Field Trip for RioMAR Consortium, 2011:

Maastrichtian Shelf Deltas and linked Deepwater Systems, Washakie Basin, Wyoming

Rawlins, Wyoming, October 14-17

Field Leaders: Cornel Olariu & Ron Steel, UT Austin

The objective of the fieldtrip is to examine outcrops of the coastal-plain, shoreline, shelf, and deepwater slope of the Maastrichtian, Washakie Basin in Wyoming and calibrate these to well logs and well-log correlations, thus building a 3-D image of the infill of the basin. In addition to examining the various sub-environments in outcrops, we will lay weight on how the deltaic supply system behaved on the shelf, and systematically built the Fox Hills-Lewis shelf-margin sedimentary prism. We will look at how sediment was sometimes stored on the shelf, sometimes bypassed the shelf break, and discuss how we recognize the location of the subtle (1 degree gradient change) but critical shelf edge to this system. Beyond the shelf break we will examine turbidite slope channels in outcrops and basin-floor fans in the well-log data. On the largest scale (basin fill scale) we will emphasize the clinoformal time lines that are used to correctly correlate strata, also enabling us to visualize the migration of landscape/seascape key surfaces across the lithostratigraphy of the basin. The clinoforms prograded at a rate of more than 40km/my.
PARTICIPANTS

PDVSA: Maria Mora & Paolo Discipleo
Woodside: Robert Seggie
Devon: Erik Kvale & Aaron Peterson
BG-Group: John Fisher
ENI: Massimo Rossi
Petrobras: Marco Moraes &
Shell: Ru Smith & Zoltan Sylvester
Piret Plink-Bjorklund & Fabien (CSM)
David Mohrig, Cornel Olariu & Ron Steel (UT)
Chris Armstrong, Josh Dixon & Anjali Fernandez (UT)

OVERVIEW SCHEDULE

14th evening: Meet up at Holiday Inn Express at east end of Rawlins. Introduction to the meeting and the fieldtrip

15th morning: Riomar Consortium talks

15th afternoon: Clinoform 9 and 10 topsets on the eastern side of the Washakie Basin

16th morning: Riomar talks/Business Meeting

16th afternoon: Lewis Slope channels at Dad

17th morning: Clinoform 9 on the western side of the basin at the Black Buttes Mine

17th afternoon: drive back to Denver

SAFETY INSTRUCTIONS
October 14th Overnight in Rawlings, WY, at Holiday Inn Express

Physical Address:
201 AIRPORT ROAD
RAWLINS, WYOMING  82301
United States

Business Phone:
1-307-324-3760 (main)
1-307-324-3762 (fax main)

Map with the location of the hotel (Rawlins) and the outcrops. Note the lower left scale is about 27 miles. The driving directions from Denver to Denver is taking about 4 hours.
Participants should inform the excursion leaders of any relevant condition that may affect their performance in the field. The main possible hazards during the trip are (1) driving, (2) falling (loose) rocks, (3) wildlife, and (4) temperature/humidity/wind.

(1) The traffic/driving in Wyoming is relative easy/relaxed, but please pay extra attention to truck traffic on highways. Drive slowly on dirt roads. The distances are relatively long (more than 100 miles per day) so if drivers feel tired we can switch drivers. We need **4-wheel drive vehicles** to be sure we can get out from some unpaved roads in case it rains. We will drive in convoy and make sure that at road bifurcations everyone takes the right road. On some occasions we will drive on unpaved roads that might be dusty (impairing vision to the cars behind), narrow with a lot of curves and in case of rain might be slippery. Extra attention is needed while driving on dirt roads. We will have Walkie-Talkie contact between cars.

At times we will stop by the side of the road. Please watch for traffic carefully both ways, even if it is a small less busy road.

