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Nature and Variability of the Plio-Pleistocene Unit in the 200 West Area of the Hanford Site

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Nature and Variability of the Plio-Pleistocene Unit in the 200 West Area of the Hanford Site

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METRIC CONVERSION CHART

The following conversion chart is provided to aid the reader in conversion.

Into Metric Units

If You Know	*Multiply By*	*To Get*
Length		
inches	25.4	millimeters
inches	2.54	centimeters
feet	0.305	meters
yards	0.914	meters
miles	1.609	kilometers
Area		
sq. inches	6.452	sq. centimeters
sq. feet	0.093	sq. meters
sq. yards	.0836	sq. meters
sq. miles	2.6	sq. kilometers
acres	0.405	hectares
Mass (weight)		
ounces	28.35	grams
pounds	0.454	kilograms
ton	0.907	metric ton
Volume		
teaspoons	5	milliliters
tablespoons	15	milliliters
fluid ounces	30	milliliters
cups	0.24	liters
pints	0.47	liters
quarts	0.95	liters
gallons	3.8	liters
cubic feet	0.028	cubic meters
cubic yards	0.765	cubic meters
Temperature		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius

Out of Metric Units

If You Know	*Multiply By*	*To Get*
Length		
millimeters	0.039	inches
centimeters	0.394	inches
meters	3.281	feet
meters	1.094	yards
kilometers	0.621	miles
Area		
sq. centimeters	0.155	sq. inches
sq. meters	10.76	sq. feet
sq. meters	1.196	sq. yards
sq. kilometers	0.4	sq. miles
hectares	2.47	acres
Mass (weight)		
grams	0.035	ounces
kilograms	2.205	pounds
metric ton	1.102	ton
Volume		
milliliters	0.033	fluid ounces
liters	2.1	pints
liters	1.057	quarts
liters	0.264	gallons
cubic meters	35.315	cubic feet
cubic meters	1.308	cubic yards
Temperature		
Celsius	multiply by 9/5, then add 32	Fahrenheit

1.0 INTRODUCTION

The Plio-Pleistocene unit is present in the vadose zone underlying the carbon tetrachloride disposal sites in the 200 West Area and elsewhere at the Hanford Site. Previous work indicated that carbonate-rich Plio-Pleistocene deposits are relatively continuous in the west-central part of the Hanford Site and act as a low-permeability barrier to vertical movement of fluids in the vadose zone (DOE 1988). Recognition that this so-called "caliche" layer may temporarily perch liquids, resulting in lateral diversion within the vadose zone, drew attention to the potential influence of the "caliche" layer on the migration and distribution of the carbon tetrachloride (DOE-RL 1991) and prompted this investigation. Furthermore, during site remediation using soil-vapor extraction, the carbonate-rich material was observed to act as a low-permeability barrier to vertical air flow (Rohay 1999). The carbonate-rich material effectively divided the vadose zone being remediated into two zones–one from the ground surface to the top of the caliche layer, and one from the bottom of the caliche layer to groundwater.

The objective of this study is to characterize the nature and variability of these carbonate-rich Plio-Pleistocene deposits. The goal of this research is to support site remediation by determining the extent to which the caliche layer influences (1) the migration of waste streams and distribution of contaminants within the vadose zone, and (2) the flow of soil vapor and removal of contaminants.

The Plio-Pleistocene unit contains carbonate-rich paleosols. Paleosols (ancient soil horizons) record times of depositional minima and enable geologists and soil scientists to reconstruct paleoenvironments. How long the landscape was exposed to subaerial processes and the nature of the processes during these times are important to make such reconstructions. Interpreting the extant features of paleosols requires an understanding of soil-development processes and diagenesis. The paleopedologic and paleoenvironmental interpretations, in turn, aid in understanding how the buried paleosols influence current subsurface processes such as fluid movement.

2.0 GEOLOGIC SETTING

The Pasco Basin is a structural depression in the Columbia Plateau (DOE 1988). Segmented, narrow, asymmetric anticlines and broad, flat synclines characterize the structural geology of the Hanford Site (Figure 2-1). The study area, which includes the 200 West Area, is on the northern limb of the Cold Creek syncline.

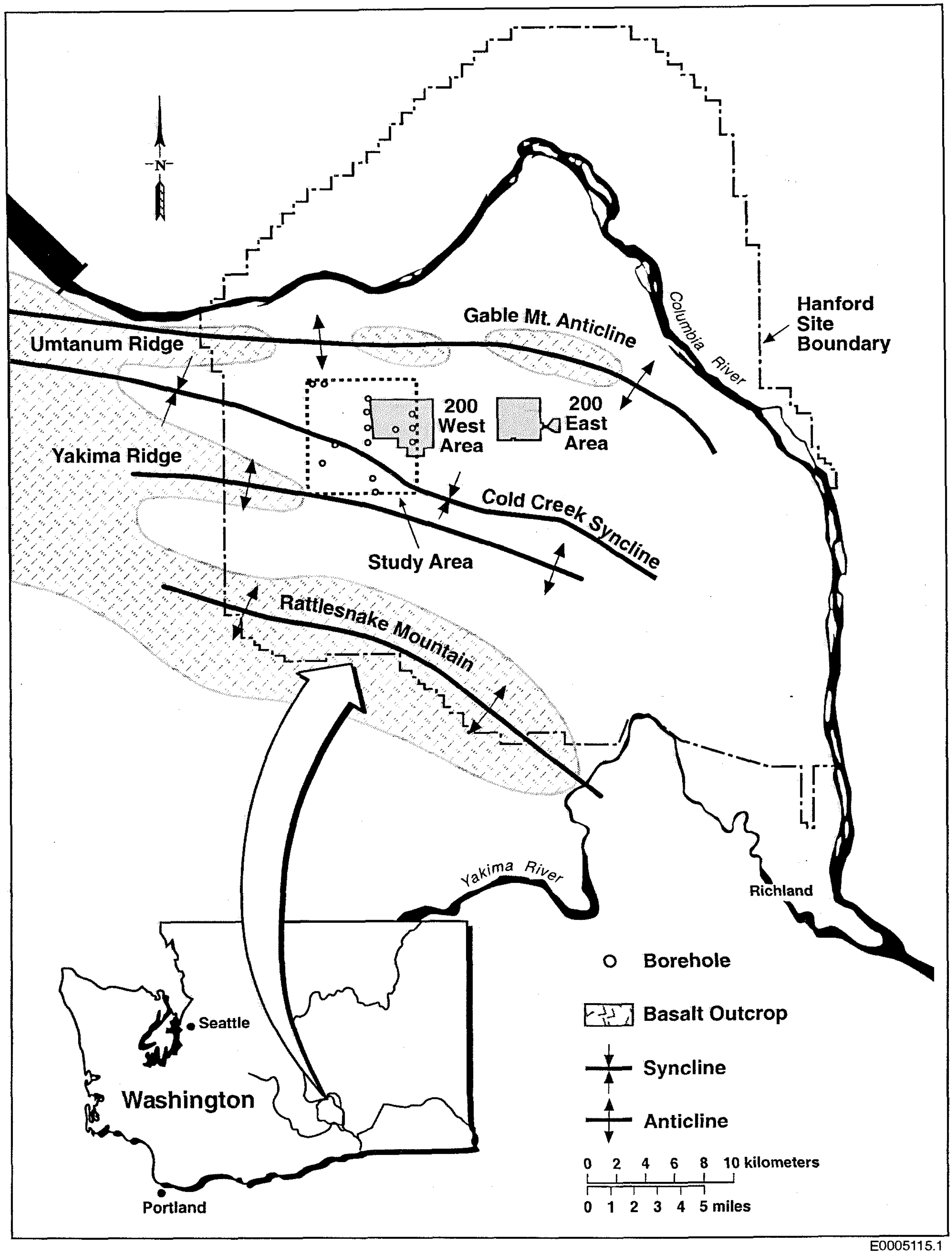
Thick deposits of Miocene continental flood basalts (up to 3,000 m) and younger sediments (up to 230 m) accumulated in the Pasco Basin (DOE 1988, DOE-RL 1991). The suprabasalt sediments include the late Miocene to Pliocene Ringold Formation, the Plio-Pleistocene unit, and the Pleistocene Hanford formation (informal name). Holocene alluvium, loess, and eolian sand locally veneer the Hanford formation deposits.

The Ringold Formation consists of fluvial gravel and sand, overbank deposits, and lacustrine silty sand, silt, and clay deposited by the ancestral Columbia River system (Tallman et al. 1981, DOE 1988, Lindsey 1995). The Hanford formation is composed of glaciofluvial gravel, sand, and silt deposited by cataclysmic flood waters released from western Montana and northern Idaho when ice dams were breached during the last ice age. The Hanford formation is informally divided into a gravelly facies (Pasco gravels) that represents former flood bars and a laminated or bedded sand and silt facies (Touchet beds) that represents slack-water deposits (DOE 1988).

The Plio-Pleistocene unit includes all material overlying the Ringold Formation and underlying the Hanford formation. Major rivers (Columbia, Yakima, and Snake) and local sidestreams deposited Plio-Pleistocene alluvium in the Pasco basin; wind reworked and redeposited some sediments. The rock types transported from the northern Rocky Mountains, Idaho batholith, Okanogan Highlands, Cascade Range, and Wallowa Terrane by the major rivers consist of quartzite and other metasedimentary rocks, gneiss, basalt, andesite, rhyolite, greenstone, and silicic metavolcanic rocks. Local sources contributed basalt and material reworked from previously deposited sediments. These two different sources, distal and local, are the basis for dividing the Plio-Pleistocene unit into two subunits in this study.

The Plio-Pleistocene unit has been divided into three subunits: (1) the Plio-Pleistocene subunit, (2) early "Palouse" soil, and (3) pre-Missoula gravels (Myers et al. 1979, Tallman et al. 1981, Bjornstad 1984, DOE 1988, Last et al. 1989, Lindsey et al. 1991, Reidel et al. 1992). A unified Plio-Pleistocene unit consisting of two subunits (locally derived and distantly derived) better represents this interval in the cores of this study because of uncertainties in the stratigraphic relationships among the three subunits and a paucity of evidence to define a later, separate eolian subunit (the early "Palouse" soil).

Figure 2-1. Location of the Hanford Site in South-Central Washington.



2.1 DISTANTLY DERIVED SUBUNIT

The predominantly felsic gravel with a quartzo-feldspathic sand matrix that composes this subunit displays fluvial sedimentary structures indicating a Columbia River source (Fecht et al. 1985, DOE 1988). This gravel is the only unit found between the Ringold Formation and the Hanford formation in the east-central Cold Creek syncline and at the east end of Gable Mountain anticline in the subsurface east and south of 200 East Area (Figure 2-1). These so-called pre-Missoula gravels (PSPL 1982) are up to 25 m thick, appear whitish or bleached, and truncate underlying strata (DOE 1988). Reversed magnetic polarity indicates these gravels are older than 780 ka (early Pleistocene). Their stratigraphic relationship with other Plio-Pleistocene mainstream and sidestream deposits, however, is not clear, nor is the nature of the contact with the overlying Hanford formation.

2.2 LOCALLY DERIVED SUBUNIT

The poorly sorted, basalt-dominated gravel that composes this subunit indicates that this alluvium is of local origin. This gravel is interbedded with sand and silt that vary from bedded or laminated to massive. Several forms of secondary carbonate accumulations are developed in sediments of this subunit including disseminated (which lightens the matrix and reacts slightly with dilute [10%] hydrochloric acid [HCl] but is otherwise indistinct), filaments, nodules, massive (which impregnates the matrix imparting a white color and reacts strongly to violently with HCl), and partial to complete carbonate coatings on clasts (see Appendix A). This subunit is found in the west-central limb of the Cold Creek syncline in the subsurface west, southwest, and within the 200 West Area (Figure 2-1). Thickness (up to 20 m) and facies distribution are related to depositional environment as well as to the erosional surface on the top of the Ringold Formation and post-depositional erosion by the cataclysmic Missoula floods (Hanford formation). Cold Creek, which drains Umtanum and Yakima Ridges, deposited this subunit along a northwest-trending channel. The gravels mark the course of a channel(s), whereas the fine-grained material represents overbank deposition or eolian reworking. In the limited and incomplete cores examined, little evidence exists for the distinction of a later, separate eolian unit; thus, the early "Palouse" soil (DOE 1988) is not discussed in this report.

Carbonate developed subaerially during hiatuses or low rates of deposition; morphologic development generally reflects the length of time that surfaces were exposed. No other soil horizons are associated with the carbonate, however. One or a combination of the following processes could account for their absence: erosion, or engulfment due to cumulic soil formation or climatic change. Composite carbonate horizons (carbonate horizons stacked on top of each other) reveal repeated periods of soil development. Groundwater processes may have influenced the morphology of some of these horizons.

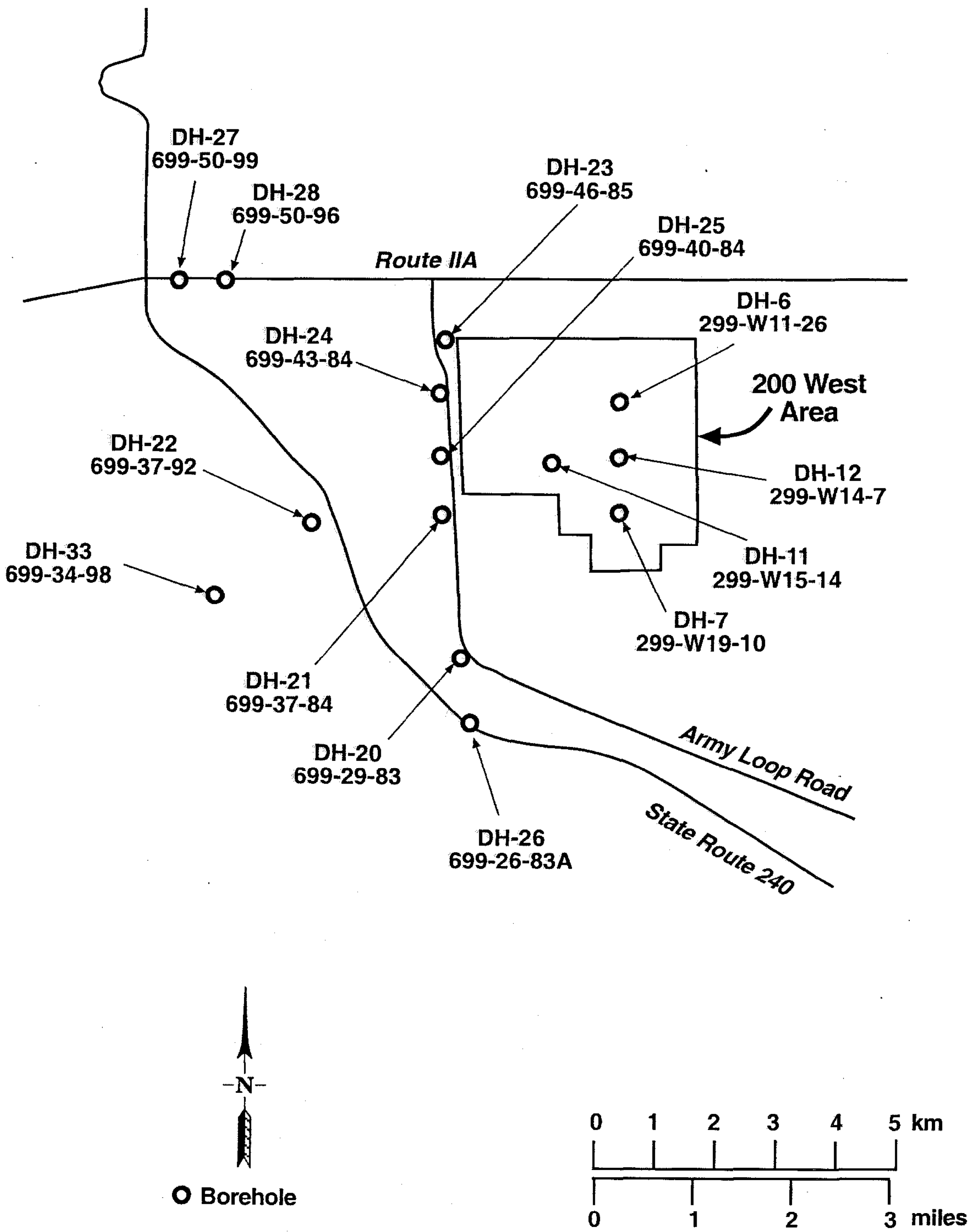
3.0 INVESTIGATION METHODS

A soil-stratigraphic approach was used to study the Plio-Pleistocene deposits. Descriptions of paleosol sections in drill core incorporated elements used in modern field-based soil studies (e.g., Birkeland 1999) including (1) horizon designation, thickness, and boundary characteristics; (2) dry and moist color; (3) structure; (4) carbonate form, distribution, and degree of effervescence in reaction with dilute (10%) hydrochloric acid (HCl); and (5) frequency and size of any root traces or pores. These attributes were examined to help assess the genesis of the deposits. Appendix A includes descriptions of the morphologic stages of $CaCO_3$ development (Gile et al. 1966, Machette 1985, Birkeland 1999).

Detailed, soil-stratigraphic descriptions and "field" interpretations of the post-Ringold sediments were made in 14 cores collected during characterization studies for the Basalt Waste Isolation Project (BWIP). These cores were taken from the 200 West Area and vicinity (Figure 3-1). Descriptions, interpretations, sketches, and sample lists of the Plio-Pleistocene portions of all 14 BWIP cores studied are presented in Appendix B.

In order to interpret paleosol genesis, samples were taken for (1) standard soil analyses including particle-size distribution (on a carbonate-free basis), percent calcium carbonate, bulk density, and hygroscopic moisture content; (2) stable isotopic analyses ($\delta^{13}C$ and $\delta^{18}O$); and (3) thin sections for micromorphologic study. In support of ongoing groundwater modeling studies, samples were also taken for hydraulic conductivity (saturated and unsaturated) and moisture retention analyses. Laboratory analytical results (textural classification based on grain size, percent calcium carbonate, and isotopic analyses) for the Plio-Pleistocene samples collected from 10 cores (DH–6, 7, 11, 12, 21, 24, 25, 26, 27, 33) are provided in Appendix C. Descriptions and interpretations of thin sections from the Plio-Pleistocene portions of the drill core samples within and along the perimeter of the 200 West Area are presented in Appendix D. Photomicrographs of thin sections from six cores (DH–6, 11, 12, 24, 25, 33) are provided in Appendix E. The elevations and thicknesses of Plio-Pleistocene surfaces for all 14 BWIP cores studied are presented in Appendix F.

Figure 3-1. Location of the Core Samples Studied for This Report.



4.0 DISTRIBUTION, EXTENT, AND FACIES OF THE LOCALLY DERIVED PLIO-PLEISTOCENE DEPOSITS

The deposits that make up the locally derived Plio-Pleistocene subunit are restricted to the west-central part of the Hanford Site. In and near the 200 West Area, local sources (from Umtanum and Yakima Ridges, Figure 2-1) contributed basalt and material reworked from previously deposited sediments. As such, the lithology ranges from basalt-dominated gravel to sand and silt; carbonate is irregularly dispersed throughout.

The distribution of the Plio-Pleistocene deposits depends in part on erosion of the underlying Miocene-Pliocene fluvial/lacustrine Ringold Formation and post-depositional erosion by the cataclysmic Missoula floods. The erosional surface on the top of the Ringold Formation has up to 25 m (80 ft) of relief in the study area and delineates a former channel of Cold Creek or unnamed drainages of Umtanum and Yakima Ridges (Figure 4-1). The top of the Plio-Pleistocene interval is also an irregular surface and may reflect original depositional topography or post-depositional erosion by Cold Creek or Missoula flood waters (Figure 4-2). The thickness of the Plio-Pleistocene unit can be interpreted as representing deposition along a northwest-trending channel (Figure 4-3) (Slate 1996).

The facies of the Plio-Pleistocene deposits further support the idea of deposition along a northwest-trending channel (Figure 4-3). The gravelly material marks the course of a channel, whereas the fine-grained material reflects overbank deposition. The occurrence of carbonate layers in the gravelly material suggests that the channel was either intermittent or meandered in its thalweg (e.g., DH–22). This indicates a hiatus in gravel deposition that enabled carbonate to develop. Where overbank deposition was repetitive, multiple paleosols exist (Slate 1996).

4.1 DISTRIBUTION AND FACIES OF THE PLIO-PLEISTOCENE DEPOSITS IN THE 200 WEST AREA

Four of the cores studied for this report are located within the 200 West Area (Figure 3-1). The Plio-Pleistocene deposits are described specifically for this area because of their potential impact on distribution and remediation of contaminated wastes disposed to the soil column in the 200 West Area. The locations of these four cores and the primary carbon tetrachloride disposal sites are shown in Figure 4-4.

The Plio-Pleistocene unit and corresponding carbonate layers in the 200 West Area can be thought of as two different facies (Figure 4-3). The deposits of the DH–12 and DH–7 cores make up one facies, and the deposits of the DH–11 and DH–6 cores compose the other. The number of calcium carbonate ($CaCO_3$) layers, thickness, and gravel distribution varies between these two facies (Table 4-1).

Figure 4-1. Structure-Contour Map of the Top of the Ringold Formation as Interpreted from Boreholes Shown in the Figure.

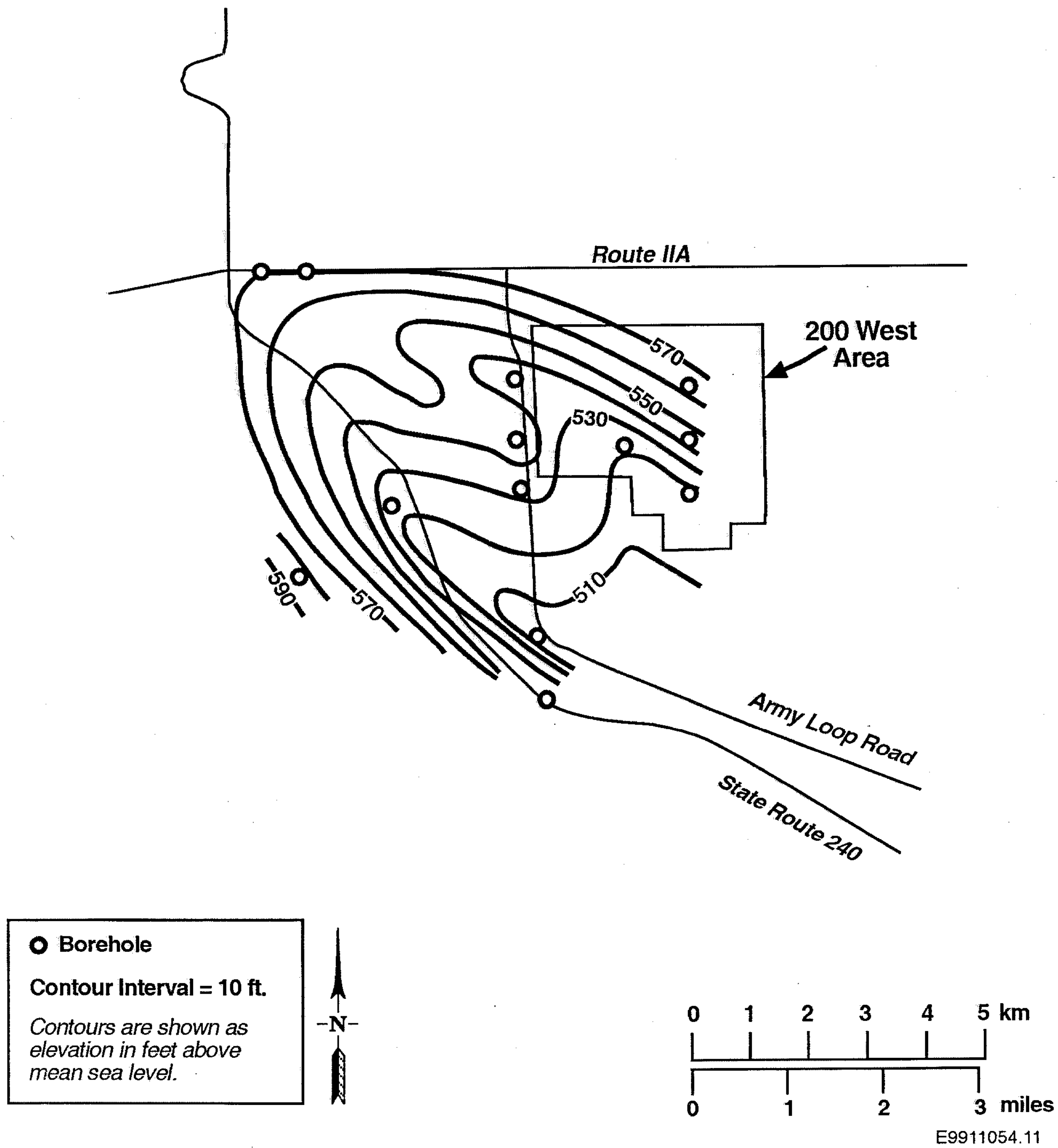


Figure 4-2. Structure-Contour Map of the Top of the Plio-Pleistocene Unit as Interpreted from Boreholes Shown in the Figure.

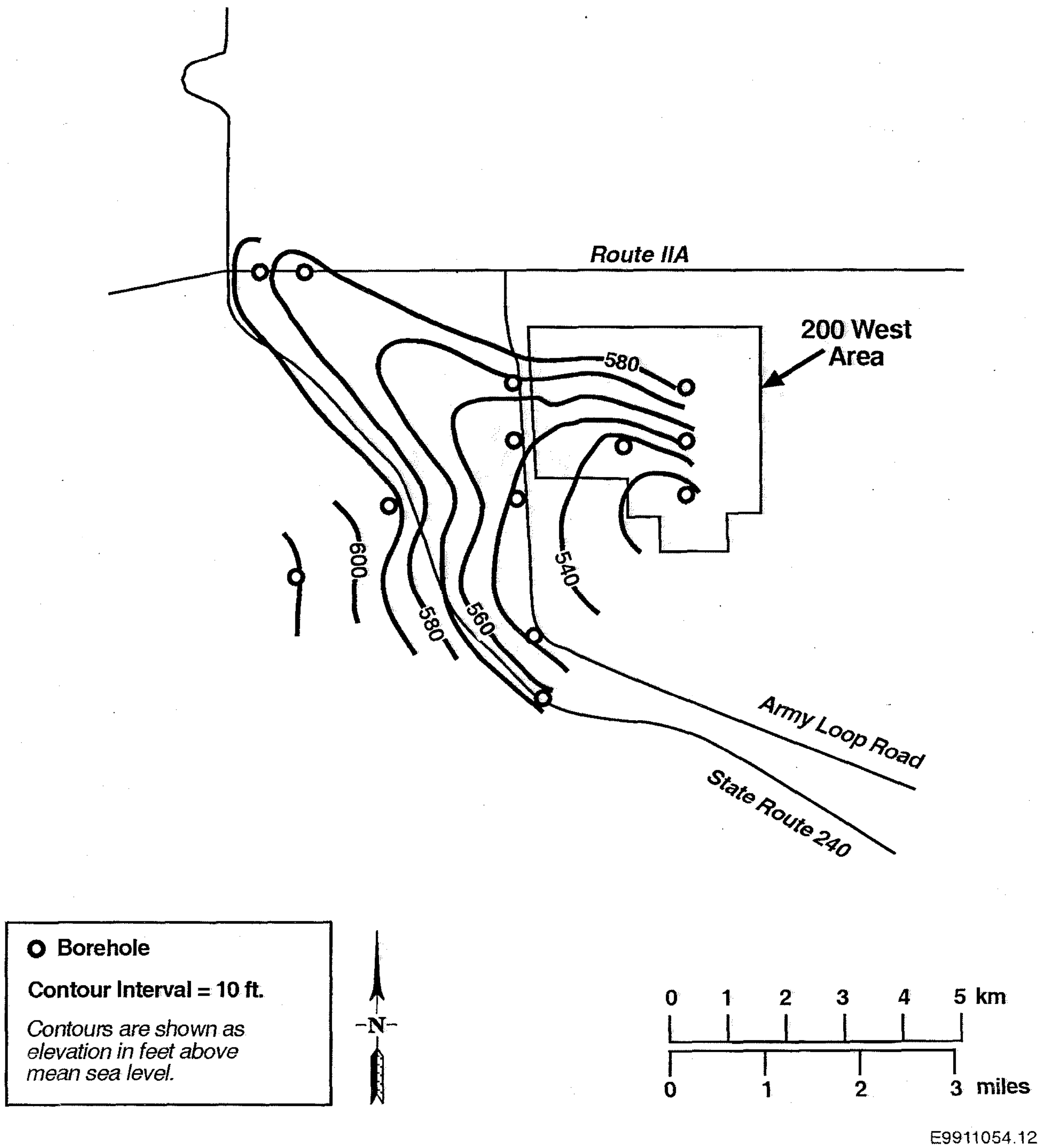


Figure 4-3. Combined Isopach and Facies Map of the Plio-Pleistocene Unit as Interpreted from Boreholes Shown in the Figure.

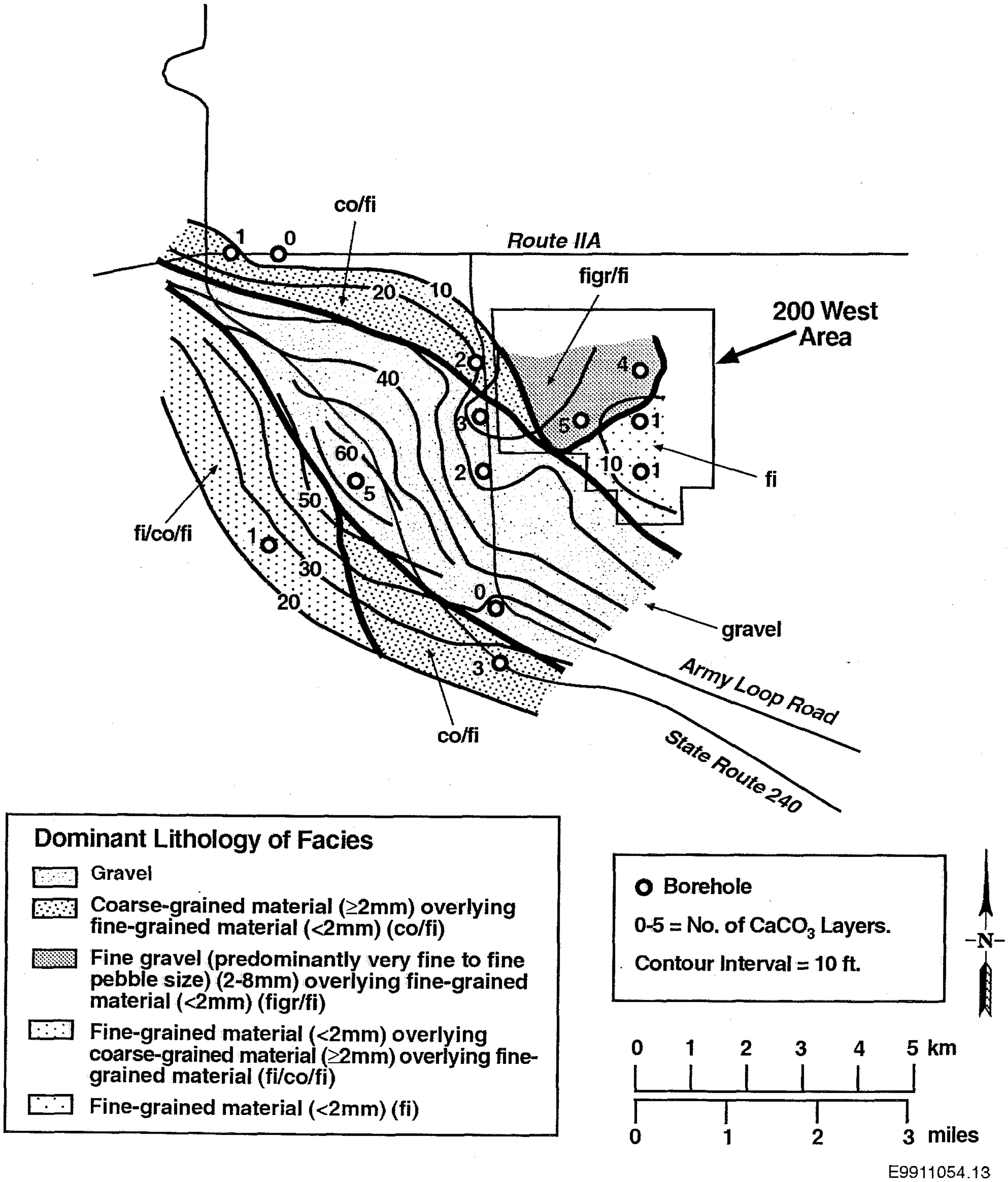


Figure 4-4. Location of the Primary Carbon Tetrachloride Disposal Sites and Cores Studied Within and Along the Perimeter of the 200 West Area.

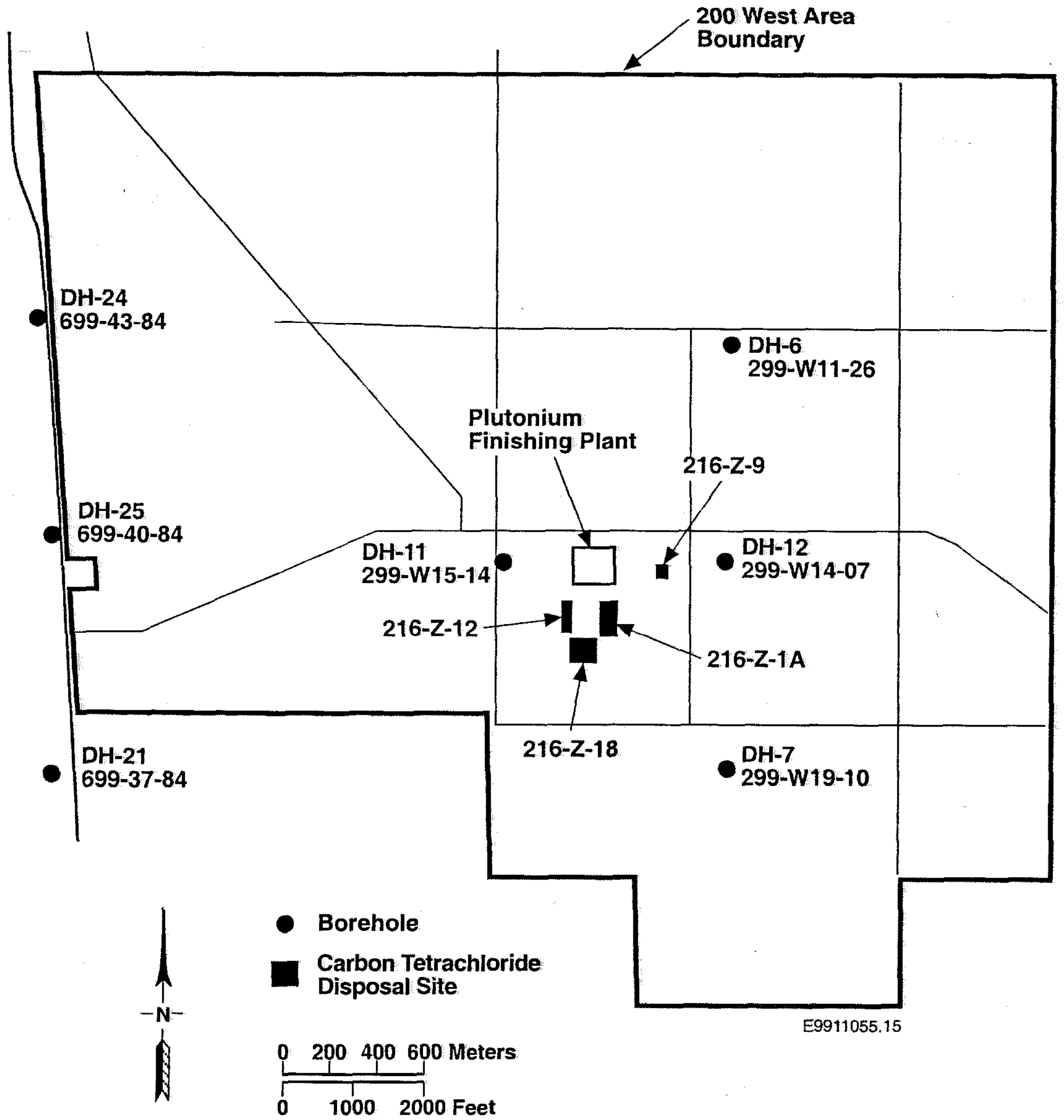


Table 4-1. Characteristics Observed in Cores Within the 200 West Area.

Core Location	Number of $CaCO_3$ Layers	Thickness of Plio-Pleistocene Unit (ft) [m]	Gravel Distribution
Facies represented by southeast pair			
DH–12	1	2.4 [0.73]	Few pebbles, except near base of Plio-Pleistocene unit
DH–7	1	7.0 [2.1]	Few pebbles
Facies represented by northwest pair			
DH–11	5	12.4 [3.8]	Very fine-fine pebbles throughout, but more in upper two-thirds of Plio-Pleistocene unit
DH–6	4	17.0 [5.2]	Very fine-fine pebbles throughout, but more in upper two-thirds of Plio-Pleistocene unit

All of the carbonate layers in the four 200 West Area cores are interpreted as former soil horizons constituting paleosols because the carbonate contents of the collective layers decrease with depth.

The multiple paleosols in the northwest pair (DH–11 and DH–6) are stacked on top of one another, with less well-developed carbonate material or undeveloped parent material separating the well-developed carbonate layers. This pattern of multiple paleosols indicates repetitive overbank deposition. Parent-material characteristics including medium- to coarse-grained sand, and laminae or bedding indicate deposition by fluvial processes. Where few instances of overbank deposition occurred, the paleosols are either composite and are thus thicker (e.g., DH–7) or are well developed but potentially eroded (e.g., DH–12).

The fine nature and thinness of the Plio-Pleistocene deposits in the 200 West Area compared with those of other cores examined suggests that deposition was limited in the 200 West Area. The Plio-Pleistocene deposits in the 200 West Area are interpreted as overbank deposits in the southeast pair of boreholes (DH–12 and DH–7) and either overbank or avulsion-splay deposits in the northwest pair (DH–11 and DH–6). (An avulsion-splay deposit results when the stream in one channel abruptly shifts to another channel.)

The Plio-Pleistocene facies/thickness map (Figure 4-3) and the structure-contour maps of the top of the Ringold Formation (Figure 4-1) and the top of the Plio-Pleistocene unit (Figure 4-2) indicate that deposition of the Plio-Pleistocene unit was initially dispersed along more than one channel. This may have led to intermittent or overbank deposition in the 200 West Area. The main locus of Plio-Pleistocene deposition was west of the 200 West Area in a northwest-trending direction, with DH–22 and DH–20 closely approximating the axis (Figure 4-3; see Figure 3-1 for borehole locations). By the end of Plio-Pleistocene deposition, the channel locus shifted east, near the southwest corner of the 200 West Area, with DH–27 and DH–25 closely approximating the axis (Figure 4-2).

The paleosols of DH–12 and DH–7 may be correlative, but that of DH–12 is better developed than that of DH–7. The DH–12 paleosol is stage IV (laminar layer of carbonate; >60% $CaCO_3$ when gravel content is low, that is, below 20%), whereas the DH–7 paleosol is stage III+ (massive carbonate; 40% to 60% $CaCO_3$ for low-gravel content soils). Better development of the DH–12 paleosol relative to the DH–7 paleosol would be expected because the Plio-Pleistocene unit in DH–12 is thinner, and thus development of the paleosol is concentrated across a narrower interval.

Correlating the paleosols of DH–11 and DH–6, however, is more tenuous. The five paleosols of DH–11 are compressed in a narrower zone than are the four paleosols of DH–6 (Table 4-1). Also, 0.4 m (1.3 ft) of core is missing from either of the two lower paleosols in DH–6 (Appendix B).

A synopsis of the morphology and development of each paleosol follows.

Southeast Pair

DH–12 (299-W14-7): East of carbon tetrachloride disposal sites. DH–12 has a well-developed, 0.73-m (2.4-ft)-thick paleosol at 38.9- to 39.6-m (127.6- to 130-ft) depth (167.5 to 166.7 m [549.4 to 547 ft] above sea level). Maximum $CaCO_3$ development is stage IV (Gile et al. 1966, Machette 1985, Birkeland 1999; Appendix A). Microscopic examination suggests the upper 0.15 m (0.5 ft) of the paleosol may have been reworked or transported.

DH–7 (299-W19-10): Southeast of carbon tetrachloride disposal sites. DH–7 has a well-developed, 2.1-m (7.0-ft)-thick paleosol at 49- to 51.2-m (161- to 168-ft) depth (158.8 to 156.7 m [521 to 514 ft] above sea level). Maximum $CaCO_3$ development is stage III+. Microscopic examination suggests that at least the upper 0.12 m (0.4 ft) of the paleosol may have been redeposited.

Northwest Pair

DH–11 (299-W15-14): West of carbon tetrachloride disposal sites. DH–11 has five well-developed paleosols stacked on top of each other from 47.7- to 51.5-m (156.6- to 169-ft) depth (164.4 to 160.6 m [539.4 to 527 ft] above sea level). The paleosols are interpreted as superimposed soils—the upper part of the underlying (buried) soil was influenced by pedogenesis of the soil above. Maximum $CaCO_3$ development is stage IV. Microscopic examination suggests that some of the constituents are reworked, probably from the subjacent paleosol. Micritic $CaCO_3$ predominates, but sparry $CaCO_3$ is present in many samples. Sparry $CaCO_3$ indicates a long or slow formation time. Weathered, vesicular volcanic-glass shards are the likely source of opaline silica; both were observed in many of the thin sections. Clay is present both as a weathering by-product and as a pedogenic (illuvial) feature.

DH–6 (299-W11-26): Northeast of carbon tetrachloride disposal sites. DH–6 has four well-developed paleosols stacked on top of each other from 34.4- to 39.6-m (113- to 130-ft) depth (177 to 171.9 m [581 to 564 ft] above sea level). The paleosols are interpreted as superimposed soils—the upper part of the underlying (buried) soil was influenced by pedogenesis of the soil above. Maximum $CaCO_3$ development is stage III+. Microscopic examination suggests that these paleosols developed in place for a lengthy period of time. As in the samples from DH–11, micritic $CaCO_3$ predominates, but sparry $CaCO_3$ is a greater percentage of all three samples examined relative to those of DH–11. Clay forms distinct bands either around grains or filling voids. Weathered, vesicular volcanic-glass shards are the likely source of opaline silica; both were observed in all three of the thin sections.

4.2 DISTRIBUTION AND FACIES OF THE PLIO-PLEISTOCENE DEPOSITS ON THE WESTERN PERIMETER OF THE 200 WEST AREA

The Plio-Pleistocene unit and corresponding carbonate layers of the three boreholes along the western perimeter of the 200 West Area are more gravelly overall than the corresponding intervals in the boreholes of the 200 West Area (Figure 4-3). These three boreholes were nearer to the inferred axis of the channel that deposited the locally derived Plio-Pleistocene subunit than those within the 200 West Area. Basalt is the predominant clast type in all three cores. The proximity to the channel or locus of deposition explains why these cores would have coarser sediment (Figures 4-1, 4-2, and 4-3). The Plio-Pleistocene deposits of DH–21 (the southernmost of the three, Figures 3-1 and 4-4) are gravelly throughout. DH–25 has 0.3 m (1 ft) of sandy material at the base, but is otherwise gravelly. The Plio-Pleistocene deposits of DH–24 (the northernmost of the three) are finer grained overall than those of DH–21 and DH–25; the lower part is predominantly sandy, and it is coarser near the top.

The genesis of the carbonate layers in the three cores along the western perimeter of the 200 West Area may include some groundwater modification in addition to soil-forming processes that occur in the vadose zone. Abrupt upper and lower boundaries to a few of the carbonate layers and unusual $CaCO_3$ textures suggest groundwater modification.

Correlating the paleosols of these three boreholes is difficult because the uppermost cores recovered from both DH–24 and DH–25 are within the Plio-Pleistocene unit; thus, the top of the Plio-Pleistocene unit and therefore the basal depth of the Hanford formation are unknown. Additionally, core is missing from both DH–24 (1.06 m [3.5 ft]) and DH–21 (1.2 m [4 ft]) (Appendix B). With these caveats in mind, note the similarities among the numbers of $CaCO_3$ layers, the thicknesses of the paleosols, and gravel distributions (Table 4-2).

Table 4-2. Characteristics Observed in Cores from the Western Perimeter of the 200 West Area.

Core Location	Number of $CaCO_3$ Layers	Thickness of Paleosols (ft) [m]	Gravel Distribution
DH–24	2	5.0+ [1.5+]	Top more gravelly, sandier near base
DH–25	3	5.7 [1.7]	Basal 0.3 m (1 ft) sandy, remainder is gravelly
DH–21	2	6.5+ [1.9+]	Gravelly throughout

A synopsis of the morphology and development of each paleosol follows.

DH–24 (699-43-84): West-northwest of carbon tetrachloride disposal sites. The uppermost recovered core in DH–24 is in Plio-Pleistocene deposits; the base of the Hanford formation was not collected. Therefore, the observed thickness of the Plio-Pleistocene unit in DH–24 is a minimum. DH–24 has two paleosols separated by missing core and possible clastic-dike material. The upper paleosol is between 23.9- and 24.2-m (78.3- and 79.5-ft) depth (168.9 to 168.5 m [554.1 to 552.9 ft] above sea level), and the lower paleosol is from 25.4 to 26.5 m (83.4 to 86.9 ft) (167.3 to 166.3 [549.0 to 545.5 ft] above sea level).

The upper paleosol is characterized by primarily massive $CaCO_3$ vertically juxtaposed with a subordinate mixture of $CaCO_3$-free sands and pebbles underlain by massive $CaCO_3$ (stage III), which appears to increase with depth. Microscopic examination of a thin section from the upper part of the upper paleosol suggests that some of the constituents are reworked or redeposited.

