Hydrogeology of the Franklin County Landfill Site, Cache Valley, Idaho

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Abstract

The Franklin County, Idaho landfill is located on deltaic sediments deposited where the Bear River emptied into Pleistocene Lake Bonneville and its predecessors over the last few hundred thousand years. The sediments of the delta consist of fine-grained, lithic-rich sands, silts and clays deposited in distributary channel and mouth bar, wave-influenced shoreface, delta front and pro-delta bottom water settings.

The sands and muds are generally thinly bedded, and there are numerous lateral pinchouts and erosional surfaces within them. The prodelta deposits consists of interbedded, planar-laminated silt and clay. They resulted from alternating silt and clay transport and settleout. Delta front deposits are characterized by rippled fine sand and silt beds and interbedded sand, silt, and clay couplets that reveal an environment in which seasonal channelized spring floods were the primary mechanisms of sediment delivery. The delta front deposits also contain abundant dewatering structures suggesting rapid deposition and oscillation ripples indicating periodic wave-reworking. The distributary channel and mouth bar deposits have scoured bases and consist of planar and trough cross stratified sand containing current ripples, climbing ripples and planar lamination.

Careful measurement of exposed stratigraphic sections north of the Bear River near Riverdale reveal seven shallowing-upward cycles, representing both switching of delta lobes and climatically-controlled progradational-regressive cycles. This suggests that several lake cycles of Lake Bonneville, representing perhaps the last several hundred thousand years, may be represented. This is not consistent with past work, which suggests that only one lake cycle is present and that Bear River delta sediments in Cache Valley are entirely less than 30,000 years old.

The sands within the delta are rich in lithic fragments, including vitric rhyolitic

tuffs. These sand grains are in various stages of devitrification; the resulting zeolite minerals will act to adsorb cations from fluids that may percolate through the sands.

The permeability is generally low and water flow paths are contorted. Zones of most rapid transmission of water are located at the boundaries between interbedded clay and silt deposits and overlying sands. In outcrop these horizons are sometimes saturated. The muddy sediments are quite "tight" with respect to groundwater flow. Internal three-dimensional variations in hydraulic conductivity are complex.

The rate and distribution of groundwater flow vertically and horizontally through the deltaic sediments has yet to be quantitatively examined. The County and the contractor (MSE) have been unable to schedule the pump test we outlined in our initial grant request. The test is still planned but the date is beyond our control.

Introduction.

Project Specifications

This grant was submitted 12/15/95, for a project period of 6/1/95 to 5/31/96. Proposed deliverables included.

a) Description of geologic and hydrogeologic properties of the Quaternary Bonneville Formation.

b) Description of the geologic, hydrogeologic and geochemical properties of the local bedrock aquifer, the Miocene Cache Valley Formation

c) A several-day aquifer test, including a 48 hour pump test, to determine standard aquifer properties.

This report contains deliverable (a) and (b). The water quality testing and the pump test required for part of deliverable (b) and all of (c) have not been completed due to delays with Franklin County and MSE Engineering. The pump test has not yet been scheduled. When the test is scheduled we can produce the rest of the specified deliverables.

Regional Setting and Generalized Lake History

Northern Cache Valley is located in southeastern Idaho and is situated in the northern Basin and Range Province (Figure 1). It is bounded by the Portneuf Range to the north, the Bear River Range to the east, the Bannock and Malad Ranges to the west, and the Wellsville Mountains to the south. The bedrock within the surrounding ranges is Late Proterozoic to Mississippian in the age (Oriel and Platt, 1980; Link, 1982), and occupies the Paris thrust sheet of the Idaho-Wyoming thrust belt.

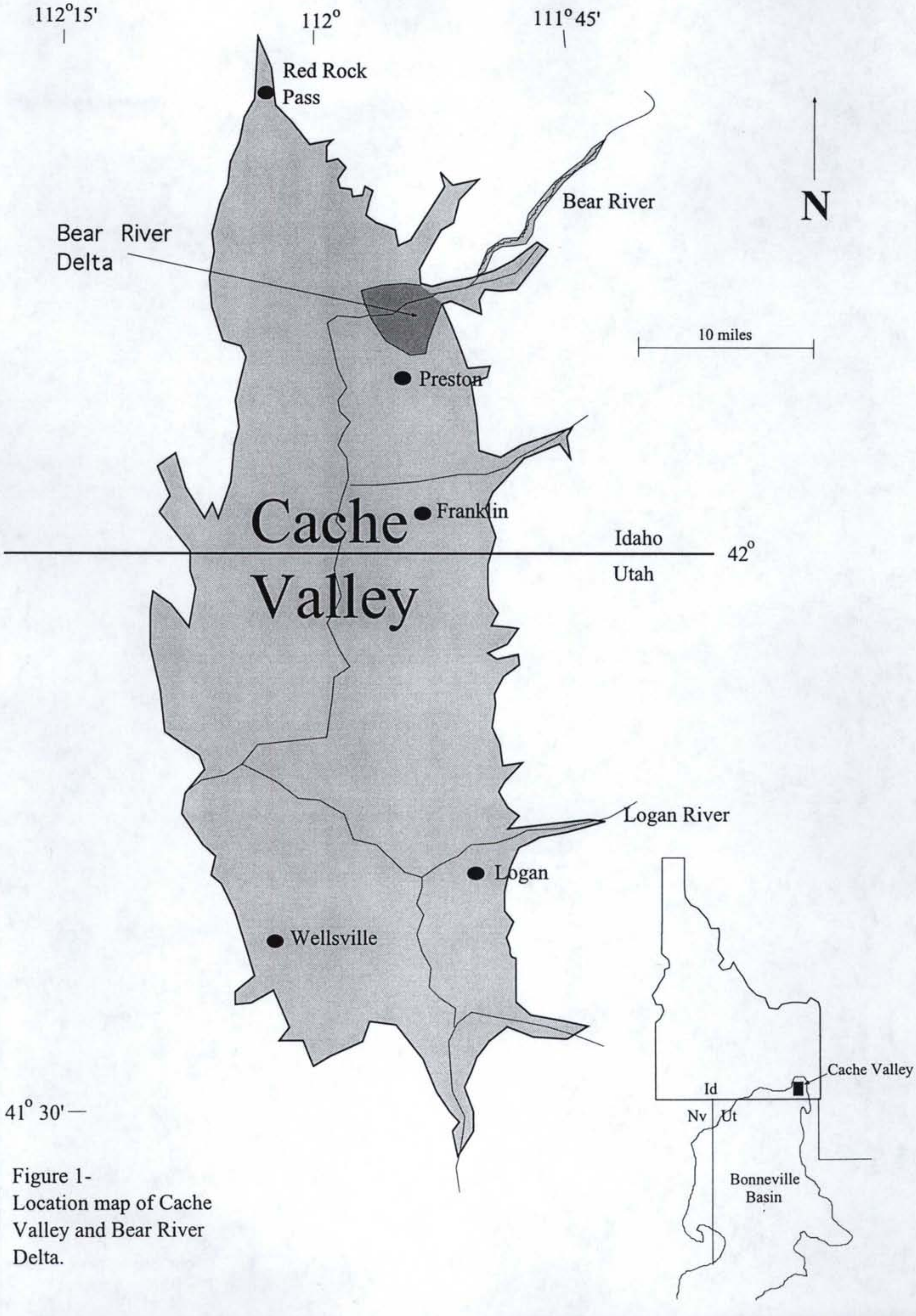


Figure 1-
Location map of Cache Valley and Bear River Delta.

The principal drainage within northern Cache Valley is the Bear River (Bright, 1963; Bjorkland and McGreevy, 1971; Mahoney and others, 1987; Link and others, 1987), which enters Cache Valley through the northeastern corner at Oneida Narrows, and exits through the southwest corner of southern Cache Valley at Bear River Narrows.

Northern Cache Valley formed as a result of Neogene extension, probably within the last 10 Ma. Extension was largely contemporaneous with rhyolitic volcanism occurring on the Snake River Plain (SRP) (Rodgers and others, 1990; Pierce and Morgan, 1992). Basin subsidence resulted in the accumulation of largely locally-derived sediments derived from rising horst block rocks. Later, in Pleistocene time, sediment derived more distant sources along the Bear River system began to fill the valley. In addition to deposition of sands and silts derived from Neoproterozoic through Mesozoic sediments of the Idaho-Wyoming thrust belt, rhyolitic and basaltic volcanic and volcaniclastic rocks of the Miocene and Pliocene Salt Lake Group and correlative units accumulated within the subsiding basins south of the Snake River Plain (Mansfield, 1927; Allmendinger, 1982; Sacks and Platt, 1985; Rodgers and others, 1990; Pierce and Morgan, 1992; Kellogg and others, 1994). In Cache Valley, the Salt Lake Group varies in thickness, from zero to a maximum of 3280 m (10,700 ft).

The Quaternary Bonneville Formation in Cache Valley rests unconformably upon tilted Neoproterozoic, Cambrian, and Neogene strata (Oriel and Platt, 1980). Bonneville sediments are over 152 m (500 ft) thick within northern Cache Valley (Bright, 1963). The Bonneville Formation was deposited within the Bonneville Basin, and consists of shoreline, deltaic, and other lacustrine facies of pluvial Lake Bonneville. (Scott and others, 1982; Oviatt and Currey, 1987; McCoy, 1987). As outlined below, our work suggests that lake sediments from previous pluvial lake cycles (at least back to the Little Valley cycle at about 150 ka, and perhaps the Pokes Point cycle at 200 ka) are present in the Bear River Delta (c.f. Bouchard et al, 1996).

Cache Valley makes up the northeastern arm of the Bonneville Basin (Figure 1). The Bonneville Basin was essentially closed from approximately 20 Ma to 14.5 ka (10,000,000 to 14,000 years ago) (Eardley et al., 1973; Williams, 1994). . All entering drainages terminated within the basin. Consequently, water escaped the basin only through evaporation and subsurface flow (Bright, 1963). Numerous lake cycles are represented in the main Bonneville basin and no doubt are also present in Cache Valley, though no specific deep drill holes have documented this history.

All of these lakes enlarged and contracted due to climatic fluctuations. The Bonneville Lake Cycle and the corresponding sediments (Bonneville Formation), are thought to represent only the last 150 ka. What is generally thought of as Bonneville

Formation contains deposits of at least two lake cycles: Little Valley (150-90 ka) and Bonneville (25-14.5 ka) (Scott and others, 1983). During the Bonneville Lake Cycle, the lake reached its highest elevation at 1551 m (5090 ft), covering an area of 51,530 km^2. Lake Bonneville overflowed at 14.5 ka at the Zenda Threshold (north of Red Rock Pass) (Malde, 1960; Scott and others, 1983) dropping the lake to an elevation of 1445 m (4740 ft) (Provo level). The lake dropped to its present Great Salt Lake level by 11.5 ka (Oviatt and others, 1992).

The balance involving inflow (precipitation; surface drainages) and outflow (evaporation; subsurface flow) resulted in numerous smaller-scale lake level fluctuations during the Little Valley and Lake Bonneville Cycles (Bright, 1963).

Unconformities between Lake Bonneville lake cycle and Provo lake cycle sediments mark the lake's regression from its highstand at 1551 m (5090 ft) to its elevation at the Provo level at 1445 m (4740 ft). An unconformity between Lake Provo deposits and younger fluvial deposits marks the lake's regression and a pronounced interval of incision and drop of base level from the Provo level to the current lake level of the Great Salt Lake (Oviatt and others, 1992). In the Preston area, unconformities exist between the fine-grained Lake Bonneville delta and those of the coarser-grained lake Provo delta, as well as between the Lake Provo delta deposits and the overlying fluvial deposits (Mahoney and others, 1987).

A large fine-grained delta system was deposited by the Bear River as it entered Lake Bonneville and Lake Provo, and contains the only Bonneville Formation sediments within northern Cache Valley (Bright, 1963). The delta is 9 miles long, extending southwest from Oneida Narrows and terminating just south of Clifton Hill (Little Mountain) (Mahoney and others, 1987; Link and others, 1987). The sands, silts, and clays are well exposed along the margins of the Bear River (Riverdale Cliffs) located approximately 4 miles north of Preston, Idaho and 4 miles southwest of Oneida Narrows (Figures 1 & 2). The Riverdale Cliffs expose ~152 m (500 ft) of the Bear River Delta. Based on well log data, a minimum of 84 m (275 ft) of the delta lies beneath the present position of the Bear River within the Riverdale Cliffs area.

Methodology

The majority of the data were collected from two localities within the study area. The first locality lies along the Riverdale Cliffs north of the Bear River approximately 4 miles northwest of Preston, Idaho (Figure 2). This is the locality described by Mahoney and others (1987). The deltaic sediments are best exposed in this location. The second site is the Franklin County landfill located approximately 8 miles southwest of Oneida Narrows and 4.5 miles north of the town of Preston (Figure 2). The majority of the landfill site is located on the SE 1/4 of section 6, T 15 S, R 40 E, and the remaining land is located on the SW 1/4 of section 5, T 15 S, R 40 E.

