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Borehole Summary Report for Waste Treatment Plant Seismic Borehole C4996

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January 2007

Prepared by Freestone Environmental Services, Inc.
and Fluor Hanford, Inc.
for the Pacific Northwest National Laboratory
under Contract DE-AC05-76RL01830
with the U.S. Department of Energy

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Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

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ACRONYMS

bgs	below ground surface
FH	Fluor Hanford, Inc.
Freestone	Freestone Environmental Services, Inc.
ICN	Interim Change Notice
PNNL	Pacific Northwest National Laboratory
SAP	sampling and analysis plan
WTP	Waste Treatment Plant

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1.0 INTRODUCTION

This report presents the field-generated borehole log, lithologic summary, and the record of samples collected during the recent drilling and sampling of the basalt interval of borehole C4996 at the Waste Treatment Plant (WTP) on the Hanford Site. Borehole C4996 was one of four exploratory borings, one core hole and three boreholes, drilled to investigate and acquire detailed stratigraphic and down-hole seismic data. This data will be used to define potential seismic impacts and refine design specifications for the Hanford Site WTP. All completed well locations are shown in Figure 1.

Requirement documents controlling the borehole drilling and geologic logging include the *Sampling and Analysis Plan Waste Treatment Plant Seismic Boreholes Project* (herein referred to as the WTP SAP) (PNNL-15848) and the Fluor Hanford, Inc (FH) Groundwater Remediation Project Procedure "Geologic Logging" (GRP-EE-01-7.0).

All data in this report are presented in the English units in which they were measured.

1.1 PURPOSE

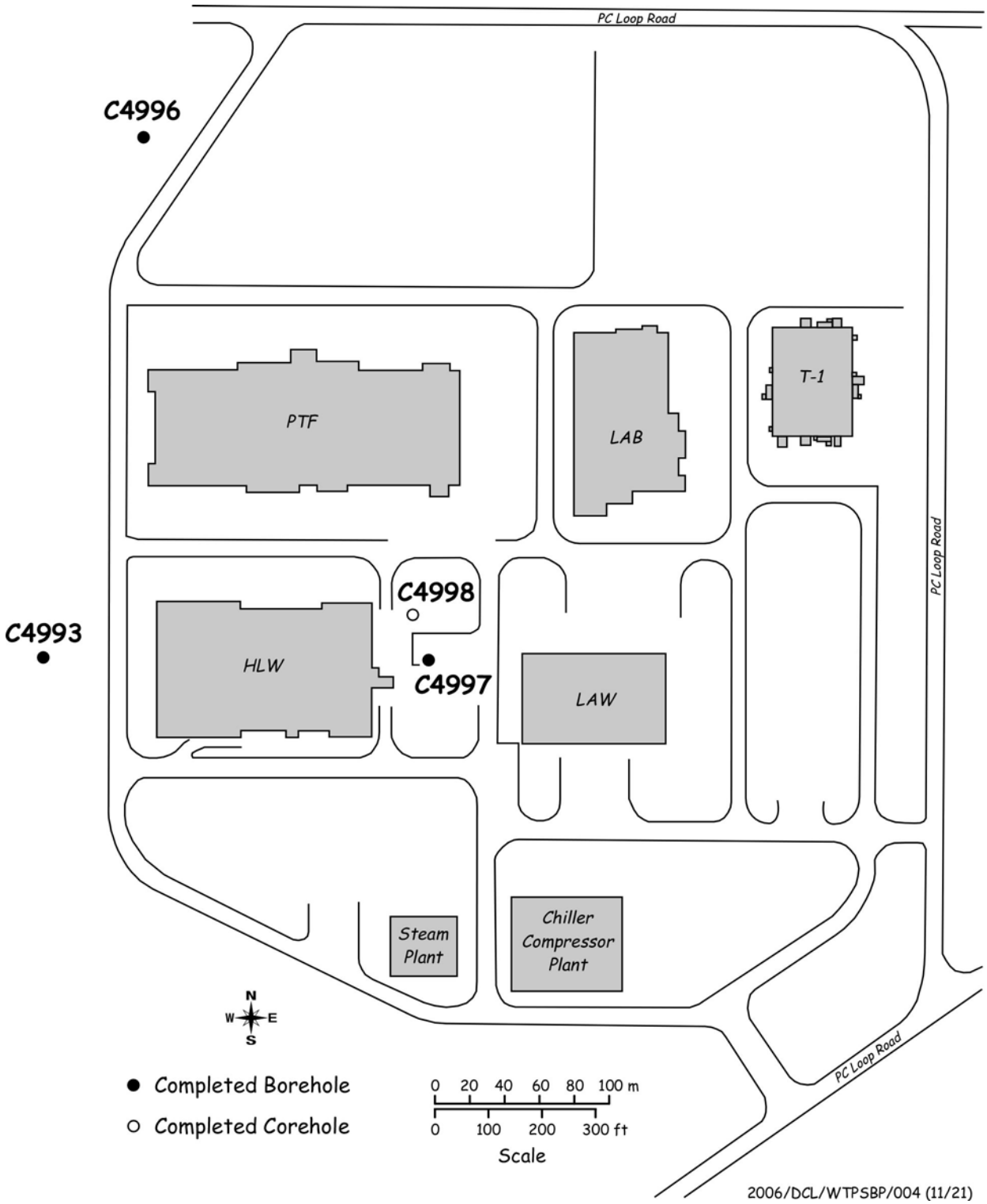
The purpose of this document is to compile field records and summarize observations and measurements made by the wellsite geologist during the drilling, the visual characterization of the cuttings, and sample collection process during the drilling of borehole C4996. This information was recorded at the wellsite on the borehole log form (FH form A-6003-642). The borehole log for C4996 is presented in Appendix A.

1.2 SCOPE

Freestone Environmental Services, Inc. (Freestone) was subcontracted to Fluor Hanford (FH) to support geologic logging during the drilling of the basalt interval of borehole C4996. The scope of work for the C4996 wellsite geology support activity was to collect, examine, describe, and containerize rock chips from 5-ft depth intervals or recognized changes in lithology during the drilling of borehole C4996. The wellsite support contract solely addressed the drilling of the basalt and sedimentary interbed stratigraphy of borehole C4996 and excluded support work during the drilling of the upper unconsolidated sediment interval (0 to 390 ft below ground surface [bgs]) of C4996. Entry hole geologic logging and cuttings sampling was performed by another project subcontractor. Significant data were collected by other project sub-contractors in the form of drill performance data, health and safety monitoring records, and borehole geophysical logs. This information will be released in separate project documents.

The overall objectives, applicable procedures and standards, and organizational responsibilities are stated in Revision 0 of the WTP SAP (PNNL–15848a) and subsequent revisions. The borehole through the unconsolidated zone and part way into the basalt was completed using Revision 1a of the WTP SAP (PNNL-15848b) and Interim Change Notice (ICN) 15848-1.1. Continued drilling of C4996 used the requirements from Revision 2 of the WTP SAP (PNNL-15848c) and ICNs 15848-2.1 and 15848-2.2. Subsequent direction from Pacific Northwest National Laboratory (PNNL) increased the total depth of C4996 to drill through an additional underlying basalt flow and interbed.

Figure 1. Location of WTP Seismic Boreholes (Gardner et al. 2006).



2.0 BACKGROUND

The seismic design basis for the WTP at the Department of Energy's (DOE) Hanford Site near Richland, Washington was re-evaluated 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 (DNFSB) 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 which enveloped the remaining uncertainties. The uncertainties in these response spectra were enveloped at approximately the 84^{th} 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 sedimentary interbeds below the WTP. The velocity structure of the upper four basalt flows (Saddle Mountains Basalt) and the interlayered sedimentary interbeds (Ellensburg Formation), produces strong reductions in modeled earthquake ground motions propagating through them. Uncertainty in the strength of velocity contrasts between these basalts and interbeds primarily resulted from an absence of measured shear wave velocities (Vs) in the interbeds. For this study, 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 feet below ground surface (Figure 1). The three boreholes are within 500 feet of and surrounding the high level waste vitrification and pretreatment facilities of the WTP, which were the Performance Category 3 (PC3) structures affected by the interim design spectra. The corehole is co-located with the borehole closest to the two PC-3 structures. These new measurements are expected to reduce the uncertainty in the modeled site response that is caused by the lack of direct knowledge of the Vs contrasts within these layers.

The entry hole intervals for all seismic boreholes were drilled with a cable tool drill rig and cased through the unconsolidated gravels, sands and silts down to the top of the basalt. The initial borehole, C4998, was drilled with a core rig to provide physical samples for detailed characterization and testing of the basalt and sedimentary interbeds. The remaining three boreholes in the program, including C4996, were drilled by rotary drill equipment and tri-cone

bits which produced rock chips and finer material as the drill cuttings. Bentonite mud was used as the drilling fluid to support the hole and return drill chips to the surface.

The borehole diameter of C4996 was 7.625-in. diameter button-type tri-cone rock bit. The borehole was drilled over the period July 31 to September 6, 2006 and reached a total depth of 1467.8 ft bgs.

2.1 QUALITY ASSURANCE AND QUALITY CONTROL REQUIREMENTS

The WTP SAP (PNNL-15848) established organizational responsibilities, actions to be completed, and specified that geology aspects were to be recorded using GRP-EE-01-7.0. In response to these requirements, Freestone prepared a desk instruction (Freestone 2006, *Desk Instruction for Records Management to Support Waste Treatment Plant – PNNL Seismic Boreholes Project*) to ensure the integrity of sample and records. These desk instructions are provided in Appendix D of this document.

The Freestone instruction emphasized the importance of maintaining accurate measurements and concise and consistent record keeping. It also emphasized training, control of records, quality control, inspection and approval of records, change control of records, and physical control of a duplicate records, as well as physical transfer of custody of samples and records. The desk instruction identified samples as physical records. Freestone utilized an independent quality control process to assure accuracy, consistency, and legibility of records.

3.0 GEOLOGICAL SAMPLING

For the Freestone scope of work, rotary drill cuttings of basalt were the most frequently collected samples and made up the bulk of the materials archived. Within the WTP SAP (PNNL-15848), PNNL provided a reference stratigraphic description with anticipated depths and projected unit thicknesses at Borehole C4996. In addition, geologic information was available from the concurrent drilling of the nearby C4998 corehole. PNNL also supplied reference photographs of core from two older core holes. All available sources were utilized to anticipate unit contacts and facies changes.

The WTP SAP required collection of drill cuttings from 5-ft depth intervals or when changes in lithology were recognized to the total depth of the borehole. A continuous effort was made to monitor the borehole depth since the rig-mounted geolograph did not always provide an accurate record of drill depth. A borehole depth tally was provided by the driller to identify the borehole depth.

The basalt cuttings were generally collected from the shale shaker located alongside the rotary drill rig. The collection process involved scraping a shovel full of cuttings from the discharge slide end of the vibrating shaker table, which screened the cutting from the bentonite drilling fluid. Most samples were then washed with water while held in a hand screen to remove the drilling mud and particles of mud additives. As orally directed by the PNNL Project Geologist, cuttings from some intervals were not washed.

When drilling through the sedimentary interbeds, most zones did not return cuttings of a size that collected on the shaker table discharge slide. In this case, some cuttings could be directly collected with the hand-screen from the discharge side of the surface casing. Additional cuttings in the form of a thickened slurry could be collected in a jar directly from the sand cyclones on the shale shaker. It was noted in the borehole log that the bottled slurry samples might not be representative of the interbed lithology interval, because of intermixing caused by intermittent operation of the sand pump in the shale shaker (see Section 4.3 “Notes on Geology and Sampling Techniques”).

The individual grab sample was divided and portions were stored in a labeled one-pint volume glass jars, a cloth sample-collection bag and in a plastic cuttings tray. A representative portion was inspected by eye, 10 power hand lens, 50 power pocket microscope, and/or variable-power binocular microscope and the depth range and geologic description was recorded on the borehole log form. The description was made based upon the rock type, color, fracture pattern, mineralogy, crystals found, and other features that could be visibly distinguished. Borehole log sheets were duplicated and filed as in-progress-working records as soon as they were completed in draft.

Borehole logging was coordinated with the drilling progress to note drilling characteristics, such as drilling speed and torque or vibration of the drill stem as may be experienced in fracture zones. Communication with the driller was maintained to identify when depth errors were introduced to the geolograph. Bottles, chip trays, and air dried sample bags were moved inside of the support trailer as soon as the container was filled.

The borehole log for C4996 is located in Appendix A. The inventory of samples collected during drilling is provided in Appendix B. Appendix C, “Borehole C4996 Log Summary,” summarizes the observations recorded in the borehole log sheets. A photographic log of the drill

cuttings that were collected in the chip trays was prepared by PNNL and is included as Appendix E.

4.0 BOREHOLE GEOLOGY

The geology of the Hanford Site and the deep subsurface has been investigated in previous studies, most importantly during the Basalt Waste Isolation Project (BWIP) and is presented in detail in *Geologic Studies of the Columbia Plateau—A Status Report* (RHO-BWI-ST-4), and Volume 2 of the *Site Characterization Plan* (DOE/RW-0164) along with other documents.

Following is the background geologic description, as well as a summary of the observed geology of the units encountered during the drilling of borehole C4996. The overall sequence drilled can be generally summarized as basalt flows alternating with sedimentary units.

4.1 BASALT UNITS

4.1.1 Elephant Mountain Member of the Saddle Mountains Basalt

The Elephant Mountain Member is the uppermost Columbia River Basalts unit present in the study area and is separated from the underlying Pomona Member by the Rattlesnake Ridge interbed of the Ellensburg Formation. Beneath the Hanford Site, this single flow has an average thickness of 100 ft with a range of 15 ft. In borehole C4996, the Elephant Mountain basalt has a total thickness of 101 ft and was encountered between 349 ft and 450 ft bgs. This member was medium- to fine-grained with abundant microphenocrysts of plagioclase. Clay, zeolites, calcite, pyrite, and silica are present as fracture and joint fillings, though their exact distribution depends on distribution and dimension of fractures and joints within the basalt flow, as well as the physiochemical properties of the minerals themselves (see Section 4.3 “Notes on Geology and Sampling Techniques”). Calcite and pyrite were noted in the chip samples; though the most common secondary mineral was a green clay.

Evidence for internal features such as plagioclase microphenocrysts, vesicles, and filled fractures/cavities were observed in chip samples, though not uniformly throughout the entire flow (Appendix A). One possible reason for this observed characteristic may be related to the destructive nature of mud rotary drilling, the speed of the bit, and the depth from which the chip sample material was transported (Section 4.3 “Notes on Geology and Sampling Techniques”). The flow top was highly vesicular, amygdaloidal, and oxidized to a reddish-brown color at the contact with the overlying Ringold Formation sediments. The flow bottom was also oxidized, though vesiculation and secondary minerals were much less apparent.

4.1.2 Pomona Member of the Saddle Mountains Basalt

The Pomona Member basalt overlies the Esquatzel Member basalt and was separated from it by the Selah interbed of the Ellensburg Formation. In the Hanford Area, this single flow had an average thickness of 185 ft with a range of 10 ft. In borehole C4996, the Pomona member was 200.5 ft thick and was encountered between 495 ft and 699.5 ft bgs. This member was logged as fine-grained, glassy, and containing plagioclase (and rarely olivine) phenocrysts. Clay, zeolites and silica were found as fracture and joint fillings in the literature, however, only clay and silica (chalcedony, opal) were observed in the chip samples. A blue-green clay was most often present.

Evidence for internal features such as plagioclase phenocrysts, vesicles, and filled fractures/cavities were observed in chip samples, though not distributed uniformly throughout the entire flow (see Section 4.1.1). The flow top of the Pomona Member was extremely brecciated and scoriaceous, with a large amount of palagonite present. Palagonite is a tan or brown colloidal material that is a result of the hydration of basaltic glass and shows that this lava flow probably encountered surface water while still in a molten state. The flow bottom was determined based on the disappearance of basalt from the chip samples.

4.1.3 Esquatzel Member of the Saddle Mountains Basalt

The Esquatzel Member lies above the Umatilla Member and is separated from it by the Cold Creek Interbed of the Ellensburg Formation. Locally, this single flow has an average thickness of 100 ft with a range of 10 ft. In borehole C4996, the Esquatzel Member had a total thickness of 94.5 ft and was encountered between 720 ft and 814.5 ft bgs. This member was fine-grained and plagioclase-phyric, often containing plagioclase glomerocrysts and clinopyroxene microphenocrysts. In chip samples, only fragments of plagioclase phenocrysts were observed. Clay, zeolites and silica were found as fracture and joint fillings in the literature, however, only clay and pyrite were observed in the chip samples.

Evidence for internal features such as plagioclase phenocrysts, vesicles, and filled fractures/cavities were observed in chip samples, though not uniformly throughout the entire flow (see Section 4.1.1). The flow top of the Esquatzel Member is highly weathered to green clay. The presence of fracturing and vesiculation was not readily apparent from the chip samples; however, the driller reported an increase in penetration rate during the first approximately 10 ft of the basalt. Changes in drilling behavior and clay-rich samples from the flow bottom indicate that a moderately-fractured interval overlies a baked contact of basalt and/or sediment. Poor sample returns over this interval, however, render this interpretation tenuous at best.

4.1.4 Umatilla member of the Saddle Mountains Basalt

The Umatilla Member is the lowermost and oldest member of the Saddle Mountains Basalt and consists of two flows in the study area, the Umatilla and the Sillusi. The requirements of this particular study did not call for a distinction between these two flows, so this basalt interval was referred to as the Umatilla Member. In the Hanford Area vicinity, this member has an average thickness of 150 ft with a range of 10 ft. In borehole C4996, the Umatilla basalt had a total thickness of 156 ft and was encountered between 910.8 ft and 1066.8 ft bgs. This unit is fine-grained, plagioclase-phyric, and often extremely glassy, with $\leq$ 80% glass in some previously-analyzed samples. Plagioclase glomerocrysts and olivine microphenocrysts may also be present, though rare. Clay, zeolites and silica are found as fracture and joint fillings in the literature, however, only clay and pyrite were observed in the chip samples, blue-green clay being the most common.

Evidence for internal features such as plagioclase phenocrysts, vesicles, and filled fractures/cavities were observed in chip samples, though not uniformly throughout the entire flow (see Section 4.1.1). The flow top began abruptly with the appearance of basalt and a variety

of secondary clay-like minerals in the drill cuttings. Moderate vesiculation and a relatively high (10 to 15%) proportion of clay minerals persist approximately 50 ft into the flow. The flow bottom was preceded by a slight increase in penetration rate approximately 10 ft from the contact, though without any appreciable increase in the proportion of secondary minerals.

In the interval between 970 ft and 1000 ft bgs, geophysical data suggests the presence of a thin, discontinuous layer of sediment. This 30-ft interval displays lower density and higher conductivity readings than the surrounding basalt. Chip samples from this interval are inconclusive due to the nature of mud-rotary drilling and the sampling process (see section 4.3 Notes on Geology and Sampling Techniques), however, core samples in the same interval from the C4998 Core Hole show variably-fractured zones.

4.1.5 Priest Rapids Member of the Wanapum Basalt

The Priest Rapids Member is the uppermost member of the Wanapum Basalt and consists of two flows, the Lolo and the Rosalia flows. Locally, this member had an average thickness of 232 ft with a range of 40 ft. In borehole C4996, the Lolo flow had a total thickness of 154 ft and was encountered between 1168 ft and 1322 ft bgs. The Rosalia flow had a total thickness of 70 ft and was encountered between 1325 ft and 1395 ft. Separating the two flow units was the approximately 5 ft thick Byron interbed. In general, the Priest Rapids Member basalt described as fine- to medium-grained, glassy and with a high content of plagioclase microphenocrysts. Less common are phenocrysts and glomerocrysts of plagioclase. Micropegmatites, coarse cm-scale intergrowths of plagioclase and glass, as well as enclaves of quartz and pyroxene intergrowths, have been observed in this member from other localities. In borehole C4996, very few phenocrysts (plagioclase) and no micropegmatitic zones were found. Silica (opal, chalcedony, quartz), pyrite and clay have been observed in chip samples, presumably as fracture/joint/vesicle-filling material.

Evidence for internal features such as plagioclase phenocrysts, vesicles, and filled fractures/cavities were observed in chip samples, though not uniformly distributed throughout the entire flow (see Section 4.1.1). The flow top designation is based on the disappearance of sediment from the shale shaker and slurry cone output (see Section 3.0 “Geologic Sampling”). The Lolo flow bottom was based on the appearance of a high proportion of sediment. The Rosalia flow top began where basalt again became dominant in the samples.

4.1.6 Roza Member of the Wanapum Basalt

In the study area, the Roza Member had an average thickness of 172 ft and was encountered at 1395 ft bgs until total depth for the borehole was achieved at 1467.8 ft bgs. In the literature, this member is characterized by large plagioclase phenocrysts, though samples appear relatively non-porphyritic. The proportion of plagioclase phenocrysts observed in borehole chip samples was variable.

The tentative depth of the Roza flow top is based on changes in drill penetration rate, the presence of oxidized basalt fragments, and a slight increase observed in the amount of plagioclase phenocrysts.

4.2 SEDIMENTARY UNITS

4.2.1 Ellensburg Formation, including the Rattlesnake Ridge, Selah, Cold Creek, Mabton, and Byron Interbeds

The Ellensburg Formation includes epiclastic and volcaniclastic sedimentary rocks that are interbedded with the Columbia River Basalt Group in the central and western part of the Columbia Plateau. The interbeds encountered during the drilling (and in the greater Ellensburg Formation) were defined based on the upper- and lower-bounding basalt flows. The Rattlesnake Ridge, Selah and Cold Creek interbeds lie within the Saddle Mountains Basalt; the Mabton interbed lies between the Saddle Mountains Basalt and Wanapum Basalt; and the Byron interbed lies between the Lolo and Rosalia flows of the Priest Rapids Member.

Within the study area, the Ellensburg Formation was comprised of quartzitic to arkosic, micaceous sandstone and mudstone with minor conglomerate intervals containing abundant metamorphic and plutonic clasts. Paleosols composed of fine-grained, massive silt and clay were common. The provenance of these sediments is believed to be associated with the ancestral Columbia and Snake Rivers. Layers of airfall tuff often lie within Paleosols, indicating possible Cascade volcanism was active during Columbia River basaltic volcanism. Table 1 provides a summary of recognized interbed characteristics.

During the drilling operation, it was difficult to keep the borehole open in several zones of unconsolidated flowing sands or squeezing clays within the interbeds. It became standard practice for the drilling contractor to backfill the borehole with cement grout through the entire interbed interval to stabilize the formation and then redrill the hole.

Table 1 C4996 Summary of Sedimentary Interbeds

Unit name	Rattlesnake Ridge Interbed	Selah Interbed	Cold Creek Interbed	Mabton Interbed	Byron Interbed
Depth interval in feet (meters)	450-495 (137.3-151.0)	699.5-720 (213.3-219.6)	814.5-910.8 (248.4-277.8)	1066.8-1168 (325.4-356.2)	1322-1327 (403.2-404.7)
Thickness in feet (meters)	45 (13.7)	20.5 (6.3)	96.3 (29.4)	101.2 (30.9)	5 +/- 2 (1.5 +/- 0.6)
Lithology	Reddish-brown / grey-brown / orange-brown / brown / pink / grey / mud, reddish-brown / brown, fine-grained sand, reddish-brown rock fragments (near top)	Brown / green-grey / grey / green mud, very little sand, brown / tan rock fragments (near bottom)	Greenish-grey / dark bluish-grey mud, Olive green / dark green, very fine- to coarse sand (micaceous)	Green / orange / dark greenish-grey mud, Dark greenish-grey fine- to medium grained sand (micaceous), brown rock fragments	Greenish-blue mud, brown (mud?) rock fragments, mica at lower contact

Comments	Highly variable sequence of alternating mud and sand	Mud-rich interval, color progresses from brown to grey to green from top to bottom of sequence	Mud-rich interval at top and bottom, large interval of poorly-sorted, micaceous sand in the middle	The upper half of the interval is alternating muddy and mud-poor sands, lower half of interval is essentially muddy, poorly-sorted, micaceous sand	Mud-rich interval

4.3 NOTES ON GEOLOGY AND SAMPLING TECHNIQUES

The gravels, sands, and silts of the overlying unconsolidated Hanford and Ringold units were drilled in a cable drilling scope of work, prior to drilling the basalt units and sedimentary interbeds by mud-rotary drill rig. An erosional surface marked the contact between the overlying sediments and the topmost basalt unit at a depth of 349 ft. Cable drilling stopped at 364.5 ft bgs, and the entry casing was grouted in place with the top of the cement grout set at 343.5 ft bgs in the borehole.

For all drilled basalt units, several generalities were readily observable.

- Internal basalt structures and fractures were poorly represented in drill cuttings. This was probably due to the destructive nature of mud rotary drilling and the erosion of the chip surfaces as the cuttings material was transported to the surface. At a depth of 941 to 945 ft bgs, the drill bits were changed and the original hemispherical-profile button bit was replaced with a more sharply pointed button bit. Chip size was substantially reduced downward from this depth and many surficial basalt features were probably obliterated. Fracturing or jointing of any kind may be inferred for some intervals by the presence of varying amounts of secondary minerals showing a preferred plane of orientation, i.e., flattening. The difference between cooling joints and natural fracturing, however, cannot be distinguished. The C4996 borehole log included drillers' notifications of fracture zones, which were identified by observable drill responses, and drilling penetration rates.
- Identifying secondary minerals in drill cuttings was extremely difficult because the minerals share many of the same physical properties, and small grain size prohibits most simple, deterministic tests. These two factors may also contribute to the amount of that mineral observed in each sample. For example, a brittle clay particle has a greater chance of disintegrating on the way up and out of the borehole than a more plastic clay. More of the plastic clay would be present in a random sample, but would not correctly reflect the lithology at depth. The absolute amount of secondary minerals present in each chip sample, therefore, may be interpreted only on a very general scale.

Following are a general zoning pattern recognized within the basalt intervals:

- Upper basalt zones generally were fast drilling (3 to 7 ft/hr) and fractured with clay fillings in apparent fracture fillings.
- Center zones were slow drilling (1.5 to 3 ft/hr) with fewer fractures and much less clay.

- Very basal zones were alternately hard and slow drilling in the unit. Drilling rates increased to 3 to 9 ft/hr and gave good warnings when entering clay units at the top of the interbeds.

For the interbeds, cutting returns were very poor. Generally speaking, the only valuable data retrieved was for returns of clay to clay-siltstone sized materials. At times the only retrievable clay-siltstone samples were taken from the surface casing. Many of the clay-siltstone samples were disaggregated before discharged to the shale shaker. Sample returns for sand intervals were very poor. Some grab samples were directly collected from the sand pump discharges and these jar and chip tray samples of sand should be considered suspect and unrepresentative. As identified during the latter part of the sampling progress, the sand pump on the shale shaker was not running continuously while drilling. Retrieved sandy samples probably represent an admixture over an unspecified stratigraphic interval, rather than representing a discrete sand zone. Based on the rapid advance of the drill, the generation of sand waste, and the loss of drilling mud to the formation, sand zones in the interbeds appeared to be relatively unconsolidated. At no time were cuttings of cemented sands retrieved. Generally speaking, sands appeared to be only partially recovered by the drilling process.

The clay rich zones appeared to have squeezing properties, as evidenced by closing or partial closing of the borehole during drilling, reaming and geophysical logging. After initial drilling through an interbed, the hole was cemented, and then re-drilled. The remaining borehole cement column may be thin to non-existent in some intervals, as evidenced by retrieval of clay cuttings in cemented zones. Some of the squeezing zones had repetitive squeezing episodes. For some portions of the interbeds, the drillers reduced weight on the bit to avoid excessive bit advancement and potential for borehole deviation. The drillers tried to limit drill bit advance to15 to 20 ft/hr. However, the drillers also noted a decreased rate of drilling in some clay intervals due to enhanced adhesive properties of those zones. The adhesive clay conditions required the drillers to take extra time to wash out the clay to avoid clogging the drill bit. The decreased drilling rate likely resulted from using a hard-formation button bit rather than a bit with coarse teeth for drilling in the soft formations. Very few recognizable cuttings particles were retrieved while drilling through the interbeds.

