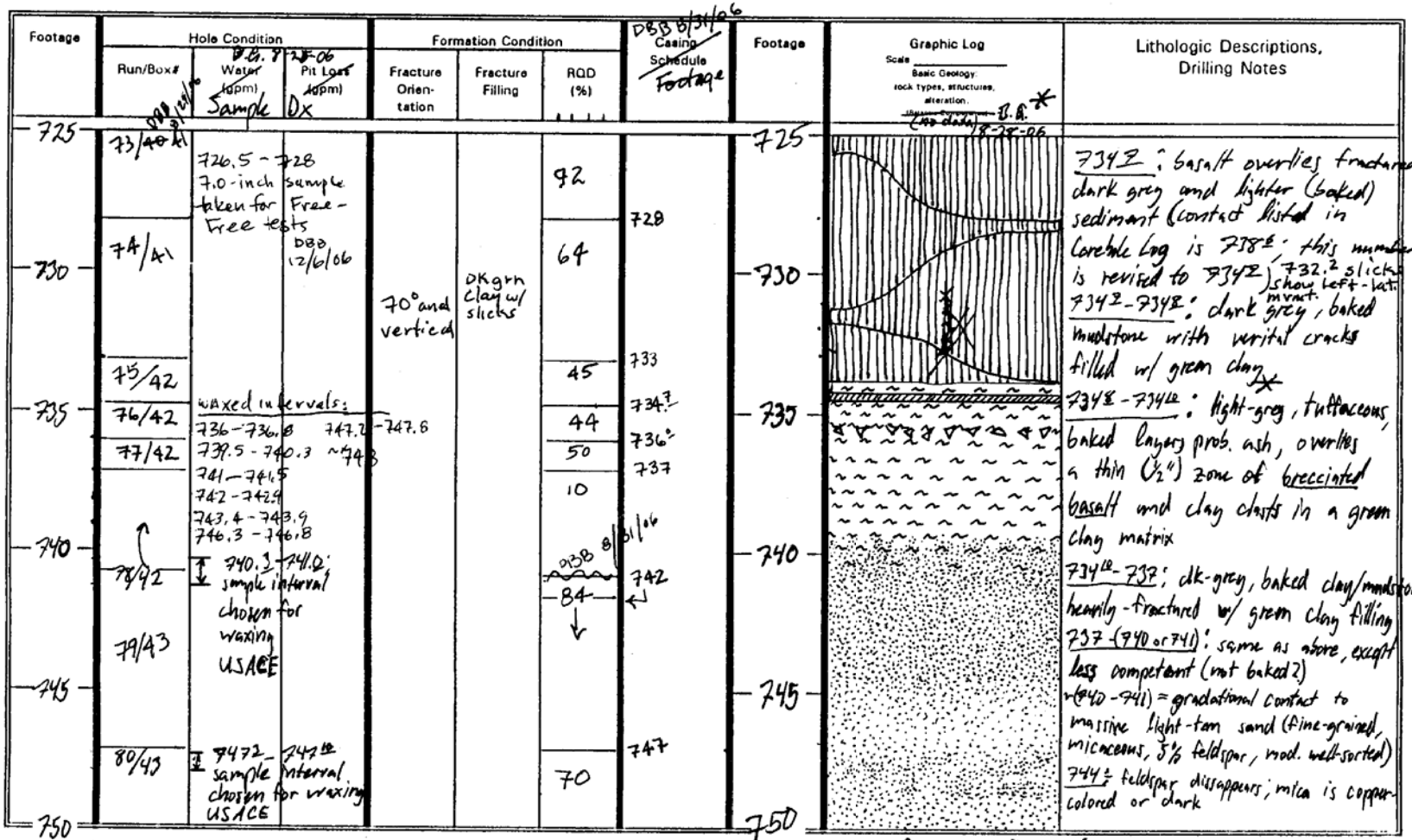
DRILL LOG

HOLE NO. C4998- core hole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY Ben García

See p.1
DBB 8/23/06

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



* 734.8 to 752° relative competence ≈ 30%

SUPPLEMENTAL

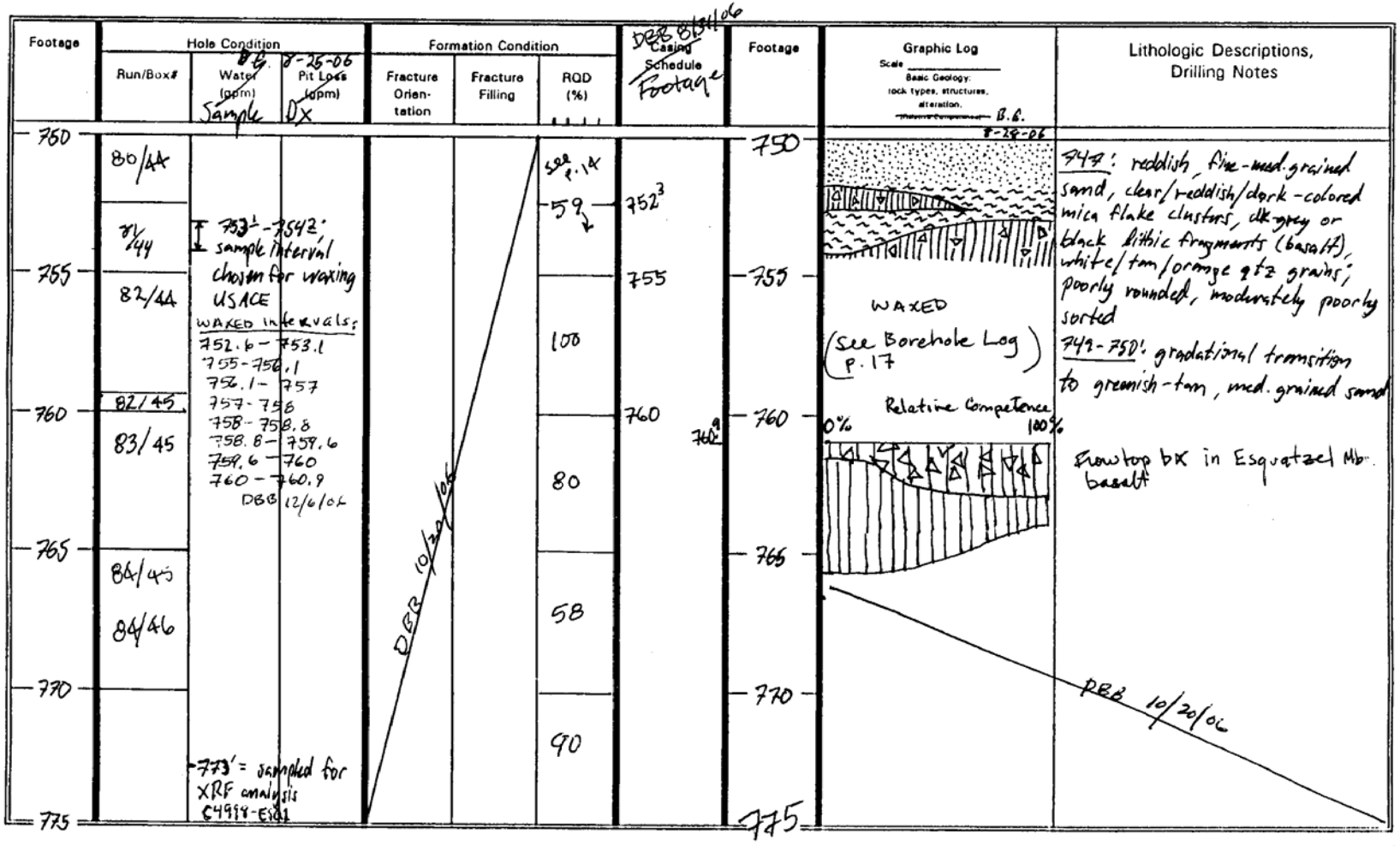
DRILL LOG

HOLE NO. C4998 - core hole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY Ben Garcia

see pg 1.
B.G.
8-25-06

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



SUPPLEMENTAL

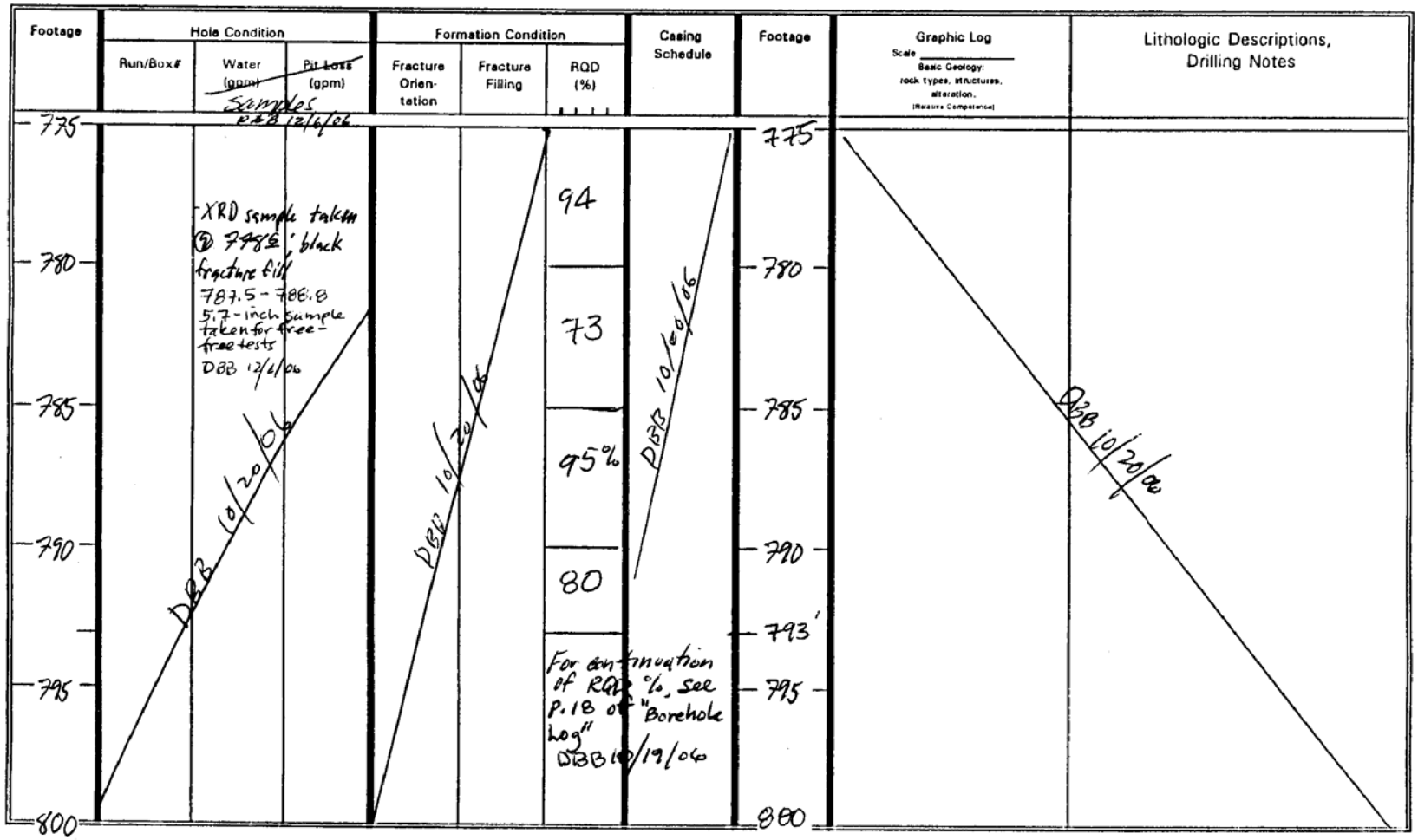
DRILL LOG

HOLE NO. C4998 - core hole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY Ben Garcia

} see p. 1

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



SUPPLEMENTAL

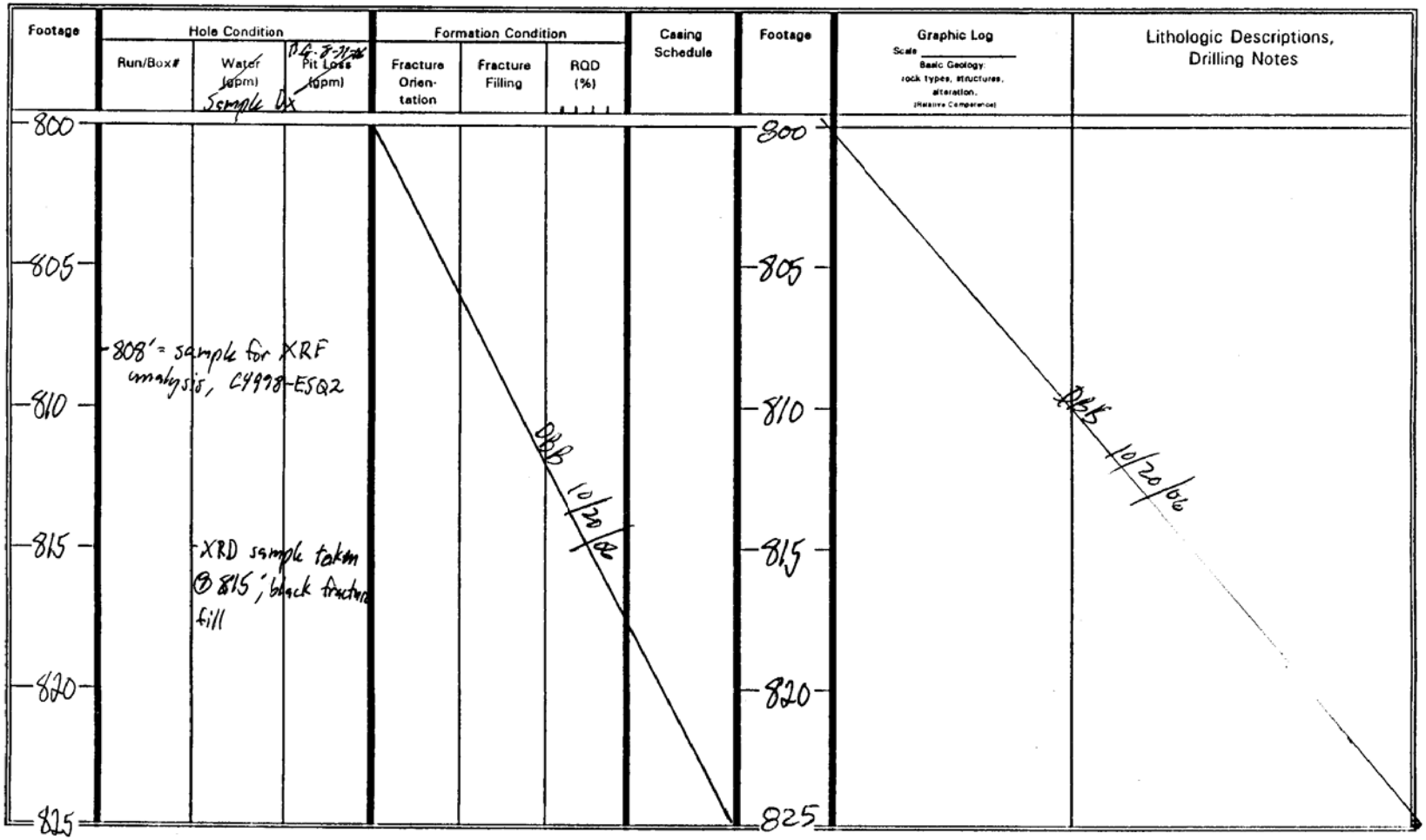
DRILL LOG

HOLE NO. C4998 - Core hole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY Ben Garcia