Stratigraphic sections were described at 8 natural exposures along the Riverdale Cliffs. Sections were measured in order to: 1. correlate the deltaic sediments in the Riverdale Cliffs with stratigraphic sections of deltaic sediments measured from borehole data from beneath the Franklin county landfill, 2. to characterize facies successions within and between the 8 stratigraphic sections to reveal fluctuating depositional environments, which in turn would provide information concerning the relative rise and fall of lake level within Lake Bonneville during the development of the Bear River Delta, and 3. characterize groundwater flow through the Bear River deltaic sediments by locating springs and saturated zones along the Riverdale Cliffs and beneath the Franklin County Landfill.

At four drilling locations within the Franklin County landfill site, subsurface samples of the Bear River deltaic deposits were collected at five foot sampling increments to depths between 300-340 ft. Sediment was collected from split spoon samples and drill cuttings. Split spoon samples represent 18 inches of a sampling interval, and drill cutting samples represent approximately 1-2 feet of a sampling interval. Additional subsurface samples of the Bear River Delta have been collected from 10 boreholes located within the Franklin County landfill site. Depths of these samples range from approximately 200-300 feet.

Deliverable A: Bonneville Formation

Stratigraphy

Stratigraphic section descriptions for eight locations along the Riverdale Cliffs are synthesized in Figure 3, and shown in detail in Figure 5). These reveal a fine-sand and mud-dominated deltaic system containing abrupt lateral and vertical facies changes. Figure 3 offers a simplified 109 meter composite stratigraphic section of the Bear River Delta. In general, the Bear River Delta contains facies representing four architectural elements: prodelta silts and clays, delta front sheet sands and silty sand and clay storm deposits, delta top channel-related silty sands, and shoreline beach gravels. The prodelta units are 1 to 7 meters thick, the delta front silty sand and clay units are 0.5 to 10 meters thick, and the silty sand delta top deposits are 0.5 to 23 meters thick.

The elevations and facies relationships of the eight stratigraphic sections measured from within the Riverdale Cliffs are shown in Figure 4. The sections begin as low as ~4558 ft and extend as high as ~4930 feet. Most units show abrupt vertical facies changes with a lesser number exhibiting a gradational change. Complete stratigraphic descriptions for the eight stratigraphic section measured within the Riverdale Cliffs are located in appendix 1.

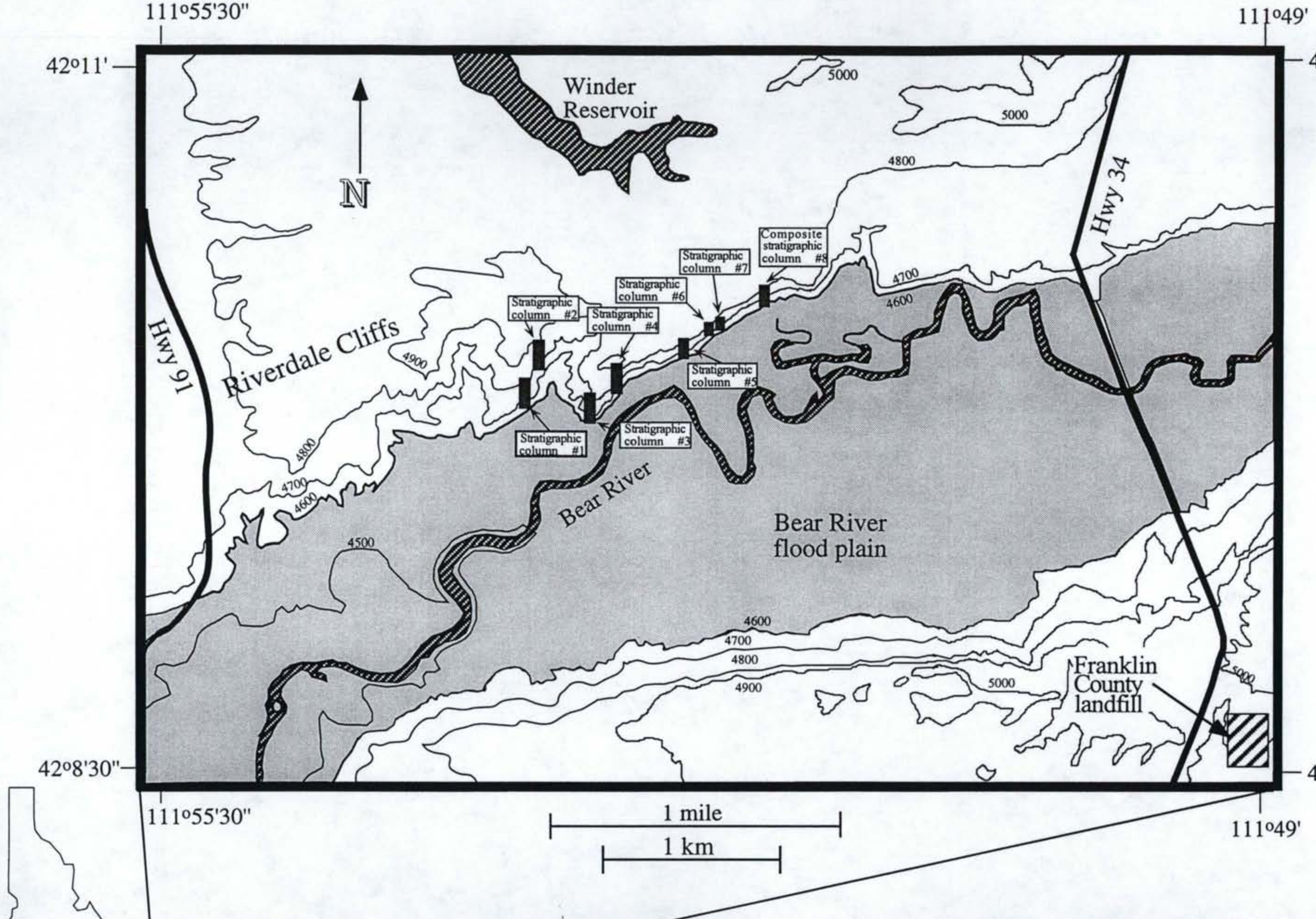
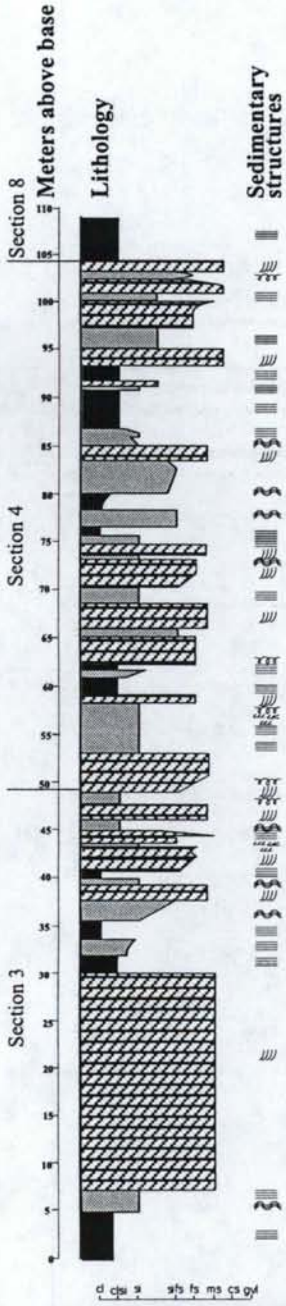


Figure 2 -
Location map of Franklin County landfill
and measured sections along Riverdale Cliffs.

Simplified Composite Stratigraphic Section



Unit number	Description	Interpretation
l	Laminated silt and clay.	Prodelta silts and clays
k	Cross-bedded, planar bedded, and structureless medium-to fine-grained sand alternating with Fine-grained sand, silt, and clay coupets and laminated silt and clay.	Distributary channel, bar finger sands, or mouth bar deposits alternating with delta front storm deposits.
j	Laminated silt and clay with climbing-rippled and cross-laminated fine-grained sand, silt, and clay couplets.	Prodelta silts and clays with either delta front storm deposits or turbidity current deposits.
i	Wave-rippled, current-rippled, and laminated fine-grained sand, silt, and clay couplets alternating with cross-bedded medium-to fine-grained sand.	Distributary channel, bar finger sands, or mouth bar deposits alternating with delta front storm deposits.
h	Alternating sand-silt-clay units with laminated clay and silt units.	Prodelta silts and clays with either delta front storm deposits or turbidity current deposits.
g	Cross-bedded, planar-bedded, climbing rippled, wave-rippled, and structureless medium-to fine-grained sand and silt alternating with fine-grained sand, silt, and clay couplets..	Distributary channel, bar finger sands, or mouth bar deposits alternating with delta front storm deposits.
f	Laminated silt and clay (structureless silt bed in center of unit).	Prodelta silts and clays.
e	Cross-bedded, planar-bedded, climbing rippled, and structureless medium-to fine-grained sand and silt interbedded with wave-rippled, cross-laminated, laminated, and structureless medium-to fine-grained sand, silt, and clay couplets interbedded with wave-rippled to structureless silt and clay.	Distributary channel, bar finger sands, or mouth bar deposits alternating with delta front storm deposits.
d	Fine-grained sand, silt, and clay couplets alternating with structureless to cross-bedded medium-to fine-grained sand and laminated silt and clay.	Distributary channel, bar finger sands, or mouth bar deposits alternating with delta front storm deposits and prodelta silts and clays.
c	Structureless and cross-bedded medium-to fine-grained sand.	Distributary channel, bar finger sands, or mouth bar deposits alternating with delta front storm deposits.
b	Fine-grained sand, silt, and clay couplets.	Delta front storm deposits.
a	Laminated clay with silt	Prodelta silts and clays.

Figure 3 -
Simplified composite stratigraphic section for the Bear River Delta. Sections 3, 4, and 8 were used for construction of the composite.

Bear River Delta Lithofacies

Lithofacies	Description	Interpretation
gm (gravel massive): Gravel; clast-supported.	No apparent internal structure. Contains tabular, subrounded clasts.	Beach or current deposit.
fsr (fine sand rippled): Fine-to medium-grained silty sand with cross-bedded to cross-laminated current ripples.	Planar and trough cross-stratified current (unidirectional) ripples (angular, parabolic, and sinusoidal). Occasional shrinkage cracks and soft sediment deformation.	Current influenced. Associated with distributary mouth bars, bar finger sands, and lake distributary channels.
fsl (Fine sand flat laminated): Fine-to medium-grained silty sand with even, continuous horizontal laminae and climbing-ripple laminae.	Curve and straight-crested climbing (~20 degrees)current ripples; both lee and stoss sides commonly preserved. Ocassional mud drapes, rip-up clasts, and soft sediment deformation.	Current influenced. Records transport along a sheetflood surface. Upper and lower flow regime.
fwr (fines wave rippled): Fine-to medium-grained silty sand and clay with wave-ripple lamination.	Symmetrical oscillation ripples with chevron interlaminae, and hummocky cross-stratification. Occasional soft sediment deformation.	Oscillating bottom currents caused by waves. Associated with reworked distributary channel, mouth bar, delta front, and prodelta deposits.
fg (fines graded): Even couplets of silty fine-to medium grained sand that grade from silt up to clay.	Normally graded sand-silt-clay sequences. Wavy-to-horizontal lamination. Cross and flat lamination common. Rare mud cracks and occasional soft sediment deformation.	Delta front storm deposits. Flood-generated sediment influxes that entered standing water.
fl (fines laminated): Planar-laminated silt and clay. Very fine-grained sand rare.	Even, sharply bounded variable mixtures of silt and clay interlaminations. Can be structureless. Occasional soft sediment deformation.	Prodelta or lacustrine deposits formed by silt and clay settleout in standing water.

Figure 4-
Lithofacies within the Bear River Delta.

Lithofacies

The following briefly describes the sedimentary attributes used to interpret the depositional environments and corresponding lithofacies classification of the Bear River Delta. Figure 4 lists the six lithofacies recognized within the Bear River Delta, and gives a description and interpretation of each.

Gravel massive (gm)

This lithofacies contains gravels that are clast supported, massive to crudely bedded, and tabular in shape. The lack of fines suggests a high amount of reworking and winnowing suggestive of a shoreline deposit, and the tabular-shaped clasts are indicative of shoreline reworking. This lithofacies is interpreted as probably a beach or shoreline deposit related to the Lake Provo cycle and formed during lowering of lake level following retreat from the Lake Bonneville shoreline.

Fine sand rippled (fsr)

This lithofacies consists of planar and trough cross-stratified current rippled fine-to medium-grained silty sand. When mud is present, mud drapes are rare and starved ripples (lenticular bedding) are common. Contacts vary from angular to tangential. Cosets range from 2 cm to ~4 meters thick, and sets range from 1 to ~30 cm thick. This lithofacies is interpreted as a current-influenced delta front or delta top deposit associated with distributary mouth bar, finger sand, and lake distributary deposits.