(2) One or possibly two locations are close to high cliffs, and because of a very slight danger of falling rocks you will be asked not to approach the base of cliff unless you are wearing a hard hat. We will have to walk on uneven terrain, off the trail, and occasionally on inclined slopes. **Strong, good quality hiking boots with good ankle support** (sneakers/training shoes are not acceptable) are required! Please stay with the group and do not lag far behind along trails. If you have to walk over wet rocks (or soil) pay extra attention as these can be slippery.

(3) Wildlife is not a great danger in the area. However, like anywhere in nature there are some specific insects and animals that need to be avoided like fire ants, spiders, snakes, scorpions or coyotes. Please watch where you step or put your hands, and stay close to the group.

One specific problem observed in the area during field work (in June, July, August) was ticks (small parasites that suck blood). While these are not an imminent danger, you can get an infection. To avoid tick bites you should have long pants (also recommended against thorns, bushes) or use insect repellant.

(4) Temperature in Wyoming in October might be low with possible lows of below 10 degrees C and maximum occasionally can get to 30’s C. In general is very dry and windy but be prepared for changing weather. We recommend you to have a rain clothes, a hat, sunscreen and insect repellant. Because of the dry and windy climate you have to be sure you stay hydrated all the time. At most of the locations there is only a short walking distance (hundreds of meters) with
the exception of two days when we will walk about 2 km. Because we will be away from the cars for few hours, we recommend that you have with you some snacks and plenty of water (1-2l)

**Emergency**
We will have with us in the field a small safety kit. In case it is needed, the Emergency Phone in US is 911. Below are addresses to some of the hospitals. Our emergency plan in case of serious injury is immediate transport to the appropriate hospital:

**In Rawlins: Memorial Hospital of Carbon County**
2221 West Elm Street, **Rawlins,** WY 82301
Tel: (307) 324-2221
Emergency Room: 307-324-8386

110 miles: **Memorial Hospital of Sweetwater County**
1200 College Drive, **Rock Springs,** WY 82901,
Tel: (307)362-3711 or (307)875-7730

60 miles: **Ivinson Memorial Hospital,**
255 N. 30th Street, **Laramie,** Wyoming 82072,
Tel: (307) 742-2141 extension 2222

**General Geologic Field Safety Protocols (from SEPM)**

1. Field safety is a shared responsibility for which each participant is accountable. Your action to address a safety concern may save a life or prevent a hospital stay.

2. Observe and follow all safety warnings and instructions from trip leaders.

3. Participants should immediately inform the excursion leaders and, if appropriate, other group members of any safety concerns that arise.

4. Participants should inform the excursion leader (in confidence) of any relevant medical condition which may affect their performance in the field (e.g. asthma, diabetes, epilepsy, vertigo, heart conditions, back problems, allergies, medication requirements, etc).

5. Strictly adhere to any clothing/equipment/hydration requirements: these are essential safety requirements specific to the weather and terrain for each field excursion.

6. Do not leave the field party group without first informing a field excursion leader.

7. **Roadside Stops Protocols:**
   - Always be vigilant of traffic: avoid causing an obstruction, distraction or other danger to other road users.
   - On roads with infrequent traffic, alert others of approaching vehicles or cyclists.
   - Take steps to warn other road users of your presence. Wherever appropriate, wear reflective jackets and make use of warning triangles.
   - Remain behind safety barriers if present: only cross the road in a safe manner at an appropriate location.
   - Do not touch protective rock-fall netting on road-cut exposures: any movement could disturb loose rocks above.
8. Protocols for cliffs, slopes and rocky terrain:
   - Wear walking boots with good grip and proper ankle support to reduce chances of slips and sprains.
   - Check your footing: step carefully and continually assess footing.
   - Do not climb rock faces or unsafe slopes. Always be guided by the leaders for the safest routes up slopes.
   - Be aware of falling rock beneath steep or overhanging cliffs: hard hats must be worn in quarries. Avoid areas of the rock face that are heavily cracked, have recent debris at the base or are overhanging.
   - Avoid passing up- or down-slope of other members of the group (to reduce the risk from dislodging rock).
   - Take care not to dislodge rocks. If by accident you do dislodge loose material, shout loudly “ROCK” whether or not you are aware of others below.
   - Avoid passing others on narrow ledges and paths: be patient and walk in single file.
   - Be extra vigilant when a path leads to an area with high exposure.
   - Stay back from cliff edges and be aware of unstable areas near edges.
   - Be aware of the possibility that wildlife (birds, deer, etc) may dislodge rocks from above.
   - Wear walking boots with good grip and proper ankle support to reduce chances of slips and sprains.
   - Be aware of the risk of slipping on wet rocks, particularly rocks covered with seaweed or algae.
   - Be aware of the risks of tides, waves and currents.

