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Mineralogic Zonation Within the Tuff Confining Unit, Yucca Flat, Nevada Test Site

by

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September 2005

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ABSTRACT

Recently acquired mineralogic data from drill hole samples in Yucca Flat show that the tuff confining unit (TCU) can be subdivided into three mineralogic zones based on the relative abundances of primary and secondary mineral assemblages. These zones are (1) an upper zone characterized by the abundance of the zeolite mineral clinoptilolite with lesser amounts of felsic and clay minerals; (2) a middle zone with felsic minerals dominant over clinoptilolite and clay minerals; and (3) a basal argillic zone where clay minerals are dominant over felsic minerals and clinoptilolite. Interpretation of the mineralogic data, along with lithologic, stratigraphic, and geophysical data from approximately 500 drill holes, reveals a three-layer mineralogic model for the TCU that shows all three zones are extensive beneath Yucca Flat.

The mineralogic model will be used to subdivide the TCU in the Yucca Flat hydrostratigraphic framework model, resulting in a more accurate and versatile framework model. In addition, the identification of the type, quantity, and distribution of minerals within each TCU layer will permit modelers to better predict the spatial distribution and extent of contaminant transport from underground tests in Yucca Flat, at both the level of the hydrologic source term and the corrective action unit.

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List of Acronyms and Abbreviations

AR	clay or argillic
BN	Bechtel Nevada
CAU	Corrective Action Unit
CT	cristobalite/tridymite
FS	felsic or felsic minerals
ft	feet
FY	Fiscal Year
K-feldspar	potassium feldspar
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
m	meters
Ma	million years ago
n	population number
SNJV	Stoller-Navarro Joint Venture
TCU	tuff confining unit
USGS	U.S. Geological Survey
XRD	X-ray diffraction
ZC	clinoptilolite

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1.0 Introduction

This report describes a three-dimensional model of mineralogic zonation within the tuff confining unit (TCU) beneath Yucca Flat (Figure 1-1). The model is the result of a three-year cooperative effort by scientists from Bechtel Nevada (BN), Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), and Stoller-Navarro Joint Venture (SNJV) to better define the nature and extent of the TCU in Yucca Flat. The TCU is important to contaminant transport models in Yucca Flat because (1) most of the underground nuclear tests in Yucca Flat were conducted either within this unit, or within the overlying alluvial and tuff aquifers, and (2) geologic models show that the TCU is laterally extensive beneath Yucca Flat which may provide a barrier between the hydrologic source term and the underlying lower carbonate aquifer.

The data and interpretations developed as a part of this study will be used to constrain contaminant transport models of the Yucca Flat Corrective Action Unit (CAU). The TCU mineralogic model will provide additional map layers (i.e., hydrostratigraphic units) for the hydrostratigraphic framework model being developed for Yucca Flat. In addition, TCU alteration minerals play a major role in retarding radionuclides via sorption and ion exchange processes (Tompson et al., 1999). Identification of the type, quantity, and distribution of these minerals will permit modelers to better predict the spatial distribution and extent of contaminant transport from underground tests in Yucca Flat, at both the hydrologic source term and CAU-level scales.

1.1 Geologic Setting

Yucca Flat is a north-south-elongated, Neogene-age basin formed in response to basin-and-range extension. Major basin development appears to have begun shortly after the eruption of the Ammonia Tanks Tuff approximately 11.5 million years ago (Ma). At its deepest point the basin probably contains more than 910 meters (m) (3,000 feet [ft]) of alluvial debris shed from the surrounding highlands during basin development. This thick alluvial section overlies a thick section of Miocene volcanic rocks of generally rhyolitic composition erupted from caldera sources located west and northwest of the basin. The volcanic rocks lie unconformably on Paleozoic sedimentary rocks (Figure 1-2).

Large down-to-the-east normal faults such as the Carpetbag, Topgallant, and Yucca faults are located near the center of the basin. These faults drop down the east side of Yucca Flat basin

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Figure 1-1
Shaded Relief Map of Yucca Flat and Vicinity
 Yellow dots are TCU study holes with detailed mineralogic analyses;
 black dots are other holes utilized for this study.

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Figure 1-2
Stratigraphic Column for Yucca Flat

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forming the deep west-tilted Yucca Flat basin proper (Figure 1-3). West of the Carpetbag-Topgallant fault system, a high, north-trending buried structural ridge separates Yucca Flat basin proper from a smaller and shallower western sub-basin. Along the buried ridge, volcanic rocks are generally absent and pre-Tertiary rocks are within 22.0 m (72 ft) of the land surface. These structural features significantly influence the distribution of the TCU beneath Yucca Flat.

The volcanic rocks beneath the basin range in age from approximately 15 to 11.5 Ma and consist mostly of nonwelded to densely welded ash-flow tuffs, ash-fall deposits, and reworked tuffs. These types of volcanic deposits typically contain large proportions of glass when originally deposited. However, with time and particularly in the presence of groundwater, the glass within the poorly welded rocks tends to alter to zeolite. This alteration significantly reduces the effective porosity of the rocks. This is the scenario that created the tuff confining unit beneath Yucca Flat. As the Yucca Flat basin developed, the unaltered glassy volcanic rocks were dropped down below the water table and altered to zeolite, significantly reducing the ability of these rocks to transmit water, and forming the TCU. As mentioned previously, the position of the TCU between the overlying alluvial and volcanic aquifers in which most of the underground nuclear tests were conducted, and the Paleozoic rocks which form the regional aquifer, make the TCU an important hydrogeologic unit in the Yucca Flat vicinity.

1.2 Acknowledgments

The author would like to thank the numerous people who contributed through the years to the successful completion of this investigation. The enthusiastic support and guidance of Gayle Pawloski (LLNL) throughout this investigation is greatly appreciated. Rick Warren's (LANL) early support, guidance, and insights were critical in establishing the initial scope and direction of the study. Brian Allen's (BN) assistance in the first year of this study is also appreciated. Sig Drellack's (BN) insights into the geology of Yucca Flat were very helpful. The author is extremely grateful to Giday WoldeGabriel and Steve Chipera of the Hydrology, Geochemistry, and Geology Group of the Earth and Environmental Sciences Division at LANL for conducting the laboratory analyses and providing the X-ray diffraction (XRD) results along with stimulating discussions and insights regarding alteration of volcanic rocks. Thanks also to Jerry Magner and the staff of the U.S. Geological Survey (USGS) Core Library and Geologic Data Center in Mercury, Nevada for their assistance during collection of the TCU samples. Insightful and stimulating discussions with Tim Rose (LLNL) and Bob Dickerson (SNJV) regarding results of stable isotope and SEM results of TCU samples were very helpful. Aaron Leavitt's (BN) help in producing maps and figures greatly improved the report. The report was improved significantly

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Figure 1-3
Color Elevation Relief Map of the Pre-Tertiary Surface
Beneath Yucca Flat Based on Gravity Data
 Red dots are TCU study holes with detailed mineralogic analyses.
 (Modified from Phelps et al., 1999)

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by the timely reviews of Margaret Townsend (BN), Sigmund Drellack, Stuart Rawlinson (BN), Gayle Pawloski, Giday WoldeGabriel, and Justin Evans (BN).

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2.0 Data Analysis

Work on the TCU study began in October 1999, with the compilation and evaluation of existing data from Yucca Flat drill holes, including lithologic and geophysical logs, and mineralogic and chemical analyses (Prothro et al., 1999, written communication). A preliminary analysis of the existing data indicated that the TCU was mineralogically zoned with regard to major alteration minerals including: (1) an upper zone of predominantly clinoptilolite alteration; (2) a middle zone of more complex alteration mineralogy; and (3) a basal zone of pervasive argillic alteration. This zonation is similar to that described by Hoover (1968) for zeolite zonation at the Nevada Test Site. To further investigate and define the mineralogic zonation within the TCU, 17 holes were selected for additional sampling in Fiscal Year (FY) 2000. The holes are TW6c, UE2co, U3cn5, U3mh, U3mi, UE4a, UE4ab, UE4aL, UE7ax, UE7bc, UE7f, UE8c, UE9cp, U10as, UE10bd, UE10bf, and UE15d. These study holes were selected on the basis of various criteria such as location, thickness of TCU encountered, amount of existing analytical data, and type and quality of available lithologic samples.

Lithologic samples from 134 depths were collected during FY 2000 from 16 of the 17 study holes (Prothro, 2000, written communication). Samples from 18 additional depths in U3mi, UE7ax, UE7bc, and UE7f, that had been acquired during previous studies and stored at LANL, were also utilized. Laboratory analyses performed in FY 2000 on the 152 TCU study samples included XRD, X-ray fluorescence, and wet chemical analysis for divalent iron.

Results from the XRD analyses were compiled in FY 2004, with an additional 32 existing LANL XRD results from U3mh and U3mi, for a total of 184 mineralogical analyses (Appendix A). Published XRD results from TW6c, UE4a, and UE15d were reviewed but not integrated into the TCU data set due to differences in how the older results are reported.

Analysis of the XRD results confirmed and better defined the 3-layer model for alteration minerals within the TCU beneath Yucca Flat (see Section 3.0). Stratigraphic, lithologic, and geophysical data were compared with the mineralogic data from the 17 holes to investigate controlling factors on the mineralogic zonation. These data were also correlated and compared from hole to hole to further investigate controlling factors as well as lateral variation. As a result, it was determined that existing lithologic descriptions and geophysical logs could be utilized to provide a first approximation of the tops of mineralogic layers in other Yucca Flat drill holes that lacked sufficient mineralogic data. Stratigraphic data (Drellack and Thompson, 1990; Pawloski, 1997, written communication; Drellack and Gonzales, 1998, written

communication), lithologic descriptions, and geophysical logs from approximately 500 drill holes in Yucca Flat were utilized. The tops of each mineralogic layer as well as the top of the pre-Tertiary surface were recorded (Appendix B) and the thickness of each zone calculated. The resulting thickness data were plotted on a base map of Yucca Flat consisting of a color elevation relief map of the pre-Tertiary surface based on gravity (Phelps et al., 1999) with basin faults from the draft Yucca Flat CAU framework model (Drellack and Gonzales, 1998). The thickness data for each mineralogic layer were hand-contoured to produce isopach maps showing the extent and thickness of the layers beneath Yucca Flat. Thickness contours were digitized and transferred to a shaded relief map of the land surface in the Yucca Flat vicinity for final presentation.

3.0 Mineralogic Zones

Zeolite, felsic minerals (quartz, potassium-feldspar [K-feldspar], and plagioclase), and clay minerals account for approximately 90 percent of the TCU mineralogy based on XRD data from the TCU study holes (Figure 3-1). Zeolite is the most abundant mineral averaging 41 percent, followed closely by felsic minerals at 35 percent and clay minerals considerably less at 15 percent. A plot of the percentages of the 3 major mineral assemblages with respect to sample depth shows that the relative abundances of these minerals change with depth and define a 3-layer model of major mineral distribution within the TCU (Figure 3-2). The amount of zeolite appears to decrease in abundance with depth whereas both felsic and clay minerals increase. At the deepest levels, clay minerals dramatically increase whereas zeolite and felsic minerals decrease. These mineralogical changes can be grouped into 3 zones: (1) an upper zone dominated by the zeolite mineral clinoptilolite (ZC) with lesser amounts of felsic minerals (FS) and clay minerals (AR) and generally represented by the formula $ZC \gg FS \gg AR$; (2) a middle zone with felsic minerals dominant over clinoptilolite and clay minerals ($ZC < FS \gg AR$); and (3) a basal argillic zone with clay minerals dominant over felsic minerals and clinoptilolite ($ZC \ll FS < AR$). The 3 zones are designated from highest to lowest as the ZC zone, FS zone, and AR zone. Figure 3-3 provides a graphical comparison of the major mineralogy of the three zones. Table 3-1 lists the various minerals that occur within each zone and their relative abundance.

The three mineralogical zones can be traced laterally beneath Yucca Flat as shown in Figure 3-4. The figure also shows that the depth relationships with respect to each zone (i.e., the ZC zone occurs above the FS zone and the AR zone occurs at the base of the Tertiary section) are consistent in each drill hole, and the occurrence of the zones is independent of elevation. This is particularly evident when comparing drill hole U3mh with U3cn5 in Figure 3-4. Although U3mh is structurally higher in elevation than U3cn5, all three zones are present in both holes.

3.1 ZC Zone

The top of the ZC zone in Yucca Flat typically corresponds to the top of the TCU, which is established at the level of pervasive zeolitization, a subsurface horizon that has been successfully recognized and mapped in Yucca Flat for many years. Therefore, the top of the ZC zone in most drill holes was available from several existing sources. A draft version of the drill hole database for the Yucca Flat hydrostratigraphic framework model (in progress) provided elevations for the top of the TCU for many Yucca Flat drill holes. This database was compiled from Drellack and

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Figure 3-1
Mineral Abundances for the TCU in Yucca Flat

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Figure 3-2
Abundances of the Major TCU Minerals Versus Depth

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Figure 3-3
Relative Abundances of the Major TCU Minerals for Each of the Mineralogical Zones

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Table 3-1
List of Minerals and their Average Abundances for each TCU Mineralogic Zone

Mineral		Percent (Standard Deviation)					
		ZC Zone n = 81 ^a		FS Zone n = 49 ^a		AR Zone n = 20 ^a	
Smectite		6 (7.9)		12 (9.4)		58 (14.7)	
Kaolinite		<1 (0.1)		<1 (0.1)		1 (2.1)	
Clinoptilolite		54 (16.1)		32 (16.1)		1 (2.2)	
Mordenite		2 (4.0)		1 (1.4)		0 (0.0)	
Analcime		0 (0.0)		1 (3.2)		<1 (0.6)	
Cristobalite		1 (0.9)		1 (1.1)		0 (0.0)	
Opal-CT		10 (6.3)		6 (5.0)		0 (0.0)	
Quartz	Felsic Minerals	3 (2.6)	21	10 (8.8)	46	17 (6.6)	34
K-Feldspar		8 (4.2)		17 (9.0)		11 (6.1)	
Plagioclase		10 (5.0)		19 (6.9)		6 (5.0)	
Glass		1 (8.8)		0 (0.0)		0 (0.0)	
Hematite		0 (0.0)		<1 (0.1)		<1 (0.5)	
Biotite		2 (2.5)		3 (1.7)		2 (1.5)	
Hornblende		<1 (0.6)		<1 (0.6)		<1 (0.2)	
Calcite		<1 (2.4)		<1 (0.1)		1 (2.7)	
Dolomite		0 (0.0)		0 (0.0)		1 (2.4)	

- a Older analyses for U3mh and U3mi did not distinguish between the feldspar minerals plagioclase and K-feldspar; therefore, the population number (n) is less for these minerals.
(ZC n=70; FS n=40; AR n=13, for plagioclase and K-feldspar)

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Figure 3-4
Cross-Sectional Diagram Through Drill Holes
U3mi, U3mh, U3cn5, UE7f, and UE7ax
Showing Mineralogic Zones Within the TCU

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Thompson (1990) for drill holes in southern Yucca Flat and unpublished data for northern Yucca Flat drill holes provided by LLNL (Pawloski, 1997, written communication). Additional information on the top of the ZC zone was gleaned from lithologic descriptions.