Fine sand flat laminated (fsl)

This sediment type is composed of fine- to medium-grained silty sand with even, continuous horizontal laminae interbedded with climbing ripple laminae. It is identical to the flat-laminated sediment type of the Mesoproterozoic Belt Supergroup defined by Winston (1986). The bases of the sands are sharp and commonly erosive. Rip-ups are common within the base of these units where they overlie silty mud units. The climbing ripples are curved and straight-crested, with both the lee and stoss sides commonly preserved, indicating high deposition rates. Mud drapes and soft sediment deformation are locally present within this lithofacies. This lithofacies is interpreted as being deposited in both upper and lower flow regimes, with the laminated sands representing upper flow regime and climbing ripples representing the upper-part of the lower flow regime. This shift in flow regime may be the result of a shallowing in water depth during deposition. The occurrence of this lithofacies may be the result of periodic high-magnitude storm-generated hydraulic currents. flows and/or floods.

Fines wave rippled (fwr)

This lithofacies consists of fine-to medium-grained silty sand and clay with wave-generated cross-lamination. Types of wave-ripple structures include oscillation ripples and hummocky cross-stratification. Oscillation ripples display chevron interlaminae. Soft sediment deformation is observed within this facies. This lithofacies is interpreted as reworked delta top and delta front sands, silts, and clays, formed within the upper or lower shoreface as the result of oscillating bottom currents caused by waves. Silty clay is the most represented grain size for this facies.

Fines graded (fg)

This lithofacies consists of normally graded sand-silt-clay sequences with wavy-to-horizontal lamination (even couplets of Winston, 1986). Cross-lamination within the sands is common. The silts are commonly structureless but are locally laminated. The clays are commonly laminated. Mud cracks are rare, and soft sediment deformation is observed within the lithofacies. The sands commonly have sharp bases against the underlying clays. Oscillation ripples are common within the silt and clay tops of the sequences. This lithofacies is interpreted as formed within the upper or lower shoreface of the delta front as the result of annual storm deposits. Floods forced sediment out of the distributary channels and into standing water.

Fines laminated (fl)

This lithofacies is composed of planar-laminated silts and clays with very small percentages very fine-grained sand. The silts and clays can be structureless or wave-rippled. Contacts within the lithofacies are even and sharply bounded. Soft sediment deformation is common where silts overlie sand beds. This lithofacies is interpreted to represent prodelta and lacustrine silt and clay, settling into standing water.

Hydrogeology

The locations of springs and large water-bearing zones within the deltaic sediments are shown in Figure 5. Figure 9 is a generalized geologic profile of the subsurface under the landfill, based on a 330 ft well (MW1).

Water bearing zones are located at the boundaries between interbedded clay and silt deposits and overlying distributary channel and mouth bar sands. This is due to the high permeabilities of the coarser-grained distributary channel and mouth bar sands overlying lower permeability, finer-grained prodelta silts and clays. Several landslides have originated at this high-to-low permeability boundary. The rate and three-dimensional distribution of groundwater flow vertically and horizontally through the deltaic sediments has yet to be determined.

Sedimentary Petrology

Grain mounts were made from sands sampled from stratigraphic sections 3 and 4 in order to find mineralogical trends present within the Bear River Delta. Point counts were performed on 6 of the 18 grain mounts. The most represented minerals within the deltaic sediments include undulose monocrystalline quartz and calcite spar. The calcite spar is assumed to have formed through diagenesis. Other minerals represented within the sands include polycrystalline quartz, monocrystalline quartz, potassium feldspar, and plagioclase feldspar. Lithics represented within the sand units include porphyritic volcanic lithics which include devitrified rhyolitic ash flow tuffs and mafic igneous rocks, siltstone, chert, mica, and heavy minerals (magnetite and possibly hematite).

Figure 6 shows QtFL and QmFLt ternary plots. All points lie within the recycled orogenic portion of the QtFL ternary plot and all but one point lies within the quartzose recycled portion of the QmFLt ternary plot. This agrees well with the assumption that the sands were derived from the quartzite-rich fold and thrust belt to the east.

Figure 6 also shows stratigraphic compositional trends for monocrystalline straight quartz, porphyritic volcanic lithics, monocrystalline undulose quartz, potassium feldspar, polycrystalline quartz, and siltstone. The latter three show no obvious systematic variation up section. Polycrystalline quartz shows a slight increase and potassium feldspar a slight decrease near the center of the deltaic sequence. More pronounced changes are observed within the monocrystalline quartz and volcanic lithic percentages. At approximately 1/3 the distance up from the base of the exposed delta, monocrystalline straight quartz and porphyritic volcanic lithic percentages show a pronounced increase, at the expense of monocrystalline undulose quartz. This is interpreted to represent an increase in contribution of basaltic fragments eroded from the Gem Valley area in comparison to the normal load of sedimentary rock fragments derived from the Idaho-Wyoming thrust belt. More data points need to be plotted, however, to establish more detailed trends within the Bear River deltaic sediments.

Stratigraphic Sections for Riverdale Cliffs

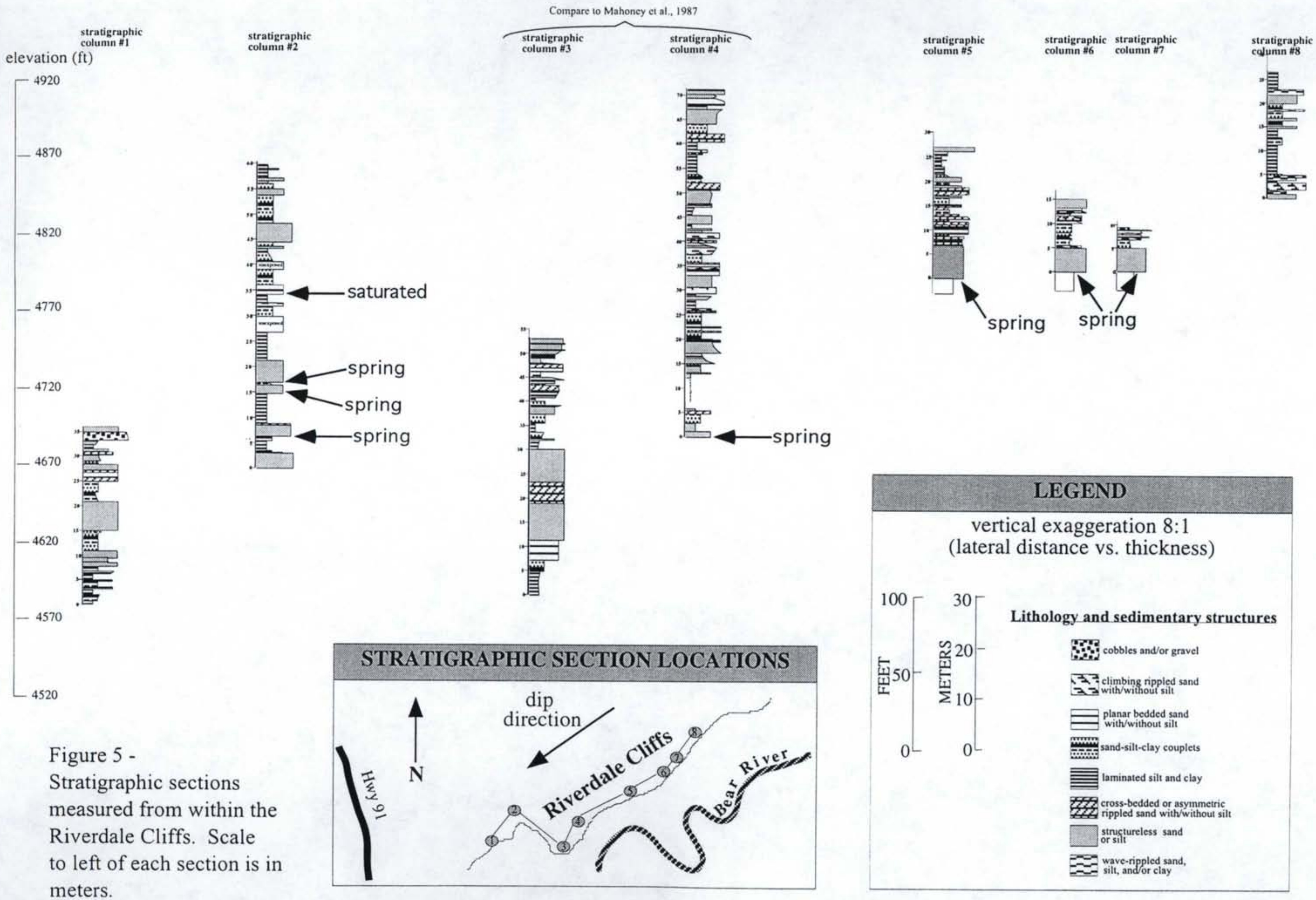


Figure 5 - Stratigraphic sections measured from within the Riverdale Cliffs. Scale to left of each section is in meters.

Interpretation of Geologic History

Sequence Stratigraphic Architecture

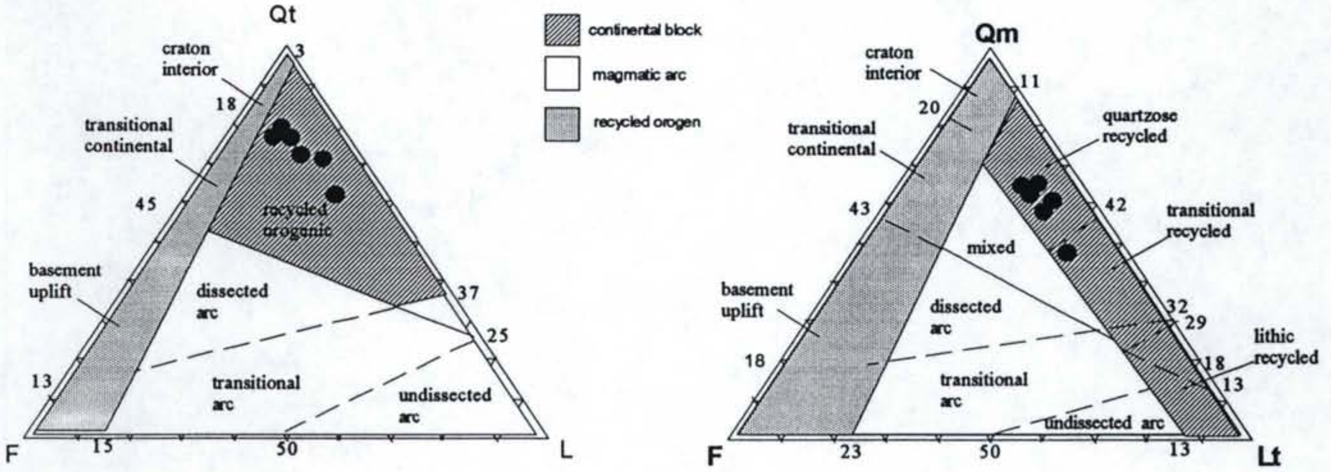
Seven upward-coarsening sedimentary cycles, interpreted to have been deposited in a fluvial-dominated deltaic system, were identified within the Riverdale Cliff outcrops. Figure 7 shows the eight measured sections with corresponding parasequence boundaries (surfaces of lake level drop or disconformities) and flooding surfaces (surfaces of rapid lake level rise). "Parasequence boundaries" were drawn below regressive lowstand deposits where delta top deposits appeared to unconformably overly more distal delta front and prodelta deposits.