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ICN 15848-2.2, 2006, Interim Change Notice, dated August 22, 2006, Pacific Northwest National Laboratory, Richland, Washington.

Myers CW et al. 1979. Geologic Studies of the Columbia Plateau—A Status Report. RHO-BWI-ST-4, Rockwell Hanford Operations, Richland, Washington.

PNNL-15848a, 2006, *Sampling and Analysis Plan Waste Treatment Plant Seismic Boreholes Project*, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-15848b, 2006, *Sampling and Analysis Plan Waste Treatment Plant Seismic Boreholes Project*, Rev. 1a, Pacific Northwest National Laboratory, Richland, Washington.

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

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APPENDIX A

BOREHOLE LOG FOR C4996

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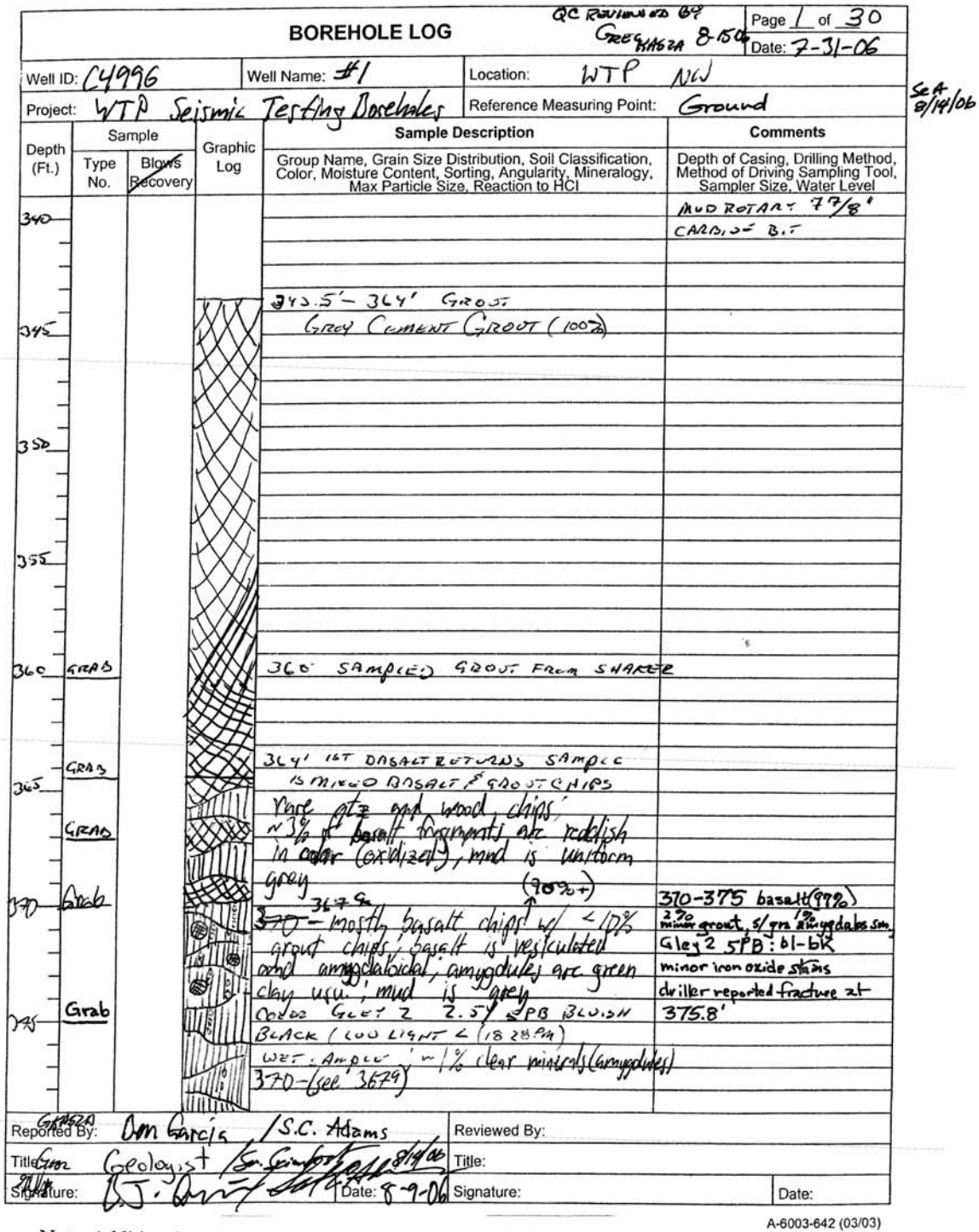


BOREHOLE LOG

QC REVIEWED BY GREG KASZA 8-15-06

Page 1 of 30

Date: 7-31-06

Well ID: C4996 | Well Name: #1 | Location: WTP NCJ

Project: WTP Seismic Testing Boreholes | Reference Measuring Point: Ground

SEA 8/14/06

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
340					MUD ROTARY 7 7/8" CARBIDE B.T
				343.5' – 364' GROUT. GREY CEMENT GROUT (100%)	
345					
350					
355					
360	GRAB			360' SAMPLE: GROUT FROM SHAKER	
	GRAB			364' 1ST BASALT RETURNS SAMPLE IS MIXED BASALT & GROUT CHIPS	
365	GRAB			Rare qtz and wood chips, <3% of basalt fragments are reddish in color (oxidized), mud is uniform grey	
370	Grab			367' (70%+) 370 – mostly basalt chips w/ <10% grout chips, basalt is vesiculated and amygdaloidal, amygdules are green clay usu.; mud is grey	370-375 basalt (99%) 2% minor grout, 1% amygdules sm. Gley 2 5PB: bl-bk minor iron oxide stains driller reported fracture at 375.8'
375	Grab			Color: GLEY 2 2.5/ 5PB BLUISH BLACK (LOU LIGHT < 18 28 PM) WET. AMPLE ~ 1% clear minerals (amygdules) 370-(see 3679)	

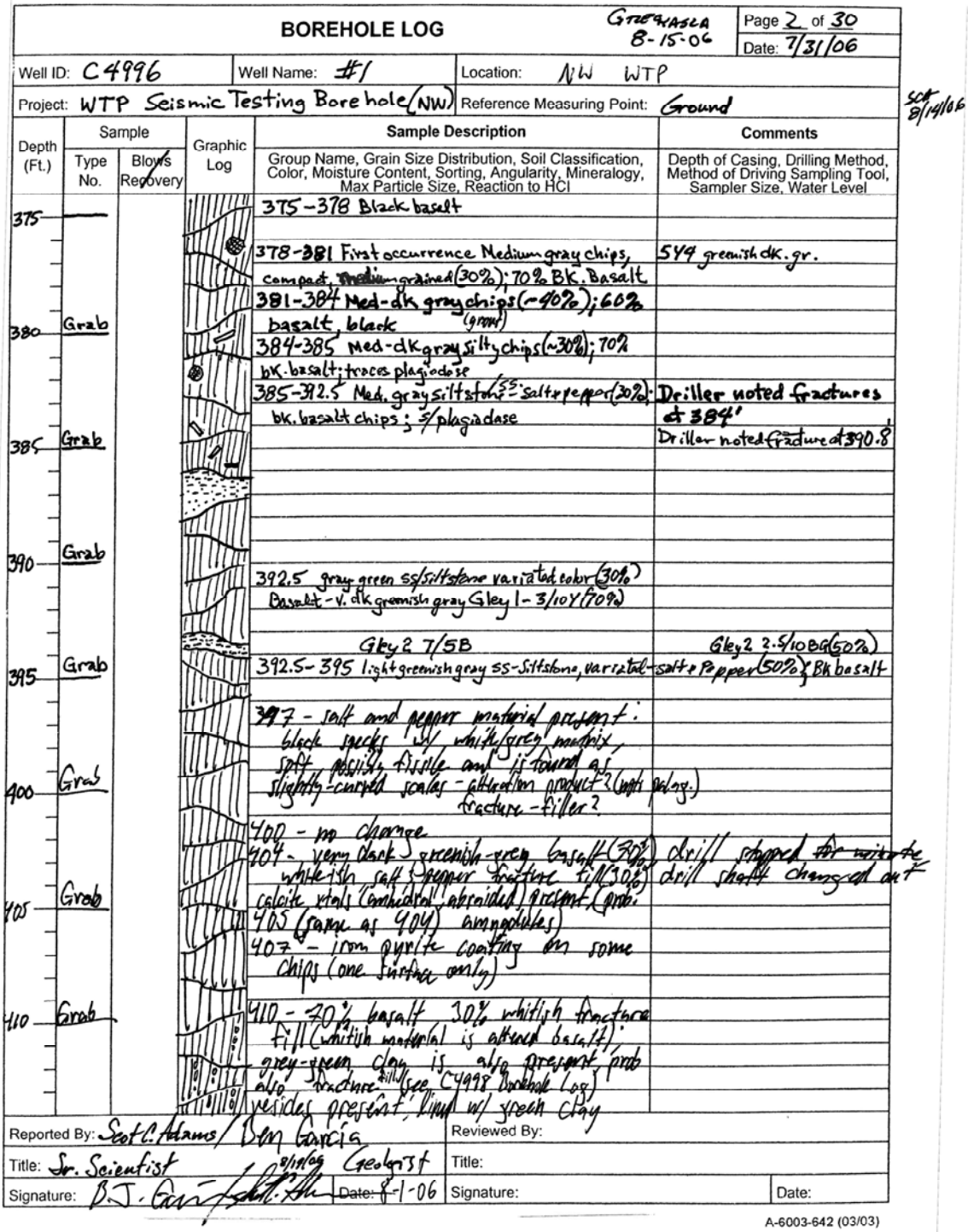
Reported By: GREG KASZA Dan Garcia / S.C. Adams | Reviewed By:

Title: Geologist | Title:

Signature: D.J. Garcia | Date: 8-9-06 | Signature: | Date:

A-6003-642 (03/03)

Note: Additional symbols used in the Graphic Log are documented in Appendix of PNNL-15848, Revision 2 CR 8/9/06



BOREHOLE LOG

GREGRASLA 8-15-06

Page 2 of 30

Date: 7/31/06

Well ID: C4996 | Well Name: #1 | Location: NW WTP

Project: WTP Seismic Testing Borehole (NW) | Reference Measuring Point: Ground

SCA 8/14/06

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
375				375-378 Black basalt	
				378-381 First occurrence Medium gray chips, compact, medium grained (30%); 70% BK. Basalt	549 greenish dk. gr.
				381-384 Med-dk gray chips (~40%); 60% basalt, black (grav)	
380	Grab			384-385 Med-dk gray silty chips (~30%); 70% bk. basalt; traces plagioclase	
				385-392.5 Med. gray siltstone/ss-salt+pepper (30%); bk. basalt chips; ⅓ plagioclase	Driller noted fractures at 384'
385	Grab				Driller noted fracture at 390.8
390	Grab			392.5 gray green ss/siltstone variated color (30%) Basalt - v. dk greenish gray Gley 1 - 3/10Y (70%)	
				Gley2 7/5B	Gley2 2.5/10BG (50%)
395	Grab			392.5-395 light greenish gray ss-Siltstone, variated - salt+Pepper (50%); Bk basalt	
				397 - salt and pepper material present: black specks w/ white/grey matrix, soft, possibly fissile and if found as slightly-curved scales - alteration product? (optl petrog.) fracture-filler?	
400	Grab			400 - no change	
				404 - very dark greenish-grey basalt (30%) drill shaped fragments with white/ish salt & pepper fracture fill (30%) drill shaft change out	
405	Grab			calcite veins (cemented, abraided) present (prob. 405 (same as 404) ammonoides)	
				407 - iron pyrite coating on some chips (one fracture only)	
410	Grab			410 - 70% basalt 30% whitish fracture fill (whitish material is altered basalt); grey-green clay is also present, prob also fracture fill (see C4998 Borehole Log) vesicles present, lined w/ green clay	

Reported By: Scot C. Adams / Ben Garcia		Reviewed By:	
Title: Sr. Scientist / Geologist		Title:	
Signature: B.J. Garcia	Date: 8-1-06	Signature:	Date:

A-6003-642 (03/03)

Note: Additional symbols used in the Graphic Log are documented in Appendix of PNNL-15848, Revision 2 CR 8/9/06

QS. Document Review
Grasso 9-15-06

BOREHOLE LOG

Page 3 of 30
Date: 7-31-06

Well ID: C4996 | Well Name: | Location: NW WTP
Project: WTP Seismic Testing Borehole #1 | Reference Measuring Point: Ground

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
415	GRAB	GR 9-15-06		415 - 70% basalt 30% whitish material (speckled) Color is GLEY 2 2.5/5PB bluish black, green clay and white Krystalline mineral as fracture fill	
420	GRAB	GR 9-15-06		basalt: 70% bas - 30% altered basalt (whitish, speckled), glass rind on fragment (only one found)	
425	GRAB	GR 9-15-06		basalt: 80% bas - 20% speckled grains glassy, scoriaceous material found (probably from scoriaceous enclave as seen in C4998 Borehole Log by D.D. Dermett)	
430	Grab			430-436' Basalt (80%); Speckled (same as above - 20%) traces of greenish-black platy fracture filling; hard-slow drilling sm. cuttings;	
435	Grab			435-436' basalt-bk, dense layer	V. slow drilling 435-436'
				436-440' Basalt, bk-dk gn (70%) dense Basalt - lt-med gray speckled; V. minor clear plag; V. minor orange-wt. fragment; Cutting sizes larger than above (30%)	faster drilling 436-
440	Grab			440-446' Basalt, bk-dk gr (80%) Basalt - med. gray speckled (~20%)	
					443' Minor zone Wt + Clear Chips
445	Grab	Elephant Mountain		446-447' Basalt BK-Gn. Basalt Black, glassy, minor White & black micro veins w/ plag; zeolas; phenocrysts	444-445 Minor DK. gn vein filling 447' gn. microveins;
	CONTACT	Rattle-Snake Ridge Interbed		447-450' Mixed brown color shift s/brown clay balls-sm.; Yellow Green-opal? s/Red-bn altered Rx fragments (basalt?)	Rapid advance 447-451'
450					

SCH 8/28/06

Reported By: Don Garcia / Scot C. Adams | Reviewed By:
Title: Geologist / Sr. Scientist | Title:
Signature: [signature] Date: 8/7/06 | Signature: Date:

A-6003-642 (03/03)

Note: Additional symbols used in the Graphic Log are documented in Appendix of PNNL-15848, Revision 2 CR 8/9/06

BOREHOLE LOG — GRASTA 9-15-06 — Page 4 of 30 — Date: 8/2/06 AM

Well ID: C4996 | Well Name: | Location: #1 WTP #1 (NW)

Project: WTP Seismic Testing Borehole(NW) | Reference Measuring Point: Ground by driller

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
					450' Color change brown
450	bag jar CC			450-451 s/red-brown rock chips	
				1/2"+ clay balls gray-bn.; 4-opal opaque	452' Clay balls (1st Occurrence)
				451-454 Reddish brown clay, R-Bn Rx (1st Occ.)	Rapid advance 451-453'
				455-Reddish grainy Rx frags (1st Occ)	
455	bag jar CC			456 Reddish sandstone? frags + mixed Rx from above	Rapid advance 453-460
				457 Reddish cream clay; mixed Rd.SS + Rx from above	
				458 Creamy-Pink clay + mixed Rx from above	Reduced drill pressure to get samples
				459 Lt. Gr-Cream, Plastic, silty clay	
460	bag jar CC			460 Lt Gray, Soft, plastic, silty clay	very soft, very plastic
				460 Lt Gray clay, very plastic, sticky, soft	460-465 Poor returns
					Scraped samples off shale shaker
465	bag jar CC		NO RETURNS	465-469' No sample returns, even on top of	shale shaker
				469-470' V. poor Sample from shale shaker (from ?) mixed materials	
470	bag			470-475 No cuttings returned; some sand, unconsolidated returned, bn-gr	potential flowing sand
				Sand slurry collected from 474-475'	
475	bag jar CC			475'-480' No chips returned	
				Collected jar of sand slurry - bn-gr.	
480	jar CC			(see 475') no chips returned	
485	jar CC			grey-brown med-coarse sand slurry, no chips returned	mud is grey-brown

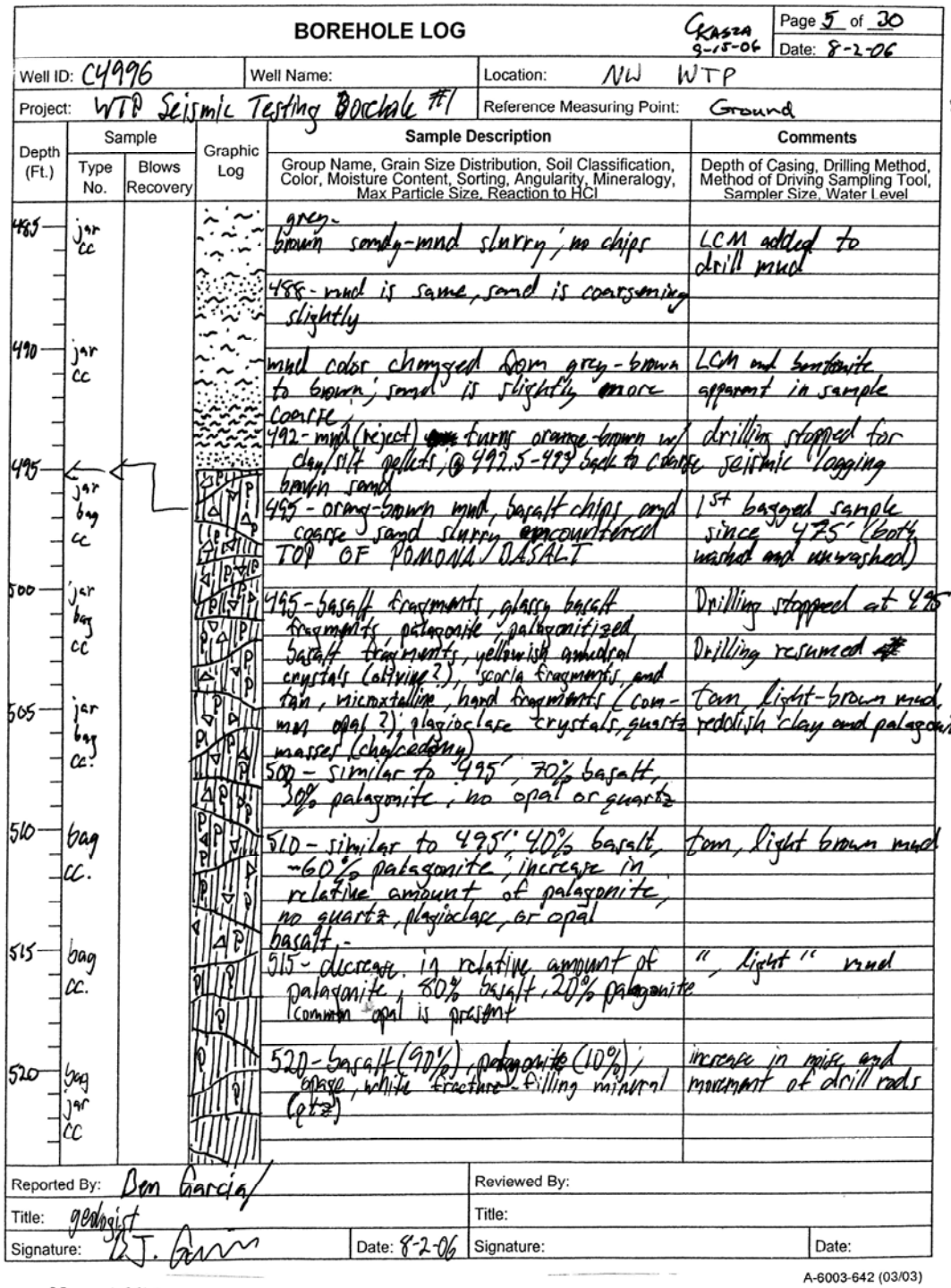
Reported By: Scott C. Hanny / Ben Garcia | Reviewed By:

Title: Sr. Scientist / Geologist | Title:

Signature: [signature] / D.J. Garcia Date: 8/2/06 | Signature: | Date:

A-6003-642 (03/03)

Note: Additional symbols used in the Graphic Log are documented in Appendix of PNNL-15848, Revision 2 CR 8/9/06



BOREHOLE LOG

Grasza 9-15-06

Page 5 of 30

Date: 8-2-06

Well ID: C4996 | Well Name: | Location: NW WTP

Project: WTP Seismic Testing Borehole #1 | Reference Measuring Point: Ground

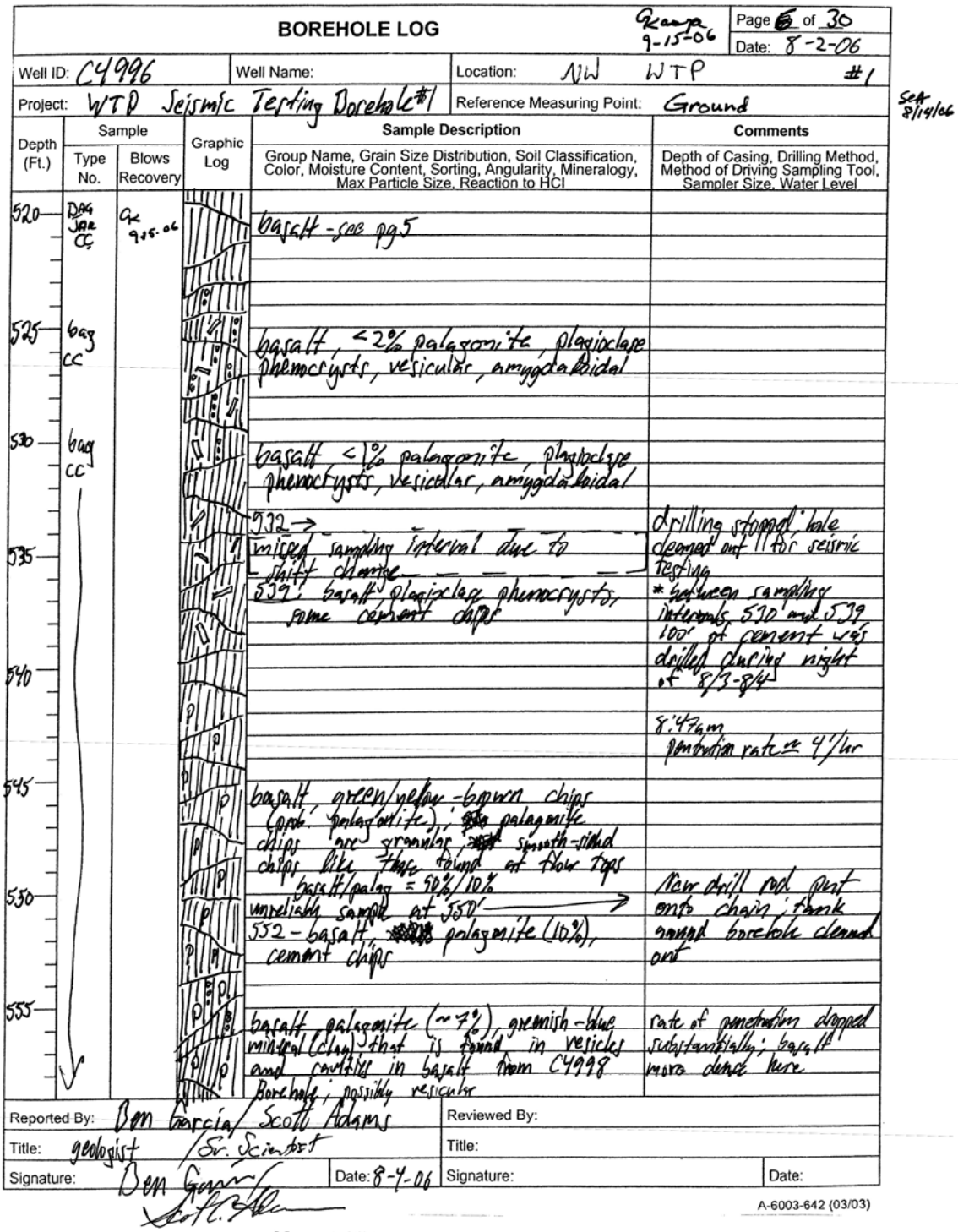
8/17/06 SCN

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
485	jar cc			grey-brown sandy-mud slurry, no chips	LCM added to drill mud
				488 - mud is same, sand is coarsening slightly	
490	jar cc			mud color changed from grey-brown to brown; sand is slightly more coarse	LCM and bentonite apparent in sample
				492 - mud (reject) turns orange-brown w/ clay/silt pellets; @ 492.5-493 back to coarse brown sand	drilling stopped for seismic logging
495	jar bag cc			495 - orang-brown mud, basalt chips and coarse sand slurry encountered TOP OF POMONA BASALT	1st bagged sample since 475' (both washed and unwashed)
500	jar bag cc			495 - basalt fragments, glassy basalt fragments palagonite, palagonitized basalt fragments, yellowish anhedral crystals (olivine?), scoria fragments, and tan, microcrystalline, hard fragments (common opal?), plagioclase crystals, quartz masses (chalcedony)	Drilling stopped at 495' Drilling resumed at tan, light-brown mud, reddish clay and palagonite
505	jar bag cc			500 - similar to 495', 70% basalt, 30% palagonite, no opal or quartz	
510	bag cc.			510 - similar to 495', 40% basalt, ~60% palagonite, increase in relative amount of palagonite, no quartz, plagioclase, or opal basalt.	tan, light brown mud
515	bag cc.			515 - decrease in relative amount of palagonite, 80% basalt, 20% palagonite common opal is present	", light" mud
520	bag jar cc			520 - basalt (90%), palagonite (10%); vesicular, white fracture-filling mineral (qtz)	increase in mist and movement of drill rods

Reported By: Don Garcia		Reviewed By:	
Title: geologist		Title:	
Signature: D.J. Garcia	Date: 8-2-06	Signature:	Date:

A-6003-642 (03/03)

Note: Additional symbols used in the Graphic Log are documented in Appendix of PNNL-15848, Revision 2 CR 8/9/06



BOREHOLE LOG

Ramp 9-15-06

Page 6 of 30

Date: 8-2-06

Well ID: C4996 | Well Name: | Location: NW WTP #1

Project: WTP Seismic Testing Borehole #1 | Reference Measuring Point: Ground

SEA 8/14/06

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)
520	DAG JAR CC	Qx 9-15-06		basalt - see pg 5	
525	bag CC			basalt, <2% palagonite, plagioclase phenocrysts, vesicular, amygdaloidal	
530	bag CC			basalt <1% palagonite, plagioclase phenocrysts, vesicular, amygdaloidal	
				532 → missed sampling interval due to shift change	drilling stopped, hole cleaned out for seismic testing
535				539: basalt, plagioclase phenocrysts, some cement chips	* between sampling intervals 530 and 539, 100' of cement was drilled during night of 8/3-8/4
540					8:47am penetration rate = 4'/hr
545				basalt, green/yellow-brown chips (prob. palagonite), palagonite chips are granular, smooth-sided chips like these found on flow tops	
550				basalt/palag = 90%/10% unreliable sample at 550' → 552 - basalt, palagonite (10%), cement chips	new drill rod pint onto chain, tank rinsed, borehole cleaned out
555				basalt, palagonite (~7%), greenish-blue mineral (clay) that is found in vesicles and cavities in basalt from C4998 Borehole, possibly vesicular	rate of penetration dropped substantially; basalt more dense here