The approximate depth at which zeolitization becomes pervasive is relatively easy to determine in drill holes using lithologic samples and geophysical logs, particularly the epithermal neutron log (Drellack, 1994, written communication). The transition from unaltered vitric tuff to zeolitic tuff is typically rather abrupt but may occur over a considerable interval characterized by interbedded vitric and zeolitic intervals (e.g., see UE7ax in Figure 3-4 and Appendix B).

3.1.1 Mineralogy of the ZC Zone

The clinoptilolite zone is defined mineralogically by zeolite dominant over felsic minerals and both being much greater in abundance than clay minerals. Other minerals that were identified within the zone include opal-cristobalite/tridymite (CT), cristobalite, biotite, hornblende, and calcite.

Zeolite

The ZC zone averages 54 percent clinoptilolite based on the 81 samples analyzed for this study. However, locally the amount of clinoptilolite can range from less than 30 percent to more than 80 percent. The zeolite mordenite also occurs within the ZC zone. Twenty-four of the 80 samples analyzed contain mordenite, typically in amounts less than 10 percent but as high as 17 percent. Typically, but not exclusively, mordenite occurs in the lower portions of the ZC zone. The zeolite analcime was not detected in any of the ZC samples. The amount of zeolite within the ZC zone typically decreases slightly with depth.

Felsic Minerals

Felsic minerals (quartz, K-feldspar, and plagioclase) on average account for 21 percent of the minerals within the ZC zone. Plagioclase is the most abundant felsic mineral, averaging 10 percent of the zone (48 percent of the felsic minerals), followed by K-feldspar at 8 percent (38 percent of the felsic minerals), and quartz at 3 percent (14 percent of the felsic minerals). In contrast to zeolite, the amount of felsic minerals within the ZC zone increases slightly with depth.

Clay Minerals

Clay minerals account for 6 percent of the minerals within the ZC zone. Almost all samples contained at least trace (<1 percent) amounts of clay minerals with 7 samples having between 20 and 38 percent clay minerals. Smectite is by far the dominant clay mineral within the ZC zone. Kaolinite was the only other clay mineral detected and that was in only one sample and at less than 1 percent.

Other Minerals

Of the remaining mineral constituents within the ZC zone, opal-CT is the most abundant, accounting for, on average, 10 percent of the ZC zone mineralogy. Like zeolite, opal-CT appears to decrease slightly in abundance with depth in the zone. Other minerals detected include biotite (2 percent), cristobalite (1 percent), and hornblende and calcite (each <1 percent). Although glass accounts for 1 percent of the mineralogy of the zone, only 2 samples contained glass. Both samples contained high proportions of glass (34 percent and 72 percent) and occur near the top of the ZC zone, and thus likely represent minor interbeds of vitric tuff within predominately zeolitic intervals. Hematite was not detected in any of the samples from the ZC zone.

3.1.2 Stratigraphy and Lithology of the ZC Zone

Depending on the level of zeolitization, the ZC zone can include stratigraphic units as young as the Rainier Mesa Tuff (11.6 Ma) and as old as Tub Spring Tuff (14.9 Ma) (Sawyer et al., 1994). Zeolitic rocks older than the Tub Spring Tuff such as the Volcanics of Oak Spring Butte are typically assigned to the underlying FS zone. The stratigraphic units of the ZC zone consist predominantly of nonwelded tuff in the form of ash-flow, ash-fall, and reworked tuffs. These volcanic deposits contain high proportions of glass shards when deposited, which are susceptible over time, to zeolitization in basin environments like Yucca Flat. Thus when zeolitized, this relatively consistent lithologic composition yields rocks with consistently high proportions of zeolite like that observed within the ZC zone. At the southern end of Yucca Flat, strongly welded Topopah Spring Tuff is intercalated within the upper portion ZC zone. Also, at the north end of Yucca Flat, strongly welded Tub Spring Tuff occurs at the base of the ZC zone.

3.1.3 Extent and Thickness of the ZC Zone

The ZC zone is thick and extensive beneath Yucca Flat basin proper (Figure 3-5). The zone does not appear to be present on the buried ridge beneath the western portion of Yucca Flat or in the western subbasin, mainly because of the scarcity of volcanic rocks as well as the lack of zeolitic alteration due to the relatively high structural elevation. Within Yucca Flat basin proper, the thickness of the ZC zone averages 213 m (700 ft) calculated from measured thicknesses in drill

Figure 3-5
Isopach Map of the ZC Zone
 Black dots show drill hole control.

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holes that penetrate a complete section of the zone. However, in north central Yucca Flat proper where the highest concentration of drill holes that encounter the zone are present, the thickness of the zone varies considerably from less than 100 m (329 ft) to more than 300 m (984 ft). The maximum measured thickness is 440 m (1,444 ft) at UE4f. The occurrence of more than 300 m (984 ft) of the ZC zone in drill holes UE6d#3 and UE6e suggests that the ZC zone is also thick and extensive beneath southern Yucca Flat where few drill holes penetrate deep enough to encounter the zone. It appears that the zone thins toward the northern end of Yucca Flat basin proper due to the rise in elevation of the volcanic rocks and the subsequent lowering stratigraphically of the level of zeolitization as well as the erosion of post-Volcanics of Oak Spring Butte units during basin development.

3.2 FS Zone

Examination of Figure 3-4 indicates that although the occurrence of the FS zone seems independent of elevation, the thickness may be controlled by depth. For example, at U3cn5 and UE7f, the FS zone is much thicker than at U3mh and UE7ax which are considerably higher in elevation. However, a closer examination of the figure shows that the top of the FS zone is near the top of the Volcanics of Oak Spring Butte. A comparison of U3mi and U3mh reveals that although U3mi is lower in elevation than U3mh, the FS zone is not present in U3mi. However, the Volcanics of Oak Spring Butte are also not present in U3mi. Also, the Volcanics of Oak Spring Butte are much thicker in U3cn5 and UE7ax compared with U3mh and UE7ax. All this seems to indicate that the occurrence of the FS zone may be controlled more by stratigraphy than by elevation and depth. Based on lithologic descriptions and geophysical logs, the Volcanics of Oak Spring Butte and older Tertiary units in Yucca Flat include a more diverse assemblage of lithologic units than the overlying units that compose the ZC zone. The lithologic composition of the FS zone is discussed in more detail in Section 3.2.2, but in general, lithologic units of the FS zone contain more felsic-rich units such as devitrified welded ash-flow tuff and tuffaceous sandstone. Thus the amount of original glass available for zeolitization is less within the FS zone, resulting in a general decrease in the amount of zeolite within the zone as reflected in the XRD data.

It is possible that some of the higher felsic mineral contents observed within the FS zone are the result of higher temperature quartzo-feldspathic or hydrothermal alteration (Prothro and Warren, 2001). However, substantial amounts of low-temperature alteration minerals such as clinoptilolite are present throughout the FS zone. Results of oxygen isotope analyses of whole rock samples from the FS zone in UE7f are consistent with these low-temperature alteration minerals found within the FS zone in UE7f (Dickerson et al., 2004). In addition, stable isotope analyses of calcite

lining fractures within the TCU beneath Yucca Flat indicate that the calcite formed at temperatures less than 100 degrees Celsius. Also, many calcite veins show a pedogenic carbon signature indicating that calcite within the TCU was deposited by groundwater moving downward and not upward through Paleozoic carbonate rocks as would be expected with hydrothermal activity (Dickerson et al., 2004).

As a first approximation, the top of the FS zone was determined in drill holes lacking mineralogic analyses by identifying the top of the Volcanics of Oak Spring Butte using existing stratigraphic and lithologic information. For the vast majority of holes, this method yielded a correct top for the FS zone because the level of zeolitization was stratigraphically above the Volcanics of Oak Spring Butte. However, in a few drill holes the level of zeolitization was within the Volcanics of Oak Spring Butte, and in these cases the top of the FS zone was picked at the top of zeolitization.

3.2.1 Mineralogy of the FS Zone

The FS zone is defined by felsic minerals generally more abundant than zeolite, with both more abundant than clay minerals. However, the mineralogic variability within the FS zone is greater than that for the ZC and AR zones.

Zeolite

Although felsic minerals are the most abundant mineral constituents of the FS zone, zeolite still constitutes a significant portion of the zone, averaging 34 percent of the mineral composition. Like the ZC zone, clinoptilolite is by far the dominant zeolite mineral within the FS zone, accounting for, on average, 32 percent of the zone mineralogy. However, clinoptilolite abundance within the zone ranges from 0 to more than 70 percent, reflecting the mineralogic variability that is characteristic of the zone.

Other zeolite minerals that occur within the zone include mordenite and analcime. Eight of the 49 samples analyzed from the FS zone contain mordenite. All 8 samples contain less than 7 percent mordenite, producing an average of 1 percent for the zone overall. Six samples contain analcime, all less than 10 percent except for one sample in UE7f that contains 20 percent analcime. Overall, the average amount of analcime within the FS zone is 1 percent.

Felsic Minerals

Forty-six percent of the minerals of the FS zone consist of the felsic minerals quartz, K-feldspar, and plagioclase. Like the ZC zone, the most abundant felsic mineral in the FS zone is plagioclase at 19 percent, followed by K-feldspar at 17 percent, and quartz at 10 percent.

Clay Minerals

Although clay minerals are more abundant in the FS zone than in the ZC zone, they are still a rather minor constituent within the FS zone where they constitute on average 12 percent of the mineralogy. This is almost exclusively in the form of smectite with only one sample showing trace amounts of kaolinite. Although averaging only 12 percent, smectite abundance ranges from 0 to as high as 37 percent in the samples analyzed.

Other Minerals

Other minerals detected in samples from the FS zone include opal-CT (6 percent), biotite (3 percent), cristobalite (1 percent), and trace amounts of hematite, hornblende, and calcite. No glass was detected in any of the samples from the FS zone.

3.2.2 Stratigraphy and Lithology of the FS Zone

The top of the FS zone typically corresponds to the highest zeolitic unit within the Volcanics of Oak Spring Butte or older Tertiary rocks. Thus the zone can include all stratigraphic units from the top of the Volcanics of Oak Spring Butte to the top of pre-Tertiary rocks. This interval contains a more diverse assemblage of lithologic units than those that compose the overlying ZC zone. In addition to nonwelded tuffs, rocks of the FS zone include welded ash-flow tuff, tuffaceous sandstone, and paleocolluvium. This more diverse lithologic composition is reflected in a more variable mineralogy. Rocks deposited with high proportions of felsic minerals either through mechanical processes (e.g., tuffaceous sandstone) or devitrification (e.g. welded ash-flow tuff) will have lower relative proportions of glass that can be altered to zeolite minerals.

3.2.3 Extent and Thickness of the FS Zone

Because the FS zone consists of zeolitized Volcanics of Oak Spring Butte and older Tertiary units, the extent and thickness of the zone is controlled mainly by the distribution of the Volcanics of Oak Spring Butte and older rocks, but also by the level of zeolitization. In the Yucca Flat basin proper, the FS zone is thick and extensive (Figure 3-6). The average thickness of the zone is 126 m (413 ft) calculated from measured thicknesses in drill holes that encountered a complete section of the zone. However, the thickness appears to be highly variable, ranging from a few tens of meters to more than 300 m (984 ft). This variability is likely due to pre-eruption topography and the degree of development (i.e., elevation) of the underlying argillic zone. Some of the variability may be apparent, resulting from portions of the older volcanic rocks being faulted out in some drill holes. The greatest thickness of FS zone

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Figure 3-6
Isopach Map of the FS Zone
Black dots show drill hole control.

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encountered in a drill hole in Yucca Flat is 313 m (1,027 ft) at UE6e, suggesting that the FS zone is thick and extensive beneath southern Yucca Flat where few drill holes penetrate deep enough to encounter the zone. Similarly, thick (> 200 m [> 656 ft]) occurrences of FS zone in the central and extreme northern portions of Yucca Flat proper suggest that the FS zone is also relatively thick and extensive in eastern portions of Area 2 and western portions of Area 9 of northern Yucca Flat where existing drill hole information is insufficient to determine the thickness of the zone.

The FS zone is not present on the buried ridge where volcanic rocks are generally absent. The zone is also not present in the western sub-basin due to the lack of zeolitic alteration in the area, though older volcanic units are present.

3.3 AR Zone

Geologists working in Yucca Flat have known for decades that in many places beneath the basin the volcanic rocks at the base of the Tertiary section are highly argillized (Hoover, 1968; Drellack, 1994, written communication). The top of the AR zone is defined as the level below which almost all the rocks are pervasively argillic down to the top of the pre-Tertiary rocks. Other zones of pervasive argillic alteration occur throughout the volcanic section. Some of these zones intercepted by drill holes represent argillization along faults (Drellack, 1994, written communication). Others occur at the top of welded ash-flow tuffs such as the Redrock Valley Tuff. Although these argillic zones can be traced laterally for some distance beneath Yucca Flat, they are relatively thin and separated by significant intervals of non-argillic rocks, so they are not included within the AR zone. Many of these argillic zones occur within the FS zone and contribute to the characteristic mineralogic variability of the FS zone.

The pervasive argillic alteration of the AR zone has distinguishing characteristics that are readily observed macroscopically in lithologic samples and with geophysical logs. The argillic rocks tend to be darker in color than the overlying zeolitic rocks, exhibiting characteristic shades of red and brown that typically become darker with depth (Figure 3-7). Core segments from the argillic zone are typically moderately indurated to friable, with a decrease in induration with depth that is probably due to a systematic increase in argillization with depth through the zone. Core segments from the lower portion of the zone are typically highly broken, with waxy slickensided partings common. The outer surfaces of core segments from the AR zone are conspicuously rough in appearance and feel. This contrasts sharply with the much smoother surfaces of core

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Figure 3-7
Photograph of Argillic Rocks in Drill Hole UE7f

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segments from overlying zones. Also, many core segments from the AR zone have a thin mudcake adhering to the sides of the core. This results from mud being generated during coring of the argillic rocks. The rocks of the AR zone also exhibit characteristic signatures on geophysical logs. Highly argillic tuffs typically exhibit resistivities of less than 10 ohm-meters, which is considerably less than zeolitic tuffs (Carroll, 1990), and thus can usually be identified with electric logs (Figure 3-8). Also, zones of pervasive argillic alteration tend to be less stable during drilling than zones of zeolitic alteration, resulting many times in conspicuous borehole enlargements that are easily identified on caliper logs. These characteristics permit the confident identification of the AR zone in numerous drill holes lacking sufficient mineralogic data.