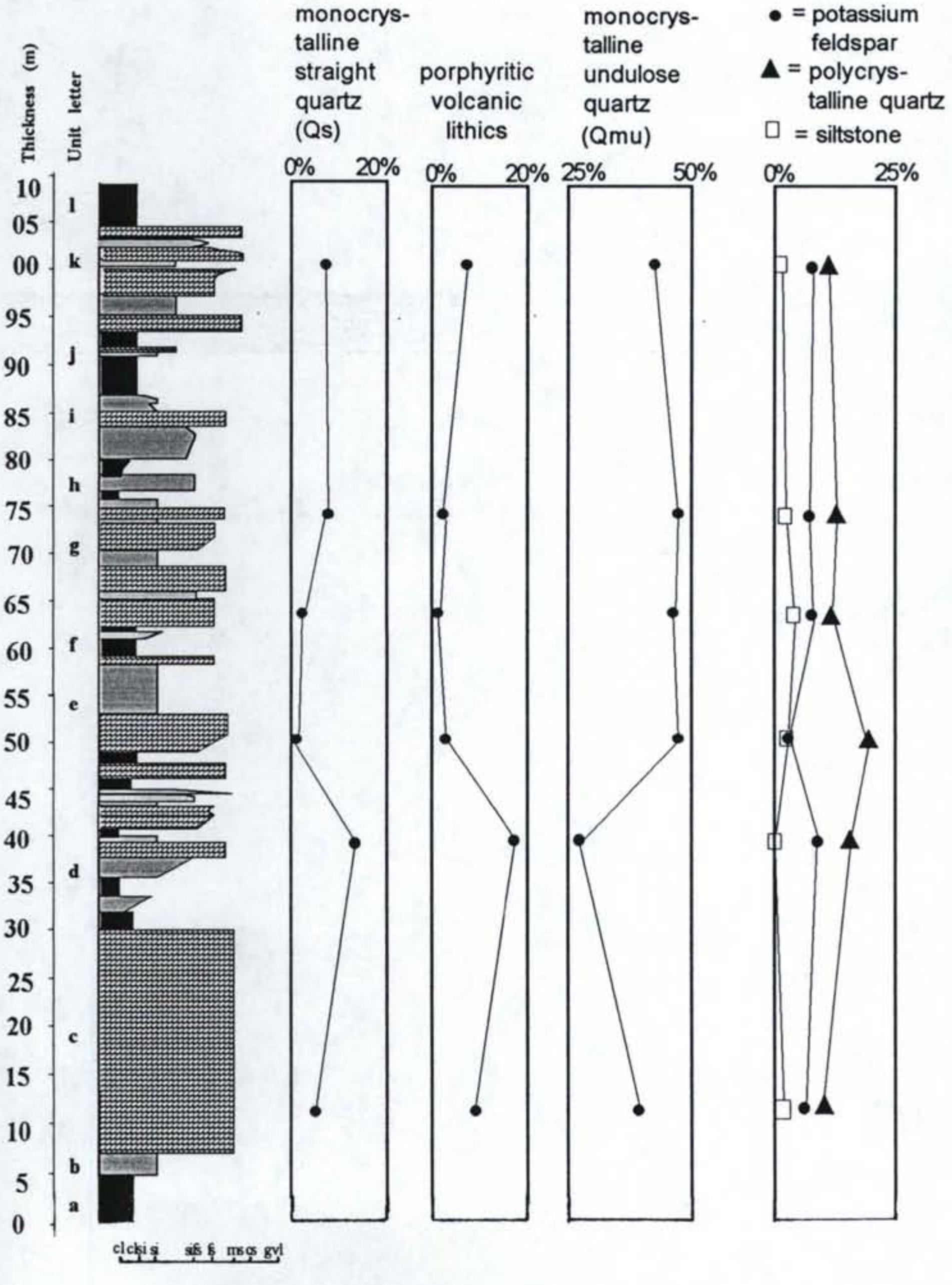
Flooding surfaces are defined as a surface separating younger from older strata across which there is evidence of an abrupt increase in water depth (Van Wagoner, 1995). Eight flooding surfaces were identified within the Bear River Delta. The flooding surfaces were placed between parasequence boundaries where a significant amount of prodelta silt and clay overly delta front deposits.

Lowstand systems tracts are defined as being bounded below by a sequence or parasequence boundary and above by the first major flooding surface, called the transgressive surface (Van Wagoner, 1995). In the Bear River Delta, the Lowstand systems tract are interpreted to consist of a lowstand wedge containing fine-to coarse-grained silty sand and possibly gravel. Seven lowstand systems tracts are interpreted to exist within the Bear River Delta. They most commonly overlie more distal lithofacies such as prodelta silts and clays and delta front couplets and flat laminated and climbing ripple silty sand deposits.

Highstand systems tracts are defined as being bounded below by a downlap (or flooding) surface and above by the next sequence or parasequence boundary (Van Wagoner, 1995). In the Bear River Delta, there are interpreted to be six highstand systems tracts which consist of prodelta silts and clays and delta front couplets and flat laminated and climbing ripple silty sand deposits.

The parasequences vary laterally and vertically in their progradational, aggradational, and retrogradational nature. Between parasequence 2 and 3, the parasequence changes from showing one progradational cycle to three progradational cycles to the northeast. Figure 7 nicely exhibits the lateral and vertical changes occurring within and between each parasequence cycle. At least some of the observed progradational, aggradational, and retrogradational changes are interpreted to represent autocyclic alternations of facies due to changes in sediment supply delta- lobe switching.





Key

Qt = total quartz (monocrystalline and polycrystallline quartz)

Qm = monocrystalline quartz only

F = plageoclase and potassium feldspars

L = lithics

Lt = total lithics (includes polycrystalline quartz as a lithic))

Figure 6 -

QtFL and QmFlt ternary plots for sand units of the Bear River Delta, and Stratigraphic compositional trends for sand units of the Bear River Delta.

Sequence Stratigraphic Architecture

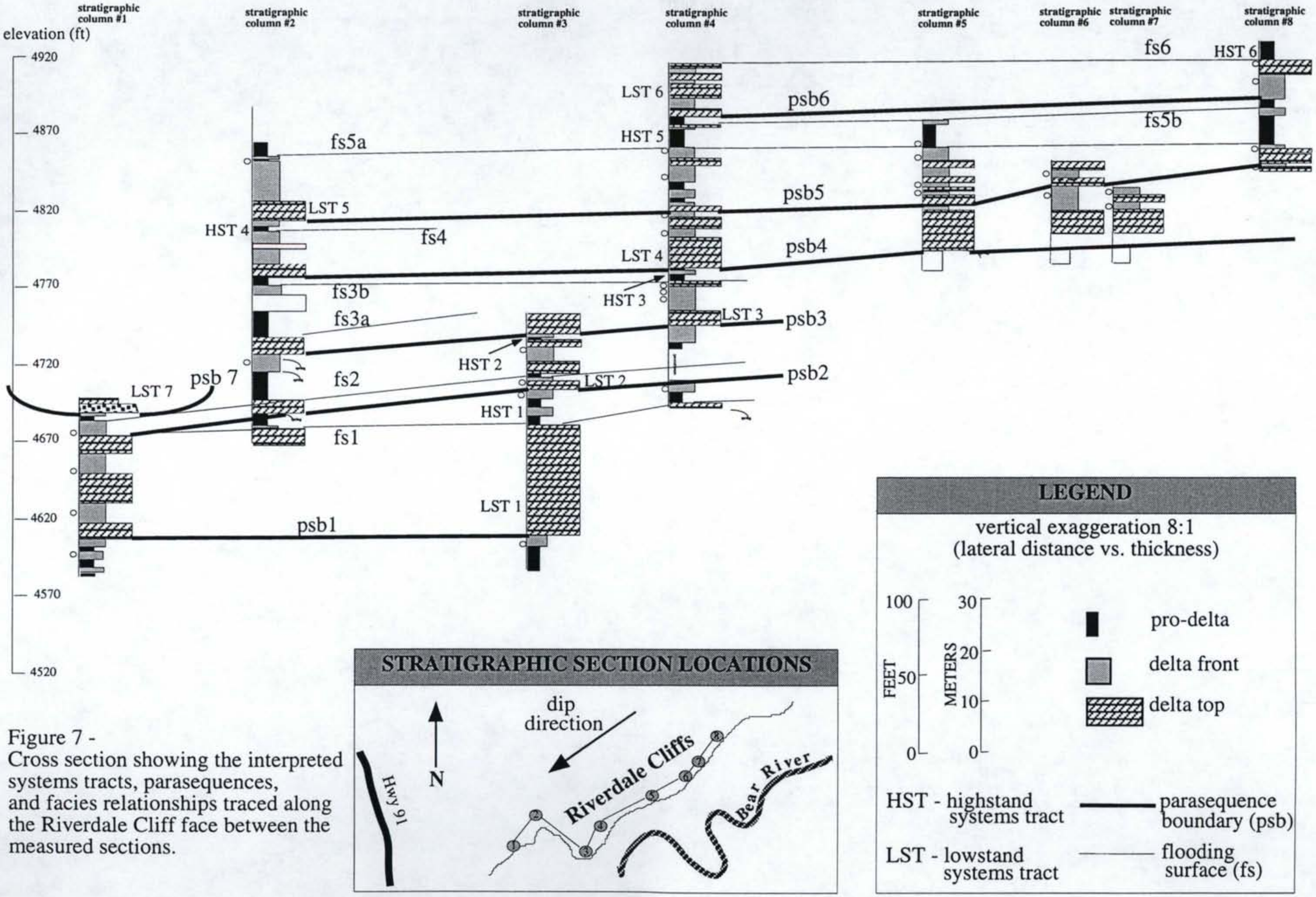
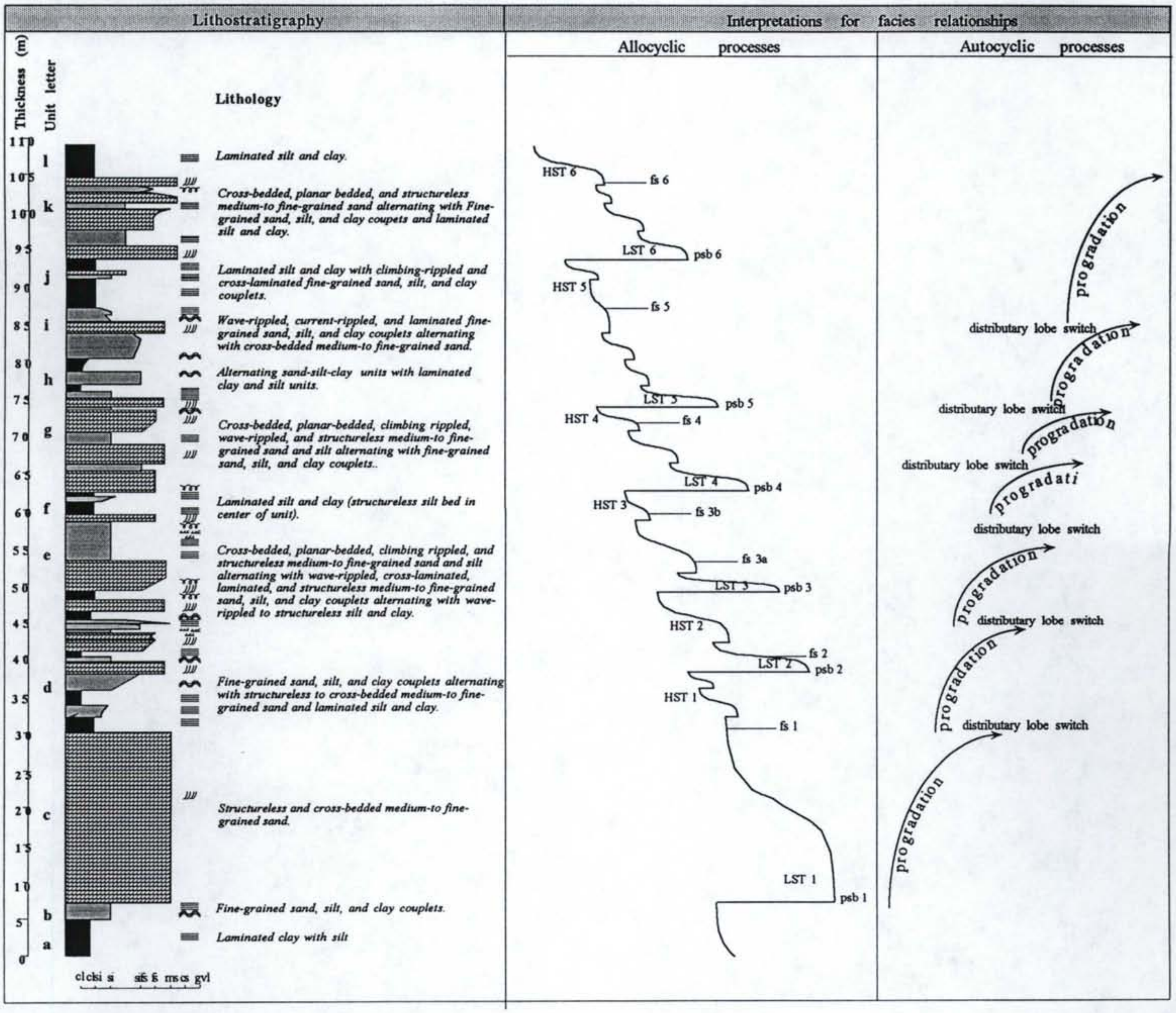


Figure 7 -
Cross section showing the interpreted systems tracts, parasequences, and facies relationships traced along the Riverdale Cliff face between the measured sections.

Simplified Composite Stratigraphic Section and Interpretations for facies Relationships



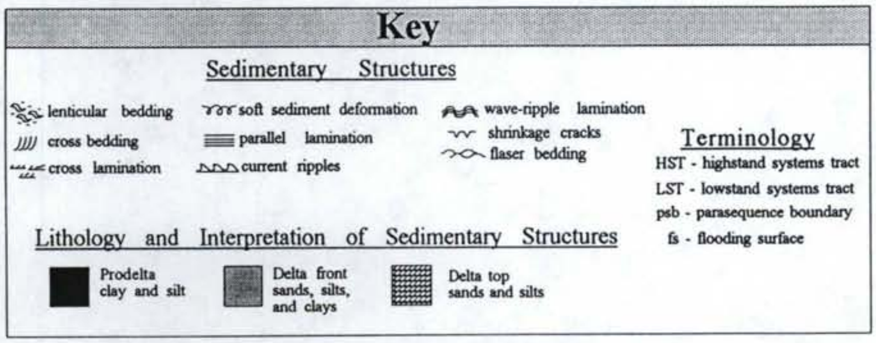


Figure 8 -
Simplified composite stratigraphic section measured sections of the Bear River Delta along with two possible interpretations for facies relationships.