Reported By: Ben Garcia / Scott Adams | Reviewed By:

Title: geologist / Sr. Scientist | Title:

Signature: Ben Garcia Scott C. Adams | Date: 8-4-06 | Signature: | Date:

A-6003-642 (03/03)

Note: Additional symbols used in the Graphic Log are documented in Appendix c
PNNL-15848. Revision 2 CR 8/9/06

BOREHOLE LOG

Grouted 9-15-05

Page 7 of 30

Date: 8-4-06

Well ID: C4996 | Well Name: | Location: NW WTP #1

Project: WTP Seismic Drilling Borehole | Reference Measuring Point: Ground

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
560	bag CC			basalt, palagonite (5%), greenish-blue secondary mineral	
565	bag CC			basalt, palagonite (3%), greenish-blue secondary mineral, red-brown clay (<1%)	
570	bag CC			basalt palagonite (<2%), greenish-blue secondary mineral (5%), red-brown clay (<1%)	
575	Jar bag CC			570-590' Basalt, bk; s/opaline fracture-tan; plagioclase phenocrysts; cemented clay bands Rd-Br to tan (~10%). Basalt is compact w/ minor vesicles Basalt gr-bk mottled (~15%); opal-bl-wt-clear, trace	575-580'-hard drilling
580	Jar Bag CC				580-585' Driller noted fractures and more rapid drilling
585	Jar Bag CC				585'- Driller noted harder drilling-slower
590	Jar Bag CC				590-596' penetration rt: ~1.8 ft/hr
595	SAA CC			black basalt, minor palagonite (<2%), greenish blue mineral (possibly chalcedony, ~5%) red-brown clay (<1%), whitish, opaque fracture filling mineral (<1%)	596 - increase in avg. penetration rate ~ 2.2 ft/hr

Reported By: Ben Garcia / Scot C. Adams | Reviewed By:

Title: Geologist / Sr. Scientist | Title:

Signature: B.J. Garcia / Scot C. Adams Date: 8-4-06 | Signature: Date:

A-6003-642 (03/03)

Note: Additional symbols used in the Graphic Log are documented in Appendix of PNNL-15848, Revision 2 CR 8/9/06

BOREHOLE LOG

GRASZA 9-15-06 | Page 8 of 30 | Date: 8/5/06

Well ID: C4996 | Well Name: | Location: WTP NW #1 (NW)

Project: WTP Seismic Drilling Borehole #1 | Reference Measuring Point: Ground

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
600	bag cc			Basalt, palagonite (<1%) - blue green mineral (<2%), red-brown clay (<1%)	Slight decrease in drilling rate; very hard drilling
605	bag cc			Basalt; same as above	
610	bag Jar cc	Sent 8/14/06		608-610' Basalt - BK+Gray (~98%) Clay - Limonite - mottled orange-brown; vein-filling white; vesicle filling - clear+cream. 610-620.8' Basalt BK+Gray (~98%) vesicle filling - cream - orange with s/clear. No limonite-like material was noted, no plagioclase	Driller noted fracture zone at 613'; temperature increase?
615	Bag Jar cc				Geolographer error corrected. 620.3' Sample collected as composite Driller noted fracture at 620.3'
620	Bag Jar cc				624' Geolograph Corrected
625	Bag Jar cc				627' S/grout in cuttings from cleaning chip tank
630	bag jar cc			basalt, palagonite, opaque-white mineral, green-blue clay (basalt is 98% of sample), vesicular; plagioclase phenocrysts, 1-1.5 mm in length color GLEY2 2.5/5PB, bluish black	slight increase in penetration rate
635	bag cc			Basalt (99%), opaque-white to tan mineral, green-blue clay mineral color GLEY2, 2.5/5B, bluish Black	stopped at 636.5' equipment behind drill rig cab was smoking Drilling started 1544

Reported By: Don Garcia / Scott Adams/Idaho Geo | Reviewed By:

Title: geologist | Title:

Signature: D.T. Garcia 8/14/06 Date: 8-5-06 | Signature: | Date:

A-6003-642 (03/03)

Note: Additional symbols used in the Graphic Log are documented in Appendix of PNNL-15848, Revision 2 CR 8/9/06

BOREHOLE LOG

Grasza 9-15-06

Page 9 of 20

Date: 8/8/06 7CR 8/11/06

Well ID: C4996 | Well Name: | Location: WTP NW | Reference Measuring Point: GROUND

Project: WTP Seismic Drilling BOREHOLE #1

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
640	bag jar CC			640 CR 8/9/06	640-645: Slow drilling avg 2 ft/hr
				~~640~~-645:	
645	bag jar CC			Basalt - aphanitic, color: GLEY 2 2.5/5B no phenocrysts, white 2nd clay minerals on some surfaces <5%	Hard Drilling <2 ft/hr
				Small cuttings avg: 3-4mm x 1cm	645-650 ft drilling rate was <1.5 ft/hr
				645-650:	
650	bag jar CC			Basalt - aphanitic	
651 jar				color: GLEY 2 2.5/5B	Rig broke down after sample was taken at 650 ft bgs
				clay <1%	
				color 7.5 YR 4/4	
				greenish, blue 2nd minerals on few surfaces	
655	bag jar CC			650-655: aphanitic basalt, 1% tan-brown mineral (fractures?) XRD CR 8/9/06	Rig speed up to ~2.5 to 3 ft/hr
				Colors GLEY 2 3/10 BG	
				655-660': aphanitic basalt 1% palagonite, 1% blue-green clay	CR 8/9/06
660	bag jar CC			found in fractures	Rig has ~~steam~~ stayed at ~3 ft/hr
				Colors GLEY 2 2.5/10B6	
				660-665' Basalt, 1% tan-brown mineral, 1% blue-green clay, few phenocrysts	
665	bag jar CC			665-670: Aphanitic Basalt with blue-green clay on few surfaces <1%, 2% tan mineral, no phenocrysts in basalt.	
670	bag jar CC			670-675: Aphanitic Basalt, no phenocrysts	Slow drilling 1.5 ft/hr @ 670.5-672 ft
				Color: GLEY 2 2.5/10BG	
				<1% blue green clay	
				<1% brown mineral	Still avg 1.5 ft/hr @ 675 ft
675	bag jar CC			675-680: Basalt w/ characteristics of 670-675	

Reported By: Colleen Rust / Steve Ahlquist | Reviewed By:

Title: Geologist | Title:

Signature: S. Ahlquist C. Rust | Date: 8-7-06 | Signature: | Date:

A-6003-642 (03/03)

Note: Additional symbols used in the Graphic Log are documented in Appendix of PNNL-15848, Revision 2 CR 8/9/06

BOREHOLE LOG GRAB A 9-15-06 | Page 10 of 30 | Date: 8/9/06

Well ID: C4996 | Well Name: | Location: WTP NW

Project: WTP Seismic Borehole #1 | Reference Measuring Point: GROUND

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
680	bag jar cc			680-681.5 Aphanitic basalt Increase in brown-yellow minerals palagonite 5%	
685	bag jar cc			681.5-685: Aphanitic basalt, decrease in brown minerals <2%	
690	bag jar cc			685-690: aphanitic basalt continued decrease in brown minerals <1%	
695	bag jar cc			690-695: aphanitic basalt w/ few palagonite, no phenocrysts	
698	bag jar cc			695-698: aphanitic basalt, few (1%) brown minerals, microveins w/plagioclase green-blue fracture minerals	
699.5	CONTACT			699.5': grey mud/clay slurry w/ ~5% basalt chips (see jar)	NOTE: Pipe was pulled up 20' and allowed to recirculate, so mud chips from walls mixed w/sample
700	jar			701.2': grey clay w/ brown pockets of clay With ~20% basalt chips (see note →)	
701.2	jar, cc			701.7: same as 701.2 but fewer basalt chips present ~10-15% (see note →)	
701.7	jar			TOP OF SELAH INTERBED	
705				705': No chips sampled through shaker	
706	GRAB			706': Hand GRAB (in column): Brown + green-grey clay	
708	GRAB cc			708: Same as 706', Brown clay in larger pieces	
710	jar			710': No chips recovered, only sand/mud slurry, see jar	
711.8	GRAB cc			711.8: Brown + grey clay w/ ~5% basalt	
715	GRAB cc			715': Brown clay had larger pieces, very plastic Grey clay was very sticky in comparison, few basalt chips (~5%)	
716.9	GRAB			716.9': Green clay + Brown clay, more basalt	
718.6	GRAB			718.6': mostly green clay (~90%) w/ brown clay and basalt (10%)	

8/24/06

Reported By: Steve Ahlquist / Colleen Rust | Reviewed By:

Title: Geologist | Title:

Signature: S. Ahlquist / Colleen Rust | Date: 8/9/06 | Signature: | Date:

A-6003-642 (03/03)

Note: Additional symbols used in the Graphic Log are documented in Appendix of PNNL-15848, Revision 2 CR 8/9/06

BOREHOLE LOG

RELEASED 9-15-06 | Page 11 of 30 | Date: 8/10/06

Well ID: C4996 | Well Name: | Location: NW WTP

Project: HTP Seismic Borehole #1 | Reference Measuring Point: Ground

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
720		bag jar cc		720'- 95% basalt with ~5% green clay	
		CONTACT		TOP OF ESQUATZEL BASALT	
				→ brown/tan minerals present	
					VERY FAST DRILLING!
725		BAG GL-9-15-06		with vesicles present	10 ft/hr drilling rate
				728'-730': Aphanitic basalt, abundant green-blue minerals present in fractures	
728		bag jar cc		of core C4998 + ~1% brown mineral	DRILL SLOWED BACK DOWN
730		bag jar cc		730-735': Aphanitic basalt, green clay (~5%) and green-blue minerals	~2 ft/hr drilling rate
				790-740 (SA 8/10/06)	
				735-740: Aphanitic basalt	
735		bag jar cc		1% blue-green mineral in fractures	drilling at ~1.5 ft/hr
				1% brown-red mineral	
				1% New green-white mineral, platey w/ smooth flat surfaces	
740		bag jar cc			
				740-745: Dark gray to black aphanitic basalt,	
				5% blue green minerals	Drilling stopped at 7410 for
745		bag jar cc		1% brown red mineral	geophysical survey
				745-750: aphanitic basalt, black to grey with a glassy texture similar to samples	
				720-745: >5% blue-green mineral, some is very friable, 1% tan mineral	Cement plug was poured 8/11/06 to an uncertain depth.
750		bag jar cc		750-755: aphanitic basalt, plagioclase phenocrysts, pyrite on surface, blue-green + tan-brown mineral	Cement poured again on 8/12/06 to a final depth of 620 ft bgs.
				755: Basalt (~50%) Green-blue mineral (~50%), highest % seen <1% brown mineral, with some clay, phenocrysts	
755		bag jar cc			Geologic ~2.5ft off recalibrated (1500) 8/13/06

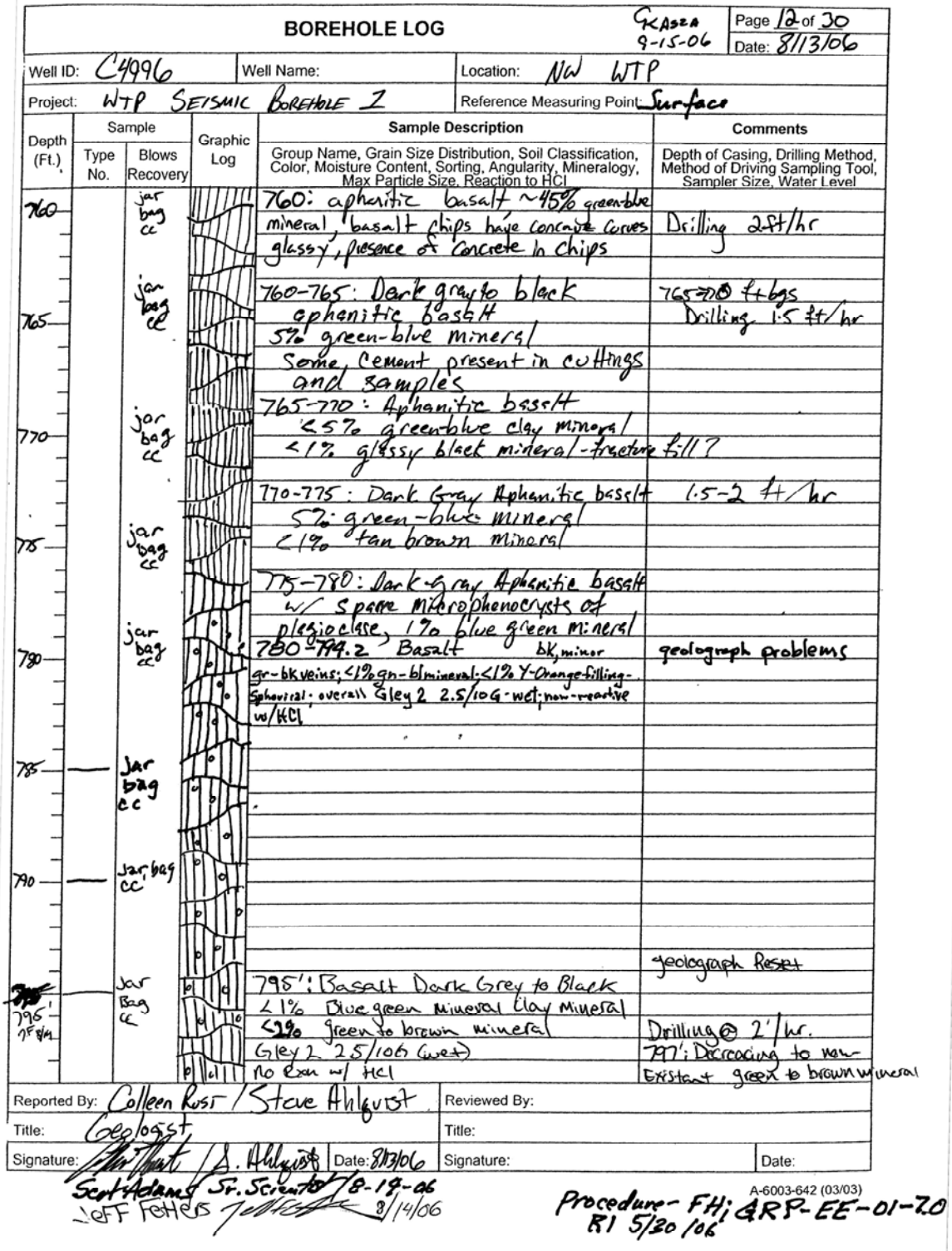
Reported By: Colleen Rust / Steve Ahlquist | Reviewed By:

Title: Geologist / Geologist | Title:

Signature: C. Rust / S. Ahlquist | Date: 8/10/06 | Signature: | Date:

A-6003-642 (03/03)

Note: Additional symbols used in the Graphic Log are documented in Appendix of PNNL-15848, Revision 2 CR 8/9/06



BOREHOLE LOG

GKASZA 9-15-06

Page 12 of 30

Date: 8/13/06

Well ID: C4996 | Well Name: | Location: NW WTP

Project: WTP SEISMIC BOREHOLE 1 | Reference Measuring Point: Surface

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
760		jar bag cc		760: aphanitic basalt ~45% greenblue mineral, basalt chips have concave curves glassy, presence of concrete in chips	Drilling 2ft/hr
765		jar bag cc		760-765: Dark gray to black aphenitic basalt 5% green-blue mineral Some cement present in cuttings and samples	765=0 ft bgs Drilling 1.5 ft/hr
770		jar bag cc		765-770: Aphanitic basalt <5% greenblue clay mineral <1% glassy black mineral - fracture fill?	
775		jar bag cc		770-775: Dark Gray Aphanitic basalt 5% green-blue mineral <1% tan brown mineral	1.5-2 ft/hr
780		jar bag cc		775-780: Dark-gray Aphanitic basalt w/ sparse microphenocrysts of plagioclase, 1% blue green mineral	
785		Jar bag cc		780-799.2 Basalt bk, minor gr-bk veins; <1% gn-bl mineral; <1% Y-Orange filling - Spherical; overall 5GY 2.5/10G - wet; non-reactive w/HCl	geolograph problems
790		Jar bag cc			
795		Jar Bag cc		795': Basalt Dark Grey to Black <1% Blue green Mineral Clay Mineral <2% green to brown mineral 5GY 2.5/10G (wet) no Rxn w/ HCl	geolograph Reset Drilling @ 2'/hr. 797': Decreasing to non-Existant green to brown mineral

Reported By: Colleen Rust / Steve Ahlquist | Reviewed By:

Title: Geologist | Title:

Signature: C. Rust / S. Ahlquist | Date: 8/13/06 | Signature: | Date:

Scott Adams Sr. Scientist 8-19-06

JEFF FOTHERS 8/14/06

A-6003-642 (03/03)

Procedure - FH: GRP-EE-01-7.0 R1 5/20/06

BOREHOLE LOG

GRAZA 9-15-06

Page 13 of 30

Date: 8/14/06

Well ID: C4996 | Well Name: | Location: MW WTP

Project: WTP Seismic Borehole 1 | Reference Measuring Point: Surface

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
800	Bag Jar CC			800-804 Aphanitic Basalt; No Blue Green clay mineral seen, 1% Brown/Green mineral, Few glassy black minerals present; 2gey 2.5/10y minor gray grout pieces	Drilling @ 15-2'/hr No core to compare w/ 803': slight ↑ Drill rate
805	Bag Jar CC			804-819.5' Basalt aphanitic, two tone Black and dk. gray, <1% Yellow/orange vesicle fillings, chips are flat shaped like paper, < blue-green fragment @ 809' ~1%	increasing Brown/tan mineral chips becoming smaller in size 805-810' Drilling slow/hard
810	Bag Jar CC			812-814.5 blue-green fragments jumped to ~7%	very hard, cutting differently 811.5' driller reported faster cutting
		Equivalent		814.5 Apparent break through - rapid cutting 814.5-820. Siltstone, Poorly consolidated, Soft, poor cutting return, Gley1 3/10Y	812-813' - 4'/hr drilling rate Poor sample return 814.5→
815	Bag Jar CC	Cold Creek Interbed		820-825 Same as above 825-827 SS-Siltstone 80% Grayish green Gley1 5/5GY; 20% Plats - rusty tan	Cold Creek Interbed at 814.5 - CONTACT
820	Bag Jar CC	not enough sample		827-830 Clayey Siltstone greenish gray Gley 5/5G 4 Poor Sample recovery - clay chips only	Geology problems 823-828 Reset at 828'
825	Bag Jar CC				drill rate ~16'/hr.
830	Bag Jar CC			830-835 Probably unconsolidated Sand from core reference - No chips water-sand recovered - Olive green 835-840 Unconsolidated sand - medium grained, olive green	only a few lag clay chips were screened. Small Jar Sample of Sand-Mud
835	No Recovery of Chips Jar CC				24 ft/hr - drilling rate 783.8' sand more firm per driller

Reported By: Jeff Fetters / Scot C. Adams | Reviewed By:

Title: Geologist / Sr. Scientist | Title:

Signature: Jeff Fetters / Scot C. Adams | Date: 8-15-06 | Signature: | Date:

PROCEDURE - PH; GRP-EE-01-20 R1 5/30/06

A-6003-642 (03/03)

BOREHOLE LOG

Page 14 of 30
Date: 8-15-06

Well ID: C 4996 | Well Name: | Location: WTP – NW
Project: WTP Seismic Borehole #1 | Reference Measuring Point: Ground

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
840	Jar CC No bag			840 – 873 Sand, medium, unconsolidated olivegreen 95% 9/2/other 5% black to Dark green mineral VF to C sand grains are Angular to sub angular; Some micas present	Collected as slurry fast drilling 11.1 ft/hr. No cuttings, only slurry Fast Drilling Rate
845	Jar CC No bag				
850	Jar CC No bag				
855	Jar CC				
860	Jar CC				
865	Jar CC			865'; Same lithology as above w/ slightly Finer sand grains. Sub Angular to Sub Rounded; Possible silt size grains	Drill Rate = 7.5'/hr ~~5%~~ basalt chips, From above?
870	Jar CC			870'; Same lithology as above Sand is med. to V-Fine, more rounding of Grains. Maybe Silt Present?	
873	grab Jar			873' more clay Poor Sample Recovery See Jar 1gray 3/N	
875	Jar CC			875'– Fine to VF grained Sand, same lithology as 840-873', higher Silt content, not as much clay as 873'; increasing black mineral ~~60%~~ 8%	Driller has begun adding water to mud mix geodagraph out of cal. Reset to correct depth

Reported By: Scot C. Adams / JEFF FETTERS | Reviewed By:
Title: Sr. Scientist / Geologist | Title:
Signature: Scot C. Adams | Date: 8/16/06 | Signature: | Date:

Procedure – FH; GRP-EE-07-28
R1 5/30/06

A-6003-642 (03/03)

BOREHOLE LOG

Groundwater 9-15-06

Page 15 of 30

Date: 8-15-06

Well ID: C4996 | Well Name: | Location: WTP- NW

Project: WTP seismic Borehole #1 | Reference Measuring Point: Ground

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
880	Jar CC			879': Clay 2Gley 4/5b; Few med sand grains w/ in clay; Dark bluish gray	
				880' Clay 2Gley 4/5b Dark bluish gray	- Sand grains are coarser than 879 sample
885	Jar CC			885': Fine to vF Sand, small ammounts of clay present; Gley1 4/10GY Dark greenish grey; Sand 60% qtz, 40% Mafics 5% Dark green/black mineral; Angular to Sub angular grains	
	grab			888': clay material sampled From shaker double contains .5-15mm Friable pices not seen in 885' sample	888' see Jar
890	Jar CC			890' same as 888' Gley1 3/5GY, no sand	890' sampled From Shaker
895	Jar CC			895': Clay Gley1 3/10Y; contains Friable ~~Pebbles~~ Pieces Seen in 888' sample but in much less quanity. Few w/r qtz vF grains visible.	
900	Jar CC No bag			895-900' Clay Green-gray, Gley1 4/5 GY silty, s/f-m. sand.	Poor Sample returns Drilling rate 9'/hr.
				900-910.8' Clay Grn-Grr, Gley1 3/5G; silty; washed in basalt + sand	
905	Jar CC No bag				
	Jar CC				
910	COLD CREEK INTERBED				Geologist stopped working @~910
No bag	Umatilla Basalt			910.8-920' Basalt top Basalt-70%; black-Gley1 2.5/5B; Basalt-15% Dk Gr.-Gley1 4/5B; 15% Blue-Green fracture filling (large pieces); minor Yellow-Orange vesicle filling; botryoidal	3.2 ft./hr.
915	Jar CC bag				

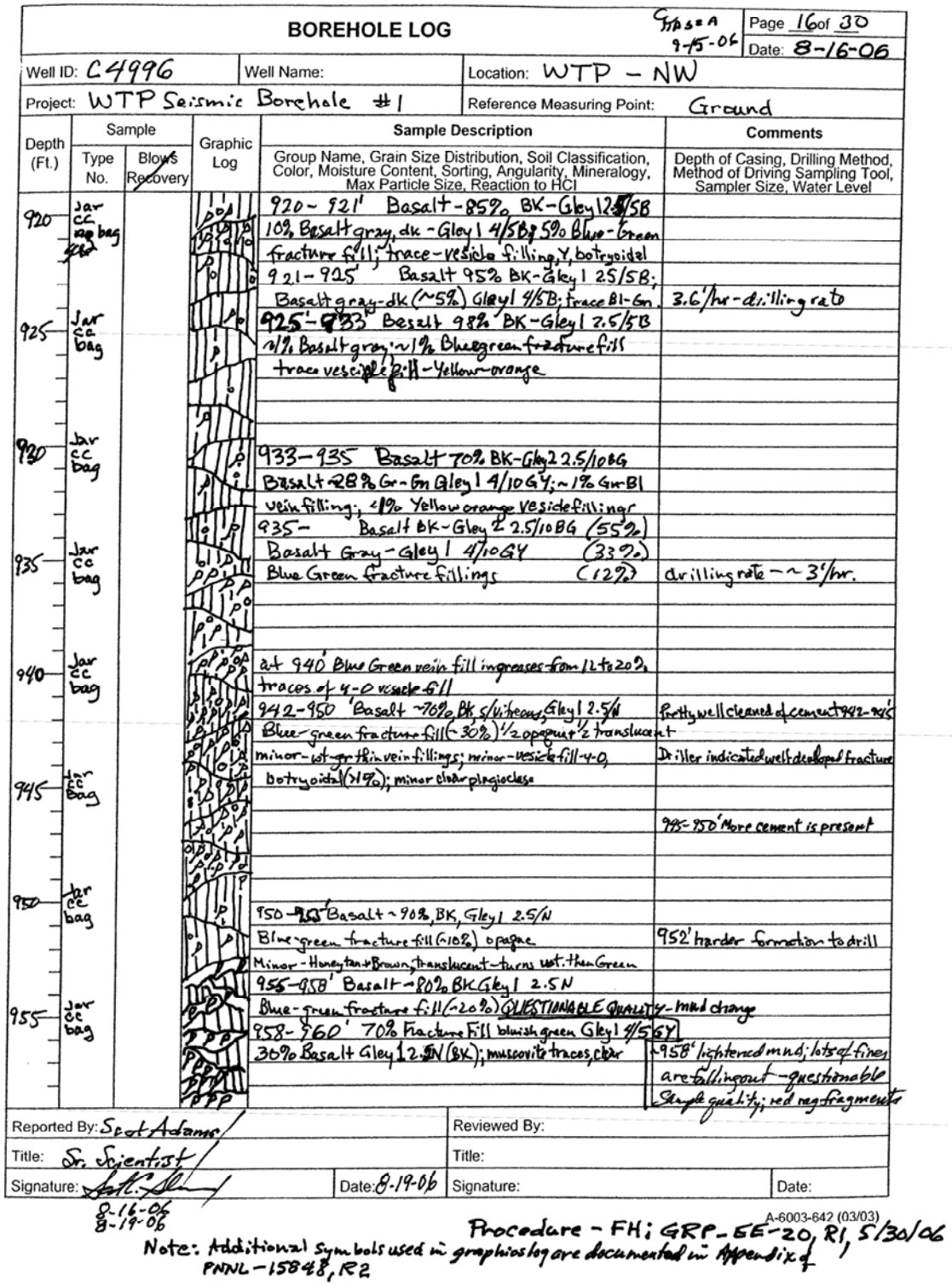
Reported By: Jeff Fehers / Scot C. Adams | Reviewed By:

Title: Geologist / Sr. Scientist | Title:

Signature: / Date: 8-16-06 | Signature: | Date:

A-6003-642 (03/03)

PROCEDURE - FH; GRP-EE-01-'20, R1, 5/30/06



BOREHOLE LOG

GPS = A 9-15-06

Page 16 of 30

Date: 8-16-06

Well ID: C4996 | Well Name: | Location: WTP – NW

Project: WTP Seismic Borehole #1 | Reference Measuring Point: Ground

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
920	Jar CC bag bag			920 – 921' Basalt – 85% BK – Gley1 2.5/5B	
				10% Basalt gray, dk – Gley1 4/5B; 5% Blue – green fracture fill; trace – vesicle filling, Y, botryoidal	
				921 – 925' Basalt 95% BK – Gley1 2.5/5B;	
				Basalt gray – dk (~5%) Gley1 4/5B; trace Bl-Gn.	3.6'/hr – drilling rate
925	Jar CC bag			925 – 933' Basalt 98% BK – Gley1 2.5/5B	
				1% Basalt gray, 1% Blue green fracture fill	
				trace vesicle fill – Yellow-orange	
930	Jar CC bag			933 – 935 Basalt 70% BK – Gley2 2.5/10BG	
				Basalt 28% Gr – Gn Gley1 4/10GY; ~1% Gn-Bl	
				vein filling; <1% Yellow orange vesicle filling	
935	Jar CC bag			935 – Basalt BK – Gley2 2.5/10BG (55%)	
				Basalt Gray – Gley1 4/10GY (33%)	
				Blue Green fracture fillings (12%)	drilling rate – ~ 3'/hr.
940	Jar CC bag			at 940' Blue Green vein fill increases from 12 to 20%,	
				traces of 4-0 vesicle fill	
				942 – 950' Basalt ~70% BK, S/vitreous, Gley1 2.5/N	Pretty well cleaned of cement 942 – 945'
				Blue – green fracture fill (~30%) 1/2 opaque 1/2 translucent	
945	Jar CC Bag			minor – wt. gr thin vein fillings; minor – vesicle fill – 4-0,	Driller indicated well developed fracture
				botryoidal (1%); minor clear plagioclase	
					945 – 950' More cement is present
950	Jar CC bag			950 – 955' Basalt ~ 90%, BK, Gley1 2.5/N	
				Blue – green fracture fill (~10%) opaque	952' harder formation to drill
				Minor – Honeytan + Brown, translucent – turns wt. then Green	
				955 – 958' Basalt ~ 80% BK Gley1 2.5N	
955	Jar CC bag			Blue – green fracture fill (~20%) QUESTIONABLE QUALITY – mud change	
				958 – 960' 70% Fracture Fill bluish green Gley1 5/5GY	
				30% Basalt Gley1 2.5N (BK); muscovite traces, clear	958' lightened mud; lots of fines are falling out – questionable sample quality; red rag fragments

Reported By: Scot Adams | Title: Sr. Scientist | Signature: [signature] 8-16-06 8-19-06 | Date: 8-19-06

Reviewed By: | Title: | Signature: | Date:

A-6003-642 (03/03)

Procedure – FH; GRP-EE-20, R1, 5/30/06

Note: Additional symbols used in graphics log are documented in Appendix of PNNL-15848, R2

BOREHOLE LOG C4A92A 9-15-06 | Page 17 of 30 | Date: 8-19-06

Well ID: C4996	Well Name:	Location: WTP NW
Project: WTP Seismic Borehole #1		Reference Measuring Point: Ground

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
960	Jar CC Bag				Drilling rate ~ 3'/hr
				960-963' Basalt, Bk, (70%) Gley 1 2.5N; 3020 Green-fracture fill bluish green, opaque; trace-muscovite	s/fines still falling out
				trace - Red-Bn vesicle fill	
				963-970' Basalt Bk (70%) Gley 1 2.5N	continued red fiber from Cloth
965	Jar CC Bag			Green-fracture fill (30); traces mica; trace R-Bn mineral	
970	Jar CC Bag				
975	Jar CC Bag			975': Basalt Gley 1 2.5/N; Small amounts of Greenish Brown clay like mineral Aphanitic texture; Trace bluish grey mineral present	Drilling ≈ 2'/hr high amounts of cement mixed w/ cuttings
980	Jar CC Bag			980'-983' Basalt Gley 1 2.5/N (Black) high amounts of bluish green/grey opaque mineral, much larger chunks than the basalt, banding present, Slight Conchoidal Fracture, Friable; Basalt cuttings very small	Bluish green/grey Material Resembles material found in core hx # 70 5546 - 562.9 Color = Gley 2 2.5/5PB When Dries, breaks apart easily
985	Jar Bag CC			981' - Decreasing Bluish green/grey material 985' - more bluish green/grey material than @ 984' but smaller size; trace Red Brown Gley 1 2.5/N	
990	Jar Bag CC			990' Basalt; same as above; no Red Brown mineral present	↑ Drill Rate
995	Jar Bag CC			Same as above, Cutting are coming off Shaker in Clumps, possibly ↑ bluish green/grey content Rinsing Removes most of it; Few Vesicals present	Drill is bouncing, possible Fracture zone ?