The appearance, distribution, and boundary characteristics of the massive $CaCO_3$ in the lower paleosol suggests that it may not be of pedogenic origin. $CaCO_3$ discrete from sand in the upper part suggests a clastic dike origin, and thus groundwater would have been high. The hackly, "popcorn" appearance of $CaCO_3$ in the mid-portion is unlike that of any soil carbonate. The apparent increase in $CaCO_3$ with depth and an abrupt base lend credence to a groundwater origin for the carbonate.

DH–25 (699-40-84): West of carbon tetrachloride disposal sites. The uppermost recovered core in DH–25 is in Plio-Pleistocene deposits; the base of the Hanford formation was not collected. Therefore, the observed thickness of the Plio-Pleistocene unit in DH–25 is a minimum. DH–25 has three paleosols in Plio-Pleistocene deposits and one developed in Ringold deposits. The three in the Plio-Pleistocene deposits are superimposed on top of one another from 25.8 to 27.5 m (84.6 to 90.3 ft) (168.7 to 167.0 m [553.6 to 547.9 ft] above sea level); the one in the Ringold deposits is separated from the others by non-pedogenically altered deposits.

The upper two paleosols exhibit weak bedding features; massive $CaCO_3$ is the main indicator of possible pedogenesis. The lower Plio-Pleistocene paleosol, which is only 0.09 m (0.3 ft) thick, consists of pervasive, massive $CaCO_3$, but the lightweight nature of the $CaCO_3$ and abrupt upper and lower boundaries suggest some groundwater modification.

DH–21 (699-37-84): West-southwest of carbon tetrachloride disposal sites. DH–21 has two paleosols separated by non-pedogenically altered deposits and missing core. The upper one is between 26- and 27.9-m (85.2- and 91.5-ft) depth (167.2 to 165.3 m [548.5 to 542.2 ft] above sea level), and the lower one, bounded by missing core (0.9 m [3 ft] above and 0.3 m [1 ft] below), is between 30.9- and 31-m (101.5- and 101.7-ft) depth (162.2 to 162.2 m [532.2 to 532 ft] above sea level). The upper paleosol may be a composite paleosol with the lower carbonate zone separated from the upper by 0.2 m (0.8 ft) of unconsolidated material. The maximum $CaCO_3$ development in the lower half of the upper paleosol is stage III/IV; the higher stage values are for a smaller percentage of $CaCO_3$ because of high gravel content (Appendix A). The lower half of the upper paleosol has $CaCO_3$ at the base and none at the top, indicating a possible groundwater origin.

5.0 PALEOSOL DEVELOPMENT AND PALEOENVIRONMENTAL CONDITIONS

The following observations and interpretation of all 14 cores to evaluate paleosol development and paleoenvironmental conditions are taken from Slate (1996).

Properties of carbonate horizons vary among the paleosols (Table 5-1). Although these carbonate layers are interpreted as paleosols, morphologic features indicate that modification may have occurred after initial development near the surface. The absence of associated soil horizons, no apparent decrease in carbonate content with depth in some of the carbonate layers (as would be expected in pedogenic carbonates), and some carbonates with fabrics that are not common to pedogenic carbonates indicate that groundwater (or capillary-fringe) processes may have influenced the morphology of some of these horizons.

Table 5-1. Properties of Carbonate Horizons in Buried Plio-Pleistocene Paleosols at the Hanford Site.

Color[a]	• Dry (variable): 2.5Y 8/3; 10YR 8/3, 8/2, 7/2 • "white" (no Munsell match) • Moist (variable): 2.5Y 7/3, 7/2; 10YR 8/3, 7/4, 7/3, 7/2, 6/4, 6/3, 6/2
Texture[b,c]	• Predominantly sandy loam • On a carbonate-free basis: sand 30-92%; silt 6-45%; clay 2-28%; gravel 0-90%
Structure	Most are massive; few are platy
Bulk Density (g/cm^3)[b]	1.4 - 2.4; mean 1.8 ± 0.2
$CaCO_3$ (%)[b]	6 – 67; mean 32 ± 15
$CaCO_3$ stage[d]	I – V; predominantly stage III

[a]Munsell color chart (Munsell Color Company 1954).
[b]Based on laboratory analyses of 40 carbonate horizons.
[c]Gravel >2.0 mm; sand 0.05-2.0 mm; silt 0.002-0.05 mm; clay <0.002 mm.
[d]Gile et al. (1966), Machette (1985).

Certain features are different between the paleosol morphology of a pedogenic carbonate and one that developed under the influence of, or was modified by, a high or fluctuating water table or capillary rise. Pedogenic carbonates have morphologic stages with the expected depth distribution: carbonate content decreases with depth, upper boundaries are sharp, and lower boundaries are diffuse. The morphologic stage attained is related to the elapsed time for soil development (Gile et al. 1966, Machette 1985). Morphologic stages of groundwater (or capillary-rise) carbonates, however, may not be depth related—carbon content may actually increase with depth and lower boundaries may be sharp. The soil horizons overlying a pedogenic carbonate and their development should bear some relationship to carbonate stage

(Birkeland 1999). But there may be no soil horizons overlying a groundwater carbonate, or if there are any present, they may bear no relationship to the carbonate stage. The position of a pedogenic Bk or Bkm horizon is sensitive to mean annual precipitation, whereas the depth to the water table and (or) the height of capillary rise controls the position of groundwater-affected Bk or Bkm horizons. Groundwater carbonates precipitate either wholly within the saturated zone or only as much as a few meters above it (Wright and Tucker 1991). Other pedogenic features may be absent; the groundwater carbonate horizon is typically massive and can be much thicker than one formed by soil processes (≥ 10 m; Wright and Tucker 1991).

Groundwater or capillary-rise influences are interpreted for the carbonate paleosols in which carbonate content appears to increase with depth and those that display unusual carbonate morphologies. Massive carbonate that is fine-grained in the upper 25 cm (0.9 ft) and pebbly in the lower 20 cm (0.6 ft) is abruptly underlain by coarse to very coarse basalt pebbles (DH–33, 34.3 to 34.4 m [112.4 to 112.8 ft] depth). Because the lower boundary to the carbonate is abrupt and there is no apparent decrease in carbonate content with depth, this carbonate may have been affected by groundwater processes. Another massive carbonate—one that becomes increasingly massive with depth—is abruptly bounded below by fine-grained, non-pedogenically altered sediments (DH–27, 66.7 to 66.8 m [218.8 to 219.3 ft] depth). Fabrics uncommon to pedogenic carbonates appear "hackly" or popcorn-like (e.g., DH–24, 25.9 to 26.0 m [84.9 to 85.3 ft] depth) or crystalline (e.g., DH–11, 50.0 to 50.1 m [164.0 to 164.5 ft] depth).

The absence of additional soil horizons other than carbonate horizons in the Plio-Pleistocene paleosols of the Hanford Site is a genetic enigma. Other soil horizons may have been eroded, or argillic or cambic horizons never developed because of either parent-material layering or short exposure times at the surface. If episodic deposition occurred, then the carbonate may have continually built upward, eradicating any argillic or cambic horizon that may have begun to form. Alternatively, carbonate may have engulfed former argillic or cambic horizons because of either (1) a change to a warmer climate in which carbonate precipitated higher up in the profile, or (2) a rise or fluctuation in the water table, or both.

6.0 RELATION OF PALEOSOLS TO DISTRIBUTION AND REMEDIATION OF CARBON TETRACHLORIDE

Carbon tetrachloride was discharged 5 to 6 m below the ground surface in the 200 West Area between 1955 and 1973 through the 216-Z-9, 216-Z-1A, 216-Z-18, and 216-Z-12 cribs. The 216-Z-9 crib is closest to DH–12; the other three cribs are closer to DH–11 (Figure 4-4). The finer and more massive carbonate horizons influence carbon tetrachloride transport by effectively slowing its rate of downward movement and potentially diverting it laterally. Carbon tetrachloride concentrations observed since 1991 are higher in and just above the zone that contains the carbonate paleosols (Rohay et al. 1994, Rohay 1999).

The relative impermeability of the thick, massive carbonate to air flow appears to restrict upward migration of vapor-phase carbon tetrachloride volatilizing from groundwater. Furthermore, during site remediation using soil-vapor extraction, the carbonate-rich material was observed to act as a low-permeability barrier to vertical air flow. The carbonate-rich material effectively divides the vadose zone being remediated into two zones—one from the ground surface to the top of the caliche layer, and one from the bottom of the caliche layer to groundwater. The restricted flow of air through the relatively impermeable carbonate layer(s) also causes a significant attenuation of barometric pressure signals propagating downward from the surface. The resulting differential pressure between the zone below the paleosurface and the ground surface can drive vapor flow through preferential pathways such as boreholes (Rohay 1996).

7.0 CONCLUSIONS

The Plio-Pleistocene sediments in the vicinity of the 200 West Area were deposited in a former sidestream alluvial channel (ancestral Cold Creek). Deposition was episodic, and carbonate soils developed during hiatuses or in a cumulic regime primarily through pedogenic processes. But soil horizons other than carbonate horizons are missing in these deposits. The morphology of some of the carbonate horizons suggests that groundwater may have influenced their development.

The Plio-Pleistocene unit in the study area is best represented as consisting of two subunits, one locally derived and one distantly derived. There is insufficient evidence to define a later, separate eolian unit (the early "Palouse" soil) based on the incomplete records of the Plio-Pleistocene unit in the 14 cores studies. Recall that core recovery from both DH–24 and DH–25 began in the Plio-Pleistocene unit; this is also true of DH–22 and possibly of DH–20. Bjornstad (1990) observed early "Palouse" soil in cores taken from burial ground 218-W-5 in the northwestern part of the 200 West Area.

The Plio-Pleistocene deposits vary in thickness from 0 to at least 20.1 m (66 ft) in the 14 cores studied. Carbonate layers are not confined to the Plio-Pleistocene deposits; some are in the Hanford formation and some formed on the Ringold erosional surface. The Plio-Pleistocene "caliche layer," composed of one to five individual carbonate layers, is not a uniform feature.

"Caliche" is a persistent feature within the Plio-Pleistocene interval of the four 200 West Area drill cores, with all four cores exhibiting a maximal stage III+ or stage IV morphology. But the thickness and number of the carbonate layers as well as the texture of the parent material vary among these four drill cores. The single carbonate layer formed in DH–7 and DH–12 may be correlative. Correlation of the carbonate layers from DH–11 to DH–6, however, is more tenuous, and correlation from DH–12 or DH–7 to either DH–11 or DH–6 would be highly speculative.

Understanding the distribution, morphology, and genesis of carbonate paleosols helps to predict the subsurface distribution of waste streams such as carbon tetrachloride. The finer and more massive carbonate horizons present a greater impediment to vertical carbon tetrachloride migration, both downward in a liquid and (or) vapor phase and upward as a vapor phase. Removal of carbon tetrachloride using soil-vapor extraction is effective in the 200 West Area subsurface, but the intervals above and below the Plio-Pleistocene unit must be treated separately.

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APPENDIX A

STAGES OF CALCIUM CARBONATE MORPHOLOGY

APPENDIX A
STAGES OF CALCIUM CARBONATE MORPHOLOGY

Adapted and modified from Birkeland (1999; p. 356-358) and Machette (1985, p. 5).

Stage	Gravel content[a]	Diagnostic morphologic characteristics	Max $CaCO_3$ content[b]
I	High	Thin, discontinuous coatings on pebbles, usually on undersides	Trace – 2
	Low	A few filaments in soil or faint coatings on ped faces	Trace – 4
I+	High	Many or all clast coatings thin and continuous	2 – 5
	Low	Filaments common	4 – 10
II	High	Continuous, thin to thick coatings on tops and undersides of pebbles; local cementation of few to several clasts; matrix loose and calcareous enough to give somewhat whitened appearance	2 – 10
	Low	Few to common nodules, soft, 0.5 cm to 4 cm in diameter, matrix noncalcareous to slightly calcareous	4 – 20
II+	High	Same as stage II, except carbonate in matrix more pervasive	8 – 15
	Low	Common nodules; matrix whitened	15 – 25
III	High	Massive accumulations between clasts; essentially continuous dispersion in matrix (K fabric)	10 – 25
	Low	Many coalesced nodules; matrix firmly to moderately cemented; also K fabric	20 – 60
III+	High	Cementation more or less continuous; most clasts have thick carbonate coats; matrix particles continuously coated with carbonate or pores plugged by carbonate	20 – 30
	Low	Most grains coated with carbonate; most pores plugged	>40
IV	Any	Thin (<0.2 cm) to moderately thick (1 cm) laminae in upper part of Km (cemented) horizon; cemented platy to weak tabular structure and indurated laminae; Km horizon is 0.5 to 1 m thick	>25 in high gravel content >60 in low gravel content
V	Any	Thick laminae (>1 cm) and thin to thick pisolites; vertical faces and fractures coated with laminated carbonate (case-hardened surface); indurated dense, strong platy to tabular structure; Km horizon is 1 to 2 m thick	>50 in high gravel content >75 in low gravel content
VI	Any	Multiple generations of laminae, breccia, and pisolites; recemented; many case-hardened surfaces; indurated and dense, thick strong tabular structure; Km horizon is commonly >2 m thick	>75 in all gravel contents

[a]High is >50% gravel; low is <20% gravel.
[b]Percent $CaCO_3$ in the <2-mm fraction of the soil.

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APPENDIX B

DESCRIPTIONS AND INTERPRETATIONS OF THE 14 BWIP CORES

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APPENDIX B

DESCRIPTIONS AND INTERPRETATIONS OF THE 14 BWIP CORES

Core:	DH-6 (299-W11-26)
Location:	east north-central 200W, N of DH-12 448095N, 2220256E (WA State Coordinates)
Interval Logged:	90' (top of core) - 141' (130'= top of Ringold Fm)
Interpreted by:	J.L. Slate
Date Described:	2/93

Depth (ft)	Description and Interpretation
90 - 93	*(But only 2' in core box.)* Fine to very coarse, quartzo-feldspathic sand, most of which is medium to coarse; the coarse to very coarse fraction has a high percentage of mafic grains. Weakly bedded. 2.5Y 7/2d; 2.5Y 4/2m. $CaCO_3$ disseminated in matrix, slightly effervescent. Sediments were likely water laid—probably Touchet beds.
93 - 103	*(9.5' of core lost, thus only 0.5' available to characterize this interval.)* Mostly fine, laminated sand but silt and medium sand at the top possibly represents a clastic dike. 2.5Y 7/2d; 2.5Y 5/3m. $CaCO_3$ disseminated in matrix, very slightly effervescent. Water laid—probably Touchet beds.
103 - 104	*Core lost.*
104 - 105	Coarse to very coarse sand and some very fine pebbles. Bedding is weak and hard to distinguish because material breaks to small pieces. Peppery appearance closest to 2.5Y 6/2d, 2.5Y 4/2m. Non- to very slightly effervescent. Water laid—probably Touchet beds.
105 - 107.5	Probable clastic dike consisting mostly of massive and laminated silt. Sand is present at bedding planes and at odd angles. Vesicles are stretched out vertically along the trend of dike injection between 106.0' and 106.5'. $CaCO_3$ disseminated in matrix, very slightly to slightly effervescent.
107.5 - 108	Laminated silt. 2.5Y 7/2d; 2.5Y 5/3m. Non- to very slightly effervescent. Water laid—probably Touchet beds.
108 - 111	*(But only 0.6' of core in box.)* Combination of mostly fine to medium, 2.5Y 7/2d, 2.5Y 5/3m sand—some up to very coarse—and massive, 10YR 8/2d, 10YR 7/2m $CaCO_3$ (stage II-III morphology) and Si(?) material. Evidence of bedding was scant: a 1-cm-thick layer of the sand was observed between the $CaCO_3$ and Si(?) material in one place. Very slightly to slightly effervescent. Well cemented and extremely hard where Si(?) is highest (basal 0.1' of interval), otherwise hard.

May represent a B/Bkq horizon of a paleosol developed on early flood deposits, possibly associated with material down to 113'.

111 - 111.5	Mostly medium to coarse sand, some up to very coarse sand and very fine pebbles. 10YR 8/2d, 2.5Y 7/2m. $CaCO_3$ is both disseminated and segregated in nodules, blebs (amorphous shapes), and laminar layers parallel to bedding planes. Browner parts are very slightly effervescent, whereas whiter parts are slightly effervescent. A silty clastic dike shoots through this interval at an angle and disrupts a laminar $CaCO_3$ layer.
111.5 - 112	Mostly fine to medium sand; 2.5Y 7/2d, 2.5Y 5/3m. No bedding is apparent as much of this interval is disaggregated, but vertically oriented, laminar silty clastic dike material was observed in one intact piece. As above, $CaCO_3$ is disseminated and segregated as nodules and blebs, but there is less $CaCO_3$ overall and the blebs decrease with depth. Very slightly to slightly effervescent.
112 - 113	Mostly coarse to very coarse sand that has an overall peppery appearance; the matrix is 2.5Y 7/2d, 2.5Y 4/3m. No bedding is apparent—tends to break into small pieces. $CaCO_3$ is massive and segregated; it is found in one solid portion (*ca.* 0.1' thick) mid interval, and in vertical contact with sand separated by a thin silty layer (*i.e.*, as a clastic dike). Sand portions are non-effervescent; $CaCO_3$ is slightly effervescent. One piece had a flesh brown (10YR 6/2d, 10YR 4/3m) Si(?) coating parallel to the clastic dike.
113 - 115.5	*(Basal depth estimated.)* Texture is difficult to determine because of $CaCO_3$ and Si(?) accumulations, but some coarse to very coarse sand grains and very fine pebbles were observed. 10YR 8/2d, 2.5Y 7/2m. This interval, for the most part, is massive and slightly effervescent. $CaCO_3$ is mostly massive, though some parts are platy. Si(?) is most prevalent in the upper 0.4' as thin layers and patchy coats (10YR 6/2d, 10YR 5/3m); these areas are very slightly effervescent. Interpreted as the upper horizon (Bkqm) of a second paleosol, and possibly associated with material down to 121'.
115.5 - 116	*(Depth estimated. Core #6 supposed to be 2' (114'-116') but only 1' in box.)* Mostly fine to medium sand but some coarse to very coarse sand and very fine, subangular pebbles. 2.5Y 7/2d (but somewhat whiter than below), 2.5Y 5/3m. Unable to assess bedding because this interval is disaggregated. $CaCO_3$ is disseminated throughout and very slightly effervescent—stage I morphology. Interpreted as a Bk horizon of a paleosol developed in locally derived (Plio-Pleistocene) rocks.
116 - 121	*(Coring record shows 2.5' lost but remainder in box is only 1', therefore 1.5' is missing.)* Poorly sorted, very fine to very coarse sand and very fine to fine, subangular pebbles. Matrix is 2.5Y 7/2d, 2.5Y 5/3m. Unable to assess bedding because this interval is also disaggregated. $CaCO_3$ is disseminated throughout and

	discontinuously coats clasts (stage I-); very slightly to slightly effervescent. Interpreted as another Bk horizon of a paleosol developed in locally derived rocks (Plio-Pleistocene?).
121 - 121.8	Texture is difficult to determine because of $CaCO_3$ and Si(?) accumulations, but at least one coarse to very coarse, rounded basalt pebble was observed. White and 10YR 8/2d, 10YR 8/3m. This interval is massive, very well indurated and slightly effervescent. $CaCO_3$ is massive and disseminated throughout (stage III+). Interpreted as the upper horizon (Bkqm) of a third paleosol, and possibly associated with material down to 124'.
121.8-122.2	Mostly fine to medium sand, some up to coarse to very coarse and a few very fine, subangular to subrounded pebbles. 10YR 7/2d (but somewhat whiter than below), 2.5Y 6/3m. Unable to assess bedding because most is disaggregated; 1f-m sbk (weak, barely observable in place, 5-20 mm diameter, subangular blocky aggregates) can be found and they are very hard to extremely hard. $CaCO_3$ is disseminated throughout; slightly effervescent (stage II-III). Interpreted as a Bkq horizon of a paleosol developed in locally derived rocks (Plio-Pleistocene?).
122.2 - 124	Mostly medium sand, but also some very fine to fine, subangular to subrounded pebbles. 10YR 7/2d and 7/3d; 10YR 5/3m and 5/4m. Interval is mostly disaggregated but 122.8'-123' is 0.5- to 1-cm-thick plates of mostly silty material encased by laminated $CaCO_3$ layers. $CaCO_3$ is otherwise disseminated throughout; very slightly effervescent (stage II?). Interpreted as a Bk(q?) horizon of a paleosol developed in locally derived rocks (Plio-Pleistocene?).
124 - 125	*(Supposedly no recovery but 0.3' of core in box. Therefore, true depth and thickness unknown.)* Massive, $CaCO_3$-cemented, mostly medium sand but also some very coarse sand and very fine pebbles. $CaCO_3$ is disseminated throughout (stage III), slightly effervescent, and is also irregularly concentrated in amorphous masses, some of which resemble pebbles but are cored by Si(?)/$CaCO_3$. The overall colors are white and 10YR 8/2d, 10YR 6/3m and 5/4m; the Si(?)/$CaCO_3$ material is 10YR 8/3d, 10YR 7/4m and 6/4m. A possible root cast of $CaCO_3$ (1-cm diameter) is cored with fine to medium sand. Interpreted as a Bkqm horizon of a fourth paleosol, and possibly associated with material down to 127' (see notes for 128'-128.7' interval).
125 - 125.5	*(Core #10 (125'-127') is only 0.7' in box.)* Medium to coarse sand in 2- to 4-mm-thick laminae. 2.5Y 7/2d, 2.5Y 5/2m. Non- to very slightly effervescent—$CaCO_3$ is disseminated. Because original layering is preserved, this interval is interpreted as a C horizon of the fourth paleosol.
125.5-125.7	*(Should possibly extend to 126' and maybe to 127', according to block which follows.)* Fine to medium sand. 2.5Y 7/3d, 2.5Y 5/3m. Unable to assess bedding because intact pieces are easily disaggregated. A 2-mm-thick gray layer (10YR

	6/1d, 10YR 4/1m)—possibly tephra(?)—was observed in some pieces but the context is indeterminate because the interval is not intact. $CaCO_3$ is both disseminated and segregated as stringers (seams) and amorphous infillings—possibly filling former root pathways; very slightly to slightly effervescent. Also interpreted as a C horizon of the fourth paleosol.
125.7 - 127	*Missing. (See notes for 125'-125.5' and 125.5'-125.7' above.)*
127 - 128	Sand ranges from fine to coarse but most is very coarse; pebbles range from very fine to fine, and are subangular. White and 10YR 8/2d; peppery, 10YR 6/1m and 7/2m. $CaCO_3$ has a hackly appearance and stage II-III morphology, but is only very slightly effervescent. No bedding features were observed. Interpreted as a Bkq horizon of a fifth paleosol, and possibly associated with material down to 130.5'.
128 - 128.7	*(This foil-wrapped section—actually only 0.5' long—is seemingly out of place. The stratigraphy would be more coherent if this section were above the preceding 127'-128' interval.)* Mostly fine sand but a small percentage is very coarse sand. 2.5Y 7/2d; moist colors are in between 2.5Y 6/2 and 5/2. Weak partings are apparent in the upper 1.5 cm, otherwise massive. Very slightly to slightly effervescent. Interpreted as a C horizon, and probably should follow 125.7'.
128.7 - 130	Mostly 2.5Y 7/2d, 2.5Y 5/2m, medium to coarse sand, also very coarse sand and very fine pebbles; rare medium to very coarse pebbles. Very coarse pebble is rounded but smaller ones are subangular. Little disseminated $CaCO_3$—matrix is very slightly effervescent. Two massive, $CaCO_3$-cemented zones are slightly effervescent: one (10YR 8/2d, 2.5Y 7/2m) is *ca.* 3 cm thick, above the very coarse pebble; the other (white when dry, 10YR 8/2m) is *ca.* 1.5 cm thick at the base of the box (130'), below a browner 0.4' thick section. Unable to assess bedding because non-$CaCO_3$ zones are easily disaggregated. Interpreted as a BCkq horizon of the fifth paleosol.
130 - 130.5	Mostly fine to medium sand that has a platy structure. 2.5Y 7/2d, 2.5Y 6/2m. $CaCO_3$ is found as scattered amorphous chunks and laminae at plate boundaries; very slightly effervescent. Interpreted as a Ckq horizon of the fifth paleosol.
130.5 - 131	Laminated silt with vesicles in a row parallel to bedding plane. 10YR 8/2d, 10YR 6/2m. Thin layers of $CaCO_3$ parallel to bedding planes and few amorphous chunks; very slightly effervescent.
131 - 132	Silt that breaks cleanly along 1- to 2-cm-thick bedding planes; beds show 2- to 4-mm-thick laminae. In between 2.5Y 8/2d and 2.5Y 8/3d; 2.5Y 7/3m. $CaCO_3$ is found as stringers and thin layers along bedding planes and between laminae; very slightly to slightly effervescent.

132 - 133.2 Very similar to above but not as light and no visible $CaCO_3$. Silt that breaks along 1- to 2-cm-thick bedding planes; beds show 2-mm-thick laminae. 2.5Y 7/3d; 2.5Y 6/3m along bedding planes, and 2.5Y 5/3m within beds. Non-effervescent.

133.2-134.6 Fine sand overlying coarse sand—a fine/coarse couplet. Laminae are apparent in coarse sand; the fine sand is disaggregated.

134.6 - 135 Finely laminated silt.

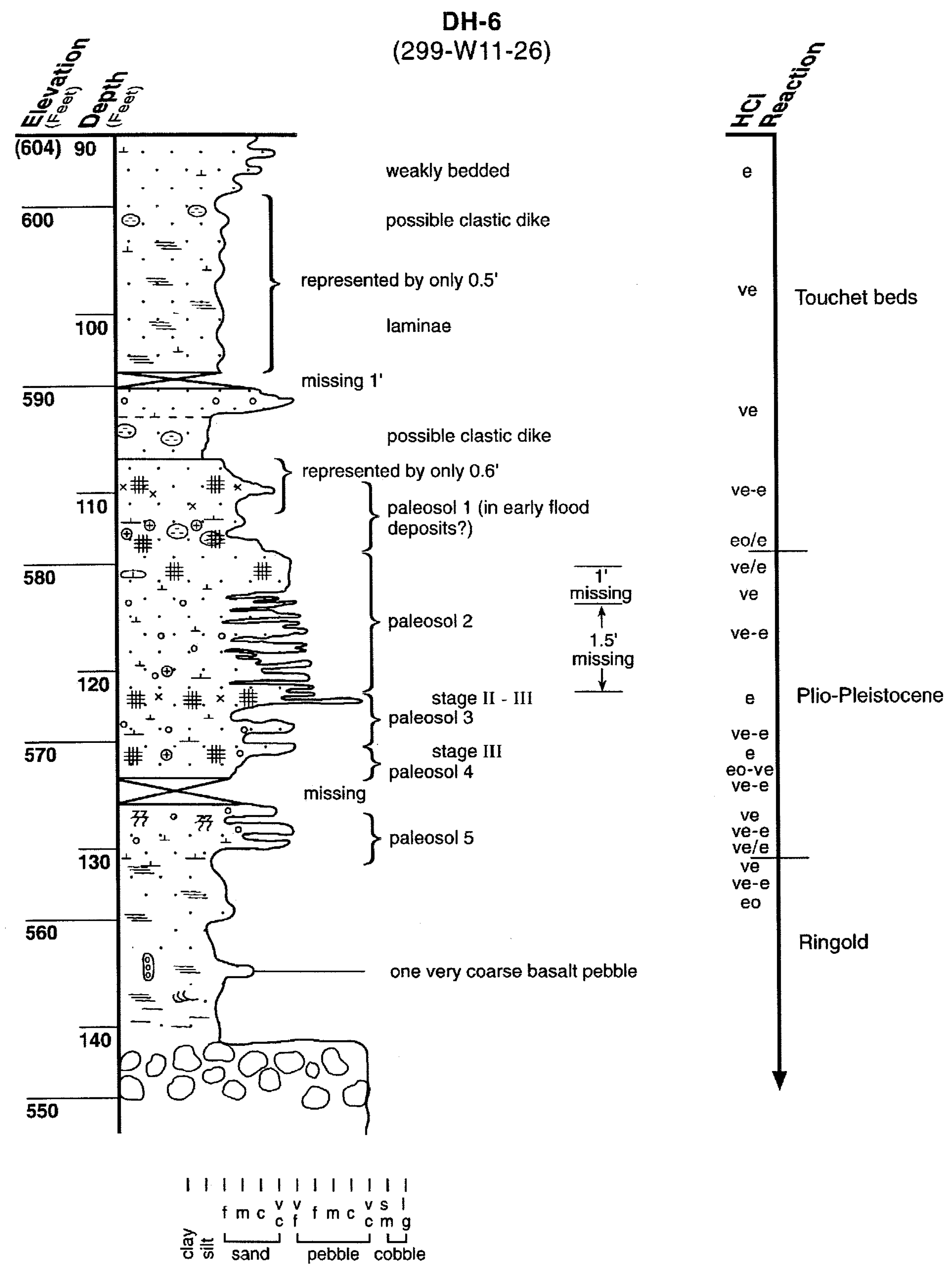
135 - 137 Both fine sand and coarse sand, but separate from each other, *i.e.*, not interbedded or gradational. Coarse sand appears as vertically oriented pockets (2- to 2.5-cm diameter, one at least 9 cm long) within the fine sand matrix.

137 - 141 *(But represented by only 1' in box.)* Top of interval is very coarse basalt pebble, underlain by finely laminated and cross-laminated silt; lowest portion is disaggregated silt.

141 - end of box (150.6') and below.
Very coarse pebbles and large and small cobbles, dominantly basalt, well rounded.

INTERPRETIVE SUMMARY

90 - 110	*(Estimated 13.5'—but at least 11.5'—missing or not recovered. Basal depth estimated.)* Touchet beds including clastic dike(s) within 105'-107.5' and possibly at the top of the 0.5' interval that represents 93'-103'.
110 - 113	*(Estimated 0.5' missing. Upper boundary estimated.)* Typical Touchet, normally graded bed(s)—fining upward sequence—including clastic dikes. $CaCO_3$ is both disseminated and segregated in nodules, blebs (amorphous shapes), and laminar layers parallel to bedding planes. May represent a paleosol developed on early flood deposits.
113 - 121	*(5' missing or not recovered. Core #7 [116-121'] recorded as 50% recovery.)* 2.5' of stage II-III(?) $CaCO_3$ underlain by disseminated $CaCO_3$ of decreasing stages of development—0.5' of stage I, and 5' of stage I-. Paleosol developed in locally derived pebbles and sands—probably Plio-Pleistocene deposits.
121 - 124	*(1' missing or not recovered. Core #8 [121-124'] recorded as 50% recovery.)* 0.8' of well-developed, stage III+ $CaCO_3$ underlain by disseminated $CaCO_3$ of decreasing stages of development—0.4' of stage II-III, and 0.8' of stage II(?). Paleosol developed in locally-derived pebbles and sands—probably Plio-Pleistocene deposits.
124 - 126.2	*(Including presumed out-of-place 0.5' interval described at 128'-128.7'. Core #9 [124-125'] recorded as 0% recovery.)* 0.3' (in the 124'-125' interval) of well-developed, stage III $CaCO_3$ is disjunct from overlying and underlying material. 1.2' of undeveloped C horizon material—some of which preserves depositional layering—underlie. This interval is thought to be one paleosol.
126.2-127.5	*Unaccounted for in reinterpreted record.*
127.5 - 130	One foot of $CaCO_3$ in sand and pebbles; $CaCO_3$ has a hackly appearance and stage II-III morphology, but is only very slightly effervescent. This interval is also disjunct from overlying and underlying material. Below are 1.3' of sand and pebbles that include two massive $CaCO_3$-cemented zones. Because the genesis of the carbonate is uncertain, either pedogenesis or a fluctuating groundwater table may be responsible for the features observed in this interval of locally derived deposits.
130 - 141	Laminated silt and sand—probably Ringold Formation deposits.



Lithology Key, continued

f = fine
m = medium
c = coarse
vc = very coarse
vf = very fine
sm = small
lg = large

clay, silt, f m c vc vf (sand), f m c vs (pebble), sm lg (cobble)

Hydrochloric Acid (HCl) Reaction

eo = non-effervescent
ve = very slightly effervescent
e = slightly effervescent
es = strongly effervescent

$CaCO_3$ = Calcium carbonate
SiO_2 = Silica (silicon dioxide)
Si = Silica
Fe = Iron

missing data

Lithology Key

- Cross-bedding
- (coarse sand) burrow fill (?)
- Laminae
- Clastic dike material
- Massive and/or cemented $CaCO_3$
- Amorphous SiO_2
- $CaCO_3$ nodules
- Disseminated $CaCO_3$
- $CaCO_3$ laminae
- Platy $CaCO_3$
- Hackly $CaCO_3$
- Basalt clast
- Current ripples
- Massive sand
- Amorphous $CaCO_3$ aggregations
- Sand adhering to pebble
- Continuous coatings
- Coatings on one side
- Patchy clast coatings
- Filamentous $CaCO_3$
- Si(?) patches or coatings on clasts
- $CaCO_3$ root cast
- $CaCO_3$ rinds and/or pieces

E9906138_1.fh8

Core: DH-6 (299-W11-26)
Location: east north-central 200W, N of DH-12
448095N, 2220256E (WA State Coordinates)
Interval Logged: 90' (top of core) - 141' (130'= top of Ringold Fm)
Interpreted by: J.L. Slate
Dates: described: 2/93; sampled: 9/93

SAMPLE LIST

Depth (ft)	Sample Type	Collector's Initials	Date	Results/Notes/Sample ID (if different)
91.0	PM	WCC	?	Samples labeled A & B
91.5	?	KAL	9/14/90	
107.5	PM	WCC	?	Samples labeled A & B
108-111	TS	JLS	9/93	not submitted, 6-110.4 (upper part)
108-111	TS	JLS	9/93	not submitted, 6-110.9 (lower part)
108-111	GS, K, BD	JLS	9/93	not submitted, 6-110
111.5	?	KAL	9/14/90	
112.4-112.6	GS, K	JLS	9/93	not submitted, 6-112.4
113.6-113.8	TS	JLS	9/93	6-113.6
114.0	PM	WCC	?	Samples labeled A & B
114.5	?	KAL	10/11/89	probably closer to 115.5
116-121	GS, K	JLS	9/93	not submitted, 6-116.5 (middle part)
121.0-121.2	TS	JLS	9/93	6-121
121.2-121.4	GS, K, BD	JLS	9/93	6-121.2
121.5-121.7	Th/U	BNB	12/7/83	probably closer to 121.4-121.6
121.7	?	KAL	9/13/90	
122.5	PM	WCC	?	Samples labeled A & B
123.1-123.3	GS, K	JLS	9/93	not submitted, 6-123.1
124.0-124.1	TS	JLS	9/93	6-124
124.1-124.3	GS, K, BD	JLS	9/93	6-124.1
125.5	?	KAL	10/11/89	probably closer to 125.4-125.5
127.4-127.6	GS, K	JLS	9/93	6-127.4
129.0-129.1	GS, K, BD	JLS	9/93	6-129
129.6-129.7	GS, K	JLS	9/93	not submitted, 6-129.6
130.2-130.3	GS, K	JLS	9/93	not submitted, 6-130.2
130.5	?	KAL	10/11/89	
133.0	PM	WCC	?	Samples labeled A & B
135.3-135.6	GS, Min	BNB	4/17/86	probably closer to 135.0-135.3
136.8	?	KAL	9/14/90	

Key to symbols:

Sample type:

- BD - bulk density
- Chem - chemistry
- GS - grain size
- HC - hydraulic conductivity
- I - isotopes (^{13}C, ^{18}O)
- K - $CaCO_3$ content
- Min - mineralogy
- PM - paleomagnetism
- Th/U - ^{230}Thorium/^{234}Uranium dating
- TL - thermoluminescence dating
- TS - thin section

Collector's initials:

- BNB - Bruce N. Bjornstad
- JLS - Janet L. Slate
- JR - ??
- JTL - John T. Lillie
- KAL - Kevin A. Lindsey
- WCC - Woodward Clyde Consult.
- ZJ - Zelma Jackson

Core: DH-7 (299-W19-10)
Location: central SE 200W, S of DH-12
442310N, 2220230E (WA State Coordinates)
Interval Logged: 148' (top of core) - 168' (top of Ringold Fm)
Interpreted by: J.L. Slate
Date Described: 1/93

Depth (ft)	Description and Interpretation
148 - 154	Mostly fine sands and silts(?); the entire interval is buff-colored (2.5Y 7/2d; 5/2m). Fining upwards sequence, from fine to medium sand up to fine sand, noted in 148'-151.5' interval. The material from 148.5' to 151.5' is loose (disaggregated); the remainder is laminated, with 153.3'-153.75' particularly well laminated. One sample in the interval 148'-148.5' has a dipping plane that separates laminated medium sand from laminated fine sand above, indicating a possible current-ripple bed form. No evidence of soil development. Non-effervescent to very slightly effervescent. Sediments were likely water laid. Could be Touchet beds?
154 - 154.8	Massive fine sand and silt. No evidence of soil development. Non-effervescent to very slightly effervescent. Could be eolian, subaerially exposed overbank, or poorly-bedded water-laid deposits.
154.8-155.1	Well-wrapped interval of core was still moist when opened, and contained a section of very slightly effervescent, laminated greenish (2.5Y 5/3m) silty clay sandwiched by non-effervescent, weakly laminated, fine sands. The silty clay portion is about 2.5" thick, and the sand layers above and below are of about equal thickness. Because this interval was foil-wrapped and portions of the core above and below are less well preserved, the encasing sand beds may be thicker than recorded here. Nevertheless, these deposits were likely water laid.
155.1 - 161	Massive fine sand, much of which is loose. The uppermost 1.5" is non-effervescent, to a depth of 156.5' is very slightly effervescent, and the remainder is slightly effervescent. No evidence of soil development. Again, could be eolian, subaerially exposed overbank, or poorly-bedded water-laid deposits.
161 - 161.2	Buff-colored, well indurated, fine to coarse sand with $CaCO_3$ nodules and few gravels. Matrix is slightly effervescent; induration may be either by $CaCO_3$ or Si cement. Could represent a former Bwk horizon.
161.2-162.1	White and 2.5Y 8/3d, 2.5Y 7/3m, well indurated, poorly sorted, fine to very coarse sand with few gravels. Matrix is slightly effervescent; induration may be either by $CaCO_3$ or Si cement; stage III $CaCO_3$ morphology. Could represent a former Bk(m) horizon.

162.1-163 White (dry) and 2.5Y 7/3m, poorly indurated, fine to coarse sand. Matrix is strongly effervescent; weakly $CaCO_3$(?) cemented (stage III). Could represent a former Bk horizon.

163-168 *(But somewhat under 2' in box.)* Buff-colored, coarse sand with $CaCO_3$ blebs (amorphous pieces) and laminated silt. Matrix is slightly effervescent and indurated; stage II. Because recovery was incomplete, the material is broken up, and drilling mud may be incorporated in the recovered samples, this interval could be interpreted as either the lower part of a Bk horizon or a coarse sandy deposit with a clastic dike.

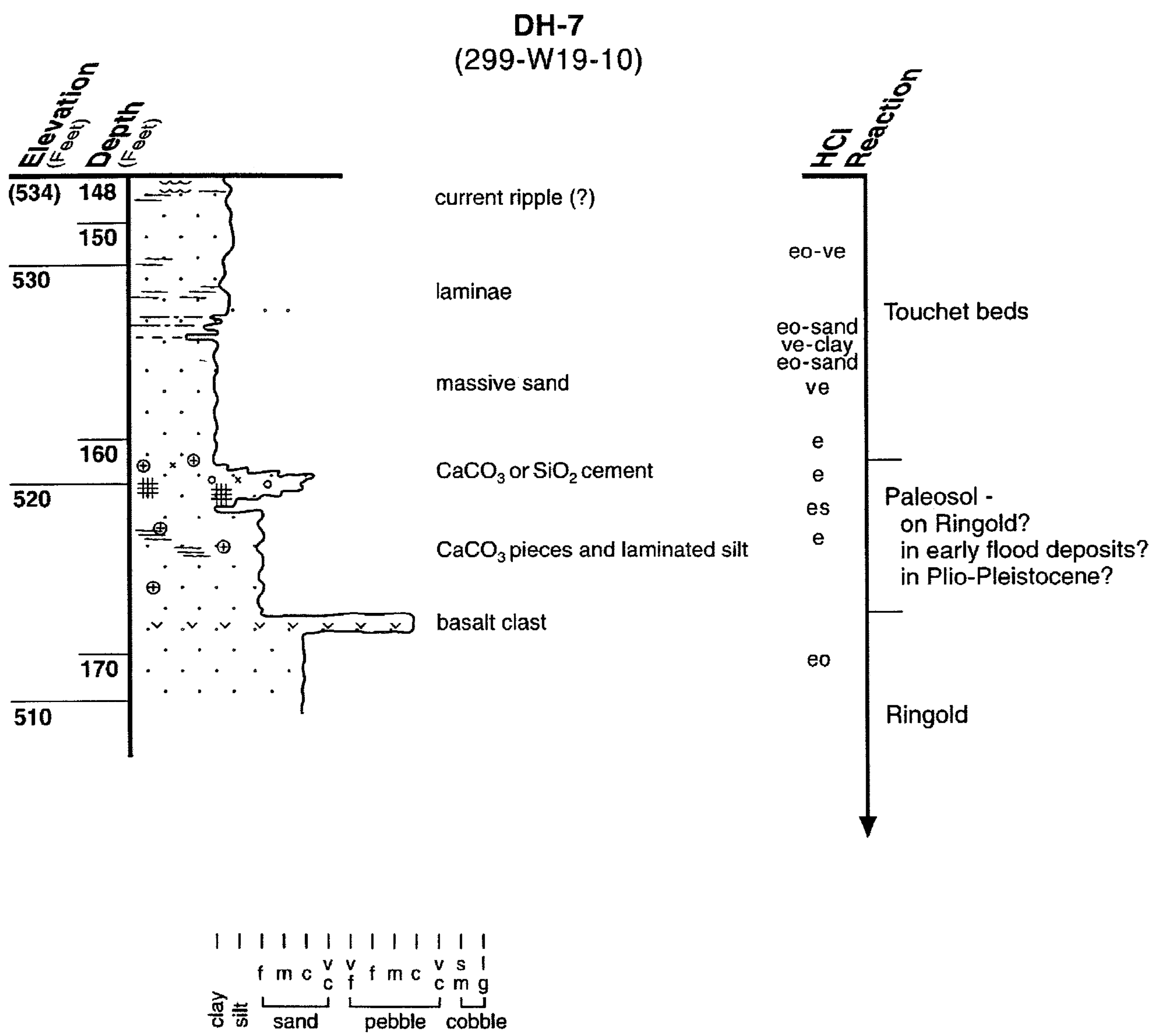
168 - 168.8 A basalt clast (3" in length) was cored at 168'. The 6" below are non-effervescent, coarse sand. This probably represents the top of the Ringold Formation.

INTERPRETIVE SUMMARY

148 - 161 Fine sand and silt exhibit laminae and current ripples(?) typical of Touchet beds. At least one fining upwards sequence was noted.

161 - 168 Paleosol—possibly developed in Ringold deposits or early flood deposits. (From 158' to 163' [Core #3] recovery was 60% or 3'.) A slightly effervescent, well-indurated sandy interval with $CaCO_3$ nodules from 161.0' to 161.2' is interpreted as a former Bwk soil horizon. The best developed carbonate (stage III+), from 161.2' to 162.1', is massive and well indurated; this is interpreted as a former Bkm soil horizon. Still massive but poorly indurated, the stage III carbonate below from 162.1' to 163.0' represents a former Bk soil horizon. The interval from 163' to 168' constitutes only 2' of material in the core box, but the drilling record lists only 1' of core material or 20% recovery in Core #4. Because recovery was incomplete, the material is broken up, and drilling mud may be incorporated in the recovered samples, this interval could be interpreted as either the lower part of a former Bk horizon (stage II) or a coarse sandy deposit with a clastic dike.

168 A basalt clast (3" in length) was cored at 168'. The 0.5' below are non-effervescent coarse sand, interpreted as the Ringold Formation.