3.3.1 Mineralogy of the AR Zone

The mineralogy of the AR zone is characterized by abundant clay, moderate amounts of felsic minerals, and the virtual absence of zeolite.

Zeolite

Zeolite minerals are rare in the AR zone, averaging approximately 1 percent. However, only 3 of the 20 samples analyzed from the AR zone contain zeolite, and all of these were in abundances less than 10 percent. Clinoptilolite was detected in 2 of the samples and analcime in 1. Mordenite was not detected.

Felsic Minerals

The felsic mineral content of the AR zone is substantial, averaging 34 percent. The relative abundances of the individual felsic minerals within the AR zone differ from the other 2 zones. Within the AR zone quartz is the most abundant felsic mineral, averaging 17 percent. K-feldspar is the second most abundant, averaging 11 percent, followed by plagioclase at 6 percent.

Clay Minerals

The AR zone averages 59 percent clay minerals. As in the other zones, smectite is the dominant clay mineral in the AR zone. It accounts for 58 percent of the mineralogy of the zone, with kaolinite averaging 1 percent. Smectite was detected in all the samples analyzed from the zone and in abundances greater than 30 percent. Kaolinite was detected in 6 of the 20 samples, in abundances of 6 percent or less.

Other Minerals

Biotite was detected in almost all the samples, averaging 2 percent for the zone. Calcite and dolomite were detected in a few of the samples, resulting in an average for the zone of 1 percent

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Figure 3-8
Diagram of Drill Hole UE7f showing Relationships Between
the Electric Log, Caliper Log, and Clay Content

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each for both minerals. Hematite occurs in 9 of the 20 samples but always less than 2 percent, and resulting in an average for the zone of less than 1 percent. However, this is still the most abundant occurrence of hematite of the three zones. No cristobalite, opal-CT, glass, or hornblende was detected in any of the samples from the AR zone.

3.3.2 Stratigraphy and Lithology of the AR Zone

Because the AR zone forms at the base of the Tertiary section directly overlying the pre-Tertiary surface, the zone typically includes the oldest Tertiary stratigraphic units in the Yucca Flat vicinity. Consequently, the AR zone contains many of the same stratigraphic and lithologic units as the FS zone.

3.3.3 Extent and Thickness of the AR Zone

The AR zone is present in both the Yucca Flat basin proper and the western sub-basin but appears to be absent on the buried ridge (Figure 3-9). Within basin areas, the AR zone appears to be rather ubiquitous, with an average thickness calculated from drill hole intercepts of 27 m (89 ft). The zone typically ranges in thickness from a few meters to more than 100 m (328 ft). Although variable, the thickness of the AR zone rarely exceed 60 m (197 ft). However at drill hole UE4af in the western sub-basin, 202 m (663 ft) of the argillic tuffs are present. This is by far the greatest thickness of the AR zone reported and may represent argillization along a high angle fault near the UE4af borehole.

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Figure 3-9
Isopach Map of the AR Zone
Black dots show drill hole control.

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4.0 Summary

Altered volcanic rocks that form the TCU beneath Yucca Flat consist mainly of 3 major mineral assemblages: zeolite, felsic minerals, and clay minerals. Based on these three mineral assemblages, the TCU can be subdivided into 3 zones representing differences in the abundance of these mineral assemblages. This three-layer model includes: (1) an upper zone called the ZC zone that is characterized by the abundance of the zeolite mineral clinoptilolite with lesser amounts of felsic and clay minerals; (2) a middle zone called the FS zone with felsic minerals dominant over clinoptilolite and clay minerals; and (3) a basal argillic zone called the AR zone where clay minerals are dominant over felsic minerals and clinoptilolite.

All 3 zones are extensive beneath the eastern half of Yucca Flat within the Yucca Flat basin proper. Only the AR zone occurs beneath western Yucca Flat within the western sub-basin. All 3 zones appear to be absent along the buried ridge that separates Yucca Flat basin proper from the western sub-basin. The ZC zone is, on average, the thickest of the 3 zones, averaging 213 m (700 ft), followed by the FS zone at 126 m (413 ft), and finally the AR zone at 27 m (89 ft).

The three-layer mineralogic model of the TCU will provide additional hydrostratigraphic layers for the Yucca Flat hydrostratigraphic framework model. In addition, the identification of the type, quantity, and distribution of alteration minerals within each TCU layer will permit modelers to better predict the spatial distribution and extent of contaminant transport from underground tests in Yucca Flat, at both the hydrologic source term and CAU-level scales.

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Appendix A

X-Ray Diffraction Results

Results of XRD Analyses for TCU Study Samples

(XRD analyses performed by the Hydrology, Geochemistry, and Geology Group, Earth and Environmental Sciences Division, Los Alamos National Laboratory)

Drill Hole	Sample Depth (ft)	Mineralogic Zone ¹	Mineral Abundance (%)																	Total (%)
			SM	KA	ZC	ZM	ZA	CR	OP	QZ	KF	PL	FE	GL	HM	BT	HN	CC	Other	
TWC	1260.6	AR	31.9	---	---	---	2.6	---	---	25.0	15.0	11.0	---	---	1.2	2.8	---	11.5	---	100.9
UE2co	1500	na	5.4	---	---	---	---	1.2	---	0.6	11.5	15.2	---	60.6	---	0.9	---	0.6	Tridymite 2.3	98.3
UE2co	1620	na	1.7	---	---	---	---	---	---	10.1	11.5	8.1	---	68.8	---	1.1	0.1	---	---	101.4
UE2co	1680	na	2.4	---	---	---	---	---	---	1.4	5.5	6.9	---	81.4	---	1.1	0.1	0.2	Dolomite 2.9	101.9
UE2co	1740	na	1.5	---	---	---	---	---	---	0.1	9.8	17.7	---	66.2	---	1.6	---	---	Illite? 3.1	100.0
UE2co	1775	AR	59.4	---	---	---	---	---	---	12.6	10.2	16.0	---	---	---	5.6	1.0	---	---	104.8
U3CN5	1420.3	ZC	3.6	---	78.1	---	---	---	5.9	0.8	5.3	5.9	---	---	---	---	---	---	---	99.6
U3CN5	1590	ZC	24.9	---	30.0	---	---	---	3.8	4.1	8.8	23.2	---	---	---	2.0	---	---	---	96.9
U3CN5	1718.4	ZC	2.6	---	64.8	---	---	---	5.4	3.7	8.5	11.1	---	---	---	---	---	---	---	96.2
U3CN5	1778.3	ZC	4.3	---	62.9	---	---	---	12.1	4.7	9.6	6.0	---	---	---	---	---	---	---	99.6
U3CN5	1828.1	ZC	1.0	---	52.9	1.5	---	---	3.4	3.7	8.7	21.1	---	---	---	5.4	0.2	---	---	97.9
U3CN5	1917.5	ZC	0.8	---	50.9	2.8	---	---	2.3	4.3	16.2	15.4	---	---	---	4.4	---	---	---	97.4
U3CN5	2002.2	ZC	1.2	---	44.1	2.9	---	---	2.8	12.8	14.6	15.1	---	---	---	4.2	1.1	---	---	98.7
U3CN5	2056	FS	23.0	0.7	19.2	5.2	---	---	---	7.9	13.8	24.5	---	---	---	4.0	---	---	---	98.2
U3CN5	2186.4	FS	1.9	---	---	---	---	---	---	29.9	37.4	28.8	---	---	0.7	3.8	---	---	---	102.5
U3CN5	2389	FS	9.3	---	18.5	3.7	---	---	---	17.9	25.2	22.1	---	---	---	5.4	---	---	---	102.1
U3CN5	2510	AR	36.4	---	---	---	---	---	---	22.0	28.7	11.9	---	---	---	4.0	---	---	---	103.0
U3CN5	2592	AR	59.5	---	5.0	---	---	---	---	24.6	6.4	8.4	---	---	---	1.0	---	---	---	104.9
U3CN5	2692	AR	55.0	---	---	---	---	---	---	24.1	10.4	3.3	---	---	0.3	2.7	---	3.0	Dolomite 6.0	104.9
U3CN5	2745.1	AR	46.6	0.7	---	---	---	---	---	21.0	15.5	1.5	---	---	---	1.3	---	1.3	Dolomite 9.2	97.2
U3CN5	2800	AR	91.4	4.0	---	---	---	---	---	4.1	7.3	0.1	---	---	---	3.7	---	---	---	110.6
U3MH	847	ZC	2.0	---	51.0	---	---	---	21.0	6.0	---	---	19.0	---	---	---	---	---	---	99.0
U3MH	900	ZC	9.2	---	47.2	---	---	---	16.1	3.1	9.3	7.9	---	---	---	5.5	0.6	---	---	98.9
U3MH	990	ZC	3.0	---	6.0	---	---	---	---	6.0	---	---	13.0	72.0	---	0.5	0.5	---	---	101.0
U3MH	1070	ZC	---	---	70.9	---	---	---	8.9	2.8	5.5	9.6	---	---	---	---	0.6	---	---	98.3
U3MH	1140	ZC	2.0	---	55.8	---	---	---	12.7	5.9	10.5	9.4	---	---	---	---	---	---	---	96.3
U3MH	1230	ZC	2.0	---	61.5	6.4	---	---	6.7	4.4	6.8	8.5	---	---	---	0.3	---	---	---	96.8
U3MH	1300	ZC	0.9	---	69.8	9.6	---	---	10.3	0.5	4.4	6.0	---	---	---	---	0.1	---	---	101.4
U3MH	1335	ZC	0.5	---	82.0	---	---	---	13.0	---	---	---	---	---	---	0.5	---	---	---	96.0
U3MH	1370	ZC	2.0	---	73.0	---	---	---	12.0	2.0	---	---	15.0	---	---	---	---	---	---	104.0
U3MH	1390	ZC	21.0	---	44.0	---	---	---	4.0	3.0	---	---	21.0	---	---	1.0	0.5	---	---	94.5
U3MH	1400	ZC	1.0	---	67.8	4.9	---	---	14.4	1.1	3.5	5.5	---	---	---	2.2	0.5	---	---	100.9
U3MH	1440	ZC	1.0	---	67.9	4.9	---	---	14.3	1.1	3.4	5.4	---	---	---	2.2	0.4	---	---	100.7
U3MH	1480	FS	1.0	---	51.0	---	---	---	10.0	8.0	---	---	35.0	---	---	1.0	0.5	---	---	106.5
U3MH	1510	FS	21.0	---	35.0	---	---	---	4.0	6.0	---	---	27.0	---	---	1.0	0.5	---	---	94.5
U3MH	1520	FS	29.0	---	24.0	---	---	---	4.0	5.0	---	---	33.0	---	---	0.5	0.5	---	---	96.0
U3MH	1530	FS	9.0	---	54.0	---	---	---	19.0	0.5	---	---	14.0	---	---	0.5	---	---	---	97.0
U3MH	1540	FS	28.0	---	29.0	---	---	---	11.0	1.0	---	---	25.0	---	---	1.0	---	---	---	95.0
U3MH	1580	FS	---	---	---	---	---	---	---	30.1	50.3	16.0	---	---	0.2	4.2	---	---	---	100.7
U3MH	1600	FS	9.0	---	50.0	---	---	---	12.0	0.5	---	---	30.5	---	---	0.5	---	---	---	102.5
U3MH	1610	FS	5.0	---	53.0	---	---	---	8.0	15.0	---	---	30.5	---	---	1.0	0.5	---	---	113.0