Reported By: Scott C. Adams / Jeff Fathers — Reviewed By:

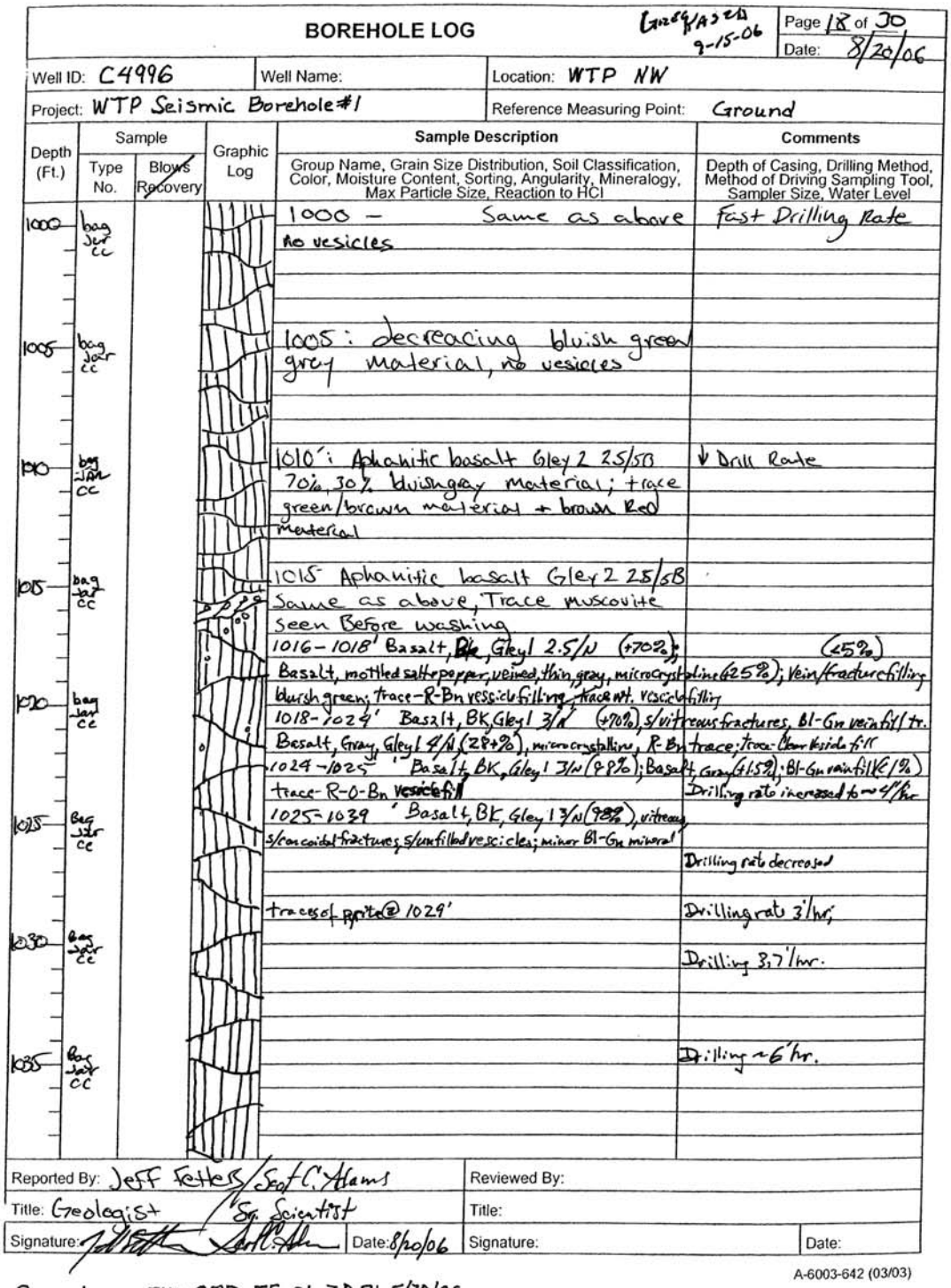
Title: Sr. Scientist / Geologist — Title:

Signature: 8/20/06 — Date: 8/20/06 — Signature: — Date:

A-6003-642 (03/03)

Procedure - FH: GRP-EE-01-7.0, RI 5/30/06

Additional Symbols used in the Graphic Log are documented in Appendix of PNNL-15848, R



BOREHOLE LOG Grab Samples 9-15-06 | Page 18 of 30 | Date: 8/20/06

Well ID: C4996 | Well Name: | Location: WTP NW

Project: WTP Seismic Borehole #1 | Reference Measuring Point: Ground

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
1000	bag Jar CC			1000 – Same as above No vesicles	Fast Drilling Rate
1005	bag Jar CC			1005: decreasing bluish green grey material, no vesicles	
1010	bag Jar CC			1010': Aphanitic basalt Gley 2 2.5/5B 70%, 30% bluish gray material; trace green/brown material + brown Red material	↓ Drill Rate
1015	bag Jar CC			1015' Aphanitic basalt Gley 2 2.5/5B Same as above, Trace muscovite Seen Before washing 1016–1018' Basalt, Blk, Gley1 2.5/N (+70%); Basalt, mottled salt+pepper, veined, thin gray, microcrystalline (25%); vein/fracture filling bluish green; trace-R-Bn vesicle filling, trace wt. vesicle filling 1018–1024' Basalt, BK, Gley1 3/N (+70%), s/vitreous fractures, Bl-Gn vein fill/tr. Basalt, Gray, Gley1 4/N (28+%), microcrystalline, R-Bn trace; trace-Clear beside fill 1024–1025' Basalt, BK, Gley1 3/N (88%); Basalt, Gray (41%); Bl-Gn vein fill (1%) trace-R-O-Bn vesicle fill 1025–1039' Basalt, BK, Gley1 3/N (98%), vitreous s/conchoidal fractures, s/unfilled vesicles; minor Bl-Gn mineral traces of pyrite @ 1029'	(<5%) Drilling rate increased to ~4'/hr Drilling rate decreased Drilling rate 3'/hr Drilling 3.7'/hr. Drilling ~6'/hr.
1020	bag Jar CC				
1025	Bag Jar CC				
1030	Bag Jar CC				
1035	Bag Jar CC				

Reported By: Jeff Fetter / Scott C. Adams | Reviewed By:

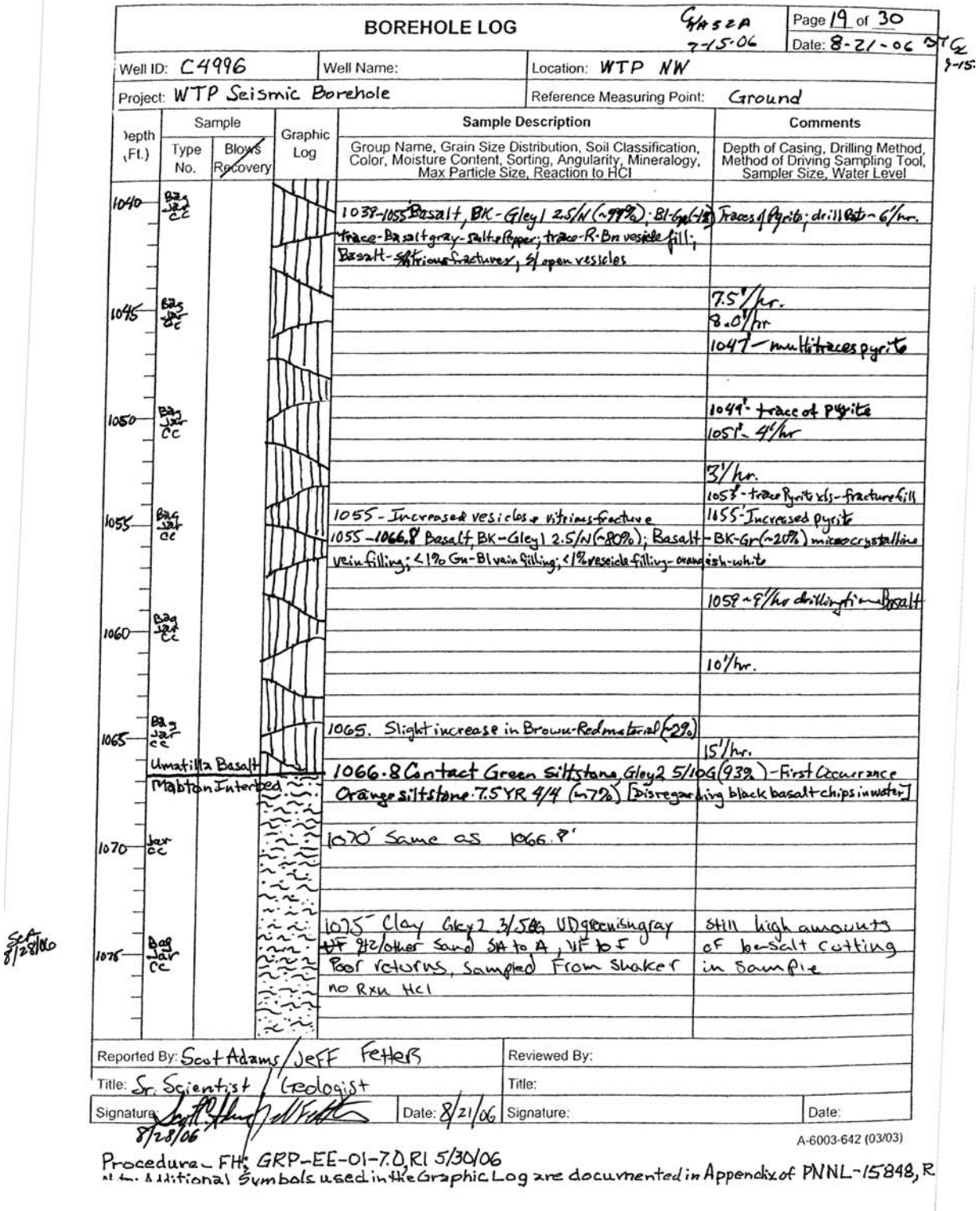
Title: Geologist / Sr. Scientist | Title:

Signature: | Date: 8/20/06 | Signature: | Date:

A-6003-642 (03/03)

Procedure – FH: GRP-EE-01-7.0, R1 5/30/06

Additional Symbols used in the Graphic Log are documented in Appendix of PNNL-15848, R



BOREHOLE LOG

C/A SZA 7-15-06

Page 19 of 30

Date: 8-21-06 STC 7-15-

Well ID: C4996 | Well Name: | Location: WTP NW

Project: WTP Seismic Borehole | Reference Measuring Point: Ground

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	Bag Jar CC			1038-1055 Basalt, BK - Gley1 2.5/N (~99%); Bl-Gy (1%) trace-Basalt gray-salt&Pepper; trace-R-Brn vesicle fill; Basalt-~~Salt~~ vitrious fractures, ~5% open vesicles	Traces of Pyrite; drill Rate ~ 6'/hr.
1045	Bag Jar CC				7.5'/hr. 8.0'/hr 1047 - multi traces pyrite
1050	Bag Jar CC				1049' - trace of pyrite 1051' - 4'/hr 3'/hr. 1053' - trace Pyrite x/s - fracture fill
1055	Bag Jar CC			1055 - Increased vesicles & vitrious fracture 1055 - 1066.8' Basalt, BK - Gley1 2.5/N (~80%); Basalt - BK-Gr (~20%) microcrystalline vein filling; <1% Gn-Bl vein filling; <1% vesicle filling - orangeish-white	1055' Increased pyrite
1060	Bag Jar CC				1058 ~ 8'/hr drilling fine Basalt 10'/hr.
1065	Bag Jar CC			1065. Slight increase in Brown-Red material (~2%)	15'/hr.
	Umatilla Basalt			1066.8 Contact Green Siltstone, Gley2 5/10G (93%) - First Occurrance	
	Mabton Interbed			Orange siltstone 7.5 YR 4/4 (~7%) [Disregarding black basalt chips in water]	
1070	Jar CC			1070' Same as 1066.8'	
1075	Bag Jar CC			1075' Clay Gley2 3/5BG UD greenish gray VF %2/other Sand SA to A, VF to F Poor returns, Sampled From Shaker no Rxn HCl	Still high amounts of bentonite cutting in Sample

SCA 8/28/06

Reported By: Scott Adams / Jeff Fethers | Reviewed By:

Title: Sr. Scientist / Geologist | Title:

Signature: 8/28/06 | Date: 8/21/06 | Signature: | Date:

A-6003-642 (03/03)

Procedure - FH: GRP-EE-01-7.0, R1 5/30/06

* Additional Symbols used in the Graphic Log are documented in Appendix of PNNL-15848, R.

BOREHOLE LOG

GJ/ASZA 9-15-06 | Page 20 of 30 | Date: 8-21-06 GJ/ASZA 9-15-06

Well ID: C4996 | Well Name: | Location: WTP NW

Project: WTP Seismic Borehole #1 | Reference Measuring Point: Ground

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
1080	cc Jar bag			1080': Sandy clay, Sand: med to C 60% QZT/other 40% basalt, SA to SR: Color Gley 2 4/10G dark greenish gray, visible Muscovite no Rxn HCl	Drilling ≈ 12'/hr
1085	cc Jar bag			1085' = Decreacing clay, just enough to make sand clump 60% QZT/other, 40% basalt C to med. A to SA no Rxn HCl	Sampled From shaker ↓ Drill Rate
1090	cc Jar bag			1090' - 1100': increased clay content ↓ grainsize of sand med to Fine 60% QZT 40% basalt, SR, Color Gley1 4/10gy no Rxn HCl	Sampled From Shaker
1095	cc Jar bag				
1100	cc Jar bag			1100' → 1103' Sand: C to Fine 60% QZT other 40% basalt, A to SA, little to no clay no Rxn HCl	Did not have to sample From Shaker top
				1103' slight increase in clay content	
1105	cc Jar bag			1105' sand, high basalt content ~75% basalt 25% QTZ/other; QTZ sand grains SA to SR basalt = Angular; Small amounts of clay material ~~Contact close?~~ had to Sample From shaker top.	Driller notes harder drilling @ 105 1108' Driller states bit is sinking faster, through hard spot
1110	Jar cc bag			~~1108~~ 1110 Sand: Same as 1105 Sample Driller Reporting hard drilling, maybe 80% basalt 20% quartz/other, no Rxn HCl	Driller notes hard drilling 1110 Possible cemented gravel layer,
1113	1st Jar bag cc			1113' higher clay content sand sized grains Possible gravel layer 85% Basalt ~~15~~ 15% QTZ/other Basaltic gravel layer? Gley 2 5/10g	1113' Driller Notes Easier drilling higher Clay content
1115	2nd Jar bag cc			Basalt grains Angular QTZ/other Rounded 1115' same as 1113' Sampel no Rxn HCl Clay is Plastic?	Sampled From Shaker

Reported By: Jeff Fetters | Reviewed By:

Title: Geologist | Title:

Signature: Jeff Fetters | Date: 9/21/06 | Signature: | Date:

A-6003-642 (03/03)

Procedure – FH: GRP-EE-01-7.0, R1 5/30/06

* Additional Symbols used in the Graphic Log are documented in Appendix of PNNL-15848, R

BOREHOLE LOG Geologist 9-15-06 | Page 21 of 30 | Date: 8/21/06

Well ID: C4996 | Well Name: | Location: WTP NW

Project: WTP Seismic Borehole | Reference Measuring Point: Ground

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)
1120					
				1125': Sandy clay, increase in sand size particles	problem with geolograph - reset to 1125 ft bgs so no sample taken at 1120 ft
1125	Bag Jar cc			40% Sand - medium to coarse -80% basalt coarse sand angular 60% clay to silt size grains Sand consists of quartz, light colored mica (muscovite), tan & brown lithics	
1130	Bag Jar cc			1130': Sandy clay, increase in clay content. Clay color: GLEY 2 5/10G Sand: medium to course 80% coarse angular basalt 20% qtz, brown lithics, mica,	6 ft/hr No returns at 1135 ft so no sample taken. Cuttings from well directly show
1135				Poor returns	
1140	Bag Jar cc			1140': Clayey Sands. medium to coarse sands, 80% angular basalt 20% qtz, lithics (brown), other decrease in clay content	same lith as 1130 ft 6 ft/hr No returns to shaker tray
1145	Bag Jar cc			1145': More clayey sand similar to 1130'-1140', increase in angular basalt cuttings Small amounts of blue-green mineral <1%	10 ft/hr
1150	Bag Jar cc			Sand: rounded qtz, brown lithics, muscovite	
1155	Bag Jar cc			1150': Mostly clay clumps in cuttings taken directly from mud at pit of well. Cuttings from shaker accumulated from 1145-1150 consist of 80% angular basalt. Samples collected from Shaker ~~1155: Non return to shaker~~	GLEY 2 5/10G 1155 ft bgs No samples taken Very little return

Reported By: Steve Ahlquist | Reviewed By:

Title: Geologist | Title:

Signature: S. Ahlquist Date: 8/21/06 | Signature: Date:

A-6003-642 (03/03)

Procedure - FH: GRP-EE-01-7.0, R1 5/30/06

Alt. - Additional Symbols used in the Graphic Log are documented in Appendix of PNNL-15848, R2

9-15-05 22

BOREHOLE LOG

CR 8/21/06

Page 1 of 30

Date: 8/21/06

Well ID: C4996 | Well Name: | Location: WTP NW

Project: WTP Seismic Borehole | Reference Measuring Point: Ground

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	Bag Jar CC			1155: Sandy clay: major increase in clay content, angular basalt cuttings, 5% medium sand: qtz, mica, lithics	Driller notes harder drilling at 1161 ft bgs
1165	Jar			1160: Dark Aphanitic basalt, 25% clay, 5% sand: medium, rounded qtz, mica, tan-brown lithics, black lithics, grey	
	Bag Jar CC	Mabton INTERBED PRIEST RAPIDS BASALT		1168: Dark Aphanitic basalt <5% rounded sand grains	Major increase in basalt content, decrease in clay/sand - Priest Rapids contact ~1168 ft
1170	CC Jar			1170: Black aphanitic basalt, 30% green-blue clay, <5% green clay, friable, appearence of opague green mineral, and red-brown per CR 8/21/06 oxidized mineral	Mud was spilled out pit into mud shaker "contamination," only a CC sample was taken
1175	CC Jar			1175: Black aphanitic basalt, 25% green-blue clay, few basalt pieces with white, appears to be veins	From well top remains were put in jar. CR 8/21/06 ~~MISSED SAMPLE~~
				1180: Same as above, with clear white mineral present	
1180	CC jar				
1181	CC jar bag			1181: Black basalt, some pieces with white crystals within basalt, presence of red-brown oxidized mineral, 30% green-blue clay, opaque tan mineral	→ NOTE: GEOGRAPH 12' off → sample depth is wrong should be 1169' or 1170'
1185	CC jar bag			1185: Black basalt, 30% green-blue clay, 1% red-brown oxidized mineral, no phenocrysts	3-4 ft/hr drilling
1190	CC jar			1190: Black aphanitic basalt, 25% green-blue clay, <1% opal mineral	
1195	CC jar bag			1195: Black aphanitic basalt, 10% green-blue clay, 5% white and black basalt veins? tan-brown opague fracture mineral, visible crystal growths on one side	Drilling stopped for cement
1198'				1198: Same as above	

Reported By: Steve Ahlquist/Colleen Rust | Reviewed By:

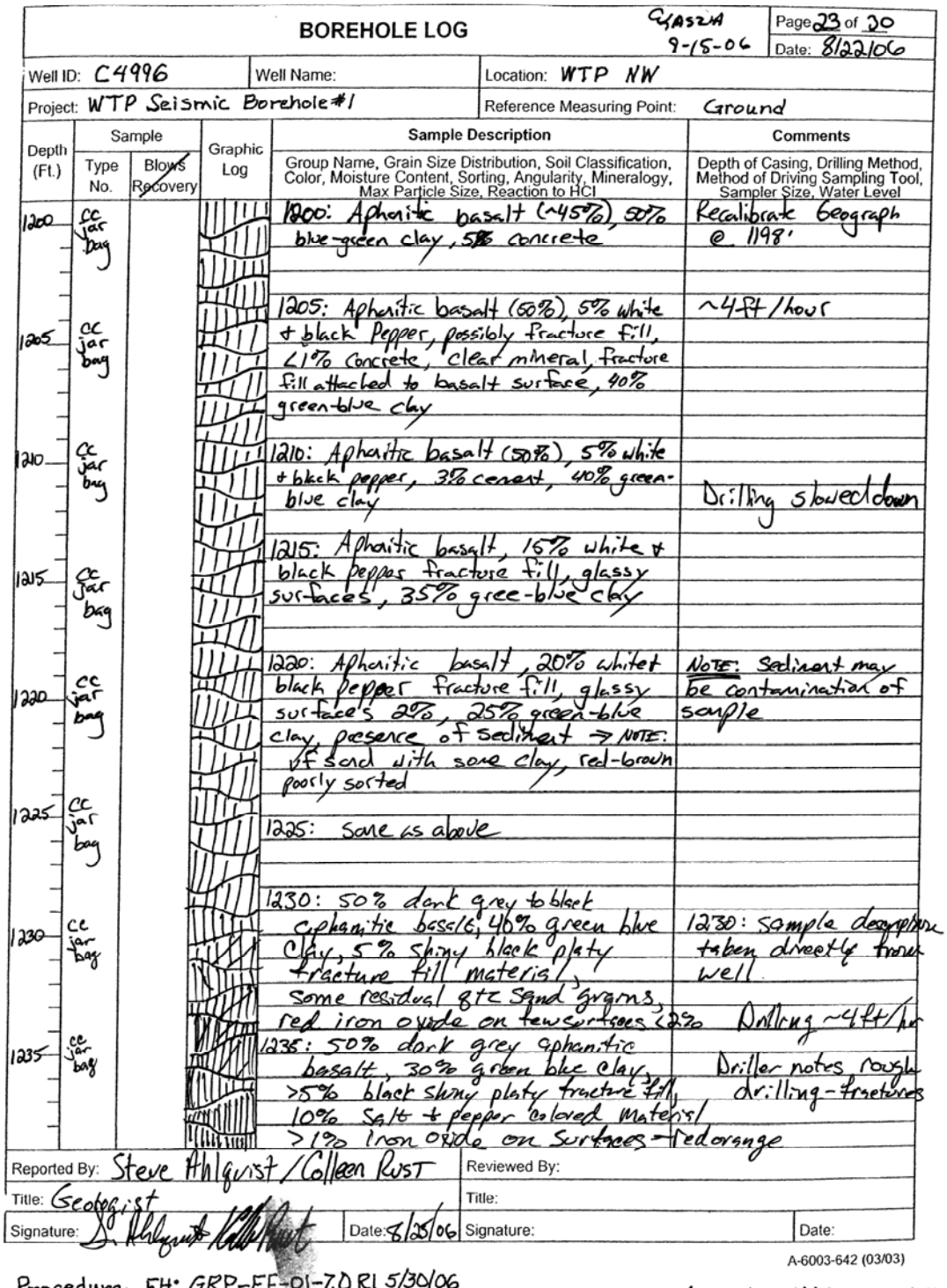
Title: Geologist | Title:

Signature: S. Ahlquist/C. Rust | Date: 8/21/06 | Signature: | Date:

A-6003-642 (03/03)

Procedure: FH: GRP-EE-01-7.0, R1 5/30/06

Note: Additional Symbols used in the Graphic Log are documented in Appendix of PNNL-15848, R2



