Preliminary Lithostratigraphy, Interpreted Geophysical Logs, and Hydrogeologic Characteristics of the 98th Street Core Hole, Albuquerque, New Mexico

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CONTENTS

FIGURES

TABLES

CONVERSION FACTORS AND ALTITUDE

Multiply	By	To obtain
inch	25.40	Millimeter
foot	0.3048	Meter
mile	1.609	Kilometer
kPa	1.45×10^{-3}	lbf/in^2

Altitude in this report is based on the National Geodetic Vertical Datum of 1929 used on 7.5-minute topographic maps in the Albuquerque area.

SYMBOLS AND TERMS

CMR = combinable magnetic resonance
K = average horizontal hydraulic conductivity (ft/day)
K_V = average vertical hydraulic conductivity (ft/day)
Ohmm = ohm-meter, a unit of resistivity or specific resistance
gAPI = a unit of natural gamma radiation, calibrated in American Petroleum Institute (API) test facilities
long-normal resistivity = (ohm-meter^2/meter)
short-normal resistivity = (ohm-meter^2/meter)
mmoh = moh-meter, a unit of conductivity
kPa = kilopascals, a unit of pressure
psi = pound-force per square inch, lbf/in^2

PRELIMINARY LITHOSTRATIGRAPHY, INTERPRETED GEOPHYSICAL LOGS, AND HYDROGEOLOGIC CHARACTERISTICS OF THE 98TH STREET CORE HOLE, ALBUQUERQUE, NEW MEXICO

By Byron D. Stone, Bruce D. Allen, Marlo Mikolas, John W. Hawley, William C. Haneberg, Peggy S. Johnson, Barry Allred, and Condé R. Thorn

ABSTRACT

Core samples, cuttings, and numerous geophysical logs obtained from the 1560 ft (475.5 m) core hole drilled at 98th Street on the west side of Albuquerque provide key stratigraphic and hydraulic-property information for the upper clastic sediments of the Santa Fe Group, which form the principal aquifer in the region. The core hole and an adjacent water-level monitoring well were drilled cooperatively by the U.S. Geological Survey (USGS) and the City of Albuquerque and investigated in collaboration with the New Mexico Bureau of Mines and Mineral Resources and the New Mexico Office of the State Engineer to improve understanding of aquifer characteristics and controls on ground-water availability and quality. The 751.5 ft (229 m) of core samples recovered from the core hole are the only undisturbed samples of nonlithified sediments of the upper part of the Santa Fe Group that have been collected in this area. These samples have allowed us, for the first time, to directly observe and characterize the lithic and sedimentologic features of this part of the section, and to correlate the detailed geologic features with geophysical-log characteristics, magnetic susceptibility measurements, hydraulic variables, and trace-element geochemistry. The adjacent well was designed to be an areally representative ground-water level and water-quality monitoring well for the Santa Fe Group aquifer. This report chiefly addresses the lithologic, stratigraphic, and hydrogeologic features determined from the 98th Street core hole; other reports address related characteristics.

Previous geologic studies predicted the stratigraphy at the site to be, from the land surface downward: 1) Quaternary alluvial and eolian valley-border sediments; 2) fluvial sand and gravel of the upper unit of the Santa Fe Group (Ceja Member of the Santa Fe Formation of Kelly, 1978; equivalent to the Sierra Ledrones Formation of Machette (1978a); 3) downward-fining basin-floor silty clay deposits and 4) fluvial sandy and silty facies of the middle unit of the Santa Fe Group (the Middle Red Member of Bryan and McCann, 1937, and Lambert, 1968). New geologic interpretations indicate that the drill site is in a fault block bounded by east-dipping normal faults and the oblique Atrisco-Rincon fault zone.

Core-hole sampling recovered 760.6 ft (231.8 m) of core, in core segments 2.1-2.375 in. (5.3-6 cm) in diameter, and 0.2-10 ft (6.1 cm-3 m) long. The core hole was cased with centered 3-in. PVC casing, and is available for geophysical logging. The monitoring-well hole contains four piezometers at depths of 1544 ft (470.6 m), 1112 ft (338.9 m), 749 ft (228.3 m), and 458 ft (139.6 m).

Sediments in the core are loose to weakly cemented gravel, sand, silt, and clay, and lithified sandstone. Laboratory analyses of particle-size distributions of 28 channel samples show that most silty sand samples are uniformly graded and poorly sorted; medium sand samples are moderately sorted. Six principal sediment types are used to describe the core; these sediment types are repeated in various combinations throughout the core and are used to define 22 lithologic units in the cored interval. The six principal sediment types contain sequences of beds having similar modal grain size and sedimentary structure, and are listed in decreasing abundance:

1) Silty fine sand, poorly sorted, containing a coarse silt matrix. Geophysical logs show highly variable baselines with deflections that are related to clay beds and sequences of silt, clay, and sorted fine sand. Density values of 2.12-2.25 g/cc and porosity values of 30-35 percent are typical.

2) Medium sand, moderately to poorly sorted. Geophysical logs show baselines of low variability with deflections that are related to clay beds and

sequences of silt, clay, and sorted fine sand. Density values of 2.05-2.20 g/cc and porosity values of 30-35 percent are typical.

3) Clayey sandy silt, poorly sorted, locally microlaminated clay and silt, generally nonplastic. Geophysical logs show highly variable baselines with deflections that are related to sequences of clay and fine sand. Density values of 2.1-2.2 g/cc and porosity values of 30-40 percent are typical.

4) Silt and clay, characteristically red to reddish brown and medium to high plasticity, massive to indistinctly microlaminated. Geophysical logs show variable baselines with broad, high-amplitude compound spikes that are related to sequences of silt and fine sand. Density values of 2.12-2.25 g/cc and porosity values of >45 percent are typical.

5) Sand and gravel, poorly sorted. Geophysical logs show variable baselines with deflections that are related to sequences of silty and sorted fine sand.

6) Sandstone, fine-to-medium grained, poorly sorted, cemented chiefly by calcite, which fills the original pore space. Geophysical logs show density values >2.25 g/cc and porosity values <30 percent.

The 22 lithologic units are correlated with recognized basin-floor fluvial lithofacies (Hawley, 1996), which include sand and gravel (lithofacies I), sand with lenses of pebbly sand, silt, and silty clay (lithofacies II), and interbedded sand, silt, and silty clay (modified lithofacies III, IV, IX).

The sediments in the core hole are correlated with three informal lithostratigraphic units. The top unit, 0-19 ft (0-5.8 m) depth, consists of Quaternary eolian sand and valley-border alluvium. Coarse-grained deposits in the 19-97 ft (5.8-29.6 m) interval are correlated with the upper unit of the Santa Fe Group. The fine-grained section in the 97-787 ft (29.6-239.9 m) interval is correlated tentatively with the middle unit of the Santa Fe Group. This section contains thick sequences of laminated red and olive-brown clay and silt overbank deposits (441-787 ft) in the distinctive Atrisco member of Connell and others (1998). The Atrisco is correlated with fine-grained zones in numerous wells throughout the central Albuquerque metropolitan area, and is recognized as a zone that separates the upper Santa Fe aquifer from underlying middle Santa Fe deposits. The lower section of the middle unit of the Santa Fe, 787-1500 ft (239.9-457.2 m) depth, includes an upper sequence of moderately sorted channel-fill medium sand, and a lower sequence of sand, silt, and clay overbank deposits. The age of the cored interval is not known precisely. The upper Santa Fe gravel is related regionally to a through-flowing river system that was established in the Rio Grande rift valleys in Early Pliocene time, $\geq$4.5 MA. The middle Santa Fe unit is dated tentatively by correlation with a fossiliferous section, in which sandy beds that directly underlie the upper Santa Fe are Late Miocene (Hemphellian), 4.6-8.9 MA. Further, the middle Santa Fe unit, with dominantly normal magnetic polarity, may have been deposited during closely spaced normal magnetic chrons 5.9-8.3 Ma.

Four hydrostratigraphic units summarize the hydrogeologic framework for the 98th Street site: 1) Quaternary valley-border deposits, 2) upper Santa Fe sand and gravel deposits, 3) middle Santa Fe overbank deposits, and 4) middle Santa Fe channel-sand deposits. Empirical values of horizontal hydraulic conductivity estimated from core samples reveal a previously unknown contrast in hydraulic conductivity in the lowest two hydrostratigraphic units. Correlations among numerous wells show that the distinctively fine-grained Atrisco member, with estimated hydraulic conductivities (K) of <0.02-17 ft/day, is a laterally extensive barrier to vertical ground-water flow. The underlying unit that contains moderately sorted medium sand is a potential aquifer production zone that should be investigated further.

Laboratory determination of vertical hydraulic conductivity values for fine-grained core samples range from 10^{-2} to 10^{-7} ft/day; recompacted sandy samples have K values of 1 to 10^{-2} ft/day. Results of tests conducted with increasing effective stress show that K values of all samples decrease with decreasing porosity. Comparison of K values from laboratory, empirical, and calculated geophysical values shows discrepancies of 1-3 orders of magnitude (ft/day), indicating that additional analyses of core samples and geophysical data are necessary for future characterization of the Santa Fe Group aquifer.

INTRODUCTION

The U.S. Geological Survey (USGS) and the City of Albuquerque drilled a stratigraphic core hole to a total depth of 1560 ft (475.4 m) into Santa Fe

Group deposits on the west side of Albuquerque from September through November, 1996 (Stone and others, 1997, Stone and Allen, 1998). The core hole is located 3.5 mi (5.6 km) west of the Rio Grande, 0.49 mi (0.77 km) north of Interstate Route 40, on the east side of 98th Street (fig. 1). The New Mexico Bureau of Mines and Mineral Resources and the New Mexico Office of the State Engineer collaborated in investigations of the core hole and an adjacent ground-water monitoring well in order to improve understanding of aquifer characteristics and controls on ground-water availability and quality. The drilling project was completed as part of the ongoing cooperative Middle Rio Grande Basin Study, early results of which are reported in Bartolino (1997) and Slate (1998).

The core hole was located at 98th Street in order to: 1) provide core samples of typical non-lithified and lithified sediments of the upper part of the Santa Fe Group, 2) characterize the hydrogeologic properties of sediments in the area, previously inferred from geologic studies (Hawley and Haase, 1992, Hawley, 1996) and the ground-water model of Kernodle and others (1995), and 3) determine core-hole stratigraphy to be calibrated with geophysical logging tools commonly used in studies of the Middle Rio Grande aquifer. The core-hole site is within 1.2-1.9 mi (2-3 km) of the Don 1, West Mesa 1 and 2, and College 1 and 2 Albuquerque municipal wells, all of which produce water with elevated values of arsenic. For example, arsenic values are as high as 50 ppb in the Don 1 well. The ground-water monitoring well at the 98th Street site, drilled to a total depth of 1547 ft (471.5 m), contains four nested piezometers. Thus, the site also provides: 4) sediment and water samples for analysis of arsenic species and determination of the origin of subsurface arsenic, and 5) an areally representative ground-water monitoring well >1 mi (1.6 km) distant from presently producing municipal wells.

The purpose of this report is to provide a preliminary description of the lithologic and stratigraphic features of the 98th Street site using field descriptions of the core samples and references to geophysical logs commonly used in analysis of well data in the Middle Rio Grande basin. The report includes laboratory analyses of particle size and hydraulic conductivity for representative channel samples, as well as description of the geologic setting, correlations with nearby wells, and preliminary estimates of hydrogeologic characteristics of hydrostratigraphic units. Separate reports present preliminary data concerning the occurrence of arsenic in the sediments from the 98th Street site (Stanton and others, 1998), preliminary magnetic characteristics of the core (Hudson and others, 1998), particle-size and hydraulic conductivity measurements of core samples (Haneberg and others, 1998a), and measure-ments of stress-dependent hydraulic conductivity of the Santa Fe Group aquifer (Haneberg and others, 1998b).

Acknowledgments

The authors commend the expertise of the USGS drilling team, Dan Sweeney, Steve Grant, Brian Bretz, Art Clark, and Don Queen, consultant, who devised strategies to deliver undisturbed core samples on schedule, and who completed the monitoring well in challenging conditions. Priscilla Gomez and Amy Gibson completed particle-size and hydraulic conductivity analyses of the samples (Haneberg and others, 1998b). In visits to the drill site, the following scientists contributed collegial discussions of Santa Fe Group stratigraphy, tectonic history of the Albuquerque Basin, and detailed geologic features of the 98th Street area: D.W. Sawyer, S.D. Connell, C.R. Menges, S.D. Personius, R.R. Shroba, and A.J. Kuhle. Doug Earp, City of Albuquerque, helped locate the holes to address the arsenic problem. Frank Titus, N.M.O.S.E. provided insights into the regional hydrogeologic setting. The manuscript benefitted from thoughtful reviews by J.M. Cole, R.W. Harrison, and M.R. Stanton.

Previous Work

Reconnaissance mapping of upper Santa Fe Group basin-fill deposits and definition of stratigraphic units in the Rio Grande valley area that includes the 98th Street drill site were originally presented by Bryan (1909, 1938), Lambert (1968), and Kelley (1977). Bjorklund and Maxwell (1961), Lambert (1968), and Kaehler (1991) also developed preliminary conceptual models of subsurface hydrogeologic conditions in the area, and constructed schematic cross sections based on available water-well data. Spiegel and Baldwin (1963) formally

proposed raising the Santa Fe Formation (Bryan, 1938) to group status; and Spiegel (1961) first documented the presence of axial fluvial deposits of the ancestral Rio Grande system in both middle and upper parts of the Santa Fe Group in the northern Albuquerque Basin. Basin-fill deposits were included in the middle and upper parts of the Santa Fe Group (Formation) by Lambert (1968) and Kelley (1977), following the (informal) Lower gray, Middle red, and Upper buff lithostratigraphic classification system originally proposed by Bryan and McCann (1937).

Previous mapping in the west valley-border area including the 98th Street drill site, and study of drilling records from the nearby West Mesa No. 1 City well revealed that thin Quaternary alluvial and eolian valley-fill sediments are underlain by a thick sequence of coarse-to-fine-grained fluvial deposits of the Upper buff to Middle red units of the Santa Fe (Lambert, 1968). Kelley (1977) mapped the surface basin-fill deposits in area as the Ceja Member of the Santa Fe Formation. He characterized the Ceja as a buff-colored sandy unit containing scattered beds of pebble to cobble gravel and a basal gravel zone (pebbly conglomerate) (Kelley, 1977, p. 20). At its type locality at the west edge of the Llano de Albuquerque 6 mi (9.7 km) west of the 98th Street site, the Ceja member is 211 ft (64.3 m) thick. Lozinsky (1988, 1994) and Lozinsky and others (1991) further described the two-part stratigraphy (piedmont-slope and basin-floor lithofacies) of the upper and middle Santa Fe in the northern Albuquerque Basin primarily from subsurface and sedimentary petrologic perspectives. They emphasized that fluvial sediments of the upper Santa Fe Group were deposited by perennial tributaries of the ancestral river system that headed in Rio Grande rift basins of the southern Rocky Mountain province and adjacent parts of the Colorado Plateau.

Recent subsurface hydrogeologic work in the northern Albuquerque Basin has been reviewed by Hawley and others (1995). They include the Ceja Member and the Sierra Ladrones Formation of Machette (1978a) in the upper Santa Fe hydrostratigraphic unit, and correlate the unnamed middle Santa Fe unit with parts of the Cochiti and Popotosa Formations mapped by Manley (1978), Machette (1978a, b), and Lozinsky and Tedford (1991) in the northern and southern parts of the Basin, respectively. Lozinsky and Hawley (1992, p. II-5) and Hawley and others (1995, p. 47) also emphasized the transitional nature of ancestral Rio Grande fluvial deposits between Middle and Upper Santa Fe units in the northern Albuquerque Basin. They further described a series of mappable lithofacies within the Santa Fe, which are recognized by grain size, mineral composition, body geometry, and inferred environments of deposition. The lithofacies classification includes coarse-grained, gravelly and sandy facies (I, II, VII, VIII) and finer grained sandy to clayey facies (III, IV, IX, X) of the basin floor, and mixed coarse and fine-grained facies (V,VI) from piedmont areas. In the 98th Street area, basin-floor fluvial lithofacies comprising sand and gravel (lithofacies I), sand with lenses of pebbly sand, silt, and silty clay (lithofacies II), and interbedded sand, silt, and silty clay (modified lithofacies III, IV, IX) are dominant in the upper and middle Santa Fe units (Hawley and Haase, 1992, Plate 3; Hawley, 1996, Plate 7).

For purposes of conceptual models of the basin hydrogeologic framework, Hawley and Haase (1992) proposed informal hydrostratigraphic subdivisions of the Santa Fe Group which broadly correspond to the upper (Sierra Ladrones-Ceja), unnamed middle (red), and lower (Zia) formational units of Lozinsky and Hawley (1992). In the 98th Street area, the upper Santa Fe hydrostratigraphic unit originally included coarse fluvial deposits of the ancestral Rio Grande and Rio Puerco systems, and an underlying unit of interbedded fine-grained sediments deposited in the structural depression between the Rio Grande and the County Dump fault (Hawley and Haase, 1992, Plate 3). The upper Santa Fe, inferred to be 900-1200 ft thick, overlies the middle Santa Fe hydrostratigraphic unit (>5000 ft thick) comprising sandy to fine-grained basin-floor sediments. Hawley (1996) subsequently placed the fine-grained beds previously correlated with the lower part of the upper Santa Fe in the transition zone at the top of the middle Santa Fe hydrostratigraphic unit. This reinterpretation was based on new analyses of subsurface information that greatly expanded the data base of geophysical logs, well cuttings, cores, and subsurface extent of hydrostratigraphic units available to Haase (1992), Lozinsky (1988, 1994), and Mozley and others (1992).

In summary, prior to completion of the 98th

Street core hole, the subsurface geology in the area was predicted to include, from top down: 1) Quaternary surficial alluvial and eolian sediments, 2) fluvial sand and gravel facies of the upper Santa Fe Group, 3) downward fining basin-floor fluvial and possible playa-lake silty clay facies of a transition zone within the middle Santa Fe Group, 4) fluvial sandy and silty facies of the middle Santa Fe Group, possibly more consolidated and cemented than overlying strata. In addition, interpretations of high-amplitude anomalies in gamma and conductivity logs for other wells could not confirm or distinguish among clay of fluvial or playa-lake origin, or stratigraphically significant volcanic-ash strata. The ground-water flow model of Kernodle and others (1995) incorporated the previous interpretation of the subsurface geology, assigning mean hydraulic conductivity values of 15 ft/day in the upper 570 ft of the saturated zone of the aquifer (378-948 ft [115.2-288.9 m] depth in the monitoring well), and 4 ft/day in the lower 550 ft (948-1498 ft [288.9-456.6 m] depth)

Location And Geologic Setting

The 98th Street core hole is located 3.5 mi (5.6 km) west of the Rio Grande, 0.49 mi (0.77 km) north of Interstate Route 40, on the east side of 98th Street (35°5'32"N, 106°44'52"W, fig. 1). The core-hole site is in the highway right-of-way managed by the New Mexico Highway and Transportation Department, District 3 Office, which granted permission for location of the core hole and monitoring well. The site is at an altitude of 5320 ft 1621.5 m), 400-450 ft (122-137 m) below the Llano de Alburquerque geomorphic surface to the west, in a small valley cut into Santa Fe deposits 2.6 mi (4.3 km) south of the Albuquerque volcanic field (fig. 1). The valley drains eastward where it converges with the surface of Quaternary fluvial terrace deposits of the inner Rio Grande valley.

The 98th Street site is located on the west side of a regional gravity-low anomaly (Heywood, 1992), which is inferred to reflect mostly thickening of the Santa Fe deposits in the Central Albuquerque basin of Hawley (1996). The drill site is in a fault block bounded by east-dipping, intrabasin normal faults (fig 1), traces of which appear as continuous linear anomalies in high-resolution aeromagnetic data (Grauch, 1998). At the surface, the western fault is expressed by linearly aligned erosional remnants of the Santa Fe Group. The vertical offset of the eastern bounding fault is inferred from stratigraphic correlations among wells in the College and West Mesa well fields (discussed below). Strata in the core-site fault block are inferred to be subhorizontal or to dip <10° to the west, in accordance with minor rotation of the fault block. To the south, the core-hole fault block is bounded south of Interstate Route 40 by the Atrisco-Rincon fault zone, an oblique transverse zone that is located at the southern ends of the north-south-trending intrabasin normal faults (Hawley, 1996).

Operations, Recovery, and Well Completion

The 98th Street core hole was drilled to a total depth of 1560 ft (475.4 m) with a mud-rotary drill, employing a wire-line inner-barrel core-recovery system. Dan Sweeney (USGS) was driller in charge of operations, assisted by Steve Grant, Bryan Bretz, and Art Clark. Drilling began on September 21, 1996, when the first core samples were recovered below the 25-ft long surface casing. Drilling and sampling continued through November 12 when the base of the coring interval was reached at 1500 ft (457.2 m) depth. A total of 230 coring drives were completed in 1496.4 ft (456.1 m).

Wire-line coring operations were attempted in each drive; however, core samples were discontinuous due to changing subsurface conditions, drilling speed, and time constraints of the drilling schedule. Sampling recovered 751.5 ft (229 m) of core, about 50 percent of the coring interval, and 48 percent of the total depth of the hole. The recovery rate was 52 percent of the actual intervals in which coring was attempted. Core samples are in segments that vary in diameter from 2.1 in. to 2.375 in. (5.3 cm to 6.0 cm), and in length from 0.2 ft to 10 ft (6 cm to 3.05 m). Sampled intervals were distributed evenly over the total drilled depth (fig. 2). Core samples recovered most sediment types, excluding loose cobbles which were not retrieved, and loose sand which was selectively lost due to hydraulic erosion by drilling fluids in front of the drill bit. Other core-retrieval problems included thin lithified zones that became lodged in the

core barrel during continuous coring, and plastic clay zones that did not break loose during retrieval. The core hole was deepened to 1560 ft (473 m) to accommodate geophysical logging tools.

A second hole for the 98th Street monitoring well was drilled 60 ft (18 m) north of the core hole, beginning on November 21, 1996. Core samples were obtained from 122-132.7 ft (37.2-40.4 m), 253-260.7 ft (77.1-79.5 m), and 314-322.5 ft (95.7-98.3 m) intervals. Ground-water sampling to evaluate arsenic values was attempted at 720 ft (219.4 m), but incomplete packing of the well screen and poor production from the silty sand strata prevented collection of representative samples. Freezing-weather conditions and resultant equipment problems delayed drilling completion of the second hole to a total depth of 1,547 ft (471.5 m) until February 3, 1997.

The core hole was cased with 3-in. PVC (polyvinyl chloride) casing, using centralizers every 40 ft (12.2 m), to a depth of 1,435 ft (437.4 m). The hole was filled with abandonment mud around the PVC casing. The hole was sealed with cement from the bottom upward to 1,320 ft (402.3 m) depth. The completed hole is available as a geophysical logging reference hole through arrangements with the U.S. Geological Survey, Albuquerque.

The monitoring-well hole was reamed to 12.25 in. (31.1 cm) diameter, and four PVC piezometers were installed and screened at depth intervals of 1,534-1,539 ft (467.5-469.1 m), 1,102-1107 ft (335.9-337.4 m), 739-744 ft (225.2-226.8 m), and 388-433 ft (118.2-132.0 m), completed on February 9, 1997. The uppermost piezometer is screened for 45 ft (12.2-24.4 m) at a depth beginning 10 ft (3 m) below the water table at 378 ft (115.2 m). The intermediate and two deepest piezometers were completed with 5-ft screens in the more permeable zones of the middle and bottom parts of production zones in the area, based on elevations of screened intervals from nearby production wells (fig.1) projected to the 98th Street site. The piezometer at 749 ft (228.3 m) depth was completed in order to sample water in a distinctive olive-colored silt-clay zone. Each piezometer is instrumented with a pressure transducer in order to obtain continuous measurements of hydraulic head. Water-quality samples will be collected from each piezometer annually or biannually as part of the areal monitoring-well network (Thorn, 1997).

LITHOLOGIC DESCRIPTION OF THE CORE

Lithologic units and common geophysical logs for the 98th Street core hole are shown in figure 2; additional geophysical logs that correlate with lithologic properties are shown in figure 3. Sediments in the core generally are compacted, stratified, loose to very weakly cemented sand, silt, clay, and gravel, and cemented sandstone (figs. 5, 6), in decreasing order of abundance. In the field, twenty-two sediment types, distinguished by their lithologic characteristics including color, particle size, sorting, sedimentary structure, and mineralogy, were used to describe individual beds or sets of similar beds in the core (see core description, Appendix A). Color values were estimated for naturally moist samples by visual comparison with standard color charts (Munsell, 1975). Basal contacts of strata generally are distinct and planar. Stratification in all parts of the core appears to be horizontal. The core samples are characterized by loose to very friable consistence for sand, and firm consistence for clay and silty clay (ASTM, 1995). For the purposes of this report, the 22 descriptive sediment types are grouped into six principal sediment types (table 1) that contain interbedded sets of beds with similar modal grain size and sedimentary structure. These six sediment types are repetitive in the cored interval (fig. 2), and are used to depict the vertical sequence of lithologic units (fig.2).

Particle-Size Parameters

Descriptions of the beds in the core samples include estimated particle-size (grain-size) parameters, which use the geologic particle-size classification that is based on the phi scale, in which:

$$\text{phi} = -\log_2 [\text{diameter, mm}]$$

Particle-size modal class and range in phi units (fig. 4) were estimated by visual comparison with a grain-size card that displays grain sizes in half-phi intervals. Sorting descriptions are based on the graphic standard deviation, σ_G, method of Folk (1980), which employs the estimated particle-diameter ratios of the 16th and

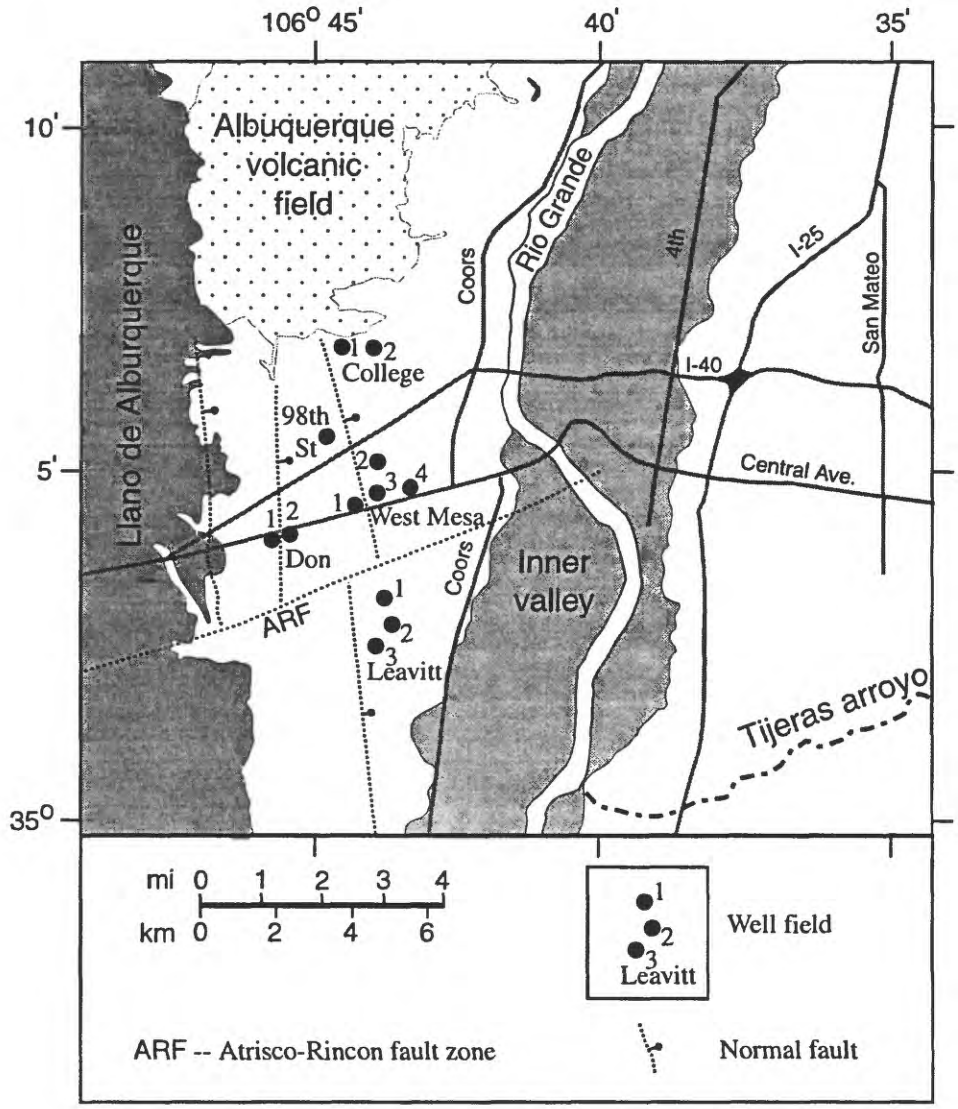


Figure 1. Location and geologic setting of the 98th Street core-hole site, and locations of neighboring wells.

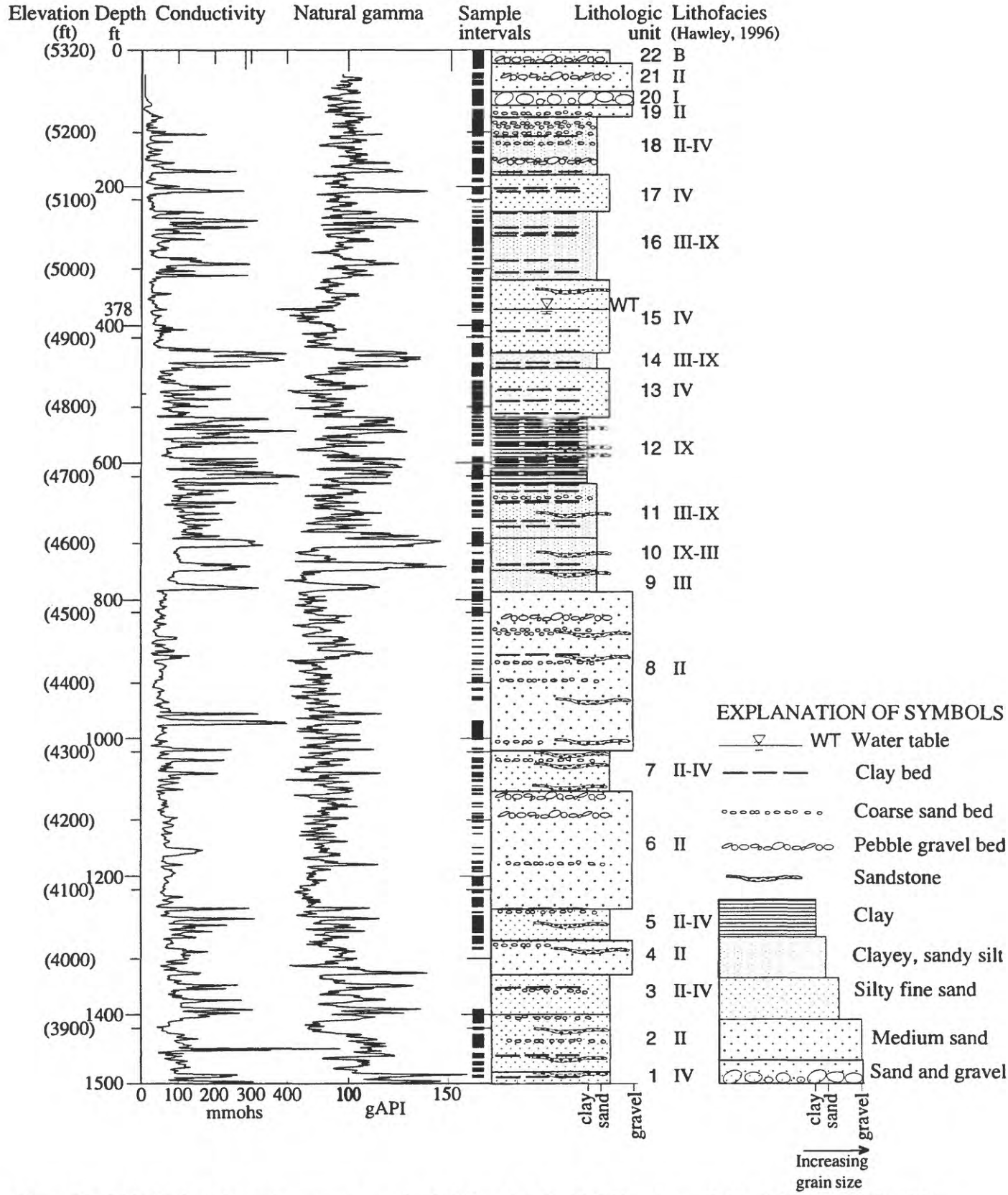


Figure 2. Lithologic units and common geophysical logs for the 98th Street core hole. Units are defined by similar modal grain size of beds, sedimentary structures, and geophysical-log characteristics. Thin beds and sets of beds composed of clay, coarse sand, gravel, or sandstone are shown as overprint patterns on the units.

84th percentile of the particle-size distribution:

$$\sigma_G = \frac{\phi 84 - \phi 16}{2}$$

in which the standard deviation is a measure of the spread in phi units of the sample. A verbal classification scale of sorting values derived from the graphic standard deviation, or from the ratio, in millimeters, of the D_{16} and D_{84} values is given in table 1.

Estimates of D_{16} and D_{84} were based on visually estimated particle diameters, consistent with the total range of particle sizes. Estimates of D_{10}, the grain size of the 10th percentile at the finer end of the grain-size distribution, are based on visually estimated particle diameters (fig. 4).

Laboratory analyses of grain-size distributions were conducted on 28 channel samples (Haneberg and others, 1998b), which integrate the grain-size distributions of multiple beds in the sampling intervals. One sample was taken from the total core samples from each of twenty lithologic units (fig. 2) in the 19-1496.4 ft (5.8-456.1 m) interval. Eight channel samples from core lengths of 1.4 ft to 2 ft (0.4-0.6 m) (Appendix D) were taken from the top 97-336 ft (29.6-102.4 m) of the cored interval. Particle-size parameters of all the core samples are based on the engineering methods (mechanical sieving of sand particles $\geq$ 0.075 mm diameter; hydrometer analysis of silt and clay particles <0.075 mm) and classification system that employ selected sieve intervals for mechanical analysis (Appendix D). Sample gradation was determined after calculating the coefficient of curvature, C_c, and the coefficient of uniformity, C_u. Equations for both coefficients are as follows:

$$C_c = \frac{(D_{30})^2}{(D_{10})D_{60})}, \text{ and}$$

$$Cu = \frac{D_{60}}{D_{10}}$$

where D_{10}, D_{30}, and D_{60} are the grain diameters at 10, 30, and 60 percent (finer) passing. A sandy sample is considered *well graded* if:

$$1 \leq C_C \leq 3, \text{ and}$$

$$C_U \geq 6$$

If either of these conditions do not hold, then the sample is said to be *poorly graded* or *uniformly graded* (Appendix D).

Table 3 shows the estimated and measured particle-size parameters for the core channel samples. The estimated values for modal size and sorting are based on estimates of the predominant sediment type in each sample interval (as in fig. 2, and table 1). All of the samples are coarse-grained (<50 percent fine particles passing the number 200 sieve [0.075 mm]), but most contain 5-12 percent fine particles and are thus classified using both coarse- and fine-soil descriptions. In general, the laboratory analyses support the estimated parameters for sediment types, such as modal size class and degree of sorting. Note

Table 1. Verbal scale of sorting values (modified from Folk, 1980)

D_{16}/D_{84}, mm Diameter ratio	phi standard Deviation	Verbal scale
1.0	0.00	
		Very well sorted
1.6	0.35	
		Well sorted
2.0	0.50	
		Moderately sorted
4.0	1.00	
8.0	1.50	Poorly sorted
16.0	2.0	
		Very poorly sorted

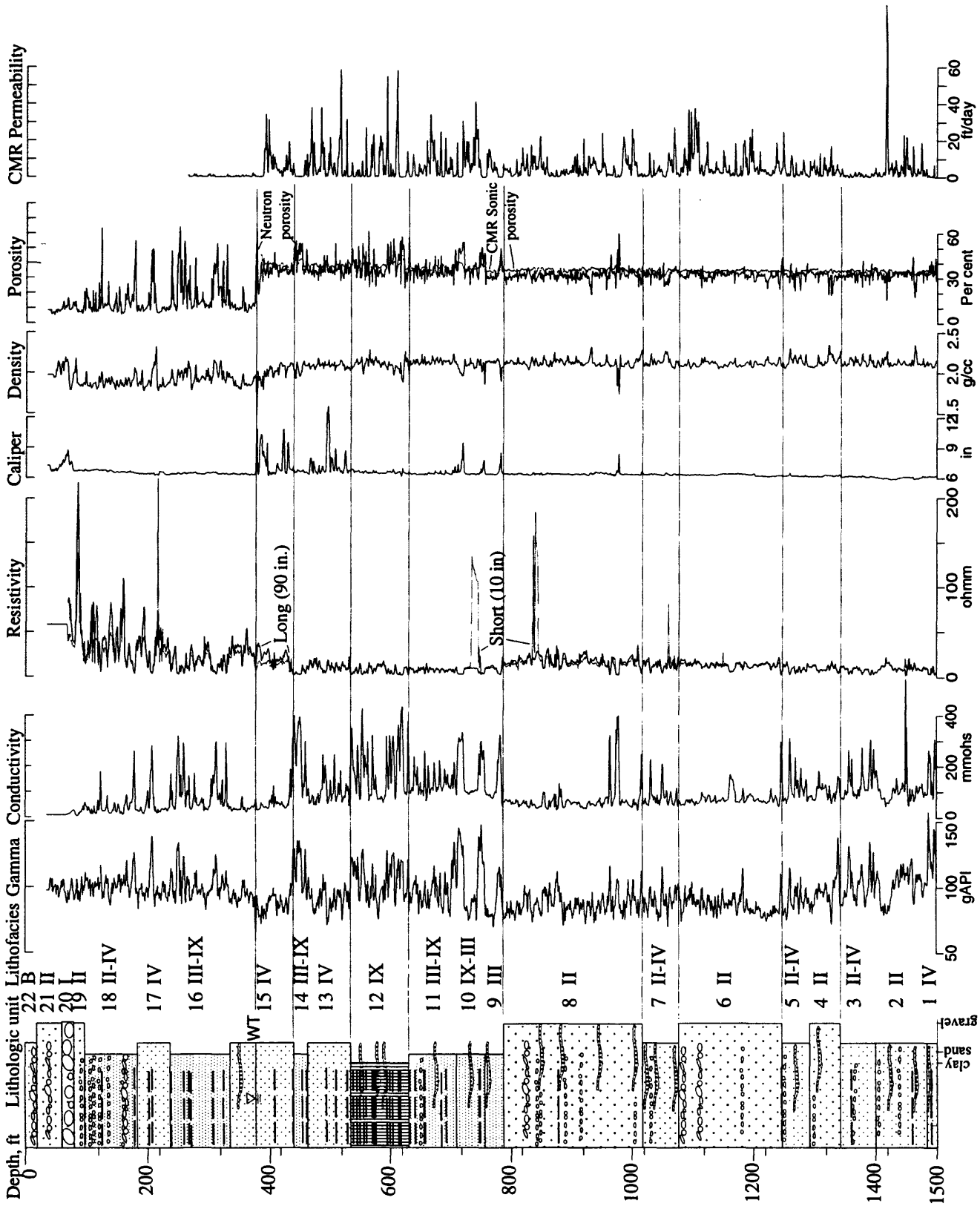


Figure 3. Selected geophysical logs and lithologic units of the 98th Street core hole.