Drill Hole	Sample Depth (ft)	Mineralogic Zone ¹	Mineral Abundance (%)																	Total (%)
			SM	KA	ZC	ZM	ZA	CR	OP	QZ	KF	PL	FE	GL	HM	BT	HN	CC	Other	
U3MH	1620	FS	9.0	---	47.0	---	---	---	7.0	8.0	---	---	29.0	---	---	1.0	---	---	---	101.0
U3MH	1640	FS	18.0	---	42.0	---	---	---	0.5	2.0	---	---	19.0	---	---	0.5	---	---	---	82.0
U3MI	500	na	12.0	---	---	---	---	12.0	---	13.0	---	---	49.0	---	1.0	0.5	---	---	Tridymite 9	96.5
U3MI	520	na	13.0	---	---	---	---	25.0	---	7.0	---	---	58.0	---	1.0	0.5	---	---	---	104.5
U3MI	550	na	1.0	---	---	---	---	---	---	4.0	---	---	10.0	85.0	---	0.5	---	---	---	100.5
U3MI	750	na	2.0	---	1.0	---	---	---	3.0	3.0	---	---	12.0	79.0	---	0.5	---	---	---	100.5
U3MI	810	ZC	6.0	---	35.0	---	---	---	13.0	1.0	---	---	33.0	---	---	16.0	0.5	---	---	104.5
U3MI	830	ZC	11.5	---	16.0	---	---	---	18.0	4.0	---	---	40.0	---	---	9.0	---	---	---	98.5
U3MI	870	ZC	1.8	---	67.5	---	---	---	6.5	1.5	14.4	8.6	---	---	---	0.5	0.9	---	---	101.8
U3MI	920	ZC	0.6	---	71.0	6.9	---	---	7.2	2.4	3.4	7.4	---	---	---	2.1	0.2	---	---	101.2
U3MI	990	ZC	1.3	---	58.4	2.4	---	---	15.5	3.0	5.7	9.1	---	---	---	0.2	0.1	---	---	95.7
U3MI	1070	ZC	11.5	---	25.0	---	---	---	21.0	2.0	---	---	33.0	---	---	6.0	2.0	---	---	100.5
U3MI	1080	ZC	15.0	---	22.0	---	---	---	11.0	1.0	---	---	37.0	---	---	6.0	2.0	---	---	94.0
U3MI	1090	ZC	3.0	---	34.0	---	---	---	22.0	6.0	---	---	26.0	---	---	2.0	1.0	---	---	94.0
U3MI	1100	ZC	7.0	---	57.0	---	---	---	10.0	3.0	---	---	21.0	---	---	0.5	---	---	---	98.5
U3MI	1120	ZC	1.2	---	55.1	3.4	---	---	8.7	2.8	12.5	11.3	---	---	---	1.8	---	---	---	96.9
U3MI	1310	ZC	0.5	---	54.9	7.7	---	---	7.0	5.7	7.6	13.5	---	---	---	0.3	---	---	---	97.3
U3MI	1400	ZC	0.7	---	58.0	16.4	---	---	4.8	3.7	7.1	8.7	---	---	---	1.1	---	---	---	100.5
U3MI	1450	ZC	0.6	---	58.0	7.6	---	---	6.8	3.6	13.3	9.3	---	---	---	---	---	---	---	99.2
U3MI	1530	ZC	0.6	---	55.2	16.6	---	---	6.5	5.0	7.0	7.9	---	---	---	---	---	---	---	98.7
U3MI	1600	ZC	1.1	---	78.8	5.9	---	---	0.8	5.0	6.9	2.9	---	---	---	---	---	---	---	101.5
U3MI	1630	ZC	8.0	---	58.0	---	---	---	---	13.0	---	---	21.0	---	---	0.5	---	---	---	100.5
U3MI	1660	AR	39.0	---	28.0	---	---	---	---	13.0	---	---	19.0	---	---	1.0	---	---	---	100.0
U3MI	1690	AR	49.0	---	---	---	---	---	---	19.0	---	---	32.0	---	---	1.0	---	---	---	101.0
U3MI	1710	AR	57.0	---	---	---	---	---	---	19.0	---	---	21.0	---	1.0	1.0	---	---	---	99.0
U3MI	1720	AR	51.0	---	---	---	---	---	---	23.0	---	---	23.0	---	1.0	1.0	---	---	---	99.0
U3MI	1730	AR	54.0	---	---	---	---	---	---	20.0	---	---	17.0	---	---	---	---	0.5	---	91.5
U3MI	1740	AR	68.0	---	---	---	---	---	---	19.0	---	---	15.0	---	---	0.5	---	---	---	102.5
U3MI	1750	AR	80.0	---	---	---	---	---	---	11.0	---	---	3.0	---	---	2.0	---	---	---	96.0
UE4AB	1350	na	---	---	1.8	---	---	---	---	4.5	5.7	5.2	---	79.5	---	0.6	---	---	---	97.3
UE4AB	1400	na	18.4	---	39.7	---	---	---	5.0	6.5	7.7	20.8	---	---	---	1.9	0.3	---	---	100.3
UE4AB	1450	na	8.8	---	16.2	---	---	---	---	0.5	9.9	17.7	---	46.3	---	0.5	0.3	---	---	100.2
UE4AB	1550	ZC	3.0	---	52.0	---	---	---	11.6	5.9	8.4	13.0	---	---	---	2.3	---	---	---	96.3
UE4AB	1625	ZC	13.5	---	71.8	---	---	---	9.2	0.7	1.8	3.4	---	---	---	0.5	---	---	---	100.8
UE4AB	1825	ZC	19.9	---	41.7	---	---	---	10.5	6.4	6.4	14.0	---	---	---	---	0.3	---	---	99.2
UE4AB	1925	ZC	9.8	---	50.6	---	---	---	4.1	8.0	11.4	11.9	---	---	---	---	0.9	---	---	96.8
UE4AB	2025	ZC	2.9	---	70.0	---	---	1.9	13.2	1.0	6.8	4.0	---	---	---	---	---	---	---	99.8
UE4AB	2125	FS	14.5	---	35.4	---	---	1.6	8.6	2.1	8.9	24.4	---	---	---	2.6	---	---	---	98.1
UE4AB	2250	FS	8.8	---	47.1	---	---	1.1	8.4	0.7	14.6	15.6	---	---	---	2.6	---	---	---	99.0
UE4AB	2350	FS	6.2	---	25.8	---	---	2.4	4.4	9.3	15.5	27.8	---	---	---	3.6	---	---	---	94.9
UE4AB	2450	FS	19.2	---	19.6	---	---	1.1	1.1	14.4	16.7	20.4	---	---	---	2.7	---	---	---	95.2
UE4AB	2510	FS	11.6	---	15.4	---	---	2.8	2.5	9.3	24.5	27.4	---	---	---	4.2	---	---	---	97.8
UE4AL	1435	na	2.1	---	56.6	---	---	1.2	5.6	4.7	10.8	14.6	---	---	---	1.1	0.1	---	---	96.8
UE4AL	1560	ZC	3.9	---	58.4	---	---	---	4.1	3.6	6.2	17.3	---	---	---	3.0	0.3	2.6	---	99.4

Drill Hole	Sample Depth (ft)	Mineralogic Zone ¹	Mineral Abundance (%)																	Total (%)
			SM	KA	ZC	ZM	ZA	CR	OP	QZ	KF	PL	FE	GL	HM	BT	HN	CC	Other	
UE4AL	1560	ZC	3.9	---	58.4	---	---	---	4.1	3.6	6.2	17.3	---	---	---	3.0	0.3	2.6	---	99.4
UE4AL	1600	ZC	4.4	---	54.1	---	---	---	6.2	5.4	11.4	14.6	---	---	---	2.0	0.1	---	---	98.2
UE4AL	1635	ZC	27.0	---	34.0	---	---	---	0.8	1.0	3.3	4.3	---	---	---	0.1	0.1	21.1	---	91.7
UE4AL	1660	ZC	5.7	---	69.1	---	---	---	6.3	2.9	7.1	6.5	---	---	---	0.7	---	---	---	98.3
UE7AX	554	na	0.1	---	39.1	---	---	0.2	38.4	6.9	4.1	9.5	---	---	---	2.1	0.3	1.6	---	102.3
UE7AX	590.4	na	22.2	---	37.0	---	---	---	4.1	4.9	7.3	23.6	---	---	---	5.3	0.3	---	---	104.7
UE7AX	634.3	na	---	---	---	---	---	---	---	---	---	---	---	100.0	---	---	---	---	---	100.0
UE7AX	658.2	na	10.3	---	41.5	---	---	0.6	0.6	1.6	6.0	25.9	---	8.6	---	3.6	2.9	---	---	101.6
UE7AX	706.1	na	1.9	---	9.4	---	---	0.3	5.4	2.4	5.4	17.2	---	58.9	---	3.3	0.8	---	---	105.0
UE7AX	729.8	na	5.5	---	0.1	---	---	---	5.5	8.1	5.8	11.2	---	62.5	---	1.9	0.8	---	---	101.4
UE7AX	764.1	na	1.8	---	0.4	---	---	---	3.5	---	11.6	15.7	---	68.9	---	1.0	---	---	---	102.9
UE7AX	789.5	ZC	0.2	---	55.5	---	---	---	14.2	4.2	11.4	12.2	---	---	---	1.7	---	---	---	99.3
UE7AX	888.5	ZC	0.3	---	56.4	13.8	---	---	11.7	2.1	4.7	7.0	---	---	---	1.1	---	---	---	97.1
UE7AX	955.3	ZC	27.4	---	43.1	2.8	---	---	10.7	0.9	5.3	9.7	---	---	---	1.2	---	---	---	101.0
UE7AX	1011.1	ZC	2.6	---	53.7	3.4	---	0.8	20.0	3.7	9.3	6.7	---	---	---	1.8	---	---	---	102.1
UE7AX	1066.8	ZC	7.4	---	38.4	---	---	0.4	28.8	6.5	10.4	3.9	---	---	---	3.7	---	---	---	99.5
UE7AX	1124.7	ZC	1.0	---	47.3	2.9	---	1.4	16.1	1.3	16.5	11.4	---	---	---	1.0	---	---	---	99.1
UE7AX	1209.7	FS	0.3	---	37.5	---	---	1.2	8.2	3.0	17.0	23.6	---	---	---	6.0	---	---	---	97.0
UE7AX	1259.8	FS	1.2	---	13.9	---	---	2.2	10.9	16.1	28.1	21.3	---	---	---	2.6	1.5	---	---	97.7
UE7AX	1291.3	FS	13.1	---	46.8	---	---	1.0	7.0	0.6	8.0	23.3	---	---	---	2.5	---	---	---	102.3
UE7AX	1320	FS	7.2	---	38.9	---	---	0.9	8.1	8.0	15.7	19.7	---	---	---	2.7	---	---	---	101.3
UE7AX	1339	FS	7.3	---	71.9	---	---	2.5	6.8	1.9	6.2	7.2	---	---	---	---	---	---	---	103.8
UE7BC	907.2	ZC	0.4	---	57.4	---	---	2.4	21.0	1.9	4.3	11.8	---	---	---	0.6	0.3	---	---	100.1
UE7BC	907.2	ZC	1.1	---	51.2	---	---	2.5	26.8	1.5	7.1	10.9	---	---	---	0.6	0.3	---	---	101.9
UE7BC	907.2	ZC	1.1	---	73.7	---	---	2.4	20.0	0.2	1.1	2.9	---	---	---	---	0.5	---	---	101.9
UE7BC	937.3	ZC	2.4	---	70.5	---	---	0.3	11.2	0.1	4.5	11.7	---	---	---	3.1	0.2	---	---	103.9
UE7BC	1077	ZC	10.6	---	56.8	---	---	0.1	1.2	1.0	5.2	19.8	---	---	---	5.5	3.9	---	---	104.1
UE7BC	1265	ZC	0.2	---	64.3	16.0	---	1.3	6.9	2.0	3.5	5.8	---	---	---	0.4	---	---	---	100.6
UE7BC	1502	ZC	---	---	84.4	9.2	---	0.6	6.8	---	0.1	1.0	---	---	---	---	---	---	---	102.1
UE7BC	1728	ZC	0.3	---	51.3	---	---	2.0	4.4	2.6	19.1	12.2	---	---	---	5.8	---	---	---	97.8
UE7BC	1990	FS	15.9	---	---	---	---	---	---	26.2	31.7	18.4	---	---	---	0.2	---	---	---	93.4
UE7BC	2201.5	FS	8.0	---	---	---	---	---	---	30.9	34.2	25.3	---	---	0.2	0.6	---	0.9	---	101.5
UE7BC	2254.5	FS	13.9	---	23.1	6.3	9.1	---	---	17.7	17.7	9.8	---	---	---	2.8	---	0.2	---	100.6
UE7BC	2377	FS	11.3	---	37.7	1.4	2.7	---	---	12.8	13.8	14.4	---	---	---	3.8	---	---	---	97.9
UE7BC	2554.1	FS	14.4	---	23.7	2.9	6.7	---	---	18.4	20.2	9.7	---	---	---	3.9	---	---	---	99.8
UE7BC	2687.1	AR	59.9	0.9	---	---	---	---	---	25.0	12.5	1.7	---	---	1.4	1.6	---	---	---	103.1
UE7F	870.6	na	---	---	---	---	---	1.7	---	1.4	9.7	22.6	---	61.9	---	4.6	---	---	---	101.9
UE7F	913.9	na	---	---	---	---	---	19.6	---	10.3	36.7	30.4	---	---	---	2.9	---	---	---	99.9
UE7F	1260.6	ZC	17.5	---	33.1	---	---	1.1	14.1	4.9	7.0	14.2	---	---	---	1.9	0.5	4.8	---	99.2
UE7F	1388.5	ZC	2.2	---	66.7	---	---	0.6	14.3	1.7	6.8	7.8	---	---	---	1.4	0.1	---	---	101.5
UE7F	1572.2	ZC	0.2	---	60.8	---	---	1.8	17.7	3.5	4.2	9.7	---	---	---	0.7	0.4	---	---	99.0
UE7F	1749.1	ZC	1.3	---	61.8	---	---	1.2	3.8	5.8	9.1	15.9	---	---	---	1.7	1.1	---	---	101.7
UE7F	1870	ZC	0.8	---	49.8	---	---	4.4	12.0	1.4	18.9	10.0	---	---	---	0.6	---	---	---	97.9
UE7F	1979.2	ZC	1.8	---	39.3	7.5	---	2.2	6.5	7.3	18.6	11.4	---	---	---	2.1	---	---	---	96.8