BOREHOLE LOG C4A52A 9-15-06 | Page 23 of 30 | Date: 8/22/06

Well ID: C4996 | Well Name: | Location: WTP NW

Project: WTP Seismic Borehole #1 | Reference Measuring Point: Ground

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)
1200	CC jar bag			1200: Aphanitic basalt (~45%), 50% blue-green clay, 5% concrete	Recalibrate Geograph @ 1198'
				1205: Aphanitic basalt (50%), 5% white & black Pepper, possibly fracture fill, <1% concrete, clear mineral fracture fill attached to basalt surface, 40% green-blue clay	~4-ft/hour
1205	CC jar bag				
1210	CC jar bag			1210: Aphanitic basalt (50%), 5% white & black pepper, 3% cement, 40% green-blue clay	Drilling slowed down
1215	CC jar bag			1215: Aphanitic basalt, 15% white & black peppas fracture fill, glassy surfaces, 35% gree-blue clay	
1220	CC jar bag			1220: Aphanitic basalt, 20% white & black pepper fracture fill, glassy surfaces 2%, 25% green-blue clay, presence of sediment → NOTE: vf sand with some clay, red-brown poorly sorted	NOTE: Sediment may be contamination of sample
1225	CC jar bag			1225: same as above	
1230	CC jar bag			1230: 50% dark grey to black aphanitic basalt, 40% green blue clay, 5% shiny black platy fracture fill materisl, some residual qtz sand grains, red iron oxide on few surfaces <2%	1230: sample description taken directly from well. Drilling ~4ft/hr
1235	CC jar bag			1235: 50% dark grey aphanitic basalt, 30% green blue clay, >5% black shiny platy fracture fill, 10% Salt & pepper colored materisl >1% iron oxide on surfaces - red orange	Driller notes rough drilling - fractures

Reported By: Steve Ahlquist / Colleen Rust | Reviewed By:

Title: Geologist | Title:

Signature: [signature] Date: 8/25/06 | Signature: Date:

A-6003-642 (03/03)

Procedure - FH: GRP-EE-01-7.0, R1 5/30/06

Additional Symbols used in the Graphic Log are documented in Appendix of PNNL-15848, R

BOREHOLE LOG

9-15-06 | Page 24 of 30 | Date: 8/25/06

Well ID: C4996 | Well Name: | Location: WTP NW

Project: WTP Seismic Borehole #1 | Reference Measuring Point: Ground

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
1240	CC jar bag			1240: 50% dark gray to black aphanitic basalt, 30% salt & pepper colored material, 20% green blue clay, orange red clay material on few surfaces <1% - moderately friable	Drill rate ~3.2 ft/hr
1245	CC jar bag			1245: 50% dark gray to black aphanitic basalt, 30% salt & pepper colored material, 15% green blue clay, 5% hard black shiny fracture fill - platy and moderately friable	
1250	CC jar bag			1250: 80% dark gray to black aphanitic basalt 10% green blue clay <5% black shiny fracture fill	Drill rate ~3.7 ft/hr
1255	CC jar bag			5% Saltation 5% salt & pepper color material/ zeolite mineral & 1% cement still present in cuttings	
1260	CC jar bag			1255: 90% Dark gray aphanitic basalt, 5% Salt & pepper colored material, ~5% green blue clay	
1265	CC jar bag			1260: Same as 1255	
1270	CC jar bag			1265: Dark gray aphanitic basalt 5% green blue clay, 5% salt & pepper colored cuttings, <1% shiny & platy black fracture fill, Iron oxide on few basalt surfaces <1%	GYRO COMPLETED DRILL RATE ~3.1 ft/hr
1275	CC jar bag			1270: Dark gray aphanitic basalt, <5% green-blue clay, 20% salt & pepper colored fracture fill, iron oxide on a few basalt surfaces <1%	
				1275: Dark gray aphanitic basalt, <1% green-blue clay, 35% salt & pepper colored fracture fill	

Reported By: Steve Ahlquist / Colleen Rust | Reviewed By:

Title: Geologist | Title:

Signature: [signature] Date: 8/25/06 | Signature: Date:

A-6003-642 (03/03)

Procedure: FH: GRP-EE-01-7.0, R1 5/30/06

Alt. text: Additional Symbols used in the Graphic Log are documented in Appendix of PNNL-15848, R

BOREHOLE LOG

KAS2A 7-15-06

Page 25 of 30

Date: 8/25/06

Well ID: C4996 | Well Name: | Location: WTP NW

Project: WTP Seismic Borehole #1 | Reference Measuring Point: Ground

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
1280	CC jar bag			1280: Dark Gray basalt, 25% salt + pepper material, ~5% green-blue clay	Drilling Rate increased to ~4.9'/hr
1285	CC jar bag			1285: same as above	Drilling Rate decreased to ~3'/hr
1290	CC jar bag			1290: Dark gray basalt, 20% salt + pepper materal, 5% green-blue clay, opaque tan mineral on a basalt surface.	Reset geograph @ 1294'
1295	CC jar bag			1295: Dark gray + Black aphanitic basalt, <5% salt + pepper material, ~50% green-blue clay, opaque tan-brown mineral of fracture fill	Driller noted rough + bumpy drilling typical of a fracture zone
1300	CC jar bag			1300: Dark gray + Black basalt, ~50% clay (~25% light green clay, ~25% darker green clay) cement is still showing up in samples	
1305	CC jar bag			1305: Dark gray + black basalt with microphenocrysts of plagioclase, 40% green blue and blue clays, small amount of shiny black platy fracture fill, cement present, <1% red to brown silty material	
1310	CC jar bag			1310: Dark gray to black aphanitic basalt, 20% salt and pepper colored cuttings, 10% green blue and light green clay, <1%: clumps of brown silt	Drilling rate ~3+/hr
1315	CC jar bag			~~1305~~: same as 1310 1315 SA 8/26/06	

Reported By: Colleen Rust / Steve Ahlquist | Reviewed By:

Title: Geologist | Title:

Signature: C. Rust / S. Ahlquist Date: 8/26/06 | Signature: | Date:

A-6003-642 (03/03)

Procedure: FH: GRP-EE-01-7.0, R1 5/30/06 SA

Additional Symbols used in the Graphic Log are documented in Appendix of PNNL-15848, R

BOREHOLE LOG

GRASCA 9-15-06

Page 26 of 30

Date: 8/26/06

Well ID: C4996	Well Name:	Location: WTP NW
Project: WTP Seismic Borehole #1		Reference Measuring Point: Ground

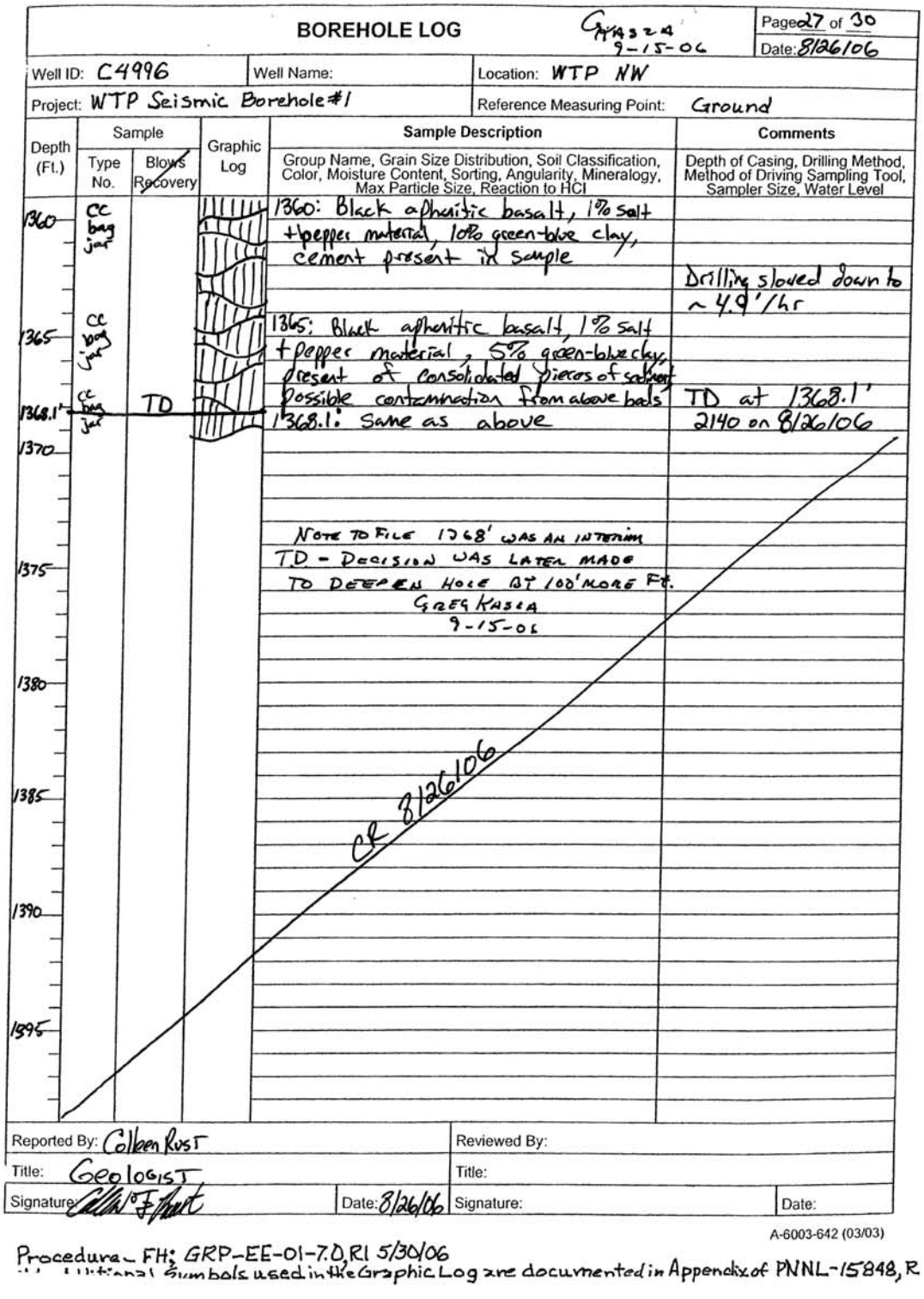
Depth (Ft.)	Sample Type No.	Sample Blows/Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
1320	CC bag jar			1320: 80% dark gray basalt with sparce plagioclase microphenocrysts, 15% salt & pepper colored cuttings, ~5% green blue clay	Driller notes much easier drilling @ 1322'
1325	CC bag jar			1322: 80% green blue clay/siltstone 15% angular - sandsized basalt cuttings, <1% brown silt clumps, trace amounts of muscovite <<1%	drill rate aug ~ 15 ft/hr
				1325: Same as 1322 - sample taken - sparce Muscovite Mica present	
1330	CC bag jar			1330: Decrease in clay/silt content ~40% 60% Dark gray to black aphanitic basalt	~ 10 ft/hr
				90% SA 8/26/06	
1335	CC bag jar			1335: ~~80%~~ dark gray aphanitic basalt, ~ 10% green blue clay, <1% brown silt clumps	
1340	CC bag jar			1340: 95% dark gray to black basalt w/ sparce plagioclase microphenocrysts, <5% green blue clay, <1% clumps of brown silt, trace amounts of gte-grains; angular	Drilling @ ~ 10 ft/hr
1345	CC bag jar			1345: Black basalt with few microphenocrysts of plagioclase, <5% green blue clay, <1% translucent green mineral	
1350	CC bag jar			1350: Black basalt - aphanitic, <5% green blue clay, small amounts (<1%) of angular gte. and translucent light green mineral, cement still present	Drill rate ~ 6.5 ft/hr
1355	CC bag jar			1355: same as above - (1350')	

Reported By: Steve Ahlquist	Reviewed By:
Title: Geologist	Title:
Signature: S. Ahlquist Date: 8/26/06	Signature: Date:

A-6003-642 (03/03)

Procedure - FH: GRP-EE-01-7.0, R1 5/30/06

* Additional Symbols used in the Graphic Log are documented in Appendix of PNNL-15848, R1



BOREHOLE LOG GW43224 9-15-06 | Page 27 of 30 | Date: 8/26/06

Well ID: C4996 | Well Name: | Location: WTP NW

Project: WTP Seismic Borehole #1 | Reference Measuring Point: Ground

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)
1360	CC bag jar			1360: Black aphanitic basalt, 1% salt + pepper material, 10% green-blue clay, cement present in sample	Drilling slowed down to ~4.9'/hr
1365	CC bag jar			1365: Black aphanitic basalt, 1% salt + pepper material, 5% green-blue clay, present of consolidated pieces of sediment possible contamination from above beds	
1368.1'	CC bag jar	TD		1368.1: Same as above	TD at 1368.1' 2140 on 8/26/06
1370					
1375				NOTE TO FILE 1368' WAS AN INTERIM T.D. - DECISION WAS LATER MADE TO DEEPEN HOLE BY 100' MORE FT. GREG KNOLL 9-15-06	
1380					
1385					
1390					
1395					

8/26/06 cf

Reported By: Colleen Rust | Reviewed By:

Title: Geologist | Title:

Signature: Colleen Rust | Date: 8/26/06 | Signature: | Date:

A-6003-642 (03/03)

Procedure: FH: GRP-EE-01-7.0, R1 5/30/06

Additional Symbols used in the Graphic Log are documented in Appendix of PNNL-15848, R

BOREHOLE LOG

Grasza 9-15-06

Page 28 of 30

Date: 8/31/06

Well ID: C4996 | Well Name: | Location: WTP NW

Project: WTP Seismic Borehole | Reference Measuring Point: Ground

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
1370	cc bag jar			1370: Dark gray aphanitic basalt, 10% green blue clay, <1% subrounded quartz grains ≤1mm, very sparce muscovite (may be contamination from Mabton), decrease in size of basalt cuttings - avg 1.5 mm diameter	penetration rate ~2ft/hr
1375	cc bag jar			1375: Dark gray to black aphanitic basalt, 5% green blue clay, 1% pale green siltstone, <1% tan to pale green chalcedony, cement	penetration ~2.3ft/hr
1380	cc bag jar			1380: black basalt with sparce microphenocrysts of plagioclase, 10% green blue clay, 2% pale green siltstone, few rounded qtz grains ≤1mm	
1385	cc bag jar			1385: black aphanitic basalt, green blue clay <5%, sperce rounded quartz grains, brown clay/silt <1%	penetration rate 3ft/hr
				SA 8/31/06	penetration rate ~6ft/hr
1390	cc bag jar			1390: Black ~~aphanitic~~ basalt - glassy, 10% shiny black platy fracture fill, ~2% green blue mineral, <1% yellow to brown chalcedony, abundant plagioclase phenocrysts	
1395	cc bag jar			1395: Same as 1390 with increase in green blue clay ~5%,	penetration ~7ft/hr
				SA 8/31/06	
1400	cc bag jar			1400: Black ~~aphanitic~~ basalt, 5% green blue clay, red iron oxide mineral on few surfaces <1%, <1% translucent green mineral, very fine basalt cuttings with few plag phenocrysts	penetration ~7ft/hr
1403	cc bag jar			1403: same as 1400	
1405	cc bag jar			1405: black aphanitic basalt, 5% green-blue clay, 5% clear white mineral, 5% white & black pieces very fine basalt cuttings	

Reported By: Steve Ahlquist / Colleen Rust | Reviewed By:

Title: Geologist | Title:

Signature: S. Ahlquist / Colleen Rust | Date: 8/31/06 | Signature: | Date:

A-6003-642 (03/03)

Procedure - FH: GRP-EE-01-7.0, R1 5/30/06

Additional Symbols used in the Graphic Log are documented in Appendix of PNNL-15848, R2

BOREHOLE LOG

GRADE A 9-15-06

Page 29 of 30

Date: 8/31/06

Well ID: C4996 | Well Name: | Location: WTP NW

Project: WTP Seismic Borehole | Reference Measuring Point: Ground

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
1410	CC bag jar			1410: black aphanitic basalt, 5% salt + pepper pieces, 5% green-blue clay, <1% clear white mineral, 1% opaque green mineral	Penetration ~11.7 ft/hr
1415	CC bag jar			1415: black aphanitic basalt, 2% salt + pepper pieces, <5% green-blue clay, <1% opaque green mineral	
1420	CC bag jar			1420: black aphanitic basalt, <5% green-blue clay, red iron oxide on mineral/rock surface >5%, 1% salt + pepper cuttings	Penetration ~5.1 ft/hr
1425	CC bag jar			1425: black aphanitic basalt, 5% green-blue clay, 5% salt + pepper cuttings with a white mineral in the same chips (~zeolite)	Penetration ~6.3 ft/hr
1430	CC bag jar			1430: black aphanitic basalt, 5% green-blue clay, 5% salt + pepper cuttings, a few surfaces with iron oxide <1% CR 9/31/06	Penetration ~6.5 ft/hr
1435	CC bag jar			CR 9/31/06 1435: ~~bt~~ same as 1430'	Penetration ~3.2 ft/hr Reset geograph to 1436.3
1440	CC bag jar			1440: black aphanitic basalt, 5% green-blue clay, >5% salt + pepper cuttings.	Penetration ~4.9 ft/hr
1445	CC bag jar			1445: black aphanitic basalt, >5% green-blue clay, 1% salt + pepper chips, <1% red iron oxide on surfaces	9/1/06 CR

Reported By: Colleen Rust | Reviewed By:

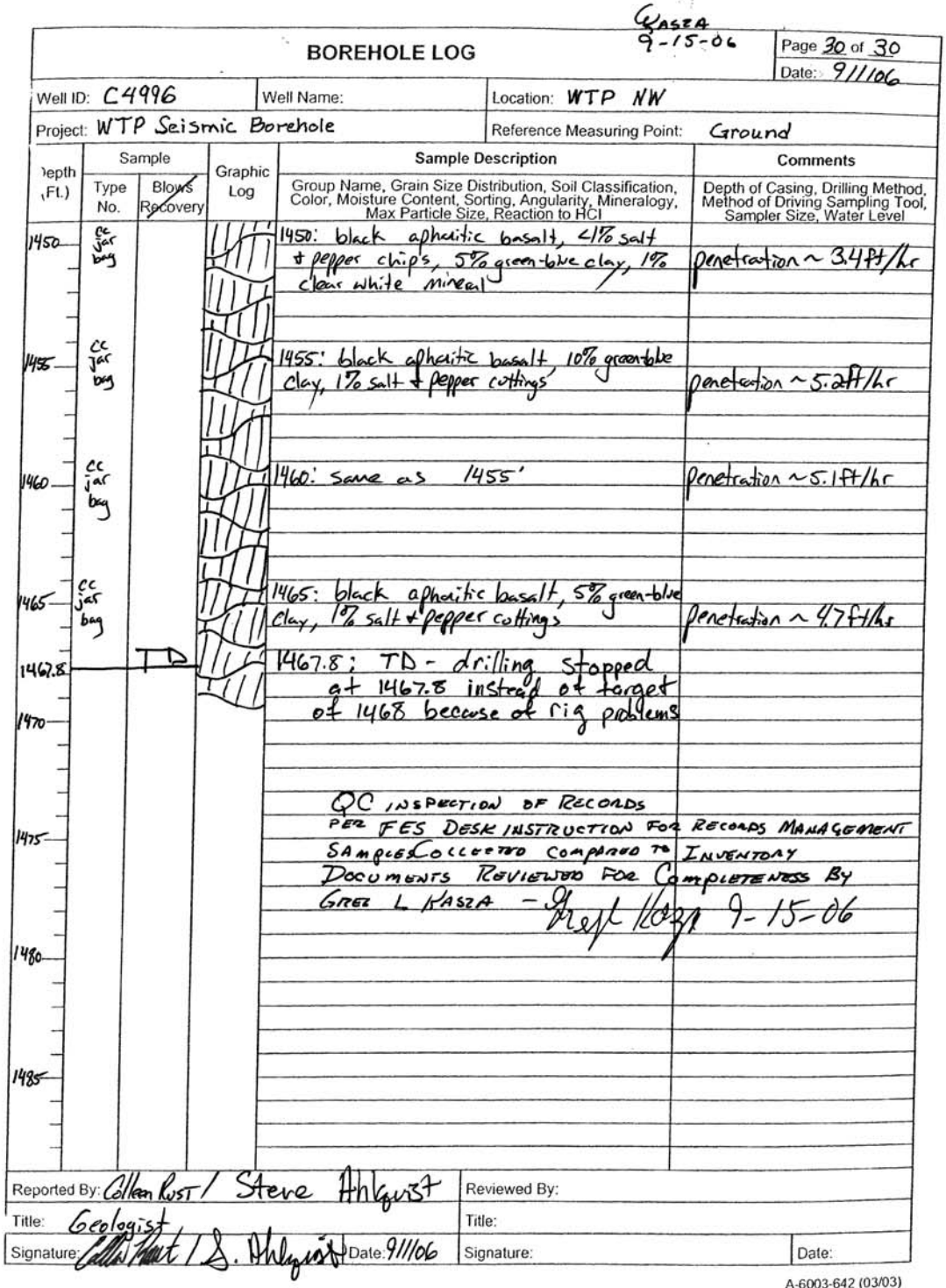
Title: Geologist | Title:

Signature: Colleen Rust | Date: 9/1/06 | Signature: | Date:

A-6003-642 (03/03)

Procedure - FH: GRP-EE-01-7.0, R1 5/30/06

* Additional Symbols used in the Graphic Log are documented in Appendix of PNNL-15848, R2



GASEA 9-15-06

BOREHOLE LOG

Page 30 of 30

Date: 9/11/06

Well ID: C4996 | Well Name: | Location: WTP NW

Project: WTP Seismic Borehole | Reference Measuring Point: Ground

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
1450	cc jar bag			1450: black aphanitic basalt, <1% salt & pepper chip's, 5% green-blue clay, 1% clear white mineral	penetration ~ 3.4ft/hr
1455	cc jar bag			1455: black aphanitic basalt, 10% green-blue clay, 1% salt & pepper cuttings	penetration ~ 5.2ft/hr
1460	cc jar bag			1460: same as 1455'	penetration ~ 5.1ft/hr
1465	cc jar bag			1465: black aphanitic basalt, 5% green-blue clay, 1% salt & pepper cuttings	penetration ~ 4.7ft/hr
1467.8		TD		1467.8; TD - drilling stopped at 1467.8 instead of target of 1468 because of rig problems	
1470					
1475					
1480					
1485					

QC INSPECTION OF RECORDS PER FES DESK INSTRUCTION FOR RECORDS MANAGEMENT
SAMPLES COLLECTED COMPARED TO INVENTORY
DOCUMENTS REVIEWED FOR COMPLETENESS BY
GREG L KASZA - Greg Kasza 9-15-06

Reported By: Colleen Rust / Steve Ahlquist | Reviewed By:

Title: Geologist | Title:

Signature: Colleen Rust / S. Ahlquist Date: 9/11/06 | Signature: | Date:

A-6003-642 (03/03)

Procedure - FH: GRP-EE-01-7.0, R1 5/30/06
Additional Symbols used in the Graphic Log are documented in Appendix of PNNL-15848, R2

APPENDIX B

BOREHOLE C4996 SAMPLE INVENTORY

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WASTE TREATMENT PLANT C4996 SAMPLE INVENTORY

A.) Sample Type Symbols:

✔ Sample collected and verified

X No sample collected

1. Questionable slurry sample. Sample may not be representative of formation as the sand pump was not run continuously.

B.) There were numerous geolograph malfunctions during drilling which were identified and corrected within a short depth interval. Some individual samples may have been collected with minor (1-3') depth errors. Special attention was given to monitoring paper read outs and digital read outs to check for the introduction of footage errors. Most errors were introduced when lifting the drill string, particularly when adding pipe.

C.) No depth corrections were added for sample return time lag.

BOTTOM DEPTH (FEET)	SAMPLE TYPE			NOTES
	JAR	CHIP	BAG	
Elephant Mountain Member Basalt				
360	X	✔	✔	Grout fill in entry hole casing
364.5	X	✔ ✔	✔	First basalt chips in grout; top of Elephant Mountain Basalt in rotary hole
367	X	✔	X	
370	X	✔	✔	
375	X	✔	✔	
380	X	✔	✔	
385	X	✔	✔	
390	X	✔	✔	
395	X	✔	✔	
400	X	✔	✔	
405	X	✔	✔	
410	X	✔	✔	
415	X	✔	✔	
420	X	✔	✔	Question mark on bag
425	X	✔	✔	
430	✔	✔	✔	Received direction to collect jar samples also
435	✔	✔	✔	
440	✔	✔	✔	
445	✔	✔	✔	

Rattlesnake Ridge Interbed				
450	✔	✔	✔	447’ contact, top of Rattlesnake Ridge Interbed; color shift to brown@447; Full shift to brown; at 450’; First occurrence of clay balls at 452’.
455	✔	✔	✔	
460	✔	✔	✔	
465	✔	✔	✔	Poor returns
470	✔	X	✔	1; Poor sample; some mud loss
475	✔	✔	✔	1. No chip returns, only slurry sand. Possible flowing sand
480	✔	✔	✔	1; No chip returns; unconsolidated sand
485	✔	✔	✔	1; No chip returns; unconsolidated sand
490	✔	✔	X	1; unconsolidated sand
492-493	✔	X	X	1; Red color change
495	✔	✔	✔ ✔ Washed, unwashed	1; unconsolidated sand; drillers noted about 1,000-1,400 gal. mud loss in the interbed.

Pomona Member Basalt				
500	✔	✔	✔	495’ top of Pomona Basalt
505	✔	✔	✔	
510	X	✔	✔	
515	X	✔	✔	
520	✔	✔	✔	
525	X	✔	✔	
530	X	✔	✔	
535	X	X	✔	Fluid loss zone
539	X	✔	X	
540	X	✔	X	
545	X	✔	✔	
550	X	✔	✔	Note: unreliable sample; sand tank was cleaned.
555	X	✔	✔	
560	X	✔	✔	
565	X	✔	X	
570	X	✔	✔	
575	✔	✔	✔	
580	✔	✔	✔	
585	✔	✔	✔	
590	✔	✔	✔	
595	X	✔	X	
600	X	✔	✔	
605	X	✔	✔	
610	✔	✔	✔	
615	✔	✔	✔	
620	✔	✔	✔	Collected at 620.3’, as composite for 5’
625	✔	✔	✔	
630	✔	✔	✔	Some grout in cuttings from cleaning chip tank.
635	X	✔	✔	
640	✔	✔	✔	
645	✔	✔	✔	
650	✔	✔	✔	
651	✔	X	X	
655	✔	✔	✔	
660	✔	✔	✔	
665	✔	✔	✔	
670	✔	✔	✔	
675	✔	✔	✔	
680	✔	✔	✔	
681.5	✔	✔	✔	Not shown on log
685	✔	X	✔	
690	✔	✔	✔	
695	✔	✔	✔	
698	✔	✔	✔	

Selah Interbed				
699.5	✔	✔	X	Contact 699.5- Selah Interbed
701.2	✔	X	X	Mainly clay. Sample impacted by raising pipe and circulating
701.7	✔	X	X	.
705	X	X	X	No chips returned.
708.4	X	✔	X	
710	✔	X	X	No chips returned.
711.8	X	✔	X	
715	X	X	X	
716.9	X	✔	X	Grab sample
718.6	✔	X	X	Grab sample
720	✔	✔	X	

Esquatzel Member Basalt				
725	X	X	X	Contact- Esquatel Basalt 720’
728	✔	✔	✔	
730	✔	✔	✔	
735	✔	✔	✔	
740	✔	✔	✔	
745	✔	✔	✔	
750	✔	✔	✔	
755	✔	✔	✔	
760	✔	✔	✔	
765	✔	✔	✔	
770	✔	✔	✔	
775	✔	✔	✔	
780	✔	✔	✔	
785	✔	✔	✔	
790	✔	✔	✔	
795	✔	✔	✔	
800	✔	✔	✔	Poor return on cuttings; sticks and leaves noted.
805	✔	✔	✔	
810	✔	✔	✔	

Cold Creek Interbed				
815	✔	✔	✔	1; Contact Cold Creek Interbed 814.5'; poor sample returns; siltstones 814.5-830'
820	✔	✔	X	1; Not enough sample return for bag
825	✔	✔	✔	1.
830	✔	✔	✔	1; poor sample returns; unconsolidated sands below 830'
835	✔	✔	X	1; poor sample returns
840	✔	✔	X	1; poor sample returns
845	✔	✔	X	1; poor sample returns
850	✔	✔	X	1; poor sample returns
855	✔	✔	X	1; poor sample returns
860	✔	✔	X	1; poor sample returns; mud changed
865	✔	✔	X	1; poor sample returns
870	✔	✔	X	1; poor sample returns
873	✔	X	X	1, clay
875	✔	✔	X	1, clay on screen
879	✔	X	X	1.
880	✔	✔	X	1.
885	✔	✔	X	1, clay on screen
888	✔	X	X	1.
890	✔	✔	X	1.
895	✔	✔	X	1; poor sample returns
900	✔	✔	X	1.
905	✔	✔	X	1.
910	✔	✔	X	1.