Table 2. Particle-size Parameters of 98th Street Core Channel Samples

Sample	Mode, phi units	D_{50}, phi units	C_C	C_U	Grading	Sorting
Unit 1 (1483'-1496')	Silty fine sand, 2-3	2.5-3	1.32	4.00	Uniform	Poorly sorted
Unit 2 (1399'-1483'	Silty fine sand, 2-3	2-2.5	1.20	2.40	Uniform	Poorly sorted
Unit 3 (1341'-1399'	Silty fine sand, 2-3	2-2.5	0.86	3.00	Uniform	Poorly sorted
Unit 4 (1291'-1341')	Medium sand, 1-2	1.5-2	1.47	3.40	Uniform	Moderately to poorly sorted
Unit 5 (1246'-1291')	Silty fine sand, 2-3	1.5-2	1.23	3.17	Uniform	Poorly sorted
Unit 6 (1076'-1246')	Medium sand, 1-2	2	1.19	2.33	Uniform	Moderately to poorly sorted
Unit 7 (1017'-1076')	Silty fine sand, 2-3	2-2.5	0.95	2.70	Uniform	Poorly sorted
Unit 8 (786'-1017')	Medium sand, 1-2	1.5-2	1.16	2.69	Uniform	Moderately to poorly sorted
Unit 9 (751'-786')	Clayey, sandy silt, 5	1-1.5	0.74	6.67	Uniform	Very poorly sorted
Unit 10 (710'-751')	Clayey, sandy silt, 5	2-2.5	0.29	8.24	Uniform	Very poorly sorted
Unit 11 (624'-710')	Clayey, sandy silt, 5	1.5-2	0.85	4.70	Uniform	Very poorly sorted
Unit 12 (535'-624')	Silt and clay, $\leq$8.5	2	1.52	9.25	Well	Poorly sorted
Unit 13 (464'-535')	Silty fine sand, 2-3	2-2.5	1.33	5.33	Uniform	Poorly sorted
Unit 14 (441'-464')	Clayey, sandy silt, 5	2-2.5	1.47	7.55	Well	Very poorly sorted
Unit 15 (336'-441')	Silty fine sand, 2-3	2-2.5	0.88	3.00	Uniform	Poorly sorted
Unit 16 (237'-336')	Clayey, sandy silt, 5	2-2.5	1.04	2.74	Uniform	Very poorly sorted
Unit 17 (183'-237')	Silty fine sand, 2-3	2-2.5	1.13	2.84	Uniform	Poorly sorted
Unit 18 (97'-183')	Clayey, sandy silt, 5	2-2.5	1.00	2.78	Uniform	Very poorly sorted
Unit 19 (80'-97')	Medium sand, 1-2	2-2.5	1.07	2.70	Uniform	Moderately to poorly sorted
Unit 21 (19'-60')	Medium sand, 1-2	1-1.5	1.10	3.92	Uniform	Moderately to poorly sorted
Unit 18 (97.2-98.6')	Fine sand, 2-2.5	2.5-3	1.02	2.93	Uniform	Moderately sorted
Unit 18 (116'-118')	Medium sand, 1.5-2	3-3.5	0.97	2.05	Uniform	Moderately sorted
Unit 18 (145.9'-147.9')	Medium sand, 1.5-2	3.5-4	1.03*	2.31*	Uniform	Moderately sorted
Unit 18 (160.9'-162.9')	Coarse sand 0.5-1	4.5-5	1.01*	4.8*	Uniform	Poorly sorted
Unit 18 (172.6'-174.5')	Silty fine sand, 2-3	3-3.5	0.90	2.4	Uniform	Poorly sorted
Unit 17 (203'-205')	Coarse sand, 0.5-1	2.5-3	1.70*	3.82*	Uniform	Poorly sorted
Unit 16 (243'-245')	Silty fine sand, 2-3	3.5-4	0.86*	3.6*	Uniform	Poorly sorted
Unit 16 (334'-336')	Medium sand, 3-3.5	3	1.13	2.67	Uniform	Moderately sorted

*Values based on estimated grain-size percentages

that measures of central tendency, D_{50} (median) and modal size class, are closely related for the coarser-grained, medium and fine sand samples. For finer-grained units, channel samples have median values coarser than the estimated modal class, possibly due to sampling error or to biased emphasis on the finer grained beds in these lithologic units. Each channel sample integrates a group of texturally related beds within each lithologic unit, which tends to produce uniformly (poorly) graded samples. Sorting values generally are inversely related to grading, such that moderately sorted medium sand is equivalent to uniformly (poorly) graded sand with relatively low C_U values (2.05-3.92). Samples of poorly sorted silty fine sand correspond to poorly graded sand and silt with C_U values of 2.4 to 5.33, and very poorly sorted clayey, sandy silt corresponds to poorly to well graded sand and silt with C_U values of 2.74 to 8.24. The sample from clay-rich unit 12, consisting of poorly sorted silt and clay, is equivalent to well graded silty sand and clayey silt with a C_U value of 9.25 (fig.4).

PRINCIPAL SEDIMENT TYPES

Six principal sediment types, each comprising beds with similar grain size, stratification, and composition, are used to describe the core, and to divide it into 22 lithologic units, each of which is composed of a single principal sediment type (fig. 2). As shown in figures 2 and 3, and described in table 4, each of these lithologic units is correlated with specific genetic lithofacies presently recognized in the Middle Rio Grande Basin (Hawley and others, 1995; Hawley, 1996). The lithologic units (lithofacies) have characteristic geophysical-log signatures, and lithic parameters that affect ground-water production (fig. 3; Haase and Lozinsky, 1992; Connell and others, 1998). In the 98th Street area, basin-floor fluvial lithofacies comprising sand and gravel (lithofacies I), sand with lenses of pebbly sand, silt, and silty clay (lithofacies II), and interbedded sand, silt, and silty clay (modified lithofacies III, IV, IX) are dominant in the upper and middle Santa Fe units. Thin beds or sets of beds containing clay, coarse sand, gravel, or sandstone are shown as overprint patterns on the lithologic units in figures 2 and 3. The six principal sediment types are described in decreasing abundance:

Silty fine sand -- Brown, yellowish brown, to light gray, consisting of a sand framework with a fine sand mode (2-3 phi), and with a range of sand particles from very fine sand to medium sand in most strata. Scattered coarse sand grains are present in some beds. Coarse silt is dispersed as a matrix that partially fills pores. Estimated sorting is poor. The value of D_{10} is estimated to be within the silt matrix. The strata commonly appear massive to indistinctly laminated (fig. 5). However, some beds contain opaque dark minerals which form distinct laminae. Sand mineralogy appears to be, in decreasing abundance: quartz, orthoclase feldspar, plagioclase feldspar, hornblende or hypersthene, magnetite, and other heavy minerals, which is similar to feldspathic litharenite to lithic arkose compositions reported for other sands in the basin (Mozley and others, 1992, Large, 1995). Quartz grains are elongated, subangular to rounded, exhibit straight extinction and preserve some crystal faces, and are inferred to be of volcanic origin. Feldspar grains are elongate, subangular. Other lithic types that commonly are interbedded with silty fine sand include silty clayey sand, silty sand, very fine sand, and clayey medium sand. Some strata composed of fine sand and fine-to-medium sand without silt matrix are present as interbedded units within these sequences. In geophysical logs (fig.3), silty fine sand is characterized by highly variable baselines, typically with deflections ranging from 76 to 120 gAPI units around a baseline value of about 100 gAPI units for natural gamma. Deflections in gamma, conductivity, and porosity logs show vertical variability of 2-5 ft (0.6-1.5 m) wave lengths, which is correlated with interbedded sequences of silt, clay, and sorted fine sand strata within the silty sand. Units typically include scattered clay strata, >0.2 ft (6 cm) thick, which produce sharp, high-amplitude spikes that are correlated between gamma (>120 to >150 gAPI units) and conductivity logs, and are inversely related to low values of resistivity. Thin clay beds, or silty clay beds produce low-amplitude spikes in both logs. Density values of 2.12-2.25 g/cc and porosity values of 30-35 percent are typical values for these parameters in unconsolidated fine sand (Pryor, 1973; Keys; 1989, Schlumberger, 1989, 1991).

Table 3. Sediment types of the 98th Street Core.

Units shown in bold type are six principal sediment types used to describe the stratigraphy of the core (fig. 2). These units include related sediment types (field descriptions) shown below each principal sediment type. Thickness percentages of the total cored interval for each principal sediment type, based on lithologic units (fig. 2), are shown in parentheses.

Principal Sediment Type Related sediment types	**Grain-Size** Mode (phi)	**Grain-Size** Range (phi)	**Grain size** D_{10} (phi)	**Color** Munsell values
Silt and clay (6.3 %)	8.5	8-12	10	2.5YR4/6, 2.5-5YR5/4
Clayey sandy silt (24.3 %)	5	2-12	8	7.5YR5/4
Silty clay	8.25			
Clayey silt	7			
Sandy clayey silt	6			
Sandy silt	4.5			
Silty fine sand (34.1 %)	3.6	7-.75	4.25	7.5YR5-6/4
Silty clayey sand	3.9			
Silty sand	3.8			
Very fine sand	3.5			
Fine sand	2.5			
Fine to medium sand	2			
Clayey medium sand	1.75			
Medium sand (33.8 %)	1.5	3-0.0	2.5	10YR5-6/2-4
Coarse sand	-.5			
Sand and gravel (1.3 %)	-1.75			
Coarse sand with granules	-1.5			
Pebble gravel	-4.5			
Cobble gravel	-6			
Sandstone (<0.3%)	2.5	5-1.5	3	10YR5/2
Medium sandstone	1.5			
Siltstone	4.75			

Medium sand -- Light brown to gray, consisting chiefly of medium sand beds, and scattered beds of medium to coarse sand, and beds of granular to pebbly sand. Sand strata consist of a sand framework with variable modes (1-2 phi), and with a range of sand particles from very fine sand to coarse sand in most strata. Pebbly sand strata consist of a sand framework with medium sand modes (1-2 phi), and with scattered or locally a framework of pebble-gravel clasts. For medium sand beds, the estimated sorting is moderate to poor, and the value of D_{10} is estimated to be within the fine sand fraction (2.5 phi). For coarse sand beds, the estimated sorting is poor, and the value of D_{10} is estimated to be within the medium sand fraction (1.5 phi). For pebbly sand beds, the estimated sorting of the sand matrix is poor, and the value of D_{10} is estimated to be within the fine sand fraction (2.5 phi). The strata commonly appear massive to indistinctly laminated. However, some beds contain distinct laminae composed of opaque or dark minerals. Sand mineralogy appears to be, in decreasing abundance: quartz, orthoclase feldspar, plagioclase feldspar, lithic fragments of quartzite, volcanic rocks, chert, granite, and heavy minerals hornblende or hypersthene, magnetite, and other heavy minerals, which is similar to feldspathic litharenite to lithic arkose compositions reported for other sands in the basin (Mozley and others, 1992, Large, 1995). Quartz grains commonly are elongated, subangular, exhibit straight extinction and preserve some crystal faces, and are inferred to be of volcanic origin. Feldspar grains are elongate, subangular. Other lithic types that commonly are interbedded with medium sand are coarse sand, and beds of granular to pebbly sand and pebble gravel. Some strata composed of fine sand, and silty fine sand are present as inter-

bedded units within these sequences. In geophysical logs (fig. 3), medium sand is characterized by baselines of low variability, typically with deflections ranging from 70 to 105 gAPI units around a baseline value of about 90 gAPI units for natural gamma. Deflections in gamma, conductivity, and porosity logs show vertical variability of 2-4-ft (0.6-1.2 m) wave lengths, which are correlated with interbedded sequences of silt, clay, and sorted fine sand strata within the sand. Units typically include scattered, thin clay strata, >0.2 ft (6 cm) thick, which produce sharp, high-amplitude spikes that are correlated between gamma (>120 to >150 gAPI units) and conductivity logs. Thin silty clay strata produce low-amplitude spikes in both logs. Density values of 2.05-2.20 g/cc and porosity values of 30-35 percent are typical values for these parameters in unconsolidated medium sand (Pryor, 1973; Keys, 1989; Schlumberger, 1989, 1991). Density values >2.25 g/cc, correlated with low porosity values, are related to thin beds of sandstone.

Clayey sandy silt -- Brown to gray, consisting of a very poorly sorted mixture of silt with variable clay matrix, with a coarse silt mode (5 phi), and with a range of particles from clay to medium sand in some strata. The value of D_{10} is estimated to be in the fine silt fraction. The strata commonly appear massive but locally are indistinctly laminated (fig.5). Some strata contain solitary or sets of microlaminations of red clay or gray silty fine sand. Air-dried samples of clayey silt have low to medium dry strength and have low plasticity or are nonplastic (ASTM, 1995). Silt and sand mineralogy appears to be dominated by light minerals, in decreasing abundance: quartz, plagioclase feldspar, and dark or opaque heavy minerals. Quartz and feldspar grains are elongated, subangular. This sediment type includes poorly sorted brown silty clay, clayey and sandy silt with scattered fine to medium sand grains, clayey silty sand, and beds composed of sets of microlaminated clay and silt. In geophysical logs (fig. 3), clayey and sandy silt sequences are characterized by highly variable baselines, typically with deflections ranging from 79 to 120 gAPI units around a baseline value of about 105 gAPI units for natural gamma. Deflections in gamma, conductivity, and porosity logs show vertical variability of 2-4 ft (0.6-1.2 m) wave lengths, which are correlated with interbedded sequences of clay and fine sand strata within the silt. Units typically include interbedded clay strata, >0.2 ft (6 cm) thick, which produce sharp, high-amplitude compound spikes that are correlated over 10-20-ft (3-6.1 m) vertical intervals between gamma (>120 to >150 gAPI units) and conductivity logs. Thin clay strata, or silty clay strata produce numerous low-amplitude spikes in both logs. Density values of 2.1-2.2 g/cc and porosity values of 30-40 percent are typical values for these parameters in unconsolidated silt (Pryor, 1973; Keys, 1989; Schlumberger, 1989, 1991).

Silt and clay -- Red to reddish brown, consisting of homogeneous to indistinctly microlaminated clay, with a clay mode ($\leq$8.5 phi), perhaps containing minor fine silt, but no coarse silt or sand, and interbedded brown to gray silt. The value of D_{10} is estimated to be in the clay fraction (10 phi). Clay strata are present as thin beds, laminae, and micro laminations (fig. 5) throughout the core. Air-dried samples of clay have medium to high dry strength and have medium to high plasticity (ASTM, 1995). Clay is identified by its red color and plasticity and this sediment type excludes other fine-grained sediment types that are nonplastic. Clay beds and associated laminated silt and clay sequences constitute a major fine-grained interval in the middle part of the core (fig. 2). In geophysical logs (fig.3), the clay and silty clay sequence is characterized by a variable baseline, typically with deflections ranging from 84 to 120 gAPI units around a baseline value of about 105 gAPI units for natural gamma. Deflections in gamma, conductivity, and porosity logs show vertical variability of 2-4 ft (0.6-1.2 m) wave lengths, which are correlated with interbedded sequences of silt, and fine sand strata within the clay. Lithologic unit 12 includes relatively thick sequences of clay strata, >0.2 ft (6 cm) thick, which produce broad, high-amplitude compound spikes that are correlated over 10-ft (3-m) vertical wave lengths between gamma (>120 to >150 gAPI units) and conductivity logs. Thin clay strata, or silty clay strata produce numerous low-amplitude spikes in both logs. Density values of 2.12-2.25 g/cc and porosity values of >45 percent are typical values for these parameters in poorly consolidated, undrained clay (Keys, 1989; Schlumberger, 1989, 1991).

Sand and gravel -- Interbedded framework gravel beds, containing sand matrix, and beds of sand. Sand strata consist of a sand framework with variable sand modes (1-3 phi). The estimated sorting of sand beds is poor, and the value of D_{10} is estimated commonly to be within the medium sand fraction (1.5 phi). Gravel beds consist of a framework gravel, with gravel modes varying from small pebbles to small cobbles, and containing a poorly sorted sand matrix. The value of D_{10} of the sand matrix is estimated to be within the fine sand fraction (2.5 phi). For pebbly sand beds, the estimated sorting of the sand matrix is poor. The strata commonly were disrupted by the drilling process. However, some core samples of thin sand and fine pebble beds were preserved and these contain distinct laminae composed of contrasting grain sizes. Sand mineralogy appears to be, in decreasing abundance: quartz, orthoclase feldspar, plagioclase feldspar, lithic fragments of quartzite, volcanic rocks, chert, granite, and heavy minerals hornblende or hypersthene, magnetite, and other heavy minerals. Quartz and feldspar grains commonly are elongated, subangular. Lithic fragments are elongate, tabular or subspherical, angular to subangular. Other sediment types that commonly are interbedded with sand and gravel include fine sand, and silty fine sand. In geophysical logs (fig. 3), sand and gravel is characterized by variable baselines, typically with deflections ranging from 88 to 106 gAPI units around a baseline value of about 98 gAPI units for natural gamma. Deflections in gamma and porosity logs show vertical variability of 3-10 ft (0.9-3 m.) wavelengths, which are correlated with interbedded sequences of silty and sorted fine sand, and gravel strata within the deposit.

Sandstone -- Light brown to gray, consisting chiefly of fine-to-medium grained sandstone, indurated and cemented by carbonate, and minor siltstone. Carbonate cement is chiefly calcite, varying from microsparry in the upper part of the core, to sparry in lower parts of the core (fig. 6). The cement virtually fills the entire original pore space, locally overgrowing iron/manganese stains on sand grains. These lithified thin beds are scattered throughout the core below the 100-ft (30-m) depth. Carbonate in nodular concretions, discontinuous patches, and thin lenses (fig. 5) is scattered throughout the core. Carbonate morphology is controlled in part by grain size of the host beds (Mozley and others, 1992) and calcite appears to have grown selectively on sand or silty sand at contacts with finer-grained sediments. In geophysical logs (fig. 3), sandstone beds are characterized by density values >2.25 g/cc and porosity values <30 percent. Thin sections of sandstone beds (fig. 6) reveal that most primary porosity has been filled with calcite cement.

Table 4. Lithologic units and related lithofacies of the 98th Street core .

Unit	Depth	Description	Lithofacies[1]
22	0-19	Fine to medium sand with scattered coarse sand and granular to pebbly sand intervals; 10YR 6/3-5/4	B--Valley border alluvial-fan sand and gravel ; sand and gravel
21	19-60	Fine to coarse sand and silty sand with granular and pebbly sand intervals; 10YR6-5/3-4.	II--Basin-floor fluvial and eolian sand; lenses of pebbly sand, silt, and silty clay
20	60-80	Pebble to cobble gravel	I--Fluvial cobble to pebble gravel, sand, silt, and silty clay
19	80-97	Fine to coarse sand and silty sand with scattered interbeds of granular and pebbly sand; 7.5-10YR5/4	II--Basin-floor fluvial and eolian sand; sand, lenses of pebbly sand, silt, and silty clay
18	97-183	Fine to coarse sand and silty sand with interbeds of silty fine sand grading into thin (<1 ft) silty clay and clay layers; granular pebbly sand from 158.9 to 64.1 ft depth;, 7.5-10YR5-4/4 (sand) 5-7.5YR5-4/4 and 2.5-5YR6/4-4/6 (clay)	II, IV--Basin-floor eolian and distal piedmont alluvial fan; sand and silt; lenses of silty clay and clay
17	183-237	Fine to coarse sand; sandy, silty clay interbred from 204.5 ft to 210.9 ft depth; 7.5YR./4-4/6 (sand), 5YR5/4 (clay)	IV
16	237-336	Interbedded silty fine to medium sand and clay and silty clay; thick clay beds (>1 ft thick) from 237.2 to 264.0 ft depth; 7.5YR6-4/4 and 7.5YR5/6 (sand), 2.5-5YR6-4/4 and 5YR5/6 (clay)	III--Basin-floor alluvial, playa lake, and eolian interbedded sand, silt, silty clay; lenses of pebbly sand IX--Basin-floor playa lake and alluvial flat, distal piedmont alluvial silty clay interbedded with silty sand, silty clay, and clay
15	336-441	Fine to medium sand and silty sand with thin lenses and interbeds of silty clay and clay; 7.5YR6-4/6 (sand), 5YR5/4 (clay)	IV
14	441-464	Interbedded silty fine sand, silty clay and clay, and fine to medium sand; some clay beds are more than 2 ft thick; 7.5YR5/4-6 (sand), 5YR5/4-4/6 (clay)	III, IX
13	464-534	Fine to medium sand and silty sand with thin interbeds of silty clay and clay; 7.5YR5/4-4/6 and 10YR6-5/4-6 (sand), 5-7.5YR5/4-4/6 (clay)	IV
12	534-630	Clay and silty clay with interbedded fine to medium silty sand; finely laminated clay beds from 544 to 606 ft depth; 7.5-10YR5-6/4 (sand), 5-7.5YR5/4-4/6 (clay)	IX
11	630-709	Fine to medium sand and silty sand with silty clay interbeds; 10YR6/3-4/4, 7.5YR6-4/4 (sand), 7.5-10YR5-4/4 (clay)	III, IX
10	709-756	Silty fine sand with laminated clay interbeds at 712.9 to	IX, III

Table 2 (continued). Lithologic units and related lithofacies of the 98th Street core .

Unit	Depth	Description	Lithofacies[1]
9	756-787	Silty fine sand with silty clay interbeds, fine to medium sand with scattered coarse sand from 770 to 780 ft depth; pebble gravel beds near 776.5 ft depth; 10YR6/6-5/4 and 10YR6/2 (sand), 5YR5/4 (clay near 784 ft depth)	III
8	787-1017	Fine to medium sand and silty sand with coarse sand layers, scattered granules, and pebbles; pebble gravel recovered near 825, 833, 843, and 860 ft; thin (<1 ft) silty clay and clay interbeds between 850 and 880 ft depths and near 978 ft; 10YR6/3-4/4, 7.5YR6-5/4 (sand)	II
7	1017-1076	Interbedded fine to coarse sand and silty sand, with thin silty clay interbeds; pebbly sand layer near 1031 ft; 10YR6/3-4/4 and 7.5YR6-5/4 (sand)	II, IV
6	1076-1246	Fine to coarse sand with granular and pebbly sand layers; pebble gravel recovered near 1085, 1113, and 1183 ft; 10YR6/2-5/4 (sand)	II
5	1246-1291	Fine to medium sand with scattered thin interbeds of silty fine sand and clayey silt; pebbly sand near 1261 and 1284 ft; 10YR6/3-5/4 (sand)	II, IV
4	1291-1341	Fine to coarse sand with granular and pebbly sand layers; pebbles recovered near 1323 and 1338 ft depths; 10YR6-4/2 and 10YR5/4 (sand)	II
3	1341-1399	Fine to medium sand and silty sand with thin intervals of compact silty and clayey silt; 10YR6/2-4/3 (sand)	II, IV
2	1399-1483	Fine to medium sand with scattered coarse and granular sand layers; 10YR5-4/1 and 10YR6/2-4/3 (sand)	II
1	1483-1500	Fine to medium sand with interbedded compact silty fine sand and clayey silt; 10YR5-4/3 (sand)	IV

[1] Lithofacies of Hawley and Haase, 1992, and Hawley, 1996

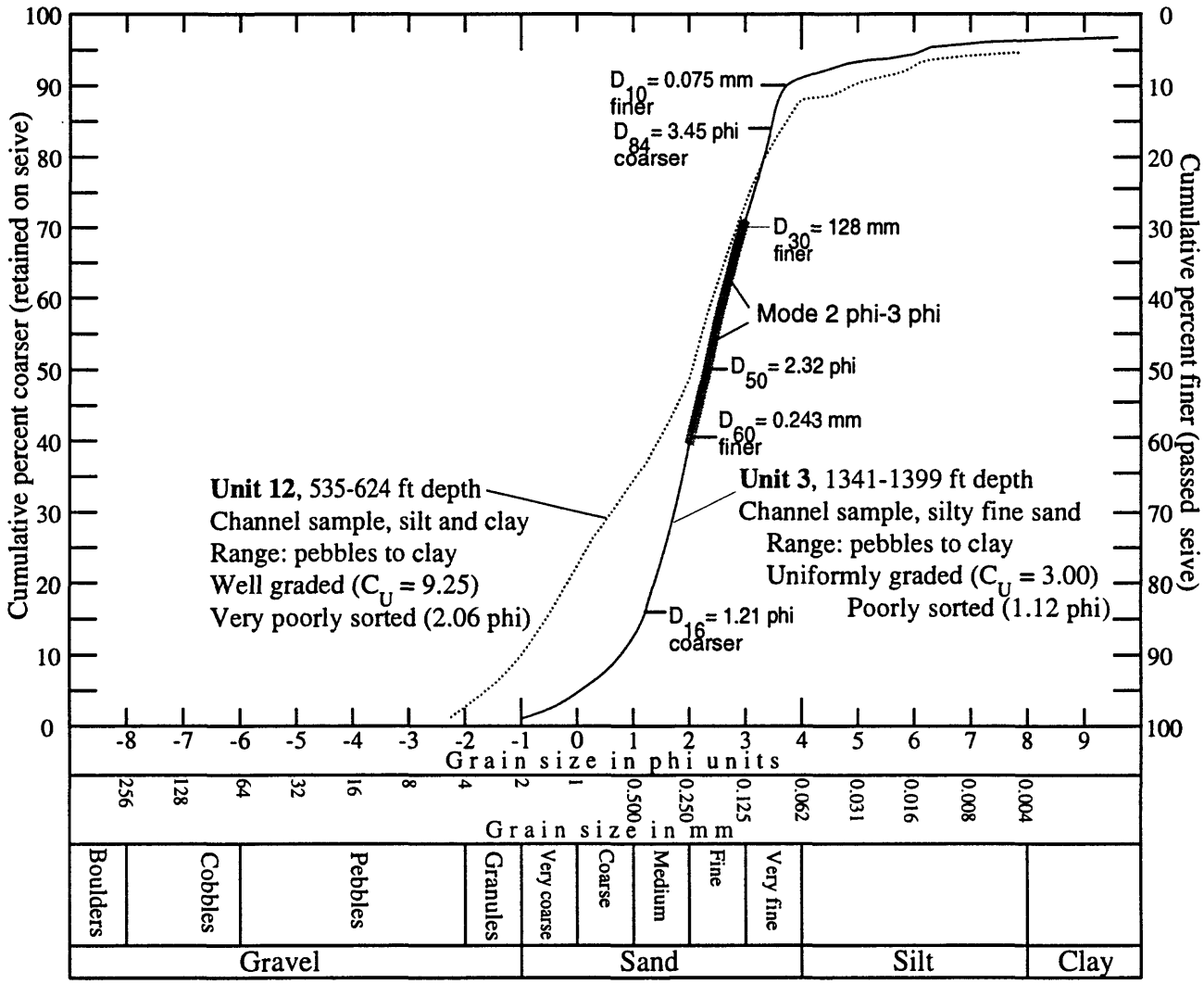
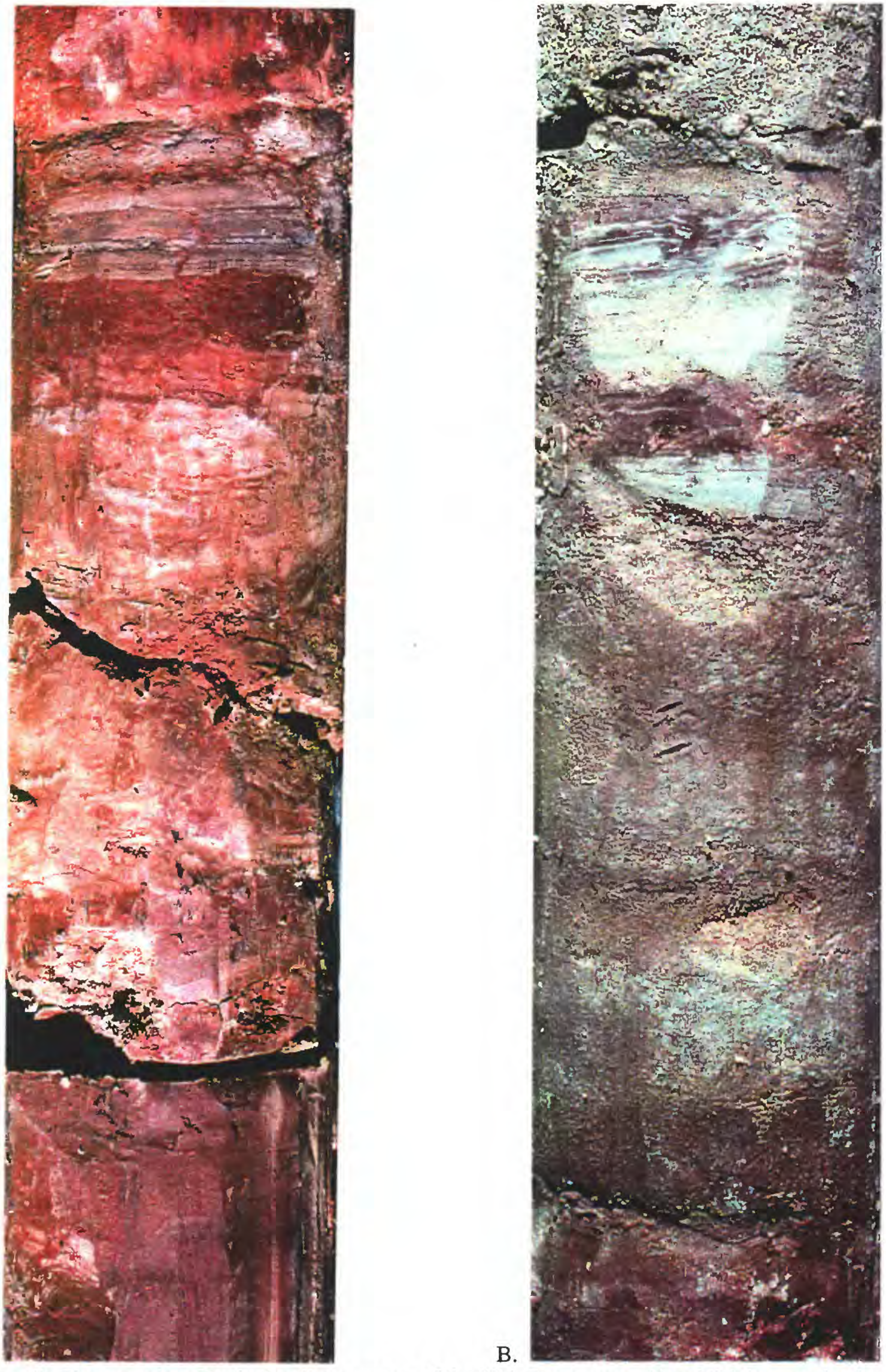


Figure 4. Cumulative particle-size curves for channel samples from lithologic unit 3 (silty fine sand), and lithologic unit 12 (silt and clay). Curve for unit 3 shows values for median (D_{50}), mode (one-phi interval), range of particle size, D_{10}, D_{30}, D_{60} (finer), D_{16}, and D_{84} (coarser) which are used to calculate sorting and gradation of the sample.



A. B.

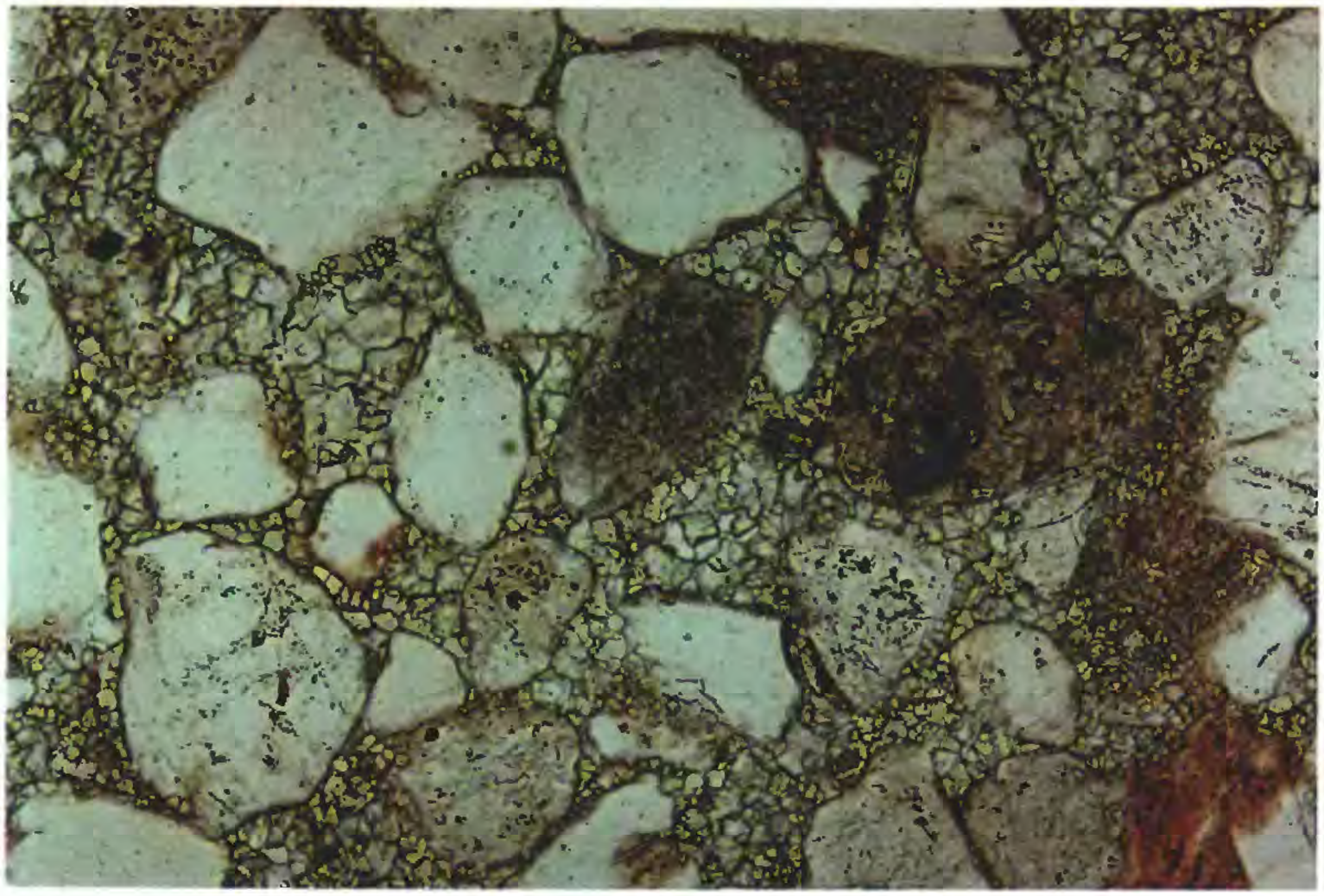
Figure 5. Photographs of typical sediment types of the 98th Street core. A) reddish brown clay lamination within microlaminated brown silty clay, silt, and clay; top of photo 555.05 ft (169.2 m) depth. B) microlaminated reddish brown clay, and light brown silt and fine sand within light brown to brown medium sand; top of photo 490.0 ft (149.3 m) depth.

C.