9. Driving Protocols:
   - Seat belts must be worn at all times.
   - Drive safely and observe driving regulations and local laws (speed limits etc)
   - If driving in convoy, keep a safe distance from the vehicle in front and keep visual contact with the vehicle behind. When driving in convoy it is the responsibility of the vehicle in front to slow down or wait for the vehicle behind, rather than the vehicle behind feeling the need to keep up with the vehicle in front
   - The use of inexpensive FRS radios can be useful to maintain communication when driving in convoy, but as their range is limited (2 to 3 km) they should not be relied upon. Passengers, not the driver, should operate the radios.

10. Environment & Property Protocols:
    - Respect private property and machinery.
    - Do not litter: check area for left litter before leaving a site; encourage participants to leave the site cleaner than it was found.
    - Avoid undue disturbance to wildlife. In national parks it is the illegal to disturb wildlife and take flora.
    - Avoid use of geologic hammers. If you do need to hammer, warn others to stand clear and do not hammer indiscriminately. In national, state and provincial parks it is as a rule illegal to remove any material including rocks.
    - Refrain from making any unnecessary permanent marks on rocks.
General Introduction - Washakie Basin

The Maastrichtian succession of the Lance-Fox Hills-Lewis shelf-margin prism resulted from the final third-order shoreline regression of the US Western Interior (Winn et al., 1987, Pyles, 2000). During the early Maastrichtian the Washakie and Great Divide basins of southern Wyoming formed a sediment sink in response to Laramide uplift movements in the Wind River Range, Granite Mountains and Rawlins Uplift (Dickinson et al., 1988; Steidtmann and Middleton, 1991). Although at present these basins are separated by the Wamsutter Arch and each of them is an individual structural trough, during the Maastrichtian they constituted a large, single Laramide depocenter (Fig. 1). The basin filled under greenhouse (Miller et al., 2004), high subsidence (Hagen et al., 1985; Flemings et al., 1986; Shuster and Steidtmann, 1988) and high sediment supply conditions (Carvajal and Steel, 2006; Carvajal et al., 2009) during a 1.8 million year time interval.

The Maastrichtian infilling of the basin was driven by 16 transgressive – regressive cycles of sedimentation across the topsets of basinwide clinothems (Carvajal and Steel, 2006; Carvajal et al., 2009) each bounded and defined by regional marine transgressive surfaces (genetic sequences - Galloway, 1989) (Fig. 1). The fluvial-to-shelf-to-deep-marine deposits along the clinoforms form a lithostratigraphy composed of Lance Fm., Fox Hills Sandstone and the Lewis shale (Love and Christiansen 1985; Winn et al. 1987; Perman 1990; McMillen and Winn 1991).

The Lance Formation, more than 200 meters thick in the Rock Springs Uplift, is a coal-bearing paralic to alluvial-plain succession (Steidtmann 1993). The Fox Hills Formation represents a sand-prone shoreline-to-shelf succession and is up to 214 meters thick (Gill et al. 1970; Steidtmann 1993). The Lewis Shale is a slope to basin-floor succession (Pyles, 2000; Pyles and Slatt, 2000; Pyles and Slatt, 2002; Pyles and Slatt, 2007) and contains deepwater mudstones and turbidite sandstones (informally referred as the Dad sandstone) in successions up to 762 meters thick (Winn et al. 1987).