seep 1

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



SUPPLEMENTAL

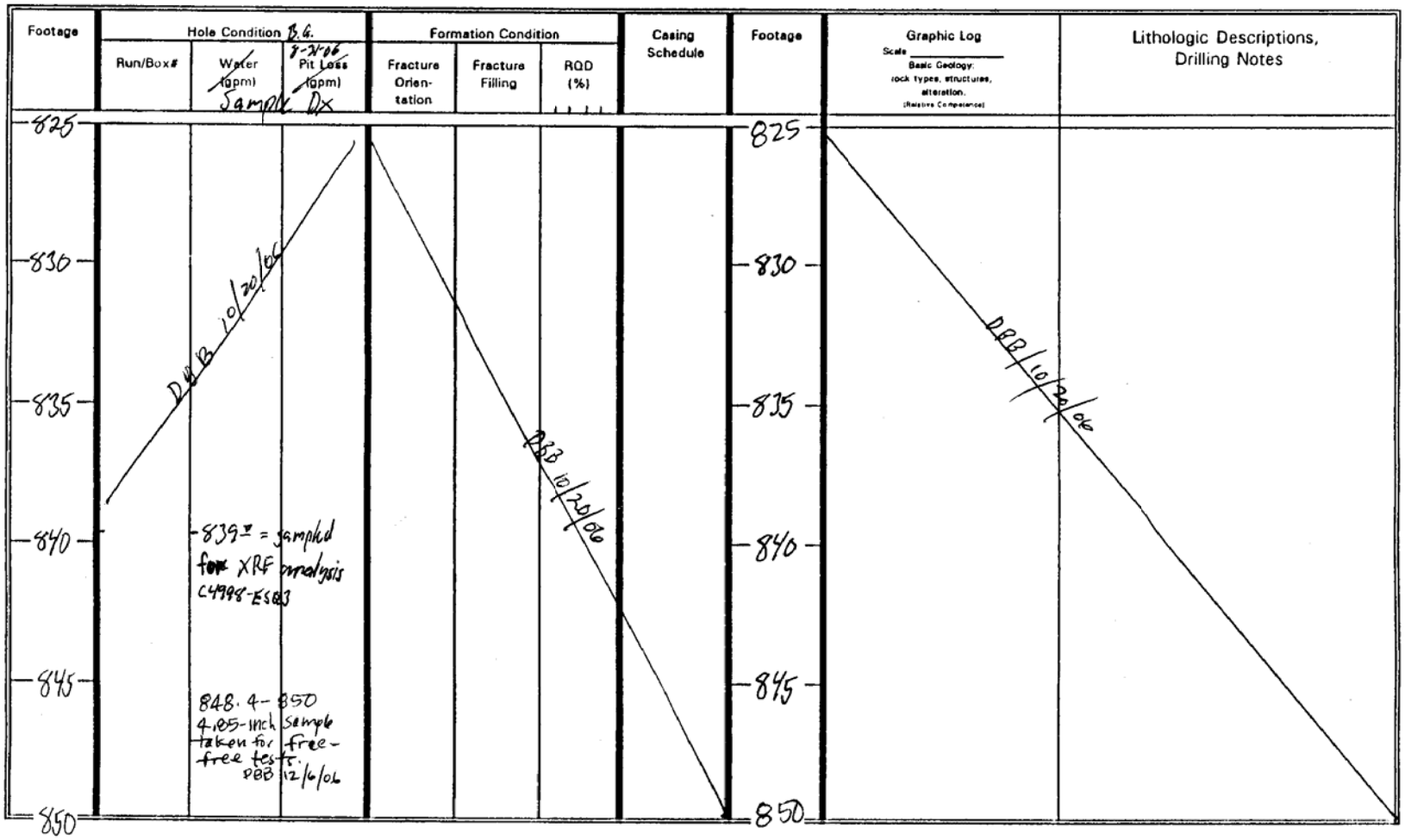
DRILL LOG

HOLE NO. C4998 - core hole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY Don Garcia

See p. 1
PBB
10/20/06

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



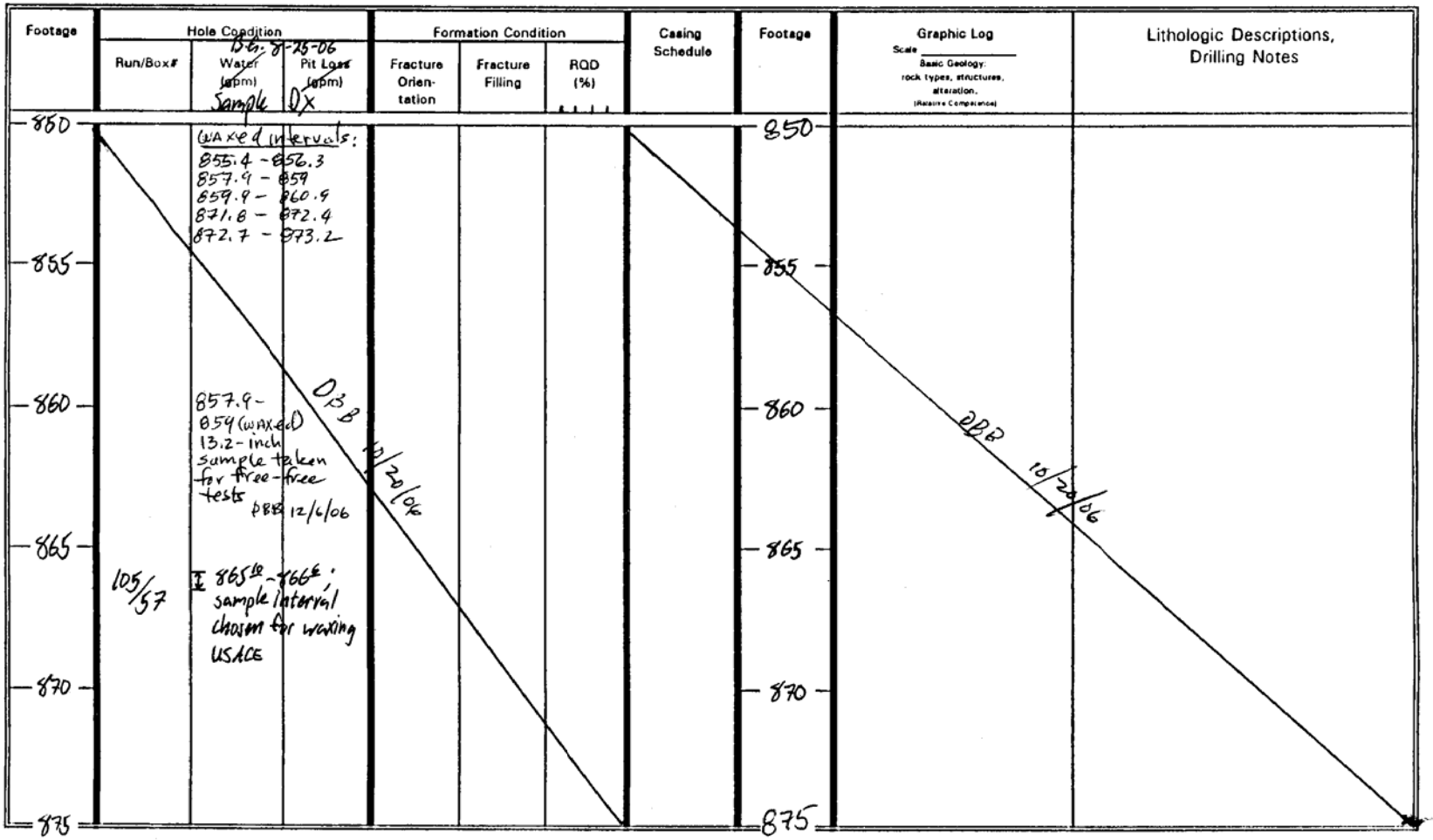
SUPPLEMENTAL

DRILL LOG

HOLE NO. C4998 - core hole

PROJECT _____
CONTRACTOR _____ } see pg. 1
DATE STARTED _____ COMPLETED _____ } D.G. 8-25-06
LOGGED BY _____

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____

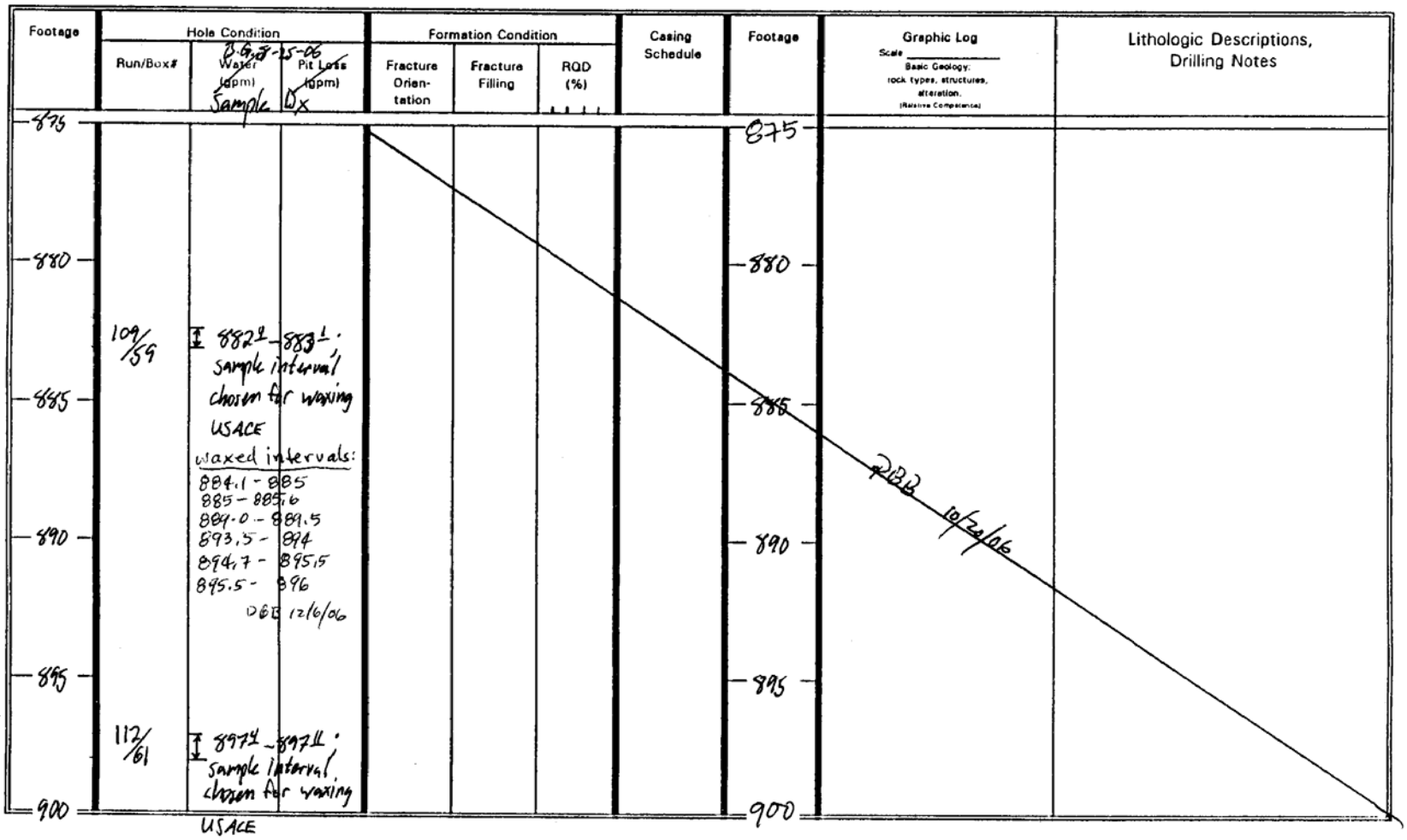


SUPPLEMENTAL
DRILL LOG

HOLE NO. C4998- core hole

PROJECT _____ } see pg. 1
CONTRACTOR _____ } B.G.
DATE STARTED _____ COMPLETED _____ } 8-25-06
LOGGED BY _____

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



SUPPLEMENTAL

DRILL LOG

HOLE NO. C4998 - Borehole

PROJECT _____
CONTRACTOR _____ } see pg. 1
DATE STARTED _____ COMPLETED _____ } B.G. 8-25-06
LOGGED BY _____

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____

Footage	Hole Condition: Run/Box#	Hole Condition: Water (ppm)	Hole Condition: Pit Loss (ppm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log	Lithologic Descriptions, Drilling Notes
900		B.G. 8-25-06 Sample	Dx					900		
905		waxed intervals 901.3 - 901.8 902.6 - 903.3 903.8 - 904.3 908.7 - 909.4 914.4 - 914.9 914.9 - 915.4 917.4 - 918 921.6 - 922.1 922.1 - 922.8 DBB 12/6/06						905		
910	115/62	I 910' - 911' sample interval chosen for waxing USACE						910		
915								915		
920								920		
925								925		