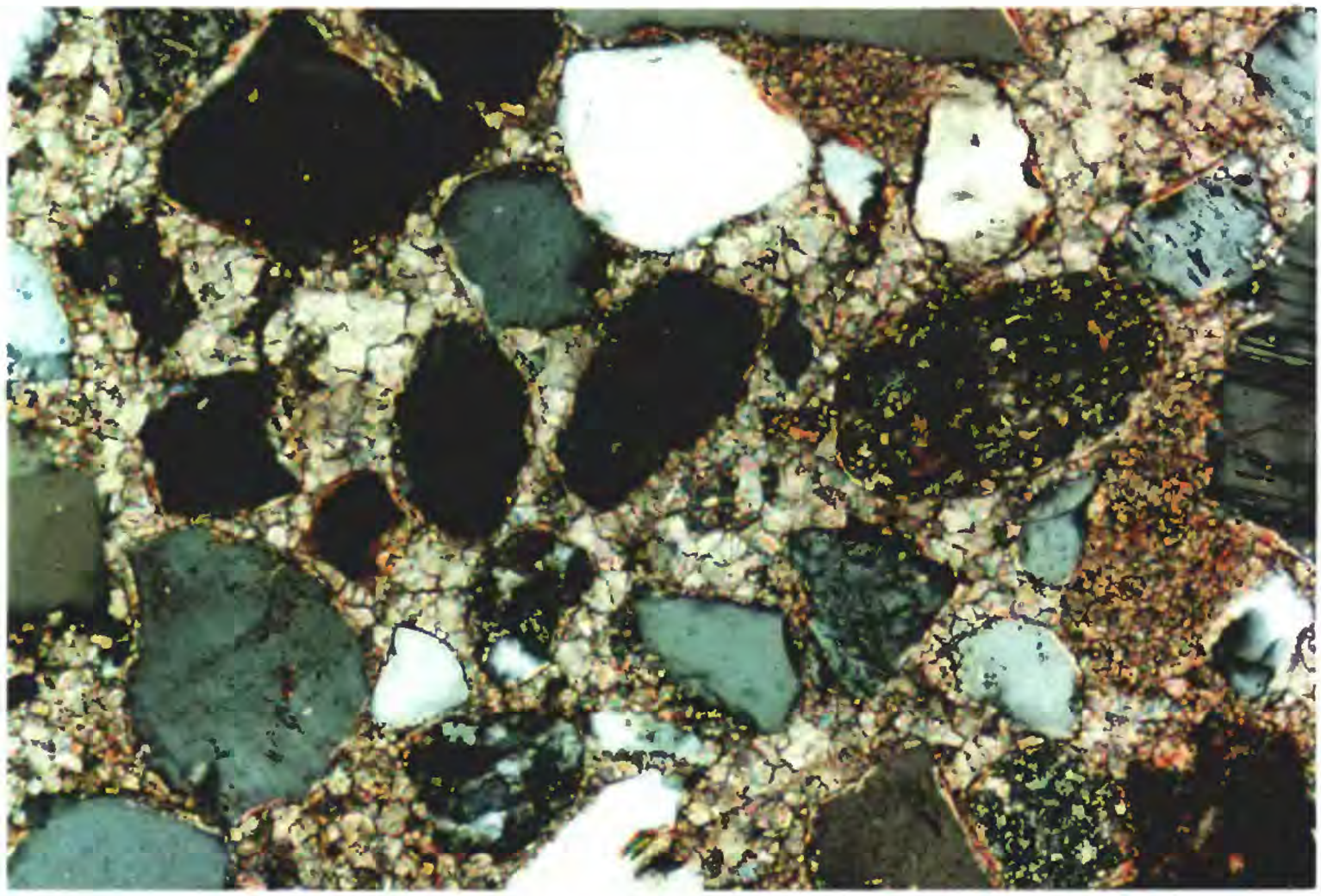
D.

Figure 5, continued. Photographs of typical sediment types of the 98th Street core. C) interbedded brown, pale brown, and yellowish brown silty fine sand, sandy clayey silt, silty clay, strong brown silty fine sand, and light gray medium sandstone; top of photo 549.2 ft (167.4 m) depth. D) reddish brown clay and irregularly carbonate-cemented clay within brown clayey fine sandy silt; top of photo 783.3 ft (238.7 m) depth.

A.



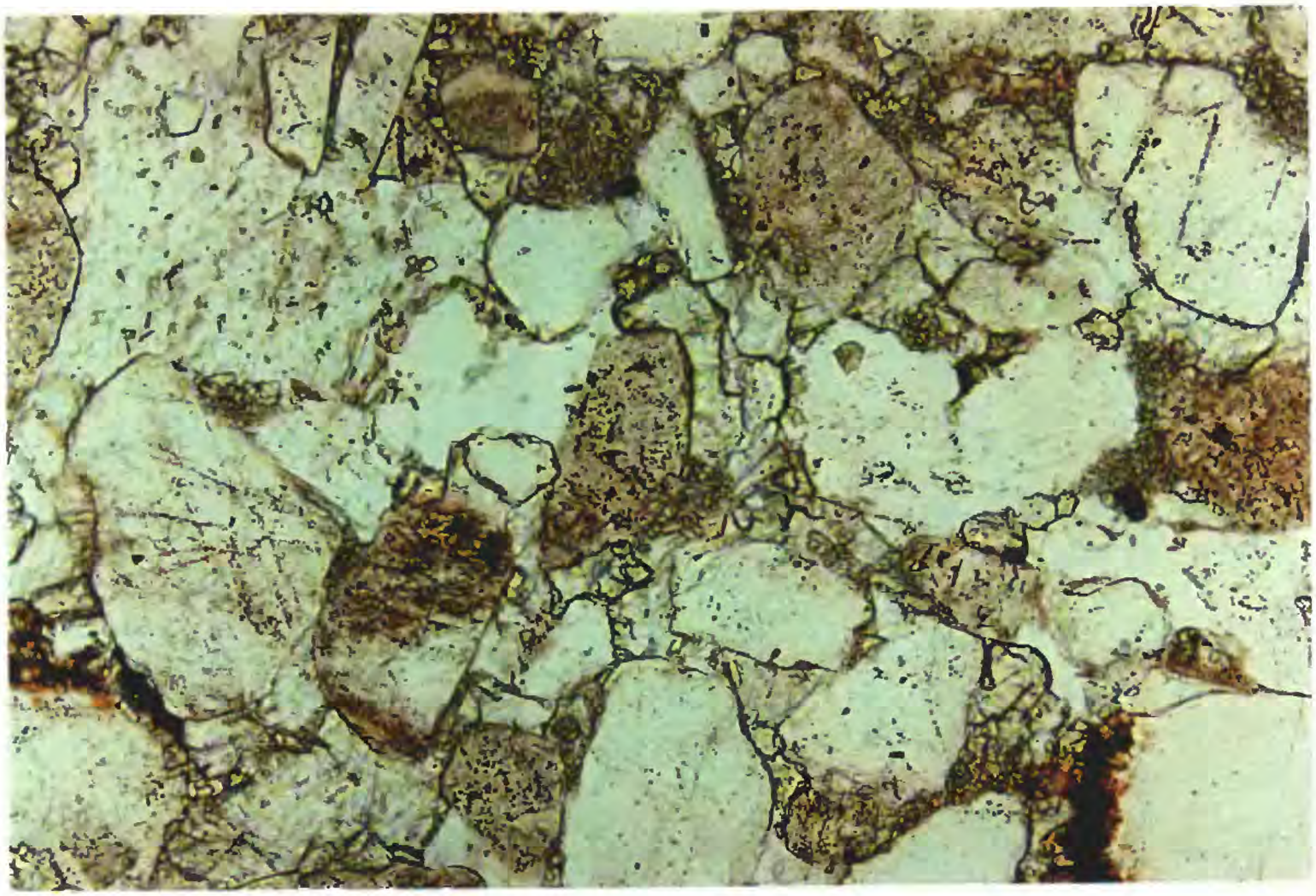
B.



Scale 0_____0.1 mm

Figure 6. Photomicrographs of thin sections of sandstone in the 98th Street core. A) fine-grained sandstone with microsparry calcite cement, 212-ft depth, plane light, (B) polarized light.

C.



D.

Scale 0 ——— 0.1 mm

Figure 6, continued. Photomicrographs of thin sections of sandstone in the 98th Street core. (C) medium-grained sandstone with sparry cement, 1005-ft depth, plane light, (D) polarized light.

LITHOSTRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS

Based on field examination of the core and analysis of geophysical logs, the sediments in the 98th Street core hole are divided into three lithostratigraphic units that are defined primarily by their grain size, color, and composition, which reflects our present understanding of the age of the upper and middle parts of the Santa Fe Group and post-Santa Fe deposits (fig. 7). Correlated lithologic units and lithofacies are shown for each unit in figure 2. The description of inferred depositional environments for each lithostratigraphic unit, including two subunits within the middle Santa Fe deposits, is based on lithic characteristics and vertical sequences of lithofacies. Stacked sequences of texturally similar lithofacies commonly are combined within the larger stratigraphic units, and thus impart characteristic lithologic properties at lithostratigraphic scale, such as the units in figure 7. In some areas, these texturally similar sequences are known also as *transition zones* or *marker zones*; the distinctively fine-grained Atrisco member is such a zone. Results of this stratigraphic analysis confirm the previous interpretations of well logs in the area (Hawley and Haase, 1992; Hawley, 1996) that included a sandy and gravelly upper unit overlying a sand-silt-clay unit 200-300 ft (60.1-91.4 m) thick, which in turn overlies sandy units. The core samples revealed the poor sorting of sand strata in the upper part of the middle Santa Fe unit, the scale of laminations in the silt-clay zones, the plasticity and inferred grain size of brown silty clay and red clay beds, the absence of volcanic ash, and the moderately sorted and noncemented nature of the sediments below 800 ft (243.8 m) depth.

Three informal lithostratigraphic units, and four closely related hydrostratigraphic units summarize the present stratigraphic framework for the 98th Street site (figs. 7, 9). The top unit, from the land surface to 19-ft (5.5 m) depth, consists of post-Santa Fe Group surficial sand and gravel, which contains moderately sorted fine sand in the upper part, and fine to medium sand with scattered coarse sand beds, pebbles and cobbles, and gravel beds in the lower part. These late Quaternary deposits include eolian sand, mixed eolian and alluvial sand, and valley-border alluvium which unconformably overlie the Santa Fe Group in the local tributary valley. These surficial sediments constitute the valley-border alluvium hydrostratigraphic unit (unit VA, fig. 9). Interbedded sand and gravel of this unit is exposed in shallow arroyo channels south of the drill site.

The underlying coarse-grained deposits, 19-97 ft (5.5-29.6 m) depth, are correlated with the upper unit of the Santa Fe Group (Hawley, 1996), equivalent to the Ceja Member of the Santa Fe Formation of Kelley (1977) that underlies the Llano de Alburquerque geomorphic surface. Regionally, the upper Santa Fe is correlated with the Sierra Ladrones Formation of Machette (1978) in the southern part of the Albuquerque basin (Hawley, 1996; Allen and others, 1998). The upper Santa Fe is composed of interbedded yellowish brown sand beds, fine to coarse and moderately well sorted, and beds of framework gravel. The proportion of gravel beds increases and the size of gravel clasts coarsens downward through the unit to cobble gravel in the interval 60-80 ft (18.6-24.4 m). This unit is the coarsest in the entire stratigraphic section and is a channel sand-and-gravel deposit that disconformably overlies the middle Santa Fe unit. The upper Santa Fe unit contains basin-floor fluvial sand and pebbly sand, and braid plain sand and pebble-cobble gravel lithofacies. Gravel clasts include abundant chert, pink granite, and quartzite, and trace amounts of petrified wood that indicate a northwest source terrane. This unit is the upper Santa Fe hydrostratigraphic unit (USF, fig. 9).

Sediments that underlie the disconformable upper Santa Fe gravelly beds below 97 ft (29.6 m) depth contain red and reddish brown clay beds, characteristic of the Middle Red Member of the Santa Fe Group of Kelley (1977) and derived from western or northwestern fluvial-lacustrine source areas of the ancestral Rio Puerco and Jemez River. The sequence of interbedded sand, silty sand, silty clay, and clay in the drill hole from 97 ft to 1500 ft (29.6-457.2 m) is correlated tentatively with the middle unit of the Santa Fe Group.

Hawley (1995) and Connell and others (1998) interpret the sandy interval between 97 ft and 441 ft (29.6-134.4 m) to be transitional between the overlying coarse-grained gravelly beds and underlying clayey strata. They correlate this sandy interval with the lower part of the Sierra Ladrones Formation, and include it in the basal zone of the upper Santa Fe.

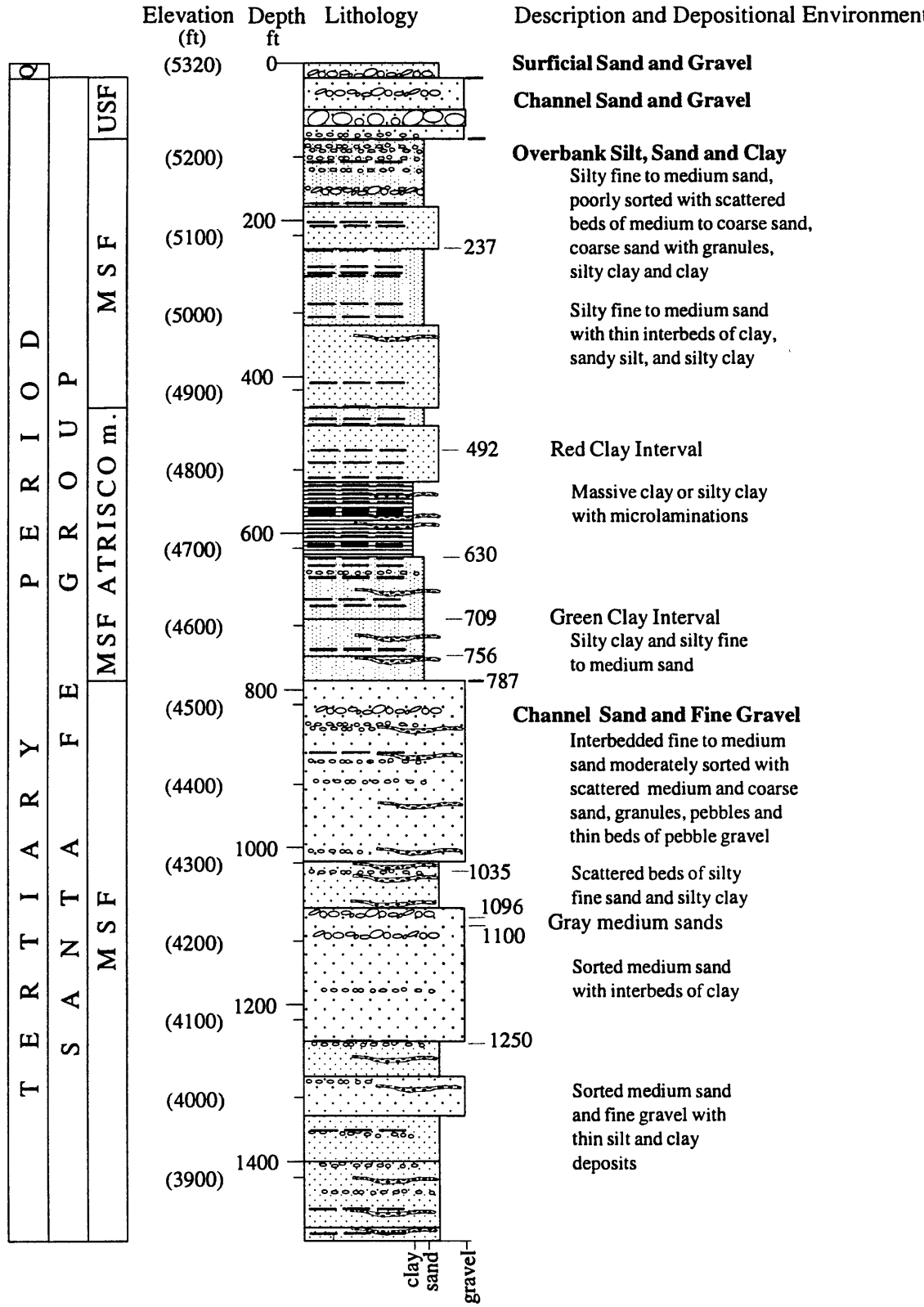


Figure 7. Preliminary lithostratigraphy and depositional environments of sediments in the 98th Street core. Age symbol Q represents Quaternary Period; symbol USF represents upper unit of the Santa Fe Group; symbol MSF represents middle unit of the Santa Fe Group; MSF Atrisco m. is the Atrisco member of the middle unit of the Santa Fe Group.

The upper part of the sandy zone, in the interval 97-237 ft (29.6-72.2 m), consists of interbedded pale brown, brown, and light brown silty, fine-to- medium sand, poorly sorted, with scattered beds of medium to coarse sand, coarse sand with granules, silty clay and clay. Massive reddish brown clay beds, 0.5-1.0 ft (15-30.5 cm) thick, were sampled at 124.4 ft (37.9 m), 178 ft (54.2 m), and 208 ft (63.4 m). The lower part of the sandy zone, at 237-441 ft (72.2-134.4 m) depth, is somewhat finer grained than the upper part, and consists of interbedded thin beds of clayey and sandy silt, silty fine sand, brown silty clay, red to reddish brown clay, and scattered beds of medium sand. Depositional environments for the zone are inferred to include fluvial interchannel overbank areas, small secondary stream channels, and ponded areas.

The 441-787 ft (134.4-239.9 m) interval is correlated with the Atrisco member (informal) of Connell and others (1998). It consists of thin-bedded fine sand, poorly sorted silty sand, and laminated silt, fine sand, and clay. Core samples and geophysical logs demonstrate that this interval is distinctly finer-grained than overlying and underlying beds, and contains numerous and relatively thick sequences of red to reddish brown clay, and silt in sets of laminated beds commonly <2 ft (0.61 m) thick, and as much as 4.45 ft (1.36 m) thick. These laminated sets locally preserve delicate microlaminations of clay and silt, but most beds contain massive clay or silty clay. A distinctive zone between 709 ft and 756 ft (216.1-230.4 m) appears olive green, consisting of light olive brown to dark grayish brown silty clay, and silty fine to medium sand.

The entire upper part of the middle Santa Fe unit (97-787 ft [29.6-239.9 m]) is inferred to contain a series of laterally extensive fluvial overbank deposits that are contained locally in 3.3-33 ft- (1-10 m) thick upward-fining units. The overbank deposits accumulated in shallow abandoned channels or backswamp ponds, the extent of which may have been related to syndepositional fault scarps that controlled the location of the main river channel, tributary stream channels, and overbank flats (Stone and Allen, 1998). An alternative playa-lake origin for these fine-grained beds seems inconsistent with lack of evidence, such as evaporite minerals, desiccated mud-flat polygons, eolian concentration of dried clay pellets, deltaic foreset strata, ripple-drift cross laminations, and wave segregated and sorted sediment in wavy bedforms (J. Smoot, USGS, personal comm. 1998). The upper part of the middle Santa Fe unit (97-787 ft [29.6-239.9 m]) constitutes the middle Santa Fe hydrostratigraphic unit MSF-2/3 (fig.9).

The lower section of the middle Santa Fe unit, 787-1500 ft (239.9-457.2 m) depth, contains an upper sequence of moderately sorted medium sand, and a lower sequence of sand and interbedded silt and clay beds. The upper sequence, which extends from 787 ft to 1,246 ft (239.9-381 m) depth, consists chiefly of brown to dark brown, interbedded fine to medium sand, moderately sorted and without silt matrix, with scattered medium and coarse sand beds, granules and pebbles, and thin beds of pebble gravel. Scattered beds of silty fine sand and silty clay were sampled in the interval 1,035-1,096 ft (315.4-334 m). At the depth of 1,096 ft (334 m), the color changes notably to lower chroma values, typically grayish brown, and grain size increases slightly with the inclusion of more medium sand beds. Sorted medium sands also are common below the depth of 1,096 ft, where these coarse beds are interbedded with scattered clay beds. Depositional environments for the 787 ft to 1,246 ft (239.9-381 m) interval include fluvial secondary stream channels and overbank areas. Gravel clasts include distinctive chert, pink granite, and other materials derived from northeastern and northern fluvial source areas. The lower part of the middle Santa Fe, below 1,246 ft (381 m) depth, contains sorted medium sand and fine gravel, and also numerous, thin silt and clay deposits, probably reflecting sedimentation in overbank areas. The entire lower part of the middle Santa Fe unit from 787 ft to 1,500 ft (239.9-457.2 m) forms the middle Santa Fe Hydrostratigraphic unit MSF-4 (fig.9).

The precise age of the deposits in the 98th Street core hole cannot be established with current data. At the top, the surficial valley-border alluvial and eolian deposits postdate erosion into the early Quaternary Llano de Alburquerque geomorphic surface. The alluvial deposits may be as old as the Tercero Alto terrace deposits east of the drill site (Bryan, 1938), possibly middle Pleistocene. The eolian deposits may range in age from middle Pleistocene to late Holocene. The age of the Llano de Alburquerque geomorphic surface is constrained by calibrated, minimal-age estimates of its Stage IV carbonate soil of >500

KA to perhaps ≥1 MA (Machette and others, 1997), which are therefore minimal constraining ages of the upper Santa Fe unit in which the soil developed. No datable tephra or macrofossils were found in our field examination of the core so that the age of any part of the section remains undefined.

The fluvial gravelly beds of the upper Santa Fe unit regionally are correlated with an integrated, through-flowing river system that was established in the Rio Grande rift basins in Early Pliocene time, ≥4.5 MA (Lozinsky and others, 1991, Chapin and Cather, 1994). The age range of the upper Santa Fe is thus limited to ≥4.5-≥1 MA, but its disconformable basal contact and cut-and-fill depositional processes suggest that its basal sediments could be <4.5 MA. The true age of the Llano de Alburquerque geomorphic surface may be considerably older than 1 MA, and the upper unit of the Santa Fe may be wholly Pliocene.

The age of the middle Santa Fe unit is estimated from regional correlation and preliminary magnetic-polarity data. At Loma Colorado, 13.7 mi (22 km) north-northeast of the 98th Street site, a sequence of sandy light brown and reddish brown beds that directly underlie gravel deposits of the upper Santa Fe unit (S.F. Personius, USGS, pers. communication, 1997) reportedly contain Late Miocene (Hemphellian) fauna (S.G. Lucas, pers. communication, 1997; 4.6-8.9 MA, Woodburne and Swisher, 1995). Preliminary paleomagnetic polarity data from the 98th Street core (Hudson and others, 1998) indicate that the middle Santa Fe unit below 97 ft (29.5 m) dominantly preserves sequences with normal magnetic polarity. These and few, short reversal sequences in the core may correlate with closely spaced normal and reversed magnetic chrons 5.9-8.3 MA in age (chrons C3An.1n-C4r.1n; Berggren and others, 1995) or with other, older, normal chrons. No thick paleosols or major unconformities were recovered in the core. It is likely that the cored interval may span less than a few million years.

COMPARISON AND CORRELATION OF THE 98th STREET WELL WITH NEARBY WELLS

The core samples collected from the 98th Street core hole and the extensive set of geophysical logs provide unprecedented opportunities to extrapolate stratigraphic correlations to other wells in the central part of the Albuquerque basin. The 98th Street core hole is the only well in the basin that provides this type of integrated lithologic, sedimentologic, and geophysical information and it provides the critical reference collection. Other water supply wells, monitoring wells, and exploratory holes in the basin are characterized only by drillers' lithologic logs, limited suites of geophysical logs, and some cuttings collections. The unique information obtained at the 98th Street site provides the basis to make comparisons and revisions to the less complete records for adjoining wells. The correlations described below give reliable evidence of critical sedimentologic and structural relationships among the drilled sections that could only be speculated prior to completion of the 98th Street core hole.

The locations of other deep wells and well fields in the area surrounding the 98th Street core hole are shown in figure 1. Figure 8 shows comparative electrical conductivity logs for the 98th Street core hole and six other nearby wells. Other logs and lithologic characteristics could also be displayed to illustrate the stratigraphic correlations, but the electrical logs are the only available, consistent, and most reliable data set for these wells.

The distinctive lithologic zone in the 98th Street hole between 441-787 ft (134.4-239.9 m), the Atrisco member of (Connell and others (1998), characterized by persistent red-brown clay is clearly identifiable in the electrical logs for the 98th Street well (fig. 8). The high clay content in this part of the section imparts an overall increase in electrical conductivity (indicated by the elevated baseline of the log trace), and the thicker beds are closely correlated with high-conductivity spikes in the log signature. The bottom of the clay-rich zone is more sharply delimited than the top; the onset of clay deposition appears to have been rather abrupt, whereas interbedding with silt and sand is more gradual in the upper part of the zone. These same electrical characteristics are present in the conductivity logs for the surrounding wells, and provide the basis for our correlation of the Atrisco member throughout the subsurface of the Albuquerque metropolitan area (fig. 8; Allen and others, 1998; Connell and others,1998). This fine-grained unit is here recognized as a zone that separates the primary upper Santa Fe aquifer system utilized in

water production in the Albuquerque, Paradise Hills, and Rio Rancho areas from older (middle) Santa Fe deposits. The only City of Albuquerque well that is screened almost completely in the lower coarse-grained interval (below 787 ft [239.9 m] in the 98th Street core hole) is Don Well No. 1 (fig.1).

Figure 8 shows correlations of the interpreted base of the Atrisco member among the wells in the west-central Albuquerque basin. Faults mapped in the surface geology or interpreted from the high-resolution aeromagnetic survey data (fig. 1; Grauch and others, 1998) account for several of the sharp offsets in the elevation of this Atrisco member. For example, nearly 450 ft of displacement is indicated between the base of the Atrisco in the Don No. 1 well and the Don No. 2 well across the down-to-the-east fault that borders the fault block containing the 98th Street site. Similarly, about 500 ft of displacement is indicated between the 98th Street well and the College No. 1 well across the eastern, down-to-the-east, bounding intrabasin fault (fig. 8).

ESTIMATED HYDROGEOLOGIC CHARACTERISTICS

Four hydrostratigraphic units that are based on the lithologic characteristics of the sediments and their correlation with lithofacies in the Middle Rio Grande basin summarize the hydrogeologic framework for the 98th Street site (fig. 9). The lithofacies have characteristic lithologic properties, geophysical signatures (fig. 3), and parameters that influence ground-water production (Haase and Lozinsky, 1992). Lithofacies are combined in hydrostratigraphic units that contrast in hydraulic conductivity and are extensive and mappable in the subsurface.

Three sets of estimated average horizontal hydraulic conductivities (K) for lithologic units in the 98th Street core hole are shown in figure 9. The estimates in column A are based on the general hydrogeologic characteristics associated with the lithofacies of Hawley and Haase (1992). The estimates in column B are the assigned mean K values used in the ground-water flow model layers of Kernodle and others (1995), which were based on the previous interpretations of the regional subsurface geology. The estimates of hydraulic conductivity in column C are based on the empirical relationships of permeability and grain size of noncemented samples of the Santa Fe Group (Detmer, 1995, fig. 3), in which hydraulic conductivity is estimated from values of D_{10} of the grain size distribution for each sample. In figure 9, an empirical K value and inferred range of values are estimated from the median and range of D_{10} values of the modal grain size in each lithologic unit in the 98th Street core. The ranges of values, in parentheses, are estimated from the variability of data points in the original analysis (Detmer, 1995, fig. 3). In column D, the estimated K values for hydrostratigraphic units are based on K values of the included lithologic units normalized to lithologic-unit thicknesses.

The estimated empirical values for K emphasize a previously unknown contrast in estimated hydraulic conductivity in the lowest two hydrostratigraphic units. Unit MSF-2/3 is correlated with the upper part of the middle Santa Fe Group (the Atrisco member and overlying sandy zone), and is composed chiefly of thin-bedded fine sand, poorly sorted silty sand, and laminated silt, fine sand and clay. The unit contains more than 30 beds of red clay, and thick sequences of clayey silt. This unit, which includes the silt-clay sequence in lithologic unit 12, 96 ft (29.2 m) thick, is inferred to be a laterally extensive (fig. 8) barrier to vertical ground-water flow in the area. The underlying unit MSF-4 comprises fluvial channel-fill sediments of the ancestral Rio Grande river system, including the thick sequences of moderately well-sorted medium sand in lithologic units 4, 6, and 8. Bedding connectivity within these units is inferred to be high, but the lateral continuity of individual lithofacies or the entire hydrostratigraphic unit is not known (fig. 8). Furthermore, estimated K values from combinable magnetic resonance data generally support the trends of empirical K values and the vertical extent of units with intermediate values of 17 ft/day (fig. 9). However, these data indicate that the estimates of 170 ft/day in lithologic units 4, 6, and 8 may be too high by a factor of 4-5, possibly due to poor sorting, cementation, or compaction of the sediments at depths below 800 ft (243.8 m). Further sedimentologic and hydraulic analyses of the core samples are needed to assess these differences as well as the accuracy of the geophysical methods.

Laboratory determination of hydraulic conductivity values of selected recompacted sandy samples

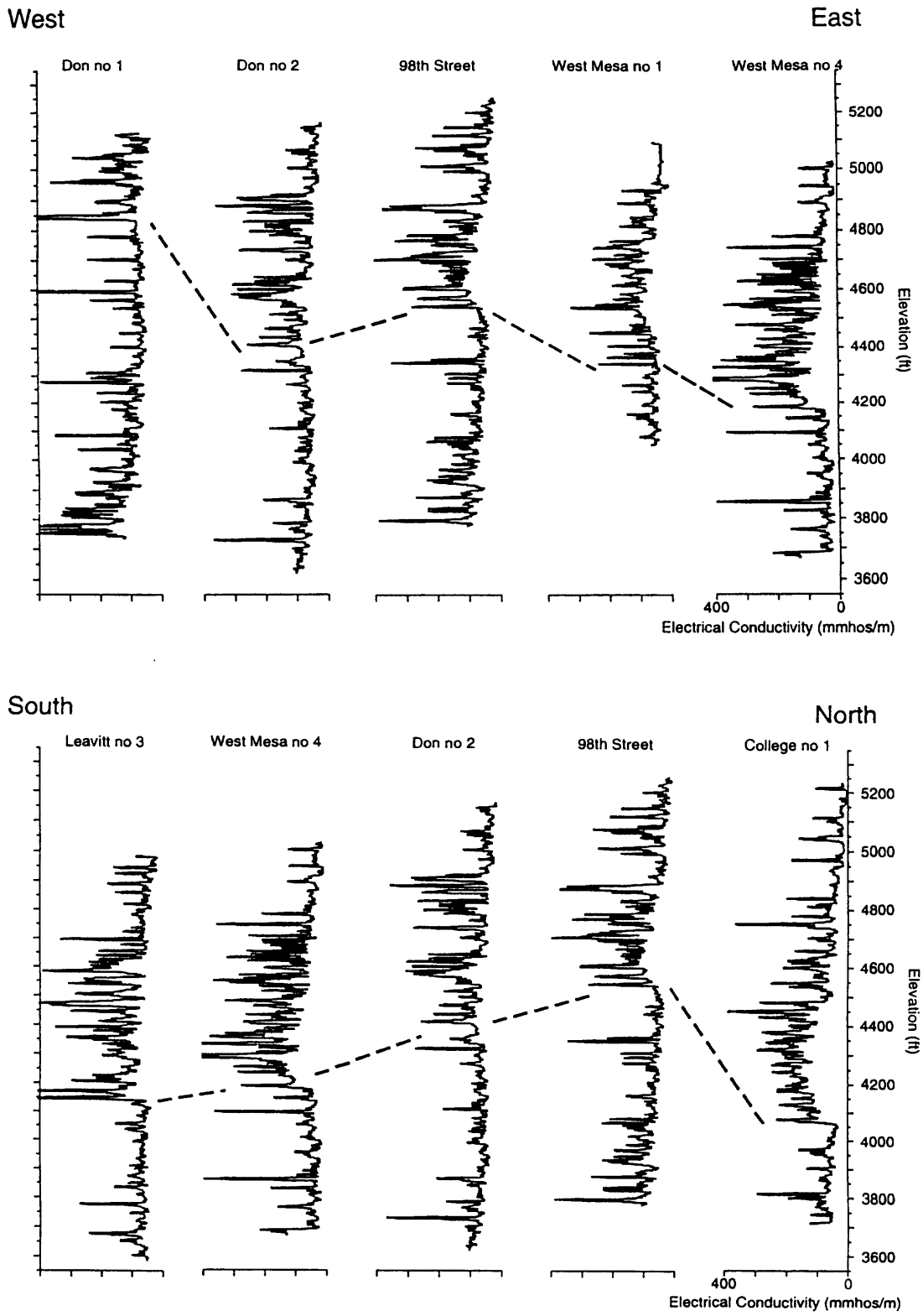


Figure 8. Correlations of the middle Santa Fe transition zone (Atrisco member) among wells in the College, West Mesa, and Don well fields (see fig. 1 for well locations).

and core samples from the upper part of the cored interval are shown in table 5. Estimates of K based on the empirical relationship of K and D_{10} of the particle-size distribution (Detmer, 1995) are included in the table for comparison. For clayey, fine-grained samples, K was determined from consolidation tests on core samples, and K values are thus values for vertical conductivity, K_V. Results are shown for low and high consolidation (effective stress) loads (10-1000 kPa [1.45-145 psi]). Plots of logarithmic K_V and logarithmic vertical effective stress generally show strong linear relationships over the range of load values (Haneberg and others, 1998). These relationships show decrease in K_V with decrease in void ratio (porosity) by two to four orders of magnitude (ft/day) (table 5). For sandy, coarse-grained samples, K was determined from permeameter tests that used disaggregated, recom-pacted samples. Results of these tests show well developed linear relationships between logarithmic confining pressure and logarithmic K. However, the hydraulic conductivity values of the predominantly sandy samples were less sensitive to changes in stress than were the clayey samples tested in the consolidometer (table 5).

All laboratory data show no apparent relationship between K and geotechnical properties, except density (porosity). The test results show that hydraulic conductivity values of all sediments of the upper Santa Fe unit are sensitive to the magnitude of effective stress corresponding to 3.3 ft to 330 ft (1-100 m) of depth. The fine-grained sediments appear to be more sensitive to changes in stress, varying by as much as four orders of magnitude. Comparison of laboratory tests of sandy, coarse-grained samples at high confining pressures with the empirical K values based on the D_{10} grain size shows that laboratory values of K are lower than minimum empirical values by 1-3 orders of magnitude. This discrepancy most likely derives in part from the different methods and time periods in which K was measured. It also may be attributed to differences in porosity (sorting and matrix, consolidation fabric, cementation) among tests conducted on *in situ* beds at the surface (Detmer) and poorly sorted channel samples from the vadose and saturated zones in the core. Comparison of minimum laboratory and empirical K values from four core samples with calculated K values derived from the CMR geophysical log (fig.4) shows further discrepencies (table 6). For fine-grained samples, the CMR K values are more than 0-2 orders of magnitude greater than the limiting D_{10} estimate for average horizontal conductivity. The CMR values are 3-6 orders of magnitude greater than the laboratory K_v values, which in turn are 2-4 orders of magnitude less than the empirical K values. These relationships indicate possible ratios of k_v/k_h of $\geq 9 \times 10^4$ (unit 16) to $\geq 1.4 \times 10^4$ to 5.8×10^7 (unit 13). For unit 13, it appears that the relatively high calculated CMR K values may be based on high porosity values that do not reflect poor sorting, consolidation, or cementation. Additional analysis of fine-grained sediments could extend the estimated range of values of Detmer (1995) and could provide another constraint on K values calculated from geophysical data.

At the 98th Street site (row 122, column 35 of the ground-water flow model of Kernodle and others, 1995), previous estimates of average hydraulic conductivity for model layers 1-8 was 15 ft/day, and 4 ft/day in model layers 9 and 10, reflecting the inferred downward fining and progressive consolidation or cementation of the middle Santa Fe deposits. The preliminary results of our analysis of the 98th Street core indicate that a downward-fining and resultant downward lowering of K is applicable in units 9-17 in the 409 ft (124.6 m) of this aquifer that is located below the water table (at 378 ft [115.2 m] depth). From depths of 787 to 1,483 ft (239.9-452 m), however, empirical K values range from 17 ft/day to 170 ft/day (5-38 ft/day, CMR data) in a sequence of lithologic units that are chiefly noncemented medium sand. Stratigraphic correlations (fig. 8; Haase, 1992, p. V-13) indicate that similar trends in lithostratigraphy and hydrogeologic characteristics of this zone have wide lateral extent over a significant area of western Albuquerque, and may represent a potential ground-water production zone whose characteristics should be further investigated. For example, as noted by Haase (1992, p. V-15) , deeper wells in the College and nearby well fields have potential for substantially increased production from correlatives of the lower coarse-grained unit. However, with discrepancies in estimated or measured K values of as much as three orders of magnitude (ft/day, tables 5, 6), additional field tests of horizontal hydraulic conductivity from isolated lithofacies, and further tests of core samples and geophysical techniques are needed to supply this basic hydraulic parameter to future studies of the Santa Fe Group aquifer.