MW1 – Franklin County Landfill
Drilled Nov–Dec 1994: From MSE notes

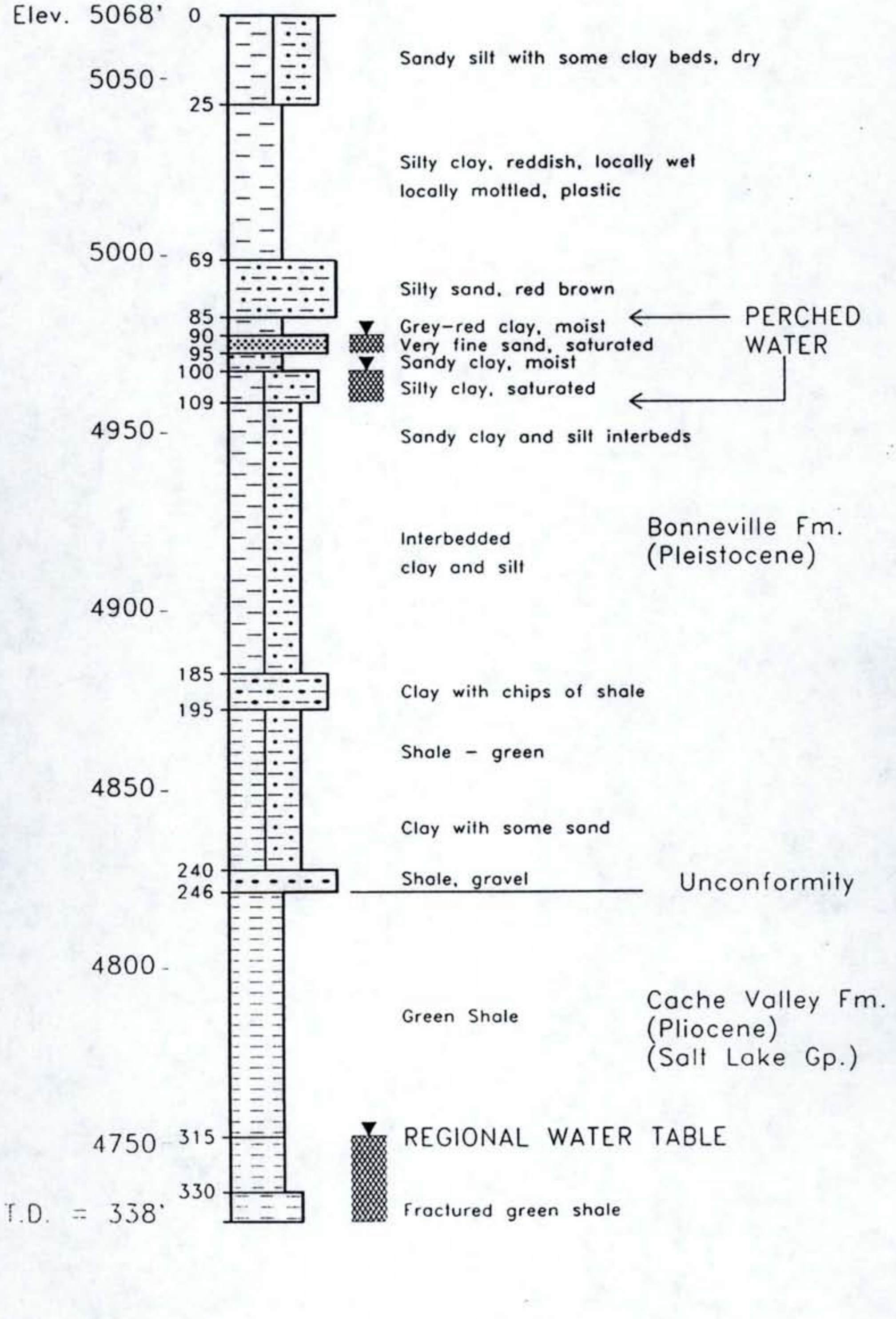


Figure 9

Other possible interpretations

It is possible that some of the observed parasequences, interpreted to represent changes in lake level, may be due to autocyclic delta-lobe switches, reflecting relative increases and decreases in sediment supply. Figure 8 demonstrates the two interpretations for facies relationships within the Bear River Delta. Onlap curves demonstrate the allocyclic interpretation, and progradational events demonstrate autocyclic interpretation. Figure 8 shows how seven progradational events or six parasequence cycles could possibly be used to explain the facies relationships within the Bear River Delta.

Deliverable B: Salt Lake Formation

Well MW1, drilled at the Franklin County Landfill in 1994, penetrated green shale of the Cache Valley Formation of the Pliocene Salt Lake Group or Formation (Figure 9). Samples from that well have been examined for sedimentary petrology. Geochemical characteristics of the samples have not yet been determined.

The Cache Valley Formation at the landfill site consists of moderately indurated tuffaceous siltstone or shale which probably originated as reworked airfall tuff. The sediments are similar to the Cache Valley Formation studied by Danzl (1982; 1985) in outcrop at Oneida Narrows, and by Winter (1989) at Glendale Reservoir immediately east of the landfill site. The sediments consist of detrital quartz, hydrated and devitrified rhyolitic glass, and detrital and authigenic clay. Authigenic minerals in these tuffaceous deposits include the zeolites clinoptilolite, the clay montmorillonite, and authigenic silica. Calcite is present locally.

The Late Pliocene Cub River diabase intrusion intrudes the Cache Valley Formation in the hills immediately east of the landfill site (Winter, 1989). If the diabase is present in the shallow subsurface, it may influence the geochemistry and hydraulic properties of the Salt Lake Formation. The diabase contains on average 54.5% silica and consists of plagioclase, augite pyroxene, and varying amounts of mafic glass, rich in iron oxide. The diabase alters to smectite clays.

The zeolite minerals present in the Cache Valley Formation will serve to adsorb cations which come in contact with them. However the hydraulic conductivity of the tuffaceous siltstone is low and it is not clear whether any landfill effluent would pass through the Cache Valley Formation if it leaked. Geochemical base line characterization of the waters beneath the landfill and the sediments themselves is pending the hydraulic testing.

Research Not Included in This Deliverable

Hydrogeologic testing of the sediments below the landfill has not been scheduled by the County and MSE Engineering. This hydrologic testing will be performed with the cooperation of MSE Engineers (Tom Sherwood). We will participate in this pump testing when the other cooperators are ready to begin it, and we will analyze drawdown data from the four wells drilled in the landfill area to model the local hydraulic parameters of the sediments of the landfill site. This delay was beyond our control and we have been in regular communication with MSE and the County.

References cited

Allmendinger, R.W., 1982, Sequence of Late Cenozoic deformation in the Blackfoot Mountains, southeastern Idaho, *in* Bonnichsen, B., and Breckenridge, R.M., eds., Cenozoic geology of Idaho: Idaho Bureau of Mines and Geology Bulletin 26, p. 505-516.

Bjorkland, L.J., and McGreevy, L.J., 1971, Groundwater resources of Cache Valley, Utah and Idaho: State of Utah Department of Natural Resources Technical Publication No. 36, 72 p.

Bouchard, D., Kaufman, D., and Quade, J., 1996, Preliminary assessment of Quaternary Bear River Bonneville Basin Paleohydrogeography reconstructed from the 87Sr/86Sr composition of lacustrine fossils: in AMQUA Program and Abstracts of the 14th Biennial Meeting, Flagstaff Az., p. 66.

Bright, R.C., 1963, Pleistocene lakes Thatcher and Bonneville, southeastern Idaho: Unpublished PhD dissertation, University of Minnesota, 292 p.

Danzl, R.B., 1982, Stratigraphy and depositional environment of the Tertiary Salt Lake Group near Oneida Narrows, southeastern Idaho: Northwest Geology, v. 11, p. 22-30.

Danzl, R.B., 1985, Depositional and diagenetic environment of the Salt Lake Group at Oneida Narrows, southeastern Idaho (M.S. thesis): Pocatello , Idaho, Idaho State University, 177 p.

Eardley, A. J., Shuey, R. T., Gvosdetsky, V., Nash, W. P., Picard, M. D., Grey, D. C., and Kukla, G. J., 1973, Lake cycles in the Bonneville Basin, Utah: Geological Society of America Bulletin v. 84, p. 211 - 216.

Gardner, M.H., and Cross, A.T., 1994, Middle Cretaceous Paleogeography of Utah *in* Peterson, J.A., and Franczyk, K.J., eds., Mesozoic Systems of the Rocky Mountain Region, USA, Rocky Mountain Section SEPM (Society for Sedimentary Geology), p. 471-502.

Link, P.K., 1982, Geology of the Upper Proterozoic Pocatello Formation, Bannock Range, S.E. Idaho [Ph.D. Dissertation]: Santa Barbara, University of California.

Link, P.K., Mahoney, J.B., McCalpin, J., and Henkelman, J.J., and Smith, B.L., 1987, Field Trip Roadlog for the Bear River Landslide Complex, Proceedings of the 23rd Symposium on Engineering Geology and Soils Engineering, Logan Utah, Utah State University, p. 334-353.

Mahoney, J.B., Link, P.K., Henkelman, J.J., McCalpin, J., and Smith, B.L., 1987, The Bear River Landslide Complex, Preston, Idaho: Geologic Considerations and Historical Perspectives: Proceedings of the 23rd Symposium on Engineering Geology and Soils Engineering, Logan Utah, Utah State University, p. 306-353.

Malde, H.E., 1968, Evidence in the Snake River Plain, Idaho, of a catastrophic flood from Pleistocene Lake Bonneville: U.S.G.S. Professional Paper 400-B, P. B295-B297.

Mansfield, G.R., 1927, Geography, geology, and mineral resources of part of southeastern Idaho: United States Geological Survey Professional Paper 152, 453 p.

McCoy, W. D., 1987, Quaternary aminostratigraphy of the Bonneville Basin, western United States: Geological Society of America Bulletin v. 98, p. 99 - 112

Nummedal, D., and Molenaar, C.M., 1995, Sequence stratigraphy of ramp-setting Plain successions: The Gallup Sandstone, New Mexico, *in* Van Wagoner, J.C., and Bertrum, G.T., eds., Sequence Stratigraphy of Foreland Basin Deposits: Outcrop and subsurface examples from the Cretaceous of North America: A.A.P.G. Memoir 64, p. 277-310.

Oriel, S.S., and Platt, L.B., *1968*, Reconnaissance geologic map of the Preston Quad, SE Idaho: U.S.G.S. open-file map, scale 1:62,500.

Oviatt, C. G., and Currey, D. B., 1987, Pre-Bonneville Quaternary lakes in the Bonneville Basin, Utah: Utah Geological Association Publication 16, p. 257 - 263

Oviatt, C.G., Currey, D.R., and Sack, D., 1992, Radiocarbon chronology of Lake Bonneville, eastern Great Basin, USA, Palaeogeography, Palaeoclimatology, Palaeoecology, Vol. 99, pp. 225-241.

Pierce, K.L., and Morgan, L.A., 1992, The track of the Yellowstone Hotspot: volcanism, faulting, and uplift, *in* Link, P.K., Kuntz, M.A., and Platt, L.B.., eds., Regional geology of eastern Idaho and western Wyoming: Geological Society of America Memoir 179, p. 1-53.

Rodgers, D.W., Hackett, W.R., and Ore, H.T., 1990, Extension of the Yellowstone plateau, eastern Snake River Plain, and Owyhee plateau: Geology, v. 18, p. 1138-1141.

Scott, W.E., McCoy, W.D., Shroba, R.R., and Rubin, M., 1983, Reinterpretation of the exposed record of the last two cycles of Lake Bonneville, western U.S.: Quaternary Research, v. 20, p. 261-285.

Taylor, D.R., and Lovell, R.W.W., 1995, High-frequency sequence stratigraphy and paleogeography of the Kenilworth Member, Blackhawk Formation, Book Cliffs, Utah, U.S.A. *in* Van Wagoner, J.C., and Bertrum, G.T., eds., Sequence Stratigraphy of Foreland Basin Deposits: Outcrop and subsurface examples from the Cretaceous of North America: A.A.P.G. Memoir 64, p. 257-276.

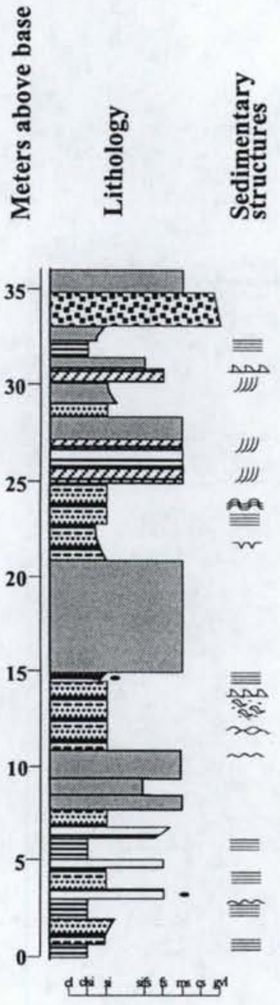
Van Wagoner, J.C., 1995, Overview of Sequence Stratigraphy of Foreland Basin Deposits: Terminology, Summary of Papers, and Glossary of Sequence Stratigraphy, *in* Van Wagoner, J.C., and Bertrum, G.T., eds., Sequence Stratigraphy of Foreland Basin Deposits: Outcrop and subsurface examples from the Cretaceous of North America: A.A.P.G. Memoir 64, p. ix-xxi.