Umatilla Member Basalt				
915	✔	✔	✔	Contact 910.8’ Top of Umatilla Basalt
920	✔	✔	✔	
925	✔	✔	✔	
930	✔	✔	✔	
935	✔	✔	✔	
940	✔	✔	✔	
945	✔	✔	✔	NEW BIT INSTALLED. The previous bit had hemispherical buttons and was replaced with a new, pointed-button bit. Downward, the chip size is approximately halved to quartered and the chip shape changes from a flat to curved flake to an equate particle, approximately coarse sand sized. Significant portions washed through the screen. *Note:* Upward red paint was frequently seen in the chips. Downward, the fresh paint on the new bit was dark metallic green and not as easily noted.
950	✔	✔	✔	Apparent cement fall in
955	✔	✔	✔	Questionable quality
960	✔	✔	✔	Mud change- lightened; fines are falling out of mud.
965	✔	✔	✔	Red cloth fibers from rag in pump start here and continue downward
970	✔	✔	✔	
975	✔	✔	✔	
980	✔	✔	✔	
985	✔	✔	✔	
990	✔	✔	✔	Approximate 3’ depth correction
995	✔	✔	X	
1000	✔	✔	✔	
1005	✔	✔	✔	
1010	✔	✔	✔	
1015	✔	✔	✔	
1020	✔	✔	✔	
1025	✔	✔	✔	
1030	✔	✔	✔	First occurrence of pyrite framboids, continuing at least down to 1053’.
1035	✔	✔	✔	
1040	✔	✔	✔	
1045	✔	✔	✔	
1050	✔	✔	✔	
1055	✔	✔	✔	
1060	✔	✔	✔	
1065	✔	✔	✔	Slight color change

Mabton Interbed				
1070	✔	✔	X	Contact 1066.8' Top of Mabton Interbed; water loss zone.
1075	✔	✔	✔	Poor sample returns
1080	✔	✔	✔	
1085	✔	✔	✔	
1090	✔	✔	✔	
1095	✔	✔	✔	Circulation problems at 1093'
1100	✔	✔	✔	
1105	✔	✔	✔	
1110	✔	✔	✔	
1113	✔	✔	✔	Thinned mud
1115	X	X	X	
1120	X	X	X	No sample taken because of identified depth error on geolograph. Was reset for the correct 1125' sample.
1125	✔	✔	✔	
1130	✔	✔	✔	
1135	X	X	X	Poor returns
1140	✔	✔	✔	
1145	✔	✔	✔	Potential mud and circulation problems noted approximately at this depth.
1150	✔	✔	✔	Sampled from surface casing
1155	✔	✔	✔	Poor returns
1160	✔	✔	✔	
1165	✔	X	X	

Priest Rapids Member Basalt				
1168	✔	✔	✔	Basalt contact, top of Priest Rapids Basalt, 1168’
1170	✔	✔ ✔	X	
1175	✔	✔	X	Drilling mud disturbance at 1168-1170.3’; Depth correction on sample of 1174’ rather than 1185.3’
1180	✔	✔	X	
1181	X	X	✔	Geolograph depth error noted- 12’; may be 1170’ or 1169’.
1185	✔	✔	✔	
1190	✔	✔	X	
1195	✔	✔	✔	Potential geolograph errors repeating. Circulation problems.
1198	✔	✔	✔	Stopped for cement & recirculation
1200	✔	✔	✔	
1205	✔	✔	✔	
1210	✔	✔	✔	
1215	✔	✔	✔	
1220	✔	✔	✔	
1225	✔	✔	✔	
1230	✔	✔	✔	
1235	✔	✔	✔	
1240	✔	✔	✔	
1245	✔	✔	✔	
1250	✔	✔	✔	
1255	✔	✔	✔	
1260	✔	✔	✔	
1265	✔	✔	✔	
1270	✔	✔	✔	
1275	✔	✔	✔	
1280	✔	✔	✔	
1285	✔	✔	✔	
1290	✔	✔	✔	
1295	✔	✔	✔	
1300	✔	✔	✔	
1305	✔	✔	✔	
1310	✔	✔	✔	
1315	✔	✔	✔	
1320	✔	✔	✔	
1322	✔	✔	✔	Not on log
1325	✔	✔	✔	
1330	✔	✔	✔	Drilling rate – 10 f/hr
1335	✔	✔	✔	
1340	✔	✔	✔	
1345	✔	✔	✔	
1350	✔	✔	✔	

1355	✔	✔	✔	
1360	✔	✔	✔	
1365	✔	✔	✔	
1368.1	✔	✔	✔	Temporary Total Depth
1370	✔	✔	✔	
1375	✔	✔	✔	
1380	✔	✔	✔	
1385	✔	✔	✔	
1390	✔	✔	✔	
1395	✔	✔	✔	
1400	✔	✔	✔	
1403	✔	X	✔	Rosa Member contact 1400'-1403' range
1405	✔	✔	✔	
1410	✔	✔	✔	Drilling rate of 6.9 ft/hr from 1404.5' to 1413.3'.
1415	✔	✔	✔	Drilling rate of 11.7 ft/hr from 1413.3' to 1417.6'.
1420	✔	✔	✔	
1425	✔	✔	✔	
1430	✔	✔	✔	
1435	✔	✔	✔	
1440	✔	✔	✔	
1445	✔	✔	✔	
1450	✔	✔	✔	
1455	✔	✔	✔	
1460	✔	✔	✔	
1465	✔	✔	✔	
1465.4 --TD--	✔	X	X	Bottom of Hole

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APPENDIX C

BOREHOLE C4996 LOG SUMMARY

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LOG SUMMARY FOR BOREHOLE C4996

This summary describes the stratigraphic sequence underlying the initial basalt member. Overlying alluvial sediments (0-349’ bgs) are described in a separate report.

		MEMBER	OBSERVED LITHOLOGY	DEPTH INTERVAL in feet below ground surface (bgs)	THICKNESS in feet (meters)
SADDLE MOUNTAINS BASALT		**Elephant Mountain Member**	Oxidized reddish at top. Greenish-blue fracture filling. Traces of plagioclase, some clear. Up to 30% salt and pepper black and white mottled microcrystalline fracture filling. Amygdaloidal fill- clear, white, green clay, orange-white. Glassy ~ 20 feet from the base. Basal brown shift and yellow-green opal and rock fragments.	349’-450’	101’ (30.8)
	ELLENSBURG FORMATION	**Rattlesnake Ridge Interbed**	Reddish-brown / grey-brown / orange-brown / brown / pink / grey / mud, reddish-brown / brown, fine-grained sand, reddish-brown rock fragments (near top)	450’-495’	48’ (13.7)
		Pomona Member	Flow-top breccia present, and heavily palagonitized. Plagioclase phenocrysts common. Up to 60 % dark green clay filling at the top, dropping to about 1% downward through most of the thickness of the unit. Yellow opal found near the top and occasionally throughout the unit. Oxidized red clay zone about 70 to 110 feet from the top.	495’-699.5’	200.5’ (61.2)
	ELLENSBURG FORMATION	**Selah Interbed**	Brown / green-grey / grey / green mud, very little sand-size fraction, brown / tan rock fragments (near bottom)	699.5’-720’	20.5’ (6.3)
		Esquatzel Member	1-5% red-brown trace mineral through most of the unit. Yellow orange vesicular fill near base, less than 1%. Blue-green secondary mineral about 1% throughout most of unit; highest percentage in flow-top. Minor plagioclase in limited intervals.	720’-814.5’	94.5’ (28.8)
SADDLE MOUNTAINS BASALT	ELLENSBURG FORMATION	**Cold Creek Interbed**	Top 20 feet is greenish-grey / dark bluish-grey mud, then about 40 feet of olive green / dark green, very fine to coarse sand, fining downward to about 35 feet of dark gray mud, then lightening to green-gray near base.	814’-940.8’	96.3’ (29.4)
		Umatilla Member	Minor phenocrysts. Vitreous zones. Blue green mineral from 1 to 30% through most of the interval. Some vesicle filling throughout most of the unit, ~1% yellow-orange, red-brown, Traces of muscovite mica throughout this interval from unknown source, some up to 2-3 mm. Some vitreous intervals.	910.8’-1066.8’	156’ (47.6)

	ELLENSBURG FORMATION	**Mabton Interbed**	Green / orange / dark greenish-grey mud in top 3-9 feet, Possible gravel layer about 50 below top, About 80 feet alternating, dark greenish-grey fine- to medium grained sand and mud, upper 40' with returns to shaker, lower 40' with no returns to the mud shaker. About 10 feet of mixed clays and basalt at the base. Some muscovite in lower sands.	1066.8'-1168'	101.2' (30.9)
WANAPUM BASALT		**Priest Rapids Member, Lolo flow**	Little evidence of plagioclase phenocrysts. 1- 50% blue green fracture fill through most of the unit. Scattered microcrystalline white-black (salt and pepper) basalt vein filling. Red-brown oxidized staining scattered through the unit.	1168'-1322'	154' (47)
	ELLENSBURG FORMATION	**Unidentified Interbed**	Greenish-blue mud, brown (mud?) rock fragments, muscovite mica at lower contact.	1322'-1327' $\pm$2'	5' $\pm$2' (1.5 $\pm$0.6)
		Priest Rapids Member, Rosalia flow	Substantially reduced content of blue-green fracture fill clay (0-10%). Basalt, with micro phenocrysts starting at 137' below top of Rosalia flow and extending to 152' below top.	1327' $\pm$2'-TD (1467.8')	NA

(1) *Note:* Samples collected in the interbed sands and silts should be considered potentially non-representative of the unit since the vortex sand pump on the mud shaker was not continually in operation. Consequently, interbed slurry samples in archive jars may contain particles from outside the sampling interval.

APPENDIX D

FREESTONE ENVIRONMENTAL SERVICES, INC.
PROJECT DESK INSTRUCTION

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FREESTONE ENVIRONMENTAL SERVICES, Inc.

DESK INSTRUCTION FOR RECORDS MANAGEMENT TO SUPPORT
WASTE TREATMENT PLANT – PNNL SEISMIC BOREHOLES PROJECT

Approved By: Signature on file Date: August 21, 2006

Daniel K. Tyler, President

Freestone Environmental Services, Inc.

Reference Documents:

Pacific Northwest National Laboratory, PNNL-15848, Sampling and Analysis Plan Waste Treatment Plant Seismic Borehole Project, - (latest revision)

Fluor Hanford, Inc., GRP-EE-01-7.0, Groundwater Remediation Project Procedure, Geologic Logging, - (latest revision)

ASTM D5434-03, Standard Practice for Preserving and Transporting Rock Core Samples

Strategy:

1) Record generators (geologists) will complete records to implement PNNL, FH, and ASTM procedures and data fields, as appropriate.
2) The Freestone Environmental Quality Control Inspector will ensure completeness, consistency, and legibility.
3) Records generated will be "working, in-progress records," until approved by QC Inspector.
4) QC verified records will employ a multiple-location storage system with photo copied records being equivalent to original records. No records will be designated as originals.
5) Drill cuttings samples will be considered records.

Records Process for Controlled-Managed Documents:

1) Records generators will document reading of the PNNL-15848 (latest revision) Sampling and Analysis Plan, the Fluor Geologic Logging procedure, and appropriate ASTM procedures. Subsequent reading of document revisions will be documented.
2) Records generators will complete field forms. After forms are completed, the forms will be signed and dated. The signature signifies completeness and self review. Record generators will place forms in the "working, in-progress record" file. Photocopies of working, in-progress records are equivalent to an original; the original and copies will not be labeled.
3) The Quality Control Inspector will be independent from generation of records. The QC Inspector will review the records for completeness, legibility, and consistency. When

deemed adequate, the QC Inspector will initial and date the record in lower left hand corner. This signifies completion by Freestone.

4) The Quality Control Inspector or designee will copy the record to one or more duplicate record locations. Designated duplicate records will be controlled in locked cabinets, briefcases, vehicles, or other protective environments.
5) Modifications
    A. Changes will utilize a single strikeout of original material, addition/revision (if any), initial, and date.
    B. Modifications by Record Generators of working, in-process forms will involve 1.) The change, 2.) Initial, 3.) Date
    C. Modifications by Quality Control Inspector of completed records will involve 1.) The change, 2.) Initial, 3.) Date, 4.) A new QC initial and date in the lower left corner, 5.) Copy and distribution to all duplicate record files, 6.) The QC Inspector can request that logs be redone to ensure legibility.
6) Records Transfers

    The QC Inspector will ensure transfer of required forms to client recipients. Informal, remaining copies and duplicate copies may then be destroyed or temporarily retained. All training records may be destroyed after completion of the project.

Sample Process:

1) Geologist/ Record Generator will identify samples on client-supplied containers, as required by client requirement documents. Special care will be exercised to ensure accuracy and marking of depths. Sample records shall correspond to paper forms for identifiers and depths.
2) Geologist/Record Generator will ensure that samples are stored and preserved from environmental damage, loss, or theft.
3) Quality Control Inspector will ensure consistency between markings on sample containers and paper records.
4) Quality Control Inspector will transfer sample containers and paper records to client organization in a timely fashion.
5) Quality Control Inspector will ensure record modifications and corrections as required by the client organization. The Quality Control Inspector will ensure distribution of corrected paper records to appropriate recipients.

Informal Materials:

Informal Materials are unofficial copies of working, in-process records; copies of completed records; supporting materials, such as articles, diagrams, scratch sheets, etc. Informal materials may be discarded, overwritten, or mutilated. Informal materials are uncontrolled with respect to storage and disposal. Informal materials need not be labeled as “copies.” Informal materials may not be distributed to individuals who are not Freestone Employees.

Roles:

Geologist/ Record Generators:	Scot Adams, Ben Garcia, Steve Ahlquist, Colleen Rust, Jeff Fetters, Erika Rincon
Quality Control Inspector:	Greg Kasza, or Steve Airhart as Alternate

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APPENDIX E

PHOTOGRAPHIC LOG OF BOREHOLE CUTTINGS

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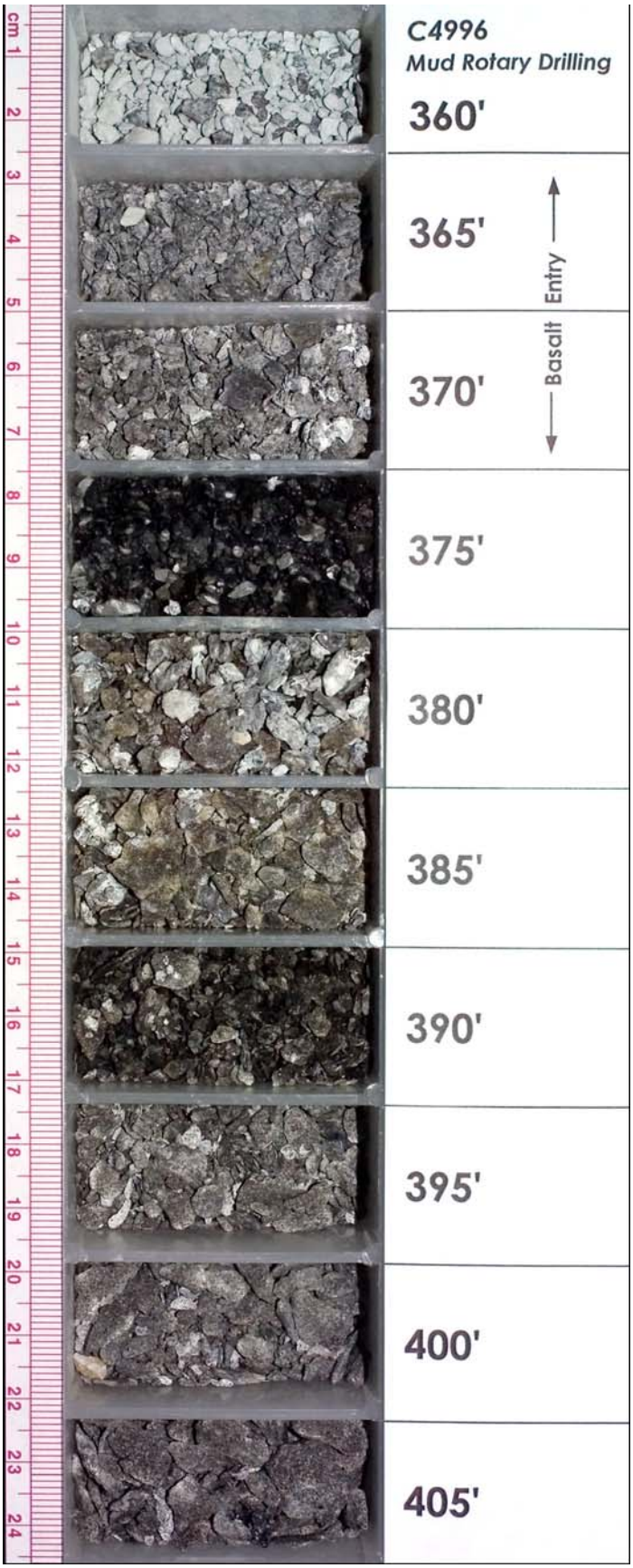
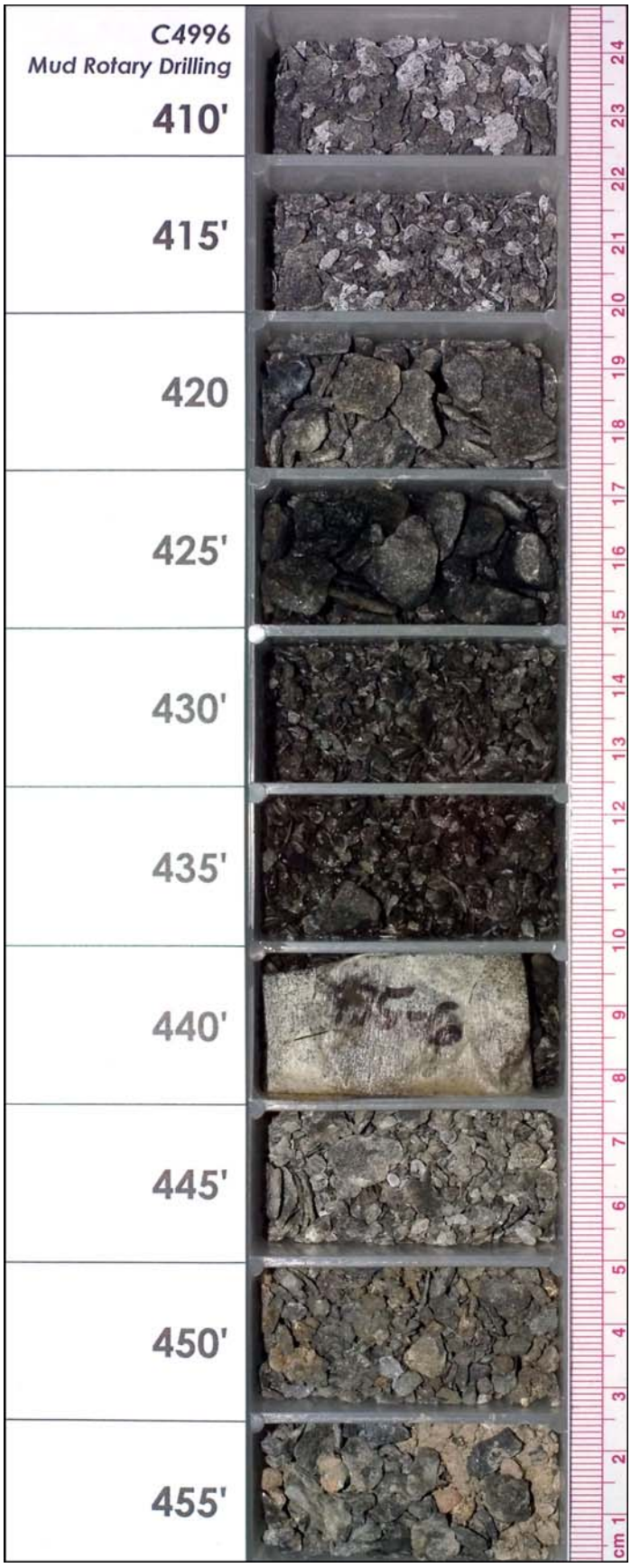
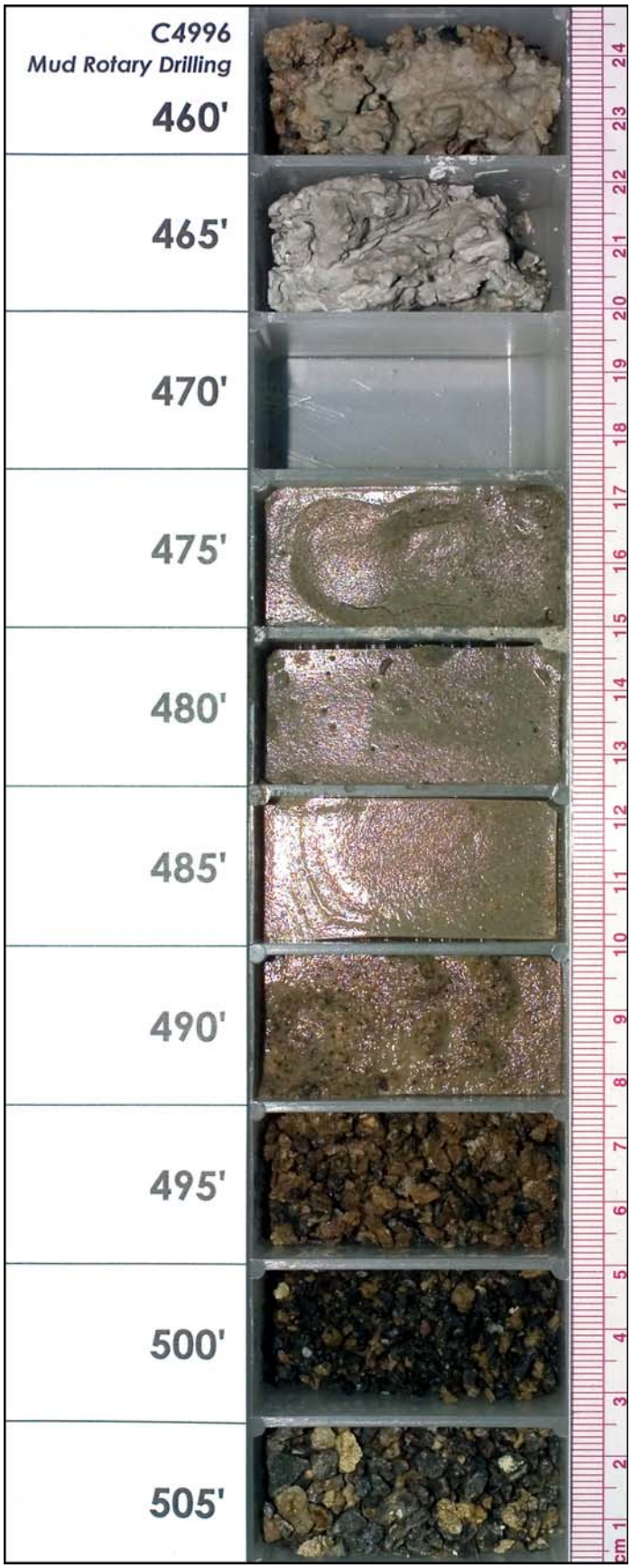
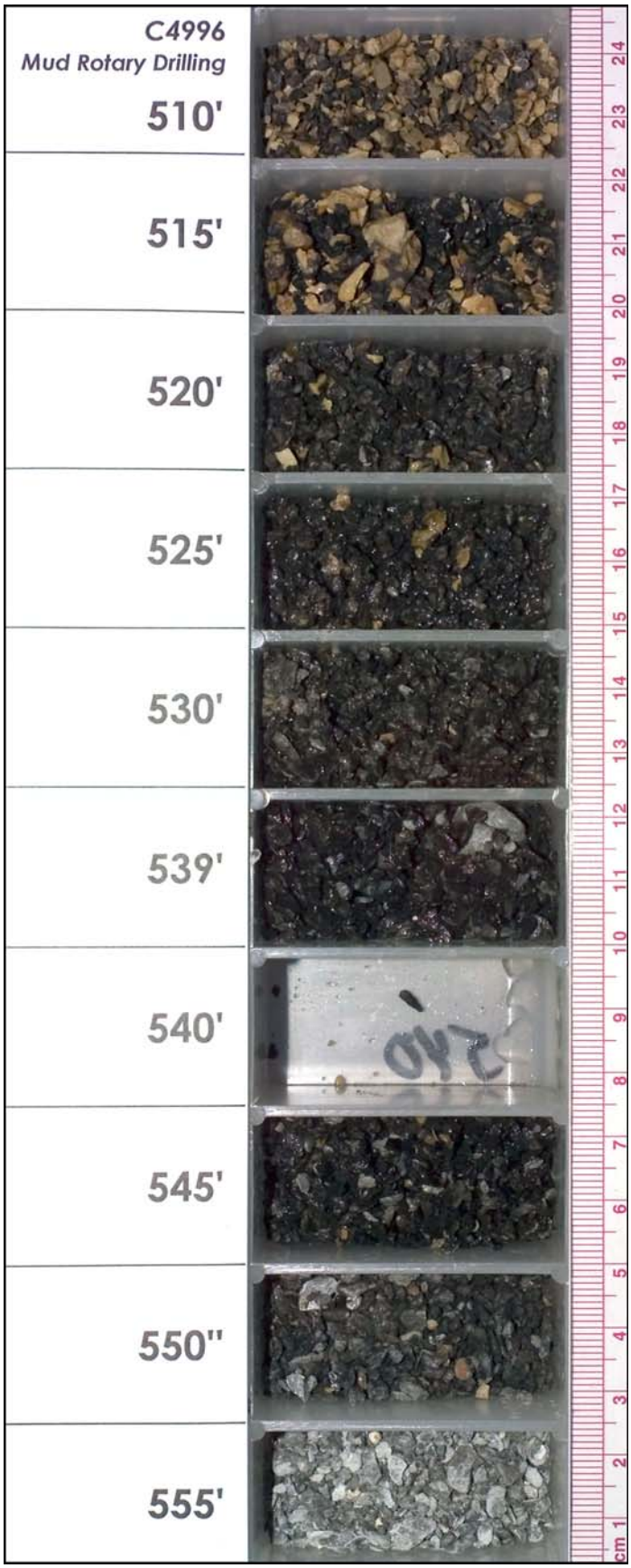
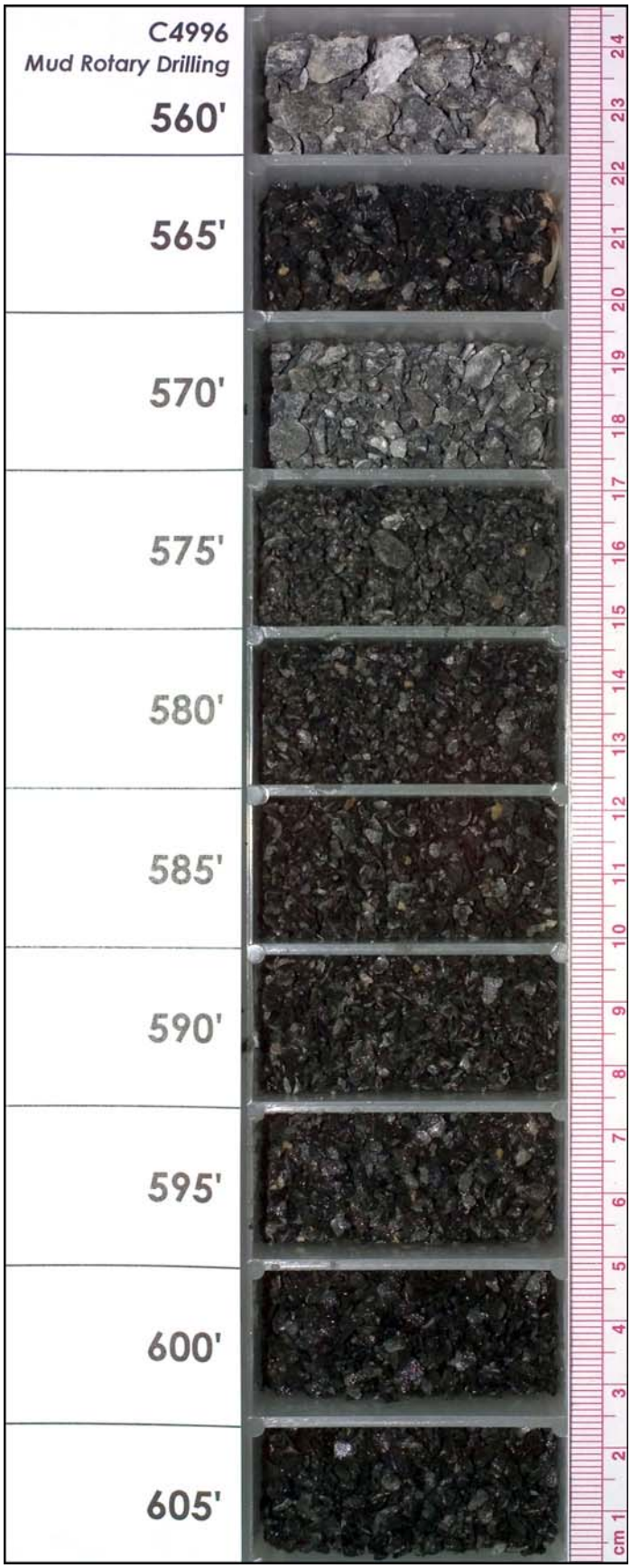