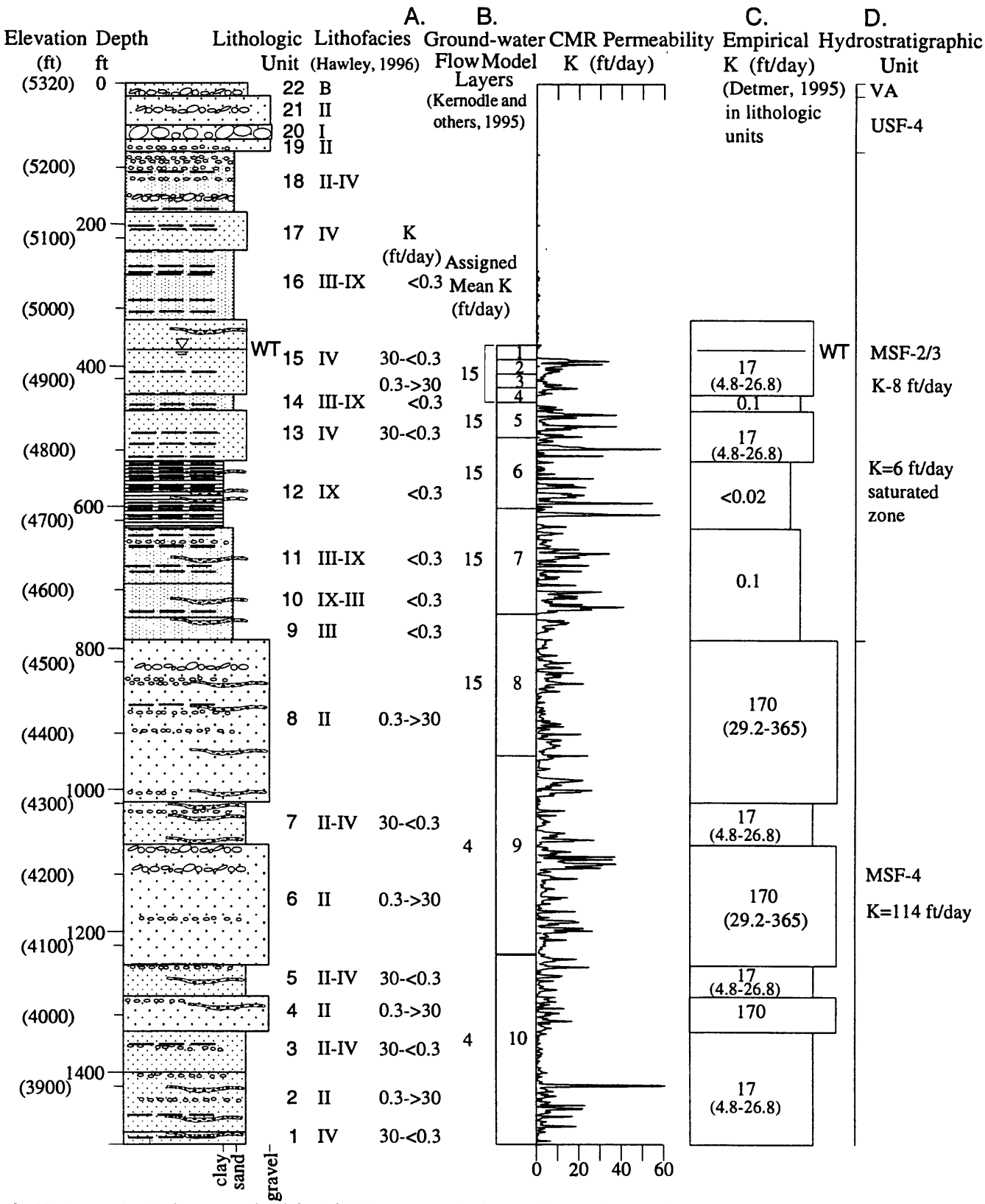


Figure 9. Hydrogeologic framework of the 98th Street core hole. Estimated hydraulic conductivity values (K) for lithologic units are based on: A) the general hydrogeologic characteristics associated with the lithofacies of Hawley and Haase (1992); B) the assigned mean K in the ground-water flow model of Kernodle and others (1995); C) the empirical relationship of permeability and grain size (d_{10}) of Detmer (1995). Estimated K values for hydrostratigraphic units (D) are based on K values for lithologic units normalized to proportional lithologic-unit thicknesses.

Table 5. Measured and computed hydraulic conductivity values for samples from the 98th Street core.

Coarse-grained samples	Grain size[1]	K, 10 kPa confining pressure, ft/day	K, 1000 kPa confining pressure, ft/day	K range based on D_{10}, ft/day
Unit 18 (Drive 14B, 98')	Fine sand	6.49×10^{-1}	3.41×10^{-2}	1.3×10^{1}-1.5×10^{2}
Unit 18 (Drive17D, 117')	Medium sand	3.74	6.8×10^{-1}	$7.4 - 1.3 \times 10^{2}$
Unit 18 (124')	Coarse sand		4.24×10^{-1}	$5.5 - 9.0 \times 10^{1}$
Unit 18 (Drive 23A, 147')	Medium sand	2.71	4.70×10^{-1}	$5.5 - 8.2 \times 10^{1}$
Unit 18 (Drive 25B, 162')	Coarse sand	1.49×10^{-1}	9.39×10^{-2}	$8.2 \times 10^{-1} - 1.1 \times 10^{1}$
Unit 18 (Drive 27'B, 173')	Silty fine sand	2.71	4.70×10^{-1}	$7.4 - 1.3 \times 10^{2}$
Unit (Drive 31B, ')	Silty fine sand	7.81×10^{-1}	3.74×10^{-1}	$5.5 - 8.2 \times 10^{1}$
Unit 17 (Drive 33A, 204')	Coarse sand	7.12×10^{-1}	5.40×10^{-2}	$5.5 - 8.2 \times 10^{1}$
Unit 16 (Drive 38A, 244')	Silty fine sand	1.01×10	1.21×10^{-2}	$1.6 - 3.6 \times 10^{1}$
Unit 16 (Drive 55B, 335')	Medium sand	7.81×10^{-1}	2.83×10^{-1}	$7.4 - 1.3 \times 10^{2}$
Fine-grained samples	**Grain size[2]**	**K_v, 10 kPa confining pressure**	**K_v, 1000 kPa confining pressure**	**K range based on D_{10}, ft/day**
Unit 18 (Drive 20, 126')	Clay	2.77×10^{-3}	1.42×10^{-6}	$<2 \times 10^{-2}$
Unit 18 (Drive 24A, 150')	Clayey, silty sand	2.71×10^{-1}	1.36×10^{-4}	1×10^{-1}
Unit 17 (Drive 37A, 228')	Silty clay	1.30×10^{-3}	2.25×10^{-6}	$<2 \times 10^{-2}$
Unit 16 (Drive 40C, 256')	Coarse sand	2.75×10^{-2}	3.37×10^{-5}	
Unit 16 (Drive 40A, 251')	Silty clay	1.33×10^{-1}	1.33×10^{-4}	$<2 \times 10^{-2}$
Unit 16 (Drive 4[4], 256')	Silty clay	4.10×10^{-2}	6.49×10^{-6}	$<2 \times 10^{-2}$
Unit 16 (Drive 5[4], 314')	Silty clay	4.93×10^{-2}	2.25×10^{-5}	$<2 \times 10^{-2}$
Unit 13 (Drive 90C, 507')	Silty clay	1.87×10^{-3}	2.83×10^{-6}	$<2 \times 10^{-2}$
Unit 13 (Drive 93B, 522')	Silty clay	9.17×10^{-2}	3.49×10^{-4}	$<2 \times 10^{-2}$

[1]Grain size from Haneberg and others (1998b); [2] Grain size from Appendix A. [3]Value from regression analysis of Haneberg and others (1998a)

Table 6. Laboratory, empirical, and geophysical hydraulic conductivity values for four samples from the 98th Street core .

Sample	Grain size	Laboratory K, 1000 kPa confining pressure, ft/day	K, range based on D_{10}, ft/day	K, CMR geophysical log[1], ft/day-
Unit 16 (335')	Medium sand	K 2.83×10^{-1}	$7.4 - 1.3 \times 10^{2}$	3.67×10^{-2}
Unit 16 (314.3')	Silty clay	K_v 2.25×10^{-5}	$<2 \times 10^{-2}$	2.40×10^{-2}
Unit 13 (507.2')	Silty clay	K_v 2.83×10^{-6}	$<2 \times 10^{-2}$	4.89
Unit 13 (522.3')	Silty clay	K_v 3.49×10^{-4}	$<2 \times 10^{-2}$	3.68

[1] Nominal values of nearest half-foot vertical intervals

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APPENDIX A

DESCRIPTIVE LITHOLOGIC LOG OF THE
98TH STREET CORE

Thin units (<0.05 ft) are described where top and bottom of unit are shown as the same depth.

Depths (ft)		Description
Top	Bottom	
0.0	19.0	Pale brown to yellowish brown (10YR6/3-5/4) and strong brown (7.5 YR5/6) fine sand, some medium sand, with scattered coarse sand and granular to pebbly sand intervals, loose, weak reaction to HCl
19.0	25.5	Light yellowish brown to dark yellowish brown (10YR6-4/4) medium sand, moderately sorted, loose, no reaction to HCl
25.5	27.0	Light yellowish brown to dark yellowish brown (10YR6-4/4) medium sand, moderately sorted, loose, no reaction to HCl
33.0	37.1	Light yellowish brown to dark yellowish brown (10YR6-4/4) gravelly coarse sand, poorly sorted, loose
37.1	37.8	Framework gravel with light yellowish brown to dark yellowish brown (10YR6-4/4) fine-to-medium, moderately sorted, loose sand matrix, gravel clasts are pebbles and small cobbles, moderately rounded, elongate to subequant, composed of granite, quartzite, basalt, sandstone
37.8	39.1	Light yellowish brown (10YR6/4) gravelly coarse sand, poorly sorted, loose, containing granules and scattered, elongate, moderately rounded pebbles
40.4	41.6	Light yellowish brown to dark yellowish brown (10YR6-4/4) gravelly coarse sand, poorly sorted, loose, containing granules and scattered, elongate, moderately rounded pebbles
43.2	43.7	Framework gravel with light yellowish brown to dark yellowish brown (10YR6-4/4) fine-to-medium, moderately sorted, loose sand matrix
43.7	45.9	Light yellowish brown (10YR6/4) coarse sand, poorly sorted, loose, no reaction to HCl
45.9	46.3	Framework gravel with light yellowish brown to dark yellowish brown (10YR6-4/4) fine-to-medium, moderately sorted, loose sand matrix
46.3	47.4	Light yellowish brown (10YR6/4) coarse sand, poorly sorted, loose, no reaction to HCl
47.4	47.9	Yellowish brown to brown (10-7.5YR5/4) medium to coarse sand, moderately sorted, loose, massive
47.9	49.0	Light yellowish brown to dark yellowish brown (10YR6-4/4) gravelly coarse sand, poorly sorted, loose
49.0	50.3	Yellowish brown to brown (10-7.5YR5/4) medium to coarse sand, moderately sorted, loose, massive
50.3	50.7	Light yellowish brown to dark yellowish brown (10YR6-4/4) gravelly coarse sand, poorly sorted, loose
50.7	51.7	Light yellowish brown (10YR6/4) coarse sand, poorly sorted, loose, no reaction to HCl
57.4	59.6	Framework gravel with light yellowish brown to dark yellowish brown (10YR6-4/4) fine-to-medium, moderately sorted, loose sand matrix, gravel clasts are pebbles and small cobbles, moderately rounded, elongate to subequant, composed of granite, quartzite, basalt, sandstone
59.6	80.3	Framework gravel with light yellowish brown to dark yellowish brown (10YR6-4/4) fine-to-medium, moderately sorted, loose sand matrix, gravel clasts are pebbles and small cobbles, moderately rounded, elongate to subequant, composed of granite, quartzite, basalt, sandstone
80.3	81.5	Yellowish brown to brown (10-7.5YR5/4) medium sand, moderately sorted, loose, massive
86.5	87.6	Light yellowish brown (10YR6/4) coarse sand, poorly sorted, loose, no reaction to HCl
87.6	88.9	Yellowish brown to brown (10-7.5YR5/4) medium to coarse sand, moderately sorted, loose, massive
88.9	90.8	Light yellowish brown to dark yellowish brown (10YR6-4/4) gravelly coarse sand, poorly sorted, loose
91.5	92.5	Light yellowish brown (10YR6/4) coarse sand, poorly sorted, loose, no reaction to HCl
92.5	95.2	Yellowish brown to brown (10-7.5YR5/4) medium sand, moderately sorted, loose, massive
95.2	96.6	Yellowish brown to brown (10-7.5YR5/4) medium sand, moderately sorted, loose, massive
96.6	96.8	Red (2.5YR4/6) silty clay, indistinctly laminated, low dry strength, nonplastic
96.8	97.7	Yellowish brown to brown (10-7.5YR5/4) medium sand, moderately sorted, loose, massive
97.7	99.0	Yellowish brown to brown (10-7.5YR5/4) fine sand, moderately sorted, loose
99.0	99.1	Reddish brown (5YR5/4) silt and silty clay, indistinctly laminated, low dry strength, nonplastic
99.1	99.2	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
99.2	99.3	Reddish brown (5YR5/4) silty clay, indistinctly laminated, low dry strength, nonplastic
99.3	99.4	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
99.4	99.4	Reddish brown (5YR5/4) silt and silty clay, indistinctly laminated, low dry strength, nonplastic
99.4	99.8	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
99.8	99.9	Reddish brown (5YR5/4) silt and silty clay, indistinctly laminated, low dry strength, nonplastic
99.9	100.6	Brown (7.5YR5/4) silty fine sand, poorly sorted
100.6	100.7	Reddish brown (5YR5/4) silt and silty clay, indistinctly laminated, low dry strength, nonplastic
100.7	101.6	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
101.6	101.7	Reddish brown (5YR5/4) silt and silty clay, indistinctly laminated, low dry strength, nonplastic
101.7	102.2	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
102.2	102.3	Reddish brown (5YR5/4) silt and silty clay, indistinctly laminated, low dry strength, nonplastic

102.3	102.8	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
102.8	102.8	Reddish brown (5YR5/4) silt and silty clay, indistinctly laminated, low dry strength, nonplastic
102.8	102.9	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
102.9	103.0	Reddish brown (5YR5/4) silt and silty clay, indistinctly laminated, low dry strength, nonplastic
103.0	103.4	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
103.4	103.6	Reddish brown (5YR5/4) silt and silty clay, indistinctly laminated, low dry strength, nonplastic
103.6	104.1	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
104.1	104.1	Reddish brown (5YR5/4) silt and silty clay, indistinctly laminated, low dry strength, nonplastic
104.1	104.2	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
104.2	104.4	Reddish brown (5YR5/4) silt and silty clay, indistinctly laminated, low dry strength, nonplastic
104.4	104.7	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
104.7	105.6	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
105.6	105.9	Yellowish brown to brown (10-7.5YR5/4) medium sand, moderately sorted, loose, massive
105.9	106.0	Reddish brown (5YR5/4) silty clay, indistinctly laminated, low dry strength, nonplastic
106.0	106.3	Yellowish brown to brown (10-7.5YR5/4) medium sand, moderately sorted, loose, massive
106.3	107.1	Yellowish brown to brown (10-7.5YR5/4) medium sand, moderately sorted, loose, massive
107.1	107.3	Light yellowish brown to dark yellowish brown (10YR6-4/4) gravelly coarse sand, poorly sorted, loose
107.3	107.8	Yellowish brown to brown (10-7.5YR5/4) medium sand, moderately sorted, loose, massive
107.8	108.1	Yellowish brown to brown (10-7.5YR5/4) medium sand, moderately sorted, loose, massive
108.1	108.4	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
108.4	109.8	Light yellowish brown (10YR6/4) coarse sand, poorly sorted, loose, no reaction to HCl
110.0	110.9	Light yellowish brown (10YR6/4) coarse sand, poorly sorted, loose
110.9	111.3	Yellowish brown to brown (10-7.5YR5/4) medium sand, moderately sorted, loose, massive
111.3	111.6	Reddish brown (5YR5/4) silty clay, indistinctly laminated, low dry strength, nonplastic
111.6	114.6	Light yellowish brown (10YR6/4) coarse sand, poorly sorted, loose, no reaction to HCl
114.6	114.8	Reddish brown (5YR5/4) silty clay, indistinctly laminated, low dry strength, nonplastic
114.8	118.7	Yellowish brown to brown (10-7.5YR5/4) medium sand, moderately sorted, loose, massive
120.0	120.4	Yellowish brown to brown (10-7.5YR5/4) medium sand, moderately sorted, loose, massive
120.4	120.8	Reddish brown (5YR5/4) silty clay, indistinctly laminated, low dry strength, nonplastic
120.8	122.6	Light yellowish brown (10YR6/4) coarse sand, poorly sorted, loose, no reaction to HCl
122.8	124.4	Yellowish brown to brown (10-7.5YR5/4) medium sand, moderately sorted, loose, massive
124.4	126.4	Red (2.5YR4/6)clay, indistinctly laminated, low dry strength, nonplastic
133.0	135.5	Light yellowish brown (10YR6/4) coarse sand, poorly sorted, loose, no reaction to HCl
135.5	135.9	Reddish brown (5YR5/4) silty clay, indistinctly laminated, low dry strength, nonplastic
135.9	138.5	Light yellowish brown (10YR6/4) coarse sand, poorly sorted, loose
140.5	144.7	Yellowish brown to brown (10-7.5YR5/4) medium sand, moderately sorted, loose, massive
145.9	146.0	Yellowish brown to brown (10-7.5YR5/4) medium sand, moderately sorted, loose, massive
146.0	147.0	Yellowish brown to brown (10-7.5YR5/4) medium sand, moderately sorted, loose, massive
147.0	147.3	Reddish brown (5YR5/4) silt and silty clay, indistinctly laminated, low dry strength, nonplastic
147.3	148.8	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
148.9	149.4	Reddish brown (5YR5/4) silty clay, indistinctly laminated, low dry strength, nonplastic
149.4	149.5	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
149.5	150.9	Reddish brown (5YR5/4) clayey silty fine sand, indistinctly laminated, low dry strength, nonplastic
150.9	151.2	Reddish brown (5YR5/4) clayey silty fine sand, poorly sorted, loose, massive
151.2	151.3	Reddish brown (5YR5/4) silty clay, indistinctly laminated, low dry strength, nonplastic
151.3	152.0	Reddish brown (5YR5/4) clayey silty very fine sand, indistinctly laminated, low dry strength, nonplastic
158.9	159.5	Light yellowish brown to dark yellowish brown (10YR6-4/4) gravelly coarse sand, poorly sorted, loose, massive
159.5	160.1	Light yellowish brown (10YR6/4) coarse sand, poorly sorted, loose, massive, no reaction to HCl
160.1	163.4	Light yellowish brown to dark yellowish brown (10YR6-4/4) gravelly coarse sand, poorly sorted, loose, massive
163.4	164.1	Framework pebble gravel
164.1	164.4	Brown (7.5YR5/4) silty fine sand, poorly sorted with abundant carbonate blebs
164.6	164.9	Light yellowish brown (10YR6/4) coarse sand, poorly sorted, loose, no reaction to HCl
164.9	165.0	Red (2.5YR4/6) silty clay, indistinctly laminated, low dry strength, nonplastic
165.0	166.1	Brown (7.5YR5/4) silty fine sand, poorly sorted, thinly bedded, loose
166.1	166.2	Red (2.5YR4/6) silty clay, indistinctly laminated, low dry strength, nonplastic
166.2	167.5	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
167.5	168.3	Reddish brown (5YR5/4) clayey silty fine sand, indistinctly laminated, low dry strength, nonplastic
168.3	169.1	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive

169.1	170.0	Pale brown (10YR6/3) medium to coarse sand, poorly sorted, loose, no reaction to HCl
170.6	172.7	Pale brown (10YR 6/3) coarse sand, moderately sorted, loose, massive
172.7	173.1	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, loose, massive
173.1	174.0	Brown (7.5YR 5/4) silty medium sand, faint fine grained laminae
174.0	174.9	Brown (7.5YR5/4) coarse sand, moderately sorted, loose
175.6	175.7	Reddish brown (5YR5/4) silty clay, indistinctly laminated, low dry strength, nonplastic
175.7	176.5	Brown (7.5YR5/4) coarse sand, moderately sorted, loose
176.5	176.6	Reddish brown (5YR5/4) silty fine sand, poorly sorted, loose, massive
176.6	177.9	Brown (7.5YR5/4) coarse sand, moderately sorted, loose
177.9	178.7	Brown (7.5YR5/4) coarse sand, moderately sorted, loose, with reddish brown (5YR5/4) clay ripup intraclasts
178.8	178.9	Reddish brown (5YR4/4) coarse sand, moderately sorted, loose, massive
178.9	179.0	Brown (7.5YR5/4) fine sandstone, carbonate cemented, strong reaction to HCl
179.0	179.1	Red (2.5YR4/6) silty clay, indistinctly laminated, low dry strength, nonplastic
179.1	179.3	Red (2.5YR4/6) silty clay with red clay laminations
179.3	179.5	Reddish brown (5YR5/4) clay, massive, medium dry strength, low plasticity
179.5	179.8	Brown (7.5YR5/4) clayey silty fine sand, poorly sorted
179.8	180.1	Reddish brown (5YR5/4) clay, massive, moderate dry strength, low plasticity
180.1	180.3	Reddish brown (5YR5/4) clayey silty fine sand, poorly sorted
180.3	181.1	Reddish brown (5YR4/4) silty clay and clay, indistinctly laminated, low dry strength, nonplastic
181.1	182.6	Reddish brown (5YR5/4) silty fine sand, poorly sorted, loose, massive
188.8	189.2	Brown to dark brown (7.5YR4/4) silty fine sand, poorly sorted, loose, massive; light brown (7.5YR6/4) thin basal carbonate cemented sandstone, moderately cemented
190.5	190.8	Pink (7.5YR7/4) coarse sand, laminated, weak carbonate cement, moderately cemented
190.8	192.6	Brown (7.5YR5/4) coarse sand, moderately sorted, loose, laminated
192.6	194.2	Brown (7.5YR5/4) coarse sand, moderately sorted, loose, massive
200.5	201.7	Brown to dark brown (7.5YR4/4) medium sand, massive
201.7	202.5	Strong brown (7.5YR4/6) coarse sand, moderately sorted, loose, massive, reddish brown (5YR5/4) clay ripup intraclasts
202.5	202.9	Strong brown (7.5YR4/6) coarse sand, moderately sorted, loose, massive
202.9	203.0	White (7.5YR8/0) sandstone, carbonate cemented, strongly cemented, strong reaction to HCl, thin basal mudstone
203.0	204.5	Brown (7.5YR5/4) coarse sand, moderately sorted, loose, indistinctly laminated
204.5	210.9	Reddish brown (5YR4/4) clay and silty clay, massive, medium dry strength, low plasticity, silty clay has interbeds and interlaminae of silt and fine sand
211.1	211.7	Light brown (7.5YR6/4) coarse sand, carbonate cemented, weakly cemented at 211.7 , and 212.0 depths; reddish yellow (7.5YR6/6) coarse sand, weakly cemented
212.0	212.4	Brown (7.5YR5/4) silty clay, interlaminated silty sand, indistinctly laminated, low dry strength, nonplastic
221.1	221.3	Brown (7.5YR5/4) medium sand, reddish brown (5YR5/4) clay laminae, white carbonate blebs, carbonate cement sandstone pieces, moderately cemented, strong reaction to HCl
221.3	222.0	Brown (7.5YR5/4) medium sand
222.0	223.4	Brown (7.5YR5/4) coarse sand, moderately sorted, loose, massive
223.4	224.1	Reddish brown (5YR5/4) medium sand, ranging from fine to coarse sand, interlaminated with light brown (7.5YR6/4) silty fine sand, poorly sorted
231.1	231.2	Reddish brown (5YR5/4) coarse sand, moderately sorted, weakly cemented
236.1	237.2	Brown (7.5YR5/4) silty medium sand, fining upward, pinkish carbonate zone
237.2	239.2	Reddish brown (5YR5/4) clay and silty clay, fining upward sequence with a carbonate cemented zone at top, strongly cemented, strong reaction to HCl
239.2	239.5	Yellowish red (5YR5/6) silty clay and brown (7.5YR5/4) silty sand, interlaminated, traces of coarse sand
243.0	243.1	Yellowish red (5YR5/6) silty clay, indistinctly laminated, low dry strength, nonplastic
243.1	243.3	Brown (7.5YR5/4) sandy silt, laminated
243.3	243.4	Brown (7.5YR5/4) fine sand, moderately sorted, loose, massive
243.4	243.9	Brown (7.5YR5/4) coarse sand, moderately sorted, loose
243.9	244.0	Brown (7.5YR5/4) silty clay, indistinctly laminated, low dry strength, nonplastic
244.0	244.3	Reddish brown (5YR5/4) clayey silty fine sand, poorly sorted, loose, massive
244.3	245.7	Strong brown (7.5YR5/6) medium sand and brown to dark brown (7.5YR4/4) silty sand, interlaminated
245.7	246.1	Strong brown (7.5YR5/6) medium sand
248.8	249.0	Brown (7.5YR5/4) medium sand, ranging from fine to coarse, massive
249.0	249.3	Reddish brown (5YR5/4) silty fine sand, poorly sorted
249.3	249.9	Reddish brown (5YR5/4) silty clay, traces of fine sand, indistinctly laminated, low dry strength, nonplastic

249.9	250.0	Reddish brown (5YR5/4) silty clay, , indistinctly laminated, low dry strength, nonplastic, white carbonate nodules
250.0	250.1	Reddish brown (5YR5/4) silty fine sand, poorly sorted, loose, massive
250.1	250.2	Reddish brown (5YR5/4) silty clay, , indistinctly laminated, low dry strength, nonplastic, carbonate nodules
250.2	251.6	Reddish brown (5YR5/4) to (2.5YR5/4) silty clay and clay, indistinctly laminated, low dry strength, nonplastic, with manganese oxide dendrites
251.6	252.0	Brown (7.5YR5/4) silty fine sand, poorly sorted, weakly carbonate cemented, thin silty clay interbeds
252.0	255.2	Reddish brown (5YR5/4) to (2.5YR5/4) silty clay and clay, faint banding, carbonate nodules
259.8	260.4	Brown (7.5YR5/4) clay, indistinctly laminated, low dry strength, nonplastic
260.4	260.8	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, loose, massive, grain size ranging from fine to medium sand, fining-upward unit, moderately cemented layers
260.8	260.9	Brown (7.5YR5/4) clayey silt and clay, interlaminated, indistinctly laminated, low dry strength, nonplastic
260.9	261.1	Reddish brown (5YR5/4) clay, indistinctly laminated, low dry strength, nonplastic
261.1	261.5	Reddish brown (5YR5/4) medium sand, ranging from fine to medium sand, red (5YR) clay interbeds
261.5	261.8	Light brown (7.5YR6/4) sandy silty clay, indistinctly laminated, low dry strength, nonplastic, red (5YR) clay laminations
261.8	262.6	Brown (7.5YR5/4) silty clay, , indistinctly laminated, low dry strength, nonplastic interbeds of fine sand
262.6	264.0	Brown (7.5YR5/4) clay, disturbed, medium sand breccia
264.0	264.8	Brown (7.5YR5/4) coarse sand, ranging from fine to coarse sand, moderately sorted, loose
264.8	265.7	Brown (7.5YR5/4) coarse sand, ranging from fine to coarse sand, moderately sorted, loose, massive
265.7	268.3	Reddish brown (5YR5/4) silty fine sand, poorly sorted, loose, massive
268.7	268.9	Light reddish brown (5YR6/4) silty fine sand, poorly sorted, loose, massive
269.9	270.1	Pinkish white (5YR8/2) medium sand, weakly cemented
270.1	270.2	Light brown (7.5YR6/4) clayey silty fine sand, poorly sorted, loose, massive
270.2	270.8	Reddish brown (5YR5/4) clay
270.8	271.0	Light reddish brown (5YR6/4) sandy clay and pinkish white (5YR8/2) silty sand, basal calcite cemented, moderately cemented
271.0	271.9	Brown (7.5YR5/4) medium sand with reddish brown (5YR5/4) clay ripups
271.9	272.7	Light brown (7.5YR6/4) silty medium sand, moderately sorted, loose, massive
273.1	274.8	Light brown (7.5YR6/4) silty fine sand, poorly sorted, loose, massive
274.8	277.2	Strong brown (7.5YR5/6) medium sand
277.2	277.7	Light brown (7.5YR6/4) clayey silty fine sand, poorly sorted, loose, massive
278.1	278.2	Strong brown (7.5YR5/6) clayey silty fine sand, poorly sorted, loose, massive
278.2	278.5	Strong brown (7.5YR5/6) silty clay with brown to dark brown (7.5YR4/2) silt stringers
278.5	278.7	Strong brown (7.5YR4/6) clay
278.7	279.2	Red (2.5YR4/6) clay with brown to dark brown (7.5YR4/2) silt laminations
279.2	279.7	Yellowish red (5YR5/6) sandy clay
279.7	279.9	Reddish brown (2.5YR5/4) clayey silty fine sand, poorly sorted, loose, massive
279.9	281.4	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
281.4	281.6	Reddish brown (2.5YR5/4) clayey silty fine sand, poorly sorted, loose, massive
281.6	281.9	Yellowish red (5YR5/6) silty clay and brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive, interlaminated
282.5	287.9	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
290.9	291.0	Light yellowish brown (10YR6/4) medium sand, moderately sorted
291.0	291.4	Light yellowish brown (10YR6/4) clayey sandy silt
291.4	291.7	Brown (7.5YR5/4) silty clay
291.7	293.8	Yellowish brown (10YR5/6) medium sand, 1.5-1.0 phi mode, ranging from fine to medium sand
293.8	294.5	Yellowish brown (10YR5/6) medium sand, 1.5-1.0 phi mode, ranging from fine to coarse sand
294.5	294.7	Pink (7.5YR7/4) coarse sand, moderately sorted, loose, weakly calcite cemented
294.7	295.1	Yellowish brown (10YR5/6) medium sand, 1.5-1.0 phi mode, ranging from fine to coarse sand, moderately sorted, loose
295.1	295.2	Pink (7.5YR7/4) coarse sand, moderately sorted, weakly calcite cemented
295.2	296.3	Strong brown (7.5YR5/6) medium sand, 2.0-1.5 phi mode, ranging from fine to coarse sand
296.3	296.5	Pink (7.5YR7/4) coarse sand, moderately sorted, loose, weakly calcite cemented
301.9	302.4	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, massive, moderately cemented
302.4	302.7	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, massive
302.7	303.0	Strong brown (7.5YR5/6) coarse sand, 1.0-0.5 phi mode, grading to medium sand 2.0-1.5 phi mode, ranging from fine to coarse sand, poorly sorted
303.0	304.4	Strong brown (7.5YR5/6) medium sand, 1.5-1.0 phi mode, moderately sorted
304.4	305.4	Reddish brown (5YR5/4) to yellowish red (5YR5/6) silty clay and clay, interlaminated

305.4	306.4	Strong brown (7.5YR5/6-4/6) clayey silty fine sand, poorly sorted, massive, 3.0-2.5 phi mode, weakly cemented
306.4	307.1	Strong brown (7.5YR5/6-4/6) clayey silty fine sand, poorly sorted, massive, 3.0-2.5 phi mode, weakly cemented
307.1	307.2	Reddish yellow (7.5YR6/6) fine sand, weakly carbonate cemented, carbonate nodules, mottled
307.2	307.5	Reddish brown (5YR5/4) clay, massive, low dry strength, low plasticity, basal silty clay
307.5	308.0	Reddish brown (5YR5/4) silty clayey fine sand, basal reddish yellow to yellowish red (5YR6/6-5/6) medium sand, 2.5-1.5 phi mode, ranging from fine to medium sand, poorly sorted, massive
311.9	312.1	Reddish brown to strong brown (7.5YR6/6-5/6) silty fine to medium sand, 2.0-1.5 phi mode
312.1	312.4	Strong brown (7.5YR5/6) silty sandy clay
312.4	313.1	Reddish brown to strong brown (7.5YR6/6-5/6) silty fine sand, poorly sorted, massive weakly cemented
313.1	313.9	Strong brown (7.5YR5/6) silty clay, indistinctly laminated, low dry strength, nonplastic
313.9	314.1	Strong brown (7.5YR5/6) silty clay, indistinctly laminated, low dry strength, nonplastic, carbonate nodules
314.1	314.3	Strong brown (7.5YR5/6) silty clay, indistinctly laminated, low dry strength, nonplastic
314.3	314.4	Strong brown (7.5YR4/6) clay, indistinctly laminated, low dry strength, nonplastic
321.5	323.8	Strong brown (7.5YR5/6) to yellowish red (5YR5/6) silty medium sand, 2.0-1.5 phi mode, ranging from fine to medium sand, fining up unit, basal reddish brown (5YR5/4) clay ripup intraclasts
323.8	324.5	Dark brown to brown (7.5YR4/4) silty clay and pink (7.5YR7/4) silty fine sand, poorly sorted, interlaminated, carbonate rich
324.5	324.7	Reddish brown (5YR4/4) clay, low dry strength, low plasticity, laminated
324.7	325.2	Dark brown to brown (7.5YR4/4) silty clay and pink (7.5YR7/4) silty fine sand, poorly sorted, interlaminated, carbonate rich
325.2	325.4	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
325.4	325.9	Reddish brown (5YR4/4) clay, low dry strength, low plasticity, laminated
325.9	326.5	Brown (7.5YR5/4) silty very fine sand, 3.0-2.5 phi mode, poorly sorted, loose, massive
326.5	326.9	Light brown (7.5YR6/4) silty fine sand, poorly sorted, massive
326.9	327.1	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, massive
327.1	327.4	Strong brown (7.5YR5/6) silty medium sand, ranging from fine to coarse sand
327.4	327.5	Reddish brown (5YR5/4) and yellowish brown (10YR5/4) clay, massive, low dry strength, nonplastic
327.5	327.9	Dark brown to brown (7.5YR4/4) silty clay and pink (7.5YR7/4) silty fine sand, poorly sorted, carbonate rich
327.9	328.4	Light brown (7.5YR6/4) to brown (7.5YR5/4) silty fine sand, poorly sorted, 2-6 millimeter laminations of reddish brown (5YR5/4) clay
328.4	328.5	Yellowish brown (10YR5/4) clay, low dry strength, nonplastic, massive
328.5	328.6	Reddish brown (5YR5/4) silty clay, massive, low dry strength, nonplastic, laminated
328.6	328.7	Brown (7.5YR5/4) silty medium sand, sand ranging from fine to coarse
332.0	332.5	Brown (7.5YR5/4) silty fine sand, poorly sorted, loose, massive
332.5	332.6	Pinkish gray (7.5YR7/2) silty very fine sand, poorly sorted, massive weakly carbonate cemented
332.6	333.5	Yellowish red (5YR4/6) silty clay and clay, basal sand
333.5	335.0	Strong brown (7.5YR5/6) medium sand, 2.0-1.5 phi mode, ranging from fine to medium sand
335.0	335.9	Strong brown (7.5YR5/6) medium sand, ranging from fine to coarse sand
335.9	336.0	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, massive, sand ranging from fine to medium
336.0	336.3	Yellowish red (5YR4/6) clay, low dry strength, nonplastic, massive
336.3	336.6	Strong brown (7.5YR5/6) fine sand, 2.5-2.0 phi mode, ranging from fine to medium sand
337.0	337.1	Yellowish red (5YR5/6) silty clay
337.1	338.5	Strong brown (7.5YR5/6) medium sand, 3.0-1.5 phi mode, ranging from fine to medium sand
342.0	342.3	Strong brown (7.5YR5/6) silty medium sand, 3.0-1.0 phi mode, ranging from fine to medium sand
342.3	342.5	Yellowish red (5YR5/6) fine sandy clay
342.5	342.5	Yellowish red (5YR5/6) silty clay, strongly cemented upper boundary
342.5	342.6	Very pale brown (10YR7/4) to light yellowish brown (10YR6/4) fine silty sand, poorly sorted, massive
346.9	347.7	Strong brown (7.5YR5/6) medium sand, 3.0-1.5 phi mode, ranging from fine to medium sand
347.7	351.8	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, massive, 3.0-2.0 phi mode, ranging from fine to medium sand, discontinuously and moderately cemented zones of silty, clayey fine sand
351.8	352.0	Strong brown (7.5YR5/6) silty fine sandstone, 3.0-2.0 phi mode, ranging from fine to medium sand, poorly sorted, massive strongly cemented, strong reaction to HCl
352.0	352.1	Strong brown (7.5YR5/6) fine sand, 3.0-2.0 phi mode, ranging from fine to medium sand, strongly cemented, strong reaction to HCl
352.1	353.3	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, 3.0-2.0 phi mode, ranging from fine to coarse sand, poorly sorted, massive
353.3	353.6	Strong brown (7.5YR5/6) fine sand, 3.0-2.0 phi mode, ranging from very fine to fine sand, moderately