Williams, S.K., 1994, Late Cenozoic tephrostratigraphy of deep sediment cores from the Bonneville Basin, northwest Utah: Geological Society of America Bulletin, v. 106, p. 1517-1530.

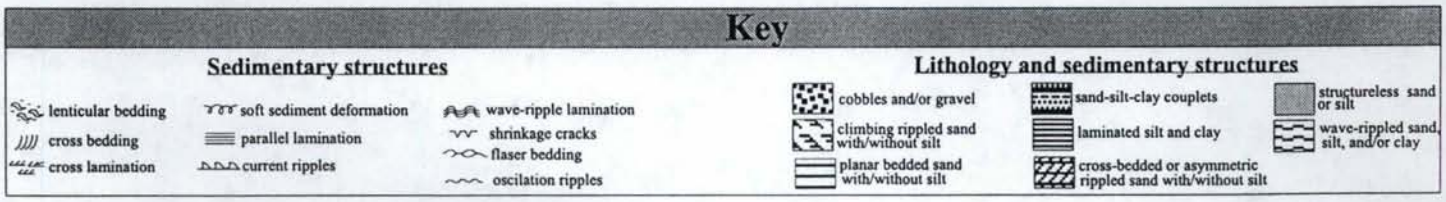
Winston, D., 1986, Sedimentology of the Ravalli Group, Middle Belt Carbonate and Missoula Group, Middle Proterozoic Belt and Supergroup, Montana, Idaho and Washington, in Roberts, S.M., ed., Belt Supergroup: A guide to Proterozoic rocks of western Montana and Adjacent areas: Montana Bureau of Mines and Geology Special Publication 94, p. 85-124.

Winter, M.B., 1989, Geology and petrology of the Cub River Diabase, A Late Pliocene differentiated mafic intrusion, northeastern Cache Valley, Idaho: M.S. Thesis, Idaho State University, 167 p.

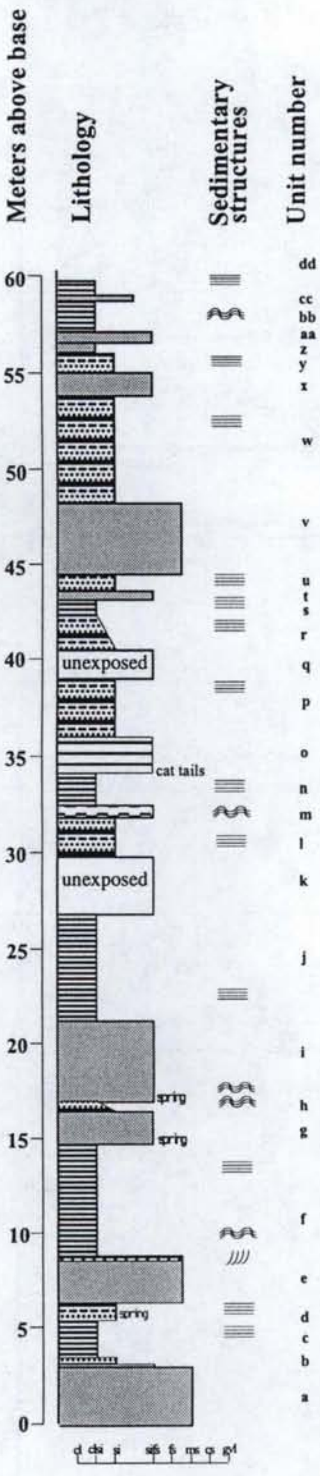
Stratigraphic Column #1



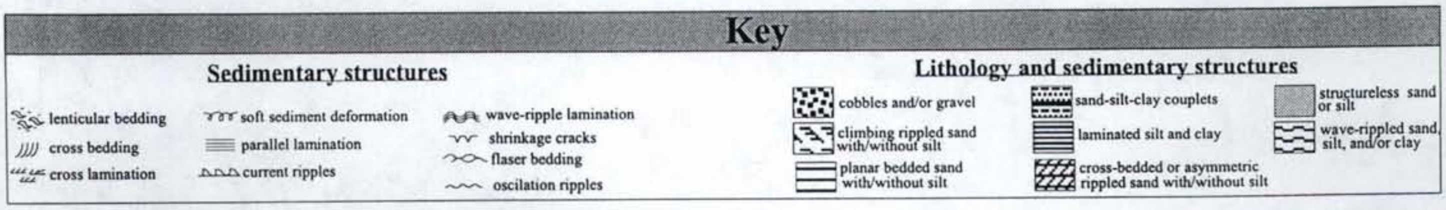
Unit number	Description	Interpretation
r	(122 cm) Structureless, coarse-to fine-grained sand.	Distributary channel, bar finger sands, or mouth bar deposit
q	(183 cm) Structureless, unsorted, cobble-fine-sand.	Either a beach deposit or a low stand fan.
p	(160 cm) Laminated, damp, silt and clay beds overlain by structureless fine-grained sand and silt.	Pro-delta deposit due to silt and clay settleout.
o	(130 cm) Cross-bedded overlain by planar-bedded, dry, medium-to fine-grained sand and silt. Center contains clay. Salty.	Distributary channel, bar finger sands, or mouth bar deposit
n	(186 cm) Structureless, damp , clay coarsening to silt and clay, coarsening to alternating fine-grained sand and silt and silt and clay beds. Fissile near center.	Delta front storm deposits.
m	(355 cm) Trough cross-bedded, planar-bedded, and massive, dry, medium-grained sand.	
l	(402 cm) Laminated, and wave-rippled, dry, fine-grained sand, silt, and clay couplets. Shrinkage cracks found at base. Salty.	Wave-reworked delta front storm deposits.
k	(610 cm) Structureless (?), dry, medium-grained sand.	Distributary channel, bar finger sands, or mouth bar deposit
j	(235 cm) Partly laminated and climbing rippled, 8 to 50 cm thick medium-to fine-grained sand, silt, and clay couplets. Top 46 cm of package contains flaser, lenticular, and wave-rippled bedding.	Wave-reworked delta front storm deposits.
i	(313 cm) Structureless (except for wave-rippled 60 cm top), subangular, well-sorted, damp, fine-to medium-grained sand and silt. Center portion of sand package mix of sand, silt and clay (wet).	Distributary channel, bar finger sands, or mouth bar deposit
h	(106 cm) Dry grading to saturated, alternating sand, silt and clay.	Delta front storm deposits.
g	(58 cm) Planar bedded, saturated, fine-grained sand with silt. Coarsens upward. Beds 1/8 to 3 cm thick.	Distributary channel, bar finger sands, or mouth bar deposit
f	(122 cm) Laminated, saturated, alternating silt and clay beds. Beds 9 cm thick.	Pro-delta deposit due to silt and clay settleout.
e	(41 cm) Lenticular bedded and planar bedded dry, fine-grained sand.	Distributary channel, bar finger sands, or mouth bar deposit
d	(123 cm) Laminated, dry, alternating silt and clay beds.	Delta front storm deposits.
c	(53 cm) Lenticular bedded and planar bedded, dry, fine-grained sand. Wave-ripples at top.	Distributary channel, bar finger sands, or mouth bar deposit
b	(119 cm) Laminated, dry, alternating silt and clay beds. Some sand intrusions within center. Fissile.	Pro-delta deposit due to silt and clay settleout.
a	(199 cm) Laminated, dry, alternating silt and clay beds overlain by alternating fine sand and silty clay beds ~8 cm thick and thickening upward. 13 couplets.	Delta front storm deposits.



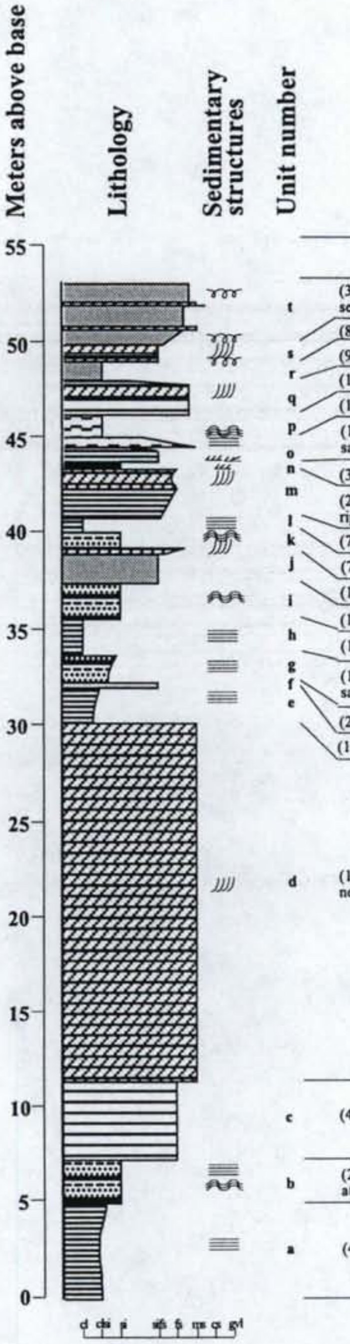
Stratigraphic Column #2



Unit number	Description	Interpretation
dd	(69 cm) Laminated, dry, silt and clay.	Pro-delta deposit due to silt and clay settleout.
cc	(41 cm) Structureless silt.	Pro-delta deposit due to silt settleout (turbidity current?).
bb	(152 cm) Ripple-laminated, dry, clay and silt.	Pro-delta deposit due to silt and clay settleout.
aa	(64 cm) Structureless, dry, fine-grained sand and silt.	Bar finger, mouth bar, or turbidity current deposit.
z	(56 cm) Structureless silt.	Pro-delta deposit due to silt settleout (turbidity current?).
y	(102 cm) Laminated, fining upward package of alternating sand, silt and clay, and clay beds.	Delta front storm deposits.
x	(123 cm) Structureless, dry, silt and sand	Pro-delta deposit due to silt settleout (turbidity current?).
w	(548 cm) Laminated, damp grading to dry, coarsening then fining upward package of alternating sand, silt and clay, and clay beds. middle 1.5 m shows 30 cm sands alternating with ~3 cm silt and clay beds. Top 1.5 m shows wave-rippled silts and clays with some alternating sands.	Delta front storm deposits and wave-reworked delta front storm deposits.
v	(366 cm) Structureless, sub-angular, well-sorted, damp and dry, fine-to medium-grained sand.	Distributary channel, bar finger sands, or mouth bar deposit
u	(81 cm) Laminated, damp, alternating sand, silt and clay, and clay beds beds fining up to interbedded fine-grained sand and silt and clay beds.	Delta front storm deposits.
t	(43 cm) Structureless, damp and dry, fine-grained sand and silt.	Bar finger, mouth bar, or turbidity current deposit.
s	(80 cm) Laminated, damp, silt and clay beds	Pro-delta deposit due to silt and clay settleout.
r	(183 cm) Laminated, damp grading to dry, alternating sand, silt and clay, and clay beds beds fining up to alternating silty clay beds.	Delta front storm deposits.
q		
p	(305 cm) Laminated, damp, alternating sand, silt and clay, and clay beds beds. Poorly exposed.	Delta front storm deposits.
o	(205 cm) Planer-bedded, dry, sand (and possibly silt). Poorly exposed.	Distributary channel, bar finger sands, or mouth bar deposit
n	(150 cm) Laminated, wet silt and clay beds. Poorly exposed.	Pro-delta deposit due to silt and clay settleout.
m	(57 cm) Wave-rippled, dry, fine-grained sand and silt.	Wave-reworked delta front or delta plain deposits.
l	(198 cm) Laminated, damp, alternating sand, silt and clay, and clay beds beds fining up to alternating fine-grained sand and siilty clay beds.	Delta front storm deposits.
k		
j	(557 cm) Laminated grading to structureless, dry grading to damp, alternating silt, clay, and silty clay beds.	Pro-delta deposit due to silt and clay settleout.
i	(427 cm) Structureless (except for wave-rippled 13 cm base, subangular, well-sorted, damp, fine-grained sand and silt. Shows a slight fining upward (reduction in amount of fine sand)	Distributary channel, bar finger sands, or mouth bar deposit
h	(43 cm) Wave-rippled, damp, medium-to fine-grained 10 cm sand beds fining up to alternating fine-grained sand and silty clay beds 1 to 2 cm thick grading to alternating clay and silt beds. Flaser bedding near center of unit.	Wave-reworked delta front storm deposits.
g	(168 cm) Structureless, subangular, well-sorted, saturated, fine-grained sand and silt	Distributary channel, bar finger sands, or mouth bar deposit
f	(597 cm) Wave-rippled grading to laminated, damp grading to dry to wet, salty, alternating silt, clay, and silty clay beds ~2.5 cm thick. Shows some grading. Overall unit fines upward.	Wave-reworked delta front storm deposits.
e	(249 cm) Structureless with top 30 cm cross-bedded grading into wave rippled, subangular, well-sorted, dry fine-medium-grained sand	Distributary channel, bar finger sands, or mouth bar deposit
d	(94 cm) Laminated, damp, alternating fine-grained sand and silty clay beds 1 to 2 cm thick	Delta front storm deposits.
c	(188 cm) Laminated, damp, alternating silt, clay, and silty clay beds ~2.5 cm thick. Some grading.	Pro-delta deposit due to silt and clay settleout.
b	(61 cm) Damp, alternating, medium-to fine-grained sand, silt, and clay. Beds 1/6 to 5 cm thick.	Delta front storm deposits.
a	(300 cm) Structureless, subangular, well-sorted, dry medium-grained sand	Distributary channel, bar finger sands, or mouth bar deposit