Sourced mainly from the north, the shelf-margin clinoforms prograded southwards at a high average rate (48 km/my) and filled the vertical accommodation of the basin at a rate of 267 m/my (Carvajal et al., 2009).
Figure 1. Geologic map of southern Wyoming showing the Washakie and Great Divide basins; outcrop exposures and well location (more than 800) are indicated (from Carvajal and Steel, 2009). A two-dimensional tracking of individual fourth-order cycles through the linked fluvial to shelf to deep-marine depositional system of the Lance Formation, Fox Hills Sandstone, and Lewis Shale is displayed on the NS cross-section (red line on the map).
October 15th afternoon. Clinoform 10 topset deposits

**Shelf deltas of Clinoform 10 on eastern side of the basin**

We will examine in detail the Lewis-Fox Hills shelf margin architecture over shorter time intervals within a single clinothem (fifth-order cycle) in terms of the dominant processes and sediment partitioning into various depositional environments from shoreline to shelf-slope break. An emphasis is placed on the deltaic complexes of the Fox Hills Formation through a detailed analysis of their facies, dimensions, orientation as they autogenically shifted during repeated cross-shelf transits.

![Figure 1](image-url)

*Figure 1. Location of the Fox Hills outcrops in the eastern part of the basin (red box in Fig. 1 from introduction)*

Outcrops of Clinothem 10 on the eastern side of the basin (Figs. 1, 2) show changes in the dominant depositional processes over short distances (3 km) as the deltas autogenically shifted from river- to tide-dominated to tidally influenced shelf-edge deltas with soft sediment deformation.
Figure 2. A) Interpreted sandstone isopach map of Clinothem 10, showing that the main accumulations of sand are on the basin floor, in the deltas, and in incisions feeding the fans; along most of the shelf edge, sandstone is 24 m thick, and even . B) Clinothem 10 outcrop to deepwater cross section showing fluvial deposits at the shelf edge (see also Figs. 6, 7), numerous slope channels, and abundant sand in deep-water fans (from Carvajal and Steel, 2009)
The proximal reaches of the outcrop display river-dominated delta-front deposits with foresets that dip basinwards at steep angles (up to 10-15) (Carvajal et al., 2009). The steepness may be due to a greater water depth in this near shelf-edge locality. The river-dominated delta-front deposits pass southwards (basinward) into coarser grained, but muddier strata. Heterolithic bedding, mud drapes and bidirectional dune foresets suggest a tidally influenced delta-front environment (Carvajal, 2007). Along the length of the outcrop a sandstone unit erosively cuts into underlying delta foreset strata. The delta foresets are mostly oriented basinward (S-SW) with subordinate dune foresets dipping landward. Locally organic matter drapes the foresets. At some outcrop locations there are logs of fossil wood pervasively burrowed by *Teredolites*. The southward reaches of the outcrop display spectacular, giant-scale soft sediment folded and slumped intervals. The erosively-based cross-stratified sandstone is interpreted as a fluvial channel, and the large-scale deformation possibly indicates nearness to the shelf-edge rollover or the river-channel’s entry to a canyon-head re-entrant (Carvajal, 2007). Paleocurrent directions measured on foresets indicate a progradation of the channel system towards the south–southwest. Subordinate mud drapes and landward-dipping foresets (N-NE), and *Teredolites* wood borings indicate tidal currents and a brackish setting.