		sorted
354.0	354.1	Brown (7.5YR5/4) silty clayey fine sand, poorly sorted, loose, massive
354.1	354.6	Brown (7.5YR5/4) silty medium sand, 2.5-1.5 phi mode, ranging from fine to medium sand
357.4	357.5	Brown (7.5YR5/4) silty medium sand, 2.5-1.5 phi, ranging from fine to medium sand, discontinuous weakly cemented zone
357.5	357.7	Strong brown (7.5YR5/6) silty medium sand, 2.5-1.5 phi mode, ranging from fine to medium sand
357.7	358.1	Reddish yellow (7.5YR6/8) clayey silty fine sand, poorly sorted, massive
358.1	359.2	Reddish yellow (7.5YR6/8) silty very fine sand, poorly sorted, loose, faintly cross-laminated
359.2	359.3	Yellowish red (5YR5/5) clay, low dry strength, nonplastic, silty laminations
359.3	359.4	Strong brown (7.5YR5/6) silt and very fine sand, interlaminated, poorly sorted, loose, massive
359.4	359.5	Yellowish red (5YR5/5) clay, low dry strength, nonplastic, silty laminations
359.5	359.9	Light brown (7.5YR6/4) silty very fine sand, ranging from fine to medium sand, poorly sorted, indistinctly laminated
359.9	361.3	Brown (7.5YR5/4) silty fine sand, poorly sorted, ranging from fine to medium sand, red (5YR) clay laminae 2 millimeters thick
361.3	361.6	Strong brown (7.5YR5/6) clayey silty fine sand, poorly sorted, laminated
361.6	361.8	Strong brown (7.5YR5/6) medium sand, 2.0-1.5 phi mode, ranging from fine to coarse sand, indistinctly laminated, moderately sorted
361.8	362.4	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, distinctly laminated, red (5YR) clay laminae
362.4	363.3	Strong brown (7.5YR5/8) medium sand, 2.0-1.5 phi mode, ranging from fine to coarse sand, distinctly laminated, clean, poorly sorted, some silty laminae
369.3	369.4	Reddish brown (5YR4/3) sandy silty clay, massive, low dry strength, nonplastic
369.4	373.9	Strong brown (7.5YR5/6) medium sand, 2.5-1.5 phi mode, laminated to indistinctly laminated
374.3	376.8	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, loose, massive
378.7	379.4	Strong brown (7.5YR5/6) medium sand, moderately sorted
379.4	381.1	Strong brown (7.5YR5/6) clayey silty medium sand, 3.0-2.0 phi mode, ranging from fine to medium sand
383.4	383.5	Yellowish red (5YR4/6) silty clay, low dry strength, nonplastic, ripup intraclasts of red clay
383.5	383.6	Yellowish red (5YR4/6) medium sand, ranging from fine to coarse sand, poorly sorted
383.6	383.7	Yellowish red (5YR4/6) "Hershey" clay
394.4	399.6	Brown (7.5YR5/4) fine sand, 2.5-2.0 phi mode, laminated, well sorted
399.6	399.9	Dark brown to brown (7.5YR4/4) medium sand, 2.0-1.5 phi mode, indistinctly laminated, moderately sorted
399.9	400.1	Dark brown to brown (7.5YR4/4) coarse sand, 1.0-0.5 phi mode, indistinctly laminated, fining up unit, well sorted
401.0	403.1	Brown (7.5YR5/4) medium sand, 2.5-1.5 phi, ranging from fine to medium sand, interlaminated, dark mineral laminae, basal crossbedding
403.1	404.1	Yellowish red (5YR5/6) silty clayey sand and strong brown (7.5YR5/6) very fine sand, 2.5-2.0 phi mode, interlaminated, poorly sorted, loose, massive
404.1	404.2	Brown (7.5YR5/4) medium sand, 2.0-1.5 phi mode, indistinctly laminated
404.2	404.3	Brown (7.5YR5/4) fine sand, 3.0-2.5 phi mode, scattered medium sand, 2.5-2.0 phi mode
404.3	404.5	Light brown (7.5YR6/4) clayey silt and very fine sand, interlaminated, poorly sorted, loose
404.5	404.7	Brown (7.5YR5/4) silty fine sand, poorly sorted, 3.0-2.5 phi mode, indistinctly laminated
404.7	405.3	Light brown (7.5YR6/4) fine sand, 2.5-2.0 phi mode, ranging from fine to medium sand, laminated, red clay microlaminations at top, clay intraclasts
405.3	405.4	Light yellowish brown (10YR6/4) silty fine sand, poorly sorted, 2.5-2.0 phi mode, ranging from fine sand to medium sand, interlaminated
405.4	405.5	Pinkish gray (7.5YR6/2) fine sand, 3.0-2.5 phi mode, weakly carbonate cemented
405.5	406.4	Brown (7.5YR5/4) fine sand, 2.5-2.0 phi mode, ranging from fine to medium sand, indistinct thin clay beds
406.4	407.8	Light brown (7.5YR6/4) silty fine sand, poorly sorted, 3.0-2.0 phi mode, laminated, carbonate rich
407.8	408.5	Yellowish red (5YR5/6) silty fine sand, poorly sorted, 3.0-2.5 phi mode, laminated
408.5	409.0	Reddish brown (5YR5/4) fine sandy silty clay, 4.0-3.5 phi, fining upward to clay
409.0	409.3	Reddish brown (5YR5/4) clay, indistinctly laminated, low dry strength, nonplastic
410.5	410.9	Light brown (7.5YR6/4) silty clay, thin beds of silty fine sand, poorly sorted
410.9	411.6	Light brown (7.5YR6/4) silty fine sand, poorly sorted, crossbedded sand, heavy mineral laminations, reddish brown (5YR5/4) 8-millimeter thick clay laminations
411.6	411.8	Light brown (7.5YR6/4) silty clay and silty very fine sand, interlaminated, poorly sorted, loose
411.8	412.0	Brown (7.5YR5/4) silty fine sand, poorly sorted, ranging from fine to medium sand, laminated
412.0	412.3	Light brown (7.5YR6/4) silty fine sand, poorly sorted, crossbedded sand, heavy mineral laminations, reddish brown (5YR5/4) 8 millimeter clay laminations
416.4	419.8	Brown (7.5YR5/4) medium sand, 2.0-1.5 phi mode, ranging from fine to coarse, compact, well sorted, 0.1

		foot moderately cemented carbonate zone
419.8	420.0	Dark yellowish brown (10YR4/4) medium sand, ranging from fine to medium sand, moderately carbonate cemented
420.0	420.1	Dark yellowish brown (10YR4/4) medium sand, ranging from fine to coarse, poorly sorted, loose
427.8	432.8	Brown (7.5YR5/4) medium sand, 3.0-1.5 phi mode, ranging from fine to medium sands, massive
432.8	435.1	Brown (7.5YR5/4) silty fine sand, poorly sorted, 3.0-2.0 phi mode, ranging from fine to medium sand
435.1	435.2	Yellowish red (5YR5/6) silty clay and clay, carbonate nodules
435.2	435.6	Reddish brown (5YR5/4) clayey silty fine sand, poorly sorted, 2.0-3.0 phi mode
435.6	436.4	Reddish brown (5YR5/4) silty fine sand, poorly sorted
436.4	436.7	Yellowish red (5YR4/6) clay
436.7	437.1	Brown (7.5YR5/4) clayey silty very fine sand
437.1	437.2	Dark brown to brown (7.5YR4/4) silty clay
437.2	437.3	Brown (7.5YR5/4) medium sand, ranging from medium to coarse sand, weakly carbonate cemented
437.3	437.9	Brown (7.5YR5/4) medium sand, ranging from fine to medium sand, silty at top, fining upward
438.4	438.6	Brown (7.5YR5/4) medium sand, ranging from fine to coarse sand, silty sand interbeds, poorly sorted
438.6	438.8	Brown (7.5YR5/4) silty fine sand, poorly sorted, sandy clay laminations
438.8	439.2	Brown (7.5YR5/3) medium sand, 2.5-1.5 phi mode, reddish gray (7.5YR5/2) laminations
439.2	439.8	Brown (7.5YR5/4) silty fine sand, poorly sorted, massive
439.8	439.9	Brown (7.5YR5/4) and reddish brown (5YR5/4) silty clay, indistinctly laminated, low dry strength, nonplastic, white carbonate nodules
439.9	441.0	Reddish brown (5YR5/3) silty fine sand, poorly sorted, ranging from fine to coarse sand,, bands of distinct carbonate cement
441.0	443.2	Reddish brown (5YR4/4) silty clay, discontinuously laminated, scattered soft carbonate nodules
443.4	443.5	Pinkish gray (5YR6/2) silt, laminated, microlaminated, dark mineral microlaminations, weakly carbonate cemented, unit coarsens upward
443.5	447.2	Yellowish red (5YR5/6) silty clay, carbonate nodules, irregular lenses, mottling
447.2	447.3	Light brown (7.5YR6/4) very fine sand, 2.5-2.0 phi mode, moderately sorted, carbonate cemented, strong HCl reaction
447.3	447.5	Yellowish red (5YR4/6) clay, indistinctly laminated, low dry strength, nonplastic, small scattered carbonate nodules, manganese staining
447.5	448.0	Reddish brown (5YR5/4) silty fine sand, poorly sorted, 2.0-3.0 phi mode, massive
456.1	457.7	Dark brown to brown (7.5YR4/4) silty clay and clay, thinly laminated
457.7	459.7	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, 2.5-3.5 phi mode, clay, sand, silt interlaminae
461.2	461.5	Brown (7.5YR5/4) silty fine sand, poorly sorted, 3.5-3.0 phi mode, clay in upper unit, fining up unit
461.5	461.7	Brown (7.5YR5/4) silty fine sand, poorly sorted, 2.5-2.0 phi mode, ranging from fine to medium sand, indistinctly laminated
461.7	461.9	Brown (7.5YR5/4) silty clay, massive, low dry strength, nonplastic, massive
461.9	462.2	Brown (7.5YR5/4) silty fine sand, poorly sorted, 2.5-1.5 phi mode, ranging from fine to medium sand, distinct clay laminae
462.2	462.3	Dark brown to brown (7.5YR4/4) silty clay
462.3	462.3	Dark brown to brown (7.5YR4/4) silty clay, carbonate layer
462.3	462.9	Dark brown to brown (7.5YR4/4) silty clay, distinct yellowish brown (10YR5/4) clayey silt interbeds
462.9	464.1	Brown (7.5YR5/4) clay, indistinctly laminated, low dry strength, nonplastic, indistinct laminae of sandy silt
464.1	464.5	Brown (7.5YR5/4) clayey silty fine sand, poorly sorted, 2.0-1.5 phi mode, ranging from fine to medium sand, clay laminae
464.5	465.6	Brown (7.5YR5/4) silty fine sand, poorly sorted, 2.0-1.5 phi mode, ranging from medium to coarse sand, poorly sorted, several basal silty clay laminae
466.1	466.7	Strong brown (7.5YR5/6) medium sand, 2.0-1.5 phi mode, ranging from very fine to medium sand, faintly laminated, reddish brown (5YR5/4) basal clay
466.7	467.0	Strong brown (7.5YR5/6) clayey silty fine sand, poorly sorted, 2.5-3.5 phi mode
467.0	467.6	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, 2.0-1.5 phi mode, ranging from fine to medium sand; strong brown (7.5YR5/6) clayey silt laminae
467.6	468.0	Dark yellowish brown (10YR4/4) silty clay
468.0	468.3	Strong brown (7.5YR5/6) medium sand, 1.5-2.5 phi mode, ranging from fine to medium sand, well sorted
468.3	468.4	Dark yellowish brown (10YR4/4) silty clay
468.4	469.0	Light brown (7.5YR6/4) medium sand, 2.0-3.0 phi mode, ranging from fine to medium sands, moderately sorted, carbonate nodules, coarsens down
469.0	469.5	Dark yellowish brown (10YR4/4) silty clay, indistinct silty laminae, carbonate nodules
469.5	469.8	Strong brown (7.5YR5/6) medium sand
469.8	470.1	Brown (7.5YR5/4) silty fine sand, poorly sorted, massive

471.1	474.1	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, 2.0-3.0 phi mode, sands ranging from fine to medium, scattered clayey silt laminae
474.1	474.6	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, 3.5-3.0 phi mode, silt laminae
474.6	475.4	Dark brown to brown (7.5YR4/4) clayey fine sand, 4.0-3.5 phi mode, clay interlaminae and interbeds
475.4	475.6	Light brown (7.5YR6/4) very fine sand, 3.0-4.0 phi mode, poorly sorted
475.6	475.6	Light brown (7.5YR6/4) fine to medium sand, poorly sorted
475.6	475.8	Brown (7.5YR5/4) clayey very fine sand, 4.0-3.5 phi mode, poorly sorted, massive
475.8	476.7	Brown (7.5YR5/4) medium sand, sands ranging from fine to coarse, poorly sorted, scattered clay laminae, wet moisture condition
483.1	483.3	Dark brown to brown (7.5YR4-5/4) silty clay and reddish brown (5YR4/4) clay, homogeneous, silty clay at base and clay in upper unit
483.3	483.8	Strong brown (7.5YR5/6) fine sand, 3.0-2.5 phi, well sorted, weakly cemented, laminated, scattered soft carbonate nodules
483.8	484.2	Strong brown (7.5YR4/6) clayey sandy silt, 3.5-3.0 phi mode, sands range from fine to coarse, brown (7.5YR5/4) clay silt
484.2	484.9	Yellowish brown (10YR5/4) medium sand, 2.0-3.0 phi mode, sands ranging from fine to coarse, poorly sorted, silty laminae
484.9	485.3	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, 3.5-3.0 phi mode, interlaminated brown (7.5YR5/4) clay layers
485.3	486.7	Light yellowish brown (10YR6/4) silty fine sand, poorly sorted, 3.0-2.0 phi mode, sands ranging from fine to medium, distinctly laminated, weakly carbonate cemented, heavy mineral laminations
486.7	487.0	Brown (7.5YR5/4) silty fine sand, poorly sorted, sands ranging from fine to medium, strong brown (7.5YR4/6) silt laminae
487.0	487.3	Brown (7.5YR5/4) fine sand
488.8	489.0	Brown (7.5YR5/4) silty clay
489.0	490.1	Brown (7.5YR5/4) medium sand, 2.0-1.5 phi mode, ranging from fine to medium sands, moderately sorted, red silty clay laminae
490.1	490.3	Reddish brown (5YR4-5/4) clay, silt, fine sand, interlaminated
490.3	490.5	Light brown to brown (7.5YR6-5/4) medium sand, sands ranging from fine to coarse, poorly sorted, weakly carbonate cemented
490.5	490.5	Reddish brown (5YR5/4) silty clay and clay, interlaminated
490.5	490.6	Light brown to brown (7.5YR6-5/4) medium sand, sands ranging from fine to coarse, poorly sorted, weakly carbonate cemented
490.6	490.7	Reddish brown (5YR5/4) silty clay and clay, interlaminated
490.7	491.3	Light brown to brown (7.5YR6-5/4) medium sand, sands ranging from fine to coarse, poorly sorted, weakly carbonate cemented
491.3	491.4	Reddish brown (5YR5/4) silt
491.4	491.5	Reddish brown (5YR5/4) silty clay
491.5	492.4	Light brown to brown (7.5YR6-5/4) medium sand, sands ranging from fine to coarse, poorly sorted, weakly carbonate cemented
492.7	493.4	Brown (7.5YR5/4) silty clay and clay, interbedded
493.4	494.7	Pink (7.5YR7/4) silty fine sand, poorly sorted, sands ranging from fine to medium, laminated, thinly bedded
494.7	494.7	Pink (7.5YR7/4) silty fine sand, poorly sorted, sands ranging from fine to medium, laminated, thinly bedded, weakly carbonate cemented
494.7	494.9	Pink (7.5YR7/4) silty fine sand, poorly sorted, sands ranging from fine to medium, laminated, thinly bedded
494.9	495.4	Light brown (7.5YR6/4) silty fine sand, poorly sorted, 3.5-3.0 phi mode, cross-laminated, heavy minerals, basal red clay interlaminae
495.4	495.8	Strong brown (7.5YR4/6) clay, indistinctly thinly bedded, low dry strength, nonplastic, bedded, basal soft carbonate nodules
495.8	496.4	Light brown (7.5YR6/4) silty fine sand, poorly sorted, 2.5-3.5 phi mode, basal red clay
497.7	498.7	Strong brown (7.5YR4/6) silty clay and clay, thinly bedded
498.7	499.8	Brown (7.5YR5/4) and strong brown (7.5YR4/6) clay, silty clay, very fine sand, thinly bedded
499.8	501.9	Brown (7.5YR5/4) silty fine sand, poorly sorted, 2.5-1.5 phi mode, sands ranging from fine to coarse, poorly sorted
501.9	505.7	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, 2.0-1.5 phi mode, sands ranging from fine to medium, indistinctly flat laminated, scattered soft carbonate nodules
505.7	505.9	Reddish brown (5YR4/4) silty clay
505.9	506.6	Brown (7.5YR5/4) silty fine sand, poorly sorted, 2.5-2.0 phi mode, indistinctly laminated
506.6	506.7	Light brown (7.5YR6/4) very fine sandy silt
506.7	506.8	Light brown (7.5YR6/4) clayey silt

506.8	507.3	Strong brown (7.5YR4/6) clay, silty clay bed, thin moderately cemented carbonate zone
507.3	507.7	Brown (7.5YR5/4) silty fine sand, poorly sorted, 2.5-2.0 phi mode, sands ranging from fine to medium
507.7	508.1	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, 2.5-2.0 phi mode, sands ranging from fine to medium
508.1	508.4	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, 2.5-2.0 phi mode, sands ranging from fine to medium, thin weakly cemented zone
508.4	510.5	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, 2.5-2.0 phi mode, sands ranging from fine to medium
510.5	510.6	Yellowish red (5YR5/6) clayey silty fine sand, poorly sorted, massive, weakly cemented
510.6	510.8	Pink (5YR7/4) fine sand, weakly carbonate cemented
510.8	510.8	Yellowish red (5YR5/6) clayey silty fine sand, poorly sorted, massive, weakly cemented
510.8	511.7	Brown (7.5YR5/4) medium sand, 1.0-2.0 phi mode, sands ranging from fine to coarse, poorly sorted
511.7	511.8	Yellowish brown (10YR5/4) silty clay, low dry strength, nonplastic, laminated
511.8	512.5	Reddish brown (5YR4/4) silty clay and clay, fining up unit
513.7	513.9	Reddish brown (5YR4/4) silty clay and clay
513.9	514.6	Yellowish brown (10YR5/4) to strong brown (7.5YR5/6) clayey silty fine sand, poorly sorted, sands ranging from fine to coarse, massive
514.6	514.9	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, 2.5-1.5 phi mode, sands ranging from fine to coarse, heavy dark mineral laminae, fining up unit
514.9	515.2	Yellowish brown (10YR5/4) clayey silty fine sand, poorly sorted, massive, weakly cemented
515.2	516.9	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, 2.5-2.0 phi mode, sands ranging from fine to medium, , massive, weakly cemented, few soft carbonate nodules
516.9	516.9	Yellowish brown (10YR5/4) silty clay
516.9	517.2	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, 3.0-2.5 phi mode, sands ranging from fine to medium, massive, weakly cemented
517.2	517.9	Yellowish brown (10YR5/4) fine sand, 3.0-2.0 phi mode, sand ranging from fine to coarse, poorly sorted, fining up unit
518.7	519.2	Yellowish brown (10YR5/4) to brown (7.5YR5/4) silty clay and clay, thinly laminated
519.2	520.8	Yellowish brown (10YR5/4) clayey silty fine sand, poorly sorted, and fine sand, 3.0-2.0 phi, interbedded, thinly bedded to thickly laminated
520.8	521.5	Yellowish brown (10YR5/4) silty medium sand, 2.5-1.5 phi mode, weakly cemented zones
521.5	522.7	Strong brown (7.5YR4/6) silty clay and clay
522.7	522.9	Brown (7.5YR5/4) fine sand, 1.5-1.0 phi mode, ranging from fine to coarse sand, poorly sorted
523.7	524.8	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, sands ranging from fine to coarse, upward fining unit at top
524.8	524.9	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, sand ranging from fine to coarse, upward fining unit at top, weakly carbonate cemented zone
524.9	525.1	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, sands ranging from fine to coarse, upward fining unit at top
525.1	525.2	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, sands ranging from fine to coarse, upward fining unit at top, weakly carbonate cemented zone
525.2	525.4	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, sands ranging from fine to coarse, upward fining unit at top
525.4	525.6	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, sands ranging from fine to coarse, upward fining unit at top, weakly carbonate cemented zone
525.6	526.0	Yellowish brown (10YR5/46-4) clayey silty very fine sand, poorly sorted, massive, weakly cemented
526.0	526.4	Brown (7.5YR5/4) silty fine sand, poorly sorted, 3.0-2.5 phi mode, wet moisture condition
526.4	526.8	Brown (7.5YR5/4) clayey silty very fine sand, poorly sorted, massive, weakly cemented
528.7	528.8	Yellowish brown (10YR5/4) clayey silty very fine sand and clayey silt, interlaminated, poorly sorted, weakly cemented
528.8	529.1	Light yellowish brown (10YR6/4) fine sand, 2.5-2.0 phi mode, sands ranging from fine to medium, weakly carbonate cemented, heavy mineral laminations
529.1	529.5	Light brown (7.5YR6/4) to light yellowish brown (10YR6/4) clay, silt, very fine sand, interlaminated
529.5	530.0	Yellowish brown (10YR5/4) medium sand, 2.0-1.0 phi mode, sands ranging from fine to coarse, cross-laminated, well sorted
530.0	530.2	Yellowish brown (10YR5/4) clayey silty fine sand, poorly sorted and silty clay, interlaminated
530.2	530.3	Reddish brown (5YR4/4) clay, low dry strength, nonplastic, massive
530.3	530.7	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, 2.5-2.0 phi mode, massive
534.0	534.3	Strong brown (7.5YR5-4/6) silty clay, red (5YR) 2 millimeter thick laminae
534.3	534.7	Light brown (7.5YR6/4) fine sand, 2.5-2.0 phi mode, ripple laminated, dark mineral laminae

534.7	534.7	Brown (7.5YR5/4) silty clay
534.7	535.0	Light brown (7.5YR6/4) fine sand, 2.5-2.0 phi mode, ripple laminated, dark mineral laminae
535.0	535.1	Strong brown (7.5YR4/6) clay
535.1	535.3	Brown (7.5YR5/4) clayey sandy silt
535.3	535.4	Strong brown (7.5YR4/6) clay
535.4	535.5	Light brown (7.5YR6/4) fine sand, 2.5-2.0 phi mode, ripple laminated, dark mineral laminae
535.5	535.6	Brown (7.5YR5/4) silty clay
535.6	535.8	Light brown (7.5YR6/4) fine sand, 2.5-2.0 phi mode, ripple laminated, dark mineral laminae
535.8	535.9	Strong brown (7.5YR4/6) clay
535.9	536.1	Brown (7.5YR5/4) clayey sandy silt
536.1	536.3	Light brown (7.5YR6/4) silty fine sand, poorly sorted, 2.5-2.0 phi mode, sands ranging from fine to coarse, crosslaminated, dark mineral
536.3	537.2	Light brown (7.5YR6/4) fine sand, 2.5-2.0 phi mode, ripple laminated, dark mineral laminae
539.0	539.4	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, ranging from fine to medium sand; brown (7.5YR5/4) silty clay laminae
539.4	539.7	Yellowish red (5YR4/6) silty sandy clay, fining up to silty clay
539.7	541.7	Reddish brown (5YR4/4) to brown (7.5YR5/4) silty clay and clay, thin silty partings, fining up unit, basal clayey sandy silt
544.0	544.2	Strong brown (7.5YR4/6) clay
544.2	544.4	Dark brown to brown (7.5YR4/4) silty clay
544.4	544.6	Light yellowish brown (10YR6/4) silty fine sand, poorly sorted, 3.0-2.0 phi mode, laminated
544.6	544.7	Strong brown (7.5YR4/6) clay, laminated, low dry strength, nonplastic
544.7	544.8	Reddish yellow (7.5YR6/6) to strong brown (7.5YR5/6) clayey sandy silt
544.8	544.9	Light yellowish brown (10YR6/4) clayey silt
544.9	545.0	Dark brown to brown (7.5YR4/4) to pale brown (10YR6/4) clay, low dry strength, nonplastic, finely laminated
545.0	545.7	Strong brown (7.5YR5/6) silty clay and clay, massive, low dry strength, nonplastic, basal laminations
545.7	546.0	Yellowish brown (10YR5/6) clayey silt, massive
546.0	546.5	Brown (7.5YR5/4) to strong brown (7.5YR5/6) sandy clayey silt, massive
546.5	546.7	Brown (7.5YR5/4) medium sand, sand ranging from fine to coarse, poorly sorted
546.7	546.8	Brown (7.5YR5/4) clayey silty very fine sand
546.8	547.6	Strong brown (7.5YR5/6) clayey silty very fine sand, poorly sorted, massive, weakly cemented
547.6	547.9	Brown (7.5YR5/4) clayey silty fine sand, poorly sorted
549.0	549.3	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, 3.5-2.5 phi mode, indistinct flat laminae
549.3	549.4	Light gray (10YR7/2) medium sandstone, grain size ranging from medium to coarse, strongly carbonate cemented, strong reaction to HCl
549.4	549.5	Brown (7.5YR5/4) silty fine sand, poorly sorted, 3.0-2.5 phi mode, indistinct laminae
549.5	549.6	Pale brown (10YR6/3) sandy clayey silt and silty clay, interlaminated
549.6	549.8	Brown (10YR5/3) and yellowish red (5YR4/6) silty clay and clay, interlaminated, microlaminated
549.8	550.0	Light gray (10YR7/2) fine sandstone, moderately sorted, strongly carbonate cement
550.0	550.5	Brown (10YR5/3) and yellowish red (5YR4/6) silty clay and clay, interlaminated, microlaminated
550.5	551.3	Yellowish red (5YR4/6) silt and silty clay, thinly bedded, indistinctly laminated
551.3	551.4	Light yellowish brown (10YR6/4) silty fine sand, poorly sorted, 2.5-2.0 phi mode
551.4	551.8	Yellowish brown (10YR5/4) silty clay, laminated
551.8	552.2	Yellowish brown (10YR5/4) clayey silty very fine sand, laminated
554.0	554.5	Brown (7.5YR5/4) fine sand, 2.5-2.0 phi mode, grain size ranging from fine to coarse sand, faintly horizontally bedded, clean
554.5	555.0	Reddish brown (5YR5/4) and yellowish brown (10YR5/4) clayey silty fine sand, poorly sorted and red clay, mottled together, not laminated
555.0	555.6	Reddish brown (5YR5/4) and pale brown (10YR6/3) silty clay, silt and clay, interbedded, microlaminated
555.6	556.0	Reddish brown (5YR4/4) clay, interbedded silty laminae
559.0	560.8	Yellowish red (5YR4/6) silty clay and clay, low dry strength, nonplastic, thinly bedded to microlaminated
560.8	561.1	Dark brown to brown (7.5YR4/4) silty clay, microlaminated at top
561.1	561.4	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, 3.0-1.5 phi mode, ranging from fine to medium sand, cross-laminated, thick silty clay laminae
561.4	561.7	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, 3.0-2.5 phi mode, laminated
561.7	561.8	Yellowish brown (10YR5/4) fine sandstone, 3.0-2.5 phi mode, strongly carbonate cemented, strong reaction to HCl
561.8	562.0	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, 3.0-2.5 phi mode, laminated silt
562.0	562.4	Reddish brown (5YR4/4) clay, medium dry strength, low plasticity, laminated, microlaminated silt

569.0	569.2	Strong brown (7.5YR4/6) sandy silty clay
569.2	569.4	Brown (7.5YR5/4) silty fine sand, poorly sorted, numerous clayey silty laminae
569.4	569.6	Pinkish gray (7.5YR6/2) silty fine sand, poorly sorted and strong brown (7.5YR4/6) silty clay, mottled
569.6	569.7	Brown (7.5YR5/4) clayey silty fine sand, poorly sorted, massive, weakly cemented
569.7	570.1	Dark red (2.5YR3/6) clay, low dry strength, nonplastic, massive, scattered pockets of sandy silt
570.1	570.2	Light yellowish brown (10YR6/4) medium sand, grain size ranging from fine to medium sand, weakly carbonate cemented
572.7	573.3	Reddish brown (5YR4/4) clay and light reddish brown (5YR6/4) silty clay, thinly bedded, laminated clays
573.3	573.4	Light brown (7.5YR6/4) clayey sandy silt, red clay interlaminae
573.4	574.1	Reddish brown (5YR4/4) clay and light reddish brown (5YR6/4) silty clay, thinly bedded, laminated clays
576.0	576.1	Brown (7.5YR5/4) medium sandstone, quartz rich, strongly carbonate cemented, strong reaction to HCl, massive
576.1	576.3	Brown (7.5YR5/4) medium sandstone, grain size ranging from medium to coarse, strongly carbonate cemented, strong reaction to HCl, moderately sorted, massive
576.3	576.4	Strong brown (7.5YR5/6) silty fine sand, poorly sorted, faint laminations
576.4	576.6	Reddish brown (5YR4/4) clay-clayey silt and yellowish brown (10YR5/4) and reddish yellow (7.5YR6/6) clayey silty very fine sand, thickly interlaminated
576.6	576.9	Strong brown (7.5YR5/6) clayey sandy silt, massive, fining up to silty clay
576.9	577.2	Yellowish red (5YR4/6) silty clay, massive, clay ripup intraclasts are platy in appearance
577.2	577.3	Dark brown to brown (7.5YR4/4) clay, indistinctly laminated, low dry strength, nonplastic massive
593.4	593.6	Very pale brown (10YR7/3) fine sandstone, 2.5-2.0 phi mode, silt interbed, laminated, weakly carbonate cemented
593.6	594.3	Light brown (7.5YR6/4) fine sandstone, 2.5-2.0 phi mode, indistinctly laminated to massive
594.3	596.8	Yellowish red (5YR4/6) and dark brown to brown (7.5YR4/4) silty clay and clay, thinly bedded, microlaminated
596.8	597.6	Yellowish red (5YR5/6) sandy clayey silt, massive
597.6	597.7	Light brown (7.5YR6/4) fine sand, 3.0-2.0 phi mode, grain size ranging from fine to coarse sand
597.7	597.8	Yellowish red (5YR5/6) sandy clayey silt, massive
597.8	597.9	Reddish yellow (7.5YR6/6) silty clay
597.9	598.6	Strong brown (7.5YR5/6) silty fine sand, poorly sorted and clayey silt, interlaminated, sands ranging from fine to medium
598.6	598.9	Yellowish red (5YR5/6) silty clay, indistinctly laminated to massive
598.9	599.7	Yellowish red (5YR5/6), light brown (7.5YR6/4), yellowish red (5YR4/6), light yellowish brown (10YR6/4) clay, laminated, thinly bedded
599.7	600.0	Reddish yellow (7.5YR6/6) clayey silty fine sand, poorly sorted and clayey silt, interbedded
600.0	601.0	Yellowish red (5YR5/6-8) silty clay, indistinctly laminated to massive, pockets of light yellowish brown (10YR6/4) silty fine sand, poorly sorted
603.8	603.9	Strong brown (7.5YR5/6) and yellowish red (5YR5/6) clay
603.9	604.6	Yellowish brown (10YR5/4) silty clay and clay, low dry strength, nonplastic, laminated
604.6	604.9	Brown (7.5YR5/4) clayey silty fine sand, poorly sorted, 3.0-2.0 phi mode
604.9	606.3	Strong brown (7.5YR5/6) and yellowish red (5YR4/6) silty clay and clay, finely laminated to thinly bedded
606.3	606.8	Reddish brown (5YR4/4) clay, low dry strength, nonplastic, massive
606.8	608.8	Yellowish brown (10YR5/4) and light yellowish brown (10YR6/4) silty sandy clay and clay, coarsening up unit
608.8	609.4	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, grain size ranging from fine to medium
609.4	609.8	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, massive, weakly cemented
609.8	611.1	Yellowish brown (10YR5/4) silty clay and clay, interlaminated
611.1	611.6	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, grain size ranging from fine to medium
611.6	613.1	Yellowish brown (10YR5/4) silty clay and clay, interlaminated
613.1	613.3	Yellowish brown (10YR5/4-6) clayey silty very fine sand, 3.0-2.0 phi mode, poorly sorted, massive, weakly cemented
613.3	614.8	Reddish brown (5YR4/3) and brown (10YR5/3) silty clay and clay, laminated, thinly bedded
614.8	616.5	Brown (10YR5/3) clayey silty fine sand, poorly sorted, 3.0-2.5 phi mode, thinly interbedded
616.5	617.1	Light brown (7.5YR6/4) clay, fine sand and silt, 3.0-2.5 phi mode, interlaminated
617.1	617.4	Reddish brown (5YR4/3) and brown (10YR5/3) silty clay and clay, laminated, thinly bedded
617.4	617.7	Reddish brown (5YR4/4) and strong brown (7.5YR5/6) clay and silty clay, thinly bedded
617.7	619.2	Brown (7.5YR5/4) silty fine sand, poorly sorted, 2.5-2.0 phi mode, sands ranging from fine to coarse, indistinctly laminated, scattered granules
619.2	619.3	Reddish brown (5YR4/4) and strong brown (7.5YR5/6) clay and silty clay, thinly bedded
619.3	621.5	Reddish brown (5YR4/4) and strong brown (7.5YR5/6) clay, silty clay, sandy clayey silt beds, thinly

		bedded
621.5	623.5	Yellowish red (5YR5/6) silty clay and clay, laminated, thinly bedded, small gray (5YR5/1) ripup clasts
623.5	624.1	Brown (10YR5/3) clayey sandy silt, thinly interbedded
624.1	624.6	Brown (10YR5/3) to yellowish brown (10YR5/4) medium sand, 2.5-2.0 phi mode, sands ranging from fine to coarse sand, poorly sorted, small soft carbonate nodules
624.6	624.8	Very dark gray (10YR3/1) clayey sandy silt, organic layer
624.8	625.2	Pale brown (10YR6/3) medium sand, 2.0-1.5 phi mode, grain size ranging from fine to coarse, poorly sorted, basal weakly carbonate cemented
625.4	625.5	Brown (7.5YR5/4) silty fine sand, poorly sorted, sands ranging from fine to coarse,
625.5	625.9	Brown (7.5YR5/4) silty fine sand, poorly sorted, grain size ranging from fine to medium sand, upper silty clay laminae
625.9	626.1	Brown (10YR5/3) silty clay and clayey silt, interbedded
626.1	626.3	Light gray (10YR7/2) silty fine sand, poorly sorted, ranging from fine to medium sand, strongly carbonate rich at top, coarsening up unit
626.3	626.5	Brown (7.5YR5/4) medium sand, grain size ranging from fine to coarse
631.5	632.5	Brown (7.5YR5/2) silty very fine sand and silty clay, interlaminated to thinly interbedded
632.5	633.0	Yellowish red (5YR5/6) clay, low dry strength, nonplastic, wavy laminations
633.0	633.4	Brown (10YR5/3) silty fine sand, poorly sorted, sands ranging from fine to coarse, laminated, thinly bedded
634.4	635.9	Brown (10YR5/3) silty fine sand, poorly sorted, grain size ranging from fine to medium sand, massive
635.9	636.5	Brown (10YR5/3) silty fine sand, poorly sorted, ranging from fine to medium sand, moderately carbonate cemented, indistinctly laminated
636.5	637.2	Brown (10YR5/3) clayey silty very fine sand and sandy clayey silt, thinly interbedded
637.2	637.5	Dark brown to brown (10YR4/3) clayey silty fine sand, poorly sorted, massive, weakly cemented
637.5	638.0	Dark brown to brown (10YR4/3) clayey sandy silt, indistinctly laminated
638.0	638.6	Dark yellowish brown (10YR4/4) clayey silty fine sand, poorly sorted, indistinctly laminated
638.6	638.9	Dark brown to brown (10YR4/3) silty fine sand, poorly sorted, ranging from fine to medium sand, basal ironoxide staining
638.9	639.1	Dark brown to brown (10YR4/3) silty fine sand, poorly sorted, ranging from fine to coarse sand
639.1	639.2	Dark yellowish brown (10YR4/4) silt and silty clay, massive
639.2	639.3	Brown (10YR5/3) sandy silt
639.3	639.8	Brown (10YR5/3) clayey silty very fine sand, poorly sorted, massive, weakly cemented
641.4	641.9	Brown (7.5YR5/4) silty fine sand, poorly sorted, grain size ranging from fine to medium sand, massive
641.9	642.3	Dark brown to brown (7.5YR4/4) sandy silty clay
642.3	642.8	Dark brown to brown (7.5YR4/4) silty clay
642.8	643.1	Brown (7.5YR5/4) clayey sandy silt, massive
643.1	643.6	Brownish yellow (10YR6/6) silty fine sand, poorly sorted, and silty clay, interlaminated, sands ranging fromfine to medium grain size
643.6	643.7	Light brown (7.5YR6/4) clayey silt and silty clay to pale brown (10YR6/3) basal medium to coarse sand, fining up unit
649.0	649.8	Yellowish brown (10YR5/4) and brown (7.5YR5/4) clayey silt, silty clay, clayey silty sand, thinly bedded, mottled
649.8	650.8	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, 2.5-2.0 phi mode, laminated
650.8	650.9	Brown (10YR5/3) and pale brown (10YR6/3) clayey silt and clay, interlaminated
650.9	651.2	Yellowish brown (10YR5/4) to light gray (10YR7/2) silty fine sand, poorly sorted, 2.5-2.0 phi mode
651.2	651.3	Very pale brown (10YR7/3) gravelly coarse sand, 2.0-1.0 phi mode, poorly sorted
651.3	651.6	Brown (10YR5/3) silty clay and silty very fine sand, 2.5-2.0 phi mode, interlaminated
651.6	651.8	Brown (10YR5/3) gravelly coarse sand, grain size ranging from fine to coarse, well sorted, weakly carbonate cemented
656.0	656.2	Pinkish gray (7.5YR6/2) medium sand, 2.5-2.0 phi mode, ranging from fine to medium sand, moderately sorted, scattered feldspar
656.2	658.1	Yellowish brown (10YR5/4) and dark brown to brown (7.5YR4/4) silty clay and clay, thinly indistinctly laminated
658.1	658.4	Pinkish gray (7.5YR6/2) silty fine sand, poorly sorted, indistinctly laminated
658.4	660.2	Yellowish brown (10YR5/4) and dark brown to brown (7.5YR4/4) silty clay and clay, thinly indistinctly laminated
660.2	662.2	Pinkish gray (7.5YR6/2) medium sand, ranging from medium to coarse sand, strongly ripple laminated
662.2	662.3	Pinkish gray (7.5YR6/2) medium sand, ranging from fine to coarse sand, strongly ripple laminated, loose
662.3	663.8	Brown (7.5YR5/4) silty clay and light gray (10YR7/2) fine sand, 3.0-2.0 phi mode, laminated, deformed
663.8	664.9	Pale brown (10YR6/3) to light brownish gray (10YR6/2) fine sand, 3.0-2.5 phi mode

