FACIES ARCHITECTURE OF SHALLOW MARINE DELTAIC SEDIMENTS AND ASSOCIATED CHANNELS IN A STORM-DOMINATED ENVIRONMENT, TURONIAN FERRON SANDSTONE, UTAH

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Abstract:

Numerous facies architectural reconstructions of the Turonian Ferron Sandstone have been generated in previous well-documented studies. This study's focus is to analyze the facies architecture of shallow marine deltaic sediments in Parasequence 5a of the Ferron as well as analyze the extent of fluvial influence within the marine deposits. Preliminary studies examining the fluvial influence within delta front sandstones have interpreted the channels as distributary channels, but several more recent evaluations show previously interpreted distributary channels as being multi-storey incised valley fill deposits. In this study, architectural elements will be determined using data from ten detailed stratigraphic logs, paleocurrent measurements, and bedding thicknesses. Stratigraphic logs were measured on a centimeter to meter scale and have been digitized in Adobe Illustrator. The area of study where sedimentological data was obtained was in the southern region of the Ferron Sandstone in Hanksville, Utah (Figure 1). The Ferron Sandstone comprises a portion of the Notom Deltaic Complex, which was present in the Cretaceous Western Interior Seaway during the Turonian (Figure 3). Future work involves the construction of bedding architecture diagrams and upon completion, architectural elements will be identified, making it evident whether the fluvial channels cutting into the marine sediments are single-storey or multi-storey. This study focuses on smaller-scale analysis of facies architecture in Parasequence 5a to investigate channel deposits that have previously been interpreted as shoreface deposits lacking the degree of fluvial influence that has now been examined in this research.

Introduction:

Deltaic systems are regressive in nature and always include a river-influenced component. They generally pass through several cycles of progradation and abandonment primarily driven by episodes of river avulsion that result in the growth of new delta lobes. (Bhattacharya, 2006). Avulsions control channel location and the degree of sediment distribution. These avulsions can be local where they only affect a small portion of the delta, as is the case with terminal distributary channels, which are also associated with mouth bar assemblages (Olariu & Bhattacharya, 2006). Terminal distributary channels are single-story deposits, representing the most distal channelized feature as well as the most active part of the channel system (Olariu & Bhattacharya, 2006). It has been hypothesized that terminal distributary channels are rarely incised (Olariu & Bhattacharya, 2006). Historically, channel facies within delta front sandstones were interpreted as distributary channels, whereas recent studies conducted on shallow marine, fluvial-influenced deltas now have more in depth interpretations distinguishing channels as either incised valley fill deposits or distributary channels (Bhattacharya & Walker, 1992; Bhattacharya, 2006). This idea is supported by interpreting preserved multi-story channels as incised fluvial filled deposit, showing rivers preserve sediment during falling stages of sea level when sediment may be stored in a compound valley (Li and Bhattacharya 2013).

The majority of modern deltas have been classified as foreset-dominated, meaning that their underlying foresets are thicker than the overlying topsets (Edmonds et al., 2011) (Figure 2). However, depositional environments such as distributary channels, interdistributary bays, and river mouth bars have been recognized as being characteristic of topset-dominated deltas based on models in which the channel depth to basin depth ratio is greater than or equal to 1 (Edmonds et al., 2011). The topsets thin basinward as the delta progrades. Topset deltas are formed in basins with shallow slope and depth, therefore it is important to study shallow marine deltaic deposits in more detail to distinguish topset deltas from foreset deltas. This study will help elaborate on the differentiation of distributary channels and incised valley fill deposits as well as evaluate facies models of topset-dominated deltas in the Ferron Sandstone Member of the Mancos Shale Formation in Utah.