C4996
Mud Rotary Drilling
360'
365'
370'
375'
380'
385'
390'
395'
400'
405'
Entry
Basalt

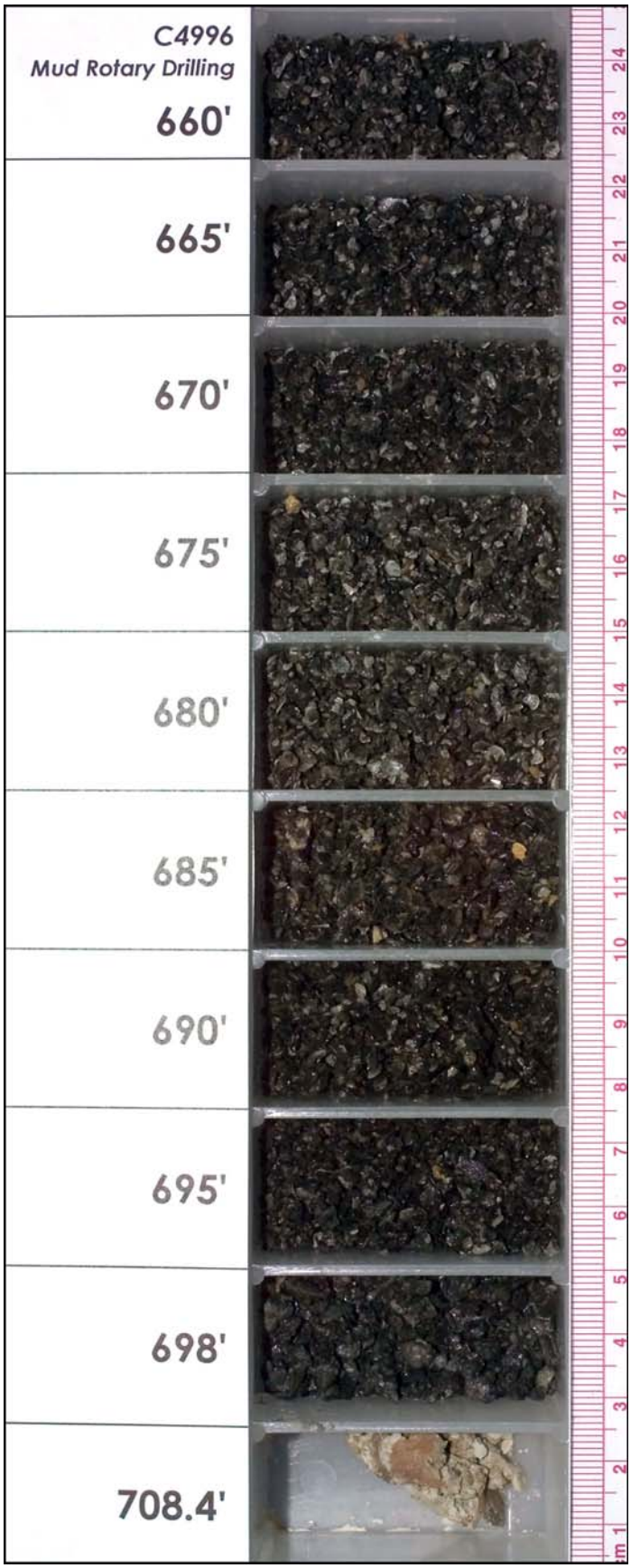

C4996
Mud Rotary Drilling
410'
415'
420
425'
430'
435'
440'
445'
450'
455'
cm 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


C4996
Mud Rotary Drilling
460'
465'
470'
475'
480'
485'
490'
495'
500'
505'
cm

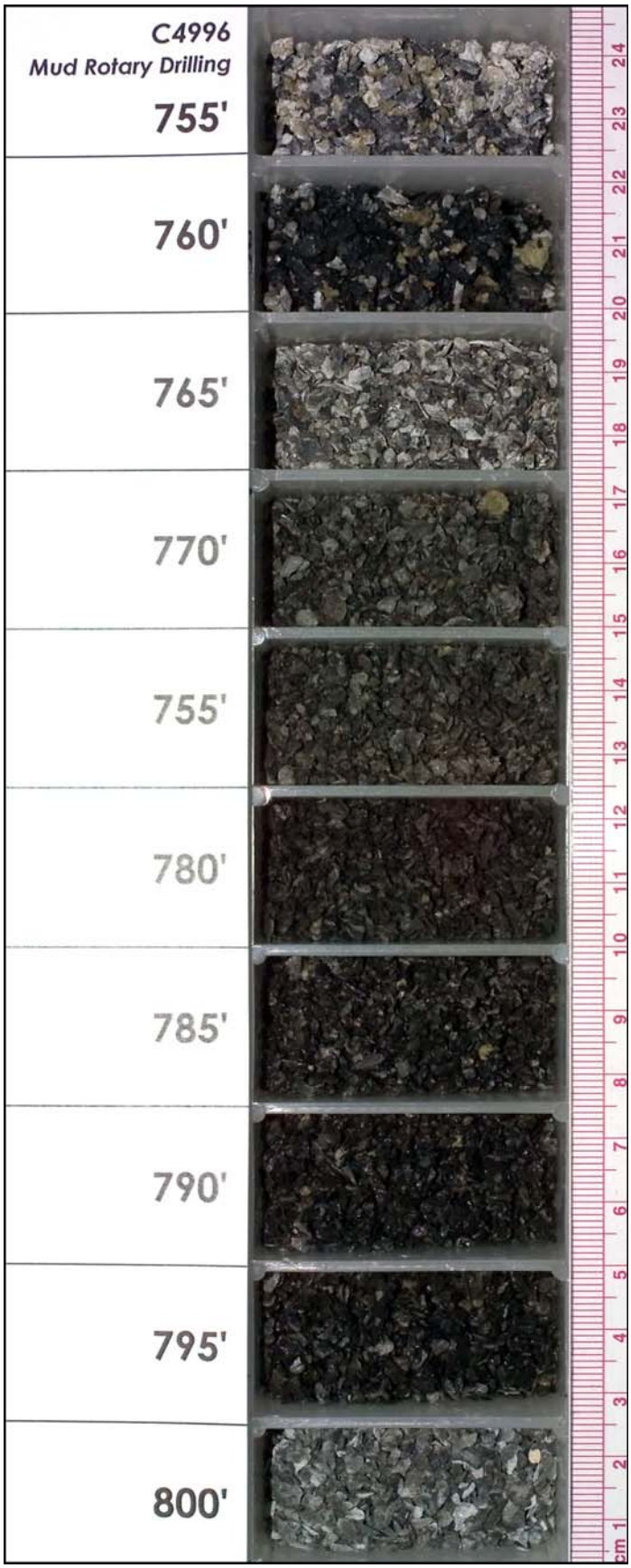

C4996
Mud Rotary Drilling
510'
515'
520'
525'
530'
539'
540'
545'
550"
555'

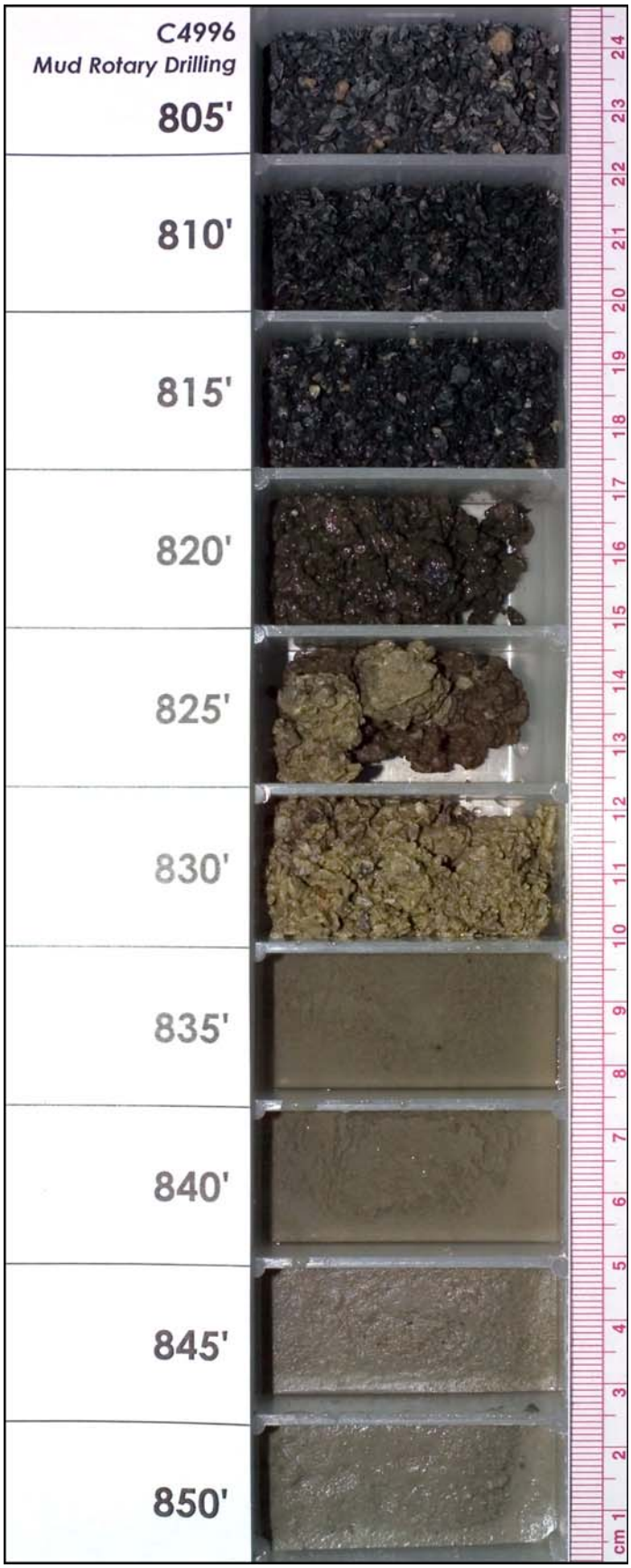

C4996
Mud Rotary Drilling
560'
565'
570'
575'
580'
585'
590'
595'
600'
605'


C4996
Mud Rotary Drilling
610'
615'
620'
625'
630'
635'
640'
645'
650'
655'
cm


C4996
Mud Rotary Drilling
660'
665'
670'
675'
680'
685'
690'
695'
698'
708.4'


C4996
Mud Rotary Drilling
711.8'
715'
716.9'
720'
728'
730'
735'
740'
745'
750'
cm


C4996
Mud Rotary Drilling
755'
760'
765'
770'
755'
780'
785'
790'
795'
800'
cm 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


C4996
Mud Rotary Drilling
805'
810'
815'
820'
825'
830'
835'
840'
845'
850'
cm 1
2
3
4
5
6
7
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10
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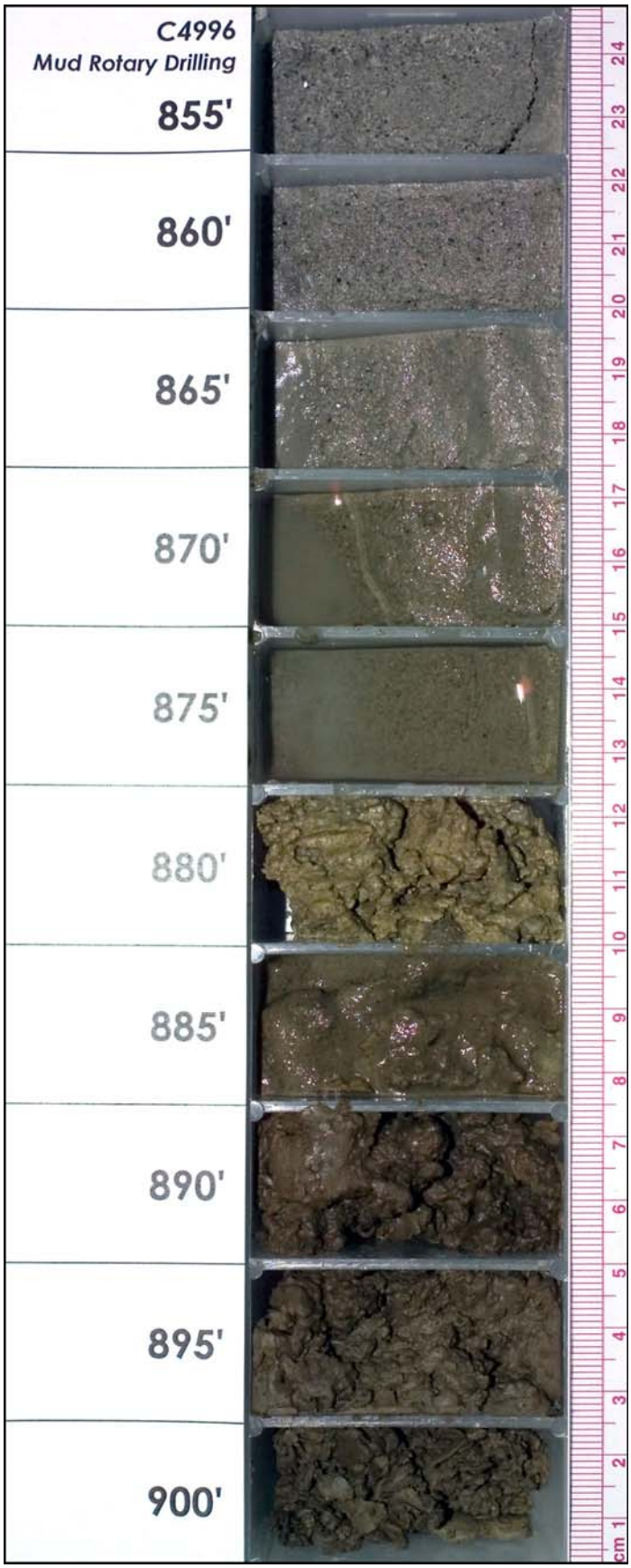
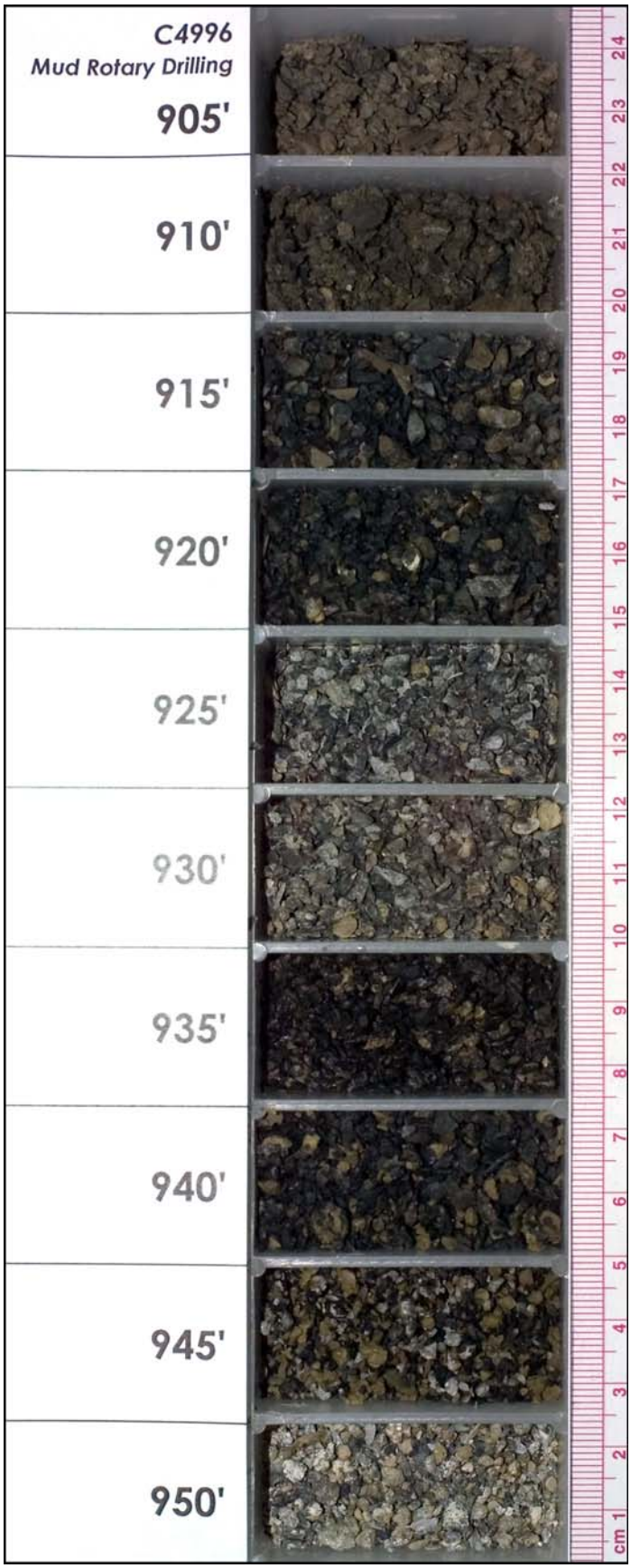
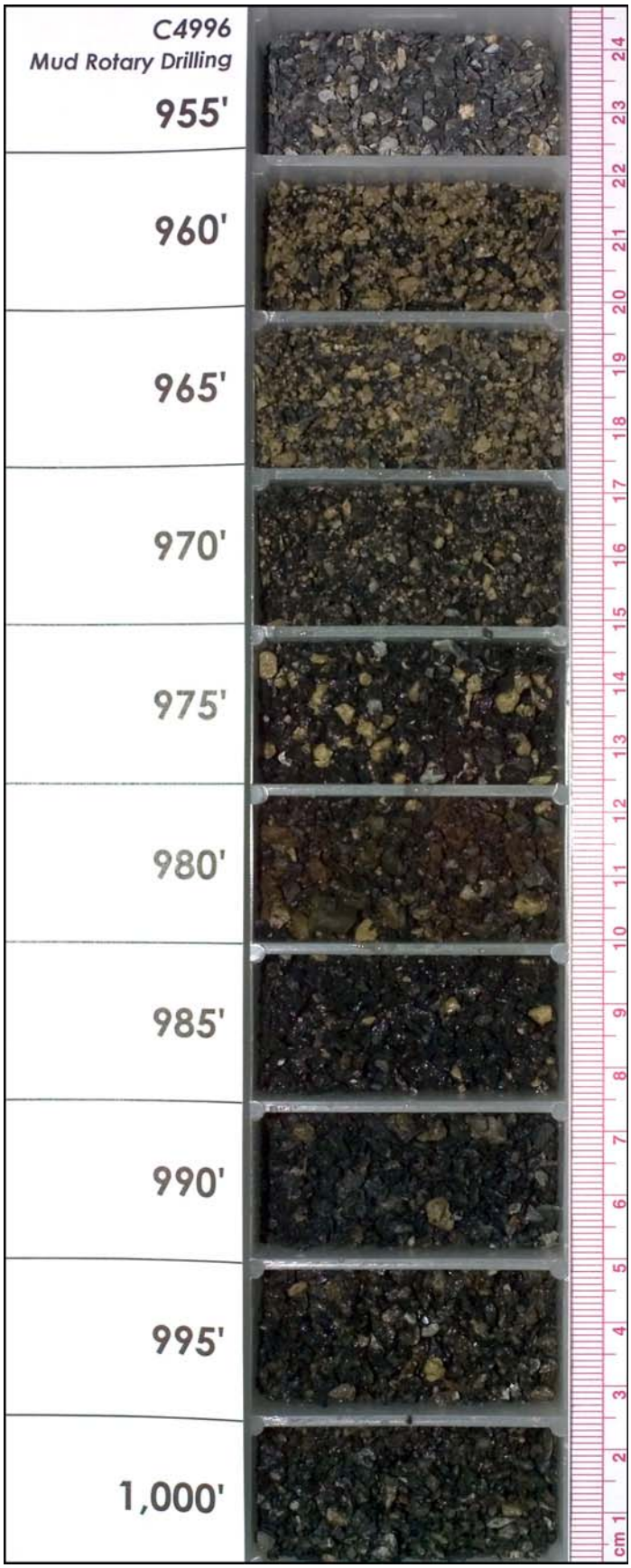
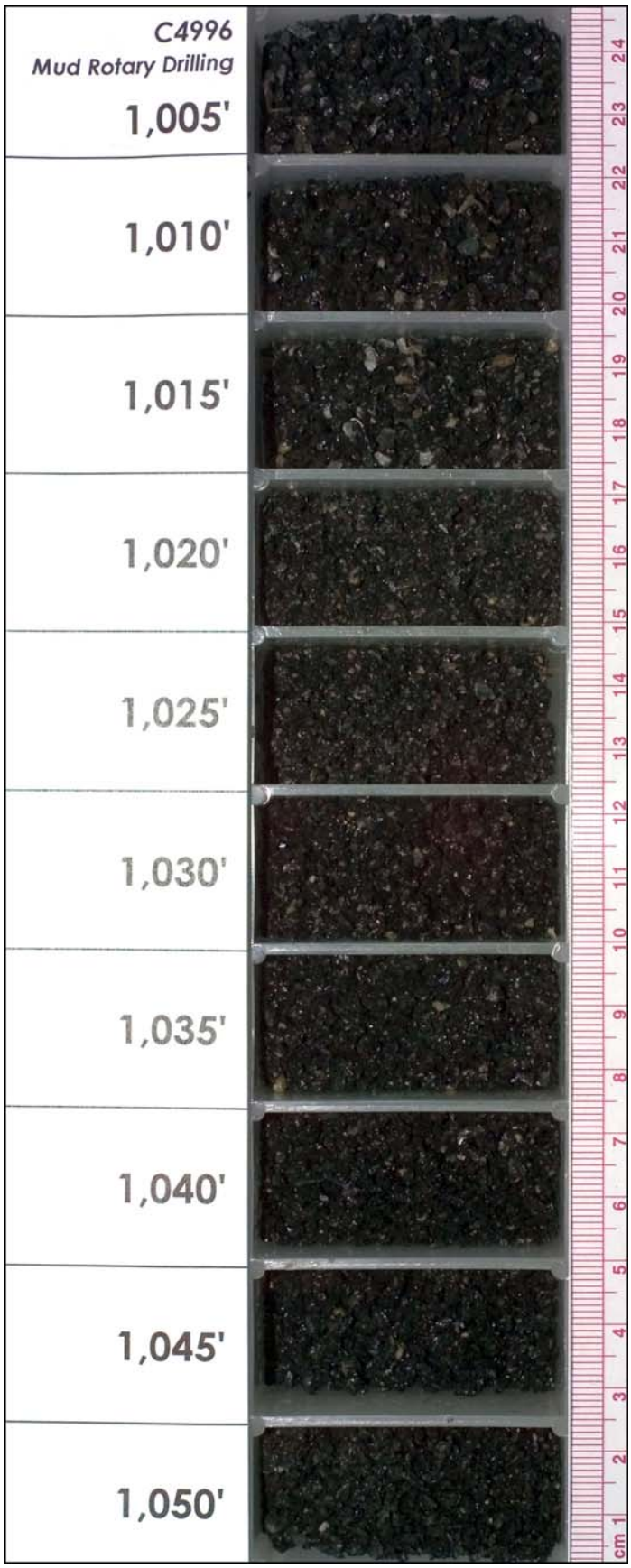
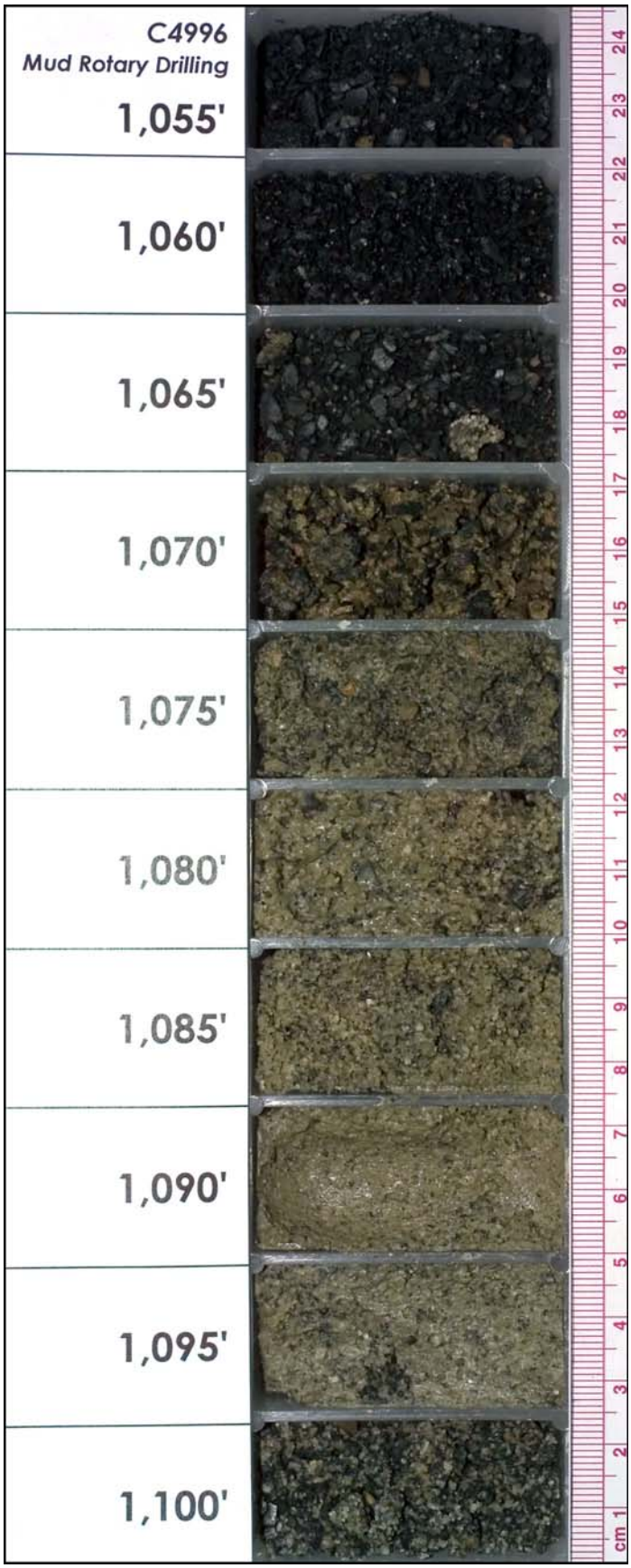
14
15
16
17
18
19
20
21
22
23
24