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m = medium
c = coarse
vc = very coarse
vf = very fine
sm = small
lg = large

clay, silt, sand (f m c vc), pebble (vf f m c vc), cobble (s m l g)

Hydrochloric Acid (HCl) Reaction

eo = non-effervescent
ve = very slightly effervescent
e = slightly effervescent
es = strongly effervescent

$CaCO_3$ = Calcium carbonate
SiO_2 = Silica (silicon dioxide)
Si = Silica
Fe = Iron

missing data

Lithology Key

- Cross-bedding
- (coarse sand) burrow fill (?)
- Laminae
- Clastic dike material
- Massive and/or cemented $CaCO_3$
- Amorphous SiO_2
- $CaCO_3$ nodules
- Disseminated $CaCO_3$
- $CaCO_3$ laminae
- Platy $CaCO_3$
- Hackly $CaCO_3$
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- Current ripples
- Massive sand
- Amorphous $CaCO_3$ aggregations
- Sand adhering to pebble
- Continuous coatings
- Coatings on one side
- Patchy clast coatings
- Filamentous $CaCO_3$
- Si(?) patches or coatings on clasts
- $CaCO_3$ root cast
- $CaCO_3$ rinds and/or pieces

E9906138_2.fh8

Core: DH-7 (299-W19-10)
Location: central SE 200W, S of DH-12
442310N, 2220230E (WA State Coordinates)
Interval Logged: 148' (top of core) - 168' (top of Ringold Fm)
Interpreted by: J.L. Slate
Dates: described: 1/93; sampled: 12/92 and 1/93

SAMPLE LIST

Depth (ft)	Sample Type	Collector's Initials	Date	Results/Notes/Sample ID (if different)
148.0-148.1	PM?	JR		ID: 78
148.1-148.3	GS, K	JLS	12/31/92	bag, not submitted
148.1-148.3	Min, Chem	JLS	12/31/92	vial, not submitted
148.5-148.8	PM	WCC		ID: 74? 79?
150.8-151.3	PM	WCC		ID:78
151.5-151.7	GS, K	JLS	12/31/92	bag, not submitted
151.5-151.7	Min, Chem	JLS	12/31/92	vial, not submitted
153.0-153.3	GS, Min	BNB	4/17/86	
154.0-154.5	PM?	JR		
154.5-154.7	GS, K	JLS	12/31/92	bag, not submitted
154.5-154.7	Min, Chem	JLS	12/31/92	vial, not submitted
155.0	PM	WCC	?	ID: 78? 88? QN2(?) on block
158.0	PM?	JR	?	ID: 78
161.0-161.2	TS	JLS	1/7/93	bag
161.2-161.4	TS	JLS	1/7/93	bag
161.3-161.6	GS, K	JLS	12/31/92	bag
161.3-161.6	Min, Chem	JLS	12/31/92	vial, not submitted
162.4-162.6	GS, K	JLS	12/31/92	bag
162.4-162.6	Min, Chem	JLS	12/31/92	vial, not submitted
168.5	PM	WCC	?	ID: 22/19/78 PO2(?) on block

Key to symbols:

Sample type:
- BD - bulk density
- Chem - chemistry
- GS - grain size
- HC - hydraulic conductivity
- I - isotopes (^{13}C, ^{18}O)
- K - $CaCO_3$ content
- Min - mineralogy
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- JR - ??
- JTL - John T. Lillie
- KAL - Kevin A. Lindsey
- WCC - Woodward Clyde Consult.
- ZJ – Zelma Jackson

Core:	DH-11 (299-W15-14)
Location:	west-central 200W 445091N, 2217134E (WA State Coordinates)
Interval Logged:	101' (top of core) - 169' (top of Ringold Fm)
Interpreted by:	J.L. Slate
Date Described:	2/93

Depth (ft)	Description and Interpretation
101 - 121	No recovery.
121 - 125	Medium-grained, quartzo-feldspathic sands with laminae and evidence of current ripples, 10YR 6/2d; 10YR 5/2m. Breaks along laminae/bedding planes. 121.0'-121.3' is gone (sampled by BNB) but presumably same as 121.3'-125.0'. Sediments were likely water laid—probably Touchet beds.
125 - 125.5	Dominantly medium to coarse sand, a minor percentage—very coarse. Some weak laminae; either poorly bedded or evidence of bedding is poorly preserved.
125.5 - 128	Medium- to fine-grained sand with laminae. Water laid.
128 - 128.2	Medium to very coarse sand with rare, angular very fine pebbles.
128.2 - 130	Medium- to fine-grained sand with laminae. Water laid.
130 - 131	Medium to very coarse, basalt-rich sand. Medium sand sorted in mm-scale laminae, and very coarse sand into 5-cm(+)-thick beds. Water laid.
131 - 132	Medium to very coarse sand, most of which is loose but few remaining intact pieces show laminae. Water laid.
132 - 133.8	Interval of medium to very coarse sand and silty-clayey(?) buff-colored material that is in contact with the sands but not interbedded. Silty-clayey material has wavy laminae that are vertically oriented; some fine sands are present on the faces of the wavy laminae. The silty-clayey material is interpreted as a dewatering feature—a clastic dike. Water laid.
133.8-134.3	Fine-grained sand with laminae. Water laid.
134.3 - 135	Medium to very coarse sand, similar to that of 132-133.8. Mostly loose but intact pieces show laminae. Water laid.
135 - 140	No recovery.

140 - 140.6	Fine sand with laminae. Uppermost 2": well laminated, fine sand and silt(?). Water laid.
140.6-141.7	Fine to very coarse sand containing laminae and silty clastic dike features as described above. Water laid.
141.7- 143	Fine to very coarse sand with laminae. Dipping (oblique) laminae—interpreted as current ripples—observed near base of box (143'). Water laid.
143 - 143.5	Fine to very coarse sand. Laminae not apparent. Shot through with silty, clastic dike material. Probably water laid.
143.5-144.5	Fine to medium sand. Some pieces broken along bedding planes; laminae also observed in intact pieces. Fragments of silty, clastic dike material observed in upper and lower parts of interval. Interval is mostly broken up. Water laid.
144.5- 145	Fine sand and silt(?). Interval broken up into mostly fine (5 to 10 mm diameter) to medium (10 to 20 mm diameter) subangular blocky structures, but some parts clearly show laminae. Rare pieces of dominantly medium sand. Interpreted as nearly pure clastic dike. Probably water laid.
145 - 145.8	Fine sand. Uppermost 1.5" are well laminated and somewhat finer grained; remainder is thickly laminated. Water laid.
145.8-146.2	Silt and fine sand(?). Well consolidated. One piece shows partings and weak laminae. Water laid.
146.2-146.8	Fine sand. Thick laminae observed in intact pieces. Much of the material is loose. Water laid.
146.8- 148	Fine sand. Thickly laminated and well consolidated; breaks along bedding planes. Water laid.
148 - 151.5	Fine sand. Weak laminae (not readily apparent) but well consolidated and breaks along bedding planes. Water laid.
151.5-152.2	Silt and fine sand. Thickly laminated and well consolidated; breaks along bedding planes (4-5 mm thick). Water laid.
152.2-156.2	Probably originally deposited as mostly medium sand intermixed with fine to very coarse sand. Subsequently shot through with silty, clastic dike material. Water laid.
156.2-156.6	As above but also some $CaCO_3$ and very fine to fine pebbles. Carbonate is mostly in the sand portion but at least one piece at the base of the interval had a 2-mm-

thick layer of $CaCO_3$ parallel to the thinly-laminated clastic dike material. Another piece of core contains a 3x2x1 cm^3 piece of $CaCO_3$ (probably bigger but cut off by coring and breakage) that has one planar edge parallel to a 7-mm-thick vertically oriented silt layer, and a 7-mm-thick vertically oriented sand layer next to that. Carbonate portions are slightly effervescent but the sand and silty clastic dike material are non-effervescent. The disposition of the $CaCO_3$ with respect to the clastic dike material suggests that the $CaCO_3$ was emplaced along with the clastic dike, another possibility is that the $CaCO_3$ formed as a result of groundwater fluctuations before the clastic dike material was injected, a third, less likely possibility is that the $CaCO_3$ formed pedogenically. A pedogenic origin does not seem likely because the sand matrix is non-effervescent.

156.6-158.2 White and 10YR 8/3d, 10YR 7/3m, $CaCO_3$-cemented, fine to very coarse sands and subangular to subrounded, very fine to fine pebbles, the uppermost 2-3 mm of which is a laminar layer. No bedding evident, poorly sorted—sands and gravels are not in contact with each other, likely "jacked" apart by $CaCO_3$. Slightly effervescent. This interval is possibly a paleosol and as such represents a stage IV carbonate (especially 157.0-157.5).

158.2 - 160 Pieces of $CaCO_3$ intermixed with loose, fine to medium sand and subangular to subrounded, very fine to fine pebbles. The pieces are 3f-co sbk (in soil terminology—strong or distinctly visible, 5-50 mm diameter, subangular blocky aggregates); most are f-m sbk (5-20 mm diameter). Matrix is slightly effervescent, 10YR 7/3d; 10YR 5/3m.

NOTE: The depth range for Box #5 was incorrectly labeled 161'-169'—Box #4 ends at 160' and because there is more than 8' of core in Box #5, Box #5 was relabeled to show the correct starting depth of 160'. Box #5 also had many sections out of place according to depth recordings on foil-wrapped sections. Many were also upside down according to "top" labels. Sections were thus rearranged for proper depth sequence; see photo.

160 - 160.3 Very similar to 158.2-160 interval with 10YR 8/2d, 10YR 6/3m $CaCO_3$ as 3f-co sbk mixed with fine to medium sand and some very fine pebbles. Both the matrix and sbk pieces are slightly effervescent. At the top of this interval is a 1-cm-thick sand that has 2f-m sbk structure (moderate or easily observable but not distinct) and is slightly darker (10YR 7/2d; 10YR 5/3m, 5/4m) and less calcareous (very slightly effervescent) than below. This section can be interpreted as either the upper part of a paleosol that was influenced by pedogenesis of the paleosol above (*i.e.*, a superimposed soil), or as a "mixed" (non-pedogenic) horizon that formed as a result of a fluctuating groundwater table.

160.3-160.8 Similar to above but $CaCO_3$ is better cemented (requiring a hammer to break open undisturbed core) and the sandy parent material is coarser. A vug with $CaCO_3$ growth was observed. The sand is mostly fine- to medium-grained but some is up to very coarse; very fine pebbles are also present. The overall color is 10YR 7/2d and 10YR 5/2m, although many portions (mostly below 161.8') are whiter—10YR 8/2d and 8/3d; 10YR 7/2m. Again, this interval is "mixed" and could be described as a B/Bkqm horizon.

160.8-161.4 This cemented interval of fine to very coarse sand and very fine pebbles breaks along planes when hit with a hammer. The overall color is 10YR 8/2d and 8/3d; 10YR 7/3m and 6/3m. Slightly to strongly effervescent. Also a B/Bkqm horizon.

161.4-161.7 Similar to above (160.8-161.4) section—very well cemented and breaks along planes (5-10 mm thick)—fine to very coarse sand. $CaCO_3$ is the dominant constituent—10YR 8/2d, 10YR 7/3m, strongly effervescent. Non-carbonate portions (10YR 7/2d; 10YR 5/2m and 5/3m, very slightly effervescent) are most apparent at boundaries between plates; a small amount was also noted intra-plate. B/Bkqm.

161.7-162.6 Hard, well cemented, fine to very coarse sand and very fine pebbles; does not slake (may indicate presence of silica), 10YR 7/2d and 10YR 5/3m. Slightly to strongly effervescent. Can be broken with knife into 2f-m sbk. Bkq(m?).

162.6 - 163 Whiter than above (white and 10YR 8/2d; 10YR 7/2m, 7/3m, and 6/3m) and more platy—breaks with hammer into *ca.* 1-cm-thick plates. Very hard, well cemented, fine to very coarse sand and very fine pebbles; does not slake (Si?). Slightly to strongly effervescent. Bkqm(?).

163 - 163.4 Similar to above—fine to very coarse sand and very fine pebbles; a hammer is required to break to plates but absorbs water rather than runs off. 10YR 7/2d and 7/3d; 10YR 6/3m and 6/4m. Slightly to strongly effervescent. Bkm(?).

163.4-164.2 More easily broken than above (not completely cemented) possibly because of a higher gravel content(?)—medium to very coarse sand and very fine to fine, subangular to subrounded pebbles. Could be the base of a fining upward deposit. Somewhat whiter—10YR 8/2d and 10YR 6/3m; slightly effervescent. Bkq(m?).

164.2-164.5 Even whiter—10YR 8/2d and 10YR 7/3m. Texture as above. Consistence is difficult to determine because material at the base of this foil-wrapped interval is mixed with wax, but above the wax parts, it is very hard to extremely hard. Slightly to strongly effervescent. Bkqm.

164.5 - 165 Very hard, well cemented, fine to very coarse sand and very fine to fine pebbles—breaks with a hammer to plates. Carbonate-rich parts do not absorb water. Slightly effervescent. White, 10YR 8/2d and 7/2d; 10YR 7/2m, 7/3m and 5/2m. Abrupt basal boundary. Bkqm.

165 - 165.4	Hard to very hard, 2f-m sbk. Fine to medium sand that contains disseminated $CaCO_3$—very slightly to slightly effervescent. 10YR 7/2d and 7/3d; 10YR 6/3m, 6/4m and 5/4m. Bkq.
165.4-165.8	Slightly hard to hard, 2f-m sbk. Fine to medium sand and very fine to fine, subangular to subrounded pebbles that contains few $CaCO_3$ nodules and vug infillings—very slightly to slightly effervescent. Same colors as above but slightly browner. Bkq.
165.8-166.5	Hard, massive, fine to medium sand and very fine to fine pebbles. $CaCO_3$ is disseminated and in seams—very slightly to slightly effervescent. 10YR 7/2d and 7/3d; 10YR 5/3m. Bkq.
166.5 - 167	Slightly hard to loose, 1f-m sbk (1 = weak, barely observable in place), fine to medium sand and very fine to fine, subangular to subrounded pebbles. $CaCO_3$ is disseminated—very slightly effervescent. 10YR 6/3d and 10YR 4/3m. Bq.
167 - 167.4	Hard and massive but broken to loose and 2f-m sbk—these pieces are hard (possibly Si-cemented?). Fine to medium sand and very fine to fine, subangular to subrounded pebbles. $CaCO_3$ is disseminated—very slightly effervescent. Bq.
167.4-167.7	Very hard to extremely hard, $CaCO_3$-cemented, massive, fine to medium sand and very fine to fine pebbles. Only one well-preserved piece and one piece of a $CaCO_3$-coated (2-3 mm thick) very coarse, rounded pebble. White and 10YR 8/1d; 10YR 7/2m. Slightly effervescent. This interval is interpreted as a former petrocalcic horizon—Bkqm.
167.7-168.6	*(But only about 0.6' present.)* Intermixed $CaCO_3$ and non-$CaCO_3$. Fine to coarse sand and very fine to fine, subangular to subrounded pebbles. $CaCO_3$ portions break to plates (mm to 2 cm thick) which are slightly hard and slightly to strongly effervescent. Non-$CaCO_3$ portions are loose to 2f-m sbk (which are slightly hard), and non-effervescent. B/Bk.
168.6 - 169	Mostly $CaCO_3$-cemented fine to medium sand and very fine to fine pebbles but several larger, rounded pebbles distinguish this interval from the one above. A very coarse pebble/small cobble (65 mm in the long dimension—sliced by coring) has a 15-mm-thick $CaCO_3$ pendant at the base; the top and sides have patchy, thin coatings. Other coarse to very coarse pebbles in this interval have patchy, thin coatings. Slightly effervescent. Bkm, possibly developed in Ringold gravels(?).
169 - 170	Silty-muddy(?) coarse sand. Very different than section above and much more similar to well sorted coarse sand below with the exception of the muddy nature and $CaCO_3$ intervals. Two $CaCO_3$ intervals are present: *ca.* 1 cm thick at the top of the section, and the other is 2-3 cm thick in mid section. These intervals are

slightly effervescent, otherwise the section is non-effervescent. The non-$CaCO_3$ portions are structureless with a soft consistence and 10YR 7/3d and 10YR 5/3m. This section is interpreted as Ringold that has been either diagenetically or pedogenically affected.

INTERPRETIVE SUMMARY

121 - 156.6 Touchet beds containing clastic dike(s) (where noted) and consisting of at least five fining upwards sequences all of which are non-effervescent with the exception of parts of the lowest one:

boundaries:	upper (fi/co) lower		thickness
(1)	121.0 (125.0) 125.5		4.5
(2)	125.5 (127.9) 128.2		2.7
(3)	128.2 (130.0) 143.5 (135-140 = no recovery)		15.3 (contains clastic dike)
(4)	143.5 (152.2) 156.2		12.7 (contains clastic dike)
(5)	156.2	156.6	0.4 (Contains clastic dike and $CaCO_3$. The disposition of the $CaCO_3$ with respect to the clastic dike material suggests that the $CaCO_3$ was emplaced along with the clastic dike, another possibility is that the $CaCO_3$ formed as a result of groundwater fluctuations before the clastic dike material was injected, a third, less likely possibility is that the $CaCO_3$ formed pedogenically.)

156.6 - 169 Four probable paleosols developed in Plio-Pleistocene deposits and one in Ringold gravels(?):

Paleosol #	Interval (ft)		Horizon interpretation
(1)	156.6 - 158.2	Bkm	Uppermost 2 to 3 mm is a laminar $CaCO_3$ layer (stage IV). Sands and gravel are not in contact with each other, likely "jacked" apart by $CaCO_3$. May have been source of $CaCO_3$ for overlying interval (which is likely a clastic dike).

	158.2 - 160.0	B/Bk	$CaCO_3$ pieces (3f-co sbk, most are f-m sbk) intermixed with sand and pebbles.

This paleosol (3.4' thick) is characterized by decreasing $CaCO_3$ with depth.

Development of this paleosol probably affected paleosol #2.

(2)	160.0 - 160.8	B/Bk(qm)	Cemented $CaCO_3$ pieces (3f-co sbk) intermixed with sand and pebbles.

This and the following section can be interpreted in two ways: either soil development proceeded in two stages—one when 160' was at the land surface and a second when the overlying paleosol (156.6') was at the surface; or, a fluctuating groundwater table caused the "mixing" of $CaCO_3$ and non-$CaCO_3$ portions.

	160.8 - 161.7	B/Bkqm	Breakage and concentration of $CaCO_3$ and opaline Si(?) along planes indicate bedding controls the position of these secondary constituents.
	161.7 - 162.6	Bkq(m?)	Hard, well-cemented. Breaks to 2f-m sbk.

Development of this paleosol (2.6' thick) affected paleosol #3.

(3)	162.6 - 163.4	Bkqm	Whiter (probably due to higher $CaCO_3$ content) and breaks to *ca.* 1-cm-thick plates.
	163.4 - 164.2	Bkq(m?)	Higher gravel content than above—could be the base of a fining upward deposit.

Development of this paleosol (1.6' thick) affected paleosol #4.

(4)	164.2 - 164.5	Bkqm1	Very hard to extremely hard.
	164.5 - 165.0	Bkqm2	Breaks to plates.
	165.0 - 165.4	Bkq1	2f-m sbk.
	165.4 - 166.5	Bkq2	2f-m sbk.
	166.5 - 167.4	Bq	1-2, f-m sbk.

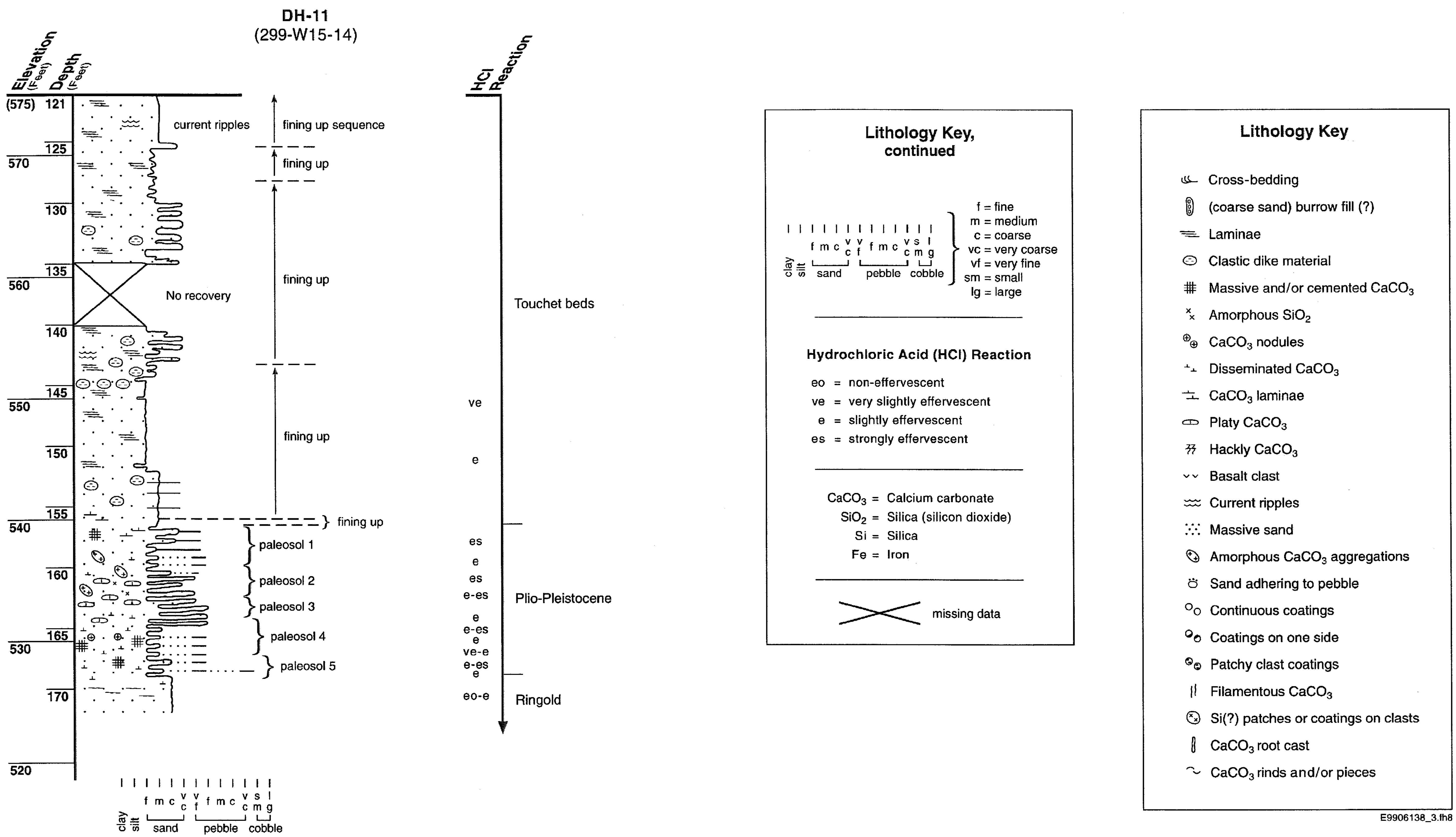
$CaCO_3$ decreases with depth.

Development of this paleosol (3.2' thick) probably affected paleosol #5 below.

(5)	167.4 - 167.7	Bkqm	Massive, $CaCO_3$ cemented.
	167.7 - 168.6	B/Bk	Intermixed $CaCO_3$ and non-$CaCO_3$.
	168.6 - 169.0	Bkm	$CaCO_3$-cemented sand and pebbles.

This paleosol (1.6' thick) possibly developed on Ringold gravels and sands.

169 - 170 This section is interpreted as Ringold sands that have been either diagenetically or pedogenically affected. Considered as a paleosol, the horizonal interpretation would be Cox/Bk.


DH-11
(299-W15-14)
Elevation (Feet)
Depth (Feet)
HCl Reaction
(575) 121
125
570
130
135
560
140
145
550
150
155
540
160
165
530
170
520
current ripples
fining up sequence
fining up
No recovery
fining up
fining up
fining up
paleosol 1
paleosol 2
paleosol 3
paleosol 4
paleosol 5
Touchet beds
ve
e
es
e
es
e-es
e
e-es
e
ve-e
e-es
e
eo-e
Plio-Pleistocene
Ringold
clay silt f m c vc vf f m c vc sm lg
sand pebble cobble
Lithology Key, continued
f = fine
m = medium
c = coarse
vc = very coarse
vf = very fine
sm = small
lg = large
Hydrochloric Acid (HCl) Reaction
eo = non-effervescent
ve = very slightly effervescent
e = slightly effervescent
es = strongly effervescent
CaCO3 = Calcium carbonate
SiO2 = Silica (silicon dioxide)
Si = Silica
Fe = Iron
missing data
Lithology Key
Cross-bedding
(coarse sand) burrow fill (?)
Laminae
Clastic dike material
Massive and/or cemented CaCO3
Amorphous SiO2
CaCO3 nodules
Disseminated CaCO3
CaCO3 laminae
Platy CaCO3
Hackly CaCO3
Basalt clast
Current ripples
Massive sand
Amorphous CaCO3 aggregations
Sand adhering to pebble
Continuous coatings
Coatings on one side
Patchy clast coatings
Filamentous CaCO3
Si(?) patches or coatings on clasts
CaCO3 root cast
CaCO3 rinds and/or pieces
E9906138_3.fh8

Core: DH-11 (299-W15-14)
Location: west-central 200W
445091N, 2217134E (WA State Coordinates)
Interval Logged: 101' (top of core) - 169' (top of Ringold Fm)
Interpreted by: J.L. Slate
Dates: described: 2/93; sampled: 9/93

SAMPLE LIST

Depth (ft)	Sample Type	Collector's Initials	Date	Results/Notes/Sample ID (if different)
121.0-121.3	GS, Min	BNB	4/17/86	
130		KAL	9/26/89	
145.8	PM?	WCC	3/16/79	
147		KAL	9/26/89	
149.5	PM?	WCC?	3/16/79?	
152.5	PM?	WCC	3/16/79	
156.7-156.8	GS, K, BD	JLS	9/93	11-156.7
156.7-156.8	TS	JLS	9/93	11-156.7
156.8	I	JLS	9/93	not submitted, 11-156.8
157.1-157.3	TS	JLS	9/93	not submitted, 11-157.1
157.3-157.4	GS, K, BD	JLS	9/93	not submitted, 11-157.3
157.1	I	JLS	9/93	not submitted, 11-157.1
157.6-157.7	TS	JLS	9/93	11-157.6
158.4-158.6	TS	JLS	9/93	11-158.4
158.4-158.6	GS, K	JLS	9/93	not submitted, 11-158.4
160.3-160.45	TS	JLS	9/93	11-160.3
160.4-160.45	GS, K, BD	JLS	9/93	not submitted, 11-160.4
167	PM?	WCC	3/16/79	should be 160.8'
161.1-161.2	GS, K, BD	JLS	9/93	11-161.1
161.2-161.3	TS	JLS	9/93	11-161.2
162	PM?	WCC	3/16/79	
162.0-162.1	GS, K, BD	JLS	9/93	11-162
162.1-162.2	TS	JLS	9/93	11-162.1
162.6-162.7	TS	JLS	9/93	11-162.6
162.7-162.8	GS, K, BD	JLS	9/93	11-162.7
163.1-163.2	TS	JLS	9/93	11-162.1
163.7-163.8	GS, K, BD	JLS	9/93	11-163.7
164.2	TL, Th/U	BNB	3/8/83	
164.3-164.4	GS, K, BD	JLS	9/93	11-164.3
164.7-164.8	TS	JLS	9/93	11-164.7
164.7-164.8	GS, K, BD	JLS	9/93	11-164.8
165		KAL	9/26/89	probably closer to 164.7-165'
165.2-165.3	GS, K	JLS	9/93	11-165.2

Depth (ft)	Sample Type	Collector's Initials	Date	Results/Notes/Sample ID (if different)
165.6-165.7	GS, K	JLS	9/93	not submitted, 11-165.6
166.1-166.2	GS, K, BD	JLS	9/93	11-166.1
166.2-166.3	TS	JLS	9/93	11-166.2
166.7-166.8	GS, K	JLS	9/93	not submitted, 11-166.7
168	TS	JLS	9/93	11-168
168.0-168.3	GS, K	JLS	9/93	11-168.2
169.4-169.5	TS	JLS	9/93	11-169.4
169.5-169.6	GS, K, BD	JLS	9/93	11-169.5

Key to symbols:

Sample type:

BD - bulk density
Chem - chemistry
GS - grain size
HC - hydraulic conductivity
I - isotopes (^{13}C,^{18}O)
K – $CaCO_3$ content
Min - mineralogy
PM - paleomagnetism
Th/U - ^{230}Thorium/^{234}Uranium dating
TL - thermoluminescence dating
TS - thin section

Collector's initials:

BNB - Bruce N. Bjornstad
JLS - Janet L. Slate
JR - ??
JTL - John T. Lillie
KAL - Kevin A. Lindsey
WCC - Woodward Clyde Consult.
ZJ - Zelma Jackson

Core:	DH-12 (299-W14-7)
Location:	east-central 200W
	445112N, 2220221E (WA State Coordinates)
Interval Logged:	100' (top of core) - 132' (top of Ringold Fm)
Interpreted by:	J.L. Slate
Date Described:	3/93

Depth (ft)	Description and Interpretation
100 - 102+	*(Core #1: 100'-107' had 21% recovery.)* Quartzo-feldspathic fine to medium sand with very fine pebbles in the lowest 0.2'. 10YR 7/2d, 10YR 5/2m. Partings and laminae are weakly developed. Non-effervescent. Interpreted as Touchet beds.
107 - 113	*(Core #2: 107'-113' had 25% recovery.)* Coarse to very coarse sand including some possible clastic dike (finer) material. (See description and interpretation section of DH-11 for identifying features of clastic dike material.) Finer material is lighter than coarser: 10YR 7/2d and 10YR 5/2m for fines; 10YR 7/1d and 10YR 5/1m for coarser material. One intact piece had 2-3 cm thick beds. Also interpreted as Touchet beds.
113 - 119	*No recovery for Core #3.*
119 - 125	*(Core #4 had no recovery according to the drilling record, but about 6" are present in the box—probably about 3" when cored.)* Mostly laminated fine sand; a coarse sand layer, 1 cm thick, was also present. Non-effervescent.
125 - 127.6	Mostly fine sand; fine to medium sand with more mafic minerals in the interval 127'-127.6', although the mineralogy is quartzo-feldspathic overall. Massive. $CaCO_3$ is disseminated; very slightly to slightly effervescent. Common, very fine to fine, vesicular pores. Could be either Early Palouse or Touchet.
127.6-127.9	Medium sand and few rounded, mafic pebbles up to coarse size. No structure or bedding is apparent. Amorphous segregations of $CaCO_3$, up to coarse pebble size, are distributed throughout; both the segregations and matrix are slightly effervescent. Colors vary with material: non-$CaCO_3$ is 10YR 7/2d and 10YR 5/2m; $CaCO_3$ is white and 10YR 8/2d, 10YR 8/2m and 8/3m. Few to common, very fine to fine, vesicular pores. Interpreted as a B/Bk(q?) horizon with stage I(?) $CaCO_3$ morphology.
127.9-128.1	Similar to above but has more $CaCO_3$—although still segregated. Dark brown Si(?) lines pebble cavities and the boundary between this interval and the one below. Medium sand and few pebbles, one up to very coarse size. Massive. Again, amorphous segregations of $CaCO_3$ are distributed throughout comprising about 50% of the material in this interval; here the segregations are strongly effer-

vescent, and the matrix is slightly effervescent. Colors vary with material: the mixture of $CaCO_3$ and matrix is 10YR 8/2d and 10YR 6/2m; the Si material is 10YR 5/2d and 10YR 3/3m. Interpreted as a Bkq, or because of its hardness, as a Bkqm horizon.

128.1-128.8 Stage III+ $CaCO_3$ morphology developed in medium sand and very fine to fine pebbles—one up to very coarse size. $CaCO_3$ is massive/amorphous except for a 4-5-mm-thick laminar layer near the top of this interval. $CaCO_3$ is distributed throughout and is strongly effervescent. Appears that $CaCO_3$ decreases with depth, as sand grains are discernible but the matrix is still whitened. 10YR 8/2d, 10YR 7/3m. Interpreted as a Bk(q?)m horizon.

128.8 - 130 Stage III $CaCO_3$ morphology developed in a matrix of indeterminate <2-mm grain size but containing many pebbles, some up to very coarse size. Pebbles are well rounded and very similar to Ringold gravels below although these are somewhat finer. $CaCO_3$ is massive and disseminated throughout; slightly to strongly effervescent. White and 10YR 8/2d, 10YR 7/3m. Interpreted as a Bk(q?)m horizon.

130 - 132 Mafic pebbles and cobbles with discontinuous $CaCO_3$ coatings (stage I-). KAL describes 130' as the top of the Ringold.

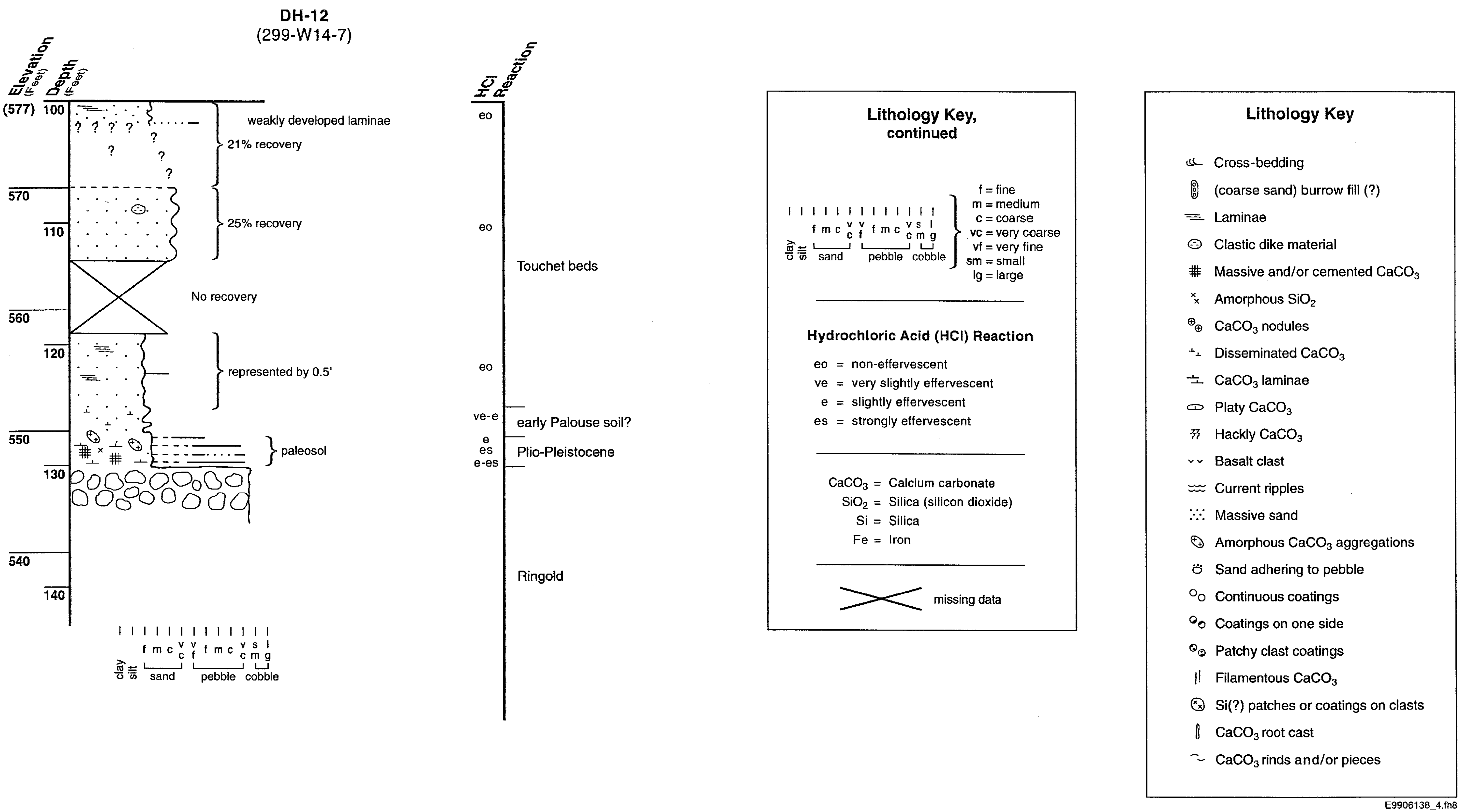
INTERPRETIVE SUMMARY

100 - 125 Touchet beds containing laminae in fine to medium sand and 2-3-cm thick beds in coarse to very coarse sand. The coarse to very coarse sand interval (107'-113') also contains clastic dike material.

125 - 127.6 The vesicular pores and massive nature of this quartzo-feldspathic, dominantly fine sand suggest that this interval is either Early Palouse soil or Touchet beds that were exposed to some subaerial modification.

127.6 - 130 $CaCO_3$ morphology (from stage I to stage IV) indicates that this interval is a paleosol. Development varies from $CaCO_3$ segregations (stage I) in the upper part (127.6'-128.1') to laminar (stage IV at 128.1') underlain by massive $CaCO_3$ (stage III); $CaCO_3$ in the stage III interval (128.1'-130') decreases with depth as the pebble content and size increase. The roundness and composition of the pebbles suggest that this paleosol may have developed in Ringold deposits, although these pebbles are somewhat finer than those below.

130 - From 130' to 132', mafic pebbles and cobbles have discontinuous $CaCO_3$ coatings (stage I-). K. A. Lindsey puts the top of the Ringold Formation at 130'.


DH-12
(299-W14-7)
Elevation (Feet)
Depth (Feet)
(577) 100
570
110
560
120
550
130
540
140
weakly developed laminae
21% recovery
25% recovery
No recovery
represented by 0.5'
paleosol
clay silt sand pebble cobble
f m c vc vf f m c vc sm lg
HCl Reaction
eo
eo
eo
ve-e
e
es
e-es
Touchet beds
early Palouse soil?
Plio-Pleistocene
Ringold
Lithology Key, continued
f = fine
m = medium
c = coarse
vc = very coarse
vf = very fine
sm = small
lg = large
Hydrochloric Acid (HCl) Reaction
eo = non-effervescent
ve = very slightly effervescent
e = slightly effervescent
es = strongly effervescent
CaCO3 = Calcium carbonate
SiO2 = Silica (silicon dioxide)
Si = Silica
Fe = Iron
missing data
Lithology Key
Cross-bedding
(coarse sand) burrow fill (?)
Laminae
Clastic dike material
Massive and/or cemented CaCO3
Amorphous SiO2
CaCO3 nodules
Disseminated CaCO3
CaCO3 laminae
Platy CaCO3
Hackly CaCO3
Basalt clast
Current ripples
Massive sand
Amorphous CaCO3 aggregations
Sand adhering to pebble
Continuous coatings
Coatings on one side
Patchy clast coatings
Filamentous CaCO3
Si(?) patches or coatings on clasts
CaCO3 root cast
CaCO3 rinds and/or pieces
E9906138_4.fh8

Core: DH-12 (299-W14-7)
Location: east-central 200W
445112N, 2220221E (WA State Coordinates)
Interval Logged: 100' (top of core) - 132' (top of Ringold Fm)
Interpreted by: J.L. Slate
Dates: described: 3/93; sampled: 9/93

SAMPLE LIST

Depth (ft)	Sample Type	Collector's Initials	Date	Results/Notes/Sample ID (if different)
100.3-100.6	GS, Min	BNB	4/17/86	
125.5	?	KAL	9/13/90	
127.6-127.9	GS, K, BD	JLS	9/93	12-127.6
127.9-128.1	TS	JLS	9/93	12-128
128.4	I	JLS	9/93	not submitted, 12-128.4
128.4-128.5	TS	JLS	9/93	12-128.4
128.5	?	KAL	9/13/90	probably closer to 128.6-128.8
128.5-128.7	GS, K, BD	JLS	9/93	12-128.5
129.0	TL, Th/U	BNB	?	probably closer to 129.4
129.6-129.8	GS, K, BD	JLS	9/93	not submitted, 12-129.6

Key to symbols:

Sample type:
- BD - bulk density
- Chem - chemistry
- GS - grain size
- HC - hydraulic conductivity
- I - isotopes (^{13}C, ^{18}O)
- K - $CaCO_3$ content
- Min - mineralogy
- PM - paleomagnetism
- Th/U - ^{230}Thorium/^{234}Uranium dating
- TL - thermoluminescence dating
- TS - thin section

Collector's initials:
- BNB - Bruce N. Bjornstad
- JLS - Janet L. Slate
- JR - ??
- JTL - John T. Lillie
- KAL - Kevin A. Lindsey
- WCC - Woodward Clyde Consult.
- ZJ - Zelma Jackson

Core:	DH-20 (699-29-83)
Location:	SW of 200W, at bend in Army Loop Rd, S of DH-21, N of DH-26 434345N, 2211941E (WA State Coordinates)
Interval Logged:	68.5' (top of core) - 122' (118'= top of Ringold Fm)
Interpreted by:	J.L. Slate
Date:	4/93

Depth (ft)	Description and Interpretation
68.5 - 70	*(Represented by only 0.3' of core.)* Fine to very coarse, disaggregated (loose), basalt and quartzite pebbles. Hard to assess sorting because only three large clasts are present; smaller ones may have rolled up from the interval below. The large pebbles are rounded whereas the smaller ones are subangular. Sand adhering to pebbles is the only matrix present and is very slightly to slightly effervescent.
70 - 72	*(Represented by only about 1.0' of core.)* As above but nearly all basalt—possibly one jasper clast but no quartzite. Moderately sorted. Again, matrix exists only as very slightly to slightly effervescent sand adhering to clasts. Patchy $CaCO_3$ coatings on some clasts.
72 – 73	*(Represented by only about 0.1' of core.)* Three subangular to subrounded basalt pebbles—hard to discern shape because they've been drilled. Slight effervescence on nearly continuous coatings on one side of two pebbles. $CaCO_3$ colors are 10YR 7/2d and 7/3d; 10YR 6/2m and 5/2m.
73 - 73.5	*(Represented by only about 0.3' of core.)* Subangular to subrounded basalt and one jasper pebble—all show drill marks. No matrix, uncemented (loose). Non-effervescent.
73.5 - 75.5	Poorly sorted, subangular to subrounded, very fine to very coarse pebbles and one small cobble in a medium to very coarse sand matrix—little matrix is present. Clasts are mostly basalt except for one jasper or Fe-stained quartzite. This interval is disaggregated, thus no bedding is apparent. Matrix is 10YR 7/2d, 10YR 4/2m; the Fe staining is 7.5YR 5/6d, 7.5YR 4/6m. Non-effervescent except for some slightly effervescent, patchy clast coatings in the lowermost 0.2'.
75.5 - 79	A core of a large basalt cobble (or possibly larger) occupies 75.5'-76'. Otherwise the interval consists of poorly sorted, subangular to subrounded, very fine to very coarse pebbles in a dominantly sand matrix which includes some silt and clay. Clasts are mostly basalt but some quartzite is present. This interval is disaggregated. Matrix colors are mixed: 10YR 7/3d and 7/4d; fines are 10YR 6/4m; coarse sand is 10YR 5/2m. Non-effervescent except for the slightly effervescent matrix adhering to the top of the large basalt cobble. White veinlets and seams are not $CaCO_3$.

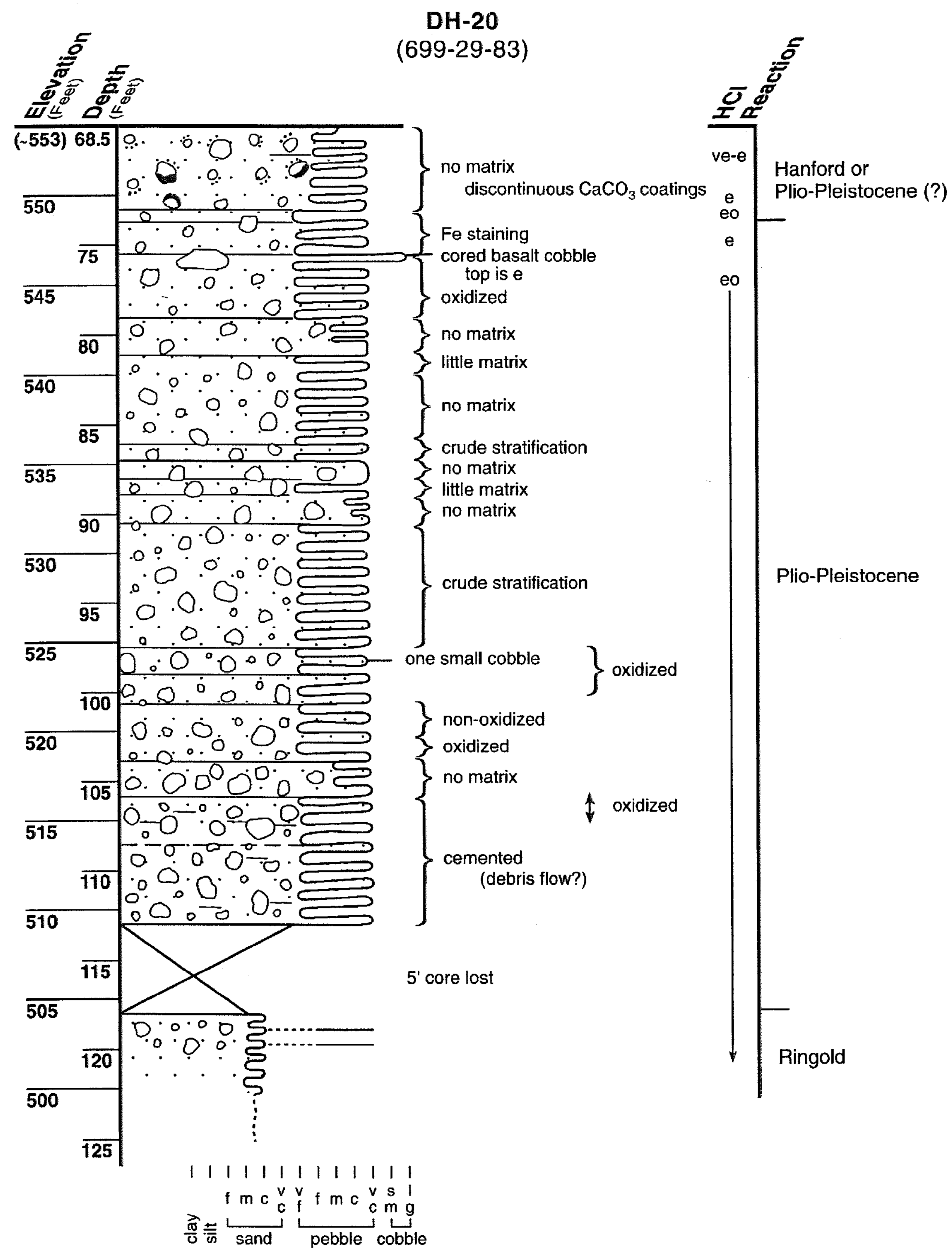
79 – 80	*(Represented by only about 0.5' of core.)* Moderately sorted, subrounded, medium to very coarse pebbles. Pebbles are mostly basalt except for one granitic clast. No matrix, uncemented (loose). Non-effervescent including a whitish coating on one clast.
80 – 81	*(Represented by only about 0.2' of core.)* Two subrounded, very coarse basalt pebbles. No matrix, uncemented (loose). Non-effervescent including patchy white areas on one clast.
81 – 86	*(But 83'-85' is represented by only 0.7' of core.)* Moderately sorted, subrounded to rounded, very fine to very coarse pebbles in a sand matrix, but little matrix is present. Pebbles are mostly basalt but some are felsic in composition. This interval is disaggregated. Matrix is 10YR 7/3d, 10YR 5/3m. Non-effervescent including clast coatings that are either patchy or continuous on one side only of clasts.
86 – 87	Moderately well-sorted bed(?) of subangular to subrounded, very fine to coarse basalt pebbles—very little matrix is present. Crude stratification is apparent in one intact piece. Matrix is 10YR 6/2d, 10YR 4/2m. Non-effervescent.
87 – 88	*(Represented by only about 0.6' of core.)* Mostly very coarse, rounded basalt pebbles; some medium to coarse, subrounded pebbles are also present. No matrix, uncemented (loose). Non-effervescent.
88 – 89	Poorly sorted, subrounded to rounded, very fine to very coarse pebbles—little matrix is present. Most of the pebbles are basalt but at least one is a quartzite and two are purplish-red rocks. No matrix, uncemented (loose). Non-effervescent.
89 - 90.5	*(Represented by only about 0.4' of core. According to block, "1' lost core—sands matrix washed away.")* Moderately sorted, subrounded to rounded, coarse to very coarse, basalt pebbles. No matrix, uncemented (loose). Non-effervescent including white-buff patches and coats on some clasts.
90.5 - 97.5	Poorly sorted, subangular to subrounded, very fine to very coarse pebbles in a sand matrix; most clasts are basalt. Crude stratification is apparent in some intact pieces. Matrix is 10YR 6/3d, 10YR 4/3m. Non-effervescent.
97.5 - 99	Similar to above but lighter colored (yellower) matrix, and one small cobble. Most clasts are disaggregated. Matrix is 10YR 7/3d and 7/4d; 10YR 5/3m and 5/4m. Non-effervescent including white-buff patches on some clasts.
99 - 100.5	Similar to above. Little matrix exists but what there is consists of two colors. Matrix 1 is: 10YR 7/3d and 6/3d; 10YR 5/3m. Matrix 2 is: 10YR 5/2d and 5/3d; 10YR 4/2m and 4/3m. This interval is disaggregated. Non-effervescent including white-buff patches on some clasts.