668.0	670.2	Brown (10YR5/3) and yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand, poorly sorted, indistinctly laminated, compact, mottled
670.3	670.4	Dark yellowish brown (10YR4/4) silty fine sand, poorly sorted and silt, 3.0-2.0 phi mode, sands ranging fromfine to coarse, laminated
670.4	670.5	Dark yellowish brown (10YR4/4) silt
670.5	671.0	Light yellowish brown (10YR6/4) silty fine sand, poorly sorted, 3.0-2.0 phi mode, sands ranging from fine to coarse
671.0	671.6	Yellowish brown (10YR5/4) clayey sand and silty clayey sand, thinly bedded
671.6	671.8	Dark brown to brown (7.5YR4/4) and yellowish brown (10YR5/4) silty clay
671.8	672.4	Yellowish brown (10YR5/4) silty medium sand, 2.5-1.5 phi, sands ranging from fine to medium, few silt clay laminae
672.4	672.7	Yellowish red (5YR4/6) and yellowish brown (10YR5/4) silty clay, low dry strength, nonplastic, microlaminated
672.7	672.9	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, massive, weakly cemented
672.9	673.9	Yellowish red (5YR4/6) and yellowish brown (10YR5/4) silty clay, microlaminated
676.3	676.9	Yellowish brown (10YR5/4) and strong brown (7.5YR5/6) sandy clayey silt and silty clay
676.9	677.1	Yellowish brown (10YR5/4) medium sandstone, 2.5-2.0 phi mode, grain size ranging from fine to coarse, strongly carbonate
678.5	679.0	Strong brown (7.5YR4/6) silty fine sand, poorly sorted, 2.5-2.0 phi mode
679.0	679.4	Dark brown to brown (7.5YR4/4) clayey silty fine sand, poorly sorted and yellowish red (5YR4/6) clay, interlaminated
679.4	679.8	Brown (7.5YR5/2-4) clayey silt and silty clay, interlaminated, thinly bedded
679.8	680.4	Brown (7.5YR5/2) silty fine sand, poorly sorted, 2.5-2.0 phi mode, loose
680.6	680.9	Light yellowish brown (10YR6/4) silty fine sand, poorly sorted, ranging from fine to coarse sand, laminated
680.9	681.1	Light yellowish brown (10YR6/4) medium sand, ranging from fine to coarse sand, weakly carbonate cemented
681.1	681.5	Light yellowish brown (10YR6/4) medium sand, grain size ranging from fine to medium sand
692.7	693.3	Dark brown to brown (7.5YR4/4) silty clay, massive, low dry strength, nonplastic
693.3	696.6	Light brown (7.5YR6/4) fine sand, 2.5-2.0 phi mode, laminated, ripple laminated, brown (10YR5/3) silt laminations
697.4	697.5	Pink (7.5YR7/4) medium sand, ranging from fine to coarse sand, weakly carbonate cemented
697.5	698.0	Pale brown (10YR6/3) fine sand, silty sand, dark brown to brown (10YR4/3) silty clay, sands ranging from fine to medium grain size, interbedded
698.0	698.1	Dark brown to brown (10YR4/3) silty clay
698.1	698.3	Brown (10YR5/3) fine sand, 2.5-1.5 phi mode, ranging from fine to coarse sand, massive, moderately sorted
702.5	702.8	Brown (7.5YR5/3) medium sand, grain size ranging from fine to coarse sand, laminated, poorly sorted
702.8	703.5	Brown (7.5YR5/3) medium sand, grain size ranging from fine to coarse sand, laminated, poorly sorted, thin interbeds of brown (10YR5/3) and dark brown to brown (10YR4/3) silty clay
703.5	703.6	Brown (7.5YR5/2) silty clay
703.6	704.1	Brown (7.5YR5/3) silty fine sand, poorly sorted, thin interlaminae of clayey silt
704.1	705.2	Dark yellowish brown (10YR4/4) silty clay, massive, low dry strength, nonplastic, upper laminations
705.2	706.5	Dark yellowish brown (10YR4/4) clayey sandy silt, thin interbeds of silty clay
706.5	708.2	Brown (10YR5/3) clayey silty very fine sand
708.2	708.7	Grayish brown (10YR5/2) clayey silty fine sand, poorly sorted, and brown (10YR5/3) silty clay and clay, mottled
708.8	710.2	Yellowish brown (10YR5/4) to dark yellowish brown (10YR4/4) silty clay, low dry strength, nonplastic, laminated
710.2	710.5	Dark grayish brown (2.5Y4/2) silty fine sand, poorly sorted, 3.0-2.5 phi mode
710.5	712.7	Grayish brown (2.5Y5/2) silty fine sand, poorly sorted and clayey silt, 3.0-2.5 phi mode, interlaminated to thinly interbedded
712.7	712.8	White (10YR8/1) fine sandstone, strongly carbonate cemented, strong reaction to HCl
712.8	712.9	White (10YR8/1) fine sand, moderately carbonate cemented
712.9	714.3	Dark grayish brown (2.5Y4/2) and dark brown to brown (7.5YR4/4) silty clay, medium dry strength, low plasticity, laminated, mottled, clay is sticky
714.3	714.5	Light brownish gray (10YR6/2) fine sand, 2.5-2.0 phi mode, moderately sorted, laminated
714.5	716.1	Dark grayish brown (2.5Y4/2) and dark brown to brown (7.5YR4/4) silty clay, laminated, mottled, clay is sticky
716.9	722.4	Dark grayish brown (2.5Y4/2) silty clay, laminated, mottled, soft sediment deformation
722.4	723.5	Light olive brown (2.5Y5/4) to grayish brown (2.5Y5/2) silty clay

723.5	723.9	Light gray (10YR7/2) medium sand, 2.0-1.5 phi mode, ranging from fine to medium sand, moderately sorted, weakly carbonate cemented, loose upper unit
732.4	733.0	Light gray (10YR7/2) dry to light brownish gray (10YR6/2) medium sandstone, 2.0-1.5 phi mode, strongly carbonate cemented, strong reaction to HCl, wet moisture condition, voids present
734.5	734.7	Light gray (10YR7/2) dry to light brownish gray (10YR6/2) medium sandstone, 2.0-1.5 phi mode strongly carbonate cemented, strong reaction to HCl, wet moisture condition, voids present
742.0	744.8	Light brownish gray (2.5Y6/2) silty fine sand, poorly sorted, crosslaminated, few carbonate-rich zones
744.8	744.9	Light brownish gray (2.5Y6/2) silty fine sand, poorly sorted, crosslaminated, weakly carbonate cemented
744.9	746.7	Grayish brown (2.5Y5/2) silty fine sand, poorly sorted, 2.0-3.0 phi mode, ranging from fine to medium sand, crosslaminated, locally irregularly strongly cemented
746.7	748.2	Light olive brown (2.5Y5/4) silty fine sand, poorly sorted, and clayey silty fine sand, poorly sorted, 3.0-2.5 phi mode, thinly bedded
748.2	749.2	Light olive brown (2.5Y5/4) silty clay, massive, medium dry strength, low plasticity
749.2	749.8	Gray to light gray (2.5Y6/0) silty clay and clay, microlaminated
749.8	750.1	Dark grayish brown (2.5Y4/2) and gray to light gray (2.5Y6/0) silty fine sand, poorly sorted and sandy silt, 3.0-2.5 phi mode, mottled
750.1	750.7	Dark grayish brown (2.5Y4/2) silty clay, massive, low dry strength, nonplastic
750.7	750.8	Gray (2.5Y5/0) silty fine sand, poorly sorted, massive, weakly cemented
752.3	754.7	Yellowish brown (10YR5/4) to dark yellowish brown (10YR4/4) clayey silty fine sand, poorly sorted, massive
754.7	756.3	Brownish yellow (10YR6/6) silty fine sand, poorly sorted, indistinctly laminated
756.3	756.8	Yellowish brown (10YR5/6-4) silty clay and silty sand, interbedded
756.8	760.4	Yellowish brown (10YR5/6-4) silty clay
760.4	760.8	Brown (10YR5/3) fine sand, 2.5-2.0 phi mode, indistinctly bedded
760.8	761.0	Brown (10YR5/3) fine sandstone, 2.5-2.0 phi mode, strongly carbonate cemented, strong reaction to HCl
761.0	761.2	Yellowish brown (10YR5/4) silty clay
761.2	762.0	Brown (10YR5/3) silty fine sand, poorly sorted, ranging from fine to medium sand, massive, loose,
769.0	770.5	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, 2.5-2.0 phi mode, moderately carbonate cemented layers
770.5	771.8	Yellowish brown (10YR5/4) medium sand, 2.0-1.5 phi mode, moderately sorted, laminated, crossbedded
771.8	773.4	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, 2.5-2.0 phi mode, soft carbonate nodules
775.1	776.5	Yellowish brown (10YR5/4) medium sand, 2.0-1.5 phi mode, ranging from fine to coarse sand, poorly sorted
776.5	776.6	Pebble gravel
776.6	778.1	Dark brown to brown (7.5YR4/4) silty sand, moderately cemented, soft carbonate nodules
778.1	778.2	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, ranging from fine to medium sand, loose
782.0	782.3	Brown (7.5YR5/4) clayey silt, basal caliche nodules
782.3	783.4	Brown (7.5YR5/4) clayey very fine sandy silt
783.4	783.5	Reddish brown (5YR5/4) clay
783.5	783.7	Brown (7.5YR5/4) clayey very fine sandy silt
783.7	783.9	Reddish brown (5YR5/4) clay, irregularly carbonate-cemented
783.9	784.5	Brown (7.5YR5/4) clayey very fine sandy silt
784.5	784.5	Reddish brown (5YR5/4) clay
784.5	784.7	Brown (7.5YR5/4) clayey very fine sandy silt
784.7	785.5	Light brownish gray (10YR6/2) medium sand, 2.0-1.5 phi mode, ranging from fine to medium sand
789.0	798.1	Brown (7.5YR5/4) medium sand, 2.0-1.5 phi mode, crossbedded, scattered moderately carbonate-cementated
799.1	799.3	Brown (7.5YR5/4) medium sand, 2.5-1.5 phi mode, ranging from fine to medium sand, caliche zone
799.3	803.4	Brown (7.5YR5/4) medium sand, 2.5-1.5 phi mode, ranging from fine to medium sand
803.4	804.1	Brown (7.5YR5/4) medium sand, 2.0-1.5 phi mode
804.1	805.0	Brown (7.5YR5/4) fine sand, 2.5-2.0 phi mode, massive
807.7	808.8	Light brown (7.5YR6/4) wet to pinkish white (7.5YR8/2) medium sand, 2.0-1.5 phi mode, indistinctly laminated, dry moisture condition
808.8	809.2	Light brown (7.5YR6/4) wet to pinkish white (7.5YR8/2) medium sand, 2.0-1.5 phi mode, indistinctly laminated, moderately cemented, dry moisture condition
812.5	821.2	Pale brown (10YR6/3) medium sand, 2.0-1.5 phi, ranging from fine to coarse sand, indistinctly bedded, indistinct soft carbonate nodules
822.0	824.0	Brown (10YR5/3) medium sand, 2.0-1.0 phi mode, ranging from medium to coarse sand, indistinctly bedded, moderately sorted, soft carbonate nodules
824.0	824.9	Brown (10YR5/3) gravelly coarse sand, wash out zones

824.9	825.1	Brown (10YR5/3) gravel, angular pebble gravel with basalt, wash out zone
825.1	825.9	Brown (10YR5/3) medium sand, 2.5-1.5 phi mode, grain size ranging from fine to medium sand
832.0	832.2	Dark brown to brown (7.5YR4/4) clayey medium sand, ranging from medium to coarse sand
832.2	832.4	Pinkish gray (7.5YR7/2) medium sand, weakly carbonate cemented
832.4	832.5	quartzite gravel, washout zone
832.5	832.9	Brown (7.5YR5/4) gravelly medium sand, ranging from medium to coarse sand, scattered pebbles and moderately cemented carbonate nodules
842.0	842.7	Dark brown to brown (7.5YR4/4) medium sand, 1.5-1.0 phi mode, ranging from medium to very coarse sand, few granules
842.7	842.8	Pebble gravel, rounded to subangular and fractured, matrix washed away, chert, basalt, quartz, granite
842.8	843.1	Brown (7.5YR5/4) medium sand, 2.5-1.5 phi mode, carbonate nodules
843.1	844.2	Brown (7.5YR5/4) coarse sand, moderately sorted, loose, and granules
848.7	849.1	Brown (7.5YR5/2) gravelly coarse sand, ranging from fine to coarse sand, poorly sorted
849.7	849.9	Pinkish gray (7.5YR7/2) medium sandstone, grain size ranging from fine to medium sand, scattered granules and small pebbles, poorly sorted, ash pebbles(?)
849.9	852.7	Brown (7.5YR5/4) medium sand matrix, ranging from fine to medium sand, scattered pebbles, volcanics, basalt, quartzite, discontinuous carbonate zones
859.7	859.9	Dark brown to brown (7.5YR4/4) coarse sand, moderately sorted, moderately cemented, HCl reaction none
859.9	860.1	Brown (7.5YR5/4) mudstone, few matrix-supported pebbles
860.1	860.3	Pebble gravel and loose pebbles, quartzite, basalt, silicic metamorphic
860.3	860.6	Brown (7.5YR5/2) medium sand, ranging from fine to coarse sand, loose
869.1	869.8	Dark brown to brown (10YR4/3) fine sand, 3.0-2.0 phi mode, ranging from fine to medium sand, laminated, heavy minerals
869.8	870.4	Dark brown to brown (10YR4/3) fine sand, 3.0-2.0 phi mode, ranging from fine to medium sand, laminated, moderately cemented, heavy minerals
870.4	870.9	Dark brown to brown (10YR4/3) medium sand, 2.0-1.5 phi mode, ranging from fine to coarse sand, massive
879.1	879.3	Brown (7.5YR5/2) medium sandstone, ranging from medium to very coarse sand, HCl reaction none, strongly carbonate cemented, strong reaction to HCl
879.3	879.4	Reddish brown (5YR4/4) clay, indistinctly laminated, low dry strength, nonplastic, abundant carbonate nodules
879.4	879.6	Dark brown to brown (10YR4/3) silty clay, low dry strength, nonplastic, massive
879.6	879.9	Dark brown to brown (10YR4/3) silty fine sand, poorly sorted, compact, massive
879.9	880.5	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand, compact, granules
880.5	880.7	Dark brown to brown (10YR4/3) silty clay, dense
889.1	889.4	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand
889.4	890.2	Yellowish brown (10YR5/4) fine sand, ranging from fine to coarse sand
890.2	890.5	Yellowish brown (10YR5/4) gravelly coarse sand, ranging from fine to coarse sand, poorly sorted, irregular weakly carbonate cement zones
890.5	890.7	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand
893.1	894.5	Yellowish brown (10YR5/4) medium sand, ranging from fine to medium sand, basal scattered soft carbonate nodules, massive
894.5	894.7	Yellowish brown (10YR5/6) medium sand, basal soft carbonate nodules, massive
894.7	894.9	Yellowish brown (10YR5/4) fine sand, ranging from fine to medium sand, weakly carbonate cemented
894.9	895.5	Brown to pale brown (10YR6-5/3) medium sand, well compacted, weakly cemented
902.0	902.7	Pale brown (10YR6/3) medium sand, ranging from fine to coarse sand, strongly cemented, strong reaction to HCl, soft carbonate nodules
909.5	909.8	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand, granules and pebbles, carbonate rich
909.8	910.7	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand, compact
913.7	914.9	Brown (7.5YR5/4) gravelly coarse sand, medium sand matrix, cross-bedded
914.9	915.9	Brown (7.5YR5/4) fine sand, 2.5-2.0 phi mode, ranging from fine to medium sand, scattered granules, cross-bedded
915.9	916.8	Brown (7.5YR5/4) gravelly coarse sand, grains size ranging from medium to coarse sand, massive
916.8	917.0	Brown (7.5YR5/4) gravelly coarse sand, ranging from medium to coarse, massive, white moderately carbonate cemented
917.0	917.2	Brown (7.5YR5/4) coarse sand, ranging from fine to coarse sand, granules, small pebbles
917.9	919.9	Yellowish brown (10YR5/4) fine sand, cross-laminated, flat laminated, well iron cemented laminae
919.9	922.5	Yellowish brown (10YR5/4) medium sand, grain size ranging from fine to coarse sand, cross-laminated, heavy mineral laminations, coarsens toward base
929.3	930.3	Yellowish brown (10YR5/4) fine sand, flat laminated, heavy minerals

930.3	930.6	Yellowish brown (10YR5/4) fine sand, flat laminated, heavy minerals
930.6	930.8	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, weak carbonate cement
930.8	931.0	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, weak carbonate cement, loose
931.0	932.1	Yellowish brown (10YR5/4) fine sand, 2.5-2.0 phi, indistinctly laminated
932.1	932.5	Yellowish brown (10YR5/4) fine sand, 2.5-2.0 phi mode, indistinctly laminated, moderately carbonate cemented
932.5	932.6	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand, massive, light yellowish brown (10YR6/4) carbonate cementation, loose sand intervals
932.6	932.8	Yellowish brown (10YR5/4) coarse sand, ranging from medium to coarse sand, loose, massive, light yellowish brown (10YR6/4) moderately carbonate cemented
932.8	933.7	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand, massive, light yellowish brown (10YR6/4) moderately carbonate cemented
942.0	942.7	Light yellowish brown (10YR6/4) medium sand, 2.5-2.0 phi mode, massive
942.7	942.8	Light yellowish brown (10YR6/4) medium sand, 2.5-2.0 phi mode, massive, moderately carbonate cemented
942.8	945.9	Light yellowish brown (10YR6/4) medium sand, 2.5-2.0 phi mode, massive
945.9	946.2	Grayish brown (10YR5/2) medium sandstone, massive, strongly carbonate cemented, strong reaction to HCl
946.2	977.0	Grayish brown (10YR5/2) medium sand, massive
977.0	977.3	Light yellowish brown (10YR6/4) clayey silt, laminated, very compact
977.3	978.5	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, very compact, clayey silty layer
978.5	979.3	Brown (10YR5/3) clayey silt, laminated, very compact
979.3	980.2	Dark brown to brown (7.5YR4/4) and brown (10YR5/3) silty clay and clay, thinly interbedded
980.2	980.8	Brown (10YR5/3) sandy clayey silt, distorted laminations
980.8	981.4	Pale brown (10YR6/3) medium sand, ranging from fine to coarse sand, weakly cemented
982.0	982.6	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand
982.6	1002.0	Yellowish brown (10YR5/4) medium sand, grain size ranging from fine to coarse sand, loose
1002.0	1003.1	Pale brown (10YR6/3) medium sand, ranging from fine to coarse sand, discontinuous well cemented carbonate zones, numerous volcanic pebbles in top .1 foot
1003.1	1004.6	Pale brown (10YR6/3) medium sand, ranging from fine to coarse sand, moderately carbonate cemented, coarser than above, silicmetamorphic shist pebble
1004.6	1005.0	Dark brown to brown (7.5YR4/2) gravelly coarse sand, manganese stained calcite cement sandstone, strongly cemented, strong reaction to HCl, clasts are quartzite, granite, volcanics
1017.0	1017.5	Brown (7.5YR5/4) silty fine sand, poorly sorted, pinkish gray (7.5YR6/2) strongly carbonate cemented, strong reaction to HCl
1017.5	1019.3	Brown (7.5YR5/4) silty fine sand, poorly sorted, ranging from fine to coarse sand, laminated, cross-laminated, very compact to strongly cemented carbonate zones
1022.0	1022.5	Dark yellowish brown (10YR4/4) fine sand, 2.5-2.0 phi mode, ranging from fine to coarse sand
1022.5	1022.8	Dark yellowish brown (10YR4/4) medium sand, ranging from fine to coarse sand, weakly carbonate cemented, soft carbonate nodules
1022.8	1023.2	Dark yellowish brown (10YR4/4) medium sandstone, magnesium stained, discontinuous strongly carbonate cemented zones
1031.0	1031.4	Dark yellowish brown (10YR4/4) gravelly coarse sand, fine sand matrix, poorly sorted
1031.4	1031.8	Yellowish brown (10YR5/4) fine sand, ranging from fine to medium sand, broken pebbles, washed out zone
1031.8	1032.1	Pink (7.5YR7/4) fine sandy silt, complete strong carbonate cementation
1032.1	1033.0	Brown (7.5YR5/2) silty fine sand, poorly sorted
1033.0	1034.1	Light brown (7.5YR6/4) fine sand, 3.0-2.5 phi mode, yellowish red (5YR5/6) red mottles, moderately carbonate cemented zone
1035.4	1035.5	Light brown (7.5YR6/4) silty fine sand, poorly sorted, grain size ranging from fine to medium sand
1035.5	1036.7	Light brown (7.5YR6/4) silty fine sand, poorly sorted, grain size ranging from fine to medium sand
1036.7	1036.5	Brown (10YR5/3) silty fine sand, poorly sorted, 2.0-1.5 phi mode, ranging from fine to medium sand
1036.5	1036.7	Pink (7.5YR7/4) silty fine sand, poorly sorted, 2.0-1.5 phi mode, ranging from fine to medium sand, moderately carbonate cement zone
1036.7	1038.1	Pink (7.5YR7/4) sandstone, strongly cemented, washed, fragments
1042.0	1043.0	Brown (10YR5/3) coarse sand, moderately sorted, moderately carbonate cemented zone, thin red clay layer
1043.0	1043.4	Pale brown (10YR6/3) silty fine sand, poorly sorted, cross-laminated, heavy minerals
1043.4	1043.9	Pale brown (10YR6/3) medium sand, ranging from fine to coarse sand, weakly laminated
1043.9	1044.0	medium sandstone, grain size ranging from medium to coarse, well cemented, strong manganese staining wad
1044.0	1044.3	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand, weakly laminated

1044.3	1044.5	Light yellowish brown (10YR6/4) clayey silty fine sand, poorly sorted, massive, weakly cemented
1044.5	1045.0	Light yellowish brown (10YR6/4) fine sand, ranging from fine to coarse sand, indistinctly laminated, basal moderate carbonate cementation
1045.0	1046.7	Light yellowish brown (10YR6/4) silty fine sand, poorly sorted
1046.7	1047.0	Light yellowish brown (10YR6/4) clayey silty very fine sand, poorly sorted, massive, weakly cemented
1052.0	1052.8	Light yellowish brown (10YR6/4) silty clayey fine sand, 3.0-2.5 phi mode, poorly sorted, massive, weakly cemented
1052.8	1053.0	Brown (7.5YR5/4) silty clay
1053.0	1053.3	Light brown (7.5YR6/4) silty clayey fine sand
1053.3	1055.1	Light yellowish brown (10YR6/4) fine sand, 2.5-2.0 phi mode
1055.1	1055.8	Light yellowish brown (10YR6/4) fine sand, 2.5-2.0 phi mode, moderately carbonate cemented
1055.8	1058.9	Light yellowish brown (10YR6/4) fine sand, 2.5-2.0 phi mode
1062.0	1064.3	Yellowish brown (10YR5/4) medium sand, 2.5-1.5 phi mode, ranging from fine to coarse sand, scattered soft carbonate nodules
1064.3	1064.5	Yellowish brown (10YR5/4) medium sand, 2.5-1.5 phi mode, ranging from fine to coarse sand, weakly carbonate cemented, scattered soft carbonate nodules
1064.5	1064.8	Yellowish brown (10YR5/4) silty clayey fine sand, 2.0-1.5 phi mode
1064.8	1065.6	Brown (10YR5/3) silty sand, 2.0-1.5 phi mode, heavy mineral laminations
1065.6	1066.1	Brown (10YR5/3) silty fine sand, poorly sorted, 2.5-2.0 phi mode
1072.0	1072.1	Pink (5YR8/3-4) silty clay, moderately cemented carbonate zone, ash or old clay (?)
1072.1	1072.2	Reddish brown (5YR5/4) clay, indistinctly laminated, transition zone
1072.2	1072.4	Yellowish brown (10YR5/4) sandy clayey silt
1076.1	1076.7	Pale brown (10YR6/3) silty fine sand, poorly sorted, 2.5-1.5 phi mode, ranging from fine to coarse sand
1076.7	1077.3	Pale brown (10YR6/3) silty clayey fine sand, sand grain size ranging from fine to medium, poorly sorted, massive, weakly cemented
1077.3	1078.9	Yellowish brown (10YR5/4) coarse sand, 1.5-1.0 phi mode, ranging from medium to coarse sand, wet moisture condition, coarsens at base
1078.9	1079.0	Yellowish brown (10YR5/4) gravelly coarse sand, moderately sorted, loose, 1.5-1.0 phi mode, granules, small pebbles
1079.0	1079.4	Yellowish brown (10YR5/4) coarse sand, 1.5-1.0 phi mode, ranging from fine to coarse sand, wet moisture condition
1082.0	1083.1	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, 2.5-2.0 phi mode
1083.1	1083.7	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand, strongly carbonate cemented, strong reaction to HCl
1083.7	1083.8	Brown (10YR5/3) gravelly coarse sand, moderately sorted, loose
1083.8	1084.1	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand, fining down unit
1084.1	1084.7	Yellowish brown (10YR5/4) silty medium sand, 2.0-1.5 phi mode, poorly sorted, massive, weakly cemented
1084.7	1084.8	Gravel, broken subrounded pebbles of basalt and volcanics
1096.3	1096.4	Grayish brown (10YR5/2) silty medium sand, moderately carbonate cementation
1096.4	1096.7	Grayish brown (10YR5/2) silty medium sand
1096.7	1097.6	Grayish brown (10YR5/2) medium sand, 2.0-1.0 phi mode
1097.6	1098.4	Grayish brown (10YR5/2) coarse sand, moderately sorted, loose, 1.0-0.5 phi mode
1098.4	1098.5	Grayish brown (10YR5/2) silty clayey fine sand, 3.0-2.5 phi mode, poorly sorted, massive, weakly cemented
1098.5	1098.7	Light brownish gray (10YR6/2) to grayish brown (2.5Y5/2) silty clayey medium sand, 2.0-1.5 phi mode
1102.0	1102.6	Light brownish gray (10YR6/2) medium sand, 2.0-1.5 phi mode, ranging from fine to coarse sand, laminated dark sand
1102.6	1102.8	Light brownish gray (10YR6/2) fine sand, 2.5-2.0 phi mode, laminated
1112.0	1112.3	Pale brown (10YR6/3) medium sand, 2.0-1.5 phi mode, flat laminated, heavy minerals
1112.3	1112.6	Pebble gravel, washed zone, basalt pebbles, carbonate cemented sand fragment
1112.6	1113.1	Brown (10YR5/3) fine sand, 2.5-2.0 phi mode, indistinctly laminated
1113.1	1113.2	Brown (10YR5/3) fine sand, 2.5-2.0 phi mode, indistinctly laminated, discontinuous moderately carbonate cementation
1113.2	1113.6	Brown (10YR5/3) fine sand, 2.5-2.0 phi mode, indistinctly laminated
1115.6	1116.5	Very pale brown (10YR7/3) fine sand, 2.5-2.0 phi mode
1116.5	1119.6	Gray (10YR5/1) medium sand, 2.0-1.5 phi mode, ranging from fine to coarse sand, laminated, scattered nodules,
1119.6	1119.6	Gray (10YR5/1) fine sand, 3.0-2.5 phi mode
1119.6	1120.1	Gray (10YR5/1) fine sand, 3.0-2.5 phi mode, weakly cemented

1120.1	1120.3	Gray (10YR5/1) fine sand, 3.0-2.5 phi mode
1122.0	1122.7	Pale brown (10YR6/3) silty fine sand, poorly sorted, 3.0-2.0 phi mode, ranging from fine to medium sand
1122.7	1122.8	Pale brown (10YR6/3) silty fine sand, poorly sorted, 3.0-2.0 phi mode, ranging from fine to medium sand, light gray (10YR7/2) moderately carbonate-cemented zone
1122.8	1122.9	Pale brown (10YR6/3) silty fine sand, poorly sorted, 3.0-2.0 phi mode, ranging from fine to medium sand
1122.9	1125.7	Pale brown (10YR6/3) silty fine sand, poorly sorted, 2.5-2.0 phi mode, sand ranging from fine to coarse, soft carbonate nodules
1125.7	1125.8	Pale brown (10YR6/3) silty fine sand, poorly sorted, 2.5-2.0 phi mode, ranging from fine to coarse sand, soft carbonate nodules, strongly cemented
1125.8	1125.9	Pale brown (10YR6/3) silty fine sand, poorly sorted, 3.0-2.5 phi mode
1132.0	1132.9	Brown (10YR5/3) silty fine sand, poorly sorted, 3.0-2.5 phi mode, ripple laminated, moderately cemented, heavy minerals
1132.9	1133.5	Brown (10YR5/3) medium sand, 2.0-1.5 phi mode, moderately cemented
1133.5	1134.5	Brown (10YR5/3) medium sand, ranging from fine to coarse sand, moderately cemented, basal soft carbonate nodules
1142.0	1142.1	Brown (10YR5/3) fine sand, ranging from fine to medium sand, moderately cemented
1142.1	1142.3	Brown (10YR5/3) fine to medium sand
1162.0	1162.8	Light brownish gray (10YR6/2) and pale brown (10YR6/3) medium to fine sand, 2.5-2.0 phi mode
1170.2	1170.4	Very pale brown (10YR7/3) fine sandstone, strongly cemented, strong reaction to HCl
1170.4	1171.5	Brown (10YR5/3) to pale brown (10YR6/3) medium sand, 2.5-1.5 phi mode
1171.5	1171.7	Brown (10YR5/3) gravelly coarse sand, 2.0-1.0 phi mode, pebbles, granite, quartzite, volcanics
1181.0	1181.4	Light gray (5Y7/1) fine sandy silt, laminated
1181.4	1181.5	Dark grayish brown (10YR4/2) clayey sandy silt
1181.5	1183.3	Light brownish gray (10YR6/2) gravelly coarse sand, 1.5-1.0 phi mode, ranging from fine to coarse sand matrix, poorly sorted, variegated, clasts of brown (10YR5/3) clay silt and silt, volcanic fragments, mica fragments, clay ripup clasts, altered volcanics
1183.3	1183.9	Light brownish gray (10YR6/2) silty fine sand, poorly sorted, ranging from fine to coarse sand, volcanics, variegated clasts
1183.9	1184.5	Brown (10YR5/3) medium to fine sand, moderately sorted
1184.5	1184.7	Brown (10YR5/3) fine sand
1184.7	1185.4	Pale brown (10YR6/3) medium sand
1189.0	1193.3	Light brownish gray (10YR6/2) to pale brown (10YR6/3) medium sand, 2.0-1.5 phi mode, laminated
1195.2	1196.5	Pale brown (10YR6/3) medium sand, 1.5-2.5 phi mode, laminated
1196.5	1196.8	Pale brown (10YR6/3) medium sand, 1.5-2.5 phi mode, laminated, white (10YR8/2) soft carbonate nodules
1196.8	1197.0	Pale brown (10YR6/3) medium sand, 1.5-2.5 phi mode, laminated
1203.0	1209.9	Yellowish brown (10YR5/4) medium sand, 2.0-1.5 phi mode, indistinctly laminated, large carbonate nodule
1209.9	1212.2	Yellowish brown (10YR5/4) medium sand, 2.0-1.5 phi mode, ranging from fine to coarse sand, massive
1213.0	1213.8	Pale brown (10YR6/3) medium sand, 2.0-3.0 phi mode, weakly laminated, wet moisture condition
1213.8	1214.0	Pale brown (10YR6/3) medium sand, ranging from fine to coarse sand, moderately cemented, soft carbonate nodules, wet moisture condition
1214.0	1215.9	Pale brown (10YR6/3) medium sand, 2.0-3.0 phi mode, weakly laminated, weakly cemented, wet moisture condition
1215.9	1217.0	Light yellowish brown (10YR6/4) to yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand, laminated, layered, weakly cemented, numerous soft carbonate nodules
1222.0	1223.0	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand
1223.0	1223.2	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand, weakly basal carbonate cemented
1223.6	1224.1	Pale brown (10YR6/3) medium sand, ranging from fine to coarse sand, weakly carbonate cemented
1224.1	1225.0	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand, few soft carbonate nodules
1225.0	1226.4	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand
1226.4	1226.4	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand, thin moderately carbonate cemented layer
1226.4	1226.5	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand
1226.5	1227.4	Light yellowish brown (10YR6/4) medium sand
1233.2	1241.7	Yellowish brown (10YR5/4) medium sand, grain size ranging from fine to coarse sand, clean, massive, carbonate nodules, wet moisture condition
1242.2	1242.8	Yellowish brown (10YR5/4) medium sand. Ranging from fine to coarse sand, discontinuous carbonate zone, very compact, weakly cemented
1242.8	1243.3	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand, very compact, weakly cemented

1244.0	1245.2	Light yellowish brown (10YR6/4) medium sand, ranging from fine to coarse sand, white carbonate cement
1245.2	1245.6	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand, loose
1245.6	1246.2	Dark yellowish brown (10YR4/4) to reddish brown (5YR4/4) silty clay, irregular pockets of fine sand
1246.2	1246.6	Reddish brown (5YR4/4) silty clay
1246.6	1247.6	Brown (10YR5/3) clayey sandy silt
1254.0	1255.8	Yellowish brown (10YR5/4) medium sand, 2.0-1.5 phi mode, ranging from fine to coarse sand, laminated, gravelly, poorly sorted
1255.8	1256.0	Brown (10YR5/3) silty fine sand, poorly sorted, massive
1256.0	1256.1	Brown (10YR5/3) silty fine sand, poorly sorted, discontinuously weakly carbonate cemented
1259.5	1260.0	White (10YR8/1) medium sand, moderately cemented carbonate zone
1260.0	1260.4	Light brownish gray (10YR6/2) medium sand, 2.5-1.5 phi mode, moderately sorted
1260.4	1260.5	Light brownish gray (10YR6/2) gravelly coarse sand, moderately sorted, loose
1260.5	1260.7	Yellowish brown (10YR5/4) medium sand, moderately discontinuous cementation
1260.7	1260.9	Yellowish brown (10YR5/4) silt, microlaminated, very compact to strongly cemented
1260.9	1261.3	Pink (7.5YR7/4) fine sand, 2.5-2.0 phi mode, laminated, discontinuously moderately cemented lenses, heavy minerals
1261.3	1261.8	Brown (10YR5/3) silt, microlamination, thin sections of very fine sand, discontinuously moderately cemented, scattered soft carbonate nodules
1261.8	1262.0	Brown (10YR5/3) silty fine sand, poorly sorted, 2.0-3.0 phi mode, laminated
1262.0	1262.5	Brown (10YR5/3) silt and clayey silt, microlaminated
1262.5	1262.7	Light brownish gray (10YR6/2) fine sand, irregularly discontinuously moderate carbonate cementation, heavy minerals
1262.7	1266.6	Brown (10YR5/3) medium sand, 2.5-1.5 phi mode, moderately sorted, laminated, heavy minerals, weak carbonate cemented zone, discontinuous, iron manganese staining
1266.6	1267.0	Brown (10YR5/3) medium sand, 2.5-1.5 phi mode, moderately sorted, laminated, heavy minerals, well cemented carbonate zone, discontinuous, iron manganese staining
1267.0	1267.7	Brown (10YR5/3) medium sand, 2.5-2.0 phi mode, ranging from fine to coarse sand
1267.7	1267.8	Yellowish brown (10YR5/4) fine sand, 3.0-2.0 phi mode, ranging from fine to medium sand, weakly cemented
1267.8	1268.0	Yellowish brown (10YR5/4) medium sandstone, strongly cemented, strong reaction to HCl, iron manganese stain
1268.0	1268.2	Yellowish brown (10YR5/4) medium sand, 3.0-2.0 phi mode, weakly cemented
1269.0	1269.1	Light gray (10YR7/2) medium sand, 2.5-1.5 phi mode, moderately cemented
1269.1	1269.7	Reddish brown (5YR4/4) silty fine sand, poorly sorted, 2.5-1.5 phi mode, ranging from fine to medium sand, red clay clasts
1269.7	1272.6	Grayish brown (10YR5/2) medium sand, 2.5-1.5 phi mode, laminated, moderately sorted, compact, heavy minerals
1272.6	1272.7	Light brownish gray (10YR6/2) fine sand, 3.0-2.5 phi mode, continuously moderately carbonate cemented
1272.7	1272.9	Light brownish gray (10YR6/2) fine sand, 3.0-2.5 phi mode
1272.9	1273.2	Light gray (10YR7/2) silt, strongly cemented, strong reaction to HCl
1273.2	1273.3	Pale brown (10YR6/2) silty fine sand, poorly sorted, laminated
1273.3	1274.6	Pale brown (10YR6/2) silty fine sand, poorly sorted, laminated, moderately carbonate cemented
1274.6	1277.0	Pale brown (10YR6/2) silty fine sand, poorly sorted, laminated
1277.0	1278.7	Pale brown (10YR6/2) silty fine sand, poorly sorted, laminated, strong continuous carbonate cemented zone
1279.0	1279.2	Brown (7.5YR5/4) silty clay
1279.2	1279.2	Yellowish brown (10YR5/4) silty clayey fine sand, poorly sorted, massive, weakly cemented
1279.2	1281.8	Pinkish gray (10YR6/2) medium sand, 2.5-1.5 phi mode, poorly sorted, slightly silty
1281.8	1281.9	Yellowish brown (10YR5/4) fine sand, 3.0-2.5 phi mode, thin weakly cemented carbonate zone
1281.9	1282.0	Yellowish brown (10YR5/4) fine sand
1282.0	1282.8	Yellowish brown (10YR5/4) fine sand, 3.0-2.5 phi mode, weakly cemented carbonate zone
1282.8	1283.3	White (10YR8/2) fine sand, strongly cemented carbonate zone
1283.3	1284.9	Brown (10YR5/3) silt and yellowish brown (10YR5/4) medium sand, 2.0-1.0 phi mode, clasts of pebble silt, clay ripup clasts
1289.0	1289.2	Light brownish gray (10YR6/2) medium sand, 2.0-1.0 phi mode, ranging from fine to coarse sand, clay ripup intraclasts
1289.2	1289.4	Pale brown (10YR6/3) fine sand, 2.5-2.0 phi mode, ranging from fine to coarse sand
1289.4	1290.0	Pale brown (10YR6/3) medium sand, ranging from fine to coarse sand, laminated, pebbles
1290.0	1290.2	Pale brown (10YR6/3) fine sand, 3.0-2.5 phi mode, some silt
1290.2	1290.4	Brown (10YR5/3) fine sand, 2.5-2.0 phi mode, ranging from fine to coarse sand