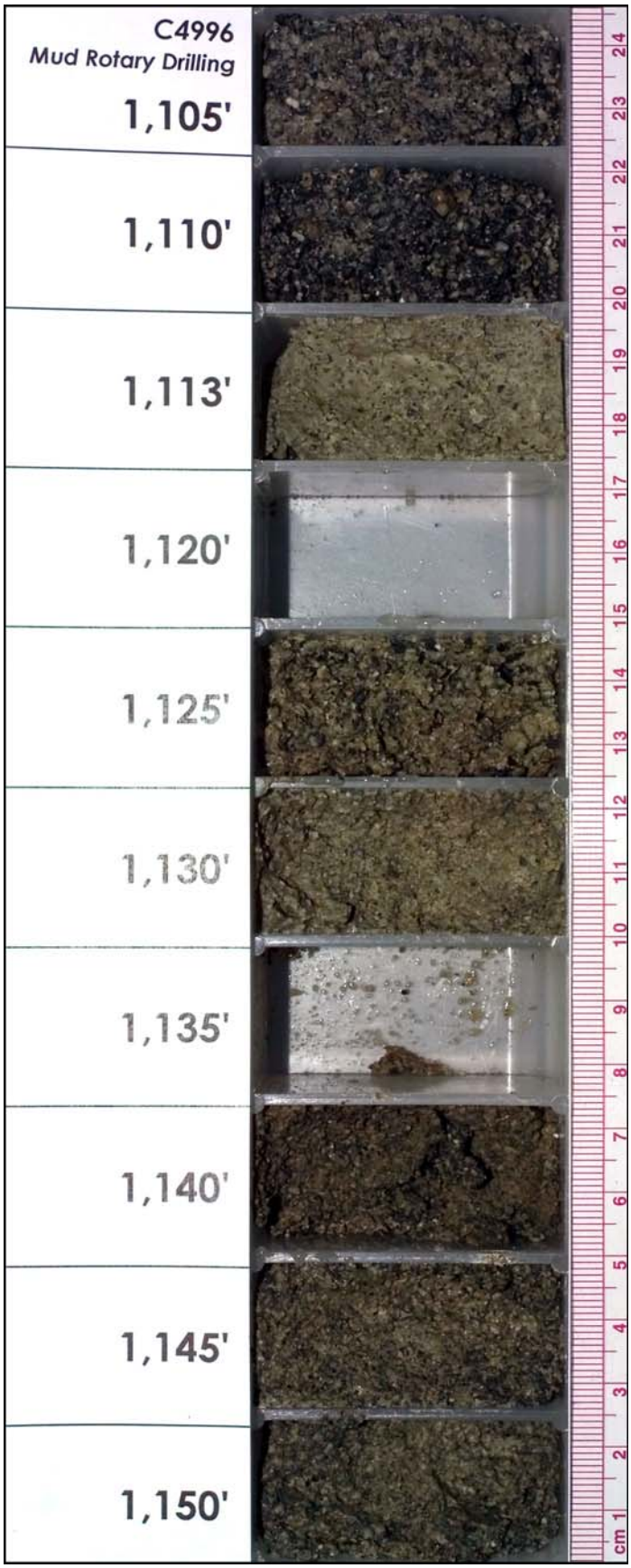

C4996
Mud Rotary Drilling
855'
860'
865'
870'
875'
880'
885'
890'
895'
900'
cm


C4996
Mud Rotary Drilling
905'
910'
915'
920'
925'
930'
935'
940'
945'
950'
cm 1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24


C4996
Mud Rotary Drilling
955'
960'
965'
970'
975'
980'
985'
990'
995'
1,000'
cm 1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24


C4996
Mud Rotary Drilling
1,005'
1,010'
1,015'
1,020'
1,025'
1,030'
1,035'
1,040'
1,045'
1,050'
cm 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


C4996
Mud Rotary Drilling
1,055'
1,060'
1,065'
1,070'
1,075'
1,080'
1,085'
1,090'
1,095'
1,100'


C4996
Mud Rotary Drilling
1,105'
1,110'
1,113'
1,120'
1,125'
1,130'
1,135'
1,140'
1,145'
1,150'
cm 1
2
3
4
5
6
7
8
9
10
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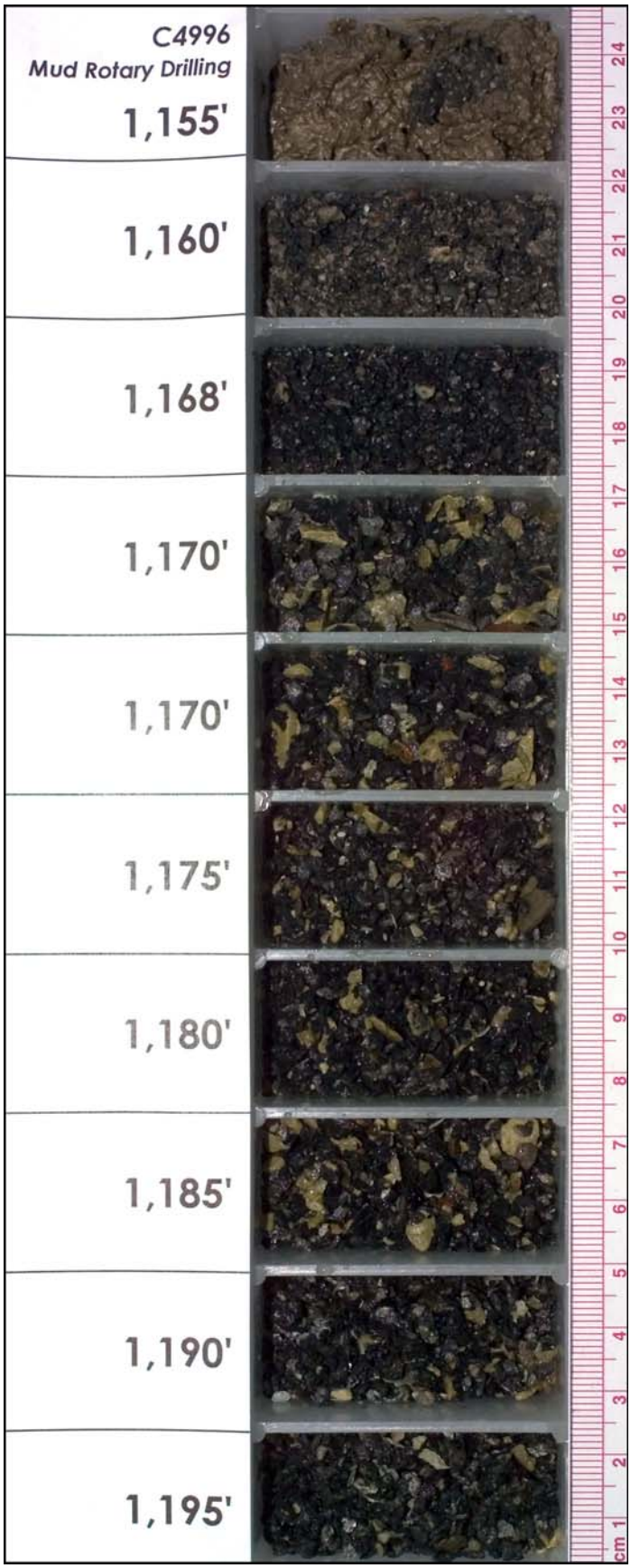
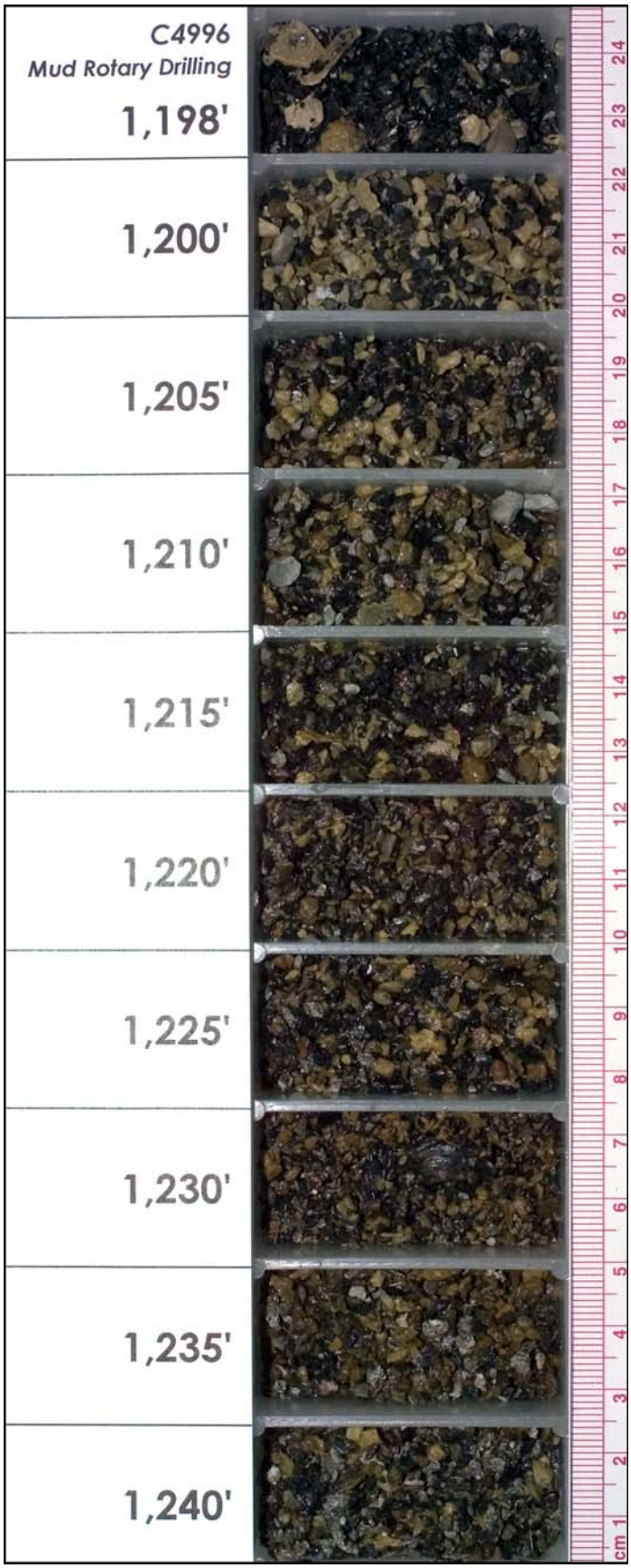
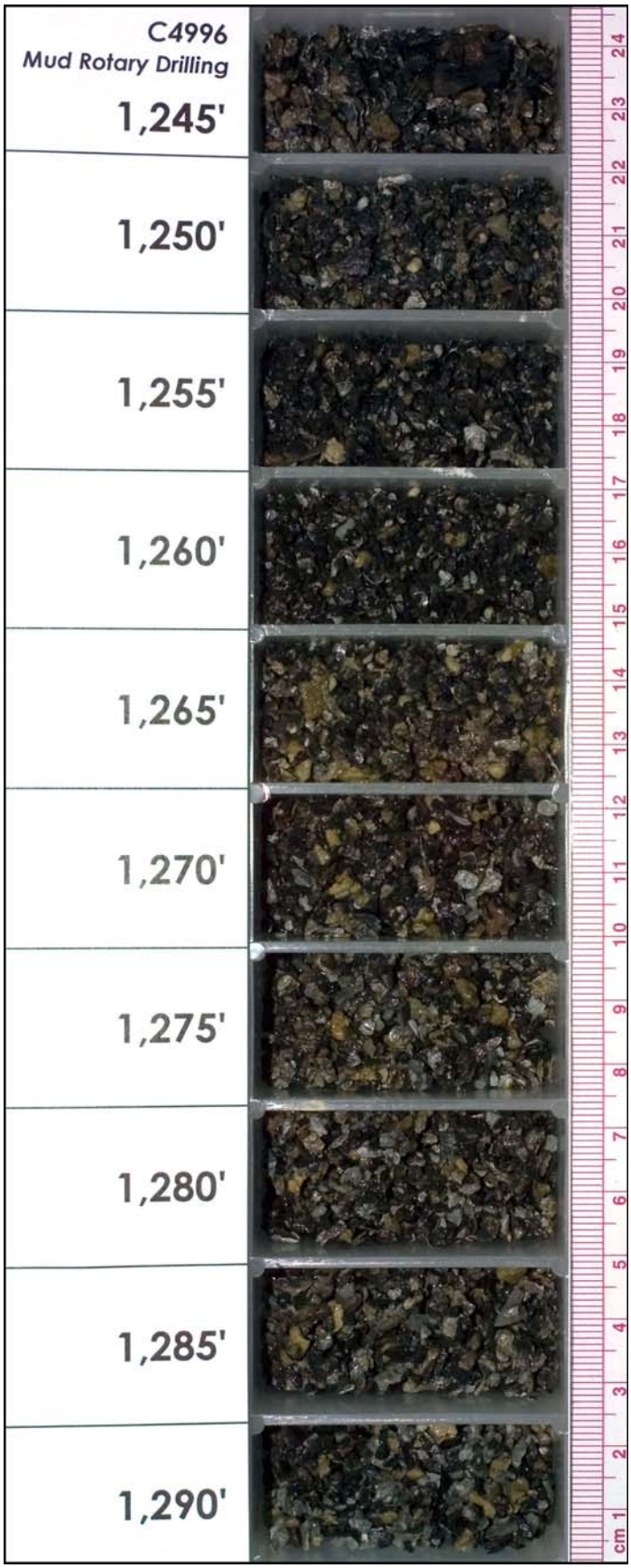
24


C4996
Mud Rotary Drilling
1,155'
1,160'
1,168'
1,170'
1,170'
1,175'
1,180'
1,185'
1,190'
1,195'
cm


C4996
Mud Rotary Drilling
1,198'
1,200'
1,205'
1,210'
1,215'
1,220'
1,225'
1,230'
1,235'
1,240'
cm


C4996
Mud Rotary Drilling
1,245'
1,250'
1,255'
1,260'
1,265'
1,270'
1,275'
1,280'
1,285'
1,290'
cm 1
2
3
4
5
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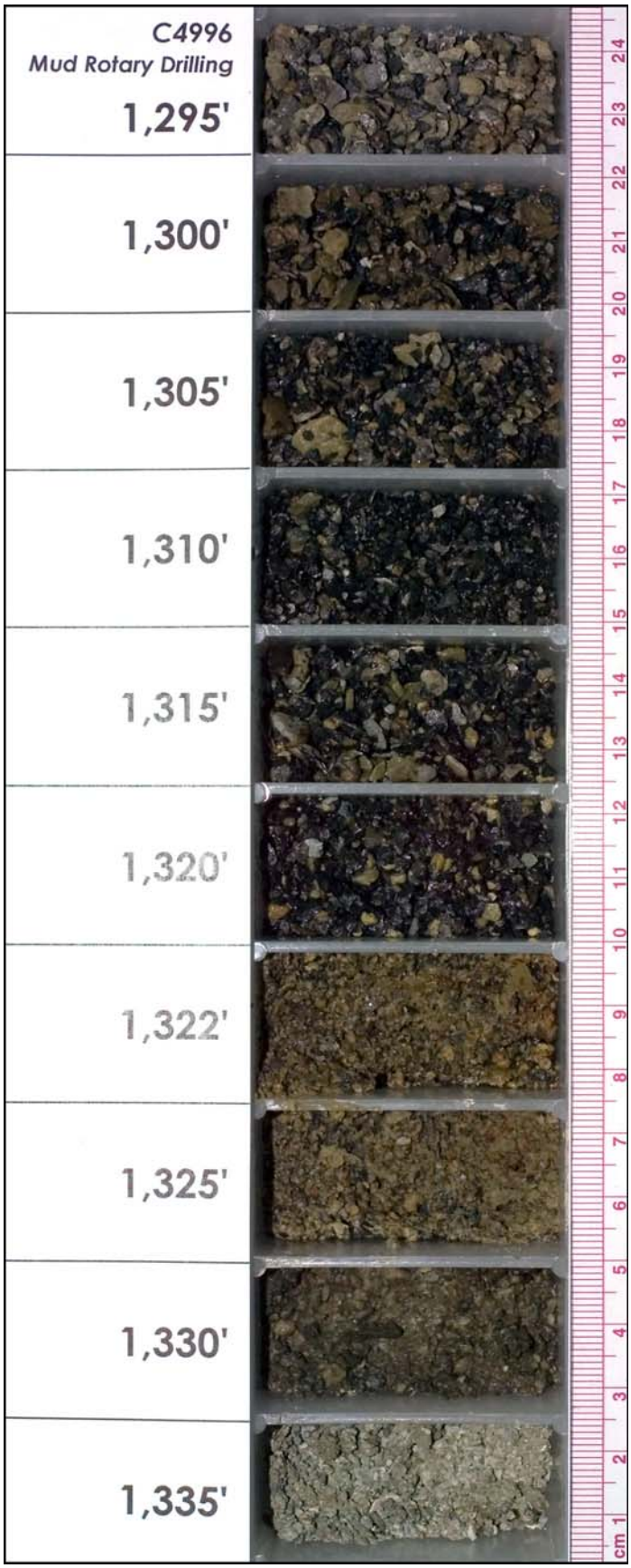
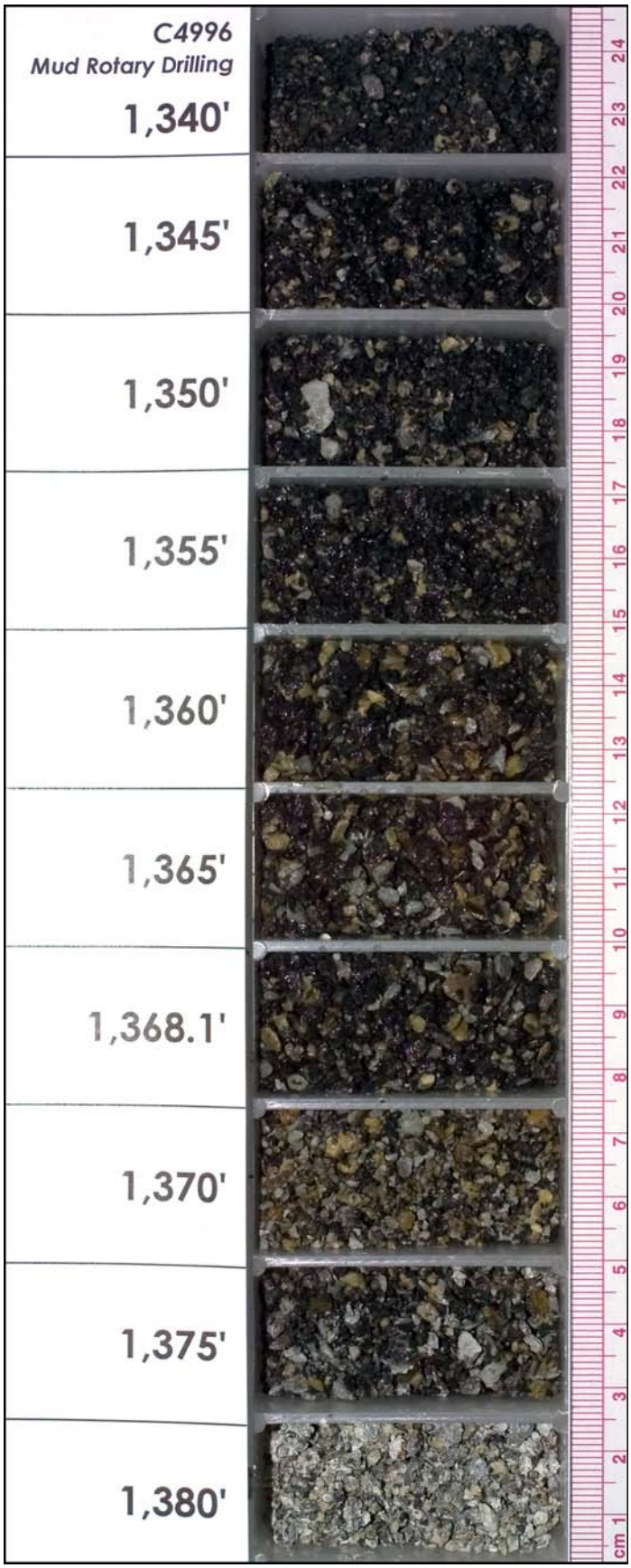
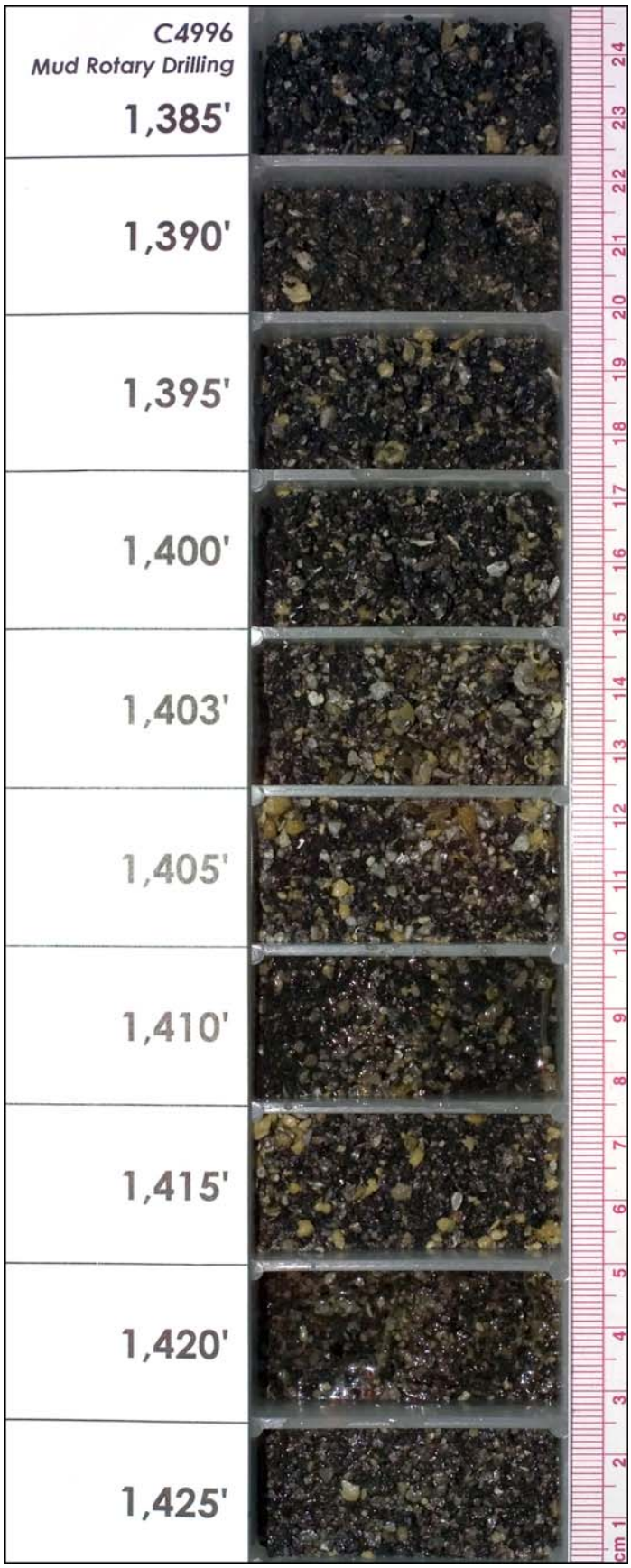
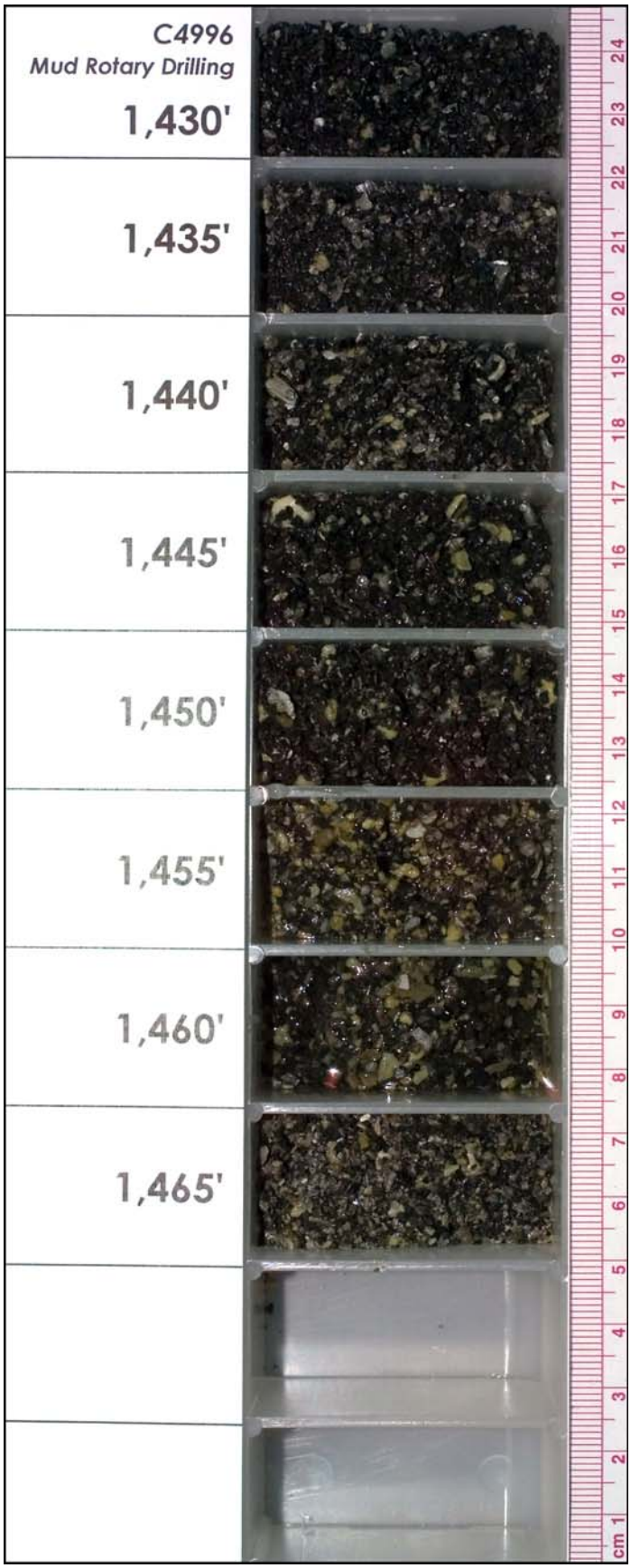

C4996
Mud Rotary Drilling
1,295'
1,300'
1,305'
1,310'
1,315'
1,320'
1,322'
1,325'
1,330'
1,335'
cm 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


C4996
Mud Rotary Drilling
1,340'
1,345'
1,350'
1,355'
1,360'
1,365'
1,368.1'
1,370'
1,375'
1,380'
cm 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


C4996
Mud Rotary Drilling
1,385'
1,390'
1,395'
1,400'
1,403'
1,405'
1,410'
1,415'
1,420'
1,425'
cm


C4996
Mud Rotary Drilling
1,430'
1,435'
1,440'
1,445'
1,450'
1,455'
1,460'
1,465'

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