Drill Hole	Sample Depth (ft)	Mineralogic Zone ¹	Mineral Abundance (%)																	Total (%)
			SM	KA	ZC	ZM	ZA	CR	OP	QZ	KF	PL	FE	GL	HM	BT	HN	CC	Other	
UE7F	2063	ZC	11.6	---	47.8	4.4	---	0.6	4.0	9.9	13.3	10.7	---	---	---	---	---	---	---	102.4
UE7F	2161	FS	2.9	---	34.9	---	---	---	1.0	15.9	19.9	17.2	---	---	---	3.9	---	---	---	95.8
UE7F	2232.5	FS	19.6	---	46.4	---	---	4.5	11.0	8.6	7.7	4.1	---	---	---	---	---	---	---	101.8
UE7F	2346.2	FS	2.0	---	44.5	---	---	---	1.7	11.9	20.4	10.1	---	---	---	3.6	---	---	---	94.3
UE7F	2429	FS	7.5	---	---	---	19.6	---	---	29.1	17.5	17.6	---	---	---	3.3	---	---	---	94.6
UE7F	2520.4	FS	36.8	---	22.8	---	---	0.2	1.4	7.0	8.8	25.7	---	---	---	2.7	---	---	---	105.4
UE7F	2561.8	FS	4.2	---	55.4	---	2.6	---	1.4	8.8	14.3	11.2	---	---	---	3.8	---	---	---	101.8
UE7F	2654	FS	8.9	---	43.5	---	0.5	---	---	20.8	13.7	12.7	---	---	---	2.8	---	---	---	102.8
UE7F	2752.8	AR	68.6	3.7	---	---	---	---	---	10.4	10.3	4.1	---	---	1.0	1.5	---	---	---	99.6
UE7F	2793.1	AR	79.2	---	---	---	---	---	---	15.7	6.7	2.0	---	---	---	---	---	---	---	103.6
UE7f	2822.3	na	---	---	---	---	---	---	---	15.8	---	---	---	---	---	---	---	66.7	Dolomite 22.1	104.6
UE8C	755	na	45.3	4.0	0.4	---	---	1.2	---	0.9	8.5	9.8	---	31.5	---	0.5	---	---	---	102.1
UE8C	795	na	1.8	---	2.9	---	---	0.4	---	16.7	31.5	28.6	---	---	---	2.9	0.2	---	Tridymite 11.2	96.2
UE8C	840	na	0.7	---	0.6	---	---	---	---	0.3	6.3	24.6	---	56.7	0.1	7.0	2.0	---	---	98.3
UE8C	880	ZC	3.2	0.8	54.9	---	---	---	1.7	4.2	9.2	17.3	---	---	---	6.0	0.9	---	---	98.2
UE8C	1160	ZC	1.0	---	71.1	---	---	---	6.2	3.9	4.5	11.4	---	---	---	2.0	0.3	---	---	100.5
UE8C	1240	ZC	1.1	---	67.8	---	---	---	12.8	4.0	3.9	8.9	---	---	---	1.6	---	---	---	100.0
UE8C	1260	FS	0.2	---	37.0	---	---	1.0	9.5	12.9	10.9	18.0	---	---	---	3.5	0.5	---	---	93.5
UE8C	1310	FS	28.0	---	36.7	---	---	0.4	10.8	1.2	7.6	14.7	---	---	---	1.0	0.3	---	---	100.7
UE9CP	1240	ZC	0.9	---	67.4	1.0	---	1.0	10.7	5.9	7.3	6.9	---	---	---	1.2	---	---	---	102.4
UE9CP	1300	ZC	24.9	---	0.5	---	---	0.6	---	2.6	7.4	26.5	---	33.8	0.4	3.4	2.1	---	---	102.5
UE9CP	1380	ZC	1.8	---	71.1	---	---	2.0	13.8	2.1	5.9	4.2	---	---	---	1.3	---	---	---	102.2
UE9CP	1440	ZC	3.3	---	58.3	---	---	2.8	17.5	0.7	9.8	9.9	---	---	---	2.5	---	---	---	104.7
UE9CP	1540	FS	1.4	---	36.7	---	---	2.4	12.2	6.0	17.6	21.0	---	---	---	3.7	3.7	---	---	104.6
UE9CP	1620	FS	13.3	---	37.4	---	---	1.0	2.9	1.7	11.2	29.9	---	---	---	2.8	---	---	---	100.2
UE9CP	1680	FS	11.0	---	30.4	2.9	---	2.7	8.5	2.4	15.4	24.3	---	---	---	4.3	---	---	---	101.9
UE9CP	1740	FS	9.3	---	45.5	1.5	---	2.4	9.0	2.3	14.3	14.9	---	---	---	2.3	---	---	---	101.4
U10as	1080	na	10.6	---	---	---	---	---	---	0.9	1.8	2.6	---	82.0	---	---	---	---	---	97.9
U10as	1130	na	---	---	---	---	---	---	2.5	5.2	5.3	5.4	---	80.7	---	0.7	---	---	---	99.8
UE10BD	1360	na	1.0	---	---	---	---	---	---	10.8	15.7	28.0	---	35.2	---	5.7	2.3	---	---	98.7
UE10BD	1480	na	5.9	---	---	---	---	---	---	1.1	12.3	23.1	---	51.1	---	4.6	1.0	---	---	99.1
UE10BD	1530	na	3.0	---	---	---	---	---	---	12.2	15.7	32.5	---	30.2	0.5	1.6	0.7	---	---	96.4
UE10BD	1550	na	12.1	0.7	---	---	---	---	---	6.1	10.3	13.2	---	50.8	0.2	1.2	0.6	---	---	95.2
UE10BD	1590	AR	61.8	5.2	8.5	---	---	---	---	3.5	7.6	12.1	---	---	0.4	3.3	---	---	---	102.5
UE10BD	1620	AR	65.1	4.2	---	---	---	---	---	13.3	9.4	6.3	---	---	0.6	0.2	---	---	---	99.0
UE10BD	1650	AR	56.9	6.0	---	---	---	---	---	20.7	6.5	5.1	---	---	0.8	1.3	---	3.0	---	100.2
UE10BF	1470	na	20.7	---	6.4	---	---	---	---	8.3	4.6	10.9	---	48.4	---	0.3	0.3	---	---	99.9
UE10BF	1560	na	9.9	---	13.3	---	---	---	4.7	8.3	7.4	5.8	---	49.3	---	---	0.9	---	---	99.6
UE10BF	1630	na	16.2	---	0.9	---	---	0.8	---	4.9	2.8	10.0	---	65.3	---	0.4	---	---	---	101.3
UE10BF	1700	na	12.5	---	1.8	---	---	0.5	0.1	1.3	3.6	3.7	---	77.4	---	0.3	---	---	---	101.2
UE10BF	1800	na	22.7	---	---	---	---	0.4	---	2.2	6.3	17.1	---	47.2	---	1.4	0.4	---	---	97.7
UE10BF	1850	ZC	14.4	---	56.0	---	---	---	14.6	4.9	3.4	5.6	---	---	---	1.1	---	---	---	99.9
UE10BF	1940	ZC	7.3	---	59.6	---	---	1.2	13.2	2.3	6.9	7.2	---	---	---	0.5	---	---	---	98.2
UE10BF	2040	ZC	21.7	---	46.5	---	---	0.9	7.1	3.2	4.9	13.1	---	---	---	2.1	---	---	---	99.6

Drill Hole	Sample Depth (ft)	Mineralogic Zone ¹	Mineral Abundance (%)																	Total (%)
			SM	KA	ZC	ZM	ZA	CR	OP	QZ	KF	PL	FE	GL	HM	BT	HN	CC	Other	
UE10BF	2120	FS	35.0	---	31.8	---	---	2.1	13.8	2.0	6.1	11.5	---	---	---	1.5	---	---	---	103.8
UE10BF	2160	FS	8.4	---	34.9	---	---	1.9	7.3	0.9	9.1	32.7	---	---	---	1.7	---	---	---	97.0
UE10BF	2200	FS	16.7	---	24.3	---	---	1.5	5.8	0.1	11.0	30.2	---	---	---	3.4	1.4	---	---	94.4
UE15D	923.3	na	4.8	---	---	---	---	10.0	---	10.8	27.8	33.6	---	11.9	---	---	---	---	---	98.9
UE15D	1010.3	ZC	14.7	---	59.9	---	---	0.5	8.1	1.5	7.1	8.6	---	---	---	---	---	---	---	100.3
UE15D	1083.7	ZC	14.0	---	63.3	---	---	0.7	8.7	0.8	2.9	6.7	---	---	---	2.6	---	---	---	99.8
UE15D	1208	ZC	4.3	---	50.0	---	---	1.0	6.3	2.6	8.5	19.2	---	---	---	5.0	0.2	---	---	97.1
UE15D	1285.3	ZC	38.1	---	24.4	---	---	1.1	7.0	2.0	9.2	12.2	---	---	---	2.2	---	---	---	96.3
UE15D	1357.8	ZC	6.6	---	54.6	---	---	1.8	19.7	0.1	9.0	8.3	---	---	---	2.0	---	---	---	102.1
UE15D	1446.3	FS	15.6	---	30.5	---	---	2.2	17.7	1.6	15.6	13.0	---	---	---	0.4	---	---	---	96.7
UE15D	1520	FS	6.4	---	29.8	---	---	0.8	4.2	6.3	15.5	24.7	---	---	---	7.8	---	---	---	95.4
UE15D	1585.2	FS	5.9	---	35.9	2.1	---	0.8	5.6	5.6	18.9	19.1	---	---	---	2.8	---	---	---	96.8
UE15D	1691.1	FS	5.6	---	43.0	---	---	1.9	6.2	10.1	13.9	14.5	---	---	---	1.7	---	---	---	96.9
UE15D	1771	FS	31.8	---	18.7	---	---	0.2	2.7	8.4	13.9	17.8	---	---	---	3.4	---	---	---	96.9

Explanation

1 = zone designation based primarily on mineralogic composition, but also considers sample lithology and stratigraphy.

--- = not present or not analyzed

na = not applicable; sample does not fall into any of the 3 TCU mineralogic zone categories.

SM = smectite

KA = kaolinite

ZC = clinoptilolite

ZM = mordenite

ZA = analcime

CR = cristobalite

OP = opal-CT

QZ = quartz

KF = potassium feldspar

PL = plagioclase

FE = feldspar, undifferentiated

GL = glass

HM = hematite

BT = biotite

HN = hornblende

CC = calcite

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Appendix B

Drill Hole Database

Drill Hole Database for the Yucca Flat TCU Study

Drill Hole	Hole Coordinates		Ground Elevation (m)	Total Depth Elevation (m)	Elevation of Top of Zone (m) (See explanation at end)			
	Easting (m) UTM	Northing (m) UTM			ZC Zone	FS Zone	AR Zone	Pz
Effinger 1	575415.5	4116089.0	1570.0	1515.1	NDE	NDE	NDE	NDE
ER 12-1	572411.2	4115494.3	1773.0	679.4	NP	NP	NP	1771.0
ER 12-2	577823.3	4114254.6	1434.2	-663.7	NP	1297	NP	1248.3
ER 2-1	583334.6	4108977.9	1285.1	492.6	701.4	NDE	NDE	NDE
ER 3-1	594657.9	4097338.8	1343.6	488.0	Faulted Out			1058.9
ER 3-2	585716.4	4099227.6	1221.6	307.2	NDE	NDE	NDE	NDE
ER 6-1	589632.4	4093417.4	1199.4	222.2	1048.2	767.2	672.7	661.4
ER 6-2	582235.1	4090744.0	1289.9	244.4	NP	NP	NP	1259.1
ER 7-1	589235.7	4103471.9	1294.4	532.4	1065.8	913.4	NP	779.3
ER 8-1	583738.4	4118738.4	1468.8	596.2	NP	1374.3	NP	1134.7
Stewart 1	591781.7	4125878.9	1412.0	?	NDE	NDE	NDE	NDE
TG2	581946.7	4099728.7	1255.8	1227.7	NP	NP	NP	1233.8
TH 3-1	588752.0	4101333.8	1260.7	1062.5	NDE	NDE	NDE	NDE
TH 3-4	589970.9	4101338.1	1281.4	1204.0	NDE	NDE	NDE	NDE
TH 3-5	589359.3	4101945.4	1283.8	1130.2	NDE	NDE	NDE	NDE
TH 3-8	589363.6	4100726.5	1260.0	1104.3	NDE	NDE	NDE	NDE
TH 3-9	589941.5	4101033.3	1272.8	677.6	910.1	?	NP	696.8
TH 3-E	589361.5	4101336.0	1271.6	473.0	918.4	?	573.6	552.6
TW3-7	585900.4	4102299.9	1239.3	546.8	733.3	NDE	NDE	NDE
TW6-B	587779.9	4092814.8	1197.6	687.0	795.2	NDE	NDE	NDE
TW6-C	588214.1	4086123.9	1195.1	676.7	1047.3	826.3	815.3	782.1
TW D	582223.6	4103325.5	1265.5	671.2	806.8		762.6	738.5
U10af	584112.9	4112078.6	1297.5	764.1	NDE	NDE	NDE	NDE
U10ah	584012.0	4112435.7	1298.8	837.0	NDE	NDE	NDE	NDE
U10an	585339.8	4113289.7	1313.1	832.7	901.6		NDE	NDE
U10ap#3	585340.3	4113063.3	1312.5	855.3	NDE	NDE	NDE	NDE
U10aq	585880.8	4113349.5	1323.4	987.6	NDE	NDE	NDE	NDE
U10aq#1	585880.7	4113364.7	1323.7	824.8	NDE	NDE	NDE	NDE
U10as	584266.0	4114406.4	1310.0	944.3	NP	NP	959.5	954.9
U10ax	585846.1	4113081.8	1321.9	1017.1	NDE	NDE	NDE	NDE
U10b	582824.6	4114419.6	1333.5	876.0	?	?	?	1153.4
U10b#1	582836.2	4114399.8	1333.2	1052.8	?	?	?	1165.3
U10b#2	582824.1	4114541.5	1334.4	912.9	?	?	?	1126.5
U10b#3	582832.2	4114419.6	1333.5	906.8	?	?	?	1165.6
U10b#4	582823.8	4114632.9	1334.7	908.0	?	?	?	1120.7
U10b#5	582823.1	4114845.9	1337.5	910.7	?	?	?	1131.4
U10b#6	582869.2	4115332.4	1345.4	1151.8	?	?	NP	1305.5
U10bc	585711.8	4112251.0	1312.2	1020.5	?	?	1039.7	1035.1
U10be	583957.8	4117105.2	1378.3	1149.7	NDE	NDE	NDE	NDE
U10bg	585684.7	4112159.4	1310.0	1089.1	NDE	NDE	NDE	NDE
U10bh	584467.4	4115187.2	1317.3	1019.9	NDE	NDE	NDE	NDE
U10c	583885.5	4111680.8	1298.4	710.2	NDE	NDE	NDE	NDE
U10c#1	583894.3	4111689.4	1298.4	366.4	?	?	?	368.5
U10ca	585732.5	4116508.7	1344.5	1079.0	1132.9	1110.4	NDE	NDE
U10cb	585703.6	4116402.5	1342.3	1112.2	1143.9	NDE	NDE	NDE
U10cc	585645.4	4116576.0	1345.1	1115.0	1161.0	NDE	NDE	NDE
U10d EX.-1	585193.3	4112751.9	1308.2	675.4	?	?	NDE	NDE
U10d EX.-2	585358.5	4113516.2	1314.6	868.7	?	?	NDE	NDE
U10dS	585374.6	4113515.6	1314.3	858.9	?	?	NDE	NDE
U10dS#1	585381.1	4113495.8	1314.3	688.5	?	?	776.0	756.2
U10e	585240.7	4111837.9	1300.3	801.9	873.6	NDE	NDE	NDE
U10i	584740.9	4115308.2	1321.3	789.4	992.1		NP	821.0
U10its1	584643.5	4117107.6	1367.3	666.3	983.0	873.5	?	698.3
U10its3	584648.4	4115706.2	1326.8	668.4	827.0	761.4	?	695.9
U10its4	583583.8	4115153.6	1312.2	792.5	869.9		?	806.2