Stratigraphic Column #3



Description	Interpretation
(320 cm) Structureless, dry, fine-to medium-grained sand and silt (coarsens upward). Large soft-sediment deformation near base and top. Climbing ripples near base and center.	Distributary channel, bar finger sands, or mouth bar deposit
(89 cm) Cross-bedded and planar bedded fine-grained sand and silt. Soft-sediment deformation at base.	Distributary channel, bar finger sands, or mouth bar deposit
(94 cm) Structureless, dry, silt and clay (conchoidal fractures)	Pro-delta deposit due to silt settleout (turbidity current?).
(172 cm) Planar bedded and cross-bedded, dry, m-f grained sand, topped by wave-rippled couplets.	Distributary channel, bar finger sands, or mouth bar deposit
(122 cm) Laminated and wave-rippled silt and clay; 3 fining up cycles topped with wave-rippled clay.	Wave-reworked delta front storm deposits.
(126 cm) Planar bedded, damp, fine-grained sand and silt ~3 to 8 cm thick. Overlain by clay bed and sand bed with clay rip-ups, grading into climbing rippled fine sand and silt.	Bar finger, mouth bar, or turbidity current deposit.
(35 cm) Laminated, dry, coarsening upward sand, silt, clay couplets. Sands cross-laminated.	Delta front storm deposits.
(246 cm) Planar-bedded, dry to damp, fine-grained sand and silt grading into cross-bedded and climbing rippled medium-to fine-grained sand	Distributary channel, bar finger sands, or mouth bar deposit
(76 cm) Laminated, damp clay laterally grading into upper sand and silt unit.	Pro-delta deposit due to silt and clay settleout.
(76 cm) Cross-laminated and wave-rippled medium-to fine-grained sand, silt, and clay ~1-6 cm thick.	Wave-reworked delta front storm deposits.
(185 cm) Structureless, damp, fine-grained sand and silt,.topped with cross-bedded m-f grained sand.	Distributary channel, bar finger sands, or mouth bar deposit
(183 cm) Wave-rippled, alternating medium-to fine-grained sand, silt and clay couplets 28 to 2 cm thick	Wave-reworked delta front storm deposits.
(183 cm) Laminated clay (poor exposure)	Pro-delta deposit due to silt and clay settleout.
(132 cm) Laminated, damp clay grading into a clay with fine sand and silt thin interbeds, grading into sand, silt, and clay couplets (damp). Couplets decrease in thickness upward.	Delta front storm deposits.
(28 cm) Structureless, dry, fine-grained sand and silt, top 1.5 cm damp.	Wave-reworked delta front or delta plain deposits.
(183 cm) Laminated, damp, clay grading up to a laminated, dry, clay with little silt.	Pro-delta deposit due to silt and clay settleout.
(1880 cm) Structureless, subangular, well-sorted, dry medium-to fine-grained sand. Cross-bedded near center. Poorly exposed (slope)	Distributary channel, bar finger sands, or mouth bar deposit
(406 cm) Planar bedded fine-grained sand.	Distributary channel, bar finger sands, or mouth bar deposit
(233 cm) Laminated, dry, alternating fine sand, silt, and clay, ~2.5 cm thick. Shows some wave-ripples at base..	Delta front storm deposits (partly reworked).
(488 cm) Laminated clay with some silt (poor exposure)	Pro-delta deposit due to silt and clay settleout.

Key

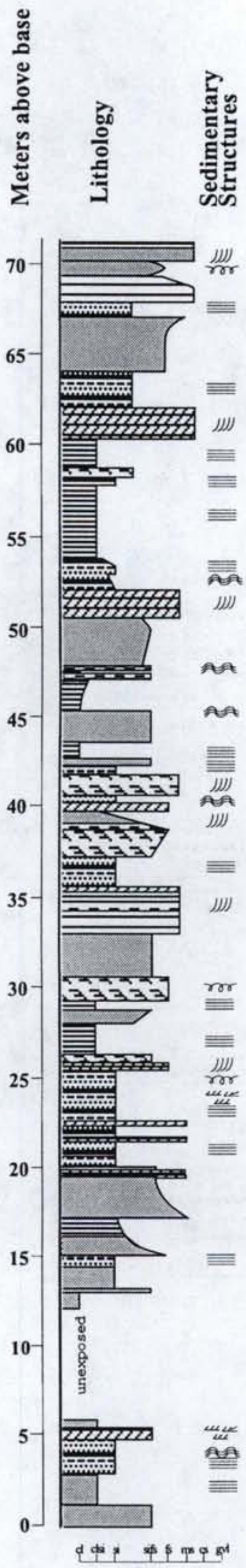
Sedimentary structures

- ≈ lenticular bedding
-)))) cross bedding
- ⫽ cross lamination
- ⌒⌒⌒ soft sediment deformation
- ≡ parallel lamination
- ⌂⌂⌂ current ripples
- ∿ wave-ripple lamination
- ⌄⌄ shrinkage cracks
- ∾ flaser bedding

Lithology and sedimentary structures

- ⁘ cobbles and/or gravel
- ▧ climbing rippled sand with/without silt
- ☰ planar bedded sand with/without silt
- ▦ sand-silt-clay couplets
- ▤ laminated silt and clay
- ▨ cross-bedded or asymmetric rippled sand with/without silt
- ▩ structureless sand or silt
- ≋ wave-rippled sand, silt, and/or clay

Stratigraphic Column #4



Unit number	Description	Interpretation
jj	(244 cm) Cross-bedded to structureless, to planar bedded, medium-to fine-grained sand with silt in center of unit.	Distributary channel, bar finger sands, or mouth bar deposit
ii	(81 cm) Laminated, fine-grained sand, silt, and clay.	Delta front storm deposits .
hh	(283 cm) Structureless (?) fine-grained sand and silt.	Distributary channel, bar finger sands, or mouth bar deposit
gg	(205 cm) Laminated, medium-to fine-grained sand, silt, and clay couplets.	Delta front storm deposits .
ff	(173 cm) Cross-bedded, dry, medium-to fine-grained sand fining up to fine-grained sand and silt.	Distributary channel, bar finger sands, or mouth bar deposit
ee	(152 cm) Laminated, silt with some clay.	Pro-delta deposit due to silt and clay settleout.
dd	(74 cm) Climbing rippled and cross-laminated, fine-grained sand, silt, and clay couplets.	Delta front storm deposits (turbidity current?).
cc	(401 cm) Laminated, silt and clay.	Pro-delta deposit due to silt and clay settleout.
bb	(178 cm) Laminated, current rippled, and cross-laminated, fine-grained sand, silt, and clay.	Partly wave-reworked delta front storm deposits.
aa	(58 cm) Planar bedded (at least partly), dry, alternating fine-grained sand, silt and clay., overlain by cross-bedded damp at base, medium-to fine-grained sand.	Distributary channel, bar finger sands, or mouth bar deposit
z	(83 cm) Wave-rippled, damp, fine-grained sand and silt.	Distributary channel, bar finger sands, or mouth bar deposit
y	(163 cm) Structureless clay grading to clay with little silt.	Pro-delta deposit due to silt and clay settleout.
x	(173 cm) Structureless, fine-grained sand and silt, alternating with one more than the other every 25 cm.	Distributary channel, bar finger sands, or mouth bar deposit
w	(89 cm) Laminated, silt and clay with beds ~1.5 to 10 cm thick.	Pro-delta deposit due to silt settleout .
v	(79 cm) Laminated, fine-grained sand, silt, and clay couplets overlain by silt with some fine sand.	Delta front storm deposits (turbidity current?).
u	(112 cm) Cross-bedded grading to climbing rippled, fine-grained sand . Large climbing ripples at top.	Distributary channel, bar finger sands, or mouth bar deposit
t	(33 cm) Wave-rippled, fine-grained sand, silt and clay couplets.	Wave-reworked delta front storm deposits.
s	(43 cm) Cross-bedded, silt grading to fine-grained sand and silt.	Distributary channel, bar finger sands, or mouth bar deposit
r	(243 cm) Climbing rippled, dry, fine-grained silty sand coarsening up to fine sand, fining again to top.	Distributary channel, bar finger sands, or mouth bar deposit
q	(160 cm) Laminated and cross-laminated, fine-grained sand, silt and clay couplets.	Delta front storm deposits.
p	(244 cm) Cross-bedded, planar bedded, and climbing rippled, dry, medium-to fine-grained sand and silt.	Distributary channel, bar finger sands, or mouth bar deposit
o	(238 cm) Structureless (except cross-bedded base), dry, medium-to fine-grained sand and silt, top damp.	
n	(130 cm) Climbing rippled, dry, fine-sand.	
m	(303 cm) Laminated (except wave-rippled at base), dry to damp, silt and clay . Structureless silt bed near center.	Pro-delta deposit due to silt and clay settleout.
l	(82 cm) Cross-bedded to climbing rippled, fine-grained sand grading to fine-grained sand and silt.	Distributary channel, bar finger sands, or mouth bar deposit
k	(531 cm) Laminated, cross-laminated, and wave-rippled medium-to fine-grained sand, silt, and clay couplets. Soft sediment deformation near top.	Delta front storm deposits (partly reworked).
j	(303 cm) Structureless, damp, medium-to fine-grained sand grading to structureless, dry, fine-grained sand and silt.	Distributary channel, bar finger sands, or mouth bar deposit
i	(196 cm) Structureless, dry, fine-grained silty sand grading to laminated and flaser bedded sand, silt, clay	Delta front storm deposits (partly reworked).
h	(70 cm) Laminated, damp, fine-grained sand, silt, and clay couplets. Flame structures.	Delta front storm deposits.
g	(231 cm) Structureless, damp, clay, overlain by fine sand and silt, overlain by dry silt and clay.	Delta front storm deposits.
f		
e	(43 cm) Structureless silt and clay.	Bar finger, mouth bar, or turbidity current deposit.
d	(64 cm) Cross-stratified, damp, fine-grained sand and silt topped with silt and clay.	Distributary channel, bar finger sands, or mouth bar deposit
c	(187 cm) Laminated and wave-rippled, damp, medium-to fine-grained sand, silt, and clay couplets.	Wave-reworked delta front or delta plain deposits.
b	(186 cm) Partly laminated, saturated, silt and clay. Two sand interbeds at top.	Pro-delta deposit due to silt and clay settleout.
a	(114 cm) Structureless, salty, saturated, fine-grained silty sand.	Wave-reworked delta front or delta plain deposits.