Southernmost reaches of the outcrop, close to the shelf edge, exhibit two upward-coarsening and -thickening successions. The lower part of the outcrop displays a heterolithic interval with thin-bedded, wavy sandstones interbedded with mud. The upper part of the section is dominated by parallel-laminated and hummocky cross-stratified thicker bedded amalgamated sandstone. Locally deformed strata are present. Trace fossil diversity and abundance indicate deposition below fair weather base. Sustained wave erosion removed mud layers between sandstone beds. Soft sediment deformation suggests sedimentary loading due to rapid deposition (high sedimentation rates) along a steep wave-dominated delta front. Upward coarsening and thickening successions record the last pulses of delta progradation just before the turn around to transgression.
Figure 3. Facies and depositional environments in Clinothem 10 outcrop: A) bedding in proximal segments of clinoform set 1, B) flat lamination in set 1, C) currentripple cross-lamination in set 1, D) erosional surface truncating set 1 (valley base), E) trough cross bedding in fluvial channel, F) paleocurrent measures in fluvial channel (n = 25, corrected for structural attitude), G) tidal bars in estuary, and H) shell lags near the base of clinoform set 2. (from Carvajal and Steel, 2009).
Figure 4. Facies in Clinothem 10 (see Fig. 3 for legend) outcrop: A) bedding in tidal facies, B) thin mud drapes on foresets, C) mud drapes on ripples, D) paleocurrents in tidal facies showing strong eastward trend parallel to the shoreline (n = 32, corrected for structural attitude), E) distal tidal facies, F) mud clast above erosional surface, G) convolute bedding in fluvial channel, a sign of proximity to the shelf edge, and H) valley base in distal outcrop area. (from Carvajal and Steel, 2009).
Figure 5.—Cross sections through the outer-shelf to shelf-edge area: A) Clinothem 9 showing a highly continuous sandstone belt composed of relatively smooth, gradually decreasing gamma-ray motifs (i.e., funnellike), interpreted to represent a storm-wave-dominated shoreline; B) Clinothem 10, showing thinner and much less developed funnels that pass upwards, often sharply, to more blocky patterns (logs 4–13); the outcrop indicates that the transition occurs at a surface of fluvial erosion, interpreted to be the base of an incised valley.
Figure 6. Outcrop photomosaic and facies photos. A. Photomosaic with the location of the fluvial, tidal and wave dominated deltas. The photomosaic is about 3 km long and the main sandstone is about 15 m high. B - Delta front foresets truncated by fluvial channel. C - Tabular bedded, flat laminated sandstone.
Figure 7. Stratigraphic measured section of clinothem 10 showing changes in facies associations along the 3 km outcrop (right is landward, left basinward).
Subsurface delta deposits of Clinoform 10 topsets

In the subsurface the deltas show multiple depocenters migrating from the inner to outer shelf most probably with some process change (Fig. 8). Note also on figure 8 that progradation rates of deltas (shoreline) are higher (5-10 times) than those of the shelf edge.
Figure 9. Strike-oriented cross-sections of clinocline 10 showing the transition of depositional environments from inner-shelf to the shelf edge A. (A’) Inner-shelf. Blocky or upward-fining log patterns suggest non-marine or delta plain character. Notice the low lateral continuity of sandstone on the inner-shelf B. (B’) Shelf-edge. Upward-coarsening log patterns suggest delta front or distributary-mouth bars. Notice the high lateral continuity of sandstone as the shelf edge is approached C. (C’) Slope. Muddy slope with scattered sandy channels.
Figure 11. Comparison of the shelf depocenter locations and sediment fairways between clinoform 9 and clinoform 10. A - Net sand map for clinoform 9 with location of the sediment paths. B - Net sand map for clinoform 10 with location of the sediment paths. C - Sediment routes from inner to outer shelf for clinoform 9. D - Sediment routes from inner to outer shelf for clinoform 10. The round circles are river drainages that discharge on the shelf.
October 16th afternoon. Examine turbidite slope-channel outcrops (Dad).

The outcrops of the Lewis Shale in the Dad area expose slope channels and unconfined turbidite sheets within the slope segments of the large scale clinoforms (see figure 1 from the introduction). From our correlation of the outcrops to the subsurface data, the channel and slope deposits could be part of Clinoforms 9, 10 or 11, most probably part of Clinoform 10 (Fig. 2).