DBB 10/20/06

SUPPLEMENTAL

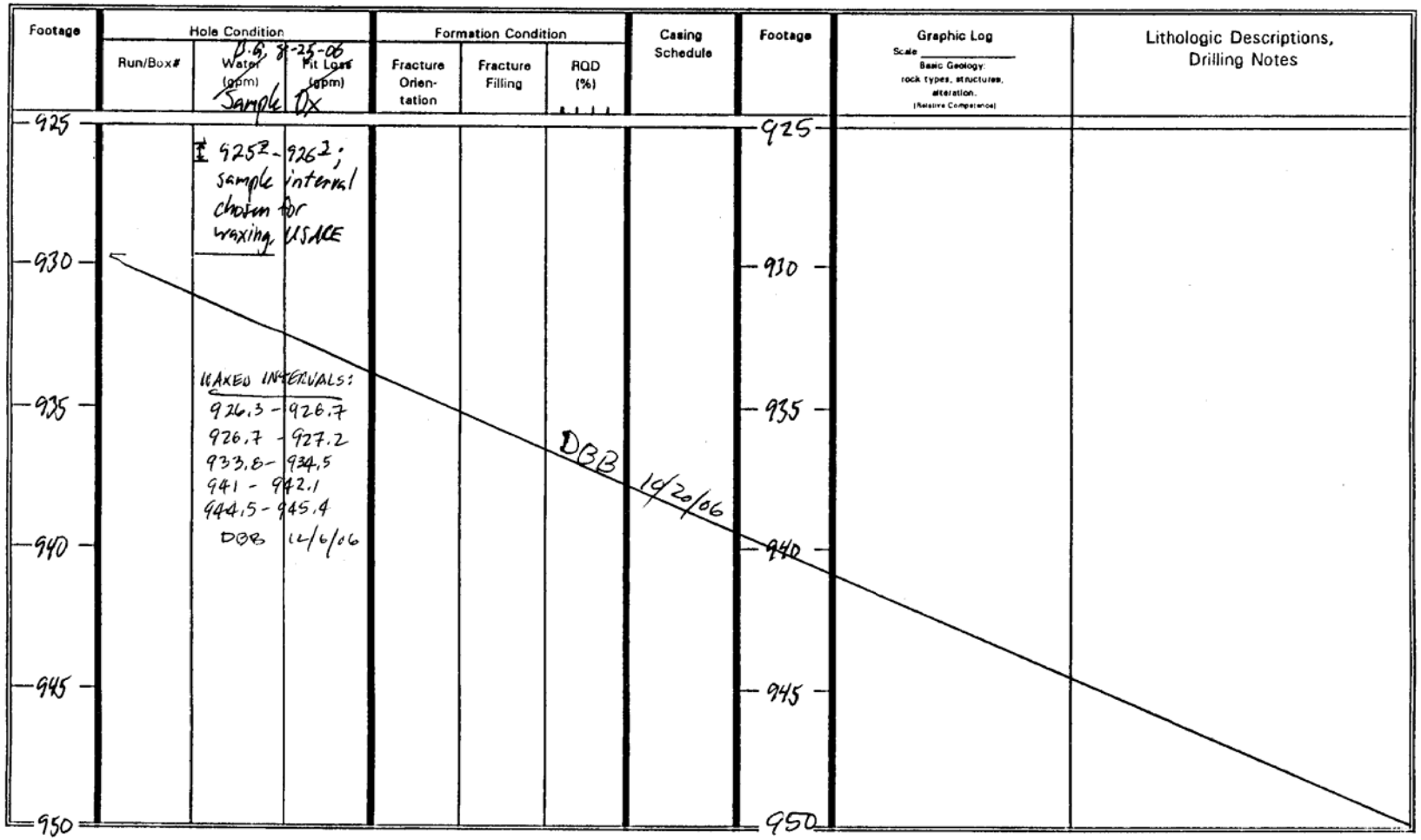
DRILL LOG

HOLE NO. C4998 - core hole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY _____

} see pg. 1 B.G. 8-25-06

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



SUPPLEMENTAL

DRILL LOG

HOLE NO. C4998- corehole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY _____

See p. 1
DBB 8/28/06

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm) DBB 9/6/06 Samples	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log (Scale _____ Basic Geology: rock types, structures, alteration. (Relative Competence))	Lithologic Descriptions, Drilling Notes
950								950		
955		two XRD samples taken @ 954'; frac. fill 957' = sampled for XRF, C4998-957								
960		965.6 – 966.5 5.3-inch sample taken for free-free testing DBB 12/6/06								
965		XRD sample taken @ 964'; fracture fill								
970		968' = sampled for XRF, C4998-968								
975								975		

DBB 10/20/06

SUPPLEMENTAL

DRILL LOG

HOLE NO. C4998-Core hole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY Ben Garcia

See p. 1
DBB
8/28/06

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log (Scale ____; Basic Geology: rock types, structures, alteration. (Relative Competence))	Lithologic Descriptions, Drilling Notes
975								975		
980		978' = sampled for XRF, C4998-978						980		
985								985		
990		989' = sampled for XRF, C4998-989 XRD sample @ 992', black, shiny fracture fill						990		
995		995-995.18 5.9-inch sample taken for Free-Free tests - DBB 12/06/06 998' = sampled for XRF analysis C4998-998						995		
1000								1000		

DBB 10/20/06

SUPPLEMENTAL

DRILL LOG

HOLE NO. C4998 - core hole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY Ben Garcia

See p. 1
988
8/28/06

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log (Scale ____ Basic Geology: rock types, structures, alteration. (Relative Competence))	Lithologic Descriptions, Drilling Notes
1000								1000		
1005								1005		
1010								1010		
1015								1015		
1020								1020		
1025								1025		

DBB 10/20/06

1013' = sampled for XRF analysis C4998-1013

1018' = sampled for XRF analysis C4998-1018

XRD sample @ 1020' - green clay at margin of vesicular zone, clear encrusting xtals

SUPPLEMENTAL

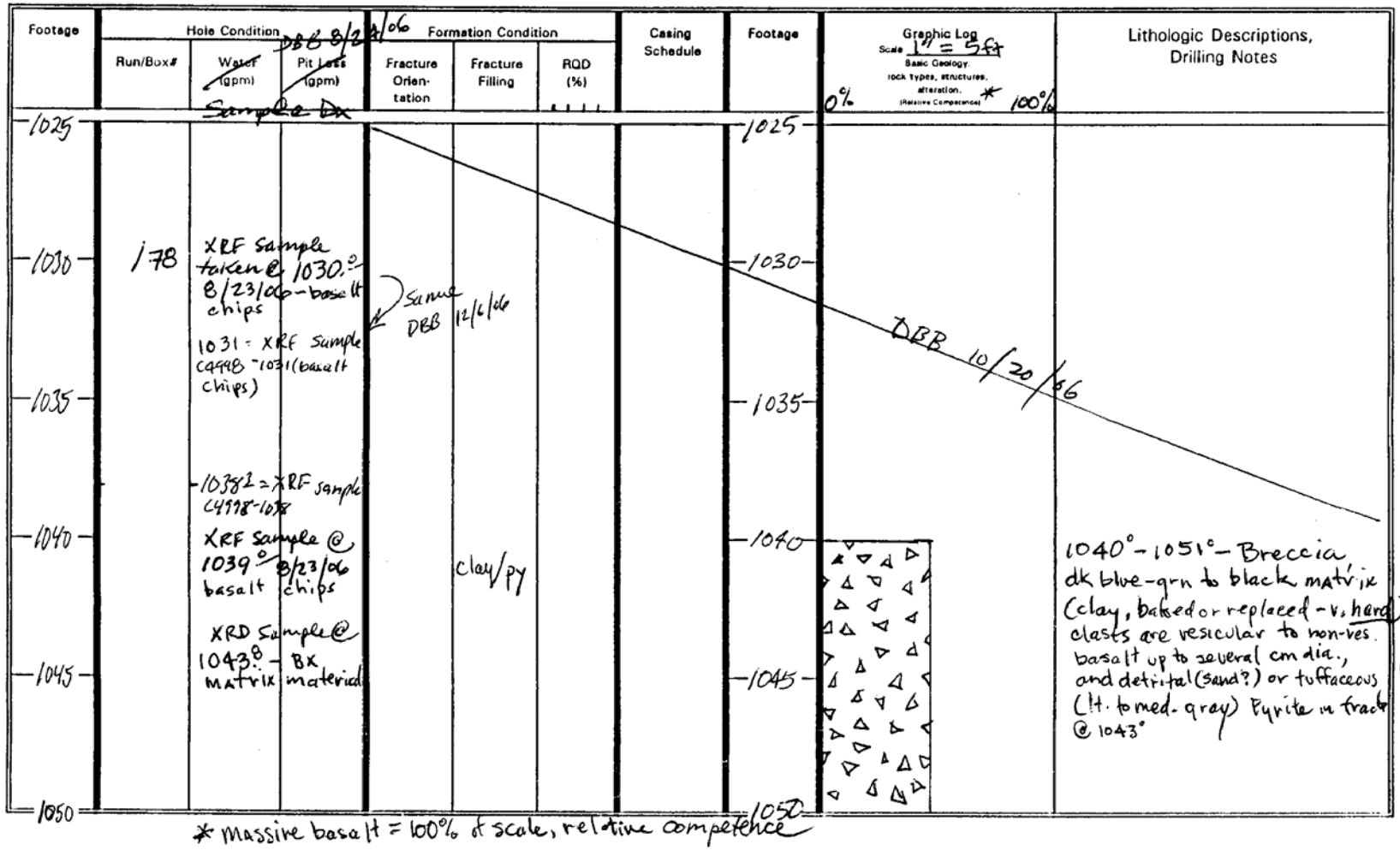
DRILL LOG

HOLE NO. C4998 - corehole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY D.B. Bennett

see p. 1
DBB 8/28/06

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



* Massive basalt = 100% of scale, relative competence

SUPPLEMENTAL

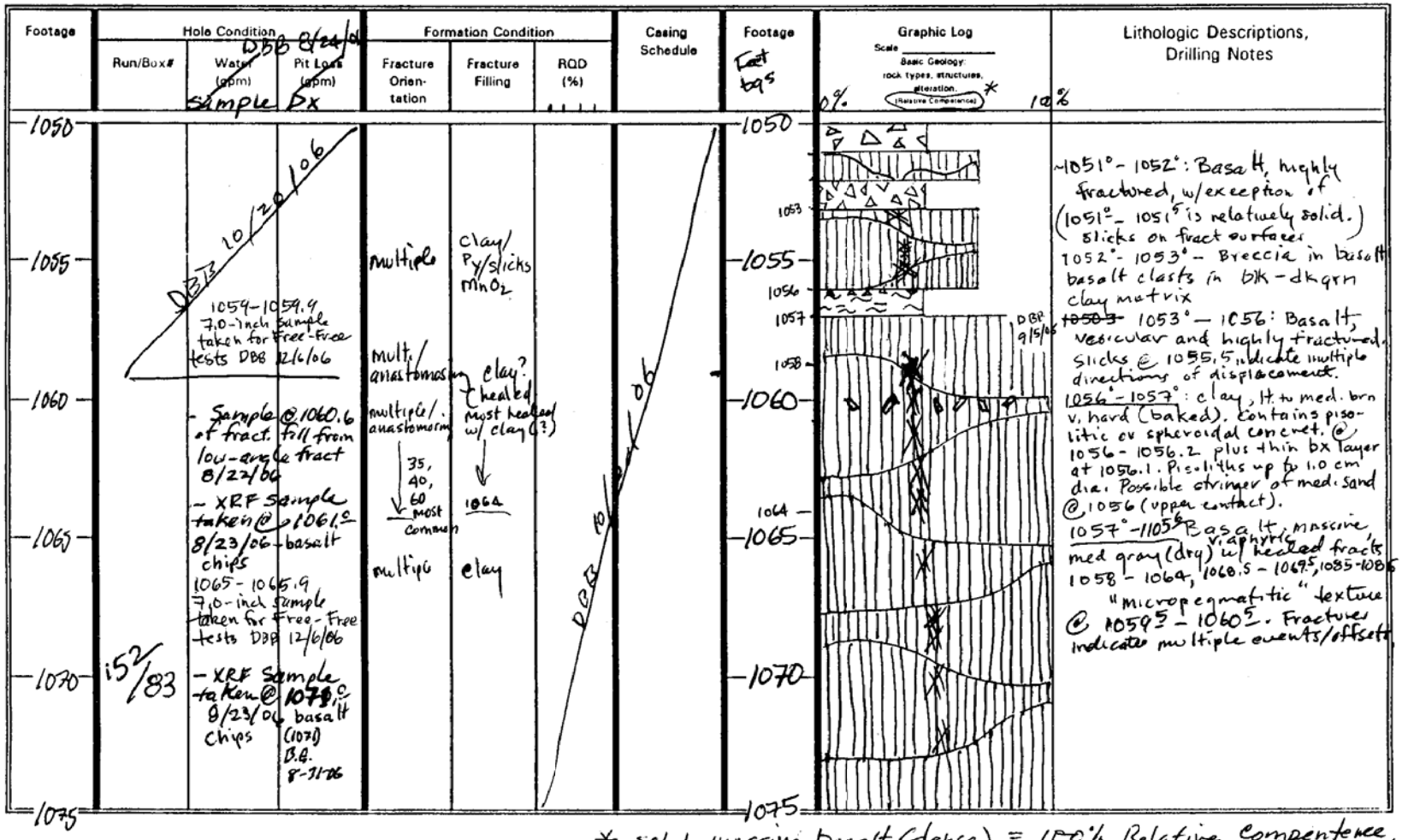
DRILL LOG

HOLE NO. C4998 - core hole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY DB Barnett

← see p. 1 → DBB 9/28/06

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



* solid, massive basalt (dense) = 100% Relative Competence.