1290.4	1290.5	Brown (10YR5/3) fine sand, weakly carbonate cemented
1299.0	1300.0	Yellowish brown (10YR5/4) medium sand, 2.5-1.5 phi mode, ranging from fine to coarse sand, granules
1300.0	1300.1	Reddish brown (5YR5/3) gravelly coarse sand, 2.0-1.5 phi mode, quartz, basalt pebbles
1300.1	1300.3	Reddish brown (5YR4/3) silty clayey sand, discontinuously moderate carbonate cementation
1300.3	1300.7	Reddish brown (5YR4/3) silty sand and silty clayey fine sand
1305.4	1305.8	Pinkish white (5YR8/2) fine sandstone, strong carbonate cementation
1305.8	1306.1	Brown (10YR5/3) medium sand, 2.5-2.0 phi mode, moderately sorted
1306.1	1308.4	Brownish yellow (10YR6/6) and grayish brown (10YR5/2) fine sand, 2.5-2.0 phi mode, ranging from fine to medium sand, some silt, moderately sorted, prominent carbonate zone with iron staining, irregular nodules throughout
1308.4	1308.5	Brownish yellow (10YR6/6) and grayish brown (10YR5/2) fine sand, 2.5-2.0 phi mode, ranging fine to coarse sand, some silt, poorly sorted, prominent carbonate zone with iron staining, irregular nodules throughout, continuous cementation
1395.9	1397.8	Light gray to gray (10YR6/1) fine sand, 3.0-2.5 phi mode, cross lamination, ripple lamination, heavy minerals, discontinuous carbonate cementation, clay clasts .75-2 cm in length
1397.8	1398.0	Light gray to gray (10YR6/1) fine sand, 3.0-2.5 phi mode, ripple cross lamination, heavy minerals, clay clasts 0.75-2 cm in length
1398.0	1398.2	Light brownish gray (10YR6/2) silt, interbedded silt clay and fine sand
1398.2	1398.6	Light brownish gray (10YR6/2) siltstone, laminated, dense, strongly cemented, strong reaction to HCl
1398.6	1398.7	Dark grayish brown (10YR4/2) fine sand, interlaminated silty clay and silt
1398.7	1399.6	Dark grayish brown (10YR4/2) siltstone and silty clay, laminated, very dense, strongly cemented, strong reaction to HCl
1399.6	1399.7	Pale brown (10YR6/3) fine sand, 3.0-2.0 phi mode, cross laminated
1399.7	1401.8	Pale brown (10YR6/3) medium sand, 2.5-1.5 phi mode, crossbedded
1401.8	1402.0	Pale brown (10YR6/3) medium sand, 2.0-1.0 phi mode, flat laminated, interlaminated very fine sand and fine sand (2.5-2.0 phi), locally cross-laminated
1402.0	1403.1	Light yellowish brown (10YR6/4) silty fine sand, poorly sorted, 3.0-2.0 phi mode, cross-laminated
1403.1	1403.3	Pale brown (10YR6/3) fine sand, 3.0-2.0 phi mode, cross-laminated
1403.3	1404.4	Pale brown (10YR6/3) fine sand, 3.0-2.0 phi mode, cross-laminated, discontinuously cemented
1405.0	1406.5	Brown (10YR5/3) medium sand, 2.5-1.0 phi mode, ranging from fine to coarse sand, interlaminated, lowest laminations contain possible pumice, clasts of green clayey silt
1406.5	1411.5	Gray (10YR5/1) medium sand, 2.0-1.5 phi mode, ranging from fine to coarse sand, granules and clasts of silt clay, small pebbles, small soft carbonate nodules
1411.5	1412.1	Gray (10YR5/1) fine sand, 2.5-2.0 phi mode, ranging from fine to medium sand
1412.1	1414.7	Gray (10YR5/1) fine sand, 2.5-2.0 phi mode, ranging from fine to medium sand, weakly discontinuously cemented
1414.7	1414.9	Gray (10YR5/1) medium sand, 2.5-2.0 phi mode, ranging from fine to coarse sand
1414.9	1415.0	Gray (10YR5/1) medium sandstone, 2.5-2.0 phi mode, grain size ranging from fine to medium, strongly cemented, strong reaction to HCl
1415.0	1416.7	Gray (10YR5/1) medium sand, 2.5-2.0 phi mode, ranging from fine to medium sand
1422.0	1422.6	Gray (10YR5/1) medium to fine sandstone pieces, strongly cemented, strong reaction to HCl
1422.6	1422.7	Yellowish brown (10YR5/4) fine sandstone, 2.5-2.0 phi mode, ranging from fine to medium sand, strongly carbonate cemented, strong reaction to HCl
1422.7	1422.9	Yellowish brown (10YR5/4) medium sand, 2.5-1.5 phi mode
1422.9	1423.9	Yellowish brown (10YR5/4) medium sandstone, 2.5-1.5 phi mode, strongly carbonate cemented, strong reaction to HCl zone
1423.9	1425.9	Yellowish brown (10YR5/4) medium sand, 2.5-1.5 phi mode
1432.0	1434.8	Brown (10YR5/3) fine sand, 2.5-2.0 phi mode, ranging from fine to coarse sand, indistinctly laminated, heavy minerals
1434.8	1435.0	Grayish brown (10YR5/2) medium sand, 2.5-1.5 phi mode, laminated, cross-laminated, rippled, well sorted, heavy minerals
1435.0	1436.4	Dark grayish brown (10YR4/2) fine sand, 2.5-2.0 phi mode, ranging from fine to medium sand, laminated, cross-laminated, moderately sorted, heavy minerals
1436.4	1437.2	Grayish brown (10YR5/2) medium sand, 2.5-1.5 phi mode, mica fragments
1437.2	1437.4	Light brownish gray (10YR6/2) silty fine sand, poorly sorted, 2.5-2.0 phi mode, cross-laminated, heavy minerals
1437.4	1437.9	Light brownish gray (10YR6/2) siltstone, strongly cemented, strong reaction to HCl
1437.9	1438.9	Grayish brown (10YR5/2) fine sand, 2.5-2.0 phi mode, ranging from fine to medium sand, flat laminated
1438.9	1439.8	Gray (10YR5/1) medium sand, 2.0-1.5 phi mode, cross-laminated, clay nodules
1439.8	1440.2	Light brownish gray (10YR6/2) medium sand, 2.5-1.5 phi mode, ranging from fine to medium sand

1440.2	1440.6	Grayish brown (10YR5/2) fine sand, 2.5-2.0 phi mode, ranging from fine to coarse sand, cross-laminated, heavy minerals
1440.6	1440.9	Light brownish gray (10YR6/2) medium sand, 2.5-1.5 phi mode, ranging from fine to coarse sand
1440.9	1442.0	Dark grayish brown (10YR4/2) fine sand, 2.5-2.0 phi mode, ranging from fine to coarse sand
1442.0	1442.5	Grayish brown (10YR5/2) medium sand, 2.0-1.5 phi mode, cross-laminated, flat laminated, heavy minerals
1442.5	1442.8	Grayish brown (10YR5/2) medium sand, 2.0-1.5 phi mode, ranging from fine to coarse sand, slightly laminated
1442.8	1444.2	Grayish brown (10YR5/2) fine sand, 2.5-2.0 phi mode, ranging from fine to coarse sand, weakly cemented, strong reaction to HCl ,carbonate zone
1444.2	1445.5	Brown (10YR5/3) medium sand, 2.0-1.5 phi mode, ranging from fine to very coarse sand few scattered silt clay clasts, iron and clay cemented, strong reaction to HCl zone
1445.5	1446.5	Dark grayish brown (10YR4/2) fine sand, 2.5-2.0 phi mode, ranging from fine to coarse sand, laminated, scattered carbonate lenses, heavy minerals with manganese stain association
1446.5	1447.1	Dark grayish brown (10YR4/2) fine sand, 3.0-2.0 phi mode, ranging from fine to coarse sand
1447.1	1448.2	Brown (10YR5/3) fine sand, 3.0-2.5 phi mode, irregular soft carbonate nodules
1448.2	1449.4	Grayish brown (10YR5/2) fine sand, 3.0-2.0 phi mode, ranging from fine to coarse sand, laminated
1449.4	1449.9	Dark grayish brown (10YR4/2) medium sand, 1.0-2.0 phi mode, thinly bedded to laminated, clasts of clay andsilt
1449.9	1451.4	Dark gray (10YR4/1) fine sand, 3.0-2.0 phi mode, ranging from fine to coarse sand, cross-laminated, heavy minerals
1452.0	1452.4	Dark grayish brown (10YR4/2) fine sand, 2.5-2.0 phi mode, ranging from fine to medium sand, laminated heavy minerals
1452.4	1452.7	Gray to grayish brown (10YR5/1-2) medium sand, 1.0-2.0 phi mode, ranging from fine to coarse sand and granules
1460.8	1462.0	Gray to grayish brown (10YR5/1-2) medium sand, 1.0-2.0 phi mode, ranging from fine to coarse sand and granules, white moderate carbonate cementation
1462.0	1462.1	Reddish brown (5YR4/3) slightly silty "Hershey clay", pockets and stringers of fine sand
1462.1	1462.3	Brown (10YR5/3) coarse sand, moderately sorted, loose, scattered granules
1462.3	1462.4	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, sand ranging from fine to medium
1462.4	1462.5	Yellowish brown (10YR5/4) coarse sand, moderately sorted, loose, green clasts
1462.5	1463.0	Yellowish brown (10YR5/4) medium sand, ranging from fine to coarse sand
1463.0	1463.2	Yellowish brown (10YR5/4) fine sandstone, manganese stained, strongly carbonate cemented, strong reaction to HCl
1463.2	1464.0	Yellowish brown (10YR5/4) silty fine sand, poorly sorted, massive, weakly cemented, strong reaction to HCl
1464.0	1466.5	Manganese stained medium sandstone, strongly carbonate cemented, strong reaction to HCl
1466.5	1467.9	Gray (10YR5/1) coarse sand, moderately sorted, loose, variegated grains of pink feldspar, pink, red, and purple volcanic rock fragments
1472.0	1472.5	Gray (10YR5/1) coarse sand, scattered granules, laminations, very dark gray (10YR3/1) concentrated heavy minerals, variegated grains of pink feldspar, pink, red, and purple volcanic rock fragments
1472.5	1473.4	Pale brown (10YR6/3) medium sand, ranging from fine to coarse sand and granules
1473.4	1474.7	Brown (10YR5/3) medium sand, 2.5-1.5 phi mode, laminated, heavy minerals
1474.7	1477.0	Yellowish brown (10YR5/4) fine sand, 3.0-2.0 phi mode, ranging from fine to coarse sand, cross-bedded, ripple laminated, heavy mineral lamination, carbonate cement zones
1477.0	1477.8	Brown to dark brown (10YR4/3) medium sand, 2.0-1.5 phi mode, laminated
1477.8	1478.3	Yellowish brown (10YR5/4) medium sand, 1.5-3.0 phi mode, ranging from fine to coarse sand, laminated, poorly sorted
1482.0	1482.2	White (10YR8/1) fine sandstone, strongly carbonate cemented, strong reaction to HCl
1482.2	1483.0	Dark brown to brown (10YR4/3) fine sand, 2.5-2.0 phi mode, ranging from fine to coarse sand, laminated, weakly carbonate cemented, strong reaction to HCl, heavy minerals
1483.0	1483.1	Brown (10YR5/3) fine sand, 2.5-2.0 phi mode, ranging from fine to coarse sand, laminated
1483.1	1483.7	Very pale brown (10YR7/3) medium sandstone, 1.5-2.5 phi mode, strongly carbonate cemented, strong reaction to HCl
1483.7	1483.9	Dark brown to brown (10YR4/3) silty very fine sand, 3.0-2.5 phi mode, laminated, heavy minerals
1483.9	1484.8	Very pale brown (10YR7/3) medium sandstone, ranging from fine to medium sand grain size, strongly carbonate cemented, strong reaction to HCl
1484.8	1485.4	Yellowish brown (10YR5/4) fine sand, 2.5-2.0 phi mode, ranging from fine to coarse sand, massive
1485.4	1486.0	Yellowish brown (10YR5/4) silty very fine sand, laminated, cross-bedded
1486.0	1486.3	Light brownish gray (10YR6/2) silt, laminated, cross-bedded, heavy minerals
1486.3	1486.6	Dark brown to brown (10YR4/3) silty very fine sand, 2.5-2.0 phi mode, laminated, heavy minerals

1486.6	1487.8	Light brownish gray (10YR6/2) silt, laminated, cross-bedded, heavy minerals
1487.8	1488.2	Dark brown to brown (10YR4/3) silty very fine sand, 2.5-2.0 phi mode, laminated, heavy minerals
1492.0	1492.3	Light gray (10YR7/2) medium sandstone, ranging from fine to coarse sand grains, strongly carbonate cemented, strong reaction to HCl
1492.3	1492.4	Reddish brown (5YR4/4) clay, laminations, heavy mineral layers
1492.4	1492.8	Brown (10YR5/3) silty clayey fine sand, 3.0-2.5 phi mode, clay lamination
1492.8	1493.7	Brown (10YR5/3) fine sand, 2.0-3.0 phi mode, ranging from fine to medium sand, laminations of silt, few carbonate nodules
1493.7	1493.9	Brown (10YR5/3) medium sand, 1.0-2.0 phi mode, ranging from fine to coarse sand, massive
1493.9	1494.0	Brown (10YR5/3) very fine sand, 3.0-2.0 phi mode, laminated
1494.0	1494.3	Dark brown to brown (10YR4/3) medium sand, 1.0-2.0 phi mode, ranging from fine to coarse sand, red clay clasts
1494.3	1494.7	Light brown (7.5YR6/4) silty fine sand, poorly sorted , 2.5-2.0 phi mode, ranging from fine to medium sand, clay clasts
1494.7	1495.7	Grayish brown (10YR5/2) silty clayey fine sand, ranging from fine to medium sand grains, laminations, heavy minerals, clay ripup clasts
1495.7	1496.3	Dark brown to brown (10YR4/3) fine sand, 2.0-3.0 phi mode, ranging from fine to medium sand
1496.3	1496.4	Brown (10YR5/3) silt and silty clay, interbedded, very compact brown (10YR5/3) very fine sandstone, strongly carbonate cemented, strong reaction to HCl, strong reaction to HCl, fining up unit

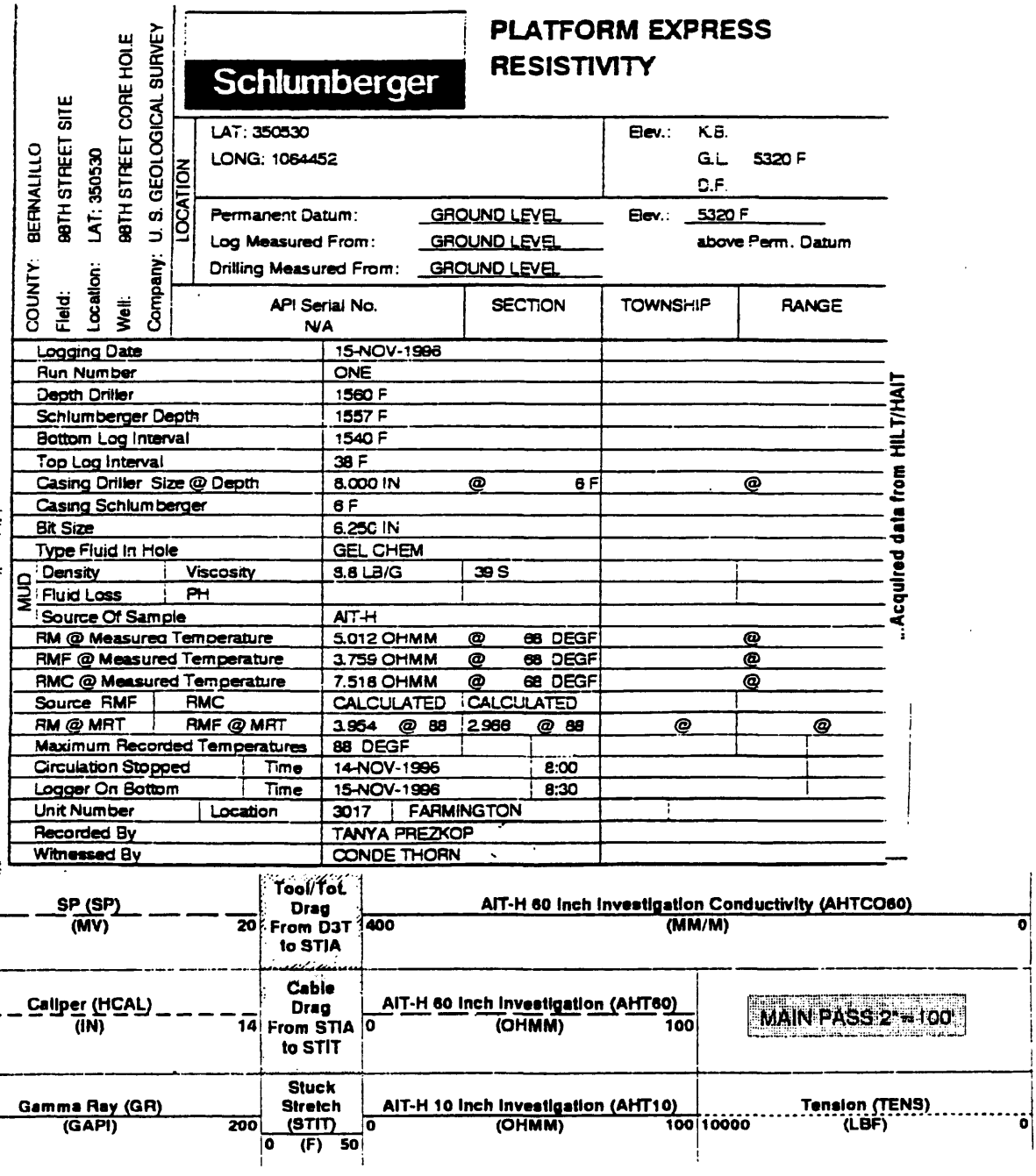
APPENDIX B

DETAILED GEOPHYSICAL LOGS FOR THE 98TH STREET CORE HOLE

Natural gamma, caliper, spontaneous potential, conductivity,
short and long resistivity, and tension

APPENDIX B.

Geophysical logs for 98th Street core hole:



Schlumberger

PLATFORM EXPRESS
RESISTIVITY

COUNTY: BERNALILLO
Field: 98TH STREET SITE
Location: LAT: 350530
Well: 98TH STREET CORE HOLE
Company: U. S. GEOLOGICAL SURVEY

LOCATION
LAT: 350530
LONG: 1064452

Elev.: K.B.
G.L. 5320 F
D.F.

Permanent Datum: GROUND LEVEL
Log Measured From: GROUND LEVEL
Drilling Measured From: GROUND LEVEL

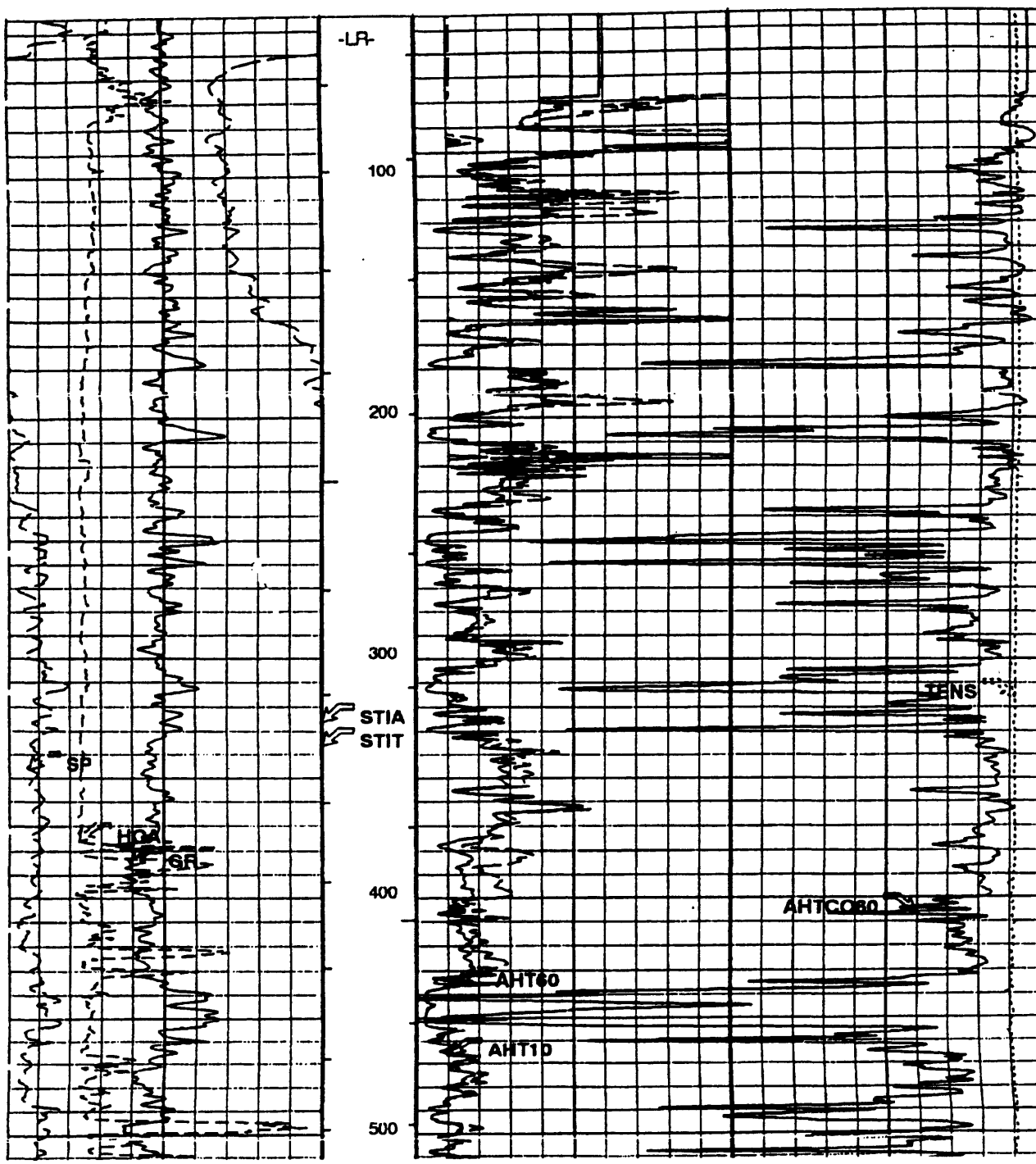
Elev.: 5320 F
above Perm. Datum

API Serial No.	SECTION	TOWNSHIP	RANGE
N/A			

Logging Date		15-NOV-1996				
Run Number		ONE				
Depth Driller		1560 F				
Schlumberger Depth		1557 F				
Bottom Log Interval		1540 F				
Top Log Interval		38 F				
Casing Driller Size @ Depth		8.000 IN	@ 6 F		@	
Casing Schlumberger		6 F				
Bit Size		6.250 IN				
Type Fluid In Hole		GEL CHEM				
MUD Density	Viscosity	8.8 LB/G	39 S			
Fluid Loss	PH					
Source Of Sample		AIT-H				
RM @ Measured Temperature		5.012 OHMM	@ 68 DEGF		@	
RMF @ Measured Temperature		3.759 OHMM	@ 68 DEGF		@	
RMC @ Measured Temperature		7.518 OHMM	@ 68 DEGF		@	
Source RMF	RMC	CALCULATED	CALCULATED			
RM @ MRT	RMF @ MRT	3.954 @ 88	2.966 @ 88	@	@	
Maximum Recorded Temperatures		88 DEGF				
Circulation Stopped	Time	14-NOV-1996	8:00			
Logger On Bottom	Time	15-NOV-1996	8:30			
Unit Number	Location	3017	FARMINGTON			
Recorded By		TANYA PREZKOP				
Witnessed By		CONDE THORN				

...Acquired data from HILT/HAIT

SP (SP) -80 (MV) 20	Tool/Tot. Drag From D3T to STIA	AIT-H 60 Inch Investigation Conductivity (AHTCO60) 400 (MM/M) 0	
Caliper (HCAL) 4 (IN) 14	Cable Drag From STIA to STIT	AIT-H 60 Inch Investigation (AHT60) 0 (OHMM) 100	MAIN PASS 2" = 100'
Gamma Ray (GR) 0 (GAPI) 200	Stuck Stretch (STIT) 0 (F) 50	AIT-H 10 Inch Investigation (AHT10) 0 (OHMM) 100	Tension (TENS) 10000 (LBF) 0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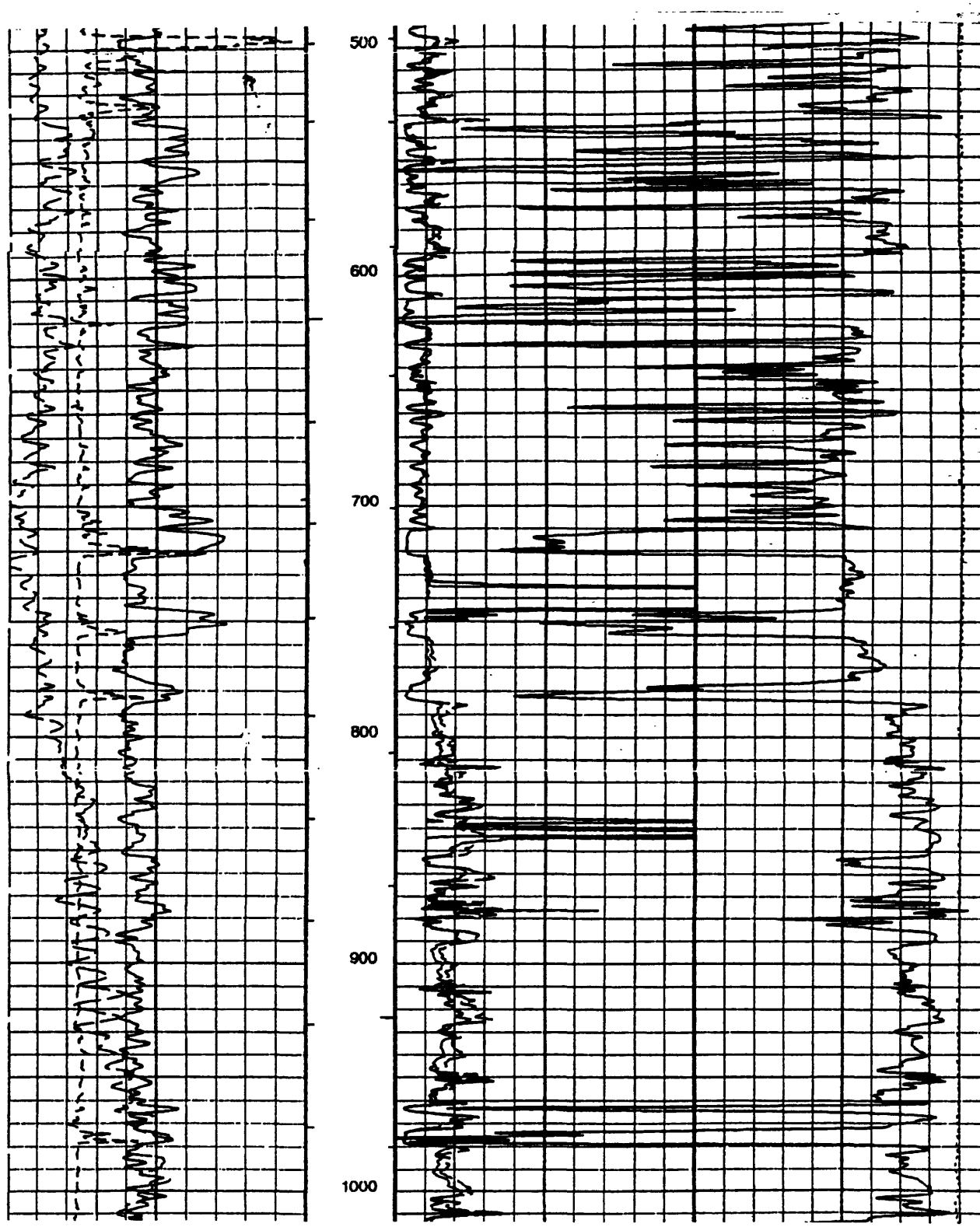
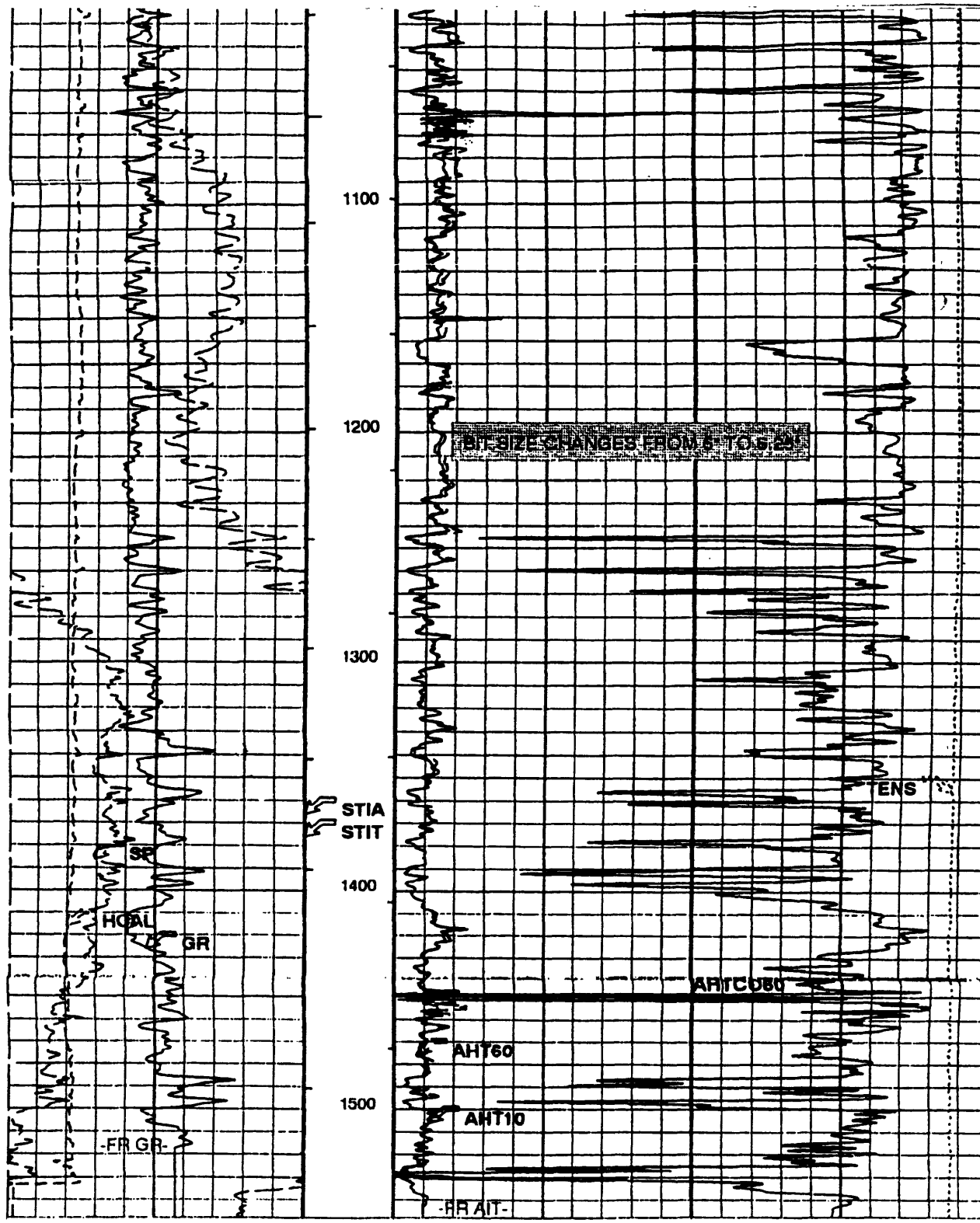
100
200
300
400
500
STIA
STIT
SP
HDA
GR
TENS
AHTCO30
AHT60
AHT10


500
600
700
800
900
1000


1100
1200
1300
1400
1500
BIT SIZE CHANGES FROM 6" TO 5.25"
STIA
STIT
SP
HCAL
GR
ENS
ARITC60
AHT60
AHT10
-FR GR-
-RR AIT-

APPENDIX C

DETAILED GEOPHYSICAL LOGS FOR THE 98TH STREET CORE HOLE

Natural gamma, caliper, formation density,
and photoelectric absorption

APPENDIX C.

Detailed geophysical logs for 98th Street core hole:

COUNTY: BERNALILLO
Field: 98TH STREET SITE
Location: LAT: 350530
Well: 98TH STREET CORE HOLE
Company: U. S. GEOLOGICAL SURVEY

Schlumberger

PLATFORM EXPRESS
POROSITY AND LITHOLOGY

LOCATION

LAT: 350530
LONG: 1064452

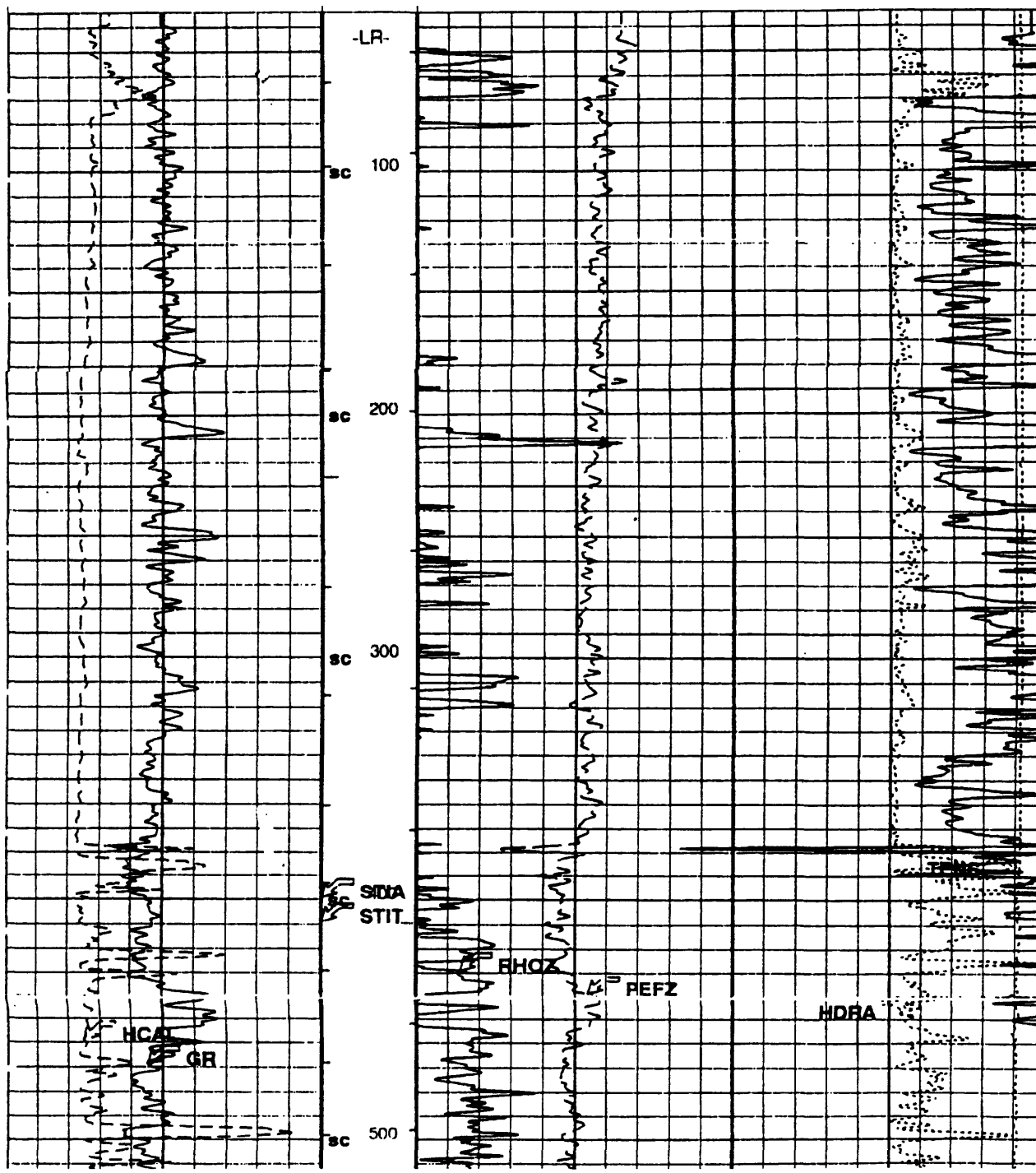
Elev.. K.B.
G.L 5320 F
D.F.