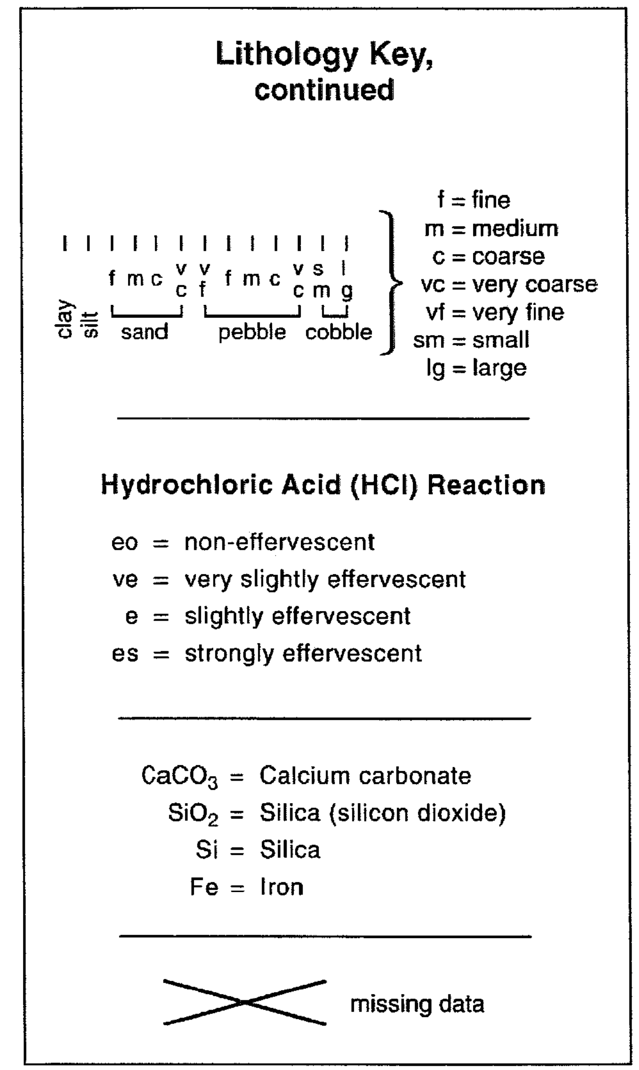
100.5 - 104	Similar to above but more matrix. Colors below 102.5' are oxidized. Matrix is 10YR 5/2d and 5/3d; 10YR 4/2m and 4/3m. This interval is also disaggregated. The upper part has fewer coatings than above—more coatings are apparent in the lower 0.8'—all are still non-effervescent. Orangish (7.5YR 7/6d, 7.5YR 6/6m) patches (Si?) on clasts in the lower 1.5'—oxidized (yellow) colors too.
104 - 106	*(Represented by only about 1.0' of core.)* Poorly sorted, subrounded to rounded, medium to very coarse pebbles—maybe even larger, some are drilled. Most are basalt; one is an orangish-red volcanic rock. No matrix, uncemented (loose). Non-effervescent.
106 - 108.5	Poorly sorted, subangular to rounded, very fine to very coarse pebbles in a sand + silt + clay matrix. Pebbles are mostly basalt and also include some jasper. Matrix colors are variable: 10YR 6/3d, 7/3d, 7/4d; 10YR 4/3m, 5/3m, 5/4m. Oxidized matrix colors are in the upper 1'. No bedding is apparent—possible debris flow(?). Non-effervescent. Below 106.6' is cemented but not indurated—cement is probably Si(?) because water is not absorbed.
108.5 - 113	*(Run 20 = 109'-113' = about 4.5' in box.)* Similar to above but all is cemented except for 110.3'-110.5' which is loose and without matrix.
113 - 118	*(5' core lost—washed away.)*
118 - 120	*(Represented by only about 0.6' of core.)* Quartzofeldspathic, medium to coarse sand including micas and rounded, fine to very coarse pebbles. Pebbles are multi-lithologic—granites, quartzites and purplish metamorphic rocks. Matrix is 10YR 7/3d; 10YR 6/3m. Stratification is apparent in intact pieces. Non-effervescent. Likely Ringold Formation.
120 - 122	Sand as above; no pebbles. Matrix is 10YR 7/2d; 10YR 5/2m. Mineral segregation delineates stratification. Non-effervescent. (Similar sand continues to about 132' in the next box.) Ringold Formation.

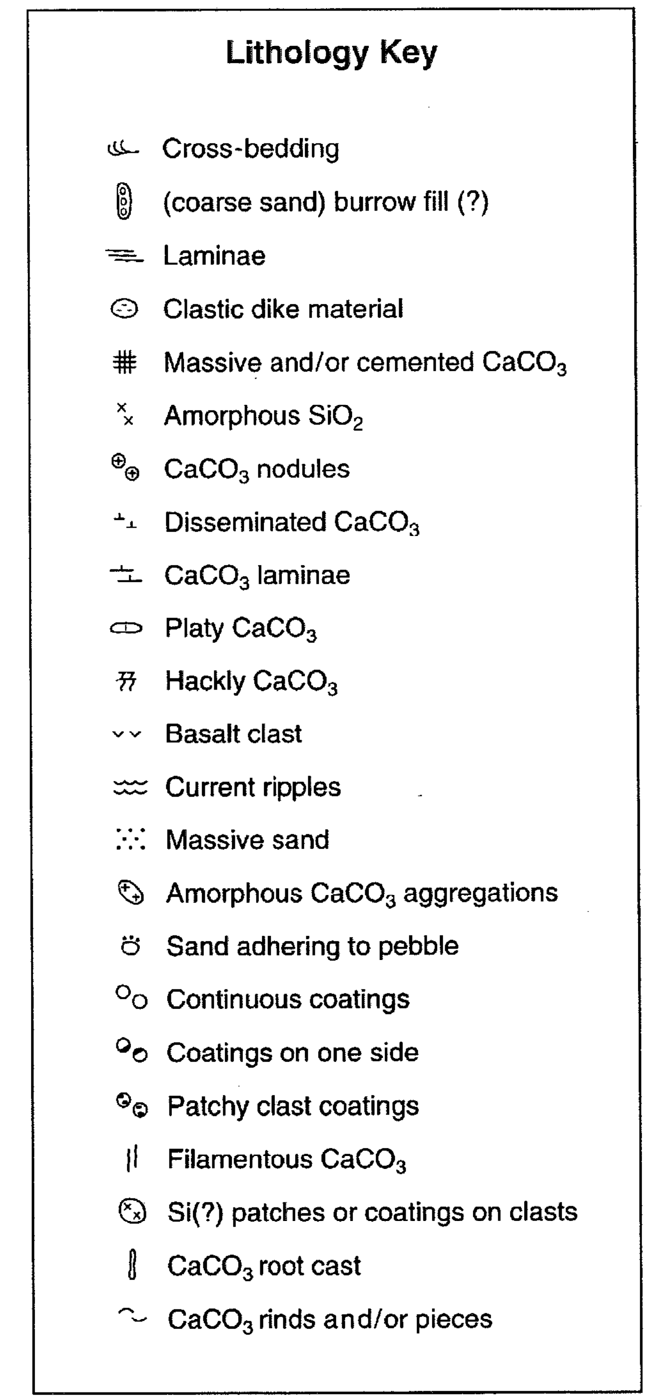
<u>INTERPRETIVE SUMMARY</u>

68.5-73.5	Hanford or Plio-Pleistocene. No matrix.
73.5-75.5	Plio-Pleistocene with Fe-staining.
75.5 - 79	Oxidized Plio-Pleistocene.
79 - 81	Plio-Pleistocene. No matrix.
81 - 82	Plio-Pleistocene. Little matrix.

82 - 86	Plio-Pleistocene. No matrix.
86 - 87	Plio-Pleistocene with crude stratification.
87 - 88	Plio-Pleistocene. No matrix.
88 - 89	Plio-Pleistocene. Little matrix.
89 - 90.5	Plio-Pleistocene. No matrix.
90.5-97.5	Plio-Pleistocene with crude stratification.
97.5-100.5	Oxidized Plio-Pleistocene.
100.5-102.5	Non-oxidized Plio-Pleistocene.
102.5-104	Oxidized Plio-Pleistocene.
104 - 106	Plio-Pleistocene. No matrix.
106 - 113	Cemented Plio-Pleistocene (debris flow?). Uppermost 1' oxidized.
113 - 118	*(5' of core missing.)*
118 -	Ringold.







E9906138_5.fh8

Core: DH-20 (699-29-83)
Location: SW of 200W, at bend in Army Loop Rd, S of DH-21, N of DH-26
434345N, 2211941E (WA State Coordinates)
Interval Logged: 68.5' (top of core) - 122' (118'= top of Ringold Fm)
Interpreted by: J.L. Slate
Dates: described: 4/93; sampled: 9/93

SAMPLE LIST

Depth (ft)	Sample Type	Collector's Initials	Date	Results/Notes/Sample ID (if different)
77.1 - 77.3	GS, K, BD	JLS	9/93	not submitted; priority 2-3, 20-77.1
93.6 - 93.8	GS, K, BD	JLS	9/93	not submitted; priority 2-3, 20-93.6
107.7 - 108.0	GS, K, BD	JLS	9/93	not submitted; priority 2-3, 20-107.7
111.9 - 112.2	GS, K, BD	JLS	9/93	not submitted; priority 2-3, 20-112

Key to symbols:

Sample type:
- BD - bulk density
- Chem - chemistry
- GS - grain size
- HC - hydraulic conductivity
- I - isotopes (^{13}C, ^{18}O)
- K - $CaCO_3$ content
- Min - mineralogy
- PM - paleomagnetism
- Th/U - ^{230}Thorium/^{234}Uranium dating
- TL - thermoluminescence dating
- TS - thin section

Collector's initials:
- BNB - Bruce N. Bjornstad
- JLS - Janet L. Slate
- JR - ??
- JTL - John T. Lillie
- KAL - Kevin A. Lindsey
- WCC - Woodward Clyde Consult.
- ZJ - Zelma Jackson

Core: DH-21 (699-37-84)
Location: just SW of 200W, along Army Loop Rd, S of DH-25, N of DH-20
442206N, 2211077E (WA State Coordinates)
Interval Logged: 76' (top of core) - 107' (102.7'= top of Ringold Fm)
Interpreted by: J.L. Slate
Date Described: 3/93

Depth (ft)	Description and Interpretation
76 - 78	*("No core rotated with tri-core bit." That is, no core.)*
78 - 84.8	Silt to fine sand with planar fine laminae and wavy vertically-oriented laminae; massive in some places. Dry colors vary from 10YR 7/2 and 7/3 to 2.5Y 7/2; moist colors vary from 10YR 5/3 and 5/4 to 2.5Y 5/2. Non-effervescent to slightly effervescent. Interpreted as Touchet beds with clastic dikes.
84.8 - 85.2	Fine to medium sand with laminae. 10YR 7/2d and 7/3d; 10YR 5/3m and 5/4m. Slightly effervescent. Interpreted as Touchet beds.
85.2 - 85.5	Fine to medium sand but no laminae are apparent. Colors are the same as above. Filamentous $CaCO_3$ throughout; slightly effervescent. Cemented but not indurated.
85.5 - 86.5	Fine to medium sand and very fine to fine pebbles; again, no laminae are apparent. Matrix is whitened throughout; slightly effervescent (stage I $CaCO_3$ morphology). Cemented but not indurated. Dry colors: 10YR 8/2, 7/2, and 7/3. Moist colors: 10YR 6/2, 6/3 and 5/3.
86.5 - 87	Medium to very coarse sand and very fine to very coarse pebbles that are sorted into layers; clasts are rounded and primarily mafic volcanic. The only bedding feature apparent is a layer of sorted very coarse sand at the base of one piece. Dry matrix colors are: 10YR 8/2, 8/3 and 7/2; moist are: 10YR 7/2, 7/3 and 6/2. $CaCO_3$ is disseminated in the matrix and forms patchy to continuous coats on clasts (stage I-II); slightly to strongly effervescent. Cemented but not indurated. Abrupt boundary with the lower unit is probably because of the higher gravel content below. (In soil terminology, the distinctness of the boundary is described as "abrupt" when the transition is <1" thick.)
87 - 88.5	Mostly very fine to very coarse pebbles and little matrix. Again, clasts are rounded and primarily mafic volcanic. No sorting is evident, and because this interval is unconsolidated, no bedding is evident. $CaCO_3$ forms a hackly texture that incorporates sand and very fine pebbles on one side only of the clasts (stage I); slightly effervescent. But because clasts are not in their original positions, I can't tell whether $CaCO_3$ formed on tops or bottoms. $CaCO_3$ colors are white and 10YR 8/2d; 10YR 7/3m.

88.5 - 89.5	$CaCO_3$-cemented very fine to very coarse pebbles in fine to very coarse sand matrix. Again, clasts are rounded and primarily mafic volcanic. No sorting or bedding is evident. 10YR 8/2 and 7/2d; 10YR 7/2 and 5/3m. $CaCO_3$ is disseminated in the matrix and discontinuously coats clasts; slightly effervescent. This interval is cemented and indurated (stage III $CaCO_3$ morphology in the matrix), possibly because of Si(?). The uppermost intact piece has $CaCO_3$ at the base and none at the top indicating a possible groundwater origin.
89.5 - 90.3	Very fine to very coarse pebbles and fine to very coarse sand; texture seems to fine upwards. Clasts are rounded and primarily mafic volcanic but some granitic clasts are also present. No bedding is evident; much of the material is loose. 10YR 7/2 and 7/3d; 10YR 4/3m. $CaCO_3$ partially coats clasts (stage I) and is disseminated in the matrix; slightly effervescent. The lower boundary is clear (transition is 1" to 2.5" thick). This interval is mostly unconsolidated except for a chunk (90'-90.2') consisting of very coarse pebble/small cobble-size basalt clasts and a very coarse pebble-size grusified granitic clast.
90.3 - 91.5	$CaCO_3$-cemented very fine to very coarse pebbles in a fine to very coarse sand matrix. No sorting is evident; bedding could not be determined. Clasts are rounded and primarily mafic volcanic. White and 10YR 8/3d; 10YR 8/2 and 5/3m. $CaCO_3$ partially coats clasts and is disseminated in the matrix (stage III morphology in the matrix). Clast tops are non-effervescent; sides are slightly to strongly effervescent; and clast bottoms are strongly effervescent. The lower boundary is abrupt. Induration and orangish patches that do not react to HCl suggest that Si may be present.
91.5 - 94.7	Very fine to very coarse pebbles in a matrix of fine to very coarse sand plus some clay and silt. No sorting is evident; bedding could not be determined. Clasts are rounded and primarily mafic volcanic. 10YR 7/4d; 10YR 4/4m. Non-effervescent. Abrupt lower boundary. Upper 1' loose with little matrix—higher pebble content.
94.7 - 95.7	Similar to above, plus one very coarse purplish volcanic pebble. Somewhat whiter: 10YR 8/3d; 10YR 7/6, 6/6 and 6/4m; 10YR 5/4m and 5/6m deeper in the section. But no reaction to HCl. Abrupt lower boundary.
95.7 - 98.5	Also similar to above, but little silt and clay. Sorting evident in the interval 96.6'-98.4'. Matrix colors are: 10YR 7/2 and 7/3d; 10YR 5/4m. Very slightly effervescent below 97', otherwise non-effervescent. All but the upper 0.2' is unconsolidated.
98.5-101.5	*(3' of core lost. Described on block as "loose gravel sands wash away, no bit pressure.")*

101.5-101.7 Very fine to very coarse (one vc) pebbles and fine to very coarse sand as matrix plus some clay and silt. Clasts are rounded but unsorted, and primarily mafic volcanic. One cemented piece breaks out as a *ca.* 15-mm-thick plate. White and 10YR 8/2 and 8/3d; 10YR 6/6 and 5/6m. Matrix is very slightly to slightly effervescent; clast bottom coatings are slightly effervescent.

101.7-102.7 *(1' of core lost—washed away according to block.)*

102.7-104.4 Very fine to very coarse pebbles and fine to very coarse sand as matrix; large clasts are prevalent. Some sorting is evident. Clasts are rounded and include mafic volcanic rocks, quartzites and granitic rocks. Bedding could not be determined. Matrix colors are: 10YR 8/3 and 8/4d; 10YR 7/4 and 6/6m. Very slightly to slightly effervescent. Lower boundary is clear. Few pieces still consolidated but not cemented.

104.4 - 107 Mostly coarse to very coarse well sorted sand with coarse to very coarse pebbles at 104.4'-106'. Clasts are rounded and include granitic and mafic volcanic rocks and quartzites. Matrix colors are: 10YR 7/3d; 10YR 5/3 and 5/4m. Laminae are evident in the lower (106'-107') intact sand section. Non-effervescent.

INTERPRETIVE SUMMARY

78 - 85.2 The fine texture, laminae and clastic dikes indicate that this interval is Touchet beds.

85.2 - 91.5 Weakly-developed (primarily stage I morphology) $CaCO_3$ paleosol(?) developed in Plio-Pleistocene or Ringold deposits. In some intervals in the lower half, a stage III matrix morphology with $CaCO_3$ at the base and none at the top indicates that this paleosol(?) formed by either groundwater processes or cumulic pedogenesis. Primarily mafic volcanic gravels suggest a Plio-Pleistocene origin but the rounded nature indicates that these gravels either traveled far (indicating a Ringold origin) or are reworked (indicating a Plio-Pleistocene reworking of Ringold deposits).

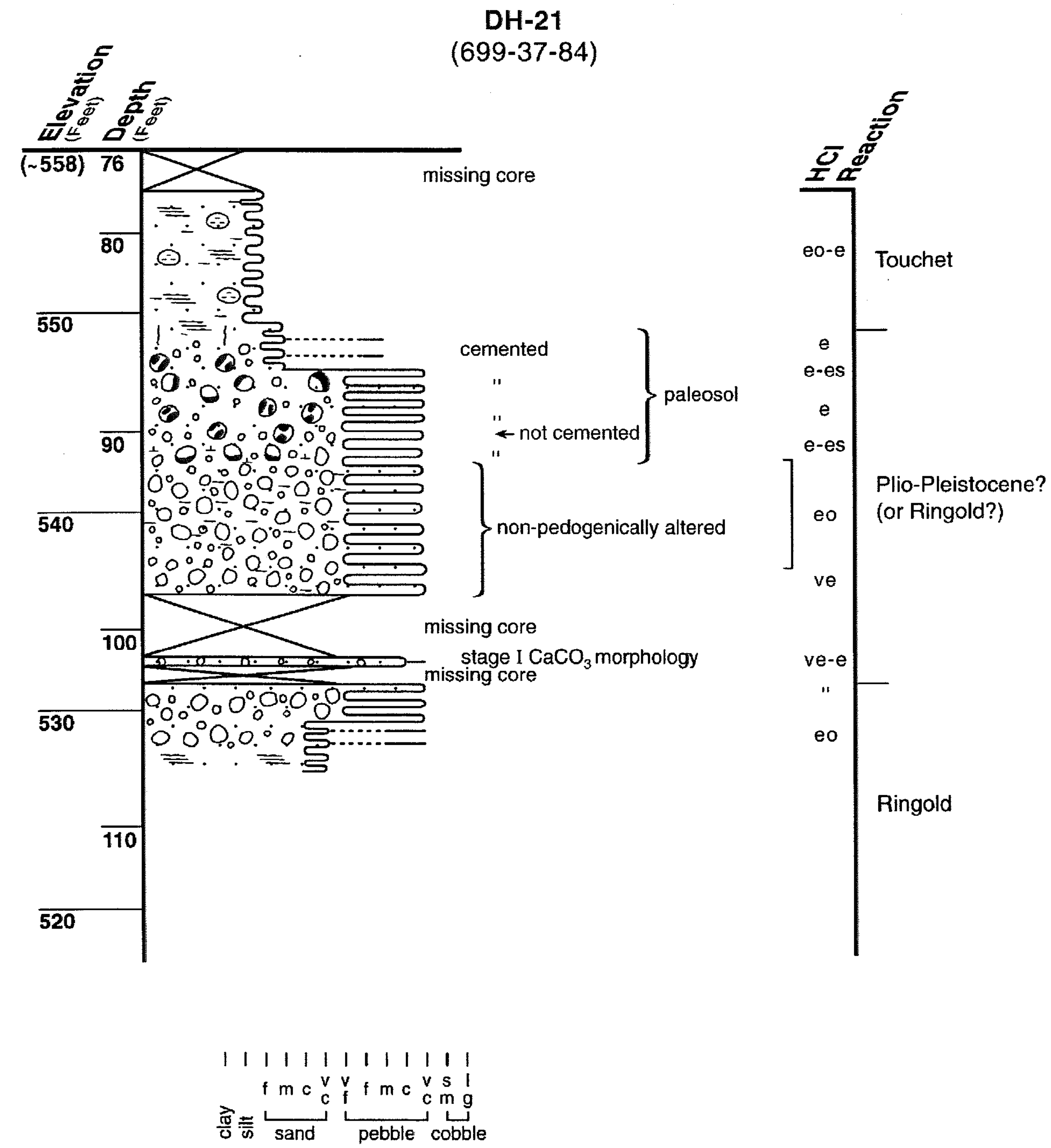
91.5 - 98.5 Non-pedogenically altered Plio-Pleistocene or Ringold deposits.

98.5-101.5 *(3' of core missing.)*

101.5-101.7 Stage I $CaCO_3$ morphology on clasts but because core is missing above and below, the context of this interval is unknown.

101.7-102.7 *(1' of core missing.)*

102.7 - The rounded and varied rock types—including mafic volcanic and granitic rocks and quartzites—are typical of Ringold deposits.



Lithology Key, continued

clay, silt, sand (f m c vc), pebble (vf f m c vc), cobble (s m l g)

- f = fine
- m = medium
- c = coarse
- vc = very coarse
- vf = very fine
- sm = small
- lg = large

Hydrochloric Acid (HCl) Reaction

- eo = non-effervescent
- ve = very slightly effervescent
- e = slightly effervescent
- es = strongly effervescent

- $CaCO_3$ = Calcium carbonate
- SiO_2 = Silica (silicon dioxide)
- Si = Silica
- Fe = Iron

missing data

Lithology Key

- Cross-bedding
- (coarse sand) burrow fill (?)
- Laminae
- Clastic dike material
- Massive and/or cemented $CaCO_3$
- Amorphous SiO_2
- $CaCO_3$ nodules
- Disseminated $CaCO_3$
- $CaCO_3$ laminae
- Platy $CaCO_3$
- Hackly $CaCO_3$
- Basalt clast
- Current ripples
- Massive sand
- Amorphous $CaCO_3$ aggregations
- Sand adhering to pebble
- Continuous coatings
- Coatings on one side
- Patchy clast coatings
- Filamentous $CaCO_3$
- Si(?) patches or coatings on clasts
- $CaCO_3$ root cast
- $CaCO_3$ rinds and/or pieces

E9906138_6.fh8

Core:	DH-21 (699-37-84)
Location:	just SW of 200W, along Army Loop Rd, S of DH-25, N of DH-20 442206N, 2211077E (WA State Coordinates)
Interval Logged:	76' (top of core) - 107' (102.7'= top of Ringold Fm)
Interpreted by:	J.L. Slate
Dates:	described: 3/93; sampled: 9/93

SAMPLE LIST

Depth (ft)	Sample Type	Collector's Initials	Date	Results/Notes/Sample ID (if different)
79.5	PM	ZJ	5/11/83	probably closer to 79.8
81	PM	ZJ	5/11/83	
82.5	PM	ZJ	5/11/83	probably closer to 82.3
83	PM	ZJ	5/11/83	
84.5	PM	ZJ	5/11/83	probably closer to 84.6
85.9-86.2	GS, K, BD	JLS	9/93	21-86
85.9-86.2	TS	JLS	9/93	21-86
86.6-86.9	GS, K, BD	JLS	9/93	not submitted, 21-86.6
88.5	Th/U	BNB		
88.6	TL	BNB	3/8/83	
90.1-90.2	GS, K, BD	JLS	9/93	21-90.1
90.1	I	JLS	9/93	not submitted, 21-90.1
91.0-91.15	GS, K, BD	JLS	9/93	21-91
106.5	PM	ZJ	5/11/83	probably closer to 106.3

Key to symbols:

Sample type:
- BD - bulk density
- Chem - chemistry
- GS - grain size
- HC - hydraulic conductivity
- I - isotopes (^{13}C, ^{18}O)
- K - $CaCO_3$ content
- Min - mineralogy
- PM - paleomagnetism
- Th/U - ^{230}Thorium/^{234}Uranium dating
- TL - thermoluminescence dating
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Collector's initials:
- BNB - Bruce N. Bjornstad
- JLS - Janet L. Slate
- JR - ??
- JTL - John T. Lillie
- KAL - Kevin A. Lindsey
- WCC - Woodward Clyde Consult.
- ZJ - Zelma Jackson

Core: DH-22 (699-37-92)
Location: west of 200W near Hwy 240, W of DH-21
441644N, 2203445E (WA State Coordinates)
Interval Logged: 54' (top of core) - 123' (121'= top of Ringold Fm)
Interpreted by: J.L. Slate
Date Described: 3/93

Depth (ft)	Description and Interpretation
54 - 55	*Missing.*
55 - 62.6	Poorly sorted but rounded, mostly basaltic pebbles and (a couple of) cobbles in a fine to very coarse sand matrix. No bedding is apparent. Variously $CaCO_3$-cemented; stage I-II on gravels; very slightly to slightly effervescent. $CaCO_3$ development decreases with depth; matrix $CaCO_3$ decreases below 60'. $CaCO_3$ matrix is white and 10YR 8/2d, 10YR 8/3m; otherwise, this interval is "salt and pepper." Interpreted as a probable paleosol in either Hanford gravels or Plio-Pleistocene deposits—the lithology and sorting slightly favor a Plio-Pleistocene interpretation.
62.6 - 65	*(3'+ in Run 9, supposedly 62.6'-64.6'.)* Again, poorly sorted but rounded, mostly basaltic pebbles and (a couple of) cobbles in a fine to very coarse sand matrix without any apparent bedding. This interval, however, is fairly well cemented with $CaCO_3$. Stage I-II on gravels; slightly to strongly effervescent (somewhat more effervescent than above); matrix $CaCO_3$ decreases in the last 0.8'. $CaCO_3$ matrix is white and 10YR 8/2d and 7/2d; 10YR 7/3m and 6/2m. Interpretation is as above—probable Plio-Pleistocene paleosol because of lithology and sorting.
65 - 66.8	As above; $CaCO_3$ decreasing with depth. Stage I-II on gravels; very slightly to slightly effervescent; matrix $CaCO_3$ decreases in the last 0.4'. Matrix colors are: white and 10YR 7/2d and 10YR 5/2m. Again, probable paleosol in Plio-Pleistocene deposits.
66.8 - 69.3	As above with an abrupt $CaCO_3$ decrease at 67.4'; possibly also Si(?) cemented. $CaCO_3$ is variable: indurated and slightly to strongly effervescent on gravels and matrix in the upper 0.6' (stage II-III); non-effervescent to very slightly effervescent on gravels below 67.4' (stage I-). Below 67.4' may be Si(?) cemented because water is not absorbed. $CaCO_3$ matrix is white and 10YR 8/2d; 10YR 7/2m. Non-$CaCO_3$ matrix is 10YR 6/2d and 10YR 4/2m. Again, probable paleosol in Plio-Pleistocene deposits.
69.3 - 74.5	As above; variously $CaCO_3$ cemented. Slightly to strongly effervescent where $CaCO_3$ is apparent; non- to very slightly effervescent where no $CaCO_3$ is apparent. $CaCO_3$ is stage I-II on gravels except in the lower 0.8' where it is stage I. $CaCO_3$ matrix is white and 10YR 8/2d; 10YR 7/2m and 6/2m. Again, probable paleosol in Plio-Pleistocene deposits.

74.5 - 76.5	*(But only about 0.5' in box.)* Well sorted, rounded, basaltic very coarse pebbles. The pebbles are loose in the box thus no bedding is apparent, and there is no matrix. Mostly non-effervescent; slightly effervescent on $CaCO_3$ patches (stage I- on some clasts). Possibly a C horizon of a paleosol.
76.5 - 83.5	*(But only about 4.0' in box.)* Poorly sorted but rounded basaltic pebbles and (a couple of) cobbles in a fine to very coarse sand matrix. No bedding is apparent. $CaCO_3$ is variable: from patchy to continuous coats on clast bottoms which are slightly effervescent; the matrix is non-effervescent. Color of the finest matrix is 10YR 7/2d and 10YR5/2m. Possibly a very weakly developed paleosol in Plio-Pleistocene deposits.
83.5 - 84	Similar to above but about 0.2' of the interval has a $CaCO_3$-cemented matrix. No apparent bedding. Matrix is very slightly to slightly effervescent. Matrix colors are 10YR 7/2d and 10YR 5/2m. Again, possibly a very weakly developed paleosol in Plio-Pleistocene deposits.
84 - 87.5	Similar to above but the cement is not $CaCO_3$ (non-effervescent). Whitish-orangish patchy clast coats which are non-effervescent may be Si(?). Matrix colors are 10YR 7/2d; 10YR 5/2m and 4/2m. Possibly a C horizon of a paleosol.
87.5 - 97	Again, poorly sorted but rounded basaltic pebbles and (a couple of) cobbles in a fine to very coarse sand matrix. No bedding is apparent. There are some white, dendritic (vein-like) coatings on rocks in combination with orangish patches (Si?) but these are non-effervescent and thus are not $CaCO_3$. Matrix sands are oxidized to: 10YR 7/4d and 6/4d; 10YR 5/6m and 4/6m. A darker phase is: 10YR 5/2d and 5/3d; 10YR 4/3m and 3/3m. Interpreted as variously oxidized alluvial fan deposits.
97 - 105	As above.
105 - 112	As above except that below 108' the material is not oxidized, there are no cobbles, and the pebbles are smaller.
112 - 113.3	Texturally immature, fine to very coarse sandstone with occasional very fine pebbles. No bedding is apparent. Non-effervescent. 10YR 5/3d; 10YR 4/3m and 3/3m.
113.3-115.4	Similar to above but gets coarser with depth. Somewhat darker too: 10YR 5/3d and 4/3d; 10YR 3/3m.
115.4-116.4	Similar to above but with more pebbles and coarser sandstone (medium to very coarse); pebbles are subangular and basaltic. 10YR 4/3d and 10YR 3/3m.

116.4 - 117 Poorly sorted but rounded, basaltic pebbles in a medium to very coarse sand matrix. No bedding is apparent. Non-effervescent. 10YR 4/1d and 10YR 3/1m. Possibly an alluvial fan deposit.

117 - 118.5 *(But only 0.6' in box.)* Moderately sorted, rounded basaltic pebbles. The only matrix remaining is adhering to clasts (as such it is similar to above). No bedding is apparent. Non-effervescent.

118.5 - 121 *Missing.*

121 - 121.3 Moderately well sorted, rounded pebbles—mostly coarse, some medium. Clasts are mostly basaltic but some quartzite is also present. The pebbles are loose in the box thus no bedding is apparent, and there is no matrix. Non-effervescent. Possible Ringold Formation.

121.3 - 123 Well sorted, quartzo-feldspathic medium to coarse sand. Cemented but not indurated. Non-effervescent. Breaks along 1- to 2-cm-thick bedding planes. Closest to 10YR 5/2 (both dry and moist). Probable Ringold Formation.

INTERPRETIVE SUMMARY

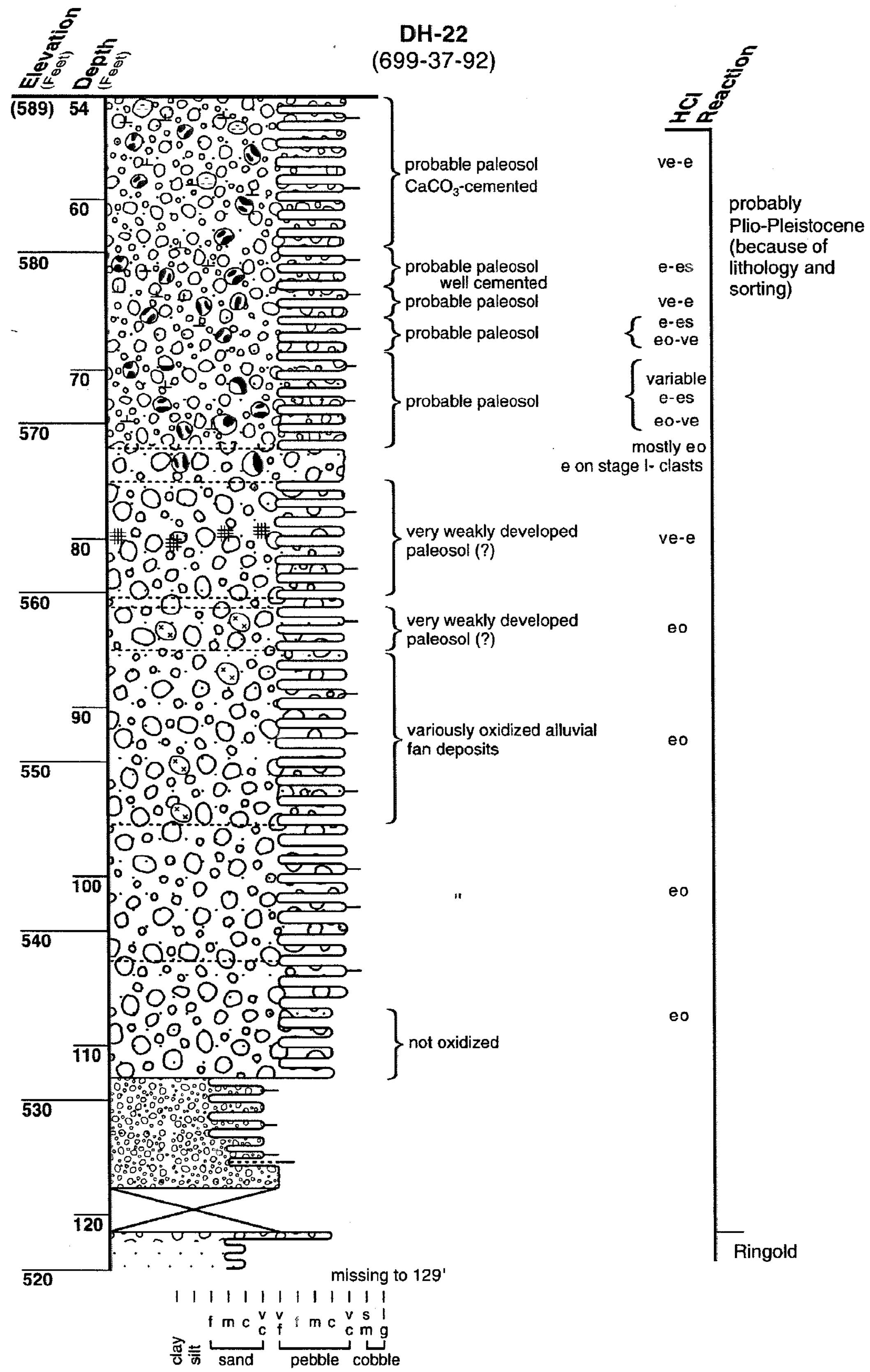
55 - 118.5 The upper 19.5' of this interval are interpreted as a series of $CaCO_3$ paleosols. Although lacking other diagnostic horizons, the $CaCO_3$ contents of these paleosols(?) do appear to decrease with depth. A locally derived (Plio-Pleistocene) origin is favored based on the basaltic lithology and poor sorting. The paleosols have the following depth distributions:

Paleosol	Depth	Thickness		Max $CaCO_3$ stage
		Total	Max $CaCO_3$	
1	55 - 62.6	7.6	5.0	I-II
2	62.6 - 65	2.4	1.6	I-II
3	65 - 66.8	1.8	1.4	I-II
4	66.8 - 69.3	2.5	0.6	III
5	69.3 - 74.5	5.2	4.4	I-II

Below 74.5', $CaCO_3$ contents decrease dramatically. One zone, 76.5'-84.0' *(but only represented by 4.5' in box)*, may represent a very weakly developed paleosol. Again, $CaCO_3$ is the only indicator of a possible paleosol, and that evidence is scant—stage I on clasts and a matrix that varies from non- to slightly effervescent. I interpret the remainder of this interval (to 118.5') as (variously oxidized) alluvial fan deposits.

118.5 - 121 *Missing.*

121 - 123 Ringold Formation. Moderately well sorted, rounded pebbles including quartzites, and quartzofeldspathic sands. Below are quartzofeldspathic sands. *(Missing 123'-129'; 129'-134' is represented by only 0.2'; missing 134'-143'; and 143'-144.5' is represented by only 0.6'.)*



Lithology Key, continued

f = fine
m = medium
c = coarse
vc = very coarse
vf = very fine
sm = small
lg = large

clay | silt | sand (f m c vc vf) | pebble (f m c) | cobble (s m l g)

Hydrochloric Acid (HCl) Reaction

eo = non-effervescent
ve = very slightly effervescent
e = slightly effervescent
es = strongly effervescent

$CaCO_3$ = Calcium carbonate
SiO_2 = Silica (silicon dioxide)
Si = Silica
Fe = Iron

X missing data

Lithology Key

- Cross-bedding
- (coarse sand) burrow fill (?)
- Laminae
- Clastic dike material
- Massive and/or cemented $CaCO_3$
- Amorphous SiO_2
- $CaCO_3$ nodules
- Disseminated $CaCO_3$
- $CaCO_3$ laminae
- Platy $CaCO_3$
- Hackly $CaCO_3$
- Basalt clast
- Current ripples
- Massive sand
- Amorphous $CaCO_3$ aggregations
- Sand adhering to pebble
- Continuous coatings
- Coatings on one side
- Patchy clast coatings
- Filamentous $CaCO_3$
- Si(?) patches or coatings on clasts
- $CaCO_3$ root cast
- $CaCO_3$ rinds and/or pieces

E9906138_7.fh8

Core:	DH-22 (699-37-92)
Location:	west of 200W near Hwy 240, W of DH-21 441644N, 2203445E (WA State Coordinates)
Interval Logged:	54' (top of core) - 123' (121'= top of Ringold Fm)
Interpreted by:	J.L. Slate
Dates:	described: 3/93; sampled: 9/93

SAMPLE LIST

Depth (ft)	Sample Type	Collector's Initials	Date	Results/Notes/Sample ID (if different)
55.15-55.4	TS	JLS	9/93	22-55.2
56.5	Th/U	JTL	6/29/81	depth estimated
64.0-64.1	GS, K, BD	JLS	9/93	not submitted, 22-64
64.1-64.2	TS	JLS	9/93	not submitted, 22-64.1
66.8-67.0	TS	JLS	9/93	not submitted, 22-66.8
71.4-71.6	GS, K, BD	JLS	9/93	not submitted, 22-71.4
112.0-112.3	PM	CS	8/81	
113.5	PM	CS	8/81	closer to 113.3-113.5
113.5-113.8	GS, Min	BNB	4/17/86	
115.0	PM	CS	8/81	closer to 114.7-115.0
115.8	PM	CS	8/81	closer to 115.4-115.6

Key to symbols:

Sample type:
- BD - bulk density
- Chem - chemistry
- GS - grain size
- HC - hydraulic conductivity
- I - isotopes (^{13}C, ^{18}O)
- K - $CaCO_3$ content
- Min - mineralogy
- PM - paleomagnetism
- Th/U - ^{230}Thorium/^{234}Uranium dating
- TL - thermoluminescence dating
- TS - thin section

Collector's initials:
- BNB - Bruce N. Bjornstad
- CS - ??
- JLS - Janet L. Slate
- JR - ??
- JTL - John T. Lillie
- KAL - Kevin A. Lindsey
- WCC - Woodward Clyde Consult.
- ZJ - Zelma Jackson

Core:	DH-23 (699-46-85)
Location:	just NW of 200W along Army Loop Road, N of DH-24 451576N, 2210651E (WA State Coordinates)
Interval Logged:	124' (top of core) - 177' (total depth)
Interpreted by:	J.L. Slate
Date Described:	3/93

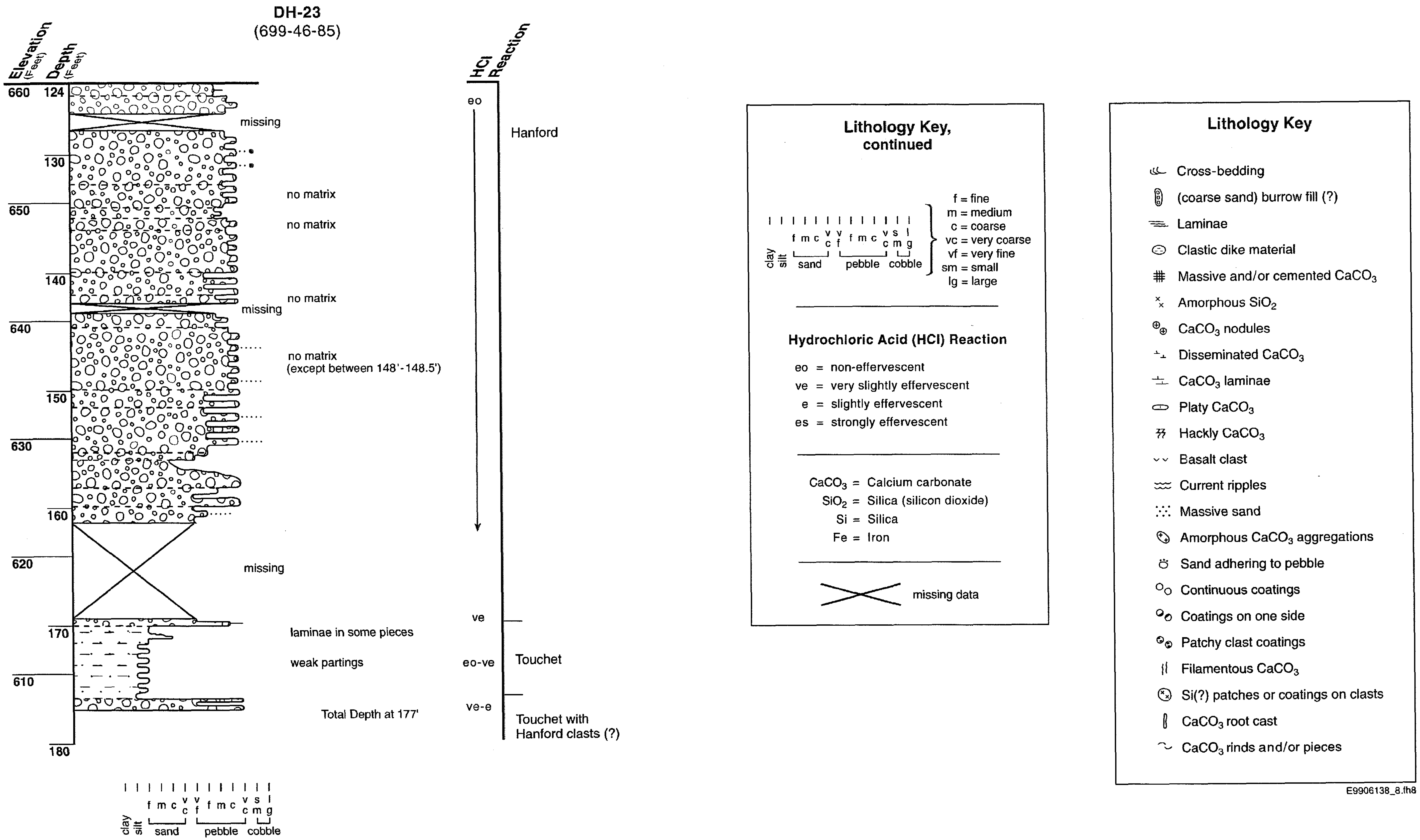
Depth (ft)	Description and Interpretation
124 - 125	Mostly pea-size gravel (medium pebble) but also some coarse pebbles and sand; moderately sorted; subrounded to rounded; mostly basalt but also some quartzite and felsic-mineral rocks. Mostly disaggregated thus no bedding is apparent. Closest color match to the matrix is: 10YR 5/1d and 10YR 3/1m. Non-effervescent. Interpreted as Hanford formation.
125 - 126.5	Mostly coarse to very coarse pebbles but also some finer pebbles and sand; moderately sorted; subrounded to rounded; mostly basalt but also some quartzite and felsic-mineral rocks. Disaggregated thus no bedding is apparent. Colors as above. Non-effervescent. Interpreted as Hanford formation.
126.5 - 128	*("1.5' lost core—wash away.")*
128 - 132.5	Similar to above plus two cored rocks—one very coarse pebble/small cobble, and one small cobble. Matrix colors are: 10YR 6/2d; 10YR 5/2m and 4/2m. Some Fe staining between 128' and 130'. Non-effervescent. Hanford fm.
132.5-134.5	Moderately sorted, rounded coarse to very coarse pebbles (possibly a few are larger—cored). Most are basalt but also some quartzite and granitic rocks. Pebbles are disaggregated thus no bedding is apparent, and there is no matrix. Non-effervescent. Hanford fm. (Abbreviated descriptions of rounded, multi-lithologic Hanford fm rocks follow.)
134.5-135.5	Medium to coarse pebbles in a sand matrix.
135.5-136.3	Coarse to very coarse pebbles; no matrix.
136.3 - 140	Coarse to very coarse pebbles (possibly a few are larger—cored) in a sand matrix.
140 - 142	Fine to very coarse pebbles in a sand matrix.
142 - 142.5	Medium to very coarse pebbles; no matrix.
142 - 143.5	*("1' lost core—washed away.")*
143.5-144.5	Medium to very coarse pebbles in a sand matrix.