SUPPLEMENTAL

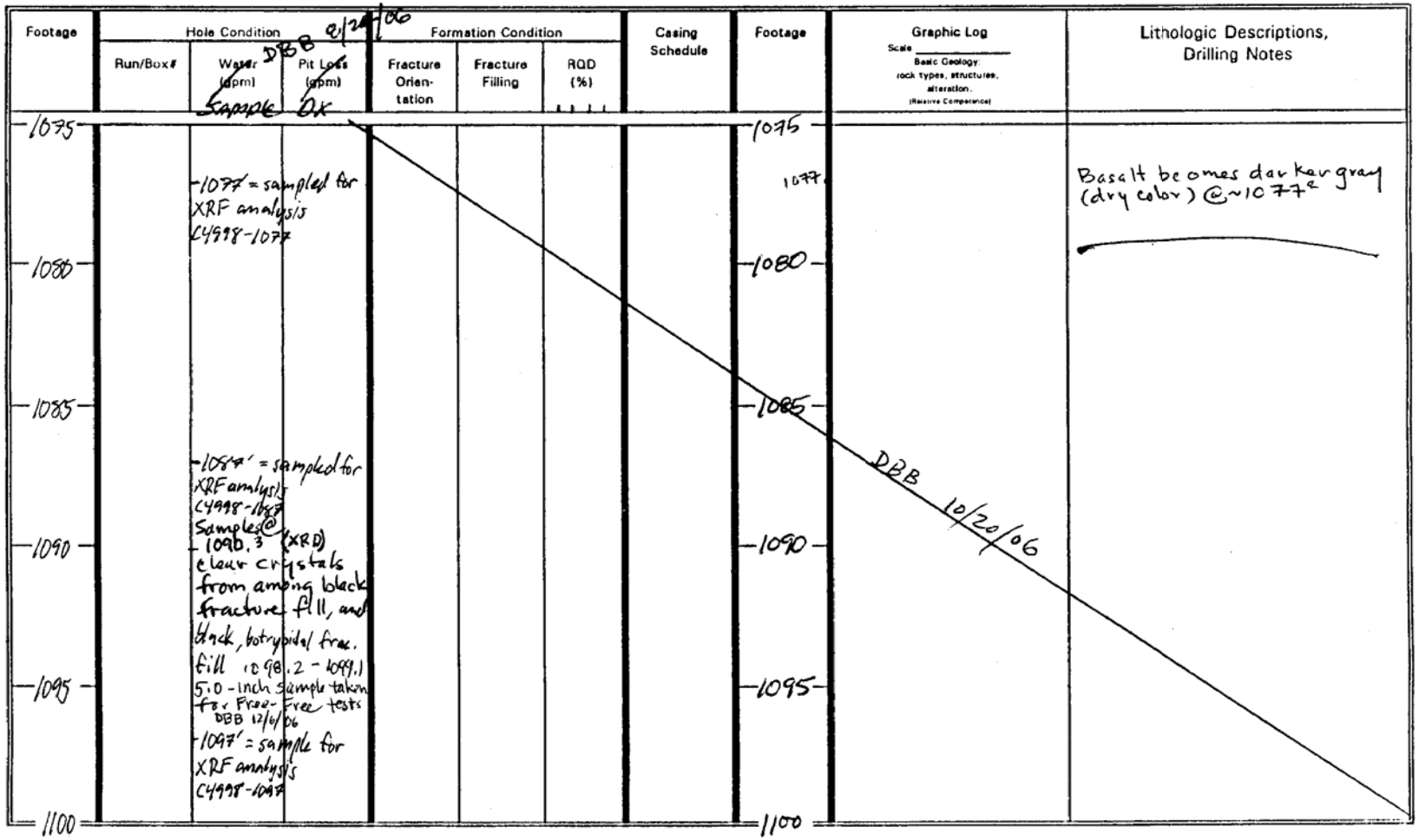
DRILL LOG

HOLE NO. C4998- corehole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY D.B. Barnett / Ben Garcia

See P. 1 DBB 6/28/04

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



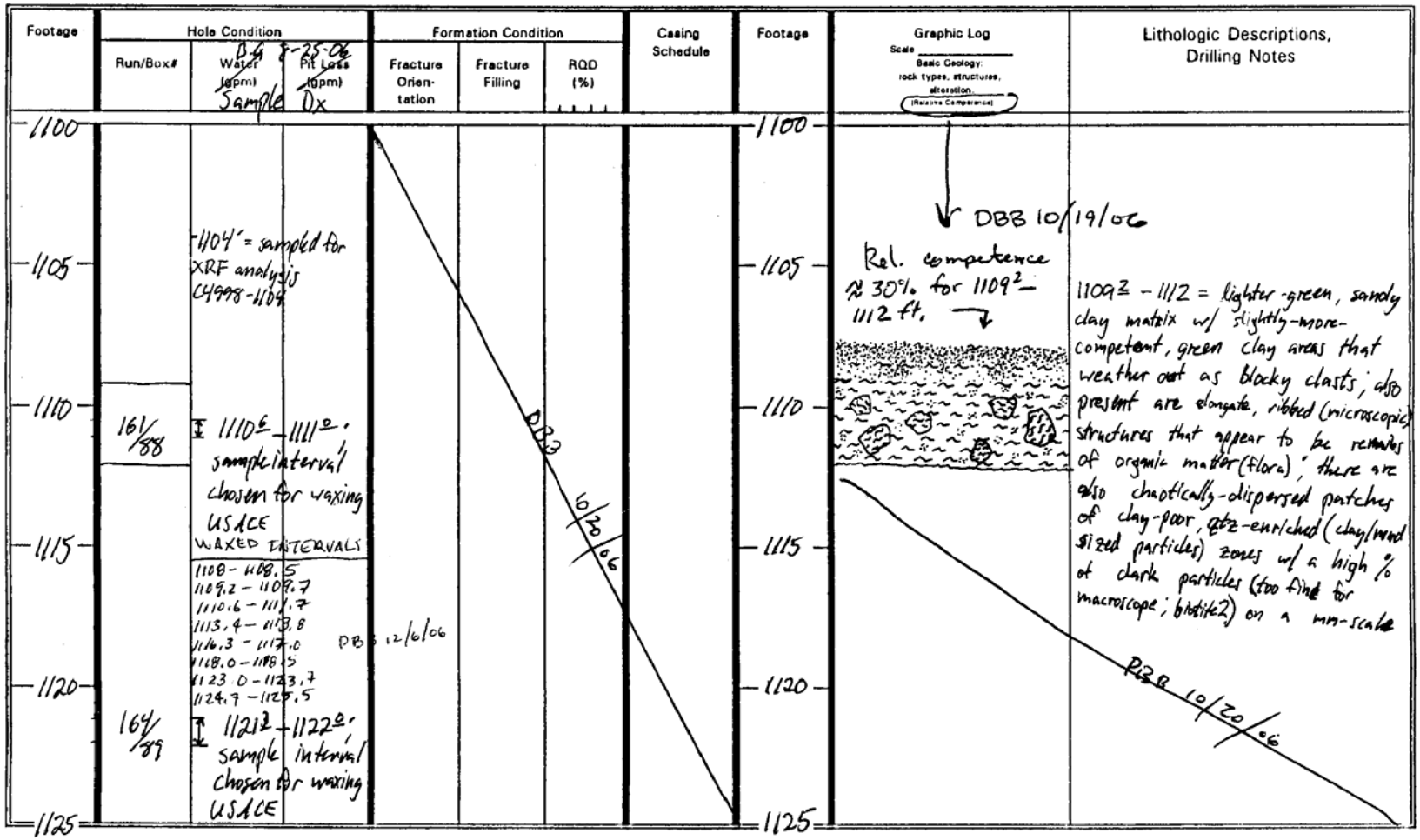
SUPPLEMENTAL

DRILL LOG

HOLE NO. C4998 - corehole

PROJECT _____ } see pg 1
CONTRACTOR _____ } D.G. 8-25-06
DATE STARTED _____ COMPLETED _____
LOGGED BY Ben Garcia

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



SUPPLEMENTAL

DRILL LOG

HOLE NO. C4998 - Corehole

PROJECT _____ } see pg. 1
CONTRACTOR _____ } B.G.
DATE STARTED _____ COMPLETED _____ } 8-25-06
LOGGED BY Ben Garcia

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm) B.G. Sample	Hole Condition: Pit Loss (gpm) 8-25-06 DX	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log (Scale ____ Basic Geology: rock types, structures, alteration (Relative Competence))	Lithologic Descriptions, Drilling Notes
1125								1125		
	165/90	1124.2 – 1127.9' sample interval chosen for waxing, USACE								
1130		WAXED INTERVALS:						1130		
		1130.6 – 1131.5								
		1131.8 – 1132.4								
		1133 – 1133.8								
1135		1134.5 – 1135						1135		
		1136.1 – 1136.8								
		1137.6 – 1138.4								
		1140 – 1140.6								
1140		1141.8 – 1142.5						1140		
		1145 – 1145.5								
		1147 – 1147.8								
		1148.2 – 1148.8								
		1149.1 – 1149.5								
		DBB 12/6/06								
1145								1145		
1150								1150		

DBB 12/20/06

SUPPLEMENTAL

DRILL LOG

HOLE NO. C4998 - corehole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY ~~D.B.Barnett~~ DBB 10/19/06

- see p. 1 -

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log (Scale ____ Basic Geology: rock types, structures, alteration. (Relative Competence))	Lithologic Descriptions, Drilling Notes
1150		~~samples~~ DBB 12/6/06						1150		
1155		WAXED INTERVALS:						1155		
		1154 - 1154.7								
		1157.2 - 1158								
		1158.4 - 1159.2								
1160		1159.7 - 1160.3						1160		
		1160.5 - 1161.0								
		1161.8 - 1162.2								
		1162.2 - 1162.7								
		1163.3 - 1164.0								
1165		1164.0 - 1164.6						1165		
		1169.8 - 1170.5								
		1172.0 - 1172.4								
		DBB 12/6/06								
1170								1170		
1175								1175		

DBB 10/20/06

SUPPLEMENTAL

DRILL LOG

HOLE NO. C4998 - Core Hole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY ~~D.B. Barnett~~ DBB 10/19/06

} - See p. 1 -

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: ~~Bit Loss~~ (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log (Scale _____; Basic Geology: rock types, structures, alteration, (Relative Competence))	Lithologic Descriptions, Drilling Notes
		DBB 12/6/06 Samples!						1175		
		WAXED INTERVALS						1180		
		1176.0 – 1176.4								
		1184.6 – 1185.0						1185		
		1190.6 – 1191.3								
		1192.0 – 1192.6								
		1194.9 – 1195.3						1190		
		1195.5 – 1196.0								
		1196.0 – 1196.9								
		1196.9 – 1198.0						1195		
		1198.7 – 1199.1								
		PBB 12/6/06								
		1198.7 – 1199.1 (WAXED) 6.0-inch Sample taken for free-free tests DBB 12/6/06						1200		

DBB 10/20/06

SUPPLEMENTAL

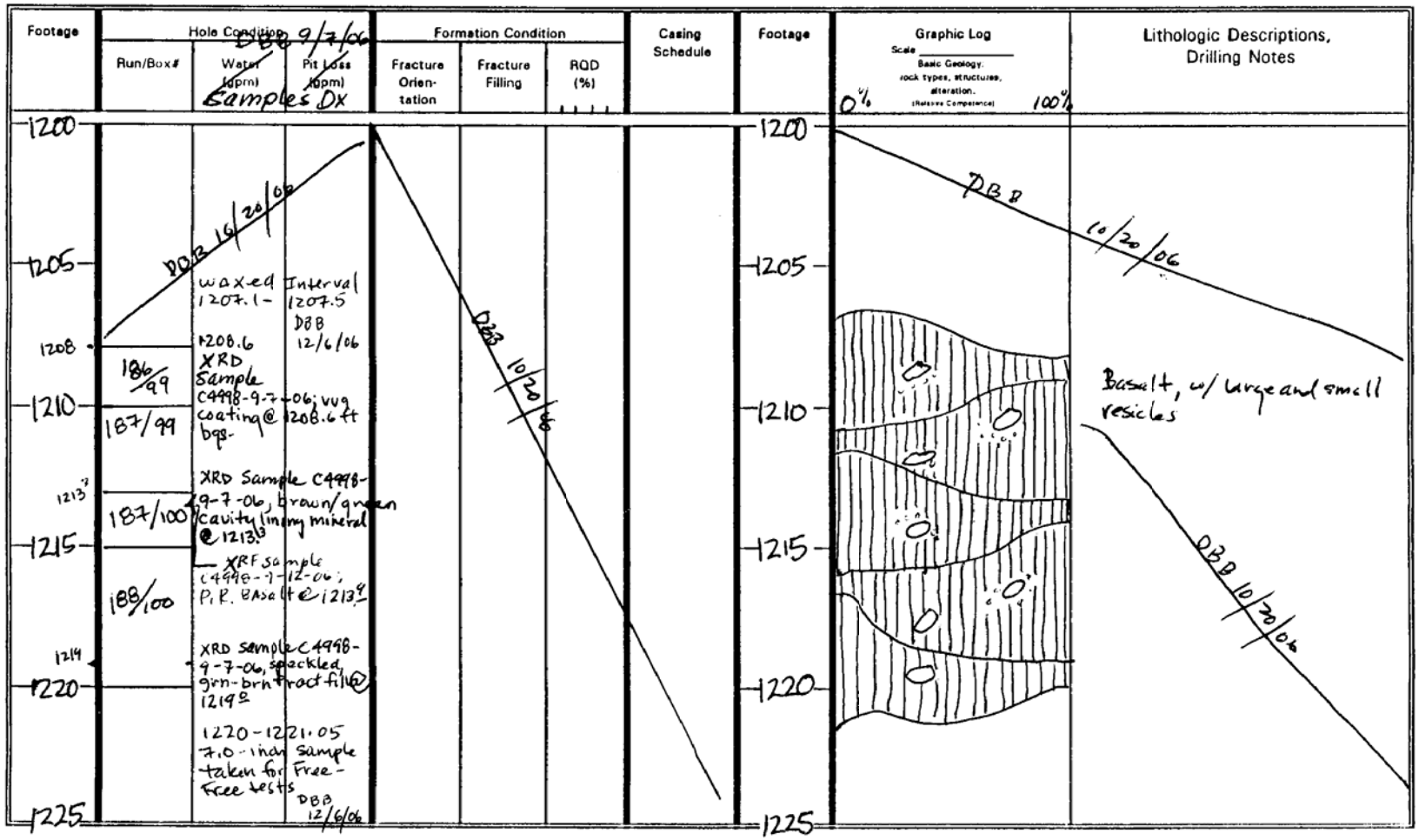
DRILL LOG

HOLE NO. C4998 - corehole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY D. B. Barnett

see p. 1

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



SUPPLEMENTAL

DRILL LOG

HOLE NO. C4998 – corehole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY D. B. Barnett, Ben Garcia

} see p. 1 {

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm) / Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log (Scale _____ Basic Geology: rock types, structures, alteration. Relative Competence)	Lithologic Descriptions, Drilling Notes
1225	190 / 101-102	DBB 9/8/06 Sample Dx					1225		
1230	191 / 102	XRD sample @ 1231.5 - green xtal from edge cavity/late chamber XRD sample C4998-9-8-06 - vesicle filling clay @ 1231.6 ft. bgs XRD sample C4998-9-8-06 green fract fill @ 1233.8 ft bgs					1230		
1235	192 / 102	1235 - 1236.7 6.95 - inch sample taken for Free-Free tests DBB 12/6/06					1235		
1240	193 / 103	XRD sample taken at 1241.5 white fracture fill					1240		
1245							1245		
1250							1250		