Drill Hole	Hole Coordinates		Ground Elevation (m)	Total Depth Elevation (m)	Elevation of Top of Zone (m) (See explanation at end)			
	Easting (m) UTM	Northing (m) UTM			ZC Zone	FS Zone	AR Zone	Pz
U10its5	583973.1	4117105.2	1378.3	662.0	915.0	793.1	?	667.0
U10k	584138.6	4113363.8	1302.4	573.6	?	?	?	587.3
U10L#1	584922.2	4112268.9	1299.7	626.7	781.5		?	692.8
U10n#1	582823.5	4114708.8	1335.6	995.8	?	?	?	1115.6
U10p	584439.7	4114120.9	1308.2	846.4	?	?	NP	874.2
U10q	584495.3	4111591.5	1291.4	779.4	NDE	NDE	NDE	NDE
U10t	585514.3	4112021.4	1306.1	763.5	882.4		?	800.1
U2am	583146.4	4109545.1	1297.8	519.1	NDE	NDE	NDE	NDE
U2ar	582841.8	4108821.2	1292.0	591.0	NDE	NDE	NDE	NDE
U2as	583612.4	4108400.4	1285.6	767.5	NDE	NDE	NDE	NDE
U2at	584072.4	4108017.4	1279.9	610.8	?	?	NDE	NDE
U2au	583943.0	4108335.1	1282.9	854.7	NDE	NDE	NDE	NDE
U2av	583141.4	4110977.3	1310.0	641.6	711.1		NDE	NDE
U2aw	582749.4	4109787.5	1301.8	641.6	NDE	NDE	NDE	NDE
U2az#1	583308.5	4107656.1	1277.7	723.0	NDE	NDE	NDE	NDE
U2br	582871.9	4111349.3	1314.3	757.7	NDE	NDE	NDE	NDE
U2bs	583637.1	4108733.2	1288.1	678.5	761.1	NDE	NDE	NDE
U2bt	584281.2	4107458.4	1274.7	726.0	872.9	?	NDE	NDE
U2bu	584281.8	4107306.0	1273.8	709.9	874.5	?	NDE	NDE
U2bz	582786.8	4112149.3	1320.7	912.3	NDE	NDE	NDE	NDE
U2ca#1	576302.0	4110495.6	1484.7	1035.7	1234.8		1068.6	1051.6
U2ce	576803.5	4110954.7	1452.1	1081.7	?	?	?	1107.0
U2cmS	577514.5	4108321.7	1396.9	916.8	?	?	NDE	NDE
U2cn	577488.3	4108504.4	1398.7	926.9	NP	?	NP	974.8
U2co	577567.8	4107986.7	1390.5	1033.9	NDE	NDE	NDE	NDE
U2cp	577928.0	4107733.2	1374.6	993.6	NDE	NDE	NDE	NDE
U2cq	578034.4	4107531.2	1371.3	929.3	NDE	NDE	NDE	NDE
U2cr	577686.8	4110988.6	1403.3	986.6	NP	NP	?	1004.3
U2cs	577997.4	4108795.7	1379.5	922.3	NDE	NDE	NDE	NDE
U2ct	578020.1	4108038.5	1374.3	917.1	NDE	NDE	NDE	NDE
U2cu	577995.7	4109283.2	1379.5	917.8	NP	NDE	NDE	NDE
U2db	581142.3	4109532.9	1314.3	681.8	NDE	NDE	NDE	NDE
U2dd#4	581724.6	4107886.1	1295.1	830.9	898.9		?	863.2
U2df	581049.8	4110534.8	1327.1	758.6	NDE	NDE	NDE	NDE
U2dg	581455.7	4109386.8	1311.2	619.4	NDE	NDE	NDE	NDE
U2dj	581421.4	4110587.6	1323.1	600.5	NDE	NDE	NDE	NDE
U2dq	581995.4	4107468.9	1289.9	886.1	NDE	NDE	NDE	NDE
U2dr	581339.6	4109927.3	1314.6	698.9	NDE	NDE	NDE	NDE
U2ds	582207.9	4107804.9	1291.1	912.3	NDE	NDE	NDE	NDE
U2dt	581536.4	4108015.8	1297.5	738.8	837.3		?	791.6
U2eh	581498.9	4111688.9	1331.4	645.6	NDE	NDE	NDE	NDE
U2ei	582803.1	4111844.6	1318.9	678.8	771.1	?	NDE	NDE
U2ek	583360.8	4109241.1	1291.4	530.0	724.4	?	NDE	NDE
U2eL	583305.8	4108417.9	1286.3	554.7	NDE	NDE	NDE	NDE
U2en	583164.3	4108798.6	1288.1	540.7	641.9	NDE	NDE	NDE
U2eq	583107.3	4107930.8	1281.1	761.1	NDE	NDE	NDE	NDE
U2er	582884.9	4112871.8	1323.4	988.2	NDE	NDE	NDE	NDE
U2es	582514.7	4111538.8	1320.4	802.2	NDE	NDE	NDE	NDE
U2et	583164.3	4113140.9	1320.4	893.7	?	?	?	901.3
U2ev	581342.7	4111306.2	1330.8	901.6	NDE	NDE	NDE	NDE
U2ew	583899.5	4108548.3	1282.9	825.7	NDE	NDE	NDE	NDE
U2ex	582414.2	4110651.7	1314.0	701.6	714.1	NDE	NDE	NDE
U2ey	582370.7	4113503.8	1336.2	1057.7	NP	NP	NP	1063.1
U2fa	581179.2	4110131.8	1317.3	585.8	NDE	NDE	NDE	NDE
U2fb	581380.5	4109135.2	1301.8	734.9	NDE	NDE	NDE	NDE
U2fd	580969.2	4109095.6	1306.7	841.6	NDE	NDE	NDE	NDE
U2fe	580885.6	4111213.2	1335.9	886.4	NDE	NDE	NDE	NDE

Drill Hole	Hole Coordinates		Ground Elevation (m)	Total Depth Elevation (m)	Elevation of Top of Zone (m) (See explanation at end)			
	Easting (m) UTM	Northing (m) UTM			ZC Zone	FS Zone	AR Zone	Pz
U2ff	580941.7	4108257.5	1303.0	937.3	NDE	NDE	NDE	NDE
U2gaS	582496.2	4110907.7	1314.3	766.6	NDE	NDE	NDE	NDE
U2gb	583468.5	4108952.0	1286.0	712.9	NDE	NDE	NDE	NDE
U2ge	581823.7	4110806.9	1321.3	736.1	NDE	NDE	NDE	NDE
U2gf	582426.6	4108875.2	1295.1	743.4	NDE	NDE	NDE	NDE
U2gg	582867.3	4110921.5	1307.3	752.2	NDE	NDE	NDE	NDE
U2gh	583945.3	4107566.6	1273.1	724.2	740.1	NDE	NDE	NDE
U2gh#1	579178.6	4111359.5	1353.3	1309.1	NP	NP	NP	1309.4
U2gj	582346.7	4110369.0	1311.6	740.1	NDE	NDE	NDE	NDE
U2n#1	582063.1	4111546.4	1326.8	634.0	NDE	NDE	NDE	NDE
U2q	584097.3	4107781.0	1278.6	864.1	NDE	NDE	NDE	NDE
U2r#1	582651.3	4109086.3	1299.1	280.4	?	?	?	282.0
U2t	583702.4	4107414.0	1278.6	582.2	NDE	NDE	NDE	NDE
U2v	582934.5	4109148.2	1297.2	526.1	NDE	NDE	NDE	NDE
U2x	583723.5	4107906.2	1282.0	500.2	NDE	NDE	NDE	NDE
U2z#1	583774.6	4108815.1	1288.7	249.0	?	?	?	326.0
U2z#2	582304.7	4110593.5	1315.5	410.3	605.3	?	NP	437.4
U2z#3	581925.3	4110180.8	1315.2	354.5	?	?	384.1	372.2
U3an#1	585597.8	4102278.1	1237.5	469.4	551.7	NDE	NDE	NDE
U3an#3	585598.0	4102307.6	1237.8	154.2	?	?	261.6	253.3
U3cn#1	586973.1	4101827.6	1241.8	491.9	NDE	NDE	NDE	NDE
U3cn#5	586921.4	4101713.2	1222.9	299.3	832.8	600.0	476.1	363.0
U3cp	587529.2	4102369.0	1253.6	799.5	887.9	NDE	NDE	NDE
U3cs	587533.2	4101211.0	1239.0	698.0	903.7	NDE	NDE	NDE
U3daS	587973.2	4101654.1	1249.1	794.9	NDE	NDE	NDE	NDE
U3daS4	587972.0	4101649.8	1249.1	775.4	886.4	NDE	NDE	NDE
U3dh	586307.5	4103157.0	1250.3	742.8	841.9	NDE	NDE	NDE
U3dL	586919.7	4102550.0	1248.8	878.4	910.4	NDE	NDE	NDE
U3do	587526.4	4103161.2	1264.3	894.0	929.0	NDE	NDE	NDE
U3dq	589071.4	4097072.1	1211.9	878.1	NDE	NDE	NDE	NDE
U3eh	586950.1	4102397.4	1247.9	775.4	NDE	NDE	NDE	NDE
U3eh#1	586942.4	4102413.8	1246.6	858.0	888.5	NDE	NDE	NDE
U3ei	587740.4	4102979.2	1264.3	730.9	895.5	NDE	NDE	NDE
U3ek	589650.4	4097074.5	1222.2	986.0	NDE	NDE	NDE	NDE
U3ev#3S	589957.0	4100975.7	1274.1	921.7	NDE	NDE	NDE	NDE
U3ev#5	589934.9	4101194.8	1279.2	918.1	1072.0	NDE	NDE	NDE
U3evS	589971.5	4101097.7	1276.8	941.5	NDE	NDE	NDE	NDE
U3fc	588761.0	4098594.7	1222.2	815.3	835.2	NDE	NDE	NDE
U3ff	590223.7	4098600.1	1253.9	970.5	NDE	NDE	NDE	NDE
U3fh	588759.2	4099204.1	1230.8	886.4	NDE	NDE	NDE	NDE
U3fk	589610.8	4099755.6	1253.0	841.6	NDE	NDE	NDE	NDE
U3fL	588756.0	4100118.3	1240.5	987.6	NDE	NDE	NDE	NDE
U3fq	586672.9	4103158.2	1254.6	843.1	934.5	NDE	NDE	NDE
U3fw	589379.2	4096098.1	1215.2	962.3	NDE	NDE	NDE	NDE
U3fx	588937.8	4100423.6	1248.8	995.8	NDE	NDE	NDE	NDE
U3gg	584786.6	4102389.5	1243.3	557.5	802.8	NDE	NDE	NDE
U3gj	590292.7	4096467.3	1234.1	980.2	1124.4	996.4	NDE	NDE
U3gk	589468.3	4096859.9	1218.0	964.4	NDE	NDE	NDE	NDE
U3gm	589385.4	4094330.7	1201.5	850.1	997.3	NDE	NDE	NDE
U3gr	589681.3	4096495.6	1221.6	968.7	977.8	NDE	NDE	NDE
U3gs#2	589692.6	4096748.5	1221.9	932.4	959.8	NDE	NDE	NDE
U3gx	587893.6	4098393.6	1215.2	808.3	819.0	NDE	NDE	NDE
U3gz	589063.9	4099205.2	1232.9	810.8	870.2	NDE	NDE	NDE
U3hg#1	588296.9	4096353.3	1207.3	759.3	783.6	NDE	NDE	NDE
U3jq	588748.3	4102312.3	1272.5	692.5	946.4	754.4	NDE	NDE
U3jq#1	588763.5	4102312.4	1272.5	594.7	946.4	752.6	632.4	597.4
U3ko	586492.8	4102456.7	1242.7	815.9	907.4	NDE	NDE	NDE

Drill Hole	Hole Coordinates		Ground Elevation (m)	Total Depth Elevation (m)	Elevation of Top of Zone (m) (See explanation at end)			
	Easting (m) UTM	Northing (m) UTM			ZC Zone	FS Zone	AR Zone	Pz
U3ks	588249.7	4096764.5	1208.8	716.6	827.8	NDE	NDE	NDE
U3kv	588070.5	4095727.8	1205.8	718.1	NDE	NDE	NDE	NDE
U3kx	587228.1	4101331.8	1237.5	795.5	829.1	NDE	NDE	NDE
U3kz	584480.9	4102754.4	1245.1	559.3	726.9	NDE	NDE	NDE
U3La	584856.9	4102755.7	1244.5	558.7	833.0	NDE	NDE	NDE
U3Lh	588081.6	4096992.5	1204.6	777.8	810.0	NDE	NDE	NDE
U3Lr	584881.0	4101536.9	1238.1	780.9	785.5	NDE	NDE	NDE
U3Lu	588585.9	4094733.5	1202.7	867.8	NDE	NDE	NDE	NDE
U3Lw	588279.4	4096993.2	1209.1	782.4	846.4	NDE	NDE	NDE
U3Ly	588278.6	4097206.5	1209.8	767.8	825.7	NDE	NDE	NDE
U3me	584882.9	4101003.7	1235.0	549.2	775.7	NDE	NDE	NDE
U3mf	584879.9	4101857.2	1239.6	569.1	803.5	NDE	NDE	NDE
U3mh	590070.5	4098751.6	1247.2	716.3	1098.8	805.2	746.0	726.9
U3mi	589703.7	4095776.2	1220.4	673.6	981.1	NP	719.0	678.2
U3mk	589600.3	4102650.5	1297.5	916.5	1015.9	NDE	NDE	NDE
U3mL	590030.3	4097441.5	1234.7	838.5	992.4	NDE	NDE	NDE
U3mL#1	590022.7	4097441.1	1234.4		992.1	NDE	NDE	NDE
U3mt	584878.9	4102131.1	1239.6	767.2	821.4	NDE	NDE	NDE
U3mu	589601.7	4102254.9	1294.2	837.0	955.2	896.4	NDE	NDE
U4a	584191.2	4106990.0	1270.7	310.0	840.9	606.2	361.2	338.0
U4ab	580723.2	4105392.3	1290.5	991.8	NDE	NDE	NDE	NDE
U4ac	580586.3	4105315.7	1292.7	1048.2	NDE	NDE	NDE	NDE
U4ad	580553.9	4105879.3	1296.0	982.1	?	?	1004.6	998.9
U4af	580782.4	4105880.1	1291.7	986.9	NP	NP	1019.2	1014.7
U4ah	581625.2	4104511.5	1274.7	924.2	953.0	NDE	NDE	NDE
U4ai	582669.3	4104386.0	1262.5	773.3	NDE	NDE	NDE	NDE
U4aj	582197.5	4106418.0	1280.2	792.5	NDE	NDE	NDE	NDE
U4ak	582801.8	4103540.8	1259.1	762.3	780.0	NDE	NDE	NDE
U4am	581415.9	4104857.8	1276.8	941.5	NDE	NDE	NDE	NDE
U4an	582279.0	4106647.2	1281.4	793.7	887.9	NDE	NDE	NDE
U4ap	581075.7	4107221.9	1294.8	952.8	993.0		?	973.8
U4ar	582551.9	4104688.1	1264.6	761.7	NDE	NDE	NDE	NDE
U4as	578065.7	4107226.6	1367.9	926.0	NDE	NDE	NDE	NDE
U4at	578112.3	4106967.7	1365.2	901.6	NDE	NDE	NDE	NDE
U4au	582788.9	4104607.0	1263.4	730.0	NDE	NDE	NDE	NDE
U4av	582680.3	4105777.1	1273.1	755.0	862.9	NDE	NDE	NDE
U4b	584359.9	4105698.3	1263.4	763.5	NDE	NDE	NDE	NDE
U4c	584133.8	4106044.2	1267.4	581.6	822.4	NDE	NDE	NDE
U4d	584162.2	4106653.8	1270.1	583.7	767.2	NDE	NDE	NDE
U4d#1	584173.7	4106663.3	1270.1	497.1	829.7	575.2	NDE	NDE
U4e	583856.7	4106866.3	1271.9	249.9	723.3	541.4	310.9	276.8
U4e#1	583719.6	4106865.5	1273.5	285.9	729.4	496.3	308.8	289.0
U4f	584199.1	4104825.6	1258.5	545.3	795.2	NDE	NDE	NDE
U4g	584315.2	4106380.1	1265.5	521.8	793.1	534.0	NDE	NDE
U4h	584007.6	4107293.2	1272.5	541.0	818.4	573.0	NDE	NDE
U4i	583012.5	4104284.5	1260.7	590.1	763.2	NDE	NDE	NDE
U4j	584319.2	4105222.4	1260.0	574.2	850.1	NDE	NDE	NDE
U4L	583986.1	4106455.1	1267.7	557.2	786.1	NDE	NDE	NDE
U4m	584164.7	4104805.3	1258.5	759.0	NDE	NDE	NDE	NDE
U4n	584184.9	4104862.7	1258.8	588.3	NDE	NDE	NDE	NDE
U4o	584466.4	4106806.9	1267.7	688.5	920.2	NDE	NDE	NDE
U4p	584501.0	4107089.2	1269.8	705.9	925.4	NDE	NDE	NDE
U4q	584589.2	4106533.4	1263.7	626.7	920.8	NDE	NDE	NDE
U4r	584186.3	4104542.7	1255.5	569.7	741.9	NDE	NDE	NDE
U4s	583978.9	4104611.5	1257.3	647.7	662.9	NDE	NDE	NDE
U4t	584590.3	4106233.2	1263.1	647.4	944.9	NDE	NDE	NDE
U4t#1	584578.1	4106233.2	1263.1	623.0	943.1	NDE	NDE	NDE