144.5 - 150	Coarse to very coarse pebbles (possibly larger—cored); no matrix except for a little between 148'-148.5'.
150 - 151.7	Fine to very coarse pebbles in a sand matrix.
151.7-155.5	Fine to very coarse pebbles (possibly larger—cored) in a sand matrix, but dominated by large rocks.
155.5 - 156	Mostly very fine to fine pebbles (some medium) and coarse to very coarse sand. Sand is 10YR 7/2d and 10YR 5/2m.
156 - 158.3	Graded bed with very coarse pebbles and cored rocks in the basal 0.5'; medium to very coarse pebbles in a sand matrix in the next 0.6'; upper is coarse to very coarse sand which is darker than the sand above (10YR 7/1d and 7/2d; 10YR 5/2m and 4/2m).
158.3 - 160	Very fine to very coarse pebbles and coarse to very coarse sand; coarser pebbles in the basal 0.7'.
160 - 161.5	Mostly very fine to fine pebbles (some medium, few coarse) in a sand matrix.
161.5 - 168	*("6.5' core lost—washed away.")*
168 - 169.5	*("1.5' core lost—washed away.")*
169.5 - 170	Very fine to coarse pebbles (one very coarse, most are fine to medium) and fine to medium cemented sand; moderately sorted; subrounded to rounded; mostly basalt but also some felsic-mineral rocks; 10YR 7/2d; 10YR 6/2m and 5/2m. No bedding is apparent. $CaCO_3$ is disseminated in the matrix which is very slightly effervescent.
170 - 170.5	Mostly fine sand (some medium) in consolidated chunks; well sorted; quartzofeldspathic. Laminae are observed in some pieces but because the interval is broken up, there is no way to discern the direction of bedding (*i.e.*, horizontal/stratified *vs.* vertical/clastic dike). 10YR 7/2d; 10YR 5/2m. $CaCO_3$ is disseminated in the matrix which is very slightly effervescent. Interpreted as Touchet beds of the Hanford fm.
170.5 - 171	Intermixed fine sand and silt(?), and medium to coarse sand in consolidated chunks. Laminae are present in one small piece, but bedding is not apparent because the pieces are all jumbled up either by coring or clastic dike injection. 10YR 7/2d and 7/3d; 10YR 6/3m and 2.5Y 6/3m. $CaCO_3$ is disseminated in the matrix which is very slightly effervescent. Interpreted as Touchet beds of the Hanford fm.

171 - 176.3	Fine sand and silt. Weak partings evident in some pieces but a generally massive appearance overall. 10YR 7/2d and 7/3d; 2.5Y 6/3m and 10YR 6/3m. $CaCO_3$ is disseminated in the matrix which varies from non- to very slightly effervescent. Interpreted as Touchet beds of the Hanford fm.
176.3 - 177	Poorly sorted, quartzofeldspathic fine sand and multi-lithologic (basalt and felsic-mineral rocks), rounded very fine to very coarse pebbles. No bedding is apparent. 10YR 7/2d and 7/3d; 10YR 6/3m and 2.5Y 6/3m. $CaCO_3$ is disseminated in the matrix which varies from very slightly to slightly effervescent. Interpreted as Touchet beds of the Hanford fm including some Pasco gravels.

INTERPRETIVE SUMMARY

124 - 161.5	Gravels of the Hanford fm.
161.5-169.5	*Missing.*
169.5 - 170	Gravels of the Hanford fm.
170 - 176.3	Touchet beds of the Hanford fm. Even though parts appear massive, an interpretation of Early Palouse does not seem consistent with the underlying material.
176.3 - 177	Touchet beds of the Hanford fm including some Pasco gravels.


DH-23
(699-46-85)
Elevation (Feet)
Depth (Feet)
HCl Reaction
660
124
missing
130
650
no matrix
no matrix
140
no matrix
missing
640
no matrix
(except between 148'-148.5')
150
630
160
620
missing
170
laminae in some pieces
weak partings
610
Total Depth at 177'
180
eo
Hanford
ve
eo-ve
Touchet
ve-e
Touchet with
Hanford clasts (?)
clay silt
f m c vc vf
sand
f m c vc
pebble
sm lg
cobble
Lithology Key, continued
f = fine
m = medium
c = coarse
vc = very coarse
vf = very fine
sm = small
lg = large
Hydrochloric Acid (HCl) Reaction
eo = non-effervescent
ve = very slightly effervescent
e = slightly effervescent
es = strongly effervescent
CaCO3 = Calcium carbonate
SiO2 = Silica (silicon dioxide)
Si = Silica
Fe = Iron
missing data
Lithology Key
Cross-bedding
(coarse sand) burrow fill (?)
Laminae
Clastic dike material
Massive and/or cemented CaCO3
Amorphous SiO2
CaCO3 nodules
Disseminated CaCO3
CaCO3 laminae
Platy CaCO3
Hackly CaCO3
Basalt clast
Current ripples
Massive sand
Amorphous CaCO3 aggregations
Sand adhering to pebble
Continuous coatings
Coatings on one side
Patchy clast coatings
Filamentous CaCO3
Si(?) patches or coatings on clasts
CaCO3 root cast
CaCO3 rinds and/or pieces
E9906138_8.fh8

Core: DH-23 (699-46-85)
Location: just NW of 200W along Army Loop Road, N of DH-24
451576N, 2210651E (WA State Coordinates)
Interval Logged: 124' (top of core) - 177' (total depth)
Interpreted by: J.L. Slate
Dates: described: 3/93; (no samples taken by JLS)

SAMPLE LIST

Depth (ft)	Sample Type	Collector's Initials	Date	Results/Notes/Sample ID (if different)
171	PM	ZJ	5/11/83	
171.1	PM	JTL	5/28/82	
172.5	PM	ZJ	5/11/83	
173	PM	JTL	5/28/82	
174	PM	ZJ	5/11/83	
175	PM	JTL	5/28/82	closer to 174.5
175.5	PM	ZJ	5/11/83	closer to 175.2
176.5	PM	ZJ	5/11/83	closer to 176.2

Key to symbols:

Sample type:
- BD - bulk density
- Chem - chemistry
- GS - grain size
- HC - hydraulic conductivity
- I - isotopes (^{13}C, ^{18}O)
- K - $CaCO_3$ content
- Min - mineralogy
- PM - paleomagnetism
- Th/U - ^{230}Thorium/^{234}Uranium dating
- TL - thermoluminescence dating
- TS - thin section

Collector's initials:
- BNB - Bruce N. Bjornstad
- JLS - Janet L. Slate
- JR - ??
- JTL - John T. Lillie
- KAL - Kevin A. Lindsey
- WCC - Woodward Clyde Consult.
- ZJ - Zelma Jackson

Core:	DH-24 (699-43-84)
Location:	west of 200W along Army Loop Road, S of DH-23, N of DH-25 448400N, 2210873E (WA State Coordinates)
Interval Logged:	78' (top of core) - 98' (top of Ringold Fm)
Interpreted by:	J.L. Slate
Date Described:	2/93

Depth (ft)	Description and Interpretation
78 - 78.3	Poorly sorted, fine sand up to coarse pebbles. Clasts are mostly basaltic; subangular to subrounded.
78.3 - 78.6	Primarily massive $CaCO_3$ (sand and pebble parent material) juxtaposed with a mixture of $CaCO_3$-free sands and pebbles (minor component) along a vertical contact. Although there are no laminae where $CaCO_3$ contacts non-$CaCO_3$, $CaCO_3$ may have intruded the massive, welded pebble and sand mixture as a dike, becoming smaller with decreasing injection direction (up). Non-$CaCO_3$ colors are: 2.5Y 7/2d and 2.5Y 5/3m. $CaCO_3$ colors are: 10YR 8/2d and 10YR 7/3m. Slightly effervescent.
78.6 - 79.5	Massive $CaCO_3$ (sand and pebble parent material). $CaCO_3$ content appears to increase with depth. 10YR 8/2d and 10YR 7/3m. Slightly effervescent.
79.5 - 83	*(3.5' of core lost—"washed" according to block.)*
83 - 83.4	Fine to medium sand mixed with $CaCO_3$ in the lowermost 0.1'. Massive but must have been moist when put in box because now solidified in "box" shape. Non-$CaCO_3$ portion (upper 0.3') is 2.5Y 7/2d and 2.5Y 5/3m and slightly effervescent. $CaCO_3$ portion (lowermost 0.1') is 10YR 8/2d and 10YR 7/4m and strongly effervescent. Some Fe oxide patches are present that are 7.5YR 5/6d and 4/6m.
83.4 - 84.6	Texture is difficult to discern because of pervasive $CaCO_3$ but consists mostly of fine to medium sand, up to coarse pebbles. Sand is discrete from the $CaCO_3$ in the upper part. Pebbles are subangular to rounded basalt and are most prevalent at the base of this interval. $CaCO_3$ has a massive, stage III morphology and is strongly effervescent. A few orangish (Si?) patches are present. $CaCO_3$ colors are: 10YR 8/2d; 10YR 7/4 and 6/4m. Non-$CaCO_3$ colors are: 2.5Y 7/2 and 10YR 7/2d; 10YR 6/4 and 6/3m. (Boundary conditions uncertain because of BNB sample taken at 84.6'.)
84.6 - 84.8	$CaCO_3$ pervasive but can see some particles that are coarse to very coarse sand size and at least one medium pebble. These particles appear basaltic and have ragged edges—sort of a dendritic appearance—as though undergoing replacement(?) by $CaCO_3$. $CaCO_3$ has a massive, stage III+ morphology and is

	strongly effervescent. White and 10YR 8/2d; 10YR 7/3m. (Assumed boundary between piece that extends from 84.7'-84.9').
84.8 - 86.2	$CaCO_3$ pervasive in fine sand up to medium pebble size. Pebbles are subrounded basalt. $CaCO_3$ appears to increase with depth; has a massive, stage III morphology; is slightly to strongly effervescent; and a hackly ("popcorn") appearance predominates. From 85.6' to 85.8', $CaCO_3$ has a chalky, smooth laminar appearance and is less dense. No other bedding features are evident. White and 10YR 8/2d; 10YR 7/3 and 2.5Y 7/4m. At the base of this interval, some parts look crystalline. (86.2' divides one column in box from another; no true boundary.)
86.2 - 86.9	Texture is hard to discern because of stage III $CaCO_3$—fine to very coarse sand but few to no pebbles makes this interval seem finer than those above. No bedding is apparent but pieces break parallel to bedding planes. $CaCO_3$ has a massive, stage III morphology and is slightly to strongly effervescent. White and 10YR 8/2d; 10YR 8/3m. Few pods (1 or 2 mm x 4 mm) of clay were observed, especially near the base of this interval. Abrupt boundary with lower unit.
86.9 - 87.2	Interbedded fine to medium sand and $CaCO_3$. Thinly to thickly laminated. $CaCO_3$ is both disseminated and in 1-mm-thick laminae; slightly effervescent. $CaCO_3$ colors are: 10YR 8/2d; 10YR 6/2m. Non-$CaCO_3$ colors are: 10YR 7/3d; 10YR 5/3 and 4/3m. Abrupt base.
87.2 - 88	Mostly medium sand but also some fine and some coarse sand. Can't discern any bedding because this interval is disaggregated. $CaCO_3$ is disseminated throughout and the matrix is slightly effervescent. 10YR 6/2 and 6/3d; 10YR 4/2 and 4/3m; darker than the interval below.
88 - 89	Fine to very coarse sand, broken into platelets 4-15 mm thick. $CaCO_3$ is both disseminated and concentrated into a 3-mm-thick, wavy laminar layer parallel to the bedding plane. Non-$CaCO_3$ interbeds are: 10YR 6/3 and 6/4d; 10YR 4/3m; and non-effervescent. $CaCO_3$ interbeds and the laminar layer are: 10YR 8/2d; 10YR 7/3m; and slightly effervescent.
89 - 89.7	Mostly fine to medium sand but up to very coarse sand. Laminae are present and 1-1.5 cm thick beds are sandwiched by $CaCO_3$ laminae. Again, $CaCO_3$ is both disseminated and concentrated as a 3-mm-thick laminae. Matrix is slightly effervescent. Non-$CaCO_3$ colors are: 10YR 7/2d; 10YR 5/3m. $CaCO_3$ colors are: white and 10YR 8/2d; 10YR 8/3m.
89.7 - 92.7	Mostly fine to coarse sand but some up to fine pebble size. Clasts are subangular basalt. Laminae are apparent in some pieces. $CaCO_3$ that is disseminated in the matrix is slightly effervescent. $CaCO_3$ is segregated as trace laminae, especially in the upper part: at 90.3', a disjunct piece contains a 3-mm-thick lamina and a root cast(?) (15 mm long, 6 mm diameter). Pods and burrow infillings(?) of

	darker and slightly coarser material exist; in one piece, laminae in this material delineate the shape of the infilling. Matrix colors are: 10YR 7/2 and 6/2d; 10YR 6/3 and 5/3m. Colors of infillings are: 10YR 5/3d and 10YR 4/3m.
92.7 - 94	Mostly medium to coarse sand but also fine to very coarse sand and up to fine pebble size. Clasts are subangular basalt. Faint laminae are apparent in some pieces. The matrix contains disseminated $CaCO_3$ and is slightly effervescent. 10YR 7/2d; 10YR 5/3m.
94 - 96	Mostly fine sand and silt but also medium to coarse sand. Weak laminae are apparent in a few pieces. $CaCO_3$ is segregated throughout as nodules, filaments, laminae and root casts(?) but is most prevalent in the upper 0.5' and lower 0.5'. The matrix is non-effervescent; $CaCO_3$ portions are slightly effervescent. 10YR 6/4 and 7/4d; 10YR 3/4, 4/4, and 5/4m. The lower boundary is transitional—becomes coarser with depth.
96 - 98	Fine to very coarse sand. Laminae are apparent in some pieces. Non-effervescent. 10YR 6/3d (closest match); 10YR 4/3m.

INTERPRETIVE SUMMARY

78.3 - 79.5	Locally derived, probably Plio-Pleistocene deposits. The upper 0.3' is primarily massive $CaCO_3$ vertically juxtaposed with a subordinate mixture of $CaCO_3$-free sands and pebbles. Such features indicate dike injection, which could mean that the $CaCO_3$ had a groundwater origin. Massive $CaCO_3$ (stage III) in the 0.9' below appears to increase with depth.
79.5 - 83	*(3.5' of core missing.)*
83 - 83.4	The mixture of sand with $CaCO_3$ and the stage III $CaCO_3$ below suggest that the sand may have intruded the $CaCO_3$ as a clastic dike.
83.4 - 86.9	Although massive $CaCO_3$ is generally associated with a stage III morphology and the morphologic terms refer to pedogenic carbonates, the appearance, distribution and boundary characteristics suggest that its origin here is not pedogenic. $CaCO_3$ discrete from sand in the upper part suggests a clastic dike origin, and thus groundwater would have been high. The hackly, "popcorn" appearance of $CaCO_3$ in the mid portion is unlike that of any soil carbonate; such a texture may indicate formation under the influence of a high groundwater table. Other features—including the underlying chalky, smooth $CaCO_3$ that is less dense, and massive $CaCO_3$ that breaks parallel to bedding planes—suggest a non-pedogenic origin. The contrasting textures—gravelly from 83.4 to 85.6, and finer from 85.6 to 86.9—may be responsible for the differences in carbonate morphology.

An abrupt base to this interval and the apparent increase in $CaCO_3$ with depth lend credence to the idea that this carbonate has a groundwater origin.

86.9 - 87.2 This transitional zone of interbedded $CaCO_3$ and sand also supports a groundwater origin for the $CaCO_3$ because the $CaCO_3$ is concentrated in laminae subparallel to depositional layering rather than as nodules in an s-matrix (material in which pedological features are usually embedded within peds or in unaggregated soil materials [Brewer 1976, p. 147]), as would be expected were this a vadose paleosol.

87.2 - 88 This interval is the perceived parent material (unaltered sediment) for the overlying carbonate-enriched zones.

88 - 89.7 Laminated oxidized sand with $CaCO_3$ interbeds indicate a groundwater origin for the $CaCO_3$.

89.7 - 92.7 Slightly effervescent, light-colored sand containing pods and burrow infillings(?) of non-effervescent, darker and coarser sand, and a root cast(?) of $CaCO_3$ suggest that this interval was influenced by surficial processes but not necessarily soil development.

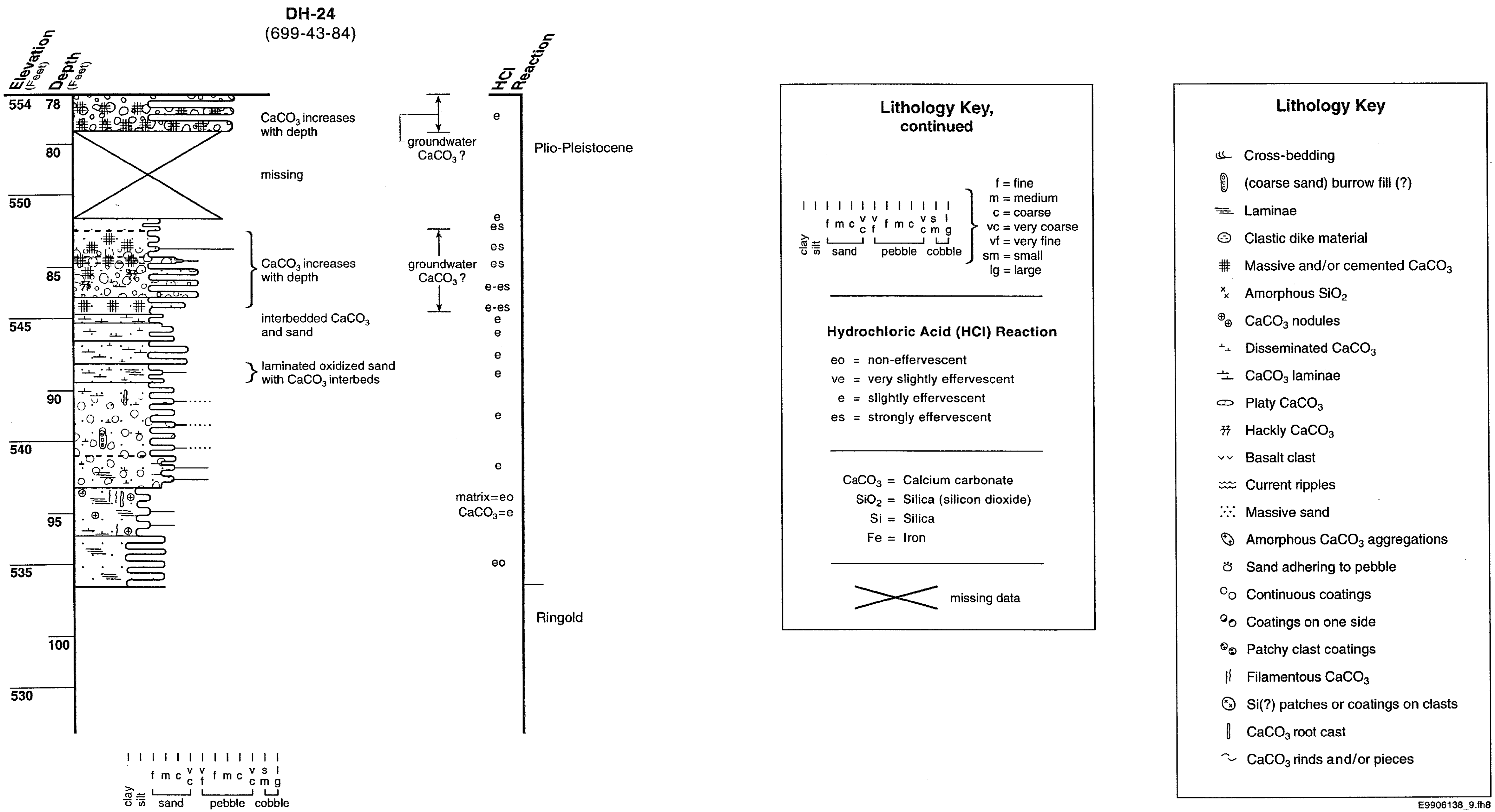
92.7 - 94 Faint laminae in coarse sand with disseminated $CaCO_3$ indicate little, if any, modification.

94 - 96 Non-effervescent fine sand and silt exhibiting some weak laminae contain nodules, filaments, laminae and root casts(?) of $CaCO_3$ mostly in the upper and lower 0.5'. These segregations and laminae suggest that the $CaCO_3$ development did not thoroughly disrupt the bedding as would be expected in a soil-forming environment.

96 - 98 Laminae in the absence of effervescence indicate no soil processes affected this interval.

REFERENCE

Brewer, R., 1976, *Fabric and Mineral Analysis of Soils*, Robert E. Krieger Publishing Co., Huntington, New York, 482 p.


DH-24
(699-43-84)
Elevation (Feet)
Depth (Feet)
HCl Reaction
554
78
80
550
85
545
90
540
95
535
100
530
CaCO3 increases with depth
missing
CaCO3 increases with depth
interbedded CaCO3 and sand
laminated oxidized sand with CaCO3 interbeds
groundwater CaCO3?
groundwater CaCO3?
e
e
es
es
es
e-es
e-es
e
e
e
e
e
e
matrix=eo
CaCO3=e
eo
Plio-Pleistocene
Ringold
clay
silt
f m c vc vf f m c vs cm lg
sand
pebble
cobble
Lithology Key, continued
f = fine
m = medium
c = coarse
vc = very coarse
vf = very fine
sm = small
lg = large
Hydrochloric Acid (HCl) Reaction
eo = non-effervescent
ve = very slightly effervescent
e = slightly effervescent
es = strongly effervescent
CaCO3 = Calcium carbonate
SiO2 = Silica (silicon dioxide)
Si = Silica
Fe = Iron
missing data
Lithology Key
Cross-bedding
(coarse sand) burrow fill (?)
Laminae
Clastic dike material
Massive and/or cemented CaCO3
Amorphous SiO2
CaCO3 nodules
Disseminated CaCO3
CaCO3 laminae
Platy CaCO3
Hackly CaCO3
Basalt clast
Current ripples
Massive sand
Amorphous CaCO3 aggregations
Sand adhering to pebble
Continuous coatings
Coatings on one side
Patchy clast coatings
Filamentous CaCO3
Si(?) patches or coatings on clasts
CaCO3 root cast
CaCO3 rinds and/or pieces
E9906138_9.lh8

Core: DH-24 (699-43-84)
Location: west of 200W along Army Loop Road, S of DH-23, N of DH-25
448400N, 2210873E (WA State Coordinates)
Interval Logged: 78' (top of core) - 98' (top of Ringold Fm)
Interpreted by: J.L. Slate
Dates: described: 2/93; sampled: 9/93

SAMPLE LIST

Depth (ft)	Sample Type	Collector's Initials	Date	Results/Notes/Sample ID (if different)
78.4	PM	BNB		
78.5-78.65	TS	JLS	9/93	24-78.5
78.65-78.8	GS, K	JLS	9/93	24-78.7
84.0	?	KAL	9/12/89	
84.2-84.3	TS	JLS	9/93	24-84.2
84.2-84.3	GS, K, BD	JLS	9/93	24-84.2
84.6	TL, Th/U	BNB		
84.6-84.7	I	JLS	9/93	not submitted, 24-84.6
84.7-84.9	TS	JLS	9/93	24-84.7
84.9-85.0	GS, K, BD	JLS	9/93	24-84.9
86.5-86.6	TS	JLS	9/93	24-86.5
86.6	PM	BNB	9/10/82	probably closer to 86.4-86.5
86.6-86.7	GS, K, BD	JLS	9/93	24-86.6
87.0-87.1	GS, K, BD	JLS	9/93	not submitted, 24-87
87.6-87.7	GS, K	JLS	9/93	not submitted, 24-87.6
88.7-88.8	GS, K	JLS	9/93	not submitted, 24-88.7
89.3-89.4	GS, K	JLS	9/93	not submitted, 24-89.3
90.0	?	KAL	9/12/89	probably closer to 90.2
91.6	PM	BNB	9/10/82	probably closer to 91.5
91.8-92.1	GS, Min	BNB	4/17/86	probably closer to 91.7-92.0

Key to symbols:

Sample type:

- BD - bulk density
- Chem - chemistry
- GS - grain size
- HC - hydraulic conductivity
- I - isotopes (^{13}C, ^{18}O)
- K - $CaCO_3$ content
- Min - mineralogy
- PM - paleomagnetism
- Th/U - ^{230}Thorium/^{234}Uranium dating
- TL - thermoluminescence dating
- TS - thin section

Collector's initials:

- BNB - Bruce N. Bjornstad
- JLS - Janet L. Slate
- JR - ??
- JTL - John T. Lillie
- KAL - Kevin A. Lindsey
- WCC - Woodward Clyde Consult.
- ZJ - Zelma Jackson

Core:	DH-25 (699-40-84)
Location:	west of 200W along Army Loop Road, S of DH-24, N of DH-21 445431N, 2211075E (WA State Coordinates)
Interval Logged:	84' (top of core) - 92' (top of Ringold Fm)
Interpreted by:	J.L. Slate
Date Described:	2/93

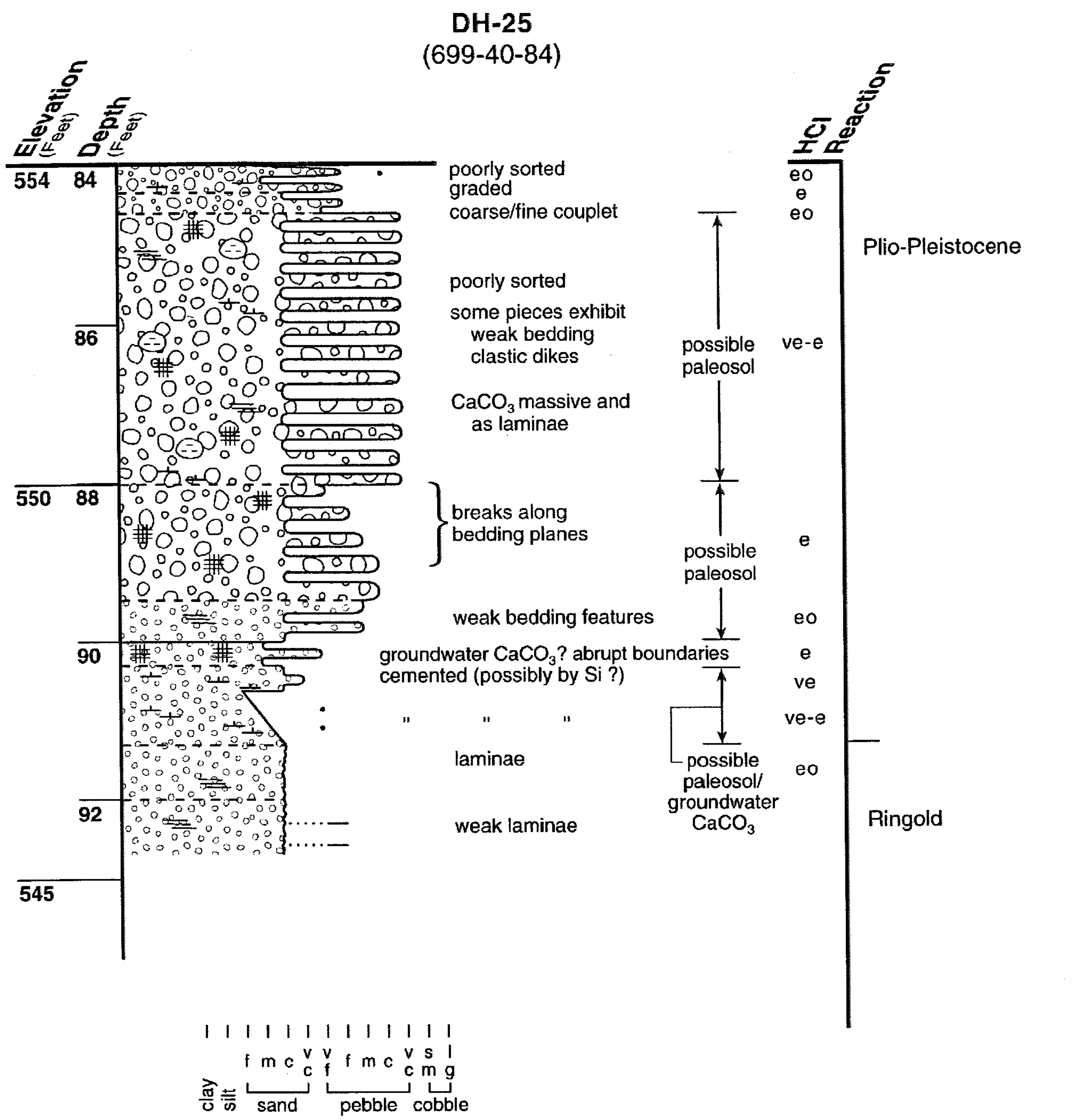
Depth (ft)	Description and Interpretation
84 - 84.1	Poorly sorted welded unit of fine to very coarse sand and subangular, very fine to fine pebbles—of which there are a higher proportion at the base—and one coarse pebble (rounded basalt). No bedding is apparent. 2.5Y 7/2d; 2.5Y 4/3m and 5/3m. $CaCO_3$ is disseminated in the uppermost 1 cm which is slightly effervescent; otherwise, non-effervescent. Mid-interval has dark pink/red (10R 5/3d; 10R 3/3m—the color of cinnabar) amorphous material (1.5 cm diameter by up to 4-cm width at top) which is non-effervescent. This interval has an abrupt boundary (less than 1" thick) with the next lower unit.
84.1 - 84.3	Graded bed (fining upward sequence) of very fine to fine pebbles up to fine to medium sand. Clasts are mostly basalt; subangular to subrounded. Beds are about 1 cm thick. Dry colors are: peppery, 2.5Y 7/2, and white; moist colors are: 2.5Y 5/3 and 5/2. $CaCO_3$ is disseminated throughout and the matrix is slightly effervescent but for a 1-cm-thick, cemented whitened zone at the top. Again, there is an abrupt boundary with the unit below.
84.3 - 84.6	This interval consists of a coarse/fine couplet: 3 cm of subangular and subrounded, very fine to fine pebbles of mostly basalt in a coarse sand matrix are overlain by coarse sand. Peppery and 2.5Y 5/2d; 2.5Y 4/2m and 3/2m. The uppermost sands are non-effervescent; the gravelly coarse sand varies from non- to very slightly effervescent—it may have been affected by the $CaCO_3$ zone below. Abrupt boundary with lower unit.
84.6 - 88	Poorly sorted gravelly coarse sand; the gravels are mostly subrounded to rounded basalt and vary from very fine to very coarse pebbles. Weak bedding features were observed in a few pieces. Clastic dikes of fine sand were apparent in some pieces throughout the interval. $CaCO_3$ is found in two forms—massive and laminae—but the distribution is patchy; effervescence is very slight to slight (where whiter). Colors vary for different components: $CaCO_3$ is white and 2.5Y 8/2d and 8/3d, 2.5Y 5/2m and 2.5Y 7/4m; non-$CaCO_3$ is 2.5Y 6/2d and 7/2d, and 2.5Y 4/3m; and clastic dike is 2.5Y 6/2d, and 2.5Y 5/2m and 4/2m. Boundary with the unit below is clear (transition takes place across 1"-2.5").
88 - 89.5	Gravelly coarse sand grading up to less gravelly coarse sand; gravels are very fine to coarse pebbles, mostly subrounded to rounded. The upper 1' is finer and better indurated; pieces break along bedding planes. $CaCO_3$ is massive throughout the

	matrix—a yellowish color indicates the possibility of some Si(?) too; slightly effervescent. 2.5Y 8/2d and 8/3d; 2.5Y 6/3m and 7/4m; the high $CaCO_3$ portion is 2.5Y 7/3m and 7/4m (dry colors as noted). Abrupt boundary with lower unit.
89.5 - 90	Gravelly coarse to very coarse sand; clasts are subrounded to subangular, mostly very fine to medium pebbles (some are coarse), almost all are basalt. Weak bedding features observed in rare intact pieces. Peppery and 2.5Y 5/1d; 2.5Y 4/3m and 3/3m. Non-effervescent; few $CaCO_3$ fragments in this interval may have been mixed from above and below. Abrupt boundary with lower unit.
90 - 90.3	Massive but lightweight (not dense) $CaCO_3$—hard to discern parent material because of pervasive $CaCO_3$, but appears to be medium to very coarse sand and very fine pebbles. No bedding is apparent. White and 2.5Y 8/2d and 10YR 8/2d; 2.5Y 7/3m and 10YR 7/3m. Slightly effervescent. Abrupt boundary with lower unit.
90.3 - 90.6	Coarse to very coarse sand. One-cm-thick beds observed. Cemented (possibly by Si) but not indurated. $CaCO_3$ is disseminated throughout but is only very slightly effervescent. Peppery and 2.5Y 7/2d; 2.5Y 5/2m.
90.6 - 91.3	Coarse sand grading up to fine sand with occasional very fine pebbles. Breaks along bedding(?) into approximately 1-cm-thick beds. $CaCO_3$ is seen as laminar layers parallel to bedding(?) planes throughout the interval; very slightly to slightly effervescent. Interval has a cemented, hard consistency which may be attributed to the presence of Si(?). Non-$CaCO_3$ colors are: 10YR 7/3d; 10YR 5/4m and 6/4m. $CaCO_3$ colors are: 10YR 8/2d and 10YR 7/3m.
91.3 - 92	Mostly coarse sand. The basal 0.3' breaks along bedding planes; laminae also observed. 10YR 7/4d and 10YR 5/4m. Non-effervescent. Probable Ringold Fm.
92 -	Coarse sand with some very fine to fine pebbles. Weak laminae were observed. The depths to the top of the Ringold Formation were previously identified at 91' by BNB and at 93' by KAL.

INTERPRETIVE SUMMARY

84 - 84.1	Possibly hydro affected(?) or welded due to drilling processes(?).
84.1 - 84.3	Plio-Pleistocene deposits—1-cm-thick $CaCO_3$-cemented zone cannot be used to make the interpretation that this is a paleosol (may be related to above deposit).
84.3 - 84.6	Plio-Pleistocene deposits.

84.6 - 88	Possibly a paleosol in Plio-Pleistocene deposits but weak bedding features are preserved in a few pieces and clastic dikes disrupt the fabric in some pieces; so it is difficult to make a definitive assessment. The massive nature of the $CaCO_3$ is the main indicator of the possibility of a paleosol. Maximum $CaCO_3$ development is stage III/IV (higher stage values for a smaller percentage of $CaCO_3$ because of high gravel content; see Appendix A).
88 - 90	Possibly another paleosol in Plio-Pleistocene deposits. But again, either pieces break along bedding planes or bedding features are preserved. Here too, the massive nature of the $CaCO_3$ is the main indicator of the possibility of a paleosol.
90 - 90.3	Possibly a groundwater $CaCO_3$ developed on either Plio-Pleistocene or Ringold deposits. The massive but lightweight nature of the $CaCO_3$, and abrupt upper and lower boundaries lead me to believe that this $CaCO_3$ was formed by groundwater influences. The pervasive $CaCO_3$ precludes assessment of parent material.
90.3 - 91.3	Possibly a groundwater calcrete/silcrete developed on Ringold deposits. The $CaCO_3$ in this interval is less pervasive than that above; bedding features are preserved. If 90'-90.3' were pedogenic, then this could be a Ck horizon to that paleosol; but the abruptness of the boundaries still needs to be explained.
91.3 -	Ringold Formation.



Lithology Key, continued

f = fine	
m = medium	
c = coarse	
vc = very coarse	
vf = very fine	
sm = small	
lg = large	

(clay, silt; sand: f m c vc vf; pebble: f m c vc s; cobble: m l g)

Hydrochloric Acid (HCl) Reaction

- eo = non-effervescent
- ve = very slightly effervescent
- e = slightly effervescent
- es = strongly effervescent

- $CaCO_3$ = Calcium carbonate
- SiO_2 = Silica (silicon dioxide)
- Si = Silica
- Fe = Iron

✕ missing data

Lithology Key

- Cross-bedding
- (coarse sand) burrow fill (?)
- Laminae
- Clastic dike material
- Massive and/or cemented $CaCO_3$
- Amorphous SiO_2
- $CaCO_3$ nodules
- Disseminated $CaCO_3$
- $CaCO_3$ laminae
- Platy $CaCO_3$
- Hackly $CaCO_3$
- Basalt clast
- Current ripples
- Massive sand
- Amorphous $CaCO_3$ aggregations
- Sand adhering to pebble
- Continuous coatings
- Coatings on one side
- Patchy clast coatings
- Filamentous $CaCO_3$
- Si(?) patches or coatings on clasts
- $CaCO_3$ root cast
- $CaCO_3$ rinds and/or pieces

E9906138_10.fh8

Core: DH-25 (699-40-84)
Location: west of 200W along Army Loop Road, S of DH-24, N of DH-21
445431N, 2211075E (WA State Coordinates)
Interval Logged: 84' (top of core) - 92' (top of Ringold Fm)
Interpreted by: J.L. Slate
Dates: described: 2/93; sampled: 9/93

SAMPLE LIST

Depth (ft)	Sample Type	Collector's Initials	Date	Results/Notes/Sample ID (if different)
85.0-85.15	GS, K, BD	JLS	9/93	25-85
85.15-85.3	TS	JLS	9/93	25-85.2
85.2	I	JLS	9/93	not submitted, 25-85.2
86.6-86.7	GS, K, BD	JLS	9/93	not submitted, 25-86.6
86.7	Th/U, TL	BNB	?	closer to 87.0'
86.7-86.9	TS	JLS	9/93	not submitted, 25-86.7
88.4	I	JLS	9/93	not submitted, 25-88.4
88.4-88.5	TS	JLS	9/93	25-88.4
88.5-88.6	GS, K, BD	JLS	9/93	25-88.5
89.7-89.8	GS, K	JLS	9/93	not submitted, 25-89.7
90.5	PM	?	6/8/92	
90.7	I	JLS	9/93	not submitted, 25-90.7
90.7-90.8	GS, K, BD	JLS	9/93	25-90.7
90.8-90.9	TS	JLS	9/93	25-90.8
91.15-91.25	GS, K	JLS	9/93	not submitted, 25-91.2

Key to symbols:

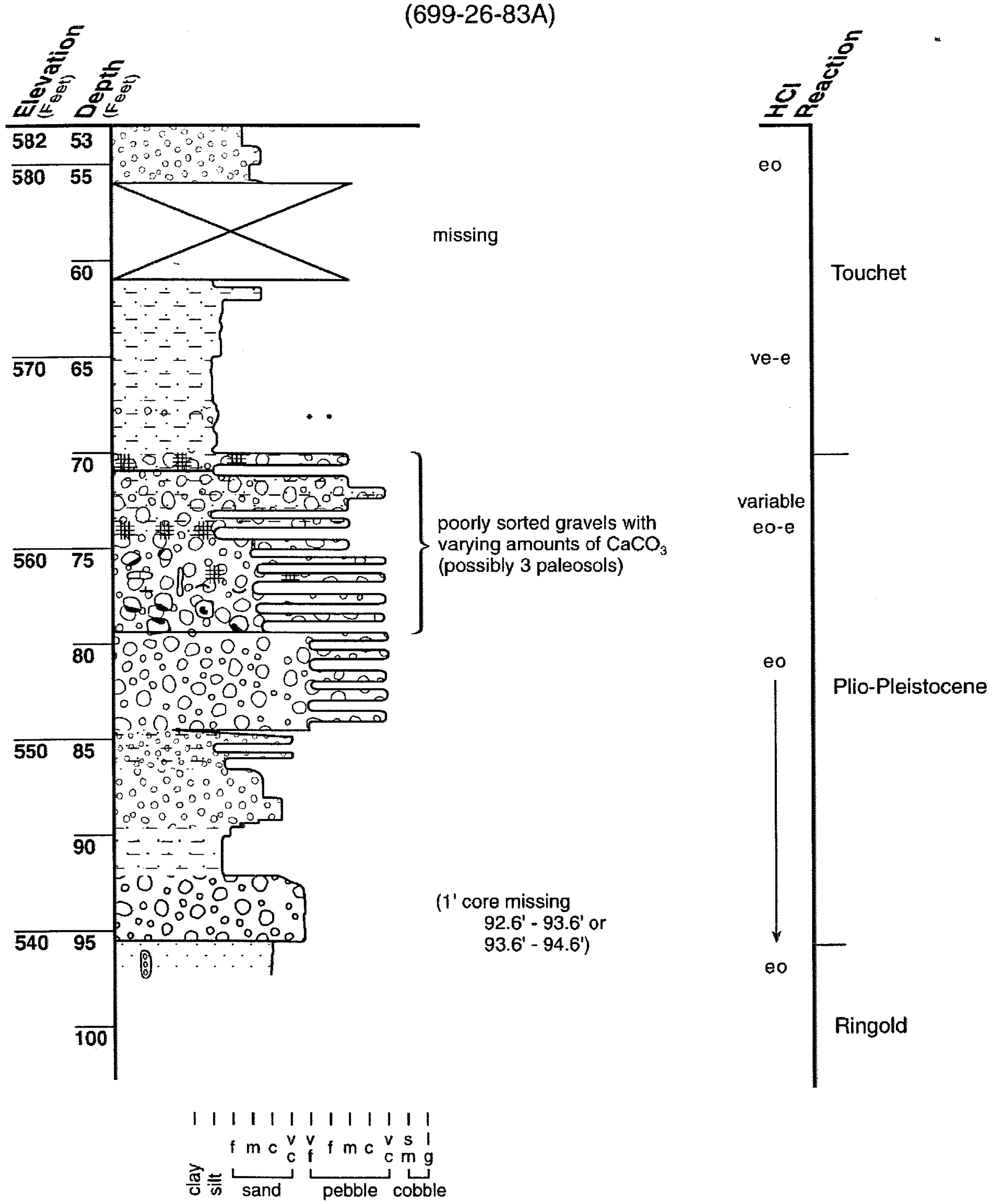
Sample type:
BD - bulk density
Chem - chemistry
GS - grain size
HC - hydraulic conductivity
I - isotopes (^{13}C, ^{18}O)
K - $CaCO_3$ content
Min - mineralogy
PM - paleomagnetism
Th/U - ^{230}Thorium/^{234}Uranium dating
TL - thermoluminescence dating
TS - thin section

Collector's initials:
BNB - Bruce N. Bjornstad
JLS - Janet L. Slate
JR - ??
JTL - John T. Lillie
KAL - Kevin A. Lindsey
WCC - Woodward Clyde Consult.
ZJ - Zelma Jackson

Core:	DH-26 (699-26-83A)
Location:	SSW of 200W, along Hwy 240, S of DH-20 430829N, 2212013E (WA State Coordinates)
Interval Logged:	53' (top of core) - 95.5' (top of Ringold Fm)
Interpreted by:	J.L. Slate
Date Described:	12/92

Depth (ft)	Description and Interpretation
53' - 70'	Buff-colored silts and fine sands, many zones of which show partings. No evidence of soil development. Fining upwards sequence noted in 53'-55' interval. Probably represents quiet-water deposition; seems too coarse for eolian. Could be Touchet beds?
70' - 79.9'	Poorly sorted gravels with varying amounts of $CaCO_3$ corresponding to different depth intervals. Some carbonate is disjunct from clasts and could represent redeposition of eroded soil. But other intervals appear to be in place, especially: 70'-70.9' massive, cemented (stage II-III $CaCO_3$ morphology) 74'-74.5' (in bag), massive, cemented, (stage II-III) poss. 74.5'-75' stage III on approx. 17-mm-thick piece (see photo—now at base of box—probably out of place and goes with BNB sampling at 74.5') 76.4'-76.7' platy in photo, look like root casts in box (stage II) But none of these intervals have Bt horizons or *any* B horizons associated with them. Also, difficult to decipher relations in Box #2 because it was "dropped," as noted on box cover. Probably represents deposition in an alluvial channel, and carbonate developed during intervening dry summers/years?
79.9'-95.5'	Carbonate-free, alternating sands+gravels and fines. Gravel-free fines are orangish brown, except 85.9'-86.5' which is buff colored. Possibly deposited in an alluvial channel where sands+gravels = flood or thalweg, and fines = waning flood, inter-flood deposition, or suspended load deposition. (One cored pebble at 80.7'-80.8' has a $CaCO_3$ coat, but none above or below—perhaps eroded and redeposited from elsewhere.)