DBB 10/20/06

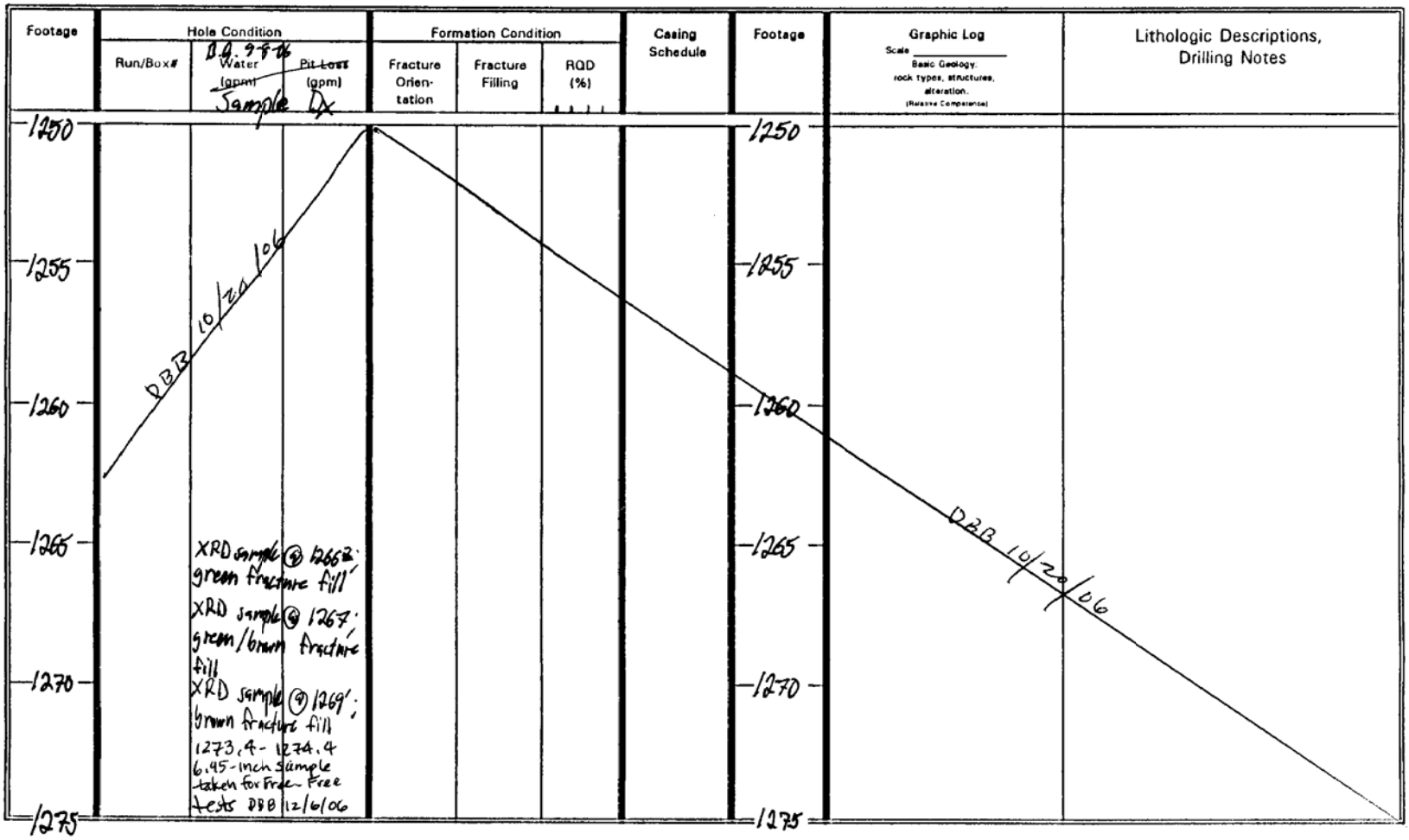
SUPPLEMENTAL

DRILL LOG

HOLE NO. C4998 - core hole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____ } see p.1. D.G. 9-8-06
LOGGED BY Ben Garcia

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



SUPPLEMENTAL

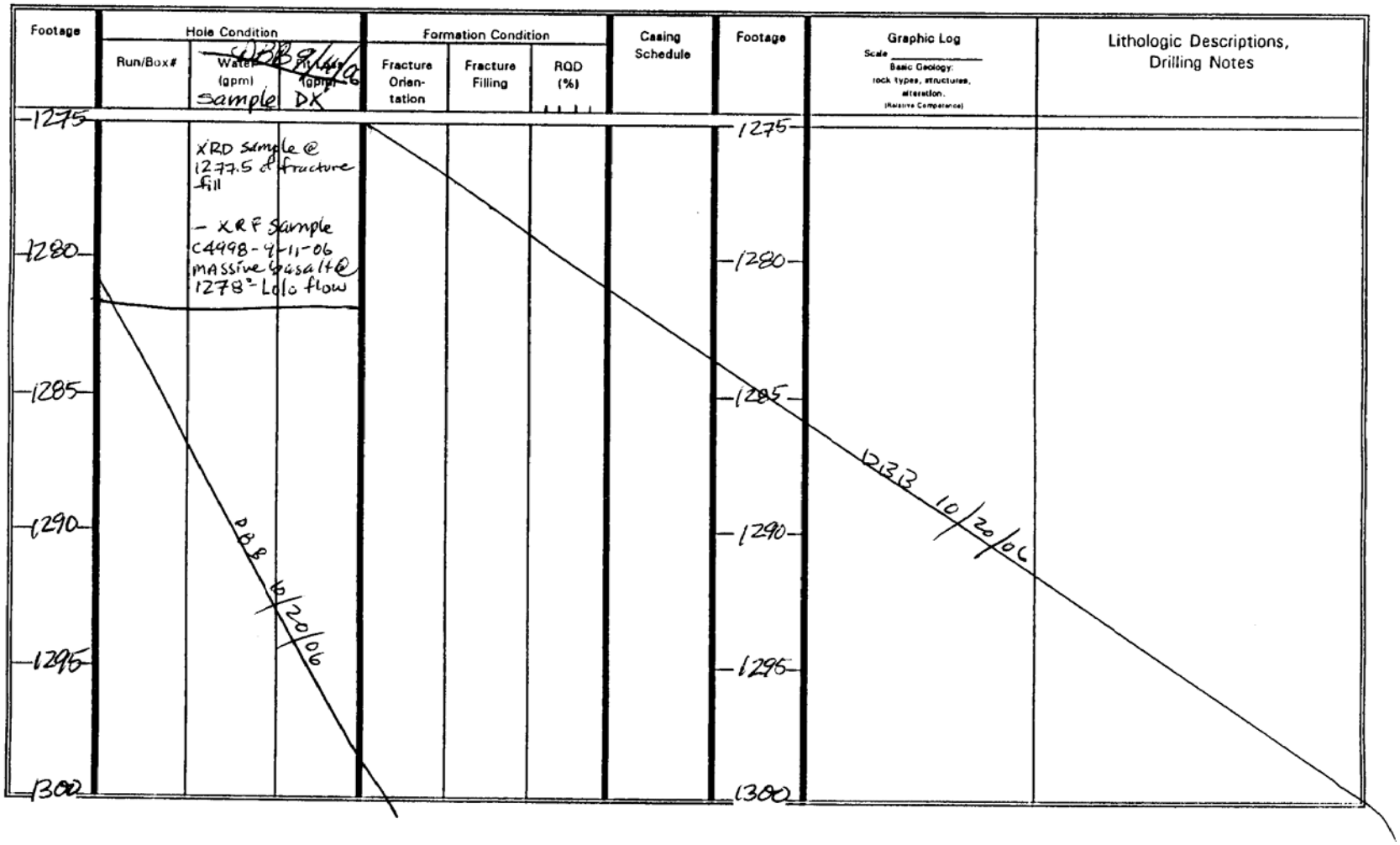
DRILL LOG

HOLE NO. C4998 – COREHOLE

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY D.B. Barnett

see p. 1
DBB 9/11/06

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



SUPPLEMENTAL

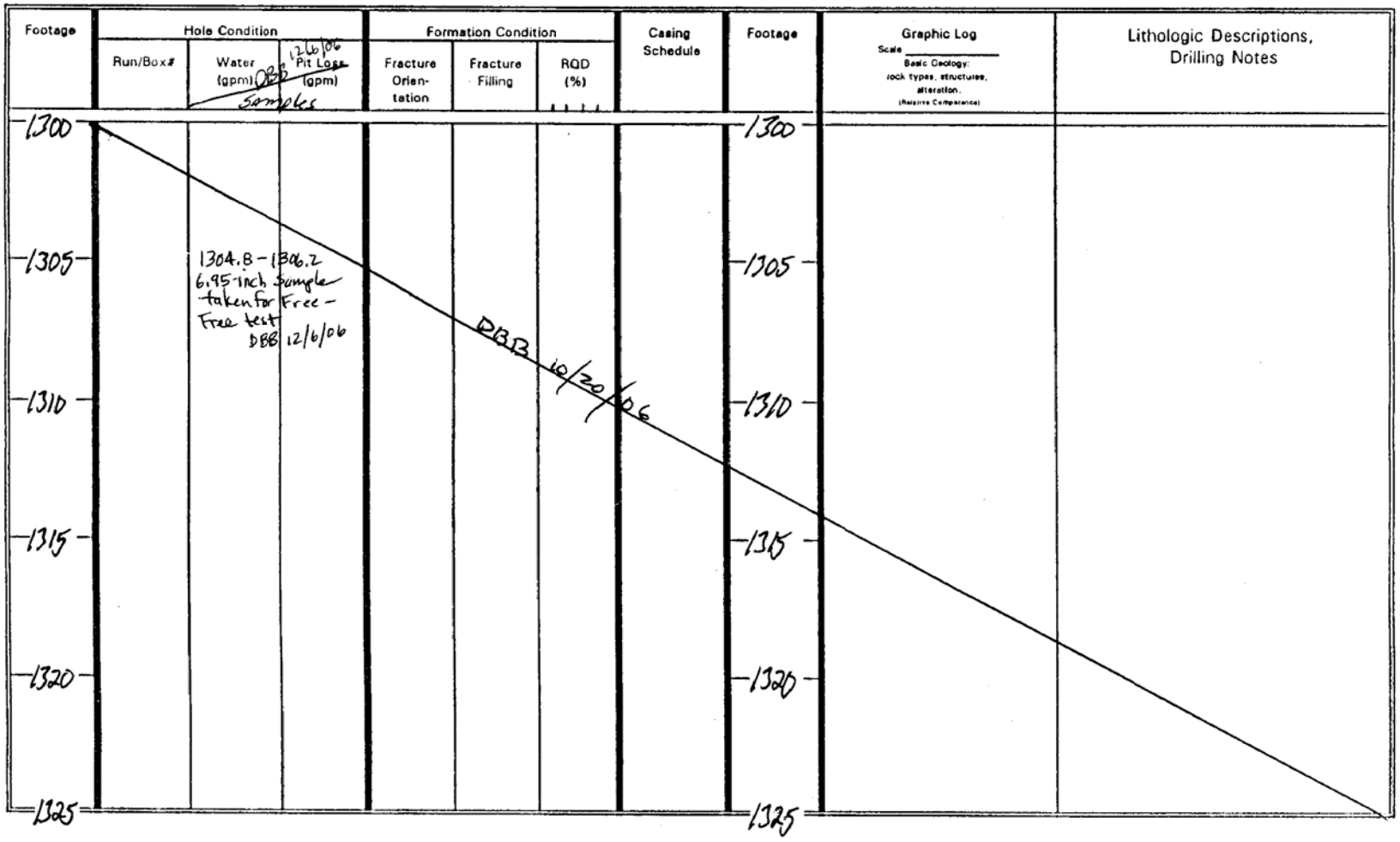
DRILL LOG

HOLE NO. C4998 - Core 6

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY _____

} see p.1
B.E. 9-18-06

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



SUPPLEMENTAL

DRILL LOG

HOLE NO. C4998-Core4

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY _____

} see p. 1 B.G. 4-18-06

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit ~~Loss~~ (ppm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log (Scale ____ Basic Geology: rock types, structures, alteration, [Relative Competence])	Lithologic Descriptions, Drilling Notes
1325		DBB 12/6/06 samples						1325		
1330		1333 – 1334.4 7.15-inch sample taken for Free-Free tests. DBB 12/6/06						1330		
1335								1335		
1340								1340		
1345								1345		
1350								1350		

DBB 12/20/06

SUPPLEMENTAL

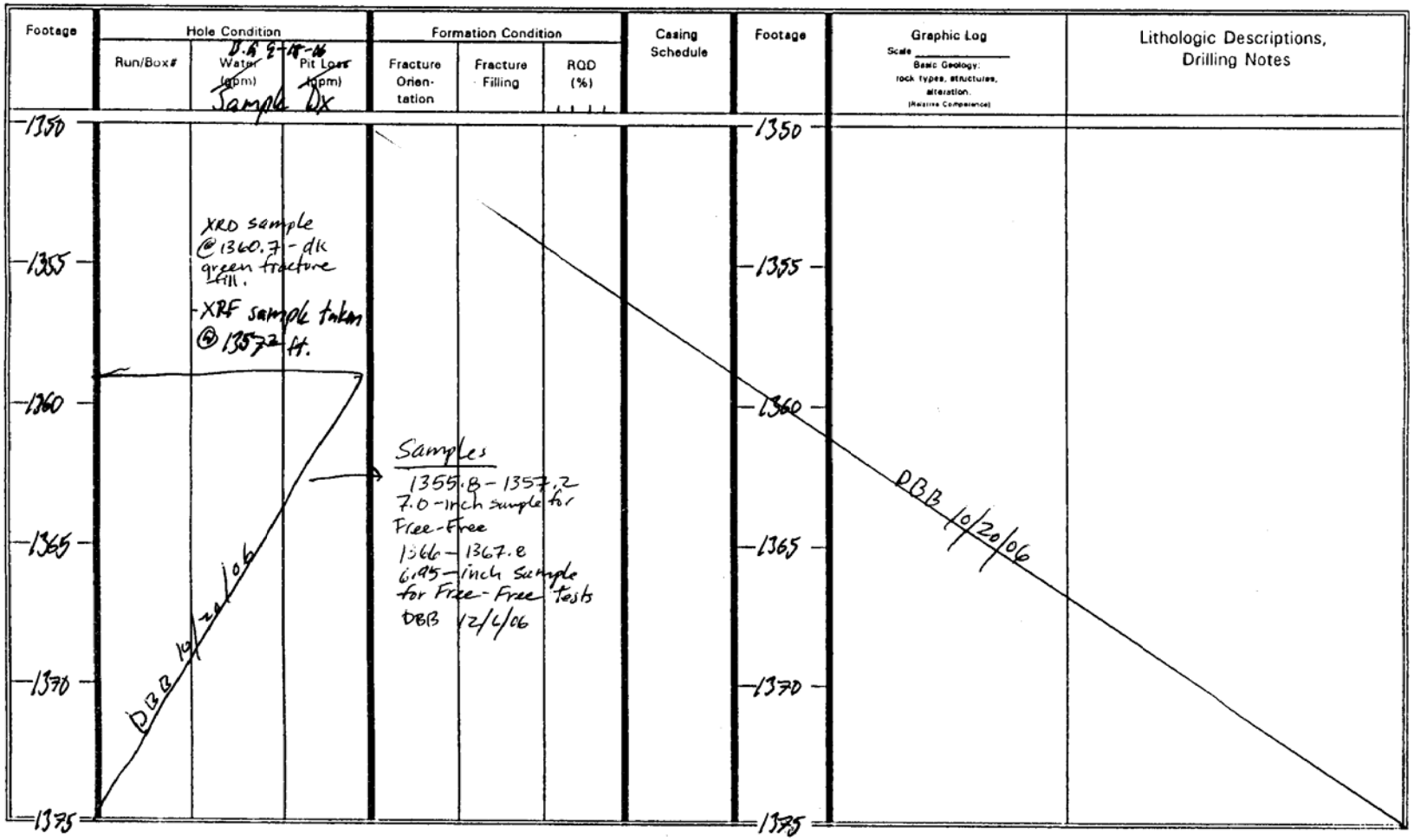
DRILL LOG

HOLE NO. C4998-Corehole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY Ben Garcia