Key

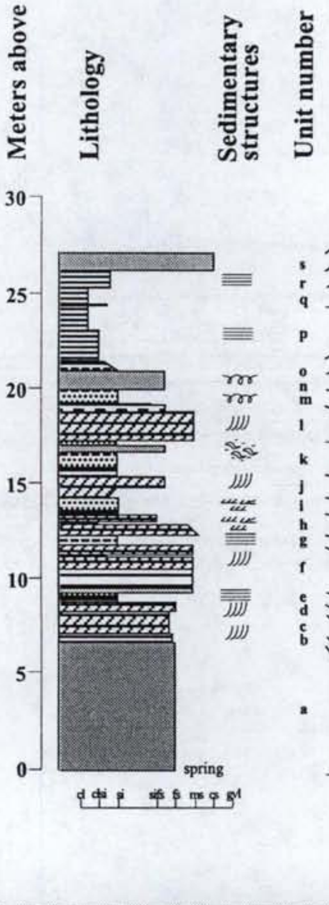
Sedimentary structures

- lenticular bedding
- cross bedding
- cross lamination
- soft sediment deformation
- parallel lamination
- current ripples
- wave-ripple lamination
- shrinkage cracks
- flaser bedding

Lithology and sedimentary structures

- cobbles and/or gravel
- climbing rippled sand with/without silt
- planar bedded sand with/without silt
- sand-silt-clay couplets
- laminated silt and clay
- cross-bedded or asymmetric rippled sand with/without silt
- structureless sand or silt
- wave-rippled sand, silt, and/or clay

Stratigraphic Column #5



Description	Interpretation
(89 cm) Structureless (?) sand (poor exposure).	Distributary channel, bar finger sands, or mouth bar deposit
(89 cm) Laminated silt and clay.	Pro-delta deposit due to silt and clay settleout.
(84 cm) Structureless silt and clay bed overlain by laminated clay.	
(303 cm) Laminated, damp, alternating sity clay beds fining upward to clay.	
(46 cm) Laminated, damp, alternating fine-medium sand, silt, clay beds. Salty, partly wave-rippled.	Wave-reworked delta front storm deposits.
(94 cm) Structureless, dry, fine-grained sand and silt	Distributary channel, bar finger sands, or mouth bar deposit
(69 cm) Laminated, damp, alternating silt, clay, and silty clay beds ~2 to 8 cm thick. 9 couplets.	Delta front storm deposits.
(194 cm) Cross-bedded, dry, medium-to fine-grained sand. Topped by wave-rippled silty fine sand.	Distributary channel, bar finger sands, or mouth bar deposit
(190 cm) Laminated, damp, to dry, alternating silt, clay, and silty clay beds ~8 cm thick. Couplets decrease in thickness upward. Lenticular at base. Wave-rippled at top.	Wave-reworked delta front storm deposits.
(108 cm) Trough and planar cross-bedded, damp, fine-grained silty sand increasing upward in sand.	Distributary channel, bar finger sands, or mouth bar deposit
(93 cm) Laminated, damp, alternating silt, clay, and si-cl beds ~2 to 8 cm thick. 8 couplets.	Delta front storm deposits.
(92 cm) Cross-bedded, dry to damp, medium-to fine-grained sand fining upward to fine sand and silt.	Distributary channel, bar finger sands, or mouth bar deposit
(51 cm) Laminated, alternating silt, clay, and silty clay beds ~3.5-11 cm thick. Wave-rippled at top.	Wave-reworked delta front storm deposits.
(257 cm) Planar beds overlain by cross-beds, damp grading to dry, medium-to fine-grained sand. Clay bed lies within the cross-bedded sands. Clay rip-ups at base of sand package	Distributary channel, bar finger sands, or mouth bar deposit
(47 cm) Laminated, damp, alternating silt, clay, and si-cl beds ~4.5 cm thick. Four couplets.	Delta front storm deposits.
(48 cm) Planar cross-bedded with some climbing ripples, well sorted, silty fine sand. Flat base.	Distributary channel, bar finger sands, or mouth bar deposit
(109 cm) Cross-bedded, damp, fine sand and silt, topped by 17 cm thick planar bed with flat base.	
(48 cm) Planar bedded (with faint ripple), damp, poorly sorted, very fine to fine-grained and silt.	
(665 cm) Structureless (?), dry, fine sand with some silt.	

Key

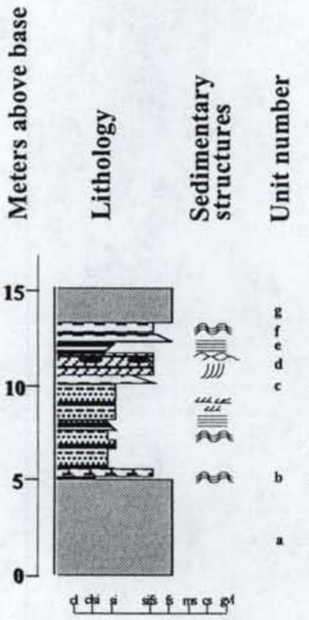
Sedimentary structures

- lenticular bedding
- cross bedding
- cross lamination
- soft sediment deformation
- parallel lamination
- current ripples
- wave-ripple lamination
- shrinkage cracks
- flaser bedding
- oscilation ripples

Lithology and sedimentary structures

- cobbles and/or gravel
- climbing rippled sand with/without silt
- planar bedded sand with/without silt
- sand-silt-clay couplets
- laminated silt and clay
- cross-bedded or asymmetric rippled sand with/without silt
- structureless sand or silt
- wave-rippled sand, silt, and/or clay

Stratigraphic Column #6



Description	Interpretation
(178 cm) Structureless (?) fine-grained sand. Cliff-forming unit (clay) approximately 4 m up.	Distributary channel, bar finger sands, or mouth bar deposit
(94 cm) Wave-rippled and laminated, fine-grained sand, silt, and clay couplets ~30 cm thick.	Delta front storm deposits partly wave-reworked .
(46 cm) Laminated, salty, clay coarsening upward to silt and clay.	Pro-delta deposit due to silt and clay settleout.
(112 cm) Planar, cross-, and flaser bedded (at top), partly damp, medium-to fine-grained sand.	Distributary channel, bar finger sands, or mouth bar deposit
(46 cm) Climbing rippled, damp, fining upward fine-grained sand and silt.	Possibly a redistributed delta front deposit.
(445 cm) Wave rippled, cross-laminated to laminated, salty, fine-grained sand, silt, and clay couplets.	Delta front storm deposits partly wave-reworked .
(39 cm) Wave-rippled, damp, silt and clay (6 cm), overlain by 43 cm climbing rippled fine-grained silty sand	Pro-delta deposits and redistributed delta front deposits.
(500 cm) Structureless (?), dry, fine-grained sand. Cattails approximately 3 m down indicating a clay-rich bed.	Distributary channel, bar finger sands, or mouth bar deposit

Key

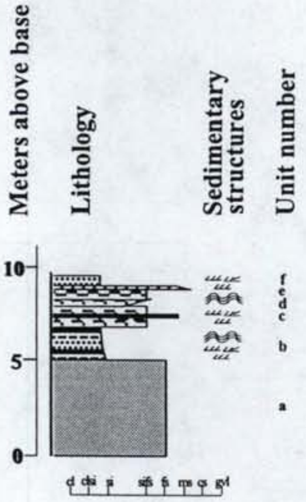
Sedimentary structures

lenticular bedding
)))) cross bedding
cross lamination
soft sediment deformation
≡ parallel lamination
current ripples
wave-ripple lamination
shrinkage cracks
flaser bedding
〰 oscillation ripples

Lithology and sedimentary structures

▦ cobbles and/or gravel
climbing rippled sand with/without silt
▭ planar bedded sand with/without silt
sand-silt-clay couplets
☰ laminated silt and clay
▨ cross-bedded or asymmetric rippled sand with/without silt
▒ structureless sand or silt
wave-rippled sand, silt, and/or clay

Stratigraphic Column #7



Description	Interpretation
(69 cm) Cross-laminated medium-grained sand fining upward to fine-grained sand. Flame structures at base. Overlain by cross-laminated, salty, medium-to fine-grained sand and silt couplets.	Delta front storm deposits
(52 cm) Wave-ripple laminated, dry, fine-grained sand and silt. Beds ~6 cm thick.	Possibly a redistributed delta front deposit or turbidite.
(31 cm) Climbing rippled, very indurated, coarsening upward, silt and clay grading to fine-grained sand and silt. Rip-up clasts at base of unit.	Distributary channel, bar finger sands, or mouth bar deposit
(113 cm) Climbing rippled, salty, fine-grained sand and silt. Cross-laminated medium-to fine-grained sand and silt within center of unit. Wave-ripple lamination at top of unit.	
(173 cm) Wave-rippled, laminated, and cross-laminated, fine-grained sand, silt, and clay couplets.	Delta front storm deposits partly wave-reworked .
(500 cm) Structureless (?), dry, fine-grained sand. Cattails approximately 3 m down indicating a clay-rich bed.	Distributary channel, bar finger sands, or mouth bar deposit

Key

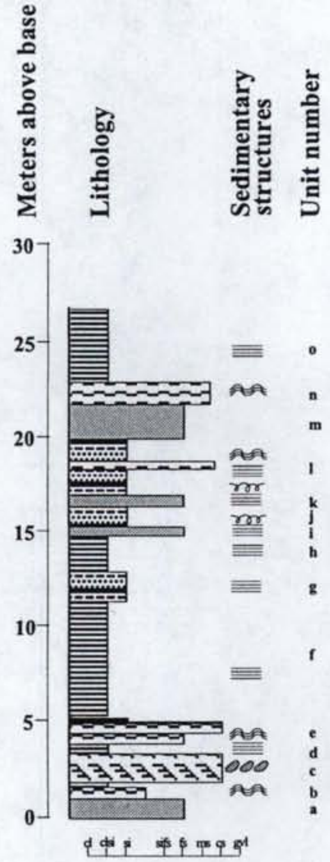
Sedimentary structures

- lenticular bedding
- cross bedding
- cross lamination
- soft sediment deformation
- parallel lamination
- current ripples
- wave-ripple lamination
- shrinkage cracks
- flaser bedding
- oscilation ripples

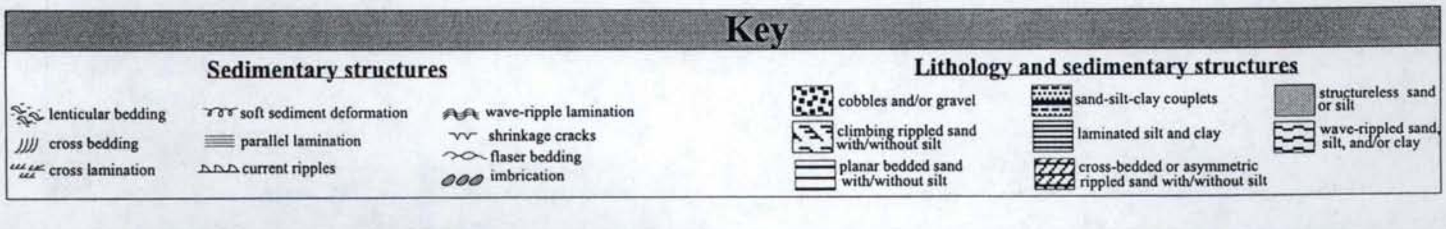
Lithology and sedimentary structures

- cobbles and/or gravel
- climbing rippled sand with/without silt
- planar bedded sand with/without silt
- sand-silt-clay couplets
- laminated silt and clay
- cross-bedded or asymmetric rippled sand with/without silt
- ▨ structureless sand or silt
- wave-rippled sand, silt, and/or clay

Stratigraphic Column #8



Description	Interpretation
(366 cm) Laminated silt and clay.	Pro-delta deposit due to silt and clay settleout.
(122 cm) Wave-rippled, dry, fine-grained sand.	Distributary channel, bar finger sands, or mouth bar deposit
(180 cm) Structureless (except planar beds at base), dry, fine-grained sand and silt. Calcite chips.	Distributary channel, bar finger sands, or mouth bar deposit
(299 cm) Laminated grading to wave-rippled, dry to damp, Fine-grained sand, silt, and clay couplets. Wave-rippled fine-grained sand in center of unit (erosive base). Convolute bedding at base.	Wave-reworked delta front storm deposits and a possible turbidity current..
(61 cm) Structureless fine-grained sand and silt.	Bar finger, mouth bar, or turbidity current deposit.
(107 cm) Laminated, fine-grained sand, silt, and clay couplets. Flame structures at base.	Delta front storm deposits.
(48 cm) Laminated to massive, dry to damp, fine-grained sand and silt.	Bar finger, mouth bar, or turbidity current deposit.
(188 cm) Laminated silt and clay (beds 2-5 cm thck). Sand interbeds within bottom 18 cm of unit.	Pro-delta deposit due to silt and clay settleout.
(156 cm) Laminated, damp, fine-grained sand, silt, and clay couplets (4 couplets).	Delta front storm deposits.
(635 cm) Laminated silt and clay. Sand interbeds within bottom 30 cm of unit.	Pro-delta deposit due to silt and clay settleout.
(129 cm) Wave-ripple laminated (climbing ripples at top) fine-grained sand and silt coarsening medium-to fine-grained sand.	Distributary channel, bar finger sands, or mouth bar deposit
(69 cm) Laminated, damp, silt and clay with sand interbeds within bottom 1/3 of unit.	Pro-delta deposit due to silt and clay settleout.
(147 cm) Climbing rippled, damp, medium-to fine-grained sand containing syndepositional thrust faults and imbricated clasts..	Distributary channel, bar finger sands, or mouth bar deposit
(84 cm) Wave-rippled silt. topped with laminated silt and clay.	Pro-delta silt deposit (reworked) and prodelta clay deposit
(104 cm) Structureless, dry, fine-grained sand and silt.	Distributary channel, bar finger sands, or mouth bar deposit



Point count data chart(in %)

MINERAL SAMPLE	Qmu (undulose)	Qs (straight)	Qp (polycrystalline)	plegeoclase feldspar	potassium felsdpar	calcite spar	siltstone	chert	mica	heavy minerals	porphyritic volcanic lithics
4-1 36' from base	39.2	5.4	10.8	0.6	6.4	25	2	0.2	0.4	0.6	9.4
4-5 129' from base	27.8	13.6	16.4	1	9.2	12	0.2	2	0.8	0	13.6
4-21B 163' from base	47.4	2.4	19	6	3.4	14	3	1.6	0	0	2.4
4-CC 205' from base	46.6	1.4	11.4	1.4	8	24.8	4.6	0.2	0.2	0.4	1.4
4-RR 243' from base	47.4	7.8	13.4	0.8	7.4	14.6	3.2	1.2	0.2	0.8	7.8
4-C 391' from base	41.8	6.8	11	1	7.6	21.6	1.6	0.6	1.2	0	6.8

Appendix 2 -
Point count data chart for 6 grain mounts collectd from the Bear River Delta within the Riverdale Cliffs.