Figure 1. The location of the turbidite deposits on the eastern outcrop belt, from Soyinka and Slatt, 2008. The same outcrop belt is exposing shallow water and non-marine deposits (clinoforms 9, 10,
Figure 2. Linkage between subsurface fans and deep water Lewis Fm. outcrops. The upper cross section is a structural section (using real depths) while the lower cross section is a stratigraphic section (drawn relative to the datum, Asquith Marker). It seems that outcrops in the Dad area are part of the clinoform 10 or 11 fans.
Figure 2. Paleogeography reconstruction according to Pyles and Slatt. (from Soyinka and Slatt, 2008).

Figure 3. Detail sketch of the slope channel outcrops in Dad area. Note that channel width is a few hundred meters.

Figure 4. Close-up of area K shown in Fig. 3B. Topographic map showing Spines 1 and 2, the channel sandstones (solid black areas), the three numbered measured sections (labelled 1, 2 and 3, with arrows), and the facies distributions (sheet and channel sandstones and thin beds). Structural dip is 12° towards the south-west. Star in lower right is the location of a regional benchmark used to position features in three-dimensional space.
Figure 4. Reconstruction model for the slope channels in Dad area. The model shows thick (70m) nested channel-levee complexes that overlie thin sheet-like slope deposits.

Figure 5. Depositional model for the Dad Sandstone Spine 1 to 2 area. Two sheet sandstones that outcrop there are shown as two light grey bands underlying the levéed channel deposits. Figure modified from Slatt et al., in press.

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<tr>
<th>Scales of heterogeneity</th>
<th>Dimensions</th>
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<td>(I) Levéed-channel system</td>
<td>1–2 km wide</td>
<td>Channel complexes separated by levées; not connected.</td>
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<tr>
<td>(II) Levéed channel complex</td>
<td>0.5 km wide; 50–70 m thick</td>
<td>Channel sands not connected.</td>
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<tr>
<td>(III) Levéed-channel sand</td>
<td>&lt;0.5 km wide; 3–12 m thick</td>
<td>Internal variability in facies and reservoir quality.</td>
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Figure 5. Slope channel deposits (Spine 1) in Dad area. Note the mudstone conglomerate at the base of the channel (lower left side of the photo).
Figure 6. Alternation of the mud-clast conglomerate beds with sandstone beds at the base of the slope channel.

Figure 7. Detail of the mud-clast conglomerate at the base of the channel. Note the erosive base of the sandstone beds.
October 17th all day. Fluvial deposits of Lance Fm. and traverse through Fox Hills storm-wave dominated shorefaces (Clinoform 9) of the western segments of the basin

**Stop 1: Fluvial deposits of Lance Formation**

Non-marine Lance Formation interfingers with the shoreline deposits of the Fox Hills sandstone and is building large scale clinoform topsets. In any one sequence the non-marine topsets are usually less than 50 m thick. The deposits are represented by fluvial channels and overbank deposits sometime with high organic-matter content. We will examine a thick sandstone unit with a sharp base (fluvial channel) that overlies organic mudstones and other overbank deposits (Figs. 1 and 2).

![Figure 1](image.png)

**Figure 1.** Fluvial channel of Lance Fm. at Black Buttes Mine. Note the sharp base of the sandstone unit. The cliff is about 6-7 m thick.
Figure 2. Fluvial channel of Lance Fm. Note the dm thick rippled sandstone encased within muds below the fluvial channel. The thin sandstone represents crevasse splay deposits. Note the channel unit that is about 5-6 m thick contain multiple sandstone units.

Figure 3. Dm thick cross-stratified coarse sandstone with mud clasts and pebbles. The photo is taken at the base of the channel form the previous figure.
The channel contains stacked cross-strata that are very coarse grained and contain pebbles (Fig. 3). Multiple bar units can be distinguished within channel. Paleo-currents are oriented toward east-southeast. More mapping is necessary to define the planview morphology (fluvial style) of the Lance channels, but from this outcrop it seems the channel pattern is braided due to the lack of lateral accretion deposits.