} see p. 1 B.G. 8-18-06

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



SUPPLEMENTAL

DRILL LOG

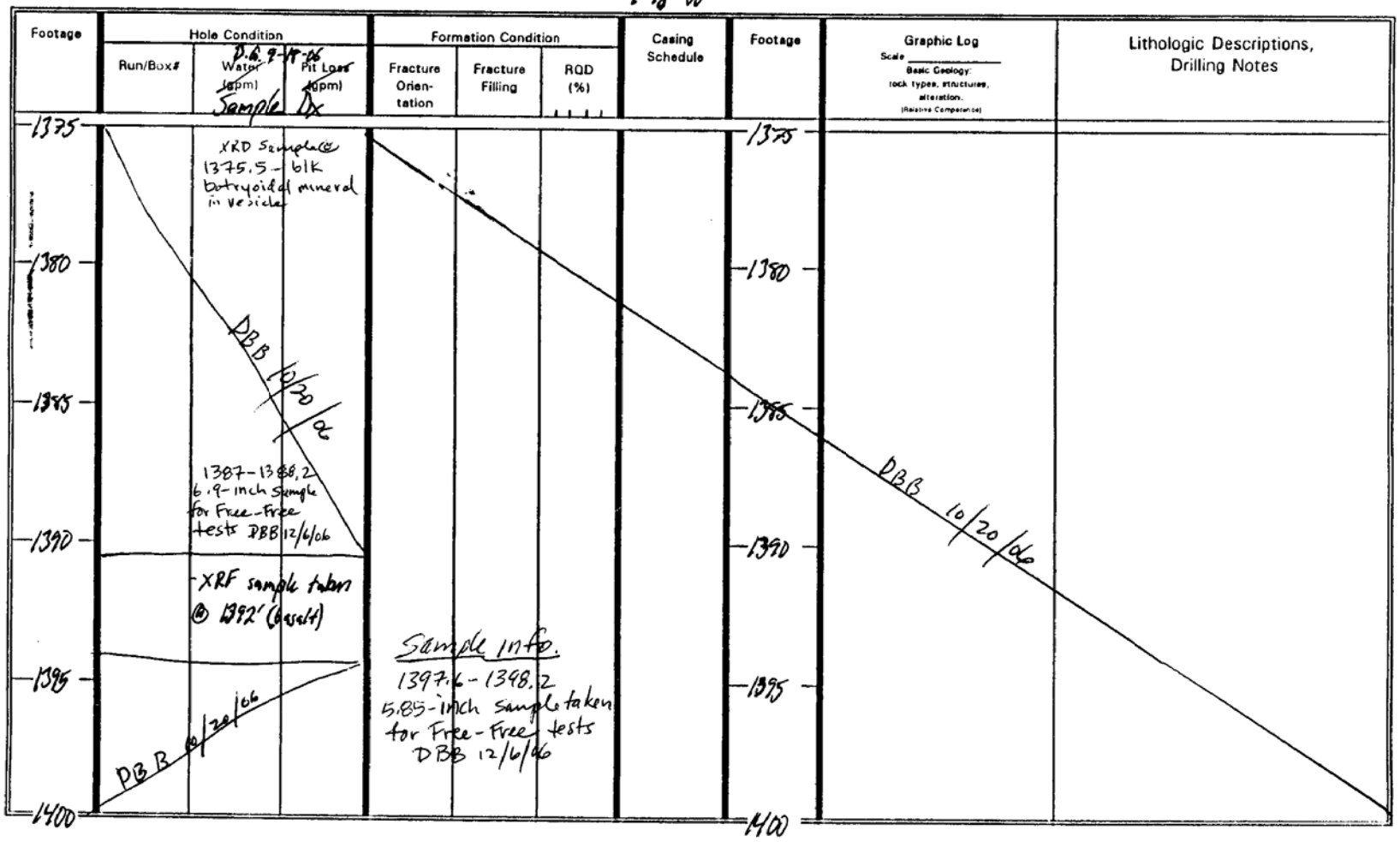
HOLE NO. C4998-Corehole

PROJECT _____
CONTRACTOR _____
DATE STARTED _____ COMPLETED _____
LOGGED BY Ben Garcia

} see p. 1

6.6. 9-18-06

TOTAL DEPTH _____ LAND SURFACE ELEV. _____
INCLINATION _____ BEARING _____
COORDINATES T ___ R ___ S _____ OTHER _____
SURVEY REFERENCES _____



Appendix D

Geophysical Logs

BOREHOLE GEOPHYSICS & HYDROPHYSICS
COLOG
A DIVISION OF LAYNE CHRISTENSEN COMPANY

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
FAX: 303.278.0135
www.cologg.com

Natural Gamma
Caliper
Compensated Density
Long Spaced Density
Short Spaced Density

Company Energy Solutions
Well C4998
Field Waste Treatement
County Benton
State Washington

COMPANY Energy Solutions
WELL C4998
FIELD USDOE WTP Hanford Site
COUNTY Benton **STATE** Washington

LOCATION
Washington State Plane
N 137780.52, E 576300.37

QTR **SEC** **TWP** **RGE**

PERMANENT DATUM GROUND LEVEL **ELEVATION** 206.61'

LOG MEAS. FROM GROUND LEVEL 0.0 ft **ABOVE PERMINANT DATUM**

DRILLING MEAS. FROM GROUND LEVEL

OTHER SERVICES

DATE ACQUIRED	15&18 Sept, 2006	15&18 Sept, 2006							
RUN NUMBER	1	2							
LOG TYPE	Natural Gamma	Caliper/Density							
DEPTH-DRILLER	1400'								
DEPTH-LOGGER	1397'								
BTM LOG INTERVAL	1393'	1396'							
TOP LOG INTERVAL	1'	2'							
RECORDED BY	A. Caster								
WITNESSED BY	J. Meisner								
PROBE TYPE, S/N	RAB 2019	HPF 1516							
LOGGING SPEED	15ft/min	12ft/min							
A.S.D.E.	NA	NA							
SAMPLE INTERVAL	0.1'	0.1'							

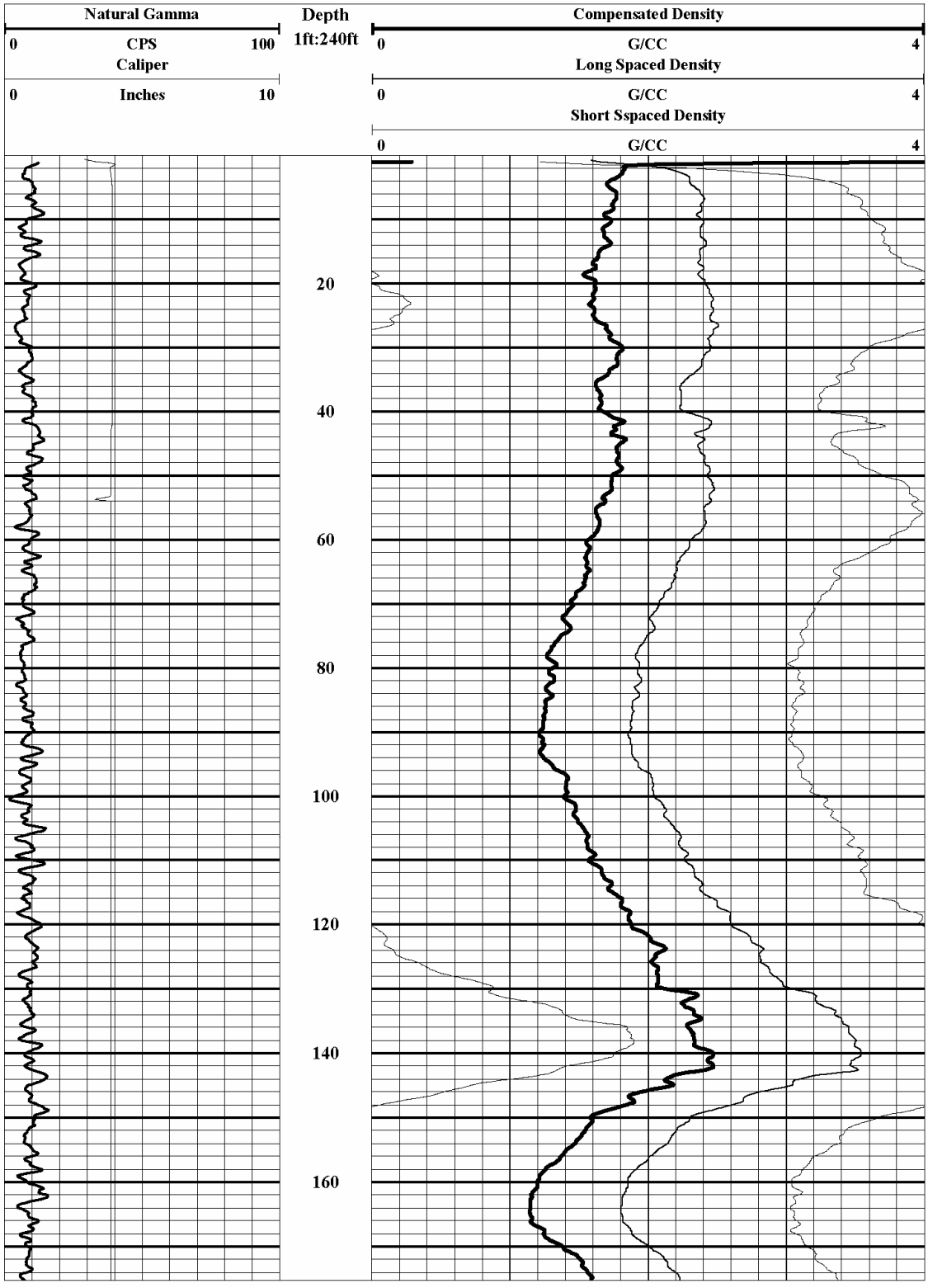
BOREHOLE RECORD **CASING RECORD**

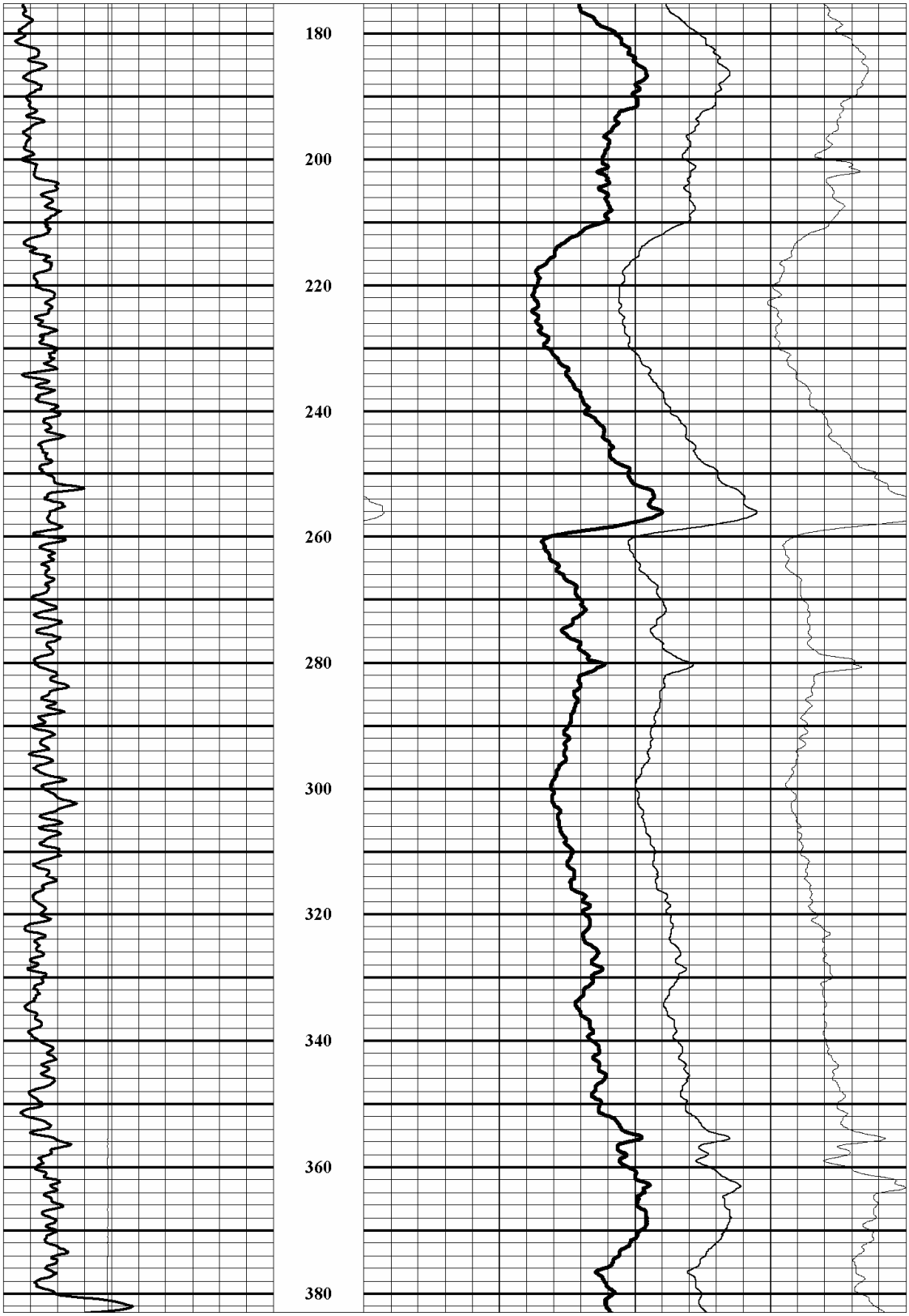
RUN No.	**BIT**	**FROM**	**TO**	**SIZE**	**WGT.**	**FROM**	**TO**
1	13.375"	G.L.	202.5'	13.375"	P110 0.5" Steel	1.5' Stickup	201'
2	9 3/4"	202.5	395'	9.625"	P110 0.5" Steel	Surface	384.5'
3	HQ 3.8"	400'	1400'	4"	Steel	1' Stickup	400'