DH-26
(699-26-83A)



Lithology Key, continued

clay, silt, sand (f m c vc vf), pebble (f m c vs), cobble (cm lg)

- f = fine
- m = medium
- c = coarse
- vc = very coarse
- vf = very fine
- sm = small
- lg = large

Hydrochloric Acid (HCl) Reaction

- eo = non-effervescent
- ve = very slightly effervescent
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- $CaCO_3$ = Calcium carbonate
- SiO_2 = Silica (silicon dioxide)
- Si = Silica
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missing data

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- Cross-bedding
- (coarse sand) burrow fill (?)
- Laminae
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- Coatings on one side
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- Filamentous $CaCO_3$
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- $CaCO_3$ root cast
- $CaCO_3$ rinds and/or pieces

E9906138_11.lh8

Core: DH-26 (699-26-83A)
Location: SSW of 200W, along Hwy 240, S of DH-20
430829N, 2212013E (WA State Coordinates)
Interval Logged: 53' (top of core) - 95.5' (top of Ringold Fm)
Interpreted by: J.L. Slate
Dates: described: 12/92; sampled: 9/93

SAMPLE LIST

Depth (ft)	Sample Type	Collector's Initials	Date	Results/Notes/Sample ID (if different)
53.7	PM	BNB	9/28/82	
55.8	PM	BNB	9/28/82	
55.9	PM	ZJ	5/16/83	
62.4	PM	BNB	9/28/82	
62.5	PM	ZJ	5/16/83	
64.0	PM	ZJ	5/16/83	
64.2-64.5	GS, Min	BNB	4/17/86	
65.0	PM	BNB	9/28/82	
65.5	PM	ZJ	5/16/83	
67.0	PM	ZJ	5/16/83	
67.2	PM	BNB	9/28/82	
70.7-70.8	GS, K, BD	JLS	9/93	26-70.7
70.7-70.8	TS	JLS	9/93	26-70.7
74.0	Th/U	BNB	3/8/83	
74.1-74.2	TS	JLS	9/93	26-74.1
74.5	TL	BNB	3/8/83	
80.1-80.3	GS, K, BD	JLS	9/93	not submitted, 26-80.1
84.8	PM	ZJ	5/16/83	
85.9	PM	ZJ	5/16/83	
86.0-86.2	GS, K, BD	JLS	9/93	not submitted, 26-86
86.0-86.2	TS	JLS	9/93	not submitted, 26-86
86.5	PM	BNB	9/28/82	
87.0	PM	ZJ	5/16/83	
89.5	PM	ZJ	5/16/83	
89.8	PM	BNB	9/28/82	
91.5	PM	ZJ	5/16/83	

Key to symbols:

Sample type:

- BD - bulk density
- Chem - chemistry
- GS - grain size
- HC - hydraulic conductivity
- I - isotopes (^{13}C, ^{18}O)
- K - $CaCO_3$ content
- Min - mineralogy
- PM - paleomagnetism
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- JLS - Janet L. Slate
- JR - ??
- JTL - John T. Lillie
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- WCC - Woodward Clyde Consult.
- ZJ - Zelma Jackson

Core:	DH-27 (699-50-99)
Location:	NW of 200W, just E of Yakima Barricade, W of DH-28 454768N, 2196455E (WA State Coordinates)
Interval Logged:	207' (top of Plio-Pleistocene?) - 221.5' (220.5'= top of Ringold Fm?)
Interpreted by:	J.L. Slate
Date Described:	5/93

Depth (ft)	Description and Interpretation
15.5 - 207	*(From top of core to KAL's interpreted top of Plio-Pleistocene.)* Hanford formation gravels (Pasco gravels) and sands and silts (Touchet beds).
207 - 213.7	*(208'-209' is missing/lost.)* Poorly sorted, subrounded, mostly basaltic very fine to very coarse pebbles and sand. No bedding is apparent. The upper 1' has more fine to medium sand than below—perhaps filtered down from above. Upper 1' is 10YR 7/2d and 10YR 5/3m. Below 209' is 10YR 6/2d and 5/1d; 10YR 4/2m and 3/2m. Non-effervescent—white patches/coatings on clasts are not $CaCO_3$.
213.7 - 215	Well sorted, quartzofeldspathic fine sand and silt. Weak laminae; tends to break along bedding planes. 10YR 7/3d; 10YR 5/4m. Non-effervescent.
215 - 216.6	Fine to medium sand with occasional very fine to fine pebbles; sand is quartzofeldspathic, and pebbles are mostly basalt. Breaks along horizontal (bedding?) planes. 10YR 6/4d; 10YR 4/3m. Non-effervescent.
216.6-217.6	Moderately sorted, mostly very fine to fine pebbles (up to coarse) in mostly fine to medium sand matrix (up to very coarse sand); pebbles are subrounded basalt. No bedding is apparent. Matrix is 10YR 5/2d; 10YR 3/2m. Non-effervescent.
217.6-218.5	Well sorted, quartzofeldspathic and micaceous fine to medium sand. One-cm-thick beds in intact pieces; otherwise, massive appearance. 10YR 7/3d and 6/3d; 10YR 4/3m. Non-effervescent.
218.5-220.5	$CaCO_3$ that becomes increasingly massive with depth and content appears to increase with depth. The upper 1' consists of amorphous $CaCO_3$ pieces segregated in fine to medium sand; the matrix is slightly effervescent and the $CaCO_3$ is strongly effervescent; 10YR 8/3d and 7/2d; 10YR 7/4m and 6/4m. Below 219.5', all is strongly effervescent; 2.5Y 8/3d and 2.5Y 7/4m. Interpreted as a probable groundwater $CaCO_3$.
220.5-221.5	Fine to coarse sand couplet with one granitic pebble; there are orange (Fe?) mottles and orangish subhorizontal laminae. Laminae are in the coarse sand and one fine sand piece at the top of an interval that has a planar top and bottom. 10YR 7/2d and 10YR 6/2m. Very slightly effervescent in the uppermost approximately 1"; otherwise non-effervescent.

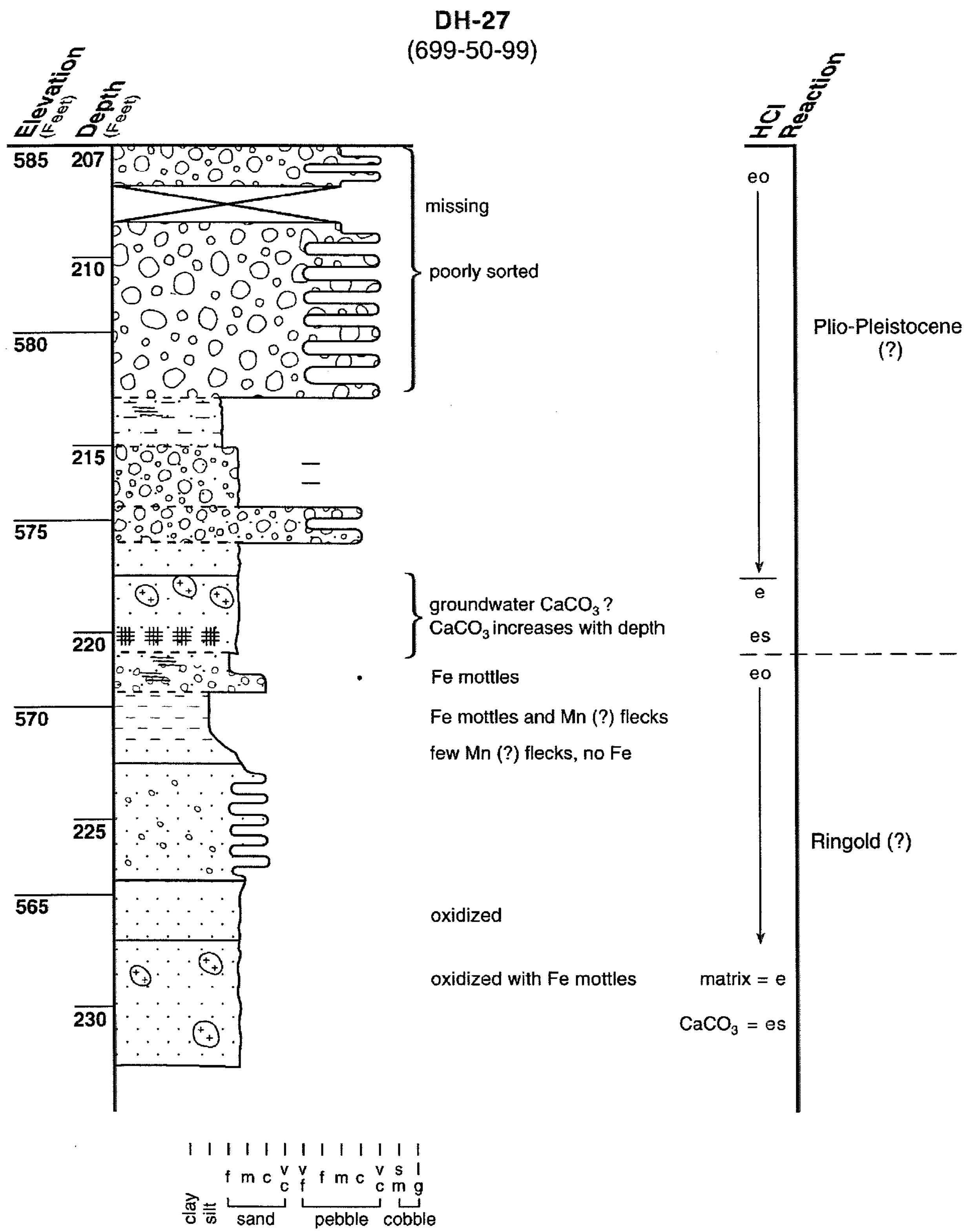
221.5-222.1	Silt with Fe(?) mottles and Mn(?) flecks—many of which are about 2 mm long and flattened parallel to horizontal (bedding?) plane, although no bedding is apparent (massive). *(Abbreviated descriptions follow.)*
222.1-222.6	Similar to above but breaks along bedding planes.
222.6-223.5	Fine to medium sand fining up to silt; massive. Few Mn(?) flecks but no Fe(?).
223.5-226.7	Variously sized sands: medium, fine and coarse. Bedding apparent in some pieces.
226.7-227.6	Oxidized (orange) fine to medium sand (finer in places). Breaks along bedding planes.
227.6-228.2	Oxidized fine to medium sand with Fe(?) mottles and $CaCO_3$ segregations; massive. Matrix is slightly effervescent; $CaCO_3$ is strongly effervescent.
228.2-231.5	Variously sized sands: fine to medium and coarse. Bedding apparent in some pieces.
231.5-233.5	Medium sand with fine to coarse pebbles at the base.
233.5-241.5	*(241.5' is the end of Box #17.)* Coarse to very coarse sand with felsic pebbles and cobbles. Most definitely Ringold Formation.

INTERPRETIVE SUMMARY

This core was previously interpreted (Landon and Bjornstad, 1986, p. B-3 and B-6) to contain no Plio-Pleistocene deposits. I believe that the above described interval could easily be interpreted as Hanford formation—$CaCO_3$ layers have been noted in the Hanford formation (Baker *et al.*, 1991). K.A. Lindsey (pers. commun., 1993) feels that the above described interval (207'-220.5') is Plio-Pleistocene based on the poor sorting and predominantly basaltic lithology of pebbles beginning at 207', and the presence of the $CaCO_3$ in the interval 218.5'-220.5'. The most convincing evidence for the top of the Ringold Formation begins at 233.5' where coarse to very coarse sand with felsic pebbles and cobbles are present.

Baker, V. R., B. N. Bjornstad, A. J. Busacca, K. R. Fecht, E. P. Kiver, U. L. Moody, J. G. Rigby, D. F. Stradling, and A. M. Tallman, 1991, "Quaternary Geology of the Columbia Plateau," in Morrison, R.B., (ed.), *Quaternary Nonglacial Geology, Conterminous U.S., Geology of North America*, v. K-2, Geological Society of America, Boulder, Colorado, p. 215-250.

Landon, R. D and B. N. Bjornstad, 1986, *Preliminary Stratigraphic and Structural Model of the Reference Repository Location, Hanford Site*, SD-BWI-TI-293, Rev. 0, Rockwell Hanford Operations, Richland, Washington.



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clay silt | f m c vc vf (sand) | f m c vs cm (pebble) | lg (cobble)

Hydrochloric Acid (HCl) Reaction

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SiO_2 = Silica (silicon dioxide)
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missing data

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- Sand adhering to pebble
- Continuous coatings
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- Patchy clast coatings
- Filamentous $CaCO_3$
- Si(?) patches or coatings on clasts
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E9906138_12.lh8

Core:	DH-27 (699-50-99)
Location:	NW of 200W, just E of Yakima Barricade, W of DH-28 454768N, 2196455E (WA State Coordinates)
Interval Logged:	207' (top of Plio-Pleistocene?) - 221.5' (220.5'= top of Ringold Fm?)
Interpreted by:	J.L. Slate
Dates:	described: 5/93; sampled: 9/93

SAMPLE LIST

Depth (ft)	Sample Type	Collector's Initials	Date	Results/Notes/Sample ID (if different)
214.2-214.3	PM	ASC	6/20/84	
216.4-216.5	PM	ASC	6/20/84	
217.9-218.1	GS, K, BD	JLS	9/93	not submitted, 27-217.9
218.1-218.2	TS	JLS	9/93	not submitted, 27-218.1
219.15-219.4	GS, K, BD	JLS	9/93	27-219.2
219.15-219.4	TS	JLS	9/93	27-219.2
220.65-220.75	GS, K, BD	JLS	9/93	27-220.7
220.7-220.8	PM	ASC	6/20/84	
220.75-220.95	TS	JLS	9/93	27-220.8
227.2-227.3	GS, K, BD	JLS	9/93	not submitted, 27-227.2
227.3-227.4	TS	JLS	9/93	not submitted, 27-227.3
227.85-228.05	TS	JLS	9/93	not submitted, 27-227.9
227.85-228.05	GS, K, BD	JLS	9/93	not submitted, 27-227.9

Key to symbols:

Sample type:
- BD - bulk density
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- I - isotopes (^{13}C, ^{18}O)
- K - $CaCO_3$ content
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- PM - paleomagnetism
- Th/U - ^{230}Thorium/^{234}Uranium dating
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- JTL - John T. Lillie
- KAL - Kevin A. Lindsey
- WCC - Woodward Clyde Consult.
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Core:	DH-28 (699-50-96)
Location:	NW of 200W, just E of Yakima Barricade, E of DH-27 454772N, 2198774E (WA State Coordinates)
Interval Logged:	100' (top of core) - 236' (KAL's top of Ringold Fm)
Interpreted by:	J.L. Slate
Date Described:	6/93

Depth (ft)	Description and Interpretation
100 - 118	*(Only 0.2' in 102'-104.5'. Only 0.3' in 105.5'-107.5'. 112'-117': "lost 5' core, washed away sand." 117'-118': "washed out 1' of core." Quotation marks refer to words written on wooden blocks in boxes.)* Moderately well sorted, rounded, mostly basalt, mostly coarse to very coarse pebbles, also coarse to very coarse sand and very fine to medium pebbles. Mostly disaggregated; no bedding apparent in consolidated sandy sections. 10YR 7/1d and 7/2d; 10YR 5/1m. Two $CaCO_3$-coated pebbles in 0.2' section (102'-104.5') which are slightly to strongly effervescent; otherwise, non-effervescent. Hanford formation gravels.
118 - 119.8	Moderately well sorted, quartzofeldspathic medium to very coarse sand, few very fine, subangular to subrounded, basalt pebbles. Molded to shape of box. 10YR 7/1d and 6/1d; 10YR 5/1m. Non-effervescent. Hanford fm.
119.8-122.2	Moderately well sorted, quartzofeldspathic medium to very coarse sand, and very fine to coarse, subangular to subrounded, mostly basalt pebbles. Mostly disaggregated. Colors as above. Matrix is very slightly effervescent; a couple of $CaCO_3$-coated clasts at 120'-120.3'. Hanford fm.
122.2-122.5	Silt(?) and fine sand interbedded and juxtaposed with medium to very coarse sand; sorted within grain sizes but overall unsorted. Very coarse sand is mostly basaltic, subangular to subrounded; fines are quartzofeldspathic and micaceous. Laminae in some intact pieces. 10YR 7/2d and 10YR 5/2m. Non- to very slightly effervescent. Hanford fm—such small fragments make it hard to tell if this could be a clastic dike or not.
122.5-127.5	*("5' lost core—suck out tube measure.")*
127.5-131.5	*("4' lost core—suck out tube.")*
131.5-136.5	*("5' lost core—wash.")*
136.5 - 138	*("1.5' lost core—wash.")*
138 - 143	*("5' lost core—wash.")*
143 - 144	*("1' lost core—wash.")*

144 - 148	*(But only 1.3' core in box.)* Moderately well sorted, subangular to subrounded, basaltic and quartzofeldspathic, mostly coarse to very coarse sand, also some medium sand and one 3-mm-thick silt/clay layer near the base of the interval. Mostly disaggregated; bedding only apparent where the silt/clay layer is. 10YR 6/1d and 10YR 4/1m. Non-effervescent. Hanford fm.
148 - 150	Fine to very coarse sand (also some very fine to fine pebbles in the upper 0.4') separated into intervals of fine to medium, medium to coarse, and medium to very coarse; moderately well sorted within intervals; basaltic, quartzofeldspathic and micaceous. Three- to 7-mm-thick beds in intact pieces of fine to medium sand. 10YR 7/1d and 6/1d; 10YR 5/1m and 4/1m. Non-effervescent. Hanford fm.
150 - 152	Moderately well sorted, subangular to subrounded, basaltic and quartzofeldspathic, mostly fine to coarse sand but up to very coarse sand. Weak bedding apparent in rare intact pieces. 10YR 6/1d and 10YR 4/1m. Non-effervescent. Hanford fm.
152 -153	*(But only 0.5' in box.)* Fairly well sorted, subangular to subrounded, basaltic and quartzofeldspathic, medium to fine sand. Weak bedding apparent in rare intact pieces. 10YR 7/1d and 10YR 5/1m. Non-effervescent. Hanford fm.
153 - 157	Poorly sorted, fine to very coarse sand and very fine to very coarse pebbles and few small cobbles; large pebbles and cobbles are rounded. Pebbles and cobbles are basalt, quartzite, volcanic porphyries, and metamorphic rocks. Fines are mostly quartzofeldspathic. Mostly disaggregated or molded to shape of box; no bedding apparent. Matrix is: 10YR 7/1d; 10YR 5/1m and 5/2m. Non-effervescent. Hanford fm.
157 - 158	*("1' core lost—wash.")*
158 - 158.2	Moderately well sorted, rounded, basaltic and quartzofeldspathic coarse to very coarse pebbles. Disaggregated. No color match due to coarseness of interval. Hanford fm.
158.2 - 162	*("3.8' lost core—qrded (or grded) and wash.")*
162 - 167	*("5' lost core—wash/qrd (or grd).")*
167 - 168	*("1' lost core—wash/qrd (or grd).")*
168 - 173	*("5' lost core—wash/qrd (or grd).")*
173 - 173.9	Massive $CaCO_3$—difficult to discern texture because of cement but some pebbles are present; some parts appear crystalline. The interior of 173'-173.4' looks like silicified tephra—light gray, glassy, amorphous, no recognizable minerals. Struc-

	ture is massive throughout. Slightly effervescent. Cemented and indurated; possibly also some Si(?) cement because of color. White; 7.5YR 8/2d and 10YR 8/2d; 7.5YR 8/2m, 7.5YR 7/2m and 10YR 7/3m. Can't tell what upper boundary was like because the core is missing but possibly was loose because it is described as being washed away; lower boundary is abrupt. Possibly a groundwater $CaCO_3$.
173.9 - 175	Fine to very coarse sand sorted into beds: upper 0.2' is medium to coarse sand; middle 0.6' is medium to very coarse sand; and lower 0.3' is fine to medium sand. Larger grains are subangular to subrounded. Composition is basaltic, quartzofeldspathic and micaceous (especially in the lower 0.3'). Bedding is apparent in intact pieces. 10YR 7/1d and 6/1d; 10YR 5/1m and 5/2m. Non-effervescent. Hanford fm.
175 - 184.1	Well sorted, predominantly fine but up to medium sand; quartzofeldspathic, micaceous, and basaltic. Most pieces examined show either bedding or laminae; others appear massive. Colors are a mixture of 10YR 7/1d and 7/2d; 10YR 5/2m. Non-effervescent. Hanford fm.
184.4-184.2	Moderately well sorted, subangular to subrounded, basaltic and quartzofeldspathic, mostly coarse to very coarse sand—some medium. No bedding apparent—pieces are contorted as if extruded wet. Sand has a salt and pepper appearance—no good matches to Munsell colors. Non-effervescent.
184.2-188.2	*("Lost 4.0', core washed out." "wash down tube"—block in Box #5.)*
188 - 193	*("5.0' lost core—washed from tube—fine sand?")*
193 - 195	*("Lost 2.0' core washed out of tube—fine sand?")*
195 - 198.8	Well sorted, quartzofeldspathic, micaceous and basaltic, mostly fine to medium sand, some up to coarse. Bedding or laminae apparent in most intact pieces. Colors are a mixture of 10YR 7/1d and 7/2d; 10YR 5/2m. Non-effervescent.
198.8 - 199	Moderately well sorted, subangular to subrounded, basaltic and quartzofeldspathic, medium to coarse sand, some up to very coarse. Bedding is not apparent—disaggregated. Sand has a salt and pepper appearance—no good matches to Munsell colors. Non-effervescent.
199 - 199.8	*("Lost 0.8' core washed out of tube.")*
199.8 - 201	Moderately well sorted, subangular to subrounded, quartzofeldspathic and basaltic, medium to coarse sand; one coarse quartzite pebble near the base of the interval. Bedding or laminae apparent in some intact pieces; otherwise massive. Sand has a salt and pepper appearance—no good matches to Munsell colors. Non-effervescent.

201 - 202.2 *("Lost 1.2' core washed out of tube.")*

202.2-203.5 Moderately well sorted, subangular to subrounded, basaltic and quartzofeldspathic, coarse to very coarse sand. Bedding apparent in largest of intact pieces; can see laminae in some smaller ones; much is disaggregated. Salt and pepper color but closest to 10YR 5/1d and 10YR 4/1m. Non-effervescent.

203.5 - 206 Similar to above—moderately well sorted, subangular to subrounded, quartzofeldspathic and basaltic, medium to coarse sand. Laminae in some intact pieces; much is disaggregated. 10YR 5/1d and 10YR 4/1m. Non-effervescent.

206 - 206.5 Moderately well sorted, quartzofeldspathic and micaceous, fine to medium sand; too fine to assess rounding. Laminated and breaks along bedding planes. 10YR 7/2d and 2.5Y 7/2d; 10YR 6/2m and 2.5Y 6/2m. Non-effervescent.

206.5-206.7 Fine to coarse sand, sorted into layers; subangular to subrounded; quartzofeldspathic and basaltic (coarse sand only) and micaceous. Laminae in rare intact pieces; otherwise disaggregated. 2.5Y 7/2d and 2.5Y 6/2m. Non-effervescent.

206.7-207.6 Well sorted, quartzofeldspathic and micaceous, fine sand; too fine to assess rounding. Subplanar zones of slightly coarser material (medium sand). Oxidized patches concentrated along planar zones. Partings that are planar and at angles were observed. 2.5Y 7/2d and 2.5Y 6/2m. Non-effervescent.

207.6 - 208 Coarsens with depth to medium sand with coarse sand intervals; sorted within intervals; subangular to subrounded; quartzofeldspathic and micaceous and basaltic (especially in coarser intervals). Weakly bedded except at the top of the interval where the bedding plane is well defined. 2.5Y 7/2d and 2.5Y 6/2m. Non-effervescent.

208 - 208.3 Coarse to very coarse sand; sorted within beds; subangular to subrounded; basaltic and quartzofeldspathic. One intact piece has a 2-cm-thick coarse sand bed and 3.5-cm-thick very coarse sand. Colors vary depending on size fraction; very coarse sand is: 10YR 5/1d and 10YR 4/1m; coarse sand is: 2.5Y 6/2m and 2.5Y 5/2m. Non-effervescent. Abrupt contact with unit below.

208.3-210.3 Well sorted, quartzofeldspathic fine sand; too fine to assess rounding. Most laminae are 4-5 mm thick; breaks along bedding planes. Layers of flattened vesicles subparallel to bedding (1-1.5 cm vertical spacing). Fe-oxide(?) laminae in the lower 0.7'. 2.5Y 7/2d and 2.5Y 5/3m. $CaCO_3$ is disseminated; very slightly to slightly effervescent.

210.3 - 211 Moderately well sorted, subangular to subrounded, quartzofeldspathic and basaltic, mostly medium sand but also fine and coarse. Laminae are both planar and at angles (cross bedding); Fe-oxide(?) laminae. 2.5Y 7/2d and 2.5Y 5/3m. Non-effervescent.

211 - 212 *("Lost 1.0' core washed out of tube.")*

212 - 212.7 Medium to coarse sand, moderately well sorted and sorted into layers; subangular to subrounded; quartzofeldspathic and basaltic; few very coarse sand particles in the upper 0.2'. Laminae in some intact pieces; otherwise, massive or disaggregated. Not a good color match; closest are: 2.5Y 5/2d and 2.5Y 4/2m. Non-effervescent.

212.7-222.4 *(215.8'-217.0': "Lost 1.2' core washed out of tube." 219.8'-222.0': "2.2' lost core—wash.")* Same as above with coarser intervals at 212.9'-213.0' and at 217.5'-217.6'. Abrupt contact with lower unit.

222.4-223.8 Well sorted, quartzofeldspathic fine sand (too fine to assess rounding) with interbeds of well sorted, quartzofeldspathic and basaltic medium sand. Laminae (2 to 4 mm thick); breaks along bedding planes. Fe-oxide(?) laminae in medium sand (223.0'-223.2'). 5Y 7/3d; 5Y 6/3m and 5/3m. $CaCO_3$ distribution is highly variable throughout; very slightly to slightly effervescent but some spots are non-effervescent.

223.8 - 227 *(227' is the end of Box #7 but there are only 1.8' in this interval.)* Interbedded medium and coarse sand (fine sand in basal 0.15' which is quartzofeldspathic); well sorted within beds; subangular to subrounded. Darker than above but still quartzofeldspathic-rich and basaltic. Bedding defined by grain size changes and occasional dark mineral bands. Not a good color match; closest are: 2.5Y 5/2d and 10YR 5/1d; 2.5Y 4/2m and 10YR 4/1m. Non-effervescent except the lowermost 0.15' (the fine sand) which is very slightly effervescent.

227 - 228 Moderately well sorted, rounded coarse to very coarse pebbles in (scant) coarse sand matrix. Pebbles are multi-lithologic: basalt, metamorphic rocks (gneiss and quartzite), and porphyritic volcanic rocks. Disaggregated (unconsolidated)—matrix is mostly absent. Matrix colors are: 2.5Y 6/2d and 2.5Y 5/2m. I interpret this as the top of the Ringold Formation based on pebble content and composition.

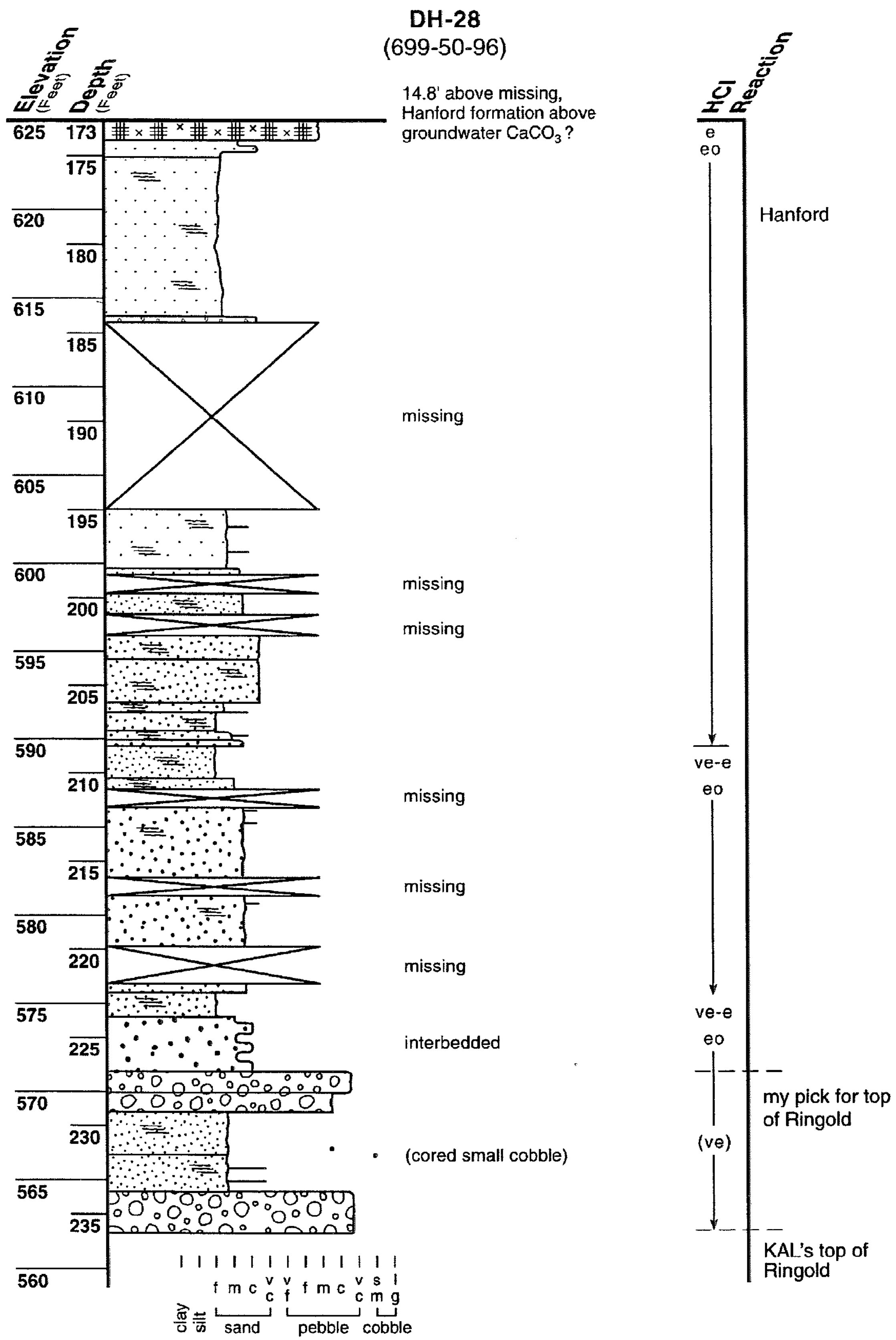
228 - 229.2 Medium to coarse pebbles in a medium to coarse sand matrix. Pebbles are moderately well sorted, rounded, and multi-lithologic: basalt, quartzite, and gneiss. Sand is quartzofeldspathic. Mostly disaggregated (unconsolidated) but even intact pieces show no bedding at this scale. 2.5Y 7/2d and 2.5Y 5/2m. Non-effervescent.

229.2-231.5 Moderately well sorted fine to medium sand; too fine to assess rounding; quartzofeldspathic, little basalt; rare medium to coarse pebbles in the lower 0.5'. Laminae apparent in rare intact pieces; most is disaggregated (unconsolidated). 2.5Y 7/2d and 2.5Y 6/2m. Non-effervescent except lowermost 0.5' which is very slightly effervescent.

231.5-233.6	At the top of the interval is a cored, small(?) quartzite cobble (8 cm max length). The interval, however, is dominantly fine to medium sand with interbeds of coarse and very coarse sand (and occasional pebbles); moderately well sorted. Pebbles are rounded, quartzofeldspathic and basaltic rocks. The sand is quartzofeldspathic. Laminae are present in intact sand pieces; much is disaggregated. Not a good color match; closest are: 2.5Y 6/2d and 2.5Y 5/2m. Non-effervescent.
233.6 - 236	Moderately well sorted, rounded, basalt, quartzite and red volcanic rock, coarse to very coarse pebbles in a quartzofeldspathic fine sand matrix. Bedding features are difficult to discern because most is disaggregated; the uppermost 0.3' is intact, however, and it appears that pebbles in this zone are sorted into layers. Matrix colors are: 2.5Y 7/2d and 2.5Y 5/2m. Non-effervescent.
236 -238.8	Much the same as above—pebbles may be slightly smaller and better sorted. K.A. Lindsey's pick for the top of the Ringold.
238.8-241.8	Sand with occasional pebbles—similar to 231.5'-233.6'.

INTERPRETIVE SUMMARY

My interpretation is that there are no Plio-Pleistocene deposits in this core—that Hanford formation deposits extend from the top of the core to 227' at which point I believe that the Ringold Formation begins.



Lithology Key, continued

clay silt | sand (f m c vc) | pebble (vf f m c vc) | cobble (sm lg)

- f = fine
- m = medium
- c = coarse
- vc = very coarse
- vf = very fine
- sm = small
- lg = large

Hydrochloric Acid (HCl) Reaction

- eo = non-effervescent
- ve = very slightly effervescent
- e = slightly effervescent
- es = strongly effervescent

- $CaCO_3$ = Calcium carbonate
- SiO_2 = Silica (silicon dioxide)
- Si = Silica
- Fe = Iron

missing data

Lithology Key

- Cross-bedding
- (coarse sand) burrow fill (?)
- Laminae
- Clastic dike material
- Massive and/or cemented $CaCO_3$
- Amorphous SiO_2
- $CaCO_3$ nodules
- Disseminated $CaCO_3$
- $CaCO_3$ laminae
- Platy $CaCO_3$
- Hackly $CaCO_3$
- Basalt clast
- Current ripples
- Massive sand
- Amorphous $CaCO_3$ aggregations
- Sand adhering to pebble
- Continuous coatings
- Coatings on one side
- Patchy clast coatings
- Filamentous $CaCO_3$
- Si(?) patches or coatings on clasts
- $CaCO_3$ root cast
- $CaCO_3$ rinds and/or pieces

E9906138_13.fh8

Core: DH-28 (699-50-96)
Location: NW of 200W, just E of Yakima Barricade, E of DH-27
454772N, 2198774E (WA State Coordinates)
Interval Logged: 100' (top of core) - 236' (KAL's top of Ringold Fm)
Interpreted by: J.L. Slate
Dates: described: 6/93; sampled: 9/93

SAMPLE LIST

Depth (ft)	Sample Type	Collector's Initials	Date	Results/Notes/Sample ID (if different)
149.1-150.1	PM	ASC	6/20/84	
151.4	PM	BNB	6/19/84	
173.4-173.6	TS	JLS	9/93	28-173.4
173.4-173.6	GS, K, BD	JLS	9/93	not submitted, 28-173.4
173.5	?	KAL	11/1/89	
175.4	PM	ASC, BNB	6/18/84	
178.4	PM	ASC, BNB	6/18/84	
180.7	PM	ASC, BNB	6/18/84	
182	?	KAL	11/1/89	
183	PM	ASC, BNB	6/18/84	
195.3	PM	ASC, BNB	6/18/84	
197.4-197.5	PM	ASC, BNB	6/18/84	
200.6	PM	ASC	6/18/84	
206.5	PM	ASC	6/18/84	
208.1-208.2	PM	ASC	6/18/84	closer to 207.6
214	?	KAL	11/1/89	
222.4-222.5	PM	ASC	6/18/84	
232	?	KAL	11/1/89	
232.8	PM	ASC	6/18/84	

Key to symbols:

Sample type:

- BD - bulk density
- Chem - chemistry
- GS - grain size
- HC - hydraulic conductivity
- I - isotopes (^{13}C, ^{18}O)
- K - $CaCO_3$ content
- Min - mineralogy
- PM - paleomagnetism
- Th/U - ^{230}Thorium/^{234}Uranium dating
- TL - thermoluminescence dating
- TS - thin section

Collector's initials:

- ASC - ??
- BNB - Bruce N. Bjornstad
- JLS - Janet L. Slate
- JR - ??
- JTL - John T. Lillie
- KAL - Kevin A. Lindsey
- WCC - Woodward Clyde Consult.
- ZJ - Zelma Jackson

Core:	DH-33 (699-34-98)
Location:	WSW of 200W, W of Hwy 240, SW of DH-22 438053N, 2198441E (WA State Coordinates)
Interval Logged:	63.04' (top of core) - 128' (126'= top of Ringold Fm)
Interpreted by:	J.L. Slate
Date Described:	3/93

Depth (ft)	Description and Interpretation
63.04 - 64.2	*Drilling cement.*
64.2 - 75.25	*(Lost 0.5': 72.87'-73.37'.)* Quartzofeldspathic fine to medium sand and/or silt. Laminae in intact pieces of sand; silt is massive or blocky. Sand is: 10YR 7/2d and 10YR 5/2m. Silt is: 10YR 7/3d and 2.5Y 6/3m. Interpreted as Touchet beds with clastic dike(s).
75.25 - 78.8	Intermixed $CaCO_3$ and fine to medium sand. In places, $CaCO_3$ is segregated into layers that appear to mimic bedding. $CaCO_3$ is disseminated throughout and found in subhorizontal layers, also in one place (at 76.6') forming concentric laminae around a void (1.5 cm diameter) filled with sand. Sand is: 10YR 7/3d and 10YR 5/3m. $CaCO_3$ is: 10YR 8/2d and 10YR 7/3m. Possibly a paleosol developed in Touchet bed deposits.
78.8 - 81.8	Mostly fine to medium sand, some coarse and occasional very fine pebbles; quartzofeldspathic. No bedding is apparent; mostly disaggregated. 10YR 6/3d; 10YR 4/3m and 5/3m. Very slightly effervescent and decreasing with depth, below 80.5' is non-effervescent.
81.8 - 82.2	Fine sand with filaments of $CaCO_3$. Laminae in some pieces; breaks along bedding planes. 10YR 7/2d and 10YR 5/2m. Non- to very slightly effervescent.
82.2 - 82.9	Quartzofeldspathic silt and fine sand in consolidated chunks. No bedding is apparent; massive. 10YR 7/3d and 10YR 6/3m. $CaCO_3$ is disseminated; slightly effervescent.
82.9 - 83.32	*("Lost 0.42'. Sed compact by drilling.")*
83.3 - 85	Quartzofeldspathic silt and fine sand. Consistence is loose to soft—most intact pieces fall apart during attempts to extract for examination, but those that do not fall apart show laminae. A vertical seam (clastic dike?) cuts through the center and another at an angle near the top of the interval. 10YR 7/3d and 10YR 5/3m. $CaCO_3$ is disseminated; very slightly to slightly effervescent. Interpreted as Touchet beds with clastic dike(s).

85 - 86	Quartzofeldspathic fine to coarse sand. There are some subhorizontal laminae in a few pieces but for the most part this interval is massive; there are concentric laminae (about 17 mm diameter) at 85.8'. 10YR 6/3d and 10YR 4/3m. $CaCO_3$ is disseminated; non- to very slightly effervescent.
86 - 87.82	Quartzofeldspathic fine to very coarse sand (coarser than above). Loose to soft consistence (as described above). There are subhorizontal laminae in some pieces and vertical laminae at 86.5'. 10YR 6/3d and 10YR 4/3m. $CaCO_3$ is disseminated and associated with clastic dike features; non- to very slightly effervescent.
87.82-89.76	*("Lost 1.94'—washed.")*
89.76-91.16	*("Lost 1.40'—washed.")*
91.16 - 92.9	Cemented but not indurated fine to coarse sand and $CaCO_3$. Breaks along subhorizontal planes above 92.4'; pieces are 1-2 cm thick. Below 92.4', plates are thinner (2-4 mm thick) and there is less $CaCO_3$. $CaCO_3$ is concentrated along subhorizontal seams and is slightly effervescent; the sand is non-effervescent. Sand is: 10YR 6/3d and 10YR 4/4m. $CaCO_3$ is: 10YR 8/2d and 8/3d; 10YR 7/4m. Possibly a paleosol or groundwater $CaCO_3$.
92.9 - 93	Fine to medium sand which forms 2-mm-thick platelets. 10YR 7/2d and 10YR 4/2m. Non- to very slightly effervescent.
93 - 94.3	Mostly fine to medium sand but also up to very coarse sand and very fine pebbles. Weakly consolidated (as above) breaks apart easily when touched except for $CaCO_3$-rich pieces. Platy fabric observed in intact pieces (especially 93.7'-94.0'); otherwise mostly loose. 10YR 7/2d and 8/2d; 10YR 5/2m and 6/2m. Uppermost 0.1' is very slightly effervescent; otherwise, $CaCO_3$ is disseminated (very slightly to slightly effervescent) and cements some pieces.
94.3 - 95.1	$CaCO_3$ cemented (but not indurated) sand, up to very fine pebbles. Strongly platy fabric. $CaCO_3$ is disseminated; slightly effervescent. 10YR 8/2d and 10YR 6/2m.
95.1 - 95.4	Mixture of cemented $CaCO_3$ and medium to coarse sand, up to very fine to fine pebbles (which are rare). $CaCO_3$ is platy; sand is blocky. $CaCO_3$ is slightly effervescent; sand is non-effervescent. $CaCO_3$ is: 10YR 8/2d and 10YR 6/2m. Sand is: 10YR 6/3d and 10YR 4/3m.
95.4 - 96.2	Cemented and indurated $CaCO_3$ and sand (mostly fine to medium sand but up to very fine pebbles). $CaCO_3$ defines layers (about 2 mm thick); otherwise, structure is massive. $CaCO_3$ is also disseminated—the matrix is slightly effervescent—and appears to decrease below 96.0'. $CaCO_3$ color is: 10YR 8/2d and 10YR 7/2m. Sand color is: 10YR 7/2d and 10YR 5/2m.

96.2 - 97.8	Mostly medium sand but ranges from fine to coarse and up to very fine pebbles. Weak partings were observed in the few intact pieces. $CaCO_3$ filaments and amorphous segregations are scattered throughout; slightly effervescent where these are found, otherwise non-effervescent. 10YR 7/3d and 6/3d; 10YR 4/3m.
97.8 - 98	Similar to 95.4'-96.2'—cemented (but not indurated) $CaCO_3$ and sand in layers. $CaCO_3$ defines layers—platy fabric. $CaCO_3$ is also disseminated; slightly effervescent. $CaCO_3$ is: 10YR 8/2d and 10YR 6/2m. Sand is: 10YR 6/3d and 10YR 4/3m.
98 - 98.6	Cemented and indurated, massive $CaCO_3$; slightly effervescent. Breaks along subparallel laminae. 10YR 8/2d and 10YR 7/2m.
98.6 - 99	Consolidated, fine to medium sand. $CaCO_3$ is concentrated in amorphous segregations which are slightly effervescent, and is disseminated at bedding planes which are non-effervescent. Partings were observed in the sand; the thickness between bedding surfaces with $CaCO_3$ traces is 1.5 cm. Sand is: 10YR 6/3d and 10YR 4/3m. $CaCO_3$ is: 10YR 8/3d; 10YR 7/3m and 7/4m.
99 - 99.94	Cemented (but not indurated) $CaCO_3$ and fine to medium sand. $CaCO_3$ is segregated in layers (along partings?) in one piece; otherwise, structure is massive. $CaCO_3$ is both disseminated and segregated into amorphous pieces/chunks; slightly effervescent. Overall colors are: 10YR 8/2d and 7/2d; 10YR 7/2m and 6/2m.
99.94-100.2	*(0.26' lost core.)*
100.2-101.8	Mostly fine to medium sand but up to very fine pebbles. Partings observed in most of the few intact pieces—most is loose. Few amorphous segregations of $CaCO_3$ are present and one 3-mm-diameter, 4-cm-length root cast; matrix is slightly effervescent. 10YR 7/2d and 10YR 4/3m.
101.8 - 103	Moderately sorted, mostly fine to medium sand but much up to very fine pebbles, rare up to very coarse pebbles; pebbles are basaltic. No bedding is apparent; massive. Down to 102.6' is cemented and indurated. $CaCO_3$ is disseminated; slightly effervescent. 10YR 7/3d and 7/2d; 10YR 5/3m.
103 - 104	Moderately sorted, coarse to very coarse sand and very fine to coarse/very coarse pebbles; pebbles are subrounded, mostly basalt. Weak partings were observed in some intact pieces (few are consolidated)—mostly loose. Non-effervescent except for $CaCO_3$ patches in the lower 0.4' which is very slightly to slightly effervescent. 10YR 7/2d and 5/1d; 10YR 5/2m and 4/1m.

104 - 112.5 *("Lost 1.2', 104.8'-106', washed." "Lost 3.04', 108'-111.04', washed." "Lost 1.0', 111.04'-112.04', washed.")* Moderately well sorted, mostly coarse to very coarse, rounded pebbles, few medium pebbles; mostly basalt but also some quartzofeldspathic rocks—quartzite and jasper. No bedding is apparent—disaggregated. Patchy $CaCO_3$ coats on some clasts which are very slightly effervescent. No matrix.