Figure 4. Organic-rich shales as part of the overbank deposits. The carbonaceous shales are alternating with thin (sub-meter) crevasse-splay sandstone beds.

**Stop 2: Traverse through storm-wave dominated western segments of Clinoform 9**

The topsets of clinoform 9 are exposed in large continuous outcrops on the western side of the basin in the Black Buttes Mine area. The outcrops expose several stacked parasequences, each about 20-30 m thick. The dominant sedimentary structures are ripple-lamination of the thin cm to dm thick sandstone beds and amalgamated hummocky cross-stratification sandstone beds (Fig. 5) that form a few meters thick sandstone cliffs. Marine trace fossils such as *Ophiomorpha*, *Planolites*, *Piscichnus*? are commonly present. The predominant, thickest part of the section is represented by hummocky cross-stratification suggesting a highly energetic environment dominated by storm waves. At the base of the thick HCS dominated sands there are coarsening and thickening upward deposits suggesting overall progradation (Fig. 5). Based on the facies and the overall succession these deposits are interpreted as shoreface ‘lobes’ of a storm-wave dominated delta.

At the top of the second parasequence an interval with oxidation crust (red in color) and calcite indicate subaerial exposure and suggests the possible presence of a sequence boundary. Above that surface the deposits are dominated by bi-directional cross-strata, cross-strata with mud drapes, and are in general more heterolitics than the underlying thick sandstone beds. These
deposits were interpreted as transgressive, tidal estuary depositional environments. The very top of the tidal unit is dominated by 3D cross strata which at the top have plant root structures preserved (Fig. 5). Above the estuary unit a few meter thick non-marine muddy interval suggest a swamp/marsh environment (behind the shoreline). At the very top a small 2-3 m thick coarsening upward unit is interpreted as bayhead delta.

Figure 5. Vertical section and facies photo of the clinoform 9 deposits on the western side of the basin (Carvajal and Steel 2009).
Figure 6.—Transects through Clinothem 9 (see red lines in inset maps for location): A) cross section from the shelf edge to the slope and basin floor, showing a well developed sandy shoreline at the shelf edge and a muddy slope and basin floor with only thin sands (thick sands below Clinothem 9 are the lateral margin of an older fan fed from the center of the basin); and B) cross section through the shelf-edge outcrop, showing a stacking of wave-dominated deltaic parasequences followed upwards by estuarine and swamp deposits. Both cross sections show a lack of any shelf-edge and slope incisions linked with the wave and tidal deposits of the shelf. Instead, there are thin hummocky beds and scarce turbidites.
Figure 8. Strike-oriented cross-sections of clinothem 9 showing the transition of depositional environments from inner-shelf to the shelf edge and slope positions A. (A’)
Inner-shelf. Blocky or upward-fining log patterns suggest non-marine or delta plain character. Evidence of lobe switching is suggested by multiple sand depocenters. Notice the low lateral continuity of sandstone on the inner-shelf. Delta complexes have a likely autogenic compensational stacking pattern. B. (B’) Shelf-edge. Upward-coarsening log patterns suggest delta front or distributary-mouth bars. Notice the high lateral continuity of sandstone as the shelf edge is approached C. (C’) Slope. The slope is muddy with scattered sandy channels which acted as conduit to bypass sediment to deep water.
Figure 7. Net sandstone maps of the topset deposits of clinothem 9 Inner-shelf deltas (C9_L1) display a lobate-elongate geometry suggesting fluvial dominated and/or tidally influenced deltas. There are coeval delta lobes (A-E) suggesting multiple rivers. Mid-to-outer shelf deltaic complexes (C9_L2) have a dip-elongate pattern suggesting a fluvial-dominated control. Younger deltaic complexes build strike-extensive sandstone belts at the shelf edge suggesting a wave-dominated control. The last net sandstone map indicates the main accumulations of sand on the basin floor in deep-water fans (from Carvajal et al., 2009).