Drill Hole	Hole Coordinates		Ground Elevation (m)	Total Depth Elevation (m)	Elevation of Top of Zone (m) (See explanation at end)			
	Easting (m) UTM	Northing (m) UTM			ZC Zone	FS Zone	AR Zone	Pz
U4u	584496.9	4104964.0	1255.8	585.2	862.6	NDE	NDE	NDE
U4u#1	584488.3	4104968.9	1255.5	753.8	859.3	NDE	NDE	NDE
U6d	588591.1	4093261.4	1198.5	802.2	866.5	NDE	NDE	NDE
U6e	588587.3	4094337.0	1201.5	744.3	842.8	NDE	NDE	NDE
U6f	588437.8	4093535.1	1199.4	803.1	836.7	NDE	NDE	NDE
U7a	585989.0	4106999.7	1296.9	474.3	946.4	?	496.5	481.3
U7aa	589599.6	4102863.8	1300.6	713.8	1078.1	910.4	?	854.0
U7ab	588742.6	4103927.6	1295.7	776.6	1042.7	798.9	NDE	NDE
U7ac	586062.8	4103430.4	1250.3	575.8	880.0	578.2	NDE	NDE
U7ad	586482.8	4106603.4	1306.1	707.1	949.5	751.3	NDE	NDE
U7ad#1	586470.1	4106595.2	1306.4	648.0	949.8	727.3	NDE	NDE
U7ae	588267.5	4104733.2	1300.3	430.7	1016.8	745.5	?	480.4
U7af	586452.3	4105321.0	1282.3	676.4	956.2	747.4	NDE	NDE
U7ag	586293.4	4107185.1	1306.4	704.4	1013.8	750.1	NDE	NDE
U7ah	585659.5	4105623.0	1274.1	295.7	853.4	600.5	512.1	411.5
U7ai	586217.1	4102791.3	1244.8	580.3	796.7	NDE	NDE	NDE
U7ajS	585621.7	4106250.9	1281.7	583.7	877.8	655.3	NDE	NDE
U7ak	585529.1	4106926.7	1285.0	599.2	840.0	NDE	NDE	NDE
U7aL	587129.7	4103312.2	1261.6	801.3	941.5	844.0	NDE	NDE
U7am	586390.6	4105625.5	1286.0	661.1	959.8	697.7	NDE	NDE
U7an	584996.1	4103457.1	1249.7	286.2	920.5	553.8	NDE	NDE
U7ao	587154.1	4104957.8	1286.3	826.0	926.6	844.3	NDE	NDE
U7ap	584882.1	4105559.3	1264.3	639.5	999.1	682.1	NDE	NDE
U7aq	584449.2	4103089.5	1247.9	144.5	687.0	394.4	?	162.8
U7at	587512.7	4107061.7	1336.2	876.0	1153.4	970.5	NP	909.2
U7au	584324.0	4103942.3	1253.0	509.3	760.8	NDE	NDE	NDE
U7av	584995.2	4103823.1	1252.4	661.7	943.1	NDE	NDE	NDE
U7aw	585536.8	4105956.2	1276.8	586.7	874.5	NDE	NDE	NDE
U7ax	587818.3	4106819.0	1337.8	956.8	1151.8	1010.1	NDE	NDE
U7ay	587120.0	4106085.2	1309.4	821.7	1029.0	858.3	NDE	NDE
U7b	588133.7	4103772.8	1281.1	810.2	915.3	NDE	NDE	NDE
U7ba	584900.2	4104756.4	1258.5	648.9	984.8	660.5	NDE	NDE
U7bc	588431.6	4103893.3	1289.0	603.2	1031.4	798.3	NDE	NDE
U7bd	588105.8	4104182.3	1287.5	677.9	953.7	799.8	NDE	NDE
U7be	586148.0	4106325.6	1292.7	683.1	966.5	748.6	NDE	NDE
U7bf	586112.8	4106629.9	1296.3	848.6	924.5	NDE	NDE	NDE
U7bg	588499.2	4106431.3	1337.5	941.2	1169.8	1001.3	NDE	NDE
U7bh	588352.5	4106546.6	1338.7	942.4	1181.7	986.6	NDE	NDE
U7bi	588930.5	4105098.1	1318.0	860.8	1069.8	911.0	NDE	NDE
U7bk	587665.5	4106940.0	1338.4	961.9	1135.4	998.5	968.4	960.1
U7bL	587485.9	4106025.5	1315.8	764.1	1053.7	779.4	NDE	NDE
U7bm	588957.4	4103409.7	1291.7	819.3	1047.9	NDE	NDE	NDE
U7bo	586866.4	4106899.1	1319.2	709.6	1057.0	819.3	NDE	NDE
U7bp	588298.9	4104471.2	1294.8	609.0	1032.7	683.7	NDE	NDE
U7br	584883.3	4105223.8	1261.0	651.4	994.3	678.8	NDE	NDE
U7bs	585994.1	4105624.1	1277.7	600.8	851.0	NDE	NDE	NDE
U7bs#1	585979.2	4105623.5	1277.7	571.5	847.3	NDE	NDE	NDE
U7bu	584808.8	4103174.3	1246.0	636.4	836.1	NDE	NDE	NDE
U7bv	588717.2	4105097.4	1310.6	914.4	1106.4	NDE	NDE	NDE
U7bw	588485.7	4103332.2	1282.0	672.4	900.7	776.0	NDE	NDE
U7by	586783.0	4106602.0	1310.6	762.0	1053.1	853.4	NDE	NDE
U7bz	586041.0	4105289.7	1272.8	575.5	877.8	673.9	631.2	614.2
U7c	587219.5	4103769.6	1269.5	878.1	934.2	NDE	NDE	NDE
U7ca	588835.0	4103653.4	1293.6	744.9	1065.0	813.5	NDE	NDE
U7cb	588718.2	4104822.8	1306.7	742.8	1065.9	819.0	NDE	NDE
U7cc	586783.5	4106358.6	1306.4	818.7	1061.0	843.1	NDE	NDE
U7cd	584902.6	4104066.2	1254.3	759.0	937.3	NDE	NDE	NDE

Drill Hole	Hole Coordinates		Ground Elevation (m)	Total Depth Elevation (m)	Elevation of Top of Zone (m) (See explanation at end)			
	Easting (m) UTM	Northing (m) UTM			ZC Zone	FS Zone	AR Zone	Pz
U7cd#1	584912.0	4104066.9	1253.9	735.8	940.3	NDE	NDE	NDE
U7e	585905.5	4104740.1	1263.7	676.4	821.7	NDE	NDE	NDE
U7f	585932.0	4105958.8	1284.1	708.1	872.6	NDE	NDE	NDE
U7g	587402.4	4103770.0	1271.6	800.7	921.1	NDE	NDE	NDE
U7h	586153.0	4103765.9	1255.2	785.5	916.8	NDE	NDE	NDE
U7i	587211.8	4105291.7	1294.2	715.1	1012.2	NDE	NDE	NDE
U7j	587087.7	4106511.4	1318.6	741.0	1044.2	NDE	NDE	NDE
U7k	585760.6	4102698.0	1240.5	661.4	NDE	NDE	NDE	NDE
U7m	589306.9	4103776.9	1304.5	786.4	1036.3	NDE	NDE	NDE
U7n	588521.3	4106212.0	1333.2	755.6	1144.2	808.9	804.1	790.7
U7n#1	588506.3	4106226.9	1333.2	750.1	1138.7	808.9	?	785.2
U7o	585686.1	4106568.0	1287.2	708.1	863.5	NDE	NDE	NDE
U7p	587644.8	4104166.9	1281.7	702.6	940.3	NDE	NDE	NDE
U7s	588741.0	4104384.4	1300.9	721.8	1011.3	743.1	NDE	NDE
U7t	588372.4	4105144.6	1307.9	728.8	1018.3	?	NDE	NDE
U7u	585690.3	4105287.9	1269.2	583.4	799.8	NDE	NDE	NDE
U7v	586510.9	4105991.6	1296.3	717.2	942.7	735.5	NDE	NDE
U7w	589308.0	4103471.9	1297.2	763.8	1035.1	844.6	NDE	NDE
U7x	588155.2	4106240.9	1328.9	795.5	1106.4	NDE	NDE	NDE
U7y	588441.0	4102969.4	1276.2	697.1	940.9	718.4	NDE	NDE
U7z	585633.1	4104205.6	1252.1	671.2	NDE	NDE	NDE	NDE
U7z#1	588669.7	4104205.3	1252.1	601.4	709.9	NDE	NDE	NDE
U8a	580092.4	4114838.7	1406.7	1047.0	1048.6	?	NDE	NDE
U8a#1	580095.1	4114866.2	1406.0	1028.7	?	?	?	1047.9
U8a#10	580032.1	4114232.7	1392.6	808.0	?	?	NP	950.7
U8a#11	580016.8	4114077.9	1391.1	798.3	?	?	?	943.1
U8a#12	579960.0	4113506.0	1383.5	875.1	1051.3		1009.2	1000.4
U8a#3	580089.2	4114802.5	1405.1	1002.2	?	?	?	1024.1
U8a#4	580091.0	4114823.8	1406.3	819.6	1061.9	NP	NP	1036.3
U8a#5	580080.4	4114717.7	1403.3	819.6	?	?	1092.4	1016.2
U8a#6	580074.2	4114656.8	1401.5	881.2	1115.0	NP	NP	1018.5
U8a#7	580068.0	4114596.4	1399.9	871.1	?	?	?	1011.0
U8a#8	580062.1	4114535.7	1398.4	868.1	?	?	1143.6	1011.3
U8a#9	580043.9	4114353.7	1394.5	827.5	?	?	?	973.5
U8b	580631.1	4114259.2	1379.8	1065.9	NDE	NDE	NDE	NDE
U8d	580000.0	4114254.6	1394.2	1094.8	NDE	NDE	NDE	NDE
U8e	581040.9	4114029.4	1367.9	758.3	NP	810.1	NDE	NDE
U8e#1	581132.2	4114037.3	1367.9	573.9	NP	839.1	669.0	649.5
U8j	580872.2	4115022.2	1388.7	779.1	1179.0	1065.6	812.0	788.7
U8k	581247.4	4114732.8	1373.4	1006.1	NP	1058.0	NDE	NDE
U8L	581288.0	4115239.7	1383.2	1150.0	NP	?	NDE	NDE
U8m	580980.9	4114443.6	1373.7	855.6	NP	969.0	NDE	NDE
U8n	580630.2	4114503.3	1384.4	807.4	1064.1	1015.3	NDE	NDE
U9s#25	585184.8	4110466.5	1286.9	782.7	851.0		NDE	NDE
U9t#28	585305.4	4110832.5	1291.1	896.4	NDE	NDE	NDE	NDE
U9u#29	585426.9	4110954.9	1293.3	947.3	NDE	NDE	NDE	NDE
U9w#21	585673.8	4109980.9	1290.5	971.4	1046.7	?	NDE	NDE
U9x#20	585796.7	4109859.2	1293.0	1012.5	?	?	NDE	NDE
U9aa#27	586159.1	4110713.7	1306.4	1098.5	?	?	?	1117.4
U9ad	584346.5	4110554.9	1290.5	737.9	?	?	NDE	NDE
U9ae	585378.4	4107419.6	1284.1	880.9	NDE	NDE	NDE	NDE
U9aj	586075.1	4108090.6	1301.2	1142.7	NDE	NDE	NDE	NDE
U9ao	584451.8	4110875.3	1289.6	785.2	NDE	NDE	NDE	NDE
U9aw	585382.0	4108118.9	1284.1	1048.8	NDE	NDE	NDE	NDE
U9ax	584826.7	4108331.8	1274.7	947.0	NDE	NDE	NDE	NDE
U9ay	585607.3	4109127.1	1286.6	1009.5	NDE	NDE	NDE	NDE
U9az	585062.4	4110618.4	1287.8	815.3	NDE	NDE	NDE	NDE