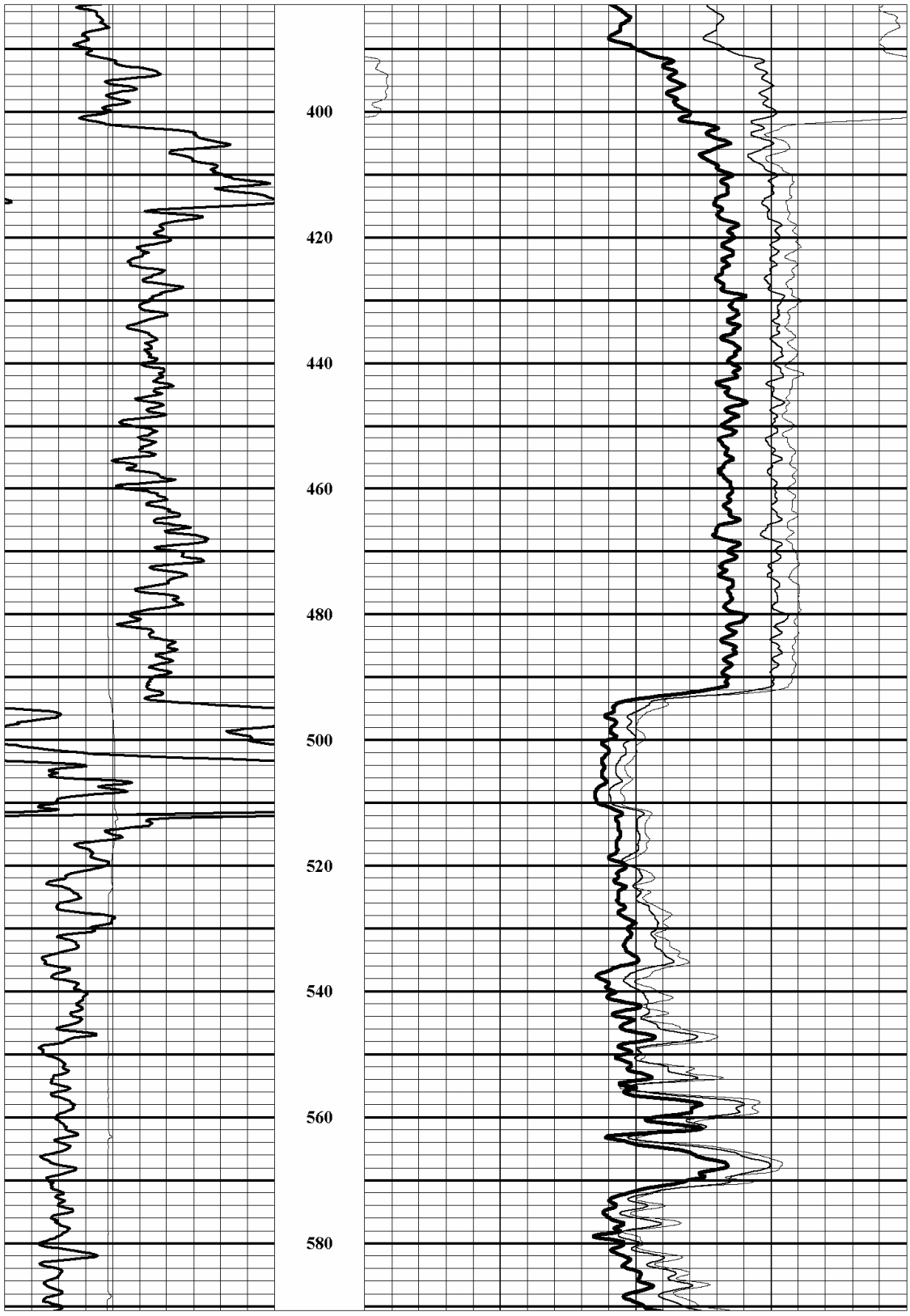
COMMENTS **NA - Not Available, N/A - Not Applicable**

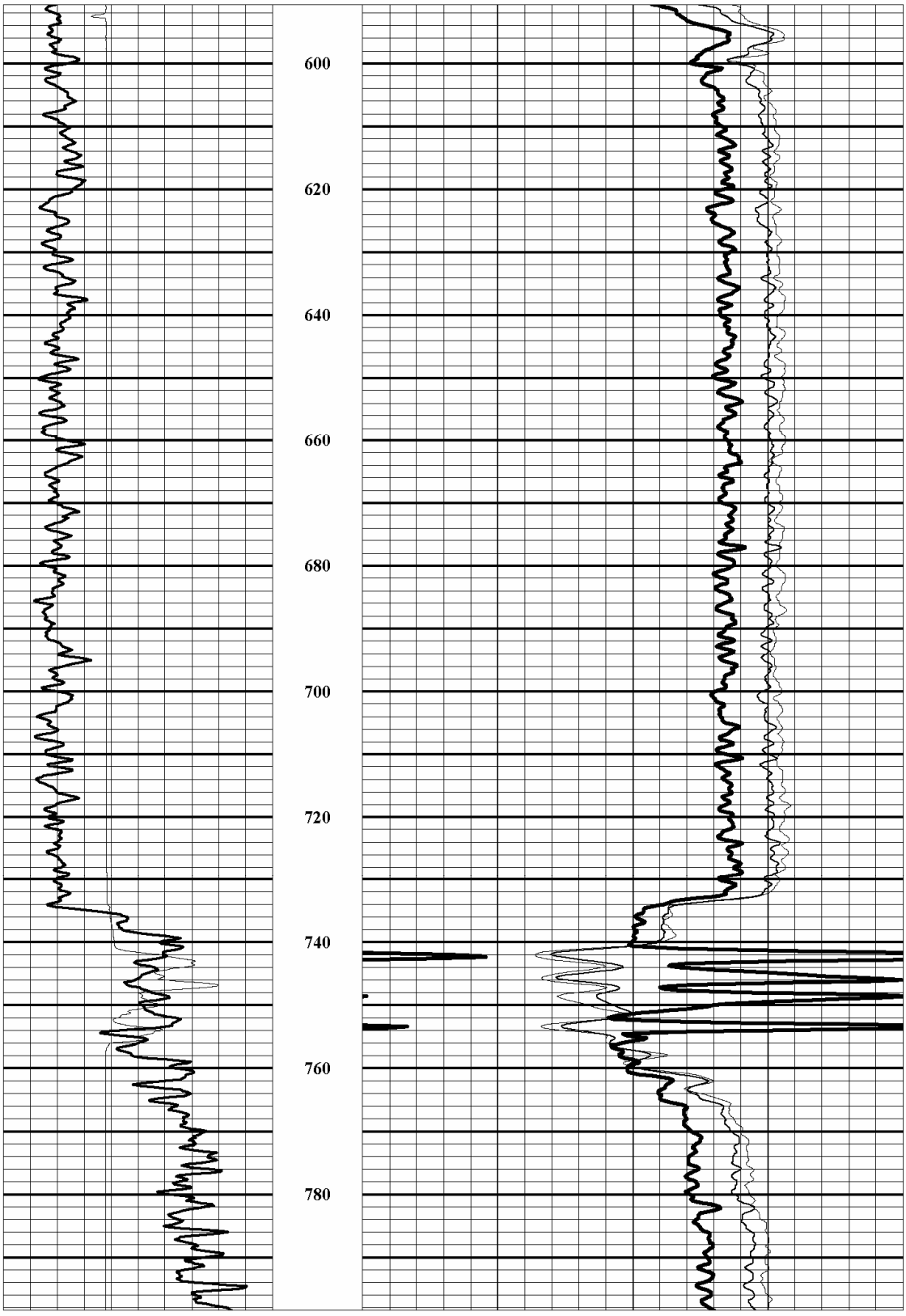
Bottom log is repeat section, middle log was ran through HQ from 1215' to 1100'and openhole from 1396' to1215',

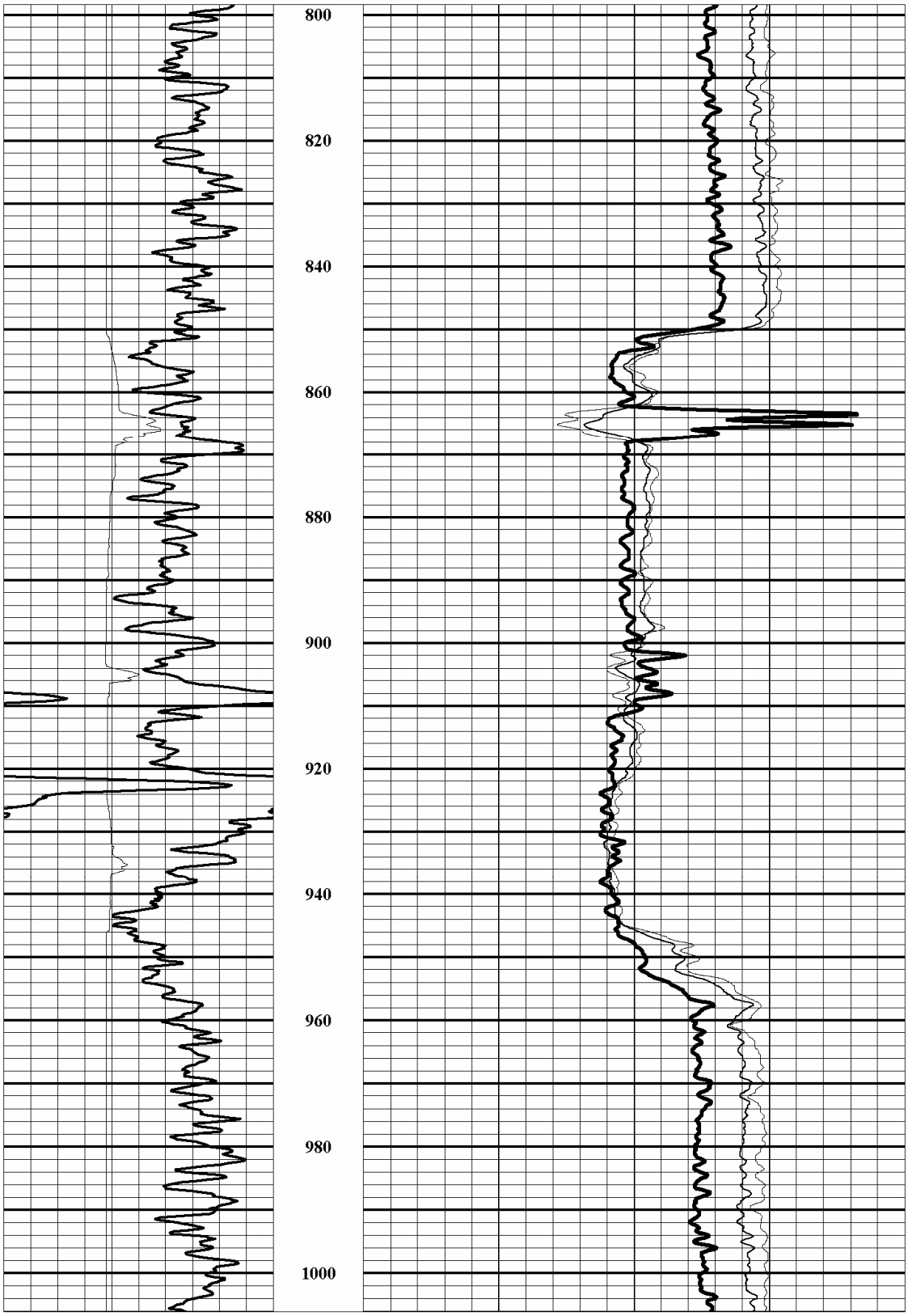
top log was ran openhole from 1170' to 400'.

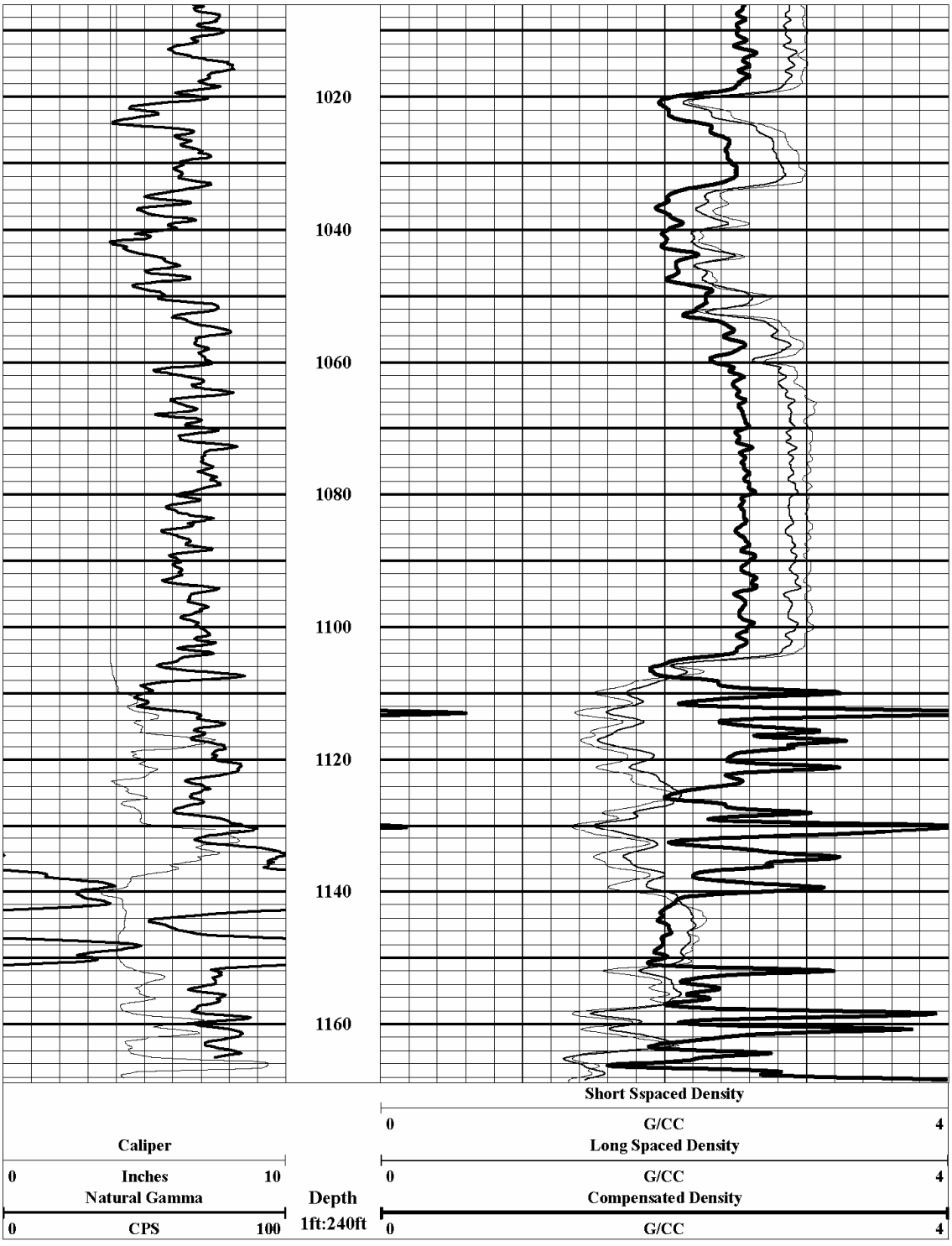

Natural Gamma
0
CPS
100
Caliper
0
Inches
10
Depth
1ft:240ft
Compensated Density
0
G/CC
4
Long Spaced Density
0
G/CC
4
Short Sspaced Density
0
G/CC
4
20
40
60
80
100
120
140
160