Objective:

The primary focus of this project is to document and analyze the detailed facies architecture of shallow marine, fluvial-influenced deposits of the Ferron Member to evaluate the presence of either multi-storey channels or single-storey channels. Distinguishing the channel type will assist in establishing whether the Notom delta is topset dominated or foreset dominated. Determining the extent of channels will be useful in calculating ancient river depth, width, paleodischarge, and mean flow velocity, which will be calculated by utilizing measurements of crossbed thickness, bar heights, and storey thickness. An in-depth facies and stratigraphic analysis will also be conducted to determine the depositional environment of the sediments. Additionally, measuring crossbed and ripple paleocurrents will help determine the direction of sediment transport as well as flow mechanism.

Literature Review:

Geologic Study Area

The Ferron Sandstone Member of the Mancos Shale Formation consists of fluvio-deltaic sediments deposited in the Western Cretaceous Interior Seaway during the Turonian age (Figure 3). The Ferron lies between the Blue Gate Shale Member above and the Tununk Shale Member below (Zhu et. al, 2012; Alaboud, 2014). Three deltaic complexes including the Vernal, Last Chance, and Notom Delta have been identified in the Ferron Sandstone and evidence shows that the Ferron was deposited in a humid, ever-wet and subtropical climate (Akyuz et. al, 2015; Li et. al, 2013). The specific area of focus is in the Southern Ferron Sandstone located in Southcentral Utah.

Terminal Distributary Channels vs Incised Valley Fills

Terminal distributary channels occur at the terminal end of a distributive channel system, representing the most active part of the channel network. They are common in shallow water, fluvial-dominated delta front deposits and range from a few meters to hundreds of meters in width and 1m-3m in depth (Olariu & Bhattacharya 2006). They are typically found in association with mouth bar assemblages as seen in *Figure 4* and form in three phases. In phase one, subaqueous channel levees are extended, the channel is widened and the flow begins to bifurcate. In phase 2, mouth bar growth and migration begins forming the terminal distributary channels at a variety of scales. Phase three involves accretion of mouth bars and filling in of terminal distributary channels, which decreases the flow velocity as well as the sediment discharge in the channel causing abandonment and diversion of flow to other channels (Olariu & Bhattacharya, 2006). Distributary channels can be easily identified as they become smaller downstream because the discharge and sediment load get progressively smaller as channels bifurcate. River-dominated deltas can contain hundreds of distributary channels, whereas wave and tide-dominated deltas contain significantly fewer channels.

Preliminary studies have been conducted to reconstruct the paleogeography of Parasequence 5a of the Ferron Sandstone Member to illustrate the pattern of distributary channels (Li et. al, 2014) (Figure 5). This study proposes facies architecture analysis that will help elaborate on the distribution of these channels, specifically in exposures farther South, where the paleogeography of Parasequence 5a has been interpreted as solely shoreface deposits.

Interpreting the bedding architecture of the fluvial channels discovered in this area will provide further detail and perhaps show that the channels in the Notom Delta are substantially more extensive than previously mapped.

Previous research studies have interpreted channel facies overlaying delta front sandstones as distributary channels (Walker & Bhattacharya, 1992). In more recent studies, previously interpreted distributary channels have been reinterpreted as multi-storey fluvial channel deposits corresponding to incised valley fill deposits (Bhattacharya, 2006). An incised valley is defined as “A fluvially eroded, elongate topographic low that is characteristically larger than a single channel, and is marked by an abrupt seaward shift of depositional facies across a regionally mappable sequence boundary at its base” (Boyd et. al, 2006). It is hypothesized that incised valley are formed from erosion governed by processes related to relative sea level fall, although it is possible that climatically-induced factors may also cause incision (Boyd et. al, 2006). Deposition of fluvial sediments occurs at the mouth of the incised valley system once sea level has reached its lowermost point. Deposition continues as transgression occurs, producing onlap (Boyd et. al, 2006). This study aims to analyze base level change and the shoreline trajectory patterns to determine the extent of the fluvial channels and to determine whether they are multi-storey or single-storey. Previously identified mega-valleys have been illustrated in a strike oriented cross-section of the Ferron Notom deltaic complex (Figure 6) (Li et al., 2011). This study will evaluate additional smaller distributary channels and/or incised valley fill deposited that have not yet been recognized in Parasequence 5a. Comparing the depth of the channels to that of the sandstone will assist in the identification of these deposits.