112.5 - 114 Cemented—and below 113.15' also indurated—massive $CaCO_3$; fines in upper 0.9', pebbly in lower 0.6'. Amorphous crystalline (drusy?) $CaCO_3$ in 113.4'-113.7'. $CaCO_3$ has a crystalline appearance where it coats clasts—breaks clean away from clast tops. No bedding is apparent; massive. $CaCO_3$ is disseminated throughout; slightly effervescent. Colors are variable. The upper 0.5' is: 10YR 8/2d and 10YR 6/4m. The lower 1.0' is: white, 10YR 8/2d, 8/3d, and 7/2d; 10YR 8/3m, 6/4m and 6/2m. The upper and lower boundaries to this interval are abrupt suggesting that this may be a groundwater $CaCO_3$.

114 - 114.8 Upper 0.3': mostly fine to medium sand but up to coarse to very coarse sand and few very fine to very coarse pebbles; sand is moderately sorted and quartzofeldspathic. Lower 0.5': small/large basalt cobble (cored) with poorly sorted sand and fine pebbles adhering at base; coarse sand is subangular to angular. No bedding is apparent; sand is disaggregated. $CaCO_3$ is disseminated throughout and is segregated into a few amorphous pieces; slightly effervescent. 10YR 7/2d and 10YR 5/3m.

114.8-115.6 Moderately sorted, angular, fine to coarse sand; quartzofeldspathic but also many basalt fragments; grain size appears to decrease slightly with depth. Weakly consolidated; much is loose. Upper 0.2' shows bedding but below bedding is not apparent except as defined by a $CaCO_3$ layer. The matrix is non-effervescent; $CaCO_3$ that forms vertical and horizontal seams (1-5 mm thick) is slightly effervescent. The color match on the sand matrix is poor because of the basaltic sand grains: 10YR 7/3d and 7/4d; 10YR 5/4m. $CaCO_3$ is: 10YR 8/1d; 10YR 7/2m.

115.6-116.2 Moderately well sorted, angular, mostly fine to medium sand but up to coarse sand intermixed with $CaCO_3$; quartzofeldspathic and many basalt grains. Consolidated although sand is readily disaggregated (soft); $CaCO_3$ cements some portions. No bedding is apparent. Sand is non-effervescent; $CaCO_3$ portions are slightly effervescent. Sand matrix is: 10YR 7/4d and 10YR 5/4m. $CaCO_3$ is: 10YR 8/2d and 10YR 7/2m.

116.2-116.9 Moderately well sorted, angular, fine to (mostly) coarse sand; quartzofeldspathic and basaltic. Consolidated; breaks along bedding planes; laminae apparent. Non-effervescent. 10YR 7/4d and 10YR 5/4m.

116.9-117.24 Moderately well sorted, angular, fine to (mostly) coarse sand and amorphous $CaCO_3$ segregations; quartzofeldspathic and basaltic. No bedding is apparent—only one intact piece (1-2.5 cm thick) besides amorphous $CaCO_3$ segregations. Sand is non-effervescent; $CaCO_3$ portions are slightly to strongly effervescent. Sand matrix is: 10YR 7/4d and 10YR 5/4m. $CaCO_3$ is: white and 10YR 8/2d; 10YR 8/2m and 7/3m.

117.24-121.5 Moderately well sorted, subangular to angular, medium to coarse sand, some up to very coarse sand; quartzofeldspathic and basaltic. There is a rounded, very coarse quartzite pebble at the base of the interval, and a few other smaller pebbles. Much is disaggregated; laminae are apparent in some intact (consolidated) pieces and these tend to break along bedding planes. Non-effervescent. 10YR 7/3d and 7/4d; 10YR 5/4m and 4/3m. All sands above and including this interval are oxidized; below sands are grayer and unoxidized.

121.5-122.6 *("Lost 0.9'—washed.")*

122.6 - 126 Moderately well sorted, subrounded to angular, medium to coarse sand, some up to very coarse sand; quartzofeldspathic and basaltic. Much is consolidated; breaks along bedding planes and has laminae—especially evident below 124.5'. Non-effervescent. 10YR 6/2d and 10YR 4/2m.

126 -127.7 *("Lost 0.79', 126.33'-127.12', washed.")* Well sorted, fine to medium sand (too fine to determine roundness); quartzofeldspathic and micaceous. Laminae; breaks along bedding planes. Non-effervescent. 10YR 6/2d and 10YR 5/2m. I interpret this as the top of the Ringold Formation.

127.7 - 128 Up to coarse sand and not as well sorted as above; much mica. Loose. Non-effervescent. 10YR 7/2d and 10YR 5/2m. (K.A. Lindsey interprets the top of Ringold as 128'.)

INTERPRETIVE SUMMARY

63 - 64.2 Drilling cement.

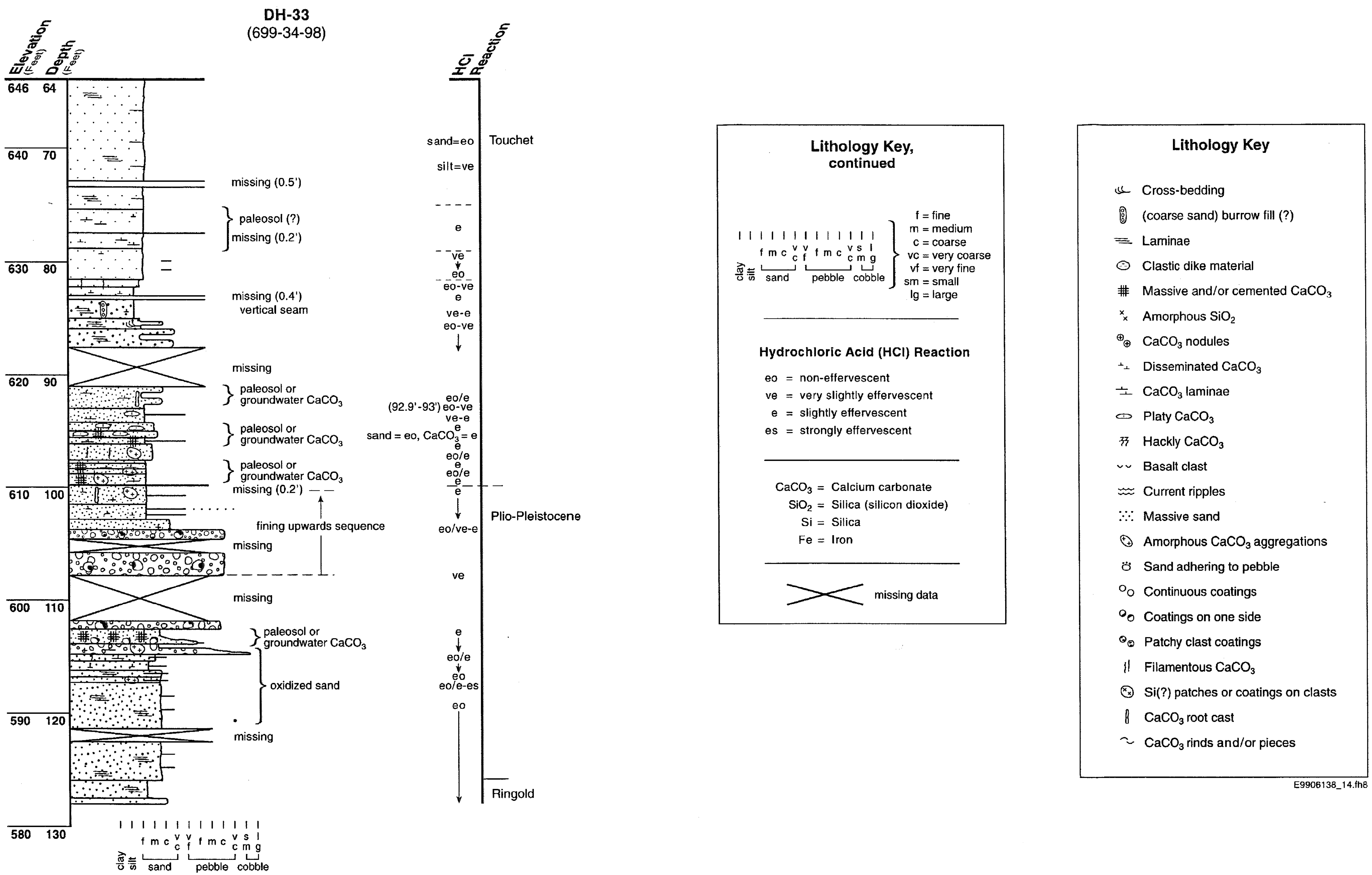
64.2 - 75.25 Touchet beds with clastic dike(s).

75.25 - 78.8 Weakly developed paleosol(?) in Touchet beds. $CaCO_3$ is both disseminated and segregated into layers that appear to mimic bedding.

78.8 - 87.82 Touchet beds—some laminae, some parts with apparent clastic dike(s).

87.82-91.16 *Lost/missing.*

91.16 -92.9	Weakly developed paleosol(?) or groundwater $CaCO_3$(?) in Touchet beds. $CaCO_3$ is concentrated along subhorizontal seams, and cemented (but not indurated) material breaks along subhorizontal planes indicating that original stratification (bedding) remains.
92.9 - 94.3	Touchet beds with platy fabric.
94.3 - 96.2	Paleosol(?) or groundwater(?)$CaCO_3$ in Touchet beds. A strongly platy fabric and cementation suggest a paleosol. But the distribution of the $CaCO_3$—not a progressive decrease with depth, and that it defines layers in places—may be indicative of a nonpedogenic origin.
96.2 - 97.8	Touchet beds are implied by the presence of weak partings.
97.8 - 99.9	$CaCO_3$—paleosol or groundwater. Similar to the $CaCO_3$ in the interval 94.3'-96.2'.
99.9-100.2	*Lost/missing.*
100.2 - 108	Plio-Pleistocene fining upwards sequence: 102.2'-103' = mostly fine to medium sand and rare pebbles 103'-104' = coarse sand and gravel 104'-108' = basalt gravels
108 - 112	*Lost/missing.*
112 - 112.5	More basalt gravels—may be a continuation of the lower part of the 100.2'-108' fining upwards sequence.
112.5 - 114	Groundwater $CaCO_3$(?) or eroded paleosol. A groundwater $CaCO_3$ seems most likely here because of the massive crystalline nature of the $CaCO_3$ and the abrupt upper and lower boundaries.
114 - 117.2	Basalt-rich oxidized sand with $CaCO_3$ in places. Bedding, for the most part, is poorly defined.
117.2-121.5	Basalt-rich oxidized sand lacking $CaCO_3$.
121.5-122.6	*Lost/missing.*
122.6 - 126	Basalt-rich unoxidized sand lacking $CaCO_3$.
126 -	Micaceous sand with laminae (no $CaCO_3$). Ringold Formation.


DH-33
(699-34-98)
Elevation (Feet)
Depth (Feet)
HCl Reaction
646 64
640 70
630 80
620 90
610 100
600 110
590 120
580 130
missing (0.5')
paleosol (?)
missing (0.2')
missing (0.4')
vertical seam
missing
paleosol or groundwater CaCO3
paleosol or groundwater CaCO3
paleosol or groundwater CaCO3
missing (0.2')
fining upwards sequence
missing
missing
paleosol or groundwater CaCO3
oxidized sand
missing
sand=eo
silt=ve
e
ve
eo
eo-ve
e
ve-e
eo-ve
eo/e
(92.9'-93') eo-ve
ve-e
sand = eo, CaCO3 = e
eo/e
eo/e
eo/ve-e
ve
e
eo/e
eo
eo/e-es
eo
Touchet
Plio-Pleistocene
Ringold
clay
silt
f m c vc vf f m c vc s m l g
sand
pebble
cobble
Lithology Key, continued
f = fine
m = medium
c = coarse
vc = very coarse
vf = very fine
sm = small
lg = large
Hydrochloric Acid (HCl) Reaction
eo = non-effervescent
ve = very slightly effervescent
e = slightly effervescent
es = strongly effervescent
CaCO3 = Calcium carbonate
SiO2 = Silica (silicon dioxide)
Si = Silica
Fe = Iron
missing data
Lithology Key
Cross-bedding
(coarse sand) burrow fill (?)
Laminae
Clastic dike material
Massive and/or cemented CaCO3
Amorphous SiO2
CaCO3 nodules
Disseminated CaCO3
CaCO3 laminae
Platy CaCO3
Hackly CaCO3
Basalt clast
Current ripples
Massive sand
Amorphous CaCO3 aggregations
Sand adhering to pebble
Continuous coatings
Coatings on one side
Patchy clast coatings
Filamentous CaCO3
Si(?) patches or coatings on clasts
CaCO3 root cast
CaCO3 rinds and/or pieces
E9906138_14.fh8

Core:	DH-33 (699-34-98)
Location:	WSW of 200W, W of Hwy 240, SW of DH-22 438053N, 2198441E (WA State Coordinates)
Interval Logged:	63.04' (top of core) - 128' (126'= top of Ringold Fm)
Interpreted by:	J.L. Slate
Dates:	described: 3/93; sampled: 9/93

SAMPLE LIST

Depth (ft)	Sample Type	Collector's Initials	Date	Results/Notes/Sample ID (if different)
69.0	?	KAL	9/28/89	
77.1-77.2	GS, K, BD	JLS	9/93	33-77.1
77.2-77.4	TS	JLS	9/93	33-77.2
79.5-79.6	GS, K, BD	JLS	9/93	33-79.5
80.0	?	KAL	9/28/89	
81.2-81.3	GS, K	JLS	9/93	not submitted, 33-81.2
82.5-82.6	GS, K, BD	JLS	9/93	not submitted, 33-82.5
82.6-82.8	TS	JLS	9/93	33-82.8
85.0	?	KAL	9/28/89	
91.7-91.8	TS	JLS	9/93	33-91.7
91.8-91.9	GS, K, BD	JLS	9/93	33-91.8
92.4	?	KAL	9/28/89	
93.9-94.0	TS	JLS	9/93	33-93.9
93.9-94.0	GS, K, BD	JLS	9/93	33-93.9
95.5-95.6	TS	JLS	9/93	33-95.5
95.6-95.65	GS, K, BD	JLS	9/93	33-95.6
96.0-96.2	TS	JLS	9/93	33-96
97.0-97.2	GS, K	JLS	9/93	not submitted, 33-97
98.35-98.45	TS	JLS	9/93	33-98.4
98.35-98.45	GS, K, BD	JLS	9/93	33-98.4
98.8-98.9	GS, K, BD	JLS	9/93	33-98.8
98.8-98.9	TS	JLS	9/93	33-98.9
99.0	?	KAL	9/28/89	
99.55-99.7	GS, K, BD	JLS	9/93	33-99.6
99.7-99.85	TS	JLS	9/93	33-99.7
100.9-101.0	GS, K	JLS	9/93	not submitted, 33-100.9
102.0-102.2	GS, K, BD	JLS	9/93	not submitted, 33-102
102.2-102.4	TS	JLS	9/93	33-102.2
103.5-103.6	GS, K	JLS	9/93	not submitted, 33-103.5
113.0	I	JLS	9/93	not submitted, 33-113
113.0-113.15	GS, K, BD	JLS	9/93	33-113
113.15-113.35	TS	JLS	9/93	33-113.2
115.7	?	KAL	9/28/89	
124.5	?	KAL	9/28/89	

Key to symbols:

Sample type:

- BD - bulk density
- Chem - chemistry
- GS - grain size
- HC - hydraulic conductivity
- I - isotopes (^{13}C, ^{18}O)
- K - $CaCO_3$ content
- Min - mineralogy
- PM - paleomagnetism
- Th/U - ^{230}Thorium/^{234}Uranium dating
- TL - thermoluminescence dating
- TS - thin section

Collector's initials:

- BNB - Bruce N. Bjornstad
- JLS - Janet L. Slate
- JR - ??
- JTL - John T. Lillie
- KAL - Kevin A. Lindsey
- WCC - Woodward Clyde Consult.
- ZJ - Zelma Jackson

APPENDIX C

LABORATORY DATA FROM DRILL CORE SAMPLES

Table C-1. Laboratory Analytical Results for Physical Properties. (2 Pages)

DH-#	Sample ID	Interval (ft)	Hygroscopic Moisture (%)[a]	Average Bulk Density (g/cm³)[b]	% $CaCO_3$[c]	Estimated CO_3 Stage[d]	% Gravel[e]	% Sand[f]	% Silt[f]	% Clay[f]	Texture
6	6-121.2	121.2-121.4	2.32	1.56	52.17	III+	0.90	52.94	38.07	8.99	Sandy loam
	6-124.1	124.1-124.3	1.41	1.84	48.23	III+	0.55	57.66	29.81	12.53	Sandy loam
	6-127.4	127.4-127.6	1.08	1.85	17.03	II	10.20	90.47	6.97	2.56	Sand
	6-129.0	129.0-129.1	0.50	1.95	43.48	III+	2.66	91.98	5.84	2.18	Sand
7	7-161.3	161.3-161.6	1.37	1.47	58.68	III+	0.00	50.18	31.81	18.01	Loam
	7-162.4	162.4-162.6	0.92	1.63	36.23	III	0.05	74.76	18.57	6.67	Loamy sand/sandy loam
11	11-156.7	156.7-156.8	0.53	1.94	61.97	IV	24.80	45.76	45.45	8.78	Loam/sandy loam
	11-161.1	161.1-161.2	1.46	1.94	41.10	III+	1.06	41.59	39.11	19.30	Loam
	11-162.0	162.0-162.1	1.51	2.00	18.59	II	2.88	58.63	26.01	15.36	Sandy loam
	11-162.7	162.7-162.8	1.20	2.01	40.03	III/III+	3.25	48.08	34.94	16.98	Loam
	11-163.7	163.7-163.8	1.41	2.13	28.26	III	31.66	64.64	22.42	12.94	Sandy loam
	11-164.3	164.3-164.4	1.36	2.04	29.84	III	3.38	64.15	22.10	13.75	Sandy loam
	11-164.8	164.7-164.8	1.46	1.83	26.94	III	6.62	49.08	37.37	13.55	Loam
	11-165.2	165.2-165.3	1.44	1.92	36.09	III	6.20	55.92	24.12	19.96	Sandy loam/sandy clay loam
	11-166.1	166.1-166.2	0.94	1.81	13.64	II	11.39	71.51	22.14	6.34	Sandy loam
	11-168.2	168.0-168.3	3.24	1.46	16.58	II	0.69	29.53	40.70	29.77	Clay loam
	11-169.5	169.5-169.6	1.73	1.63	26.36	III	0.04	77.05	9.92	13.03	Sandy loam
12	12-127.6	127.6-127.9	0.76	2.12	41.76	III/III+	12.43	63.74	30.24	6.02	Sandy loam
	12-128.5	128.5-128.7	0.98	1.87	66.97	IV	0.14	43.69	42.92	13.39	Loam
21	21-86.0	85.9-86.2	1.15	2.04	14.56	III (hi gr)	20.50	66.35	26.67	6.99	Sandy loam
	21-90.1	90.1-90.2	1.26	1.99	27.60	III/IV (hi gr)	89.82	77.17	16.58	6.25	Loamy sand/sandy loam
	21-91.0	91.0-91.15	1.42	2.12	18.44	III (hi gr)	78.36	82.46	10.65	6.89	Loamy sand
24	24-78.7	78.65-78.8	1.24	2.11	39.41	III	15.27	56.73	33.98	9.29	Sandy loam
	24-84.2	84.2-84.3	1.42	1.98	49.59	III+	3.35	58.63	25.59	15.78	Sandy loam
	24-84.9	84.9-85.0	1.49	1.84	52.05	III+	2.54	50.47	33.56	15.97	Loam/sandy loam
	24-86.6	86.6-86.7	1.74	1.78	42.46	III+	0.42	50.24	33.83	15.93	Loam/sandy loam
25	25-85.0	85.0-85.15	1.19	2.39	27.44	III/IV (hi gr)	54.38	82.46	11.02	6.51	Loamy sand
	25-88.5	88.5-88.6	1.23	1.72	27.55	III	10.52	69.46	23.85	6.69	Sandy loam
	25-90.7	90.7-90.8	1.85	1.90	13.78	II	14.94	53.10	35.77	11.12	Sandy loam/loam
26	26-70.7	70.7-70.8	1.47	2.02	19.53	III (hi gr)	56.08	67.81	26.45.	5.74	Sandy loam

Table C-1. Laboratory Analytical Results for Physical Properties. (2 Pages)

DH-#	Sample ID	Interval (ft)	Hygroscopic Moisture (%)[a]	Average Bulk Density (g/cm^3)[b]	% $CaCO_3$[c]	Estimated CO_3 Stage[d]	% Gravel[e]	% Sand[f]	% Silt[f]	% Clay[f]	Texture
27	27-219.2	219.15-219.4	0.65	1.68	24.44	III	0.00	15.65	56.70	27.65	Silty clay loam/silt loam
	27-220.7	220.65-220.75	1.07	1.65	3.40	I/II	0.00	3.16	81.44	15.40	Silt loam
33	33-77.1	77.1-77.2	1.07	1.79	48.34	III+	3.23	58.64	31.95	9.41	Sandy loam
	33-79.5	79.5-79.6	0.68	1.98	9.10	II	1.42	82.71	14.24	3.04	Loamy sand
	33-91.8	91.8-91.9	1.39	1.42	16.41	II	2.72	55.65	33.83	10.53	Sandy loam
	33-93.9	93.9-94.0	2.51	1.55	15.05	II	5.63	67.18	19.67	13.16	Sandy loam
	33-95.6	95.6-95.65	1.46	1.78	25.39	III	1.61	54.66	32.69	12.65	Sandy loam
	33-98.4	98.35-98.45	2.11	1.76	28.69	III	0.15	48.91	27.97	23.12	Sandy clay loam/loam
	33-98.8	98.8-98.9	1.40	1.77	6.21	II	2.87	57.85	32.50	9.65	Sandy loam
	33-99.6	99.55-99.7	1.38	1.77	27.94	III	1.45	61.99	24.80	13.21	Sandy loam
	33-113.0	113.0-113.15	1.92	1.49	49.16	III+	0.54	33.69	37.78	28.54	Clay loam

[a]Hygroscopic moisture is "moisture held in the soil that is in equilibrium with that in the atmosphere to which the soil is exposed" (American Geological Institute definition).
[b]Bulk density was determined by the paraffin-clod method (buoyancy method for volume determination).
[c]Total % calcium carbonate ($CaCO_3$) (of the <2-mm fraction).
[d]Estimated carbonate (CO_3) stage (refer to Appendix A). "hi gr" is high gravel content (>50%).
[e]The percent gravel is the % >2 mm (percentage of the entire sample that is >2 mm).
[f]The percent sand, silt, and clay are on a gravel-free basis (<2-mm fraction). Size ranges for gravel, sand, silt, and clay are: gravel >2.0 mm; sand 0.05-2.0 mm; silt 0.002-0.05 mm; and clay <0.002 mm.

Table C-2. LaboratoryAnalytical Results for Stable Isotopes.

Large negatives for the $\delta^{18}O$ values in this appendix indicate mainly winter precipitation from which the Cascades have stripped out the heavy water.

The $\delta^{13}C$ values in this appendix indicate a significant portion of C_4+CAM plants—estimated at an (80-60)/(20-40) mix of C_3/(C_4+CAM) mix. C_3 plants include trees, most shrubs and herbs, and cool-season grasses. C_4 plants are adapted to high light and water-stressed conditions, and include *Atriplex* (saltbush) and warm-season grasses. All cacti are CAM.

All told, these isotopic values do not indicate that the climate during the time of formation of these paleosols was greatly different from the climate of the Pasco Basin today.

DH-#	Sample ID	Interval (ft)	$\delta^{13}C$ (PDB)	$\delta^{18}O$ (PDB)	% $CaCO_3$
11	11-157.1	157.1	-5.9	-14.2	45
12	12-128.4	128.4	-5.4	-14.5	55
24	24-84.6	84.6-84.7	-5.6	-13.5	66
25	25-90.7	90.7	-6.6	-13.9	32

APPENDIX D

DESCRIPTIONS AND INTERPRETATIONS OF DRILL CORE THIN SECTIONS

APPENDIX D
DESCRIPTIONS AND INTERPRETATIONS OF DRILL CORE THIN SECTIONS

200 WEST AREA

DH–12 (299–W14–7)

Sample **12–128** (collected from the interval 127.9–128.1 ft which was macroscopically interpreted as a Bkq or Bkqm horizon) contains disjunct pieces of $CaCO_3$ laminae indicating that the material composing this interval was transported, or disaggregated due to exhumation, followed by recementation. An indicator of transport, however, is a mineral grain that has truncated $CaCO_3$ laminae on two sides (Figure E-9). The matrix is micritic indicating a pedogenic origin for the $CaCO_3$. Some circular or oblate micritic forms have oriented clay bands within and around them; also some mineral grains have thin, bright clay rims. Oriented clay suggests a pedogenic origin. Opaline silica fills or lines some pores or interstices. Volcanic glass shards may provide the material for the opaline silica; few, weathered vesicular shards were noted in the thin section. Several areas are impregnated with Mn or Fe(?) suggesting reduced (anoxic) conditions (Bullock et al. 1985).

Sample **12–128.4** (collected from the interval 128.4–128.5 ft which was macroscopically interpreted as a Bk(q?)m horizon) is an advanced calcrete. Well-developed laminae of spar and micrite form circular or arcuate patterns (Figure E-11). The matrix consists of $CaCO_3$ pelloids, or small circular forms, and ooids (ooliths) made up of micrite or fine-grained spar with spar filling the interstices (Figure E-10). Micrite encircles grains and grain aggregates. Clay bands around micritic forms (ooids) and mineral grains that are surrounded by micrite appear neoformed (formed in place, rather than translocated). A few micrite-rimmed, ovoid forms contain opaline silica. Neoformed clay and spar indicate that this interval formed in place during a long period of time (perhaps up to a few million years based on modern analogs, Gile et al. 1996) in which feldspars had a chance to weather and form clay, and micritic $CaCO_3$ and later, spar slowly accumulated.

DH–7 (299–W19–10)

Sample **7–161** (collected from the interval 161.0–161.2 ft which was macroscopically interpreted as a Bwk horizon) contains broken up pieces of relatively small and discontinuous $CaCO_3$ laminae (former petrocalcic horizon) indicating that this material was likely redeposited. But there is not much $CaCO_3$ in this thin section. The grain size is fine. Oriented clay surrounding grains suggests clay formed pedogenically. Silt-sized particles form a band that crosses the section (parallel to the long axis); cross-bedding indicates that the band is a sedimentary layer. This interval may have experienced little soil development in place; pedogenically formed constituents may have been redeposited in this layer. Alternatively, constituents could have been disaggregated or brecciated due to exhumation. Areas of Mn or Fe(?) impregnation suggest reduced conditions sometime after material was redeposited.

Sample **7–161.2** (collected from the interval 161.2–161.4 ft which was macroscopically interpreted as a Bk or Bkm horizon) also contains disjunct pieces of three laminae in layers indicating that this constituent was redeposited from elsewhere. Another indicator of redeposition is differing amounts of $CaCO_3$ coating grains—some grains have thick coats, and some have thin coats. Clay coating grains appears oriented, indicating translocation. More detailed analysis using a scanning electron microscope could reveal syntaxial structure (clay radiating into pore spaces) indicating that the clay precipitated in place, and has an *in situ*, rather than translocated, pedogenic origin (Wilson and Pittman 1977, Monger and Daugherty 1991a). Opaline silica and $CaCO_3$ are the main cementing agents for this interval; some silica was noted infilling the inner part of a pore (the outer part was $CaCO_3$). Highly weathered, vesicular volcanic glass shards may be the source of the opaline silica. Laminar $CaCO_3$ and oriented clay indicate a pedogenic origin for this interval, but how much of the pedogenesis occurred in place or elsewhere is indeterminate. Ooliths surrounded by concentric clay rings suggest a greater degree of carbonate stage development than is macroscopically indicated (Gile et al. 1996). Areas of Mn or Fe(?) impregnation suggest reduced (redoximorphic) conditions, possibly later than carbonate development (Bullock et al. 1985).

DH–11 (299–W15–14)

Samples **11–156.7** and **11–157.6** (collected from 156.7–156.8 ft and 157.6–157.7 ft, respectively, which was macroscopically interpreted as a Bkm horizon of Paleosol #1) have a fine-grained micritic matrix with $CaCO_3$ laminae. Few grains have thin clay coats; clay was also observed in a few places conforming to the linear fabric of the matrix and in another associated with a void. The linear fabric of the $CaCO_3$ matrix supports the macroscopic interpretation of a stage IV morphology; ooliths suggest an even greater degree of carbonate stage development (V) (Gile et al. 1996). The micrite matrix (or K-fabric) is typical of modern calcretes containing separated silicate grains that appear to "float" in the micrite matrix. Needle-fiber calcite suggests soil microbial precipitation (Jones and Kahle 1993, Verrecchia and Verrecchia 1994). The dark brownish/black substance that impregnates the micrite matrix appears to be Mn or Fe(?), but electron microprobe analysis is needed to confirm the interpretation.

Sample **11–158.4** (collected from the interval 158.4–158.6 ft which was macroscopically interpreted as a B/Bk horizon of Paleosol #1) is fairly fine-grained overall and mineral rich, containing many weathered grains. $CaCO_3$, where present, fills interstices and rarely encircles grains. A laminar $CaCO_3$ pendant floating in the matrix indicates redeposition or reworking. Clay thinly coats some grains, but may be mostly dispersed in the matrix giving secondary $CaCO_3$ a brownish color. (Opaline silica is another substance that could impart a brownish color.) Some areas have more clay which supports the idea that this is a "mixed" horizon. Clay coatings on silicate grains are evidence that this interval may have been a Bt horizon that was engulfed by pedogenic carbonate.

Sample **11–160.3** (collected from the interval 160.3–160.45 ft which was macroscopically interpreted as a B/Bk(qm) horizon of Paleosol #2) is fairly coarse-grained overall. Few disjunct pieces of $CaCO_3$ laminae indicate that this material was likely redeposited or reworked. Grains also are encircled with $CaCO_3$ laminae; laminae appear preferentially coated to one side of grains, arguing against transport for this material. $CaCO_3$ in some voids has a drusy texture—also noted in hand specimen—supports $CaCO_3$ formation in place. Opaline silica partially infills narrow long pores; some weathered, vesicular, volcanic-glass shards may be the source. The combination of redeposited or reworked material and features that probably formed in place supports the idea that this is a "mixed" horizon.

Sample **11–161.2** (collected from the interval 161.2–162.2 ft which was macroscopically interpreted as a B/Bkqm horizon of Paleosol #2) contains grains and grain aggregates (peds?) encircled with micrite. Concentric rings of micrite are discernible in some coatings indicating addition of $CaCO_3$ in multiple layers over a period of time. Interstices, pore linings, and some laminar layers are spar indicating that the $CaCO_3$ in this portion took a long time to form. Thin (oriented) clay coatings are the innermost layer surrounding a few grains; there are also broad bands of (unoriented) clay around many grains and (unoriented) clay dispersed in the matrix. Opaline silica infills a couple of ovoids, lines some pores, and surrounds one grain; few weathered, vesicular volcanic-glass shards may be the source. The combination of matrix clay and sparry laminae lend credence to the classification as a "mixed" horizon. A Bt horizon that was engulfed by pedogenic carbonate is another possibility based on the features observed in this thin section.

Sample **11–162.1** (collected from the interval 162.1–162.2 ft which was macroscopically interpreted as a Bkq(m?) horizon of Paleosol #2) has a micritic matrix, and is fine-grained overall. Three grains have multiple laminae of $CaCO_3$ on one side; the other side has either no $CaCO_3$ laminae, or laminae are thinner. Such configurations and the presence of $CaCO_3$ laminae unattached to grains suggest that these grains are redeposited or reworked. Both oriented and unoriented clay fills grain interstices in some areas. One piece of opaline silica was observed; again, weathered glass shards are the likely source.

Samples **11–162.6** and **11–163.1** (collected from 162.6–162.7 ft and 163.1–163.2 ft, respectively, which was macroscopically interpreted as a Bkqm horizon of Paleosol #3) have micritic $CaCO_3$ encircling grain or grain aggregates. These ooliths (or ooids) suggest a greater degree of carbonate stage development than is macroscopically indicated (Gile et al. 1996). Fine-grained spar fills interstices or lines pores. Continuous $CaCO_3$ laminae can be observed throughout the upper of the two samples (Sample 11–162.6); also a couple of pieces of $CaCO_3$ laminae are floating free in the matrix. Again, chunks of $CaCO_3$ laminae unattached to grains suggest (1) reworking or redeposition, or (2) recementation following disaggregation caused by exhumation. Both unoriented and oriented clay (interpreted as authigenic and translocated, respectively) are present in these samples. Unoriented clay is a weathering product within larger grains or as separate pieces. Oriented clay, probably the result of illuviation during pedogenesis, fills interstices of grains or lines pores or voids. Opaline silica in the upper sample (11–162.6) forms a band under a micrite layer (sample is oriented as to "up" direction), and lines or fills pores or fracture/void openings. Weathered, vesicular glass shards (in both samples) are the likely source for the opaline silica.

Sample **11–164.7** (collected from the interval 164.7–164.8 ft which was macroscopically interpreted as a Bkqm horizon of Paleosol #4) has a micrite and fine-grained spar matrix. The fine-grained spar appears secondary to micrite (precipitated after) because the spar fills interstices (around micrite) and lines pores. There is coarse-grained spar in two laminar layers—one much coarser than the other; the coarser of the two appears to fill a longitudinal void or pore or fracture, as there is still some open space. One void has needle-like growths of $CaCO_3$ in it which is indicative of biogenic processes (Jones and Kahle 1993, Verrecchia and Verrecchia 1994). Few grains have clay bands; many weathered grains have clay associated with them—either as grain coats or particulate clay nearby. Opaline silica is associated with the sparry pore infilling; weathered, vesicular glass shards are the probable source. The opaline silica is probably opal CT based on its similarity to silica deposits in Nevada for which there is XRD data (Monger and Adams 1996).

Sample **11–166.2** (collected from the interval 166.2–166.3 ft which was macroscopically interpreted as a Bkq horizon of Paleosol #4) has micrite encircling many grains and grain aggregates. Somewhat coarser or less dense micrite(?)—not very birefringent—fills interstices. Clay bands around a few grains are thin and bright, and appear oriented. The grain argillans may represent an engulfed Bt horizon, or may have formed in an allogenic Bt horizon. Diffuse clay coating grains and in interstices appears unoriented. Opaline silica lines pores and fills irregularly shaped voids. Many weathered, vesicular glass shards probably provided the silica.

Sample **11–168** (collected at 168 ft which was macroscopically interpreted as a B/Bk horizon of Paleosol #5) is clearly divided between $CaCO_3$ and non-$CaCO_3$ portions. $CaCO_3$ portions are porous micrite or fine-grained spar. These zones are mostly devoid of mineral grains; of the grains present, fewer have clay bands and bands are thinner on those that do. Non-$CaCO_3$ portions have thick clay bands encircling many grains and grain aggregates (ped argillans), which are typical of many modern Bt horizons. Clay encircling grains mostly appears oriented. There is a lot of clay in the matrix. Few weathered, vesicular glass shards were observed.

Sample **11–169.4** (collected from the interval 169.4–169.5 ft which was macroscopically interpreted as Ringold Formation that has been either diagenetically or pedogenically affected) has thick clay bands coating mineral grains (oriented) and filling interstices (unoriented). Fine-grained spar appears to fill channels or tubules or pores between zones with clay. These patterns suggest carbonate engulfment of a Bt horizon. One large pore or void is filled with mostly micrite and some fine-grained spar; micrite coats or encircles mineral grains (all of which are small and not clay-coated), and fine-grained spar fills interstices. The clay and $CaCO_3$ portions appear segregated. Highly weathered (nearly to clay), vesicular glass shards were noted. Opaline silica forms a scalloped texture on edges of $CaCO_3$.

DH–6 (299–W11–26)

Sample **6–113.6** (collected from the interval 113.6–113.8 ft which was macroscopically interpreted as a Bkqm horizon of Paleosol #2) has a micrite and fine-grained spar matrix. In general, micrite coats grains, and fine-grained spar fills interstices. Ooliths (ooids) suggest a greater degree of carbonate stage development than is macroscopically indicated. Pores and voids are lined with fine-grained spar. Oriented clay encircles some grains and lines some pores or voids; different generations (rings) are sometimes visible within the grain coatings. One grain with a thick $CaCO_3$ coating on only one side may indicate redeposition. In one zone, impure opaline silica(?) was observed lining a void; few, weathered vesicular volcanic-glass shards may provide a source for the silica. Mn or Fe(?) impregnation may indicate a period of reduced (redoximorphic) conditions, subsequent to carbonate development, that may have been caused by groundwater inundation or perched vadose water (Bullock et al. 1985).

Sample **6–121** (collected from the interval 121.0–121.2 ft which was macroscopically interpreted as a Bkqm horizon of Paleosol #3) is similar to Sample 6–113.6 in that grains are encircled by clay and $CaCO_3$, but there is more $CaCO_3$ in this section. Concentric clay rings in ooids are common features of modern well-developed calcretes (Gile et al. 1996), and suggest a greater degree of carbonate stage development than is macroscopically indicated. In some cases, bands of clay and $CaCO_3$ alternate, but clay-coated and $CaCO_3$-coated grains are usually segregated in different portions of the slide; where clay and $CaCO_3$ both encircle the grain, clay is usually the inner coating. In general, micrite encircles grains and grain aggregates, and the matrix is fine-grained spar. Some voids exhibit a drusy texture. Neoformed palygorskite clay (Figures E-1 and E-2) indicates weathering in place for a long time period (Frye et al. 1974, Monger and Daugherty 1991a). Opaline silica forms concentric rings around voids/pores and bands partially surrounding aggregates, and infills one broad zone. Few, weathered vesicular glass shards (with micritic bands surrounding them) are the probable source for the silica.

Sample **6–124** (collected from the interval 124.0–124.1 ft which was macroscopically interpreted as a Bkqm horizon of Paleosol #4) again, is similar to Samples 6–113.6 and 6–121 in that grains are encircled by $CaCO_3$ and clay. As does Sample 6–121, this section contains more $CaCO_3$ than Sample 113.6. There are zones of more coarsely crystalline $CaCO_3$ (spar or fine-grained spar) within rings encircling grains and within laminar layers. The matrix is mostly micrite, but some zones have $CaCO_3$ laminae in layers that extend through the thin section. As in Sample 6–121, some voids exhibit a drusy texture. Clay is present in several forms: (1) encircling some grains; (2) forming peds(?); (3) incorporated with the micrite in laminae; or (4) as laminae in a void, in combination with micritic laminae. Most clay appears oriented (translocated), or possibly was neoformed as the result of pressure solution (force-of-crystallization) of the silicate grains (Maliva and Siever 1988, Monger and Daugherty 1991b). Opaline silica is associated with voids: at grain edges or linear voids (Figures E-3 and E-4) or filling possible root casts (Figures E-5 and E-6). Vesicular glass shards are the likely source of the silica.

WESTERN PERIMETER OF 200 WEST AREA

DH–24 (699–43–84)

Sample **24–78.5** (collected from the interval 78.5–78.65 ft which was macroscopically interpreted as either a B/Bk horizon or simply a non-pedogenic mixture of massive $CaCO_3$ and $CaCO_3$-free sands and pebbles) has two distinct zones: one with a $CaCO_3$ matrix and one without. The non-$CaCO_3$ portion of the slide is finer grained than the portion that has a $CaCO_3$ matrix. Pieces of $CaCO_3$ matrix material, however, are found in the non-$CaCO_3$ portion. The matrix of the $CaCO_3$ portion is impure micritic $CaCO_3$; laminae are both micritic and fine-grained sparry $CaCO_3$. Thin clay bands surround some of the smaller grains. Both the differing orientations of $CaCO_3$ lamina from grain to grain, and disjunct pieces of $CaCO_3$ laminae suggest that some of the constituents are reworked or redeposited.

Sample **24–84.2** (collected from the interval 84.2–84.3 ft which was macroscopically interpreted as either a B/Bk(q)m horizon or a non-pedogenic mixture of massive $CaCO_3$ and $CaCO_3$-free sands and pebbles) has a mostly micritic matrix with some interstitial and void-filling spar and some sparry laminae. Ooids suggest a greater degree of carbonate stage development than is macroscopically indicated (Gile et al. 1996). In sparry zones, grains are coated with micrite. There are many micritic ovoids which may be void or pore infillings—in several cases, void space is still present; in these, grains do not generally have micritic coatings. But in one, grains have clay coatings which appear translocated, and one interstitial zone had clay that was probably authigenic. Micritic infillings may also be fragments of calcrete. A couple of coatings appear to have opaline silica incorporated opposite or adjacent to the $CaCO_3$; opaline silica is also inter-layered with spar.

Sample **24–84.7** (collected from the interval 84.7–84.9 ft which was macroscopically interpreted as either a Bkm horizon or a non-pedogenic massive $CaCO_3$) can be thought of as consisting of three different zones. The upper zone in this oriented slide has grains surrounded by thin coatings of spar or fine-grained spar. The matrix consists of micrite, fine-grained spar and spar that form weak laminae. Micrite surrounds some small grains and/or forms small blebs near the base of this zone. A void separates the upper zone from the middle zone. The middle zone is entirely micritic except the base which is defined by a layer of spar. Weak laminae are defined in micrite by different shades of micrite and mineral segregations. Many grains have clay bands—some of which are thin and bright which may be relicts of a Bt horizon, others are thicker, more diffuse and browner which are interpreted as neoformed or authigenic. The lower zone is bounded by a thick layer of spar at the top; the spar is devoid of mineral grains but has pieces of micrite which contain mineral grains within it. Below the spar layer, the $CaCO_3$ is broken up and consists of chunks of micrite surrounded by thin layers of spar or fine-grained spar. A few of the mineral grains within the micrite have clay encircling them. Opaline silica occurs as prominent bands or layers, and forms an interstitial network in this zone.

Sample **24–86.5** (collected from the interval 86.5–86.6 ft which was macroscopically interpreted as either a Bkm horizon or a non-pedogenic massive $CaCO_3$) has a micritic matrix. Presence of root structures, however, strongly suggests pedogenic $CaCO_3$. Some parts of the gray micritic matrix appear browner which is attributed to clay. Voids have sparry infillings and needle-fiber calcite (Figure E-14); needle-fiber calcite indicates soil microbial precipitation (Jones and Kahle 1993, Verrecchia and Verrecchia 1994). Some pores appear to be lined with opaline silica (Figures E-15 and E-16); where the silica forms a circular shape, the structure is similar to that of tree or plant cellulose—little circles are stuck together, forming two to three concentric rings around the void/pore, called honeycomb structure. These are similar to root structures in calcretes of Nevada, which are opal-A based on XRD analysis (Monger and Adams 1996).

DH–25 (699–40–84)

Sample **25–85.2** (collected from the interval 85.15–85.3 ft which was macroscopically interpreted as a B/Bk(m) horizon or a mixture of massive and laminar $CaCO_3$, and $CaCO_3$-free sands and pebbles) has a micritic matrix. Micritic, fine-grained spar, and sparry $CaCO_3$ are preferentially laminated on the bottoms of large clasts in this oriented slide; tops generally have thin micritic coatings, if any coating is discernible. Micromorphology supports the macroscopic interpretation of a stage IV carbonate. Few grains have thin, authigenic clay bands. Opaline silica was observed: (1) as a worm-like form aligned with a sparry void-infilling; (2) adjacent to a sparry convoluted lamina; (3) rimming a pore or void; and (4) on the top of a pebble in a void space. An oriented clay band was observed on top of a large micritic $CaCO_3$ piece that has grains within it (one of which has a clay coat).

Sample **25–88.4** (collected from the interval 88.4–88.5 ft which was macroscopically interpreted as a B/Bk(m) horizon or a mixture of massive $CaCO_3$ and $CaCO_3$-free sands and pebbles) is predominantly micrite with spar and fine-grained spar in the interstices. The upper part of this oriented slide appears to have more spar and less micrite than below. This would indicate plugging of the horizon with $CaCO_3$ accumulating from the top down. Once the horizon is plugged, $CaCO_3$ will form more slowly and thus larger crystals will form as $CaCO_3$ translocates into the horizon. The section contains many weathered grains and few weathered, vesicular glass shards. Some grains have oriented clay bands and oriented clay is present in the matrix, lining the edge of a pore (Figure E-17); this combined with the optical extinction pattern indicates that the clay is illuvial. Opaline silica forms a band within a micrite and clay band and under a sparry layer, and was also observed lining a pore.

Sample **25–90.8** (collected from the interval 90.8–90.9 ft which was macroscopically interpreted as a B/Bk(q?)m horizon or a non-pedogenic mixture of cemented $CaCO_3$ and opaline silica(?) and $CaCO_3$-free sands and pebbles) has clay coating most grains and lining pores (Figure E-18). Thin clay coatings appear authigenic; extinction occurs at the same time for the entire clay band. But thick clay bands on grains and lining pores appear to exhibit the wavy extinction typical of translocated clay. The matrix also contains micrite which coats some grains or fills interstices. Spar discontinuously coats the innermost edges of pores (Figure E-18) except one in which opaline silica is the innermost material.

DH–21 (699–37–84)

Sample **21–86** (collected from the interval 85.9–86.2 ft which was macroscopically interpreted as a Bk horizon) consists of large grains with micritic and fine-grained sparry $CaCO_3$ laminae that are not continuous and are not consistently oriented from grain to grain. Also, disjunct pieces of $CaCO_3$ laminae are present. These findings indicate that some of the constituents are reworked or redeposited, but of pedogenic origin. One grain has micrite on one side and fine-grained spar on the other, possibly indicating two or more episodes of formation. The matrix is impure micrite that has a greenish-brown tinge (clay?). Thin clay bands surround some of the smaller grains.