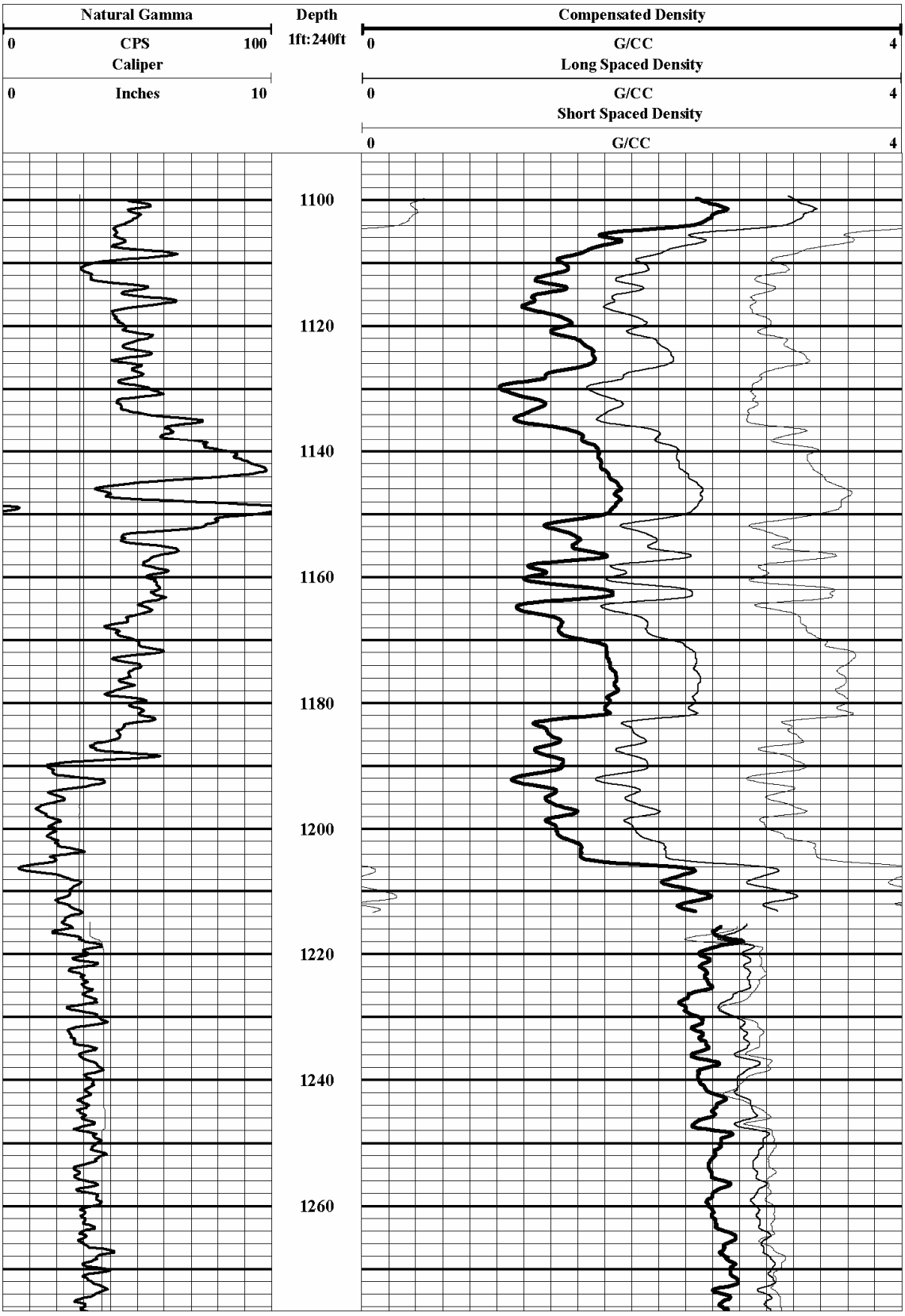

180
200
220
240
260
280
300
320
340
360
380

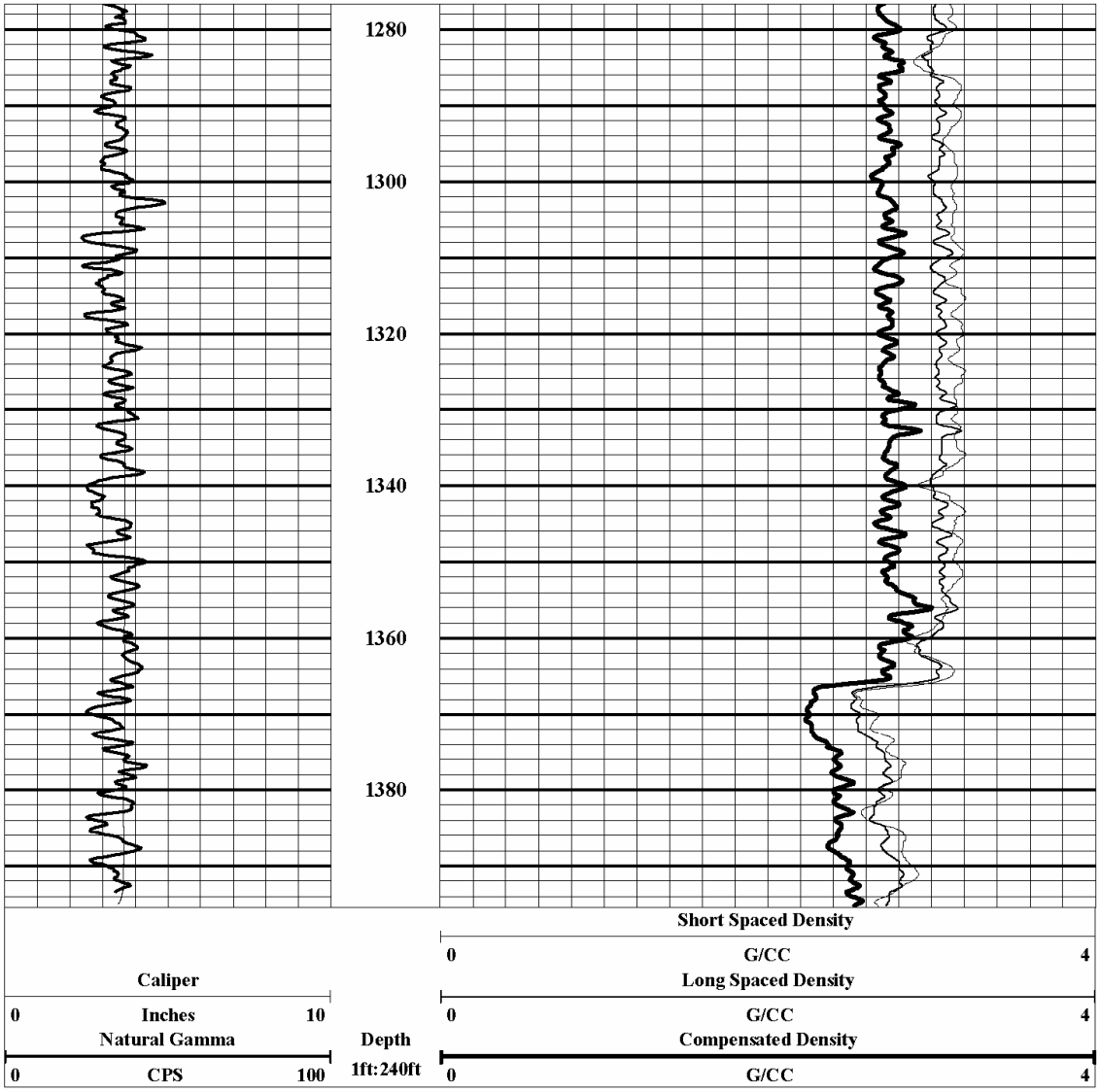

400
420
440
460
480
500
520
540
560
580

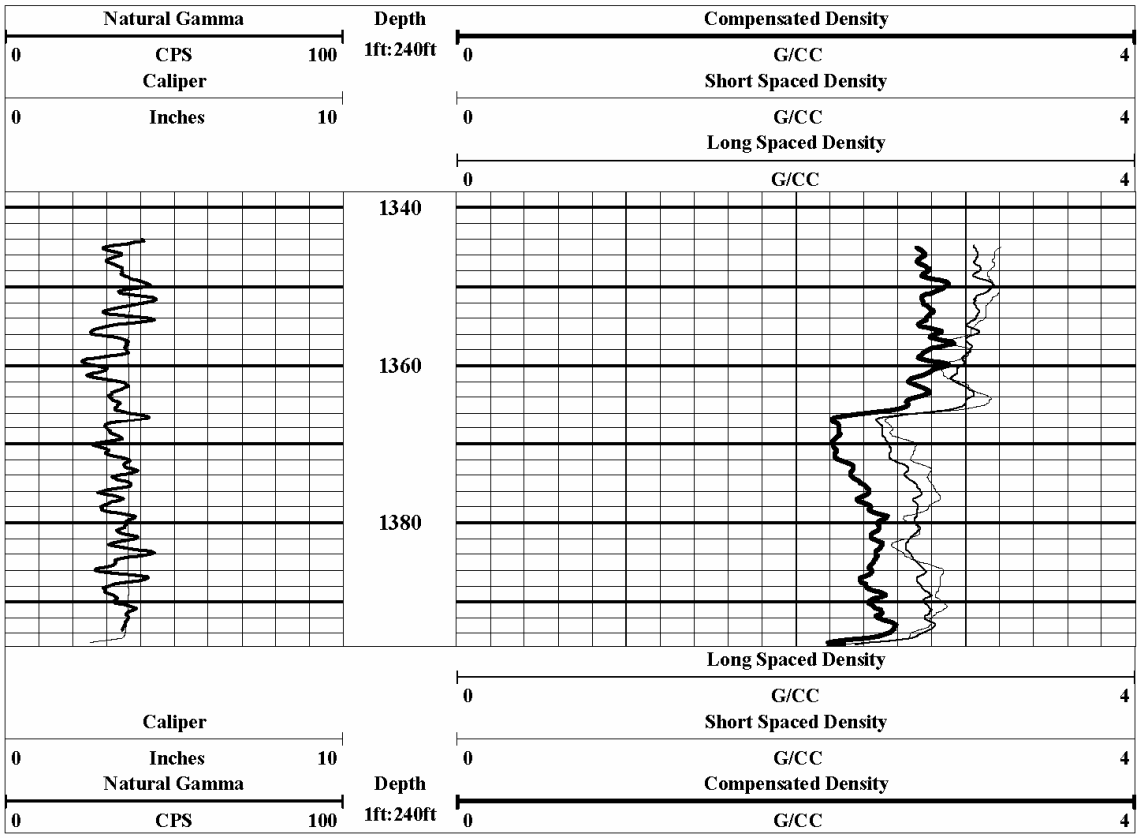

600
620
640
660
680
700
720
740
760
780


800
820
840
860
880
900
920
940
960
980
1000


1020
1040
1060
1080
1100
1120
1140
1160
Short Sspaced Density
0
G/CC
4
Caliper
Long Spaced Density
0
Inches
10
0
G/CC
4
Natural Gamma
Depth
Compensated Density
0
CPS
100
1ft:240ft
0
G/CC
4


Natural Gamma
0
CPS
100
Caliper
0
Inches
10
Depth
1ft:240ft
Compensated Density
0
G/CC
4
Long Spaced Density
0
G/CC
4
Short Spaced Density
0
G/CC
4
1100
1120
1140
1160
1180
1200
1220
1240
1260


1280
1300
1320
1340
1360
1380
Short Spaced Density
0
G/CC
4
Caliper
Long Spaced Density
0
Inches
10
0
G/CC
4
Natural Gamma
Depth
Compensated Density
0
CPS
100
1ft:240ft
0
G/CC
4


Natural Gamma
0
CPS
100
Caliper
0
Inches
10
Depth
1ft:240ft
1340
1360
1380
Compensated Density
0
G/CC
4
Short Spaced Density
0
G/CC
4
Long Spaced Density
0
G/CC
4
Long Spaced Density
0
G/CC
4
Short Spaced Density
0
G/CC
4
Caliper
0
Inches
10
Natural Gamma
0
CPS
100
Depth
1ft:240ft
Compensated Density
0
G/CC
4

Distribution

No. of Copies

OFFSITE

C. J. Costantino
4 Rockingham Road
Spring Valley, NY 10977

J. A. McCloskey
U.S. Department of Energy
Headquarters, EM-23
19901 Germantown Road
Germantown, MD 20874

B. B. Redpath
Redpath Geophysics
P.O. Box 540
Murphys, CA 95247

K. H. Stokoe II
University of Texas at Austin
Department of Civil Engineering
College of Engineering
1 University Station C1700
Austin, TX 78712

6 U.S. Army Corps of Engineers
Seattle District
P.O. Box 3755
Seattle, WA 98124-3755
A. P. Dimbirs (4)
R. O. Garrison
R. E. Smith

No. of Copies

ONSITE

7 **DOE Office of River Protection**

W. Abdul	H6-60
J. R. Eschenberg	H6-60
T. R. Hoertkorn	H6-60
L. F. Miller (4)	H6-60

2 **Bechtel National, Inc.**

L. T. Lamm	MS4-A2
M. R. Braccia	MS 5-K

Energy Solutions

M. G. Gardner	G1-62

2 **Fluor Hanford, Inc.**

S. H. Worley	E6-35
C. S. Wright	E6-35

Washington Closure Hanford

K. R. Fecht	H4-21

Washington State Department of Ecology

J. A. Caggiano	H0-57

12 **Pacific Northwest National Laboratory**

D. B. Barnett	K6-75
B. N. Bjornstad	K6-81
T. M. Brouns (5)	K9-69
S. P. Reidel	K6-75
A. C. Rohay	K6-75
Information Release (3)	P8-55