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U9ba	585599.6	4109517.2	1287.8	1098.8	NDE	NDE	NDE	NDE
U9bb	585952.2	4109751.5	1296.6	1059.5	NDE	NDE	NDE	NDE
U9bd	586581.0	4107728.5	1315.5	1126.5	NDE	NDE	NDE	NDE
U9be	586292.5	4107438.3	1307.0	1072.3	NDE	NDE	NDE	NDE
U9bg	586140.0	4107468.6	1303.3	1074.7	NDE	NDE	NDE	NDE
U9bh	586639.5	4108317.1	1313.7	1009.8	1054.6	NDE	NDE	NDE
U9bi#1	585749.2	4108469.4	1290.8	810.8	NDE	NDE	NDE	NDE
U9bi#2	586296.7	4108498.2	1303.9	862.0	NDE	NDE	NDE	NDE
U9bj	586535.7	4107606.8	1314.9	1078.7	NDE	NDE	NDE	NDE
U9bj#1	586541.8	4107606.8	1314.9	1071.1	?	?	NDE	NDE
U9bk	586490.4	4107916.2	1312.8	1160.4	NDE	NDE	NDE	NDE
U9bm	586089.3	4108117.8	1301.2	1148.8	NDE	NDE	NDE	NDE
U9bn	586381.0	4108261.4	1308.2	986.6	?	?	NDE	NDE
U9bo	586777.9	4107958.1	1320.4	1129.9	NDE	NDE	NDE	NDE
U9bp	585681.6	4107862.8	1299.7	1060.4	NDE	NDE	NDE	NDE
U9br	586397.2	4108002.7	1310.0	1002.2	NDE	NDE	NDE	NDE
U9br1	586393.0	4108009.6	1310.0	1005.2	1009.8		NDE	NDE
U9br2	586654.8	4108218.3	1315.5	1010.1	1077.8		NDE	NDE
U9bs	585774.5	4107421.3	1293.9	954.0	NDE	NDE	NDE	NDE
U9bt	586061.3	4107680.4	1301.8	1068.6	NDE	NDE	NDE	NDE
U9bu	585209.9	4107663.1	1280.8	905.9	NDE	NDE	NDE	NDE
U9bx	584631.5	4110187.5	1286.3	646.2	NDE	NDE	NDE	NDE
U9bz	585247.8	4109887.4	1283.8	1032.4	NDE	NDE	NDE	NDE
U9ca#1	584175.8	4111285.7	1293.6	315.2	708.4	?	403.0	354.5
U9cb	584997.6	4111471.1	1293.9	735.5	815.4		NDE	NDE
U9ce	584146.8	4111026.9	1293.0	608.7	640.7	?	NDE	NDE
U9cg	584466.2	4111195.3	1290.2	954.9	?	?	NDE	NDE
U9ch	585529.7	4107725.1	1288.1	867.5	NDE	NDE	NDE	NDE
U9ci	585965.5	4108579.0	1295.1	1036.0	NDE	NDE	NDE	NDE
U9ci#1	585973.4	4108578.4	1295.1	917.4	961.3	?	NDE	NDE
U9ck	585209.3	4107845.9	1280.8	944.9	NDE	NDE	NDE	NDE
U9cl	586976.9	4107775.9	1327.1	972.0	1068.0	?	NDE	NDE
U9cm	587164.9	4108127.5	1329.8	974.7	1034.1	?	NDE	NDE
U9cn	587372.7	4107792.5	1338.4	1002.5	1035.1		NDE	NDE
U9co	584517.5	4109610.9	1283.2	551.7	589.8	?	NDE	NDE
U9cq	587191.3	4107487.2	1332.6	997.0	1103.1	?	NDE	NDE
U9cr	585828.6	4109371.7	1293.0	924.2	987.9	?	NDE	NDE
U9cs	586856.1	4107486.0	1322.5	956.2	1117.1	?	NDE	NDE
U9ct	583707.4	4110339.7	1300.0	781.2	NDE	NDE	NDE	NDE
U9cv	586059.0	4108854.5	1295.7	838.5	1026.0	?	NDE	NDE
U9cw	587572.0	4107445.6	1342.6	1129.3	1146.0	?	NDE	NDE
U9d	584494.0	4108643.9	1280.5	940.6	NDE	NDE	NDE	NDE
U9x	585930.8	4108049.5	1297.8	1034.2	NDE	NDE	NDE	NDE
U9z#21	586039.8	4109982.2	1300.0	1088.7	NP	NP	NP	1093.0
U9z#24	586038.5	4110344.2	1301.8	1095.1	NP	NP	NP	1152.8
U9z#27	586037.2	4110713.2	1303.0	1039.1	NP	NP	NP	1090.0
UE 10aa	585438.2	4116409.5	1341.4	917.8	NP	1042.1	?	996.4
UE 10bd	585425.2	4112295.7	1307.3	790.7	NP	NP	824.2	802.9
UE 10bf	584509.7	4116147.2	1337.2	646.5	780.9	700.0	NP	659.3
UE 10bg	585730.5	4112159.6	1310.3	1009.5	?	?	?	1017.4
UE 10j	581526.1	4115644.0	1394.2	668.7	NP	1278.0	NP	1078.1
UE 15d	585061.4	4118300.8	1398.0	-431.1	1155.4	971.3	NP	857.0
UE 15j	592299.1	4117406.6	1452.0	1071.6	?	?	?	1420.0
UE 1a	578394.4	4100386.7	1311.6	1019.9	NP	NP	NP	1037.2
UE 1b	579003.8	4100388.8	1302.4	920.2	?	?	NP	1070.5
UE 1c	580222.7	4100393.1	1282.0	709.0	?	?	746.2	742.0
UE 1d	578713.6	4100601.1	1309.4	1048.2	?	?	1080.8	1074.7

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UE 1e	579491.9	4100238.2	1293.9	771.4	903.4		836.7	824.2
UE 1f	578813.6	4100148.0	1303.6	1089.4	NP	NP	NP	1132.9
UE 1g	579276.5	4100846.9	1299.4	859.8	?	?	NP	880.3
UE 1h	582983.3	4095222.4	1217.7	194.2	NP	NP	?	699.5
UE 1j	582445.3	4096591.8	1230.0	732.6	NP	NP	NP	781.8
UE 1L	576566.4	4100380.3	1357.6	-269.7	NP	NP	NP	1296.6
UE 1q	583722.2	4101776.6	1244.2	501.4	695.6	?	534.0	527.9
UE 1r	583673.7	4098227.3	1231.4	-43.3	431.9	?	118.9	116.4
UE 2a#1	580864.0	4108806.6	1319.7	570.0	NP	NP	674.8	585.4
UE 2aa	582406.5	4111980.3	1325.3	619.0	666.9	?	?	624.2
UE 2ab	580336.6	4111363.6	1345.1	958.0	NP	NP	NP	982.1
UE 2ac	580098.7	4109686.8	1325.9	1083.0	NP	NP	NP	1100.0
UE 2ad	578667.3	4109529.4	1355.8	1091.8	NP	NP	1120.5	1117.7
UE 2ar Ins	582830.9	4108810.5	1292.7	576.1	NDE	NDE	NDE	NDE
UE 2aw	582743.3	4109793.9	1302.1	592.5	641.9	?	NDE	NDE
UE 2ax	581408.6	4112043.2	1340.5	450.5	625.0	?	?	480.4
UE 2ax#2	581425.3	4111994.9	1339.9	593.1	627.0	?	NDE	NDE
UE 2b	581137.3	4109484.7	1313.7	243.2	?	?	309.4	286.8
UE 2ce	576803.8	4110772.2	1452.1	949.1	1158.0		NP	1115.0
UE 2co	577575.5	4107971.5	1390.5	805.0	NP	NP	852.9	847.0
UE 2dj Ins	581405.9	4110575.1	1323.1	606.9	NDE	NDE	NDE	NDE
UE 2dy	581079.7	4107907.0	1299.4	731.8	NP	NP	?	744.3
UE 2dz	581580.9	4108898.2	1302.4	570.9	?	NDE	NDE	NDE
UE 2en	583118.6	4108798.4	1288.7	671.8	?	?	NDE	NDE
UE 2en#1	583118.5	4108813.7	1288.1	526.1	?	?	NDE	NDE
UE 2ep	582921.6	4108493.0	1288.1	465.1	?	?	NDE	NDE
UE 2eu	580818.1	4112541.5	1353.6	509.3	?	?	?	550.5
UE 2fa	581148.4	4110132.3	1317.3	463.9	NDE	NDE	NDE	NDE
UE 2fa#1	580978.1	4110131.1	1319.8	445.6	NP	NP	488.9	487.7
UE 2fb	581365.3	4109112.2	1302.7	452.3	522.4		NP	510.8
UE 2s Inst	577503.9	4108321.6	1396.9	796.4	890.9		?	867.8
UE 3a	589985.6	4097075.3	1229.9	709.9	906.8	?	NDE	NDE
UE 3c	586569.3	4098115.0	1215.5	131.7	630.9	?	NDE	NDE
UE 3e	584475.5	4102814.7	1244.5	479.5	730.9	?	NDE	NDE
UE 3e#2	584475.1	4102826.9	1243.9	520.9	730.3	?	NDE	NDE
UE 3e#3	584678.5	4102876.1	1244.2	567.2	NDE	NDE	NDE	NDE
UE 3e#4	584480.7	4102811.7	1244.2	543.2	747.7	?	NDE	NDE
UE 3eh#1	586935.2	4102401.6	1247.5	858.9	NDE	NDE	NDE	NDE
UE 3Lj	584526.6	4101885.5	1239.9	301.1	715.1	409.3	359.1	338.3
UE 3mf	584885.7	4101846.5	1239.3	509.3	809.5	?	NDE	NDE
UE 3mo#1	590049.8	4095704.3	1228.0	1178.4	NDE	NDE	NDE	NDE
UE 3mo#2	590140.1	4096466.4	1230.2	1107.3	NDE	NDE	NDE	NDE
UE 4a	584389.5	4106210.0	1266.4	343.5	915.9	585.8	375.8	NDE
UE 4aa	580446.3	4105618.4	1296.6	924.8	NP	NP	951.9	930.6
UE 4ab Ins	582167.0	4106418.2	1280.5	472.7	866.0	640.4	?	505.7
UE 4ac	578145.6	4106160.3	1301.8	790.7	NP	NP	868.4	824.8
UE 4ad	581640.2	4104511.6	1274.4	831.5	953.7	?	882.1	832.4
UE 4ae Ins	582801.9	4103510.3	1258.8	509.9	769.9	?	552.3	539.8
UE 4af	579268.1	4103223.7	1312.2	857.7	NP	NP	1083.6	882.1
UE 4ah Ins	582646.6	4104363.0	1262.5	393.5	595.0	?	NP	413.6
UE 4ai	581833.7	4105191.5	1273.1	916.5	?	?	NP	941.2
UE 4aL	582212.2	4103965.4	1266.4	599.8	794.0		NP	757.4
UE 4av	582665.1	4105777.0	1273.1	415.1	872.9	679.1	496.2	461.5
UE 4b	583435.8	4104286.0	1259.1	298.1	?	?	415.1	352.6
UE 4c	583426.2	4105812.9	1268.6	646.8	826.6	729.1	705.7	670.0
UE 4f	584206.9	4104853.3	1258.5	163.4	783.0	342.6	252.1	187.1
UE 4g#2	584330.4	4106380.1	1265.5	518.2	793.1	541.3	NDE	NDE

Drill Hole	Hole Coordinates		Ground Elevation (m)	Total Depth Elevation (m)	Elevation of Top of Zone (m) (See explanation at end)			
	Easting (m) UTM	Northing (m) UTM			ZC Zone	FS Zone	AR Zone	Pz
UE 4p	584546.7	4107086.3	1269.2	469.4	937.0	623.0	511.5	490.4
UE 4t	584575.6	4106065.6	1263.1	527.6	955.2	616.9	?	NDE
UE 6d	583751.5	4093396.8	1203.0	15.5	Fault			
UE 6d#2	588629.2	4093261.5	1198.5	745.2	878.4	?	NDE	NDE
UE 6d#3	588553.0	4093261.2	1198.5	317.9	857.4	529.4	NP	378.9
UE 6e	587012.1	4093408.2	1199.7	-83.2	675.4	309.7	-3.6	-14.9
UE 7aa	589492.5	4102908.8	1298.1	641.6	1060.4	892.8	853.1	822.7
UE 7ax	587825.8	4106844.6	1338.1	923.8	1101.9	984.1	NP	928.7
UE 7az	587765.9	4104381.0	1285.6	541.6	957.4	729.4	631.5	544.4
UE 7ba	584884.9	4104756.1	1258.8	518.8	981.8	656.8	566.6	528.5
UE 7bc	588485.4	4103774.1	1287.8	462.7	1059.2	715.8	495.3	465.1
UE 7be	586150.3	4106356.0	1292.7	499.0	965.0	731.8	?	509.3
UE 7bh	589420.3	4105240.3	1331.7	994.9	1200.6	?	1017.7	1007.0
UE 7bi	588860.2	4105146.6	1316.4	662.9	1165.6	917.1	676.3	664.2
UE 7f	584527.1	4105134.5	1257.0	396.2	891.5	574.5	438.0	402.3
UE 7h	588369.8	4106564.0	1338.7	558.1	1186.3	985.1	774.8	738.2
UE 7i	586949.9	4106800.7	1319.8	426.7	1043.9	815.3	613.6	597.4
UE 7j	587516.3	4106056.1	1315.5	454.2	1045.5	769.9	630.9	613.9
UE 7k	586121.3	4104131.4	1257.6	481.0	965.0	689.2	533.1	519.4
UE 7L	585228.7	4106657.5	1275.9	447.4	849.2	737.9	655.3	634.3
UE 7m	589008.5	4105112.1	1317.7	730.6	1074.4	941.2	784.0	766.6
UE 7nS	588643.6	4106090.5	1331.1	659.0	1177.1	913.5	NP	831.2
UE 8c	581413.7	4115023.8	1376.2	922.6	NP	995.2	NP	974.1
UE 8d	581783.2	4114196.5	1352.7	972.9	NP	1047.6	NP	994.6
UE 8e Inst	580997.7	4113986.6	1368.2	615.4	NP	804.3	664.1	631.8
UE 8e#1	580913.8	4114016.7	1370.4	576.4	NP	782.1	671.5	623.6
UE 8e#2	580693.4	4113863.6	1374.0	685.2	?	?	733.9	703.4
UE 8f	580179.9	4114223.2	1389.9	704.7	?	?	744.2	737.9
UE 8h	579791.6	4114334.6	1400.3	909.5	?	?	1078.7	1025.3
UE 8i	579987.9	4114147.3	1391.7	1026.0	?	?	NDE	NDE
UE 8n	580478.1	4114441.8	1386.5	663.5	1061.9	1017.4	705.6	685.5
UE 8o	580852.5	4115417.9	1399.0	1304.5	NDE	NDE	NDE	NDE
UE 9-29#1	585556.1	4110960.8	1294.8	914.4	?	?	?	947.9
UE 9-30.5	585824.2	4111146.1	1299.7	933.9	1043.7		976.0	958.6
UE 9cn	587384.6	4107781.9	1338.4	893.4	1033.9		933.0	914.4
UE 9cp	586012.4	4109113.3	1296.3	736.7	936.6	848.2	759.9	753.8
UE 9IS25	585153.2	4110463.3	1286.9		878.5	?	?	689.8
UE 9ITS#1	586695.8	4109741.0	1321.9	1119.8	1172.5		NP	1132.9
UE 9ITS#2	586583.5	4111263.7	1319.8	1142.1	?	?	NP	1154.9
UE 9ITS#3	585794.7	4110346.7	1296.0	946.4	?	?	994.2	985.1
UE 9ITS#4	586040.6	4109738.1	1298.8	1012.2	NP	NP	NP	1021.7
UE 9ITS#5	586036.1	4111200.8	1303.3	1036.0	NP	NP	NP	1047.3
UE U22	585429.9	4110113.8	1287.2	733.4	?	?	NDE	NDE
UE U29#2	585398.1	4110925.8	1293.0		?	?	?	859.8
VW 2	581005.5	4113499.0	1362.5	319.5	847.4		609.7	582.0

Explanation

NP = Not Present; hole penetrated stratigraphic interval, but zone is not present.

NDE = Not Deep Enough; hole bottomed above zone; zone may or may not be present.

? = hole likely penetrated top of formation but existing data is insufficient to define zone.

Note: elevation that spans two columns indicates top of zeolitization determined but zone unknown.

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