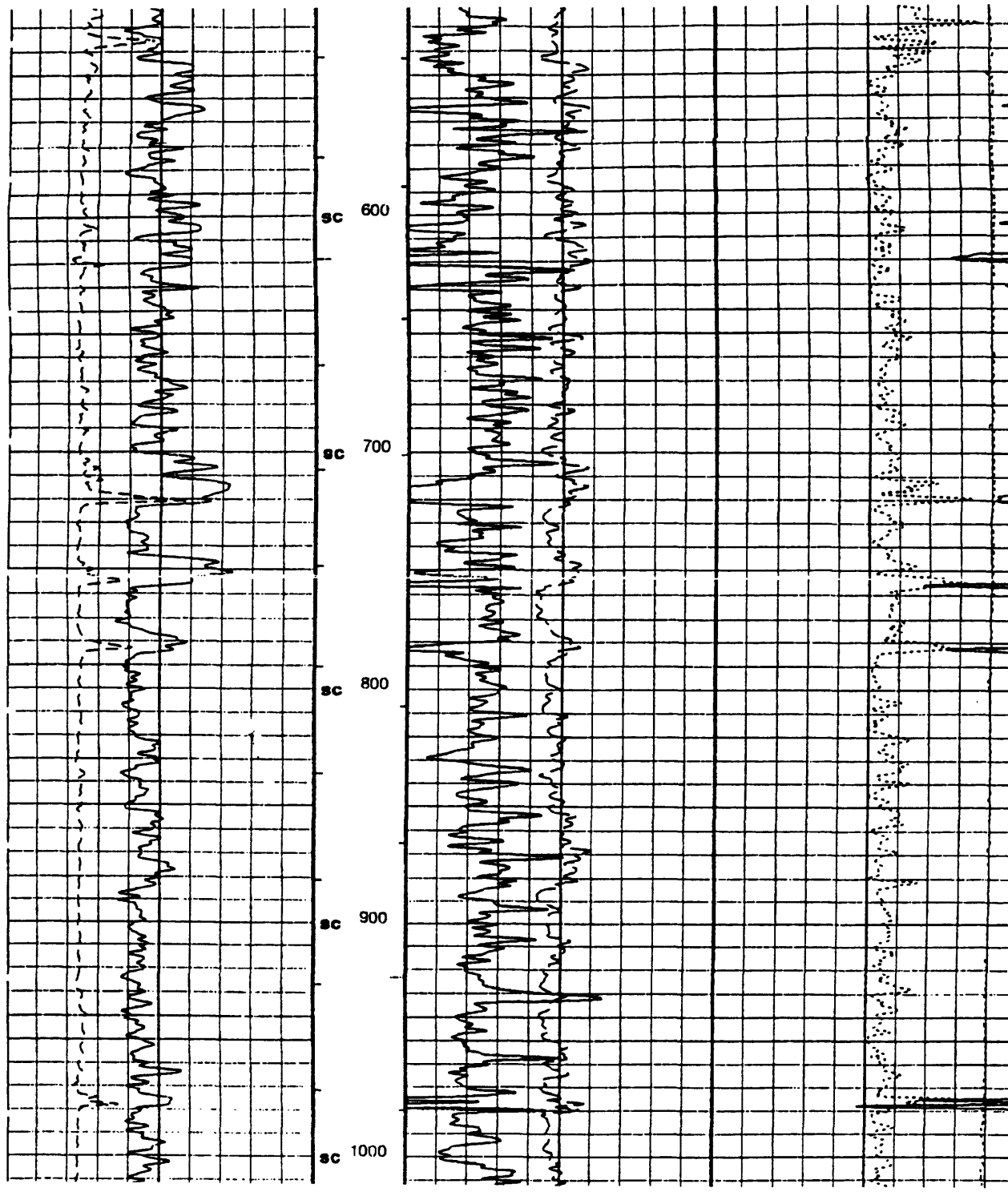
Permanent Datum: GROUND LEVEL — Elev.. 5320 F
Log Measured From: GROUND LEVEL — above Perm. Datum
Drilling Measured From: GROUND LEVEL

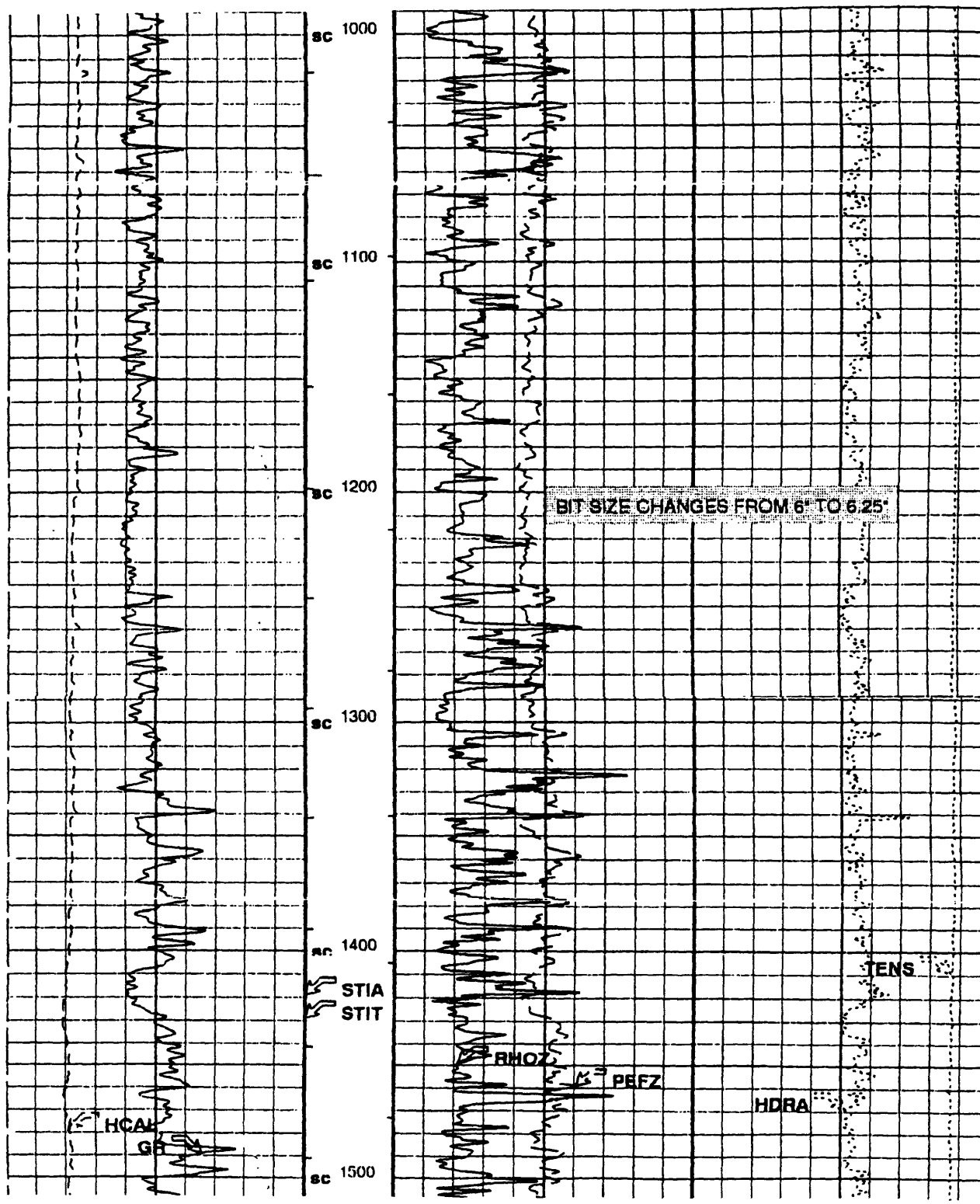
API Serial No.	SECTION	TOWNSHIP	RANGE
N/A			

Logging Date			15-NOV-1996				
Run Number			ONE				
Depth Driller			1580 F				
Schlumberger Depth			1557 F				
Bottom Log Interval			1540 F				
Top Log Interval			38 F				
Casing Driller Size @ Depth			8.000 IN	@	6 F	@	
Casing Schlumberger			6 F				
Bit Size			6.250 IN				
Type Fluid In Hole			GEL CHEM				
MUD	Density	Viscosity	8.8 LB/G	39 S			
MUD	Fluid Loss	PH					
MUD	Source Of Sample		AiT-H				
RM @ Measured Temperature			5.012 OHMM	@	68 DEGF	@	
RMF @ Measured Temperature			3.759 OHMM	@	68 DEGF	@	
RMC @ Measured Temperature			7.518 OHMM	@	68 DEGF	@	
Source RMF	RMC		CALCULATED	CALCULATED			
RM @ MRT	RMF @ MRT		3.954 @ 88	2.966 @ 88		@	@
Maximum Recorded Temperatures			88 DEGF				
Circulation Stopped	Time		14-NOV-1996	8:00			
Logger On Bottom	Time		15-NOV-1996	8:30			
Unit Number	Location		3017	FARMINGTON			
Recorded By			TANYA PREZKOP				
Witnessed By			CONDE THORN				

Caliper (HCAL) 4 (IN) 14	Cable Drag From STIA to STIT	Std. Res. Formation Density (RHOZ) 2 (G/C3) 3
Gamma Ray (GR) 0 (GAPI) 200	Stuck Stretch (STIT) 0 (F) 50	Std. Res. Formation Pe (PEFZ) 0 (----) 10
		Tension (TENS) 10000 (LBF) 0
		Density Correction (HDRA) -0.25 (G/C3) 0.25


-LR-
100
200
300
500
SIDIA
STIT
RHOZ
PEFZ
HDRA
HCAL
GR


sc
600
sc
700
sc
800
sc
900
sc
1000


SC 1000
SC 1100
SC 1200
SC 1300
SC 1400
SC 1500
BIT SIZE CHANGES FROM 6" TO 6.25"
STIA
STIT
RHOZ
PEFZ
HDRA
TENS
HCAL
GR

Appendix D.

PARTICLE-SIZE ANALYSES OF CHANNEL SAMPLES FROM THE 98TH STREET CORE

Analyses preformed by the
New Mexico Bureau of Mines and Mineral Resources Soils Laboratory
Socorro, New Mexico
September, 1997

In cooporation with
THE CITY OF ALBUQUERQUE

Particle Size Distribution Analysis

Mechanical Sieve Analysis:

Prior to sieving, samples were broken-up with a mortar and pestle. A standard set of sieves were used, including numbers 4, 10, 20, 40, 60, 140, and 200. The sample portion retained in each sieve was weighed to determine the distribution of gravel and sand size particles. Fines were collected in a pan placed at the bottom of the stacked sieves. After dry sieving, the fines (silt/clay) were set aside for later use in hydrometer analysis.

Hydrometer Analysis:

Hydrometer analysis was used to measure the silt and clay distribution of the sample that passed through the number 200 sieve. The fines collected in the pan during mechanical sieving were soaked overnight in 125 mL of sodium hexametaphosphate solution in order to disperse the grains. Afterwards, the suspension was placed in a blender for 10 minutes for further dispersion. Next, the suspension was diluted to 1000 mL with distilled water, placed in a cylinder, and the test conducted using a 152H hydrometer. A hydrometer correction of -3 was used to account for the impact of sodium hexametaphosphate on solution density. The following two equations were used for hydrometer analysis of grain size, **d**, and percent finer than, $\mathbf{P_f}$:

$$d = \sqrt{\frac{30NL}{980(G_S - G_W)t}} \quad \text{, and}$$

$$P_f = \frac{100aR}{W_S} \quad ,$$

where **N** is the coefficient of viscosity for water at test temperature, **L** is hydrometer effective depth, $\mathbf{G_S}$ is the specific gravity of the soil solids (assumed to be 2.65), $\mathbf{G_w}$ is the specific gravity of water at test temperature, **t** is time in minutes, **a** is ratio of $\mathbf{G_S}$ to 2.65, **R** is the corrected hydrometer reading, and $\mathbf{W_S}$ is the dry weight of the sample used in the hydrometer analysis.

Gradation Analysis:

Sample gradation was determined after calculating the coefficient of curvature, $\mathbf{C_C}$, and the coefficient of uniformity, $\mathbf{C_U}$. Equations for both coefficients are as follows:

$$C_C = \frac{(D_{30})^2}{(D_{10})(D_{60})} \quad \text{, and}$$

$$C_U = \frac{D_{60}}{D_{10}} \quad ,$$

where $\mathbf{D_{10}}$ is the grain diameter at 10 % passing, $\mathbf{D_{30}}$ is the grain diameter at 30 % passing, and $\mathbf{D_{60}}$ is the grain diameter at 60 % passing. A sandy sample is considered <u>well-graded</u> if:

$$1 \leq C_C \leq 3 \quad \text{, and}$$

$$C_U \geq 6 \quad .$$

If either of these conditions do not hold, then the sample is said to be <u>uniformly-graded</u>.

<u>Note:</u> These samples (Units 1-21) appear to be rotary drilling cuttings. If this is the case, residual drilling mud may skew the overall results

Unit #1: 1483 ft - 1500 ft
Mechanical Sieve Analysis

Sample Weight = 150 g
5/29/97

Sieve Number	Grain Diameter (mm)	Sieve Weight (g)	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
4	4 75	536.2	536.2	0	0	0	100
10	2	499 5	500 8	1.3	1.3	0 87	99.13
20	0.84	304 1	307.3	3 2	4.5	3	97
40	0 42	391.8	400 5	8.7	13.2	8.8	91 2
60	0 25	403 3	424.4	21.1	34.3	22.87	77 13
100	0 15	465	511.9	46.9	81.2	54 13	45.87
140	0.1	242.3	266.4	24.1	105.3	70.2	29.8
200	0.07	358.9	381.7	22.8	128 1	85.4	14.6
PAN	-	370 2	392	21.8	149 9	99.93	-

Unit #2: 1399 ft - 1483 ft
Mechanical Sieve Analysis

Sample Weight = 150 g
6/6/97

Sieve Number	Grain Diameter (mm)	Sieve Weight (g)	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
4	4.75	536 2	536.2	0	0	0	100
10	2	499 5	500.5	1	1	0 67	99 33
20	0 84	304.1	305.5	1.4	2 4	1 6	98.4
40	0.42	391.8	400.4	8.6	11	7.33	92.67
60	0.25	403.3	440.5	37.2	48.2	32.13	67 87
100	0 15	465	527.5	62 5	110 7	73.8	26.2
140	0 1	242 3	263 4	21 1	131 8	87 87	12 13
200	0 07	358 9	368.2	9 3	141 1	94.07	5 93
PAN	-	370 2	379 3	9 1	150 2	100 13	-

mm = millimeters

g = grams

Unit #3: 1341 ft - 1399 ft
Mechanical Sieve Analysis

Sample Weight = 150 g
6/6/97

Sieve Number	Grain Diameter (mm)	Sieve Weight (g)	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
4	4.75	535.1	535.1	0	0	0	100
10	2	524 5	525.9	1.4	1.4	0.93	99.07
20	0.84	404 3	411 9	7.6	9	6	94
40	0.42	280.6	297.1	16.5	25.5	17	83
60	0.25	392.3	425 7	33.4	58.9	39.27	60 73
100	0.15	243.7	280.6	36.9	95.8	63.87	36.13
140	0.1	297.9	320.6	22.7	118.5	79	21
200	0 07	238	254 9	16 9	135.4	90.27	9.73
PAN	-	349 9	364.3	14 4	149.8	99.87	-

Unit #4: 1291 ft - 1341 ft
Mechanical Sieve Analysis

Sample Weight = 200 g
6/12/97

Sieve Number	Grain Diameter (mm)	Sieve Weight (g)	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
4	4 75	536.2	536.2	0	0	0	100
10	2	499.5	501 9	2.4	2.4	1.2	98.8
20	0.84	304.1	311.6	7.5	9.9	4.95	95.05
40	0.42	391.8	426 2	34.4	44.3	22.15	77.85
60	0.25	403.3	475	71.7	116	58	42
100	0.15	465	520.2	55.2	171.2	85.6	14.4
140	0.1	242.3	256.6	14.3	185.5	92.75	7.25
200	0 07	358.9	364.9	6	191.5	95.75	4.25
PAN	-	370 2	378.7	8.5	200	100	-

mm = millimeters

g = grams

Unit #5: 1246 ft - 1291 ft
Mechanical Sieve Analysis

Sample Weight = 200 g
6/12/97

Sieve Number	Grain Diameter (mm)	Sieve Weight (g)	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
4	4.75	535.1	548.4	13.3	13 3	6.65	93.35
10	2	524 5	528.8	4.3	17 6	8 8	91 2
20	0.84	404.3	413	8 7	26 3	13 15	86.85
40	0.42	280 6	302.5	21.9	48 2	24.1	75.9
60	0.25	392.3	451.3	59	107.2	53.6	46.4
100	0 15	243.7	295.2	51.5	158.7	79.35	20 65
140	0 1	297.9	317	19.1	177 8	88.9	11.1
200	0 07	238	248.5	10.5	188.3	94.15	5.85
PAN	-	349 9	360 7	10.8	199 1	99 55	-

Unit #6: 1076 ft - 1246 ft
Mechanical Sieve Analysis

Sample Weight = 200 g
6/16/97

Sieve Number	Grain Diameter (mm)	Sieve Weight (g)	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
4	4 75	536.2	536.2	0	0	0	100
10	2	499.5	500 4	0 9	0.9	0 45	99.55
20	0 84	304.1	311.3	7 2	8 1	4.05	95.95
40	0 42	391 8	415 3	23.5	31.6	15 8	84.2
60	0 25	403 3	467.2	63.9	95 5	47.75	52 25
100	0 15	465	534 9	69 9	165.4	82.7	17.3
140	0 1	242.3	261.2	18.9	184.3	92.15	7.85
200	0 07	358.9	366.2	7 3	191 6	95.8	4.2
PAN	-	370.2	378.8	8 6	200 2	100.1	-

mm = millimeters

g = grams

Unit #7: 1017 ft - 1076 ft
Mechanical Sieve Analysis

Sample Weight = 193.8 g
6/16/97

Sieve Number	Grain Diameter (mm)	Sieve Weight (g)	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
4	4.75	535.1	539	3.9	3.9	2.01	97.99
10	2	524.5	533.1	8.6	12.5	6.45	93.55
20	0.84	404.3	419.4	15.1	27.6	14.24	85.76
40	0.42	280.6	297.7	17.1	44.7	23.07	76.93
60	0.25	392.3	425.3	33	77.7	40.09	59.91
100	0.15	243.7	302.7	59	136.7	70.54	29.46
140	0.1	297.9	325.1	27.2	163 9	84.57	15 43
200	0.07	238	256	18	181.9	93.86	6 14
PAN	-	349 9	361.8	11.9	193.8	100	-

Unit #8: 786 ft - 1017 ft
Mechanical Sieve Analysis

Sample Weight = 200 g
6/18/97

Sieve Number	Grain Diameter (mm)	Sieve Weight (g)	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
4	4.75	536.2	541.2	5	5	2.5	97.5
10	2	499.5	501.9	2.4	7.4	3.7	96.3
20	0.84	304 1	314 3	10.2	17.6	8.8	91.2
40	0.42	391.8	420 9	29.1	46.7	23.35	76.65
60	0.25	403.3	468.7	65.4	112.1	56.05	43.95
100	0.15	465	521 6	56.6	168.7	84.35	15.65
140	0 1	242.3	256 8	14.5	183.2	91.6	8.4
200	0 07	358 9	365.2	6.3	189.5	94.75	5.25
PAN	-	370 2	380 7	10.5	200	100	-

mm = millimeters

g = grams

Unit #9: 751 ft - 786 ft
Mechanical Sieve Analysis

Sample Weight = 175 g
6/18/97

Sieve Number	Grain Diameter (mm)	Sieve Weight (g)	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
4	4.75	535.1	537.7	2.6	2.6	1.49	98.51
10	2	524.5	546.9	22.4	25	14.29	85.71
20	0.84	404.3	439.1	34.8	59.8	34.17	65.83
40	0.42	280.6	305	24.4	84.2	48 11	51.89
60	0 25	392.3	414 8	22.5	106.7	60 97	39.03
100	0.15	243.7	271	27.3	134	76 57	23.43
140	0.1	297.9	313.3	15 4	149.4	85 37	14.63
200	0.07	238	247.7	9.7	159.1	90 91	9.09
PAN	-	349 9	365.8	15.9	175	100	-

Unit #10: 710 ft - 751 ft
Mechanical Sieve Analysis

Sample Weight = 186 g
6/25/97

Sieve Number	Grain Diameter (mm)	Sieve Weight (g)	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
4	4 75	536 2	544 6	8 4	8 4	4.52	95 48
10	2	499.5	535 1	35 6	44	23 66	76.34
20	0 84	304.1	327.9	23 8	67 8	36 45	63 55
40	0 42	391.8	403.5	11 7	79.5	42.74	57 26
60	0 25	403.3	412.8	9.5	89	47.85	52.15
100	0 15	465	481.1	16.1	105.1	56 51	43.49
140	0 1	242.3	269 9	27.6	132.7	71.34	28.66
200	0 07	358.9	388.8	29.9	162.6	87.42	12.58
PAN	-	370.2	392 1	21.9	184.5	99.19	-

mm = millimeters

g = grams

Unit #11: 624 ft - 710 ft
Mechanical Sieve Analysis

Sample Weight = 200 g
6/25/97

Sieve Number	Grain Diameter (mm)	Sieve Weight (g)	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
4	4 75	535.1	539 2	4.1	4.1	2.05	97.95
10	2	524.5	547.6	23.1	27.2	13.6	86.4
20	0 84	404.3	437	32 7	59.9	29.95	70.05
40	0 42	280.6	305.4	24 8	84.7	42.35	57.65
60	0 25	392.3	426.8	34 5	119.2	59.6	40.4
100	0.15	243.7	277.1	33.4	152.6	76.3	23.7
140	0.1	297.9	314.7	16 8	169.4	84.7	15.3
200	0.07	238	252.6	14 6	184	92	8
PAN	-	349 9	365 4	15 5	199.5	99.75	-

Unit #12: 535 ft - 624 ft
Mechanical Sieve Analysis

Sample Weight = 200 g
6/27/97

Sieve Number	Grain Diameter (mm)	Sieve Weight (g)	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
4	4.75	536.2	538.7	2.5	2.5	1.25	98.75
10	2	499.5	516.6	17.1	19.6	9.8	90.2
20	0.84	304 1	336.1	32	51.6	25.8	74.2
40	0 42	391.8	414.3	22.5	74.1	37.05	62.95
60	0.25	403.3	426.5	23 2	97.3	48.65	51.35
100	0.15	465	503.7	38 7	136	68	32
140	0.1	242.3	264.4	22.1	158.1	79.05	20.95
200	0.07	358.9	372.4	13.5	171.6	85.8	14.2
PAN	-	370.2	397.7	27.5	199.1	99.55	-

mm = millimeters

g = grams

Unit #13: 464 ft - 535 ft
Mechanical Sieve Analysis

Sample Weight = 200 g
6/27/97

Sieve Number	Grain Diameter (mm[1])	Sieve Weight (g[2])	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
4	4.75	535.1	535.6	0.5	0 5	0.25	99.75
10	2	524.5	529.4	4 9	5.4	2.7	97.3
20	0 84	404.3	417.9	13.6	19	9.5	90.5
40	0.42	280.6	296.3	15.7	34.7	17.35	82.65
60	0.25	392.3	426.9	34.6	69.3	34.65	65.35
100	0 15	243.7	289.7	46	115.3	57.65	42.35
140	0 1	297.9	324.5	26.6	141 9	70.95	29 05
200	0 07	238	261 6	23.6	165.5	82 75	17 25
PAN	-	349 9	384 5	34 6	200.1	100 05	-

Unit #14: 441 ft - 464 ft
Mechanical Sieve Analysis

Sample Weight = 100 g
6/30/97

Sieve Number	Grain Diameter (mm[1])	Sieve Weight (g[2])	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
4	4 75	536 2	536.2	0	0	0	100
10	2	499.5	507.2	7 7	7.7	7.7	92.3
20	0 84	304.1	317.9	13 8	21.5	21.5	78 5
40	0 42	391.8	402.3	10 5	32	32	68
60	0.25	403.3	419 8	16 5	48.5	48 5	51 5
100	0.15	465	484.8	19 8	68 3	68.3	31 7
140	0.1	242.3	254.6	12.3	80.6	80 6	19 4
200	0 07	358.9	366 7	7 8	88.4	88 4	11.6
PAN	-	370.2	381 4	11 2	99 6	99 6	-

[1] mm = millimeters

[2] g = grams

Unit #15: 336 ft - 441 ft
Mechanical Sieve Analysis

Sample Weight = 200 g
6/30/97

Sieve Number	Grain Diameter (mm[1])	Sieve Weight (g[2])	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
4	4 75	535.1	535.5	0 4	0 4	0.2	99.8
10	2	524.5	527.2	2.7	3.1	1.55	98.45
20	0 84	404.3	411.8	7.5	10.6	5.3	94.7
40	0.42	280.6	294.7	14.1	24.7	12.35	87.65
60	0.25	392.3	437.5	45.2	69.9	34.95	65.05
100	0 15	243.7	305	61.3	131.2	65.6	34.4
140	0.1	297.9	327.5	29.6	160.8	80.4	19.6
200	0.07	238	258.8	20.8	181.6	90.8	9.2
PAN	-	349.9	368.7	18.8	200.4	100.2	-

Unit #16: 237 ft - 336 ft
Mechanical Sieve Analysis

Sample Weight = 200 g
7/1/97

Sieve Number	Grain Diameter (mm[1])	Sieve Weight (g[2])	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cnmnlative Percent Retained (%)	Percent Passing (%)
4	4 75	536.2	536.2	0	0	0	100
10	2	499 5	502 5	3	3	1.5	98.5
20	0.84	304 1	320 4	16.3	19 3	9.65	90.35
40	0.42	391 8	412.7	20.9	40.2	20.1	79.9
60	0 25	403 3	441.7	38.4	78.6	39.3	60.7
100	0 15	465	529 7	64 7	143.3	71.65	28.35
140	0.1	242.3	267	24.7	168	84	16
200	0 07	358 9	372.4	13.5	181.5	90.75	9.25
PAN	-	370.2	388	17.8	199 3	99.65	-

[1] mm = millimeters

[2] g = grams

Unit #17: 183 ft - 237 ft
Mechanical Sieve Analysis

Sample Weight = 200 g
7/7/97

Sieve Number	Grain Diameter (mm)	Sieve Weight (g)	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
4	4 75	535 1	535.5	0.4	0.4	0.2	99.8
10	2	524 5	529.7	5.2	5 6	2.8	97.2
20	0.84	404.3	415.3	11	16.6	8.3	91.7
40	0 42	280 6	298.2	17.6	34.2	17 1	82.9
60	0.25	392 3	440.6	48.3	82.5	41.25	58.75
100	0.15	243.7	302.3	58 6	141.1	70.55	29 45
140	0.1	297.9	325.1	27.2	168.3	84.15	15 85
200	0.07	238	254.5	16.5	184.8	92.4	7.6
PAN	-	349 9	365.4	15 5	200 3	100.15	-

Unit #19: 80 ft - 97 ft
Mechanical Sieve Analysis

Sample Weight = 200 g
7/10/97

Sieve Number	Grain Diameter (mm)	Sieve Weight (g)	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
4	4.75	535.1	536.4	1.3	1.3	0.65	99.35
10	2	524.5	527	2.5	3.8	1.9	98.1
20	0 84	404.3	410.5	6 2	10	5	95
40	0 42	280.6	300.2	19.6	29.6	14.8	85.2
60	0.25	392.3	445.3	53	82.6	41.3	58 7
100	0.15	243.7	307.4	63.7	146.3	73.15	26 85
140	0 1	297.9	323 5	25.6	171.9	85.95	14.05
200	0 07	238	255.5	17.5	189 4	94.7	5.3
PAN	-	349 9	360 6	10.7	200.1	100.05	-

Unit #18: 97 ft - 183 ft
Mechanical Sieve Analysis

Sample Weight = 200 g
7/10/97

Sieve Number	Grain Diameter (mm)	Sieve Weight (g)	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
4	4 75	536.2	540.5	4 3	4.3	2.15	97.85
10	2	499 5	510.6	11 1	15.4	7 7	92 3
20	0 84	304.1	322.4	18.3	33.7	16 85	83.15
40	0 42	391.8	405.1	13.3	47	23.5	76.5
60	0.25	403.3	432 3	29	76	38	62
100	0 15	465	524 3	59 3	135 3	67.65	32.35
140	0 1	242.3	271 5	29 2	164.5	82 25	17 75
200	0.07	358.9	376.8	17.9	182 4	91 2	8 8
PAN	-	370 2	387 3	17.1	199.5	99 75	-

mm = millimeters

g = grams

Unit #21: 19 ft - 60 ft
Mechanical Sieve Analysis

Sample Weight = 200 g
7/14/97

Sieve Number	Grain Diameter (mm)	Sieve Weight (g)	Sieve + Retained Soil Weight (g)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
4	4 75	536.2	546.8	10.6	10.6	5.3	94.7
10	2	499 5	514.5	15	25.6	12.8	87.2
20	0 84	304.1	331.7	27.6	53.2	26.6	73.4
40	0 42	391.8	429 5	37.7	90.9	45.45	54.55
60	0.25	403 3	447.6	44.3	135.2	67.6	32.4
100	0 15	465	497.5	32.5	167.7	83.85	16.15
140	0.1	242.3	255.4	13.1	180.8	90.4	9.6
200	0 07	358.9	366.3	7.4	188.2	94.1	5.9
PAN	-	370 2	381 5	11.3	199.5	99.75	-

mm = millimeters

g = grams

Appendix E

HYDRAULIC CONDUCTIVITY FROM UNCONSOLIDATED-DRAINED, RECOMPACTED SANDY SAMPLES FROM THE 98TH STREET CORE

Analyses preformed by the
New Mexico Bureau of Mines and Mineral Resources Soils Laboratory
Socorro, New Mexico
September, 1997

In cooporation with
THE CITY OF ALBUQUERQUE

DRIVE 14B
97.2 ft - 98.6 ft
Triaxial Permeability Test

Sample Weight = 140.29 g
Sample Length = 7.40 cm
Sample Density = 1803 kg/m^3

confining pressure (psi)	hydraulic conductivity (m/s)	axial load (lbs.)
10	7.15×10^{-7}	+1
30	2.47×10^{-7}	-1
50	2.05×10^{-7}	-5
70	1.88×10^{-7}	-9
90	1.73×10^{-7}	-13

Mechanical Sieve Analysis

Sieve Number	Grain Diameter (mm)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
20	0.84	0.25	0.25	0.18	99.82
40	0.42	7.92	8.17	5.82	94.18
60	0.25	38.61	46.78	33.35	66.65
80	0.18	26.28	73.06	52.08	47.92
100	0.15	20.81	93.87	66.91	33.09
120	0.12	11.22	105.09	74.91	25.09
140	0.1	13.53	118.62	84.55	15.45
200	0.07	10.12	128.74	91.77	8.23
PAN	-	11.11	139.85	99.69	-

DRIVE 17B
116 ft - 118 ft
Triaxial Permeability Test

Sample Weight = 139.76 g
Sample Length = 7.90 cm
Sample Density = 2023 kg/m^3

confining pressure (psi)	hydraulic conductivity (m/s)	axial load (lbs.)
10	6.51×10^{-6}	+1
30	4.65×10^{-6}	-1
50	3.80×10^{-6}	-5
70	3.27×10^{-6}	-9
90	2.88×10^{-6}	-13

Mechanical Sieve Analysis

Sieve Number	Grain Diameter (mm)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
20	0.84	0.35	0.35	0.25	99.75
40	0.42	4.43	4.78	3.42	96.58
60	0.25	24.82	29.6	21.18	78.82
80	0.18	27.73	57.33	41.02	58.98
100	0.15	15.05	72.38	51.79	48.21
120	0.12	18.17	90.55	64.79	35.21
140	0.1	15.13	105.68	75.62	24.38
200	0.07	23.15	128.83	92.18	7.82
PAN	-	10.7	139.53	99.84	-

DRIVE 21B
about 136 ft
Triaxial Permeability Test

Sample Weight = [n/a] g
Sample Length = 8.34 cm
Sample Density = 2184 kg/m^3

confining pressure (psi)	hydraulic conductivity (m/s)	axial load (lbs.)
10	2.31×10^{-6}	+1
30	1.73×10^{-6}	-2
50	1.42×10^{-6}	-5
70	1.21×10^{-6}	-9
90	1.04×10^{-6}	-13

Mechanical Sieve Analysis

[not available]

DRIVE 23A
145.9 ft - 147.9 ft
Triaxial Permeability Test

Sample Weight = 141.71 g
Sample Length = 8.56 cm
Sample Density = 1773 kg/m^3

confining pressure (psi)	hydraulic conductivity (m/s)	axial load (lbs.)
10	4.67×10^{-6}	+1
30	3.35×10^{-6}	-2
50	2.73×10^{-6}	-6
70	2.32×10^{-6}	-10
90	2.02×10^{-6}	-14

Mechanical Sieve Analysis

Sieve Number	Grain Diameter (mm)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
20	0.84	0.21	0.21	0.15	99.85
40	0.42	1.11	1.32	0.93	99.07
60	0.25	14.36	15.68	11.06	88.94
80	0.18	25.79	41.47	29.26	70.74
100	0.15	24.22	65.69	46.36	53.64
120	0.12	16.42	82.11	57.94	42.06
140	0.1	17.76	99.87	70.47	29.53
200	0.07	20.68	120.55	85.07	14.93
PAN	-	20.65	141.2	99.64	-

DRIVE 25A
about 160 ft
Triaxial Permeability Test

Sample Weight = [n/a] g
Sample Length = 7.91cm
Sample Density = 1996 kg/m^3

confining pressure (psi)	hydraulic conductivity (m/s)	axial load (lbs.)
10	3.10×10^{-8}	0
30	1.40×10^{-6}	- 1
50	1.01×10^{-6}	- 6
70	8.11×10^{-7}	- 9
90	7.04×10^{-7}	- 11

Mechanical Sieve Analysis

[not available]

DRIVE 25B
160.9 ft - 162.9 ft
Triaxial Permeability Test

Sample Weight = 146.21 g
Sample Length = 8.10 cm
Sample Density = 2020 kg/m^3

confining pressure (psi)	hydraulic conductivity (m/s)	axial load (lbs.)
10	1.47×10^{-6}	+ 2
30	1.22×10^{-6}	- 2
50	1.03×10^{-6}	- 7
70	8.80×10^{-7}	- 9

Mechanical Sieve Analysis

Sieve Number	Grain Diameter (mm)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
20	0 84	0	0	0	100
40	0 42	0.48	0.48	0.33	99.67
60	0 25	6 83	7.31	5	95
80	0 18	15.35	22.66	15.5	84.5
100	0 15	24.93	47.59	32.55	67.45
120	0.12	14 49	62.08	42 46	57.54
140	0 1	19 97	82.05	56.12	43.88
200	0.07	11.38	93.43	63.9	36.1
PAN	-	51 7	145 13	99.26	-

DRIVE 27B
172.6 ft - 174.5 ft
Triaxial Permeability Test

Sample Weight = 153.17 g
Sample Length = 8.28 cm
Sample Density = 1828 kg/m^3

confining pressure (psi)	hydraulic conductivity (m/s)	axial load (lbs.)
10	2.05×10^{-6}	+ 3
30	1.69×10^{-6}	- 3
50	1.57×10^{-6}	- 5
70	1.49×10^{-6}	- 9
90	1.45×10^{-6}	- 13

Mechanical Sieve Analysis

Sieve Number	Grain Diameter (mm)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
20	0.84	0 52	0 52	0 34	99 66
40	0 42	3.11	3 63	2.37	97 63
60	0.25	29 94	33.57	21.92	78.08
80	0.18	29.92	63.49	41.45	58.55
100	0.15	25.34	88.83	57.99	42.01
120	0.12	14.61	103.44	67.53	32.47
140	0.1	18 82	122.26	79.82	20 18
200	0 07	16 89	139 15	90.85	9.15
PAN	-	13.34	152.49	99 56	-

DRIVE 33A
203 ft - 205 ft
Triaxial Permeability Test

Sample Weight = 152.25 g
Sample Length = 8.30 cm
Sample Density = 1944 kg/m^3

confining pressure (psi)	hydraulic conductivity (m/s)	axial load (lbs.)
10	8.06×10^{-7}	+ 2
30	5.09×10^{-7}	- 1
50	3.56×10^{-7}	- 6
70	2.78×10^{-7}	- 9
90	2.37×10^{-7}	- 13

Mechanical Sieve Analysis

Sieve Number	Grain Diameter (mm)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
20	0 84	0	0	0	100
40	0 42	1 08	1 08	0 71	99 29
60	0.25	38.36	39 44	25.9	74 1
80	0.18	37.59	77 03	50.59	49 41
100	0 15	25 96	102.99	67.65	32.35
120	0 12	11.58	114 57	75 25	24 75
140	0.1	11.43	126	82.76	17 24
200	0.07	7.16	133.16	87.46	12.54
PAN	-	18.54	151.7	99.64	-

DRIVE 38A
243 ft - 245 ft
Triaxial Permeability Test

Sample Weight = 137. 98 g
Sample Length = 8.51 cm
Sample Density = 1726 kg/m^3

confining pressure (psi)	hydraulic conductivity (m/s)	axial load (lbs.)
10	2.55×10^{-6}	+ 2
30	2.76×10^{-7}	- 3
50	1.95×10^{-7}	- 7
70	1.30×10^{-7}	- 11
90	9.80×10^{-8}	- 11

Mechanical Sieve Analysis

Sieve Number	Grain Diameter (mm)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
20	0 84	0 12	0 12	0 09	99 91
40	0 42	4.21	4.33	3 14	96.86
60	0 25	27.12	31.45	22.79	77 21
80	0 18	25 19	56 64	41.05	58 95
100	0 15	11 96	68.6	49 72	50.28
120	0.12	11.39	79.99	57 97	42.03
140	0.1	9 73	89.72	65 02	34 98
200	0 07	15.2	104 92	76 04	23 96
PAN	-	33.23	138 15	100.12	-

DRIVE 55B
334 ft - 336 ft
Triaxial Permeability Test

Sample Weight = 142.14 g
Sample Length = 7.40 cm
Sample Density = 1822 kg/m^3

confining pressure (psi)	hydraulic conductivity (m/s)	axial load (lbs.)
10	1.86×10^{-6}	+ 3
30	1.49×10^{-6}	- 1
50	1.34×10^{-6}	- 5
70	1.23×10^{-6}	- 9
90	1.15×10^{-6}	- 13

Mechanical Sieve Analysis

Sieve Number	Grain Diameter (mm)	Retained Soil Weight (g)	Cumulative Retained Soil Weight (g)	Cumulative Percent Retained (%)	Percent Passing (%)
20	0.84	0.18	0 18	0.13	99.87
40	0 42	3.58	3.76	2 65	97.35
60	0.25	25.01	28.77	20.24	79.76
80	0.18	38 09	66 86	47.04	52.96
100	0.15	17.62	84.48	59.43	40 57
120	0 12	16.24	100.72	70.86	29.14
140	0 1	11.57	112.29	79	21
200	0.07	16.75	129.04	90 78	9.22
PAN	-	12.51	141 55	99.58	-

Stone, Allen, Mikolas, Hawley, Haneberg, Johnson, Allred, Thom–PRELIMINARY LITHOSTRATIGRAPHY, INTERPRETED GEOPHYSICAL LOGS, AND HYDRO-GEOLOGIC CHARACTERISTICS OF THE 98TH STREET CORE HOLE, ALBUQUERQUE, NEW MEXICO–USGS/Open-File 98-210