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APPENDIX E

PHOTOMICROGRAPHS OF DRILL CORE THIN SECTIONS

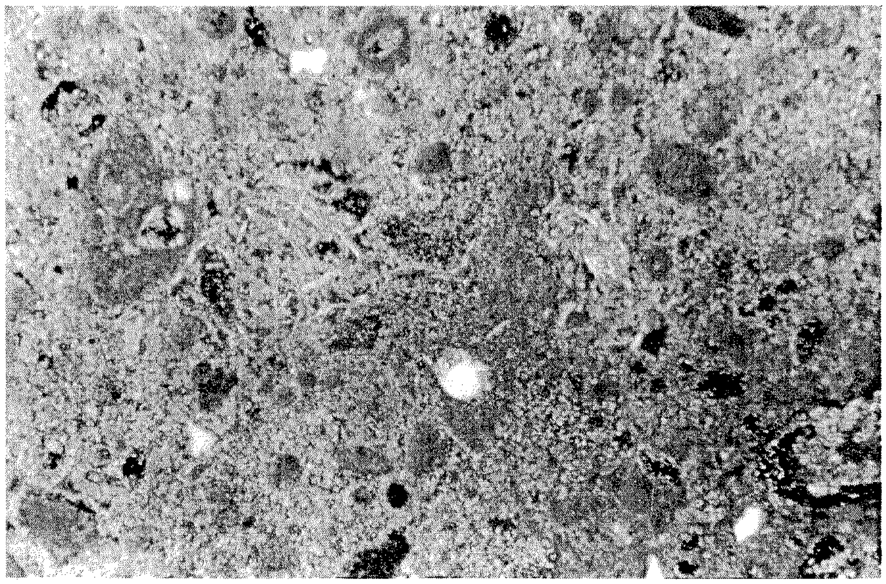
HANFORD PHOTOMICROGRAPH LOG

Interpreted by: Janet L. Slate

Figure No.	Core (DH-)	Depth (ft)	Magnification[a]	X = x-nicols PL = plane light	Description
E-1	6	121	5x	X	Two clusters of neoformed palygorskite
E-2	6	121	10x	X	Neoformed palygorskite (note cluster in lower right center)
E-3	6	124	2.5x	X	Linear void with Si(?) (at ends) and Fe-oxide(?) dendrite in center
E-4	6	124	2.5x	PL	Ditto
E-5	6	124	10x	X	Si(?) encircling micrite ovoid or filling root cast; lower = void(?) at grain boundary
E-6	6	124	10x	PL	Ditto
E-7	11	162.1	5x	X	Bright, undulating clay band; oriented clay radiates away from one grain; dark brown = Fe-oxide(?) adjacent to clay band at bottom left center; micrite on either side of clay band
E-8	12	128	1.5x	X	Root channel/pore(?) filled with spar
E-9	12	128	1.5x	X	Micrite and spar laminated pendant attached to roughly circular, mostly fine-grained spar infilling
E-10	12	128.4	5x	PL	Matrix made up of circular micritic forms (some with clay rims); interstices are fine-grained spar
E-11	12	128.4	2.5x	X	Arcuate bands of spar and micrite
E-12	24	84.7	10x	X	Bands of Si(?) infilling void ("middle-zone")
E-13	24	84.7	10x	PL	Ditto
E-14	24	86.5	10x	X	Needle-fiber calcite in void
E-15	24	86.5	10x	X	Si(?) lining pore
E-16	24	86.5	10x	PL	Ditto. (note honeycomb structure)
E-17	25	88.4	2.5x	X	Clay lining void appears oriented ("up" direction is toward the bottom of the frame)
E-18	25	90.8	2.5x	X	Spar on one side of pore/void and clay on the other
E-19	33	93.9	10x	X	Glass shard in center; clay matrix; Si(?) lining pore immediately above shard ("up" direction is toward the bottom of the frame)
E-20	33	93.9	10x	PL	Ditto
E-21	33	93.9	10x	X	Dark brown/black = Fe-oxide(?) partially lining pore
E-22	33	96	2.5x	X	Si(?) filling pore with fine-grained spar at edges and micritic matrix ("up" direction is toward the bottom of the frame)
E-23	33	96	2.5x	PL	Ditto
E-24	33	98.4	10x	X	Needle-fiber calcite in void ("up" direction is to the right)

[a]Objective	35 mm photo (long dimension)
1.5x	5.93 mm
2.5x	3.56
5.0x	1.78
10x	0.88
20x	0.44
50x	0.18

Figure E-1



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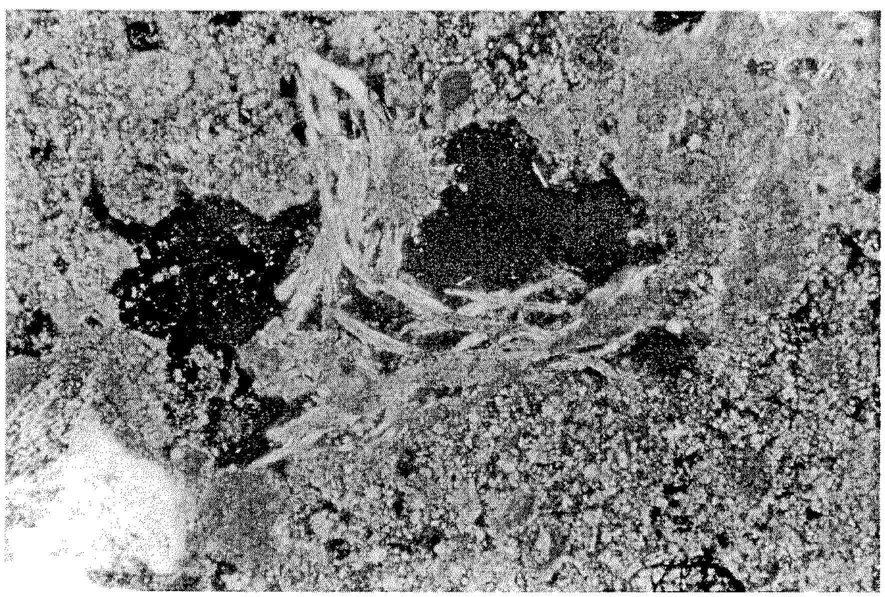

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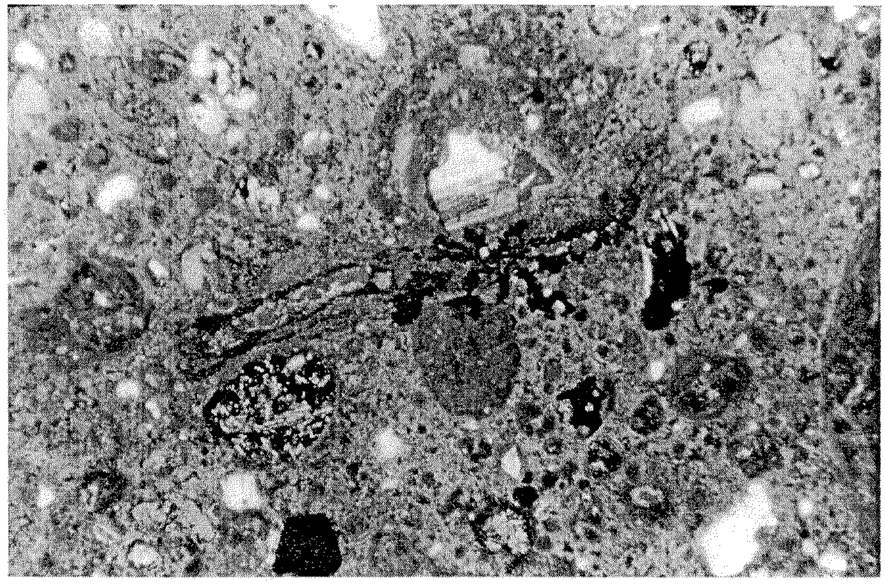

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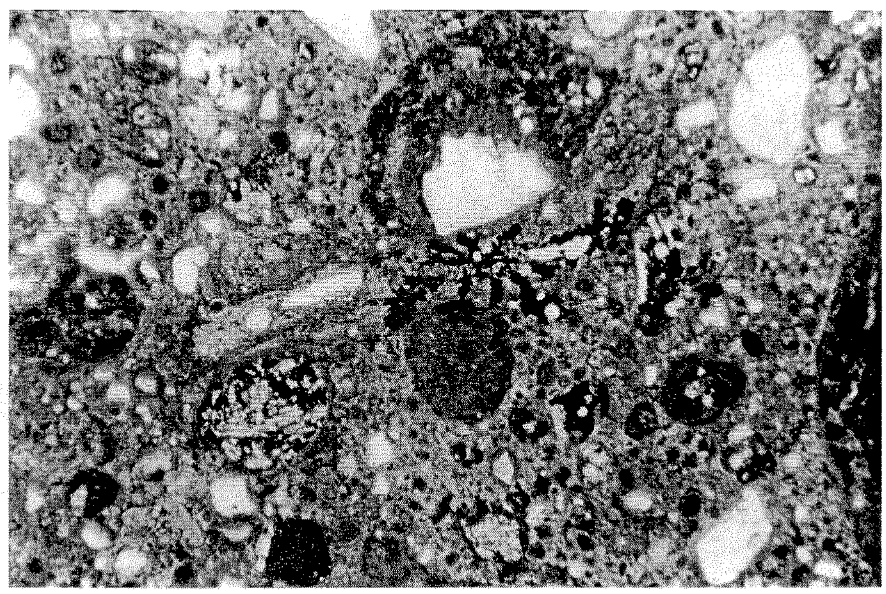

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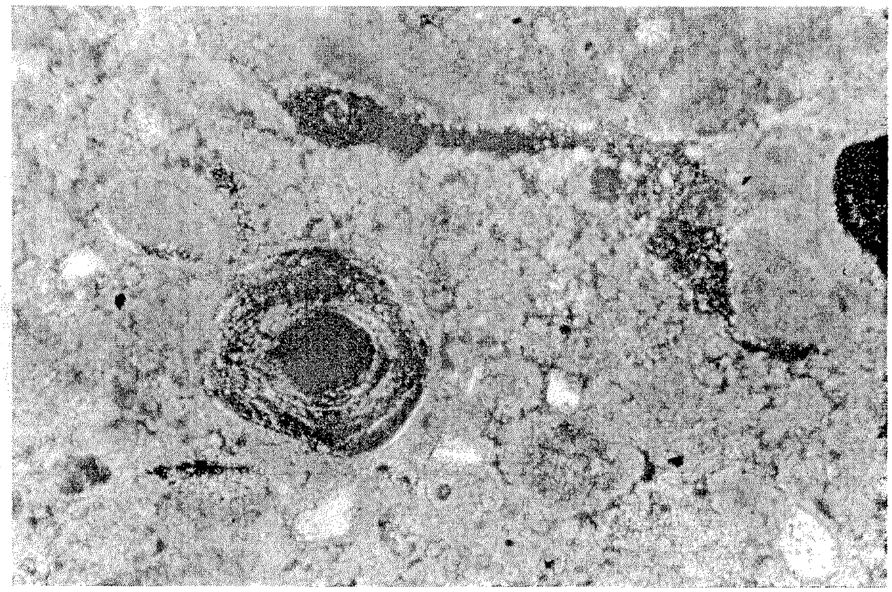

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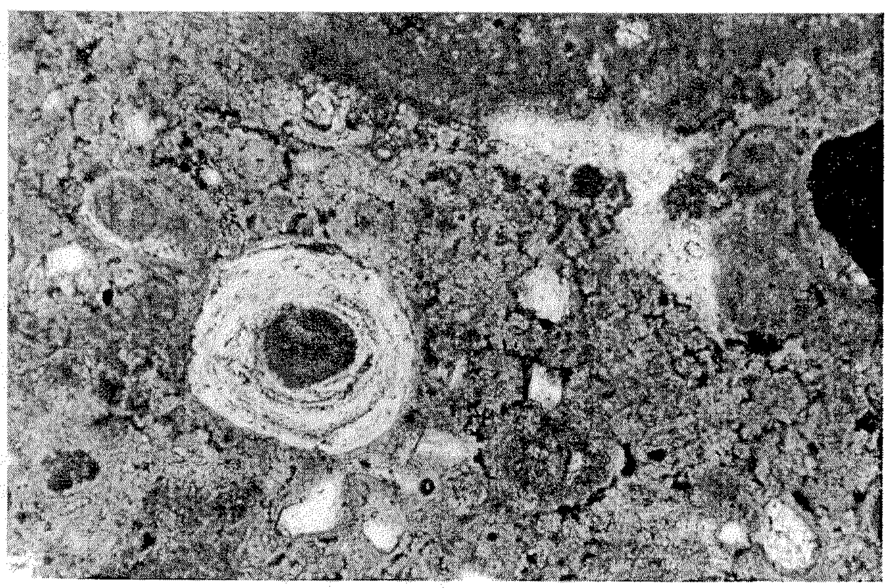


Figure E-7

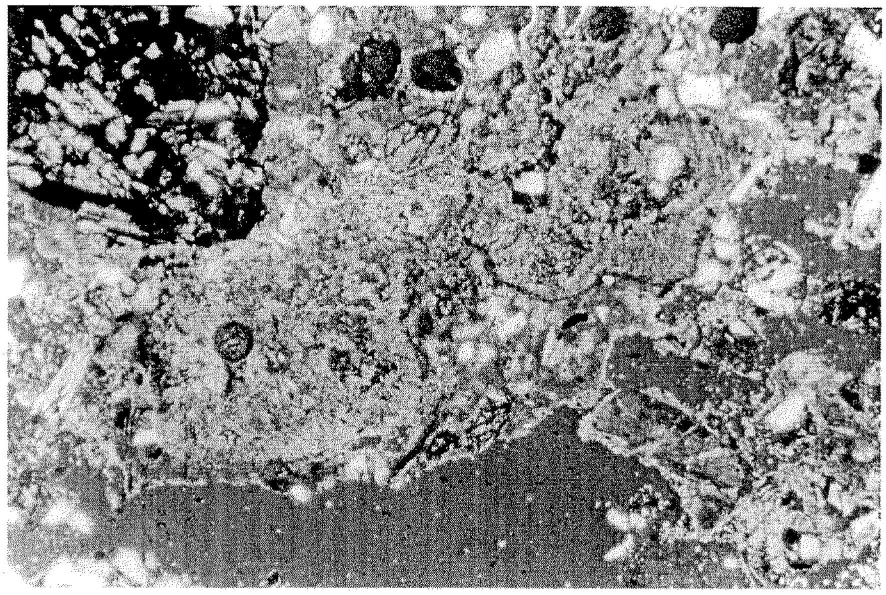


Figure E-8

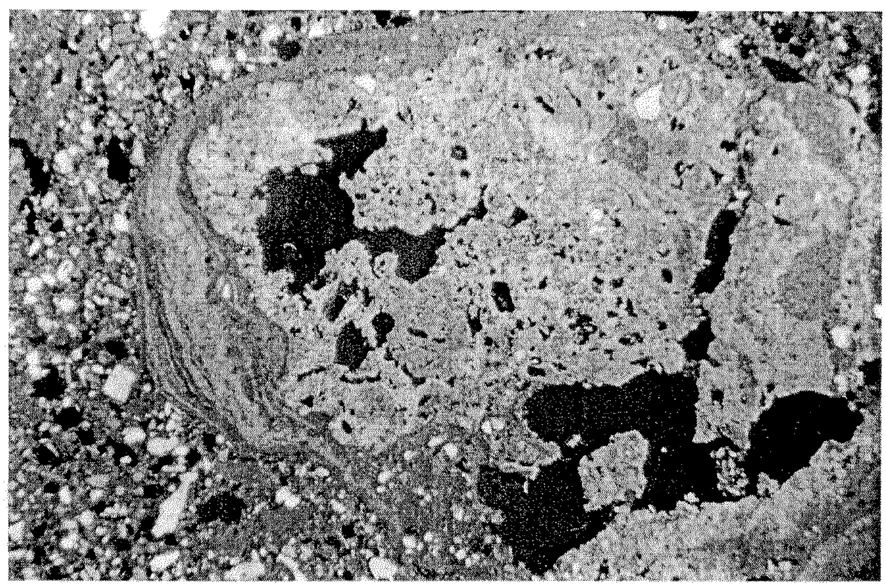


Figure E-9

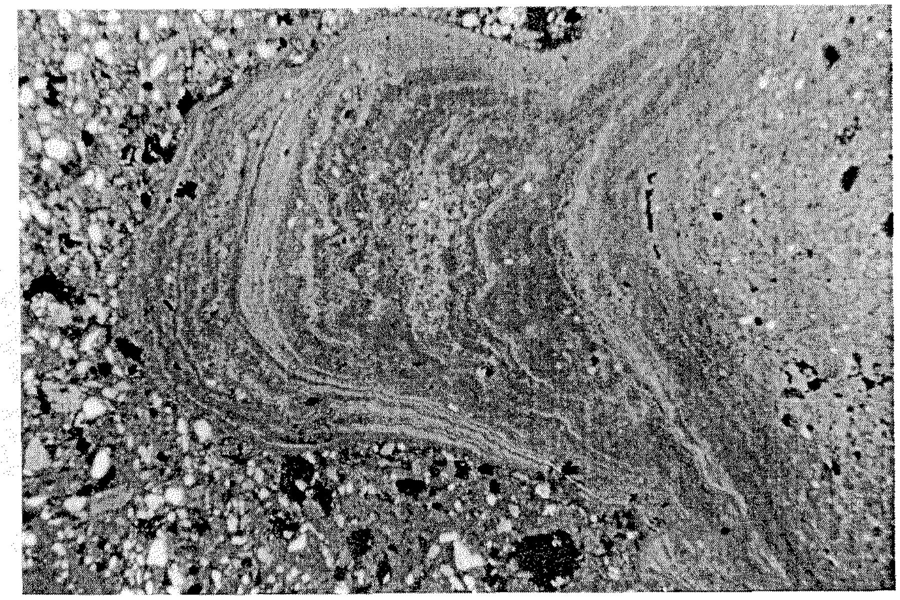


Figure E-10

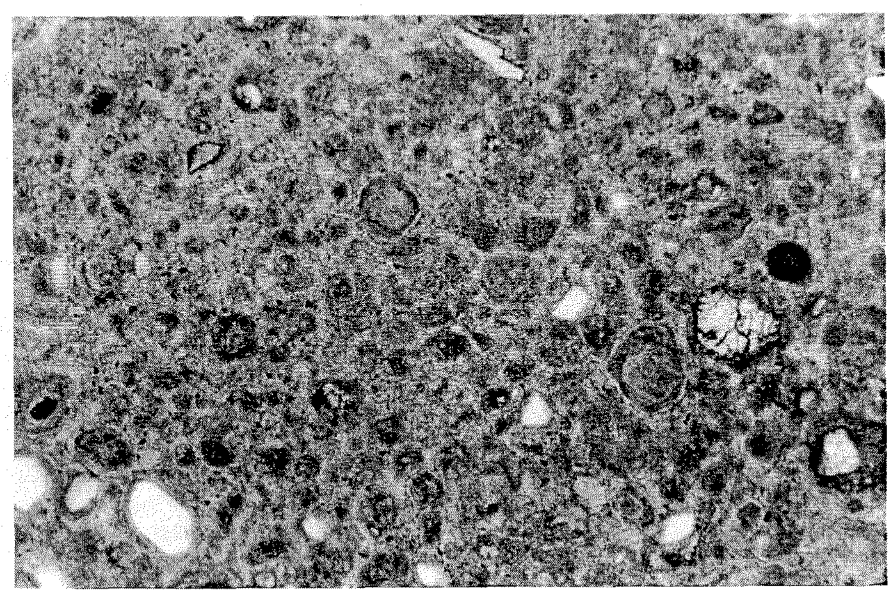
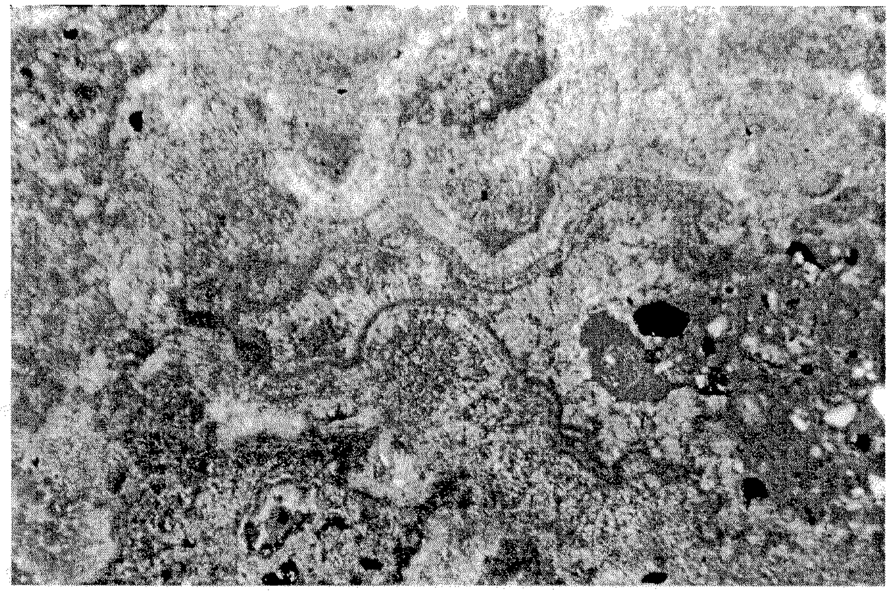


Figure E-11



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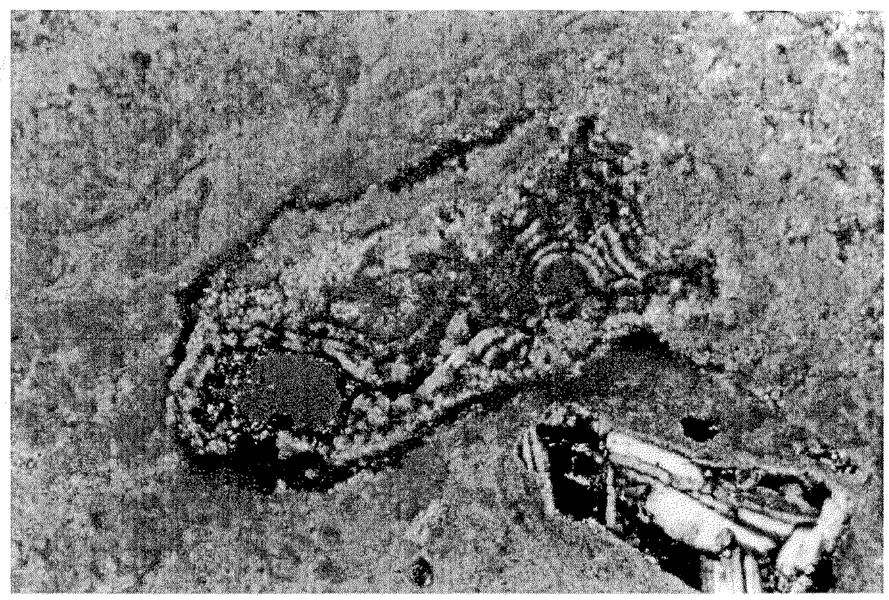

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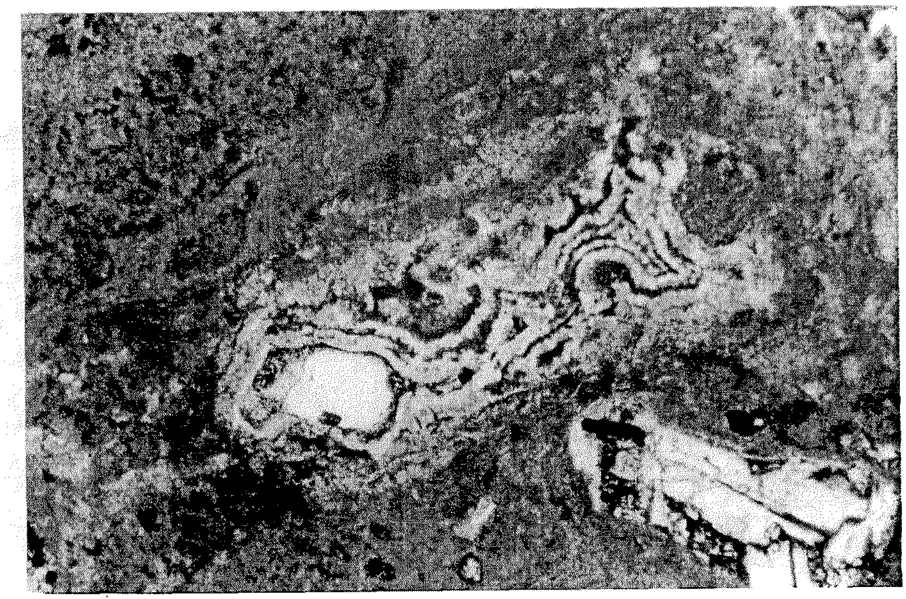

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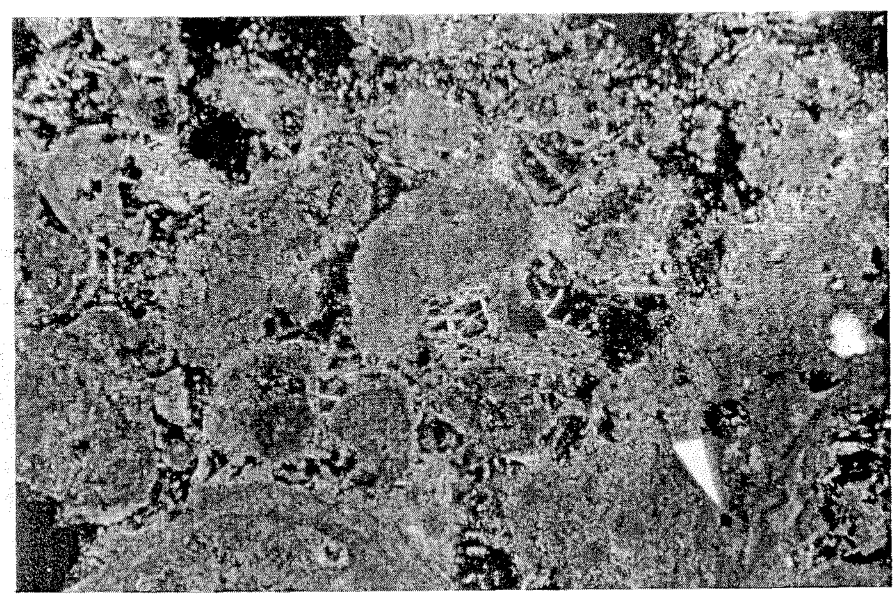

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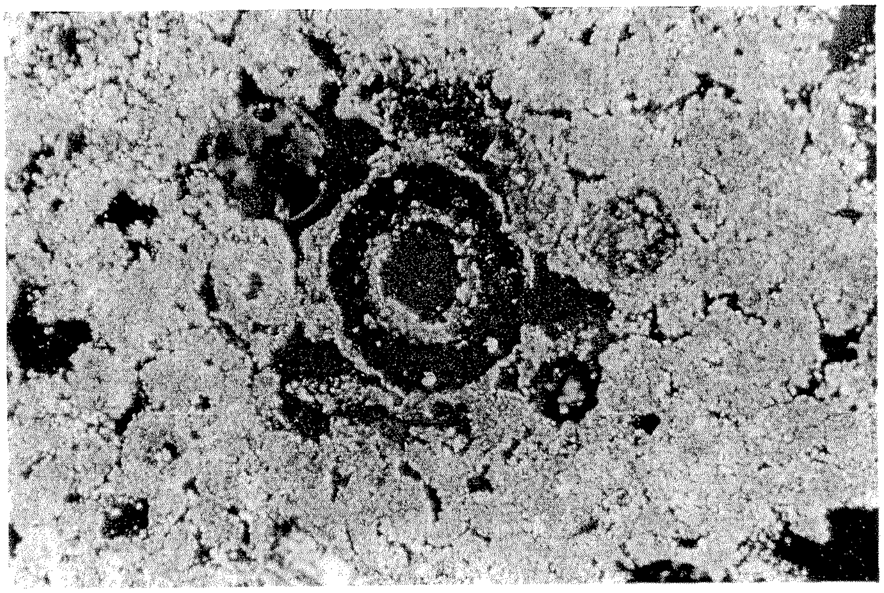

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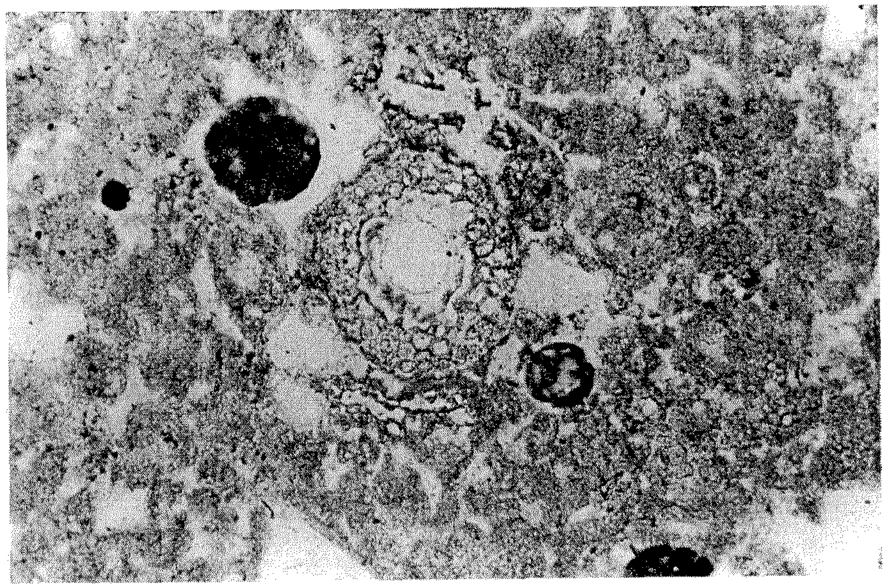

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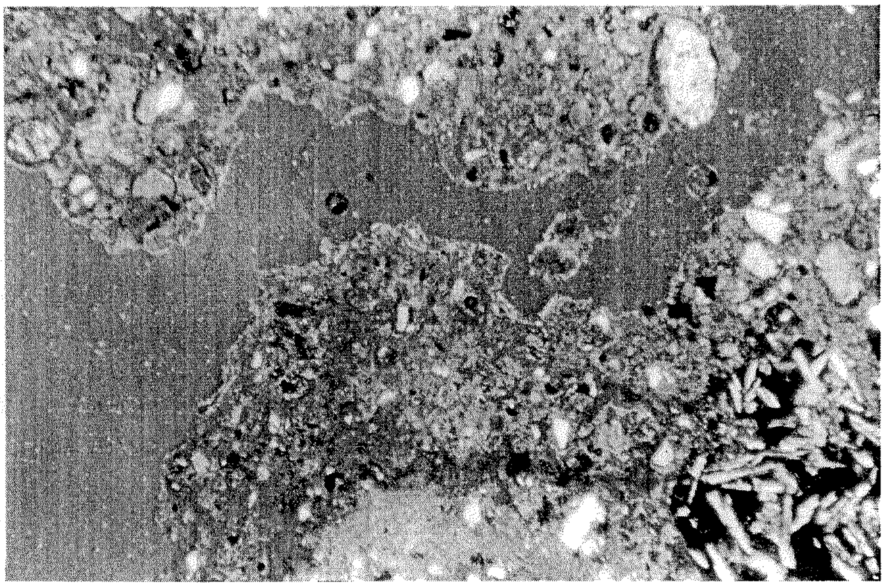

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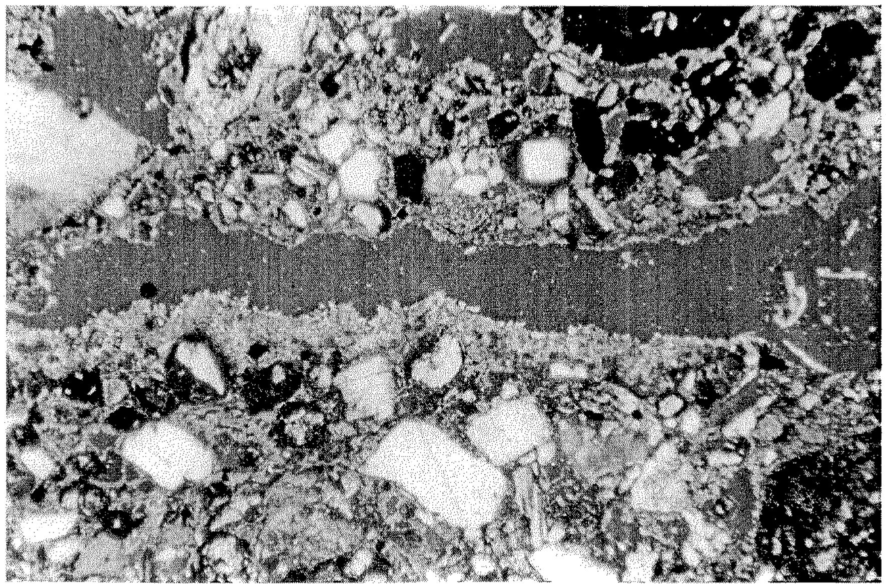

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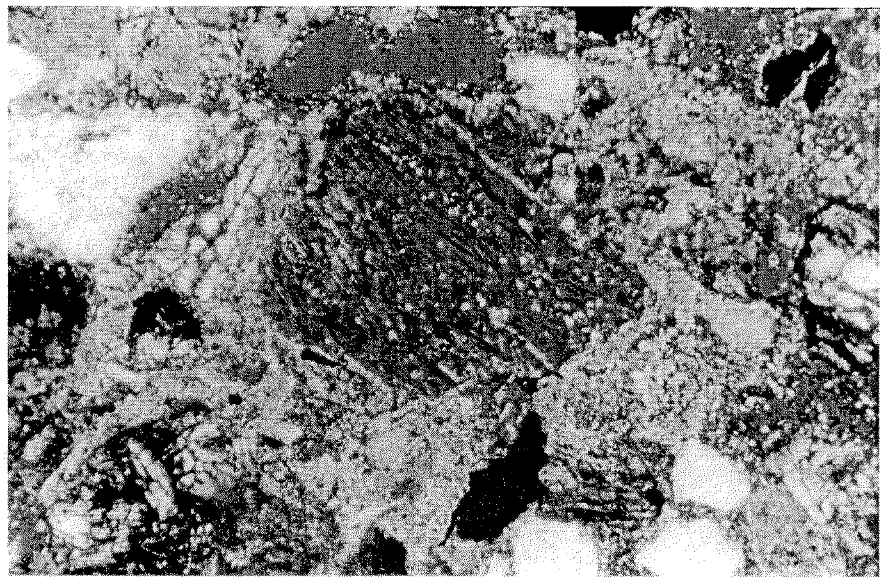
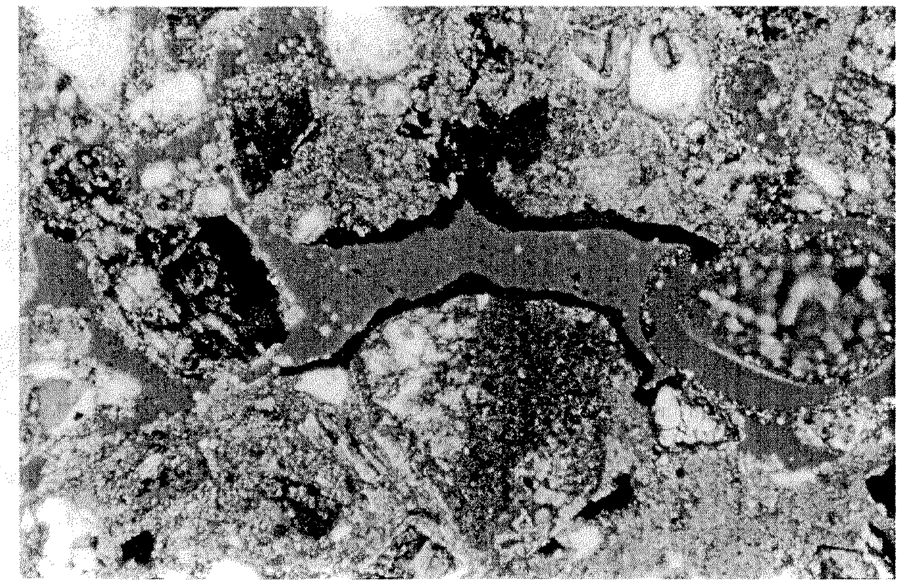


Figure E-20

Figure E-21



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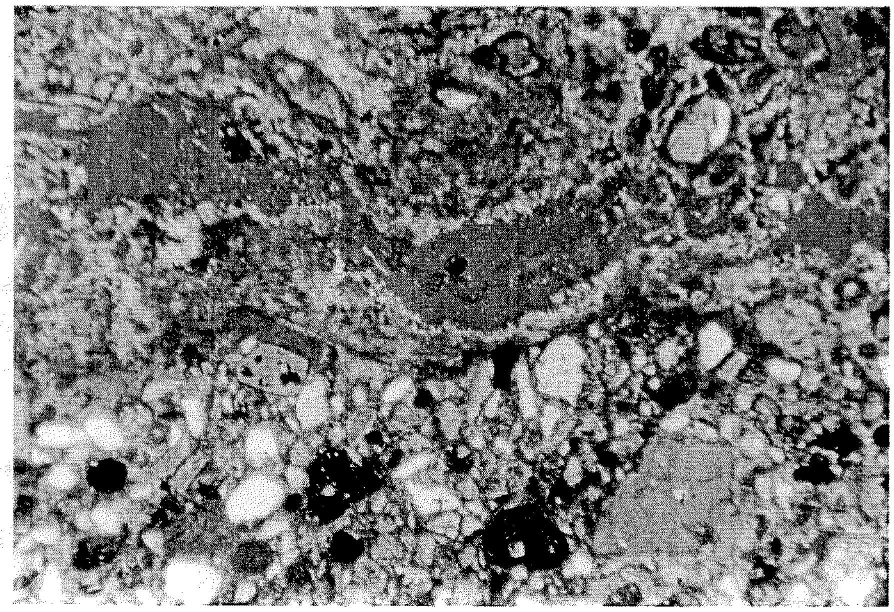

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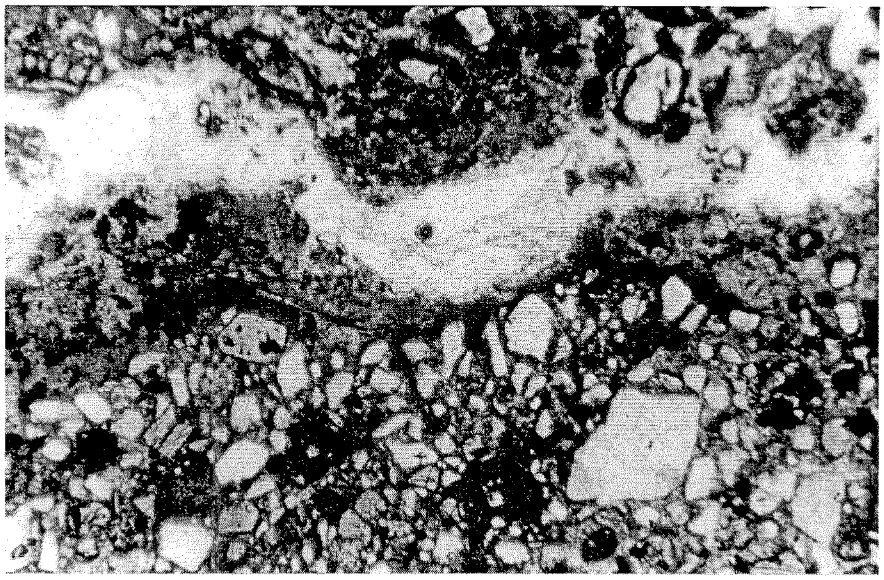

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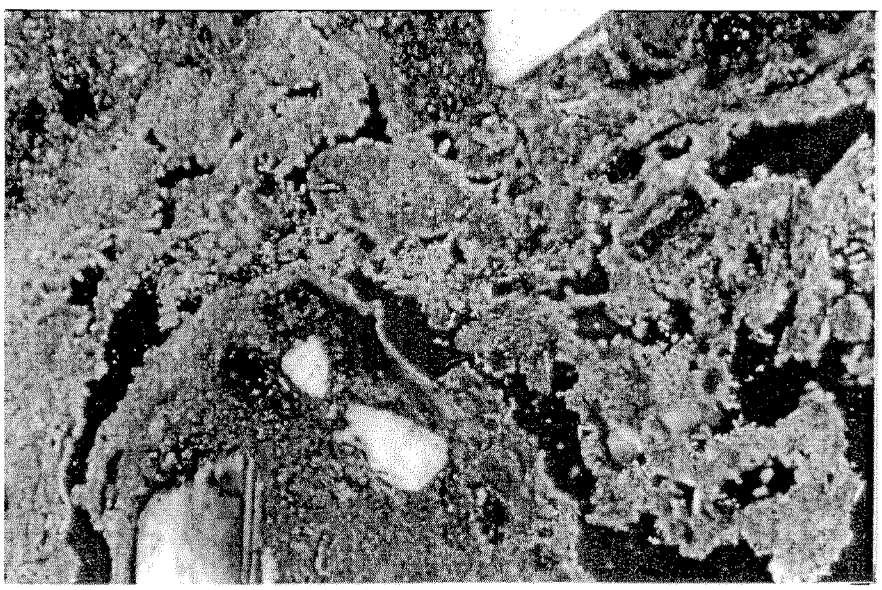

APPENDIX F

ELEVATIONS AND THICKNESSES OF PALEOSOL/CARBONATE LAYERS

Appendix F – Elevations and Thicknesses of Paleosol/Carbonate Layers

Core ID	Ground Surface Elevation	Top of Recovered Core Depth Elevation	Base of Hanford Formation Depth Elevation	Base PP = Top of Ringold Depth Elevation	Plio-Pleist Thickness Total (T) or Minimum (M)	Number of Carbonate Layers or Paleosols	1st Paleosol/carbonate Basal Depth Elevation	1st Paleosol/carbonate Thickness Pedogenic (P) or Groundwater (GW)	2nd Paleosol/carbonate Basal Depth Elevation	2nd Paleosol/carbonate Thickness Pedogenic (P) or Groundwater (GW)	3rd Paleosol/carbonate Basal Depth Elevation	3rd Paleosol/carbonate Thickness Pedogenic (P) or Groundwater (GW)	4th Paleosol/carbonate Basal Depth Elevation	4th Paleosol/carbonate Thickness Pedogenic (P) or Groundwater (GW)	5th Paleosol/carbonate Basal Depth Elevation	5th Paleosol/carbonate Thickness Pedogenic (P) or Groundwater (GW)
NW: W-E																
DH-27 699-50-99	791.9	15.5 776.4	207 584.9	221.5 570.4	14.5 T	1	220.5 571.4	2 GW/III								
DH-28 699-50-96	798.3	100 698.3	227?	227 571.3	None?	1 (in Hnfrd)	173.9 624.4	0.9 GW/III								
W. perim: N-S																
DH-23 699-46-85	784.2	124 660.2	177(TD) 607.2	not cored	unknown											
DH-24 699-43-84	632.4	78 554.4	not pres >554.4	98 534.4	20 M	2	79.5 552.9	1.5+ GW/II-III	86.9 545.5	3.5 GW/III						
DH-25 699-40-84	638.2	84 554.2	not pres >554.2	91.3 546.9	7.3 M	4 (1 on Rngd)	88 550.2	3.4 P/II-III	90 548.2	2 P/III	90.3 547.9	0.3 GW/III	91.3 546.9	0.7 GW/II		
DH-21 699-37-84	633.7	78 555.7	85.2 548.5	101.7 532	16.5 T	2	91.5 542.2	6.3 P or GW; I-II	101.7 532	0.2 P/I; core missing above & below this interval						
WSW: W-E																
DH-33 699-34-98	710	64.2 645.8	99.9? 610.1	126 584	26.1 M	5 3-4 in Tcht	78.8 631.2	3.55 P/I-II	92.9 617.1	1.7 P or GW; I-II	96.2 613.8	1.9 P or GW; I-II	99.9 610.1	2.1 P or GW; I-II	114 596	1.5 GW or P; III
DH-22 699-37-92	643.4	55 588.4	not pres >588.4	121 522.4	66 M	5+	62.6 580.8	7.6 P/I-II; 1.8 msng	65 578.4	2.4 P/I-II	66.8 576.6	1.8 P/I-II	69.3 574.1	2.5 P/III	74.5 568.9	5.2 P/I-II
SSW: N-S																
DH-20 699-29-83	621.8	68.5 553.3	73.5? 548.3	113 508.8	39.5 M	0-2 (in Hnfrd)	73 548.8	3? P/I; 1.1 pres	76 545.8	2.5 P/I						
DH-26 699-26-83A	635.3	53 582.3	70 565.3	95.5 539.8	25.5 T	3	70.9 564.4	0.9 P/II-III	75 560.3	1 P/II-III	76.7 558.6	0.3 P/II?				
200W: NS/WE																
DH-6 299-W11-26	693.6	90 603.6	113 580.6	130 563.6	17 T	5 (1 in Hnfd)	113 580.6	2.6 P/II	121 572.6	8 P/II-III	124 569.6	3 P/III	126.2 567.4	2.2 P/III	130 563.6	2.5 GW?/II-III
DH-11 299-W15-14	695.9	121 574.9	156.6 539.3	169 526.9	12.4 T	5	160 535.9	3.4 P/III	162.6 533.3	2.6 P/II-III	164.2 531.7	1.6 P/III	167.4 528.5	3.2 P/III	169 526.9	1.6 P/III
DH-12 299-W14-7	677.5	100 577.5	125 552.5	130 547.5	5 T	1	130 547.5	2.4 P/III	From 125-127.6 is either Early Palouse or subaerially modified Touchet beds.							
DH-7 299-W19-10	681.7	148 533.7	161 520.7	168 513.7	7 T	1	168 513.7	7 P/II-III								

NOTE: All datums are in feet.
Datums related to Plio-Pleistocene deposits in the BWIP cores. JL Slate, 6/29/93, updated 4/11/94, translated to PC file 9/3/99.

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