Topset Dominated Deltas

According to first-order stratigraphy models it has been assumed that deltaic systems have thicker foresets and should be classified as foreset-dominated in nature (Edmonds et al., 2011) (Figure 2). This model has been applied to ancient deltas as well as modern deltas. A recent study shows that this is not always the case as it is possible for the topset beds of a delta to be thicker than its foresets and is actually very common in modern deltas (Edmonds et al., 2011). Topset-dominated deltas are characterized as thinning basinward, as the delta progrades into deeper water, and have variable stratigraphy in comparison to foreset-dominated deltas that thicken basinward (Edmonds et al., 2011). The model proposed in the 2011 study suggests that if the calculated channel depth to basin depth ratio is greater than or equal to one, the delta is topset dominated. This model takes into account numerous variables, such as basinward distance (x), initial basin depth where the river switches from confined to unconfined flow (d_0), and slope (s) when calculating the depth of the water basin (Edmonds et al., 2011). Topset-dominated deltas have also been identified as being more common on low-slope passive margin coasts with shallow water depths, also characteristic of many deltas (Edmonds et al., 2011). They are also common in landward positions, so it is possible for a delta to be both topset-dominated landward and foreset-dominated where the delta is more seaward. The proposed study in the Southern region of the Ferron Sandstone aims to elaborate on the differentiation between deltas being classified as topset-dominated or foreseset-dominated by evaluating the channel dimensions in bedding architecture diagrams.

Methodology & Analysis:

Stratigraphic data was obtained from opposite-facing cliffs in the southern region of the Ferron Sandstone in Hanksville, Utah. Ten detailed stratigraphic logs containing shallow marine sandstone and shale beds as well as fluvial-influenced sandstone and shale beds were measured on a centimeter to meter scale (Figures 7 and 8). Analysis of detailed measured sections was conducted to examine the lithology, grain size, sedimentary structures, bedding thickness, ichnofauna, and paleocurrent flow of each rock facies. Stratigraphic data was obtained by walking out the sections and measuring the vertical facies successions using a hand lens and grain size card to obtain lithology and grain size. A Jacob's staff was used to obtain height measurements of the vertical facies succession covered by sloping sediment. A Silva compass was utilized to capture paleocurrent flow direction that was used to identify dominant flow directions. Gigapan imagery was captured to obtain high resolution gigapixel images to aid in correlating facies successions. Additionally, this imagery will be useful to construct facies bedding architecture diagrams to analyze elements such as channels and potential bar features.

Firstly, analysis was conducted by scanning stratigraphic sections onto the computer and importing the images into Adobe Illustrator where stratigraphic columns were digitized using the drawing tools with respect to Gigapan imagery. Subsequent steps will involve constructing correlation profiles and bedding architecture diagrams using techniques from Miall (1985). Further analysis includes determining the size and extent of fluvial channels as well as to analyze and interpret system tracts (Posamentier & Vail, 1988).

Timeline:

The timeline for the research project is illustrated in *Table 1*. Field work was conducted in Hanksville, Utah for approximately one month and was completed by mid-July 2015. Digitization of the ten stratigraphic logs in Adobe Illustrator was commenced in the field and was completed at home by the end of August 2015. The research proposal was submitted for the beginning of October 2015 and the literature review will take approximately one month from that time to be completed. Simultaneously, bedding architecture diagrams will be constructed and will be done before the end of 2015. Upon completion of all diagrams and necessary analysis+, a draft of the thesis will be written and completed by the beginning of March 2015. After this, reviews and edits will be made and a full revised copy of the thesis will be ready for final submission in April.

Table 1: Timeline for Thesis Process.

Task	**Completion Date**
Field Work	June to July, 2015
Digitize Measure Sections	August 2015
Research Proposal	October 2, 2015
Literature Review	November, 6, 2015
First Draft of Thesis	March 4, 2016
Final Draft of Thesis	April 8, 2016
Research Day Presentation	April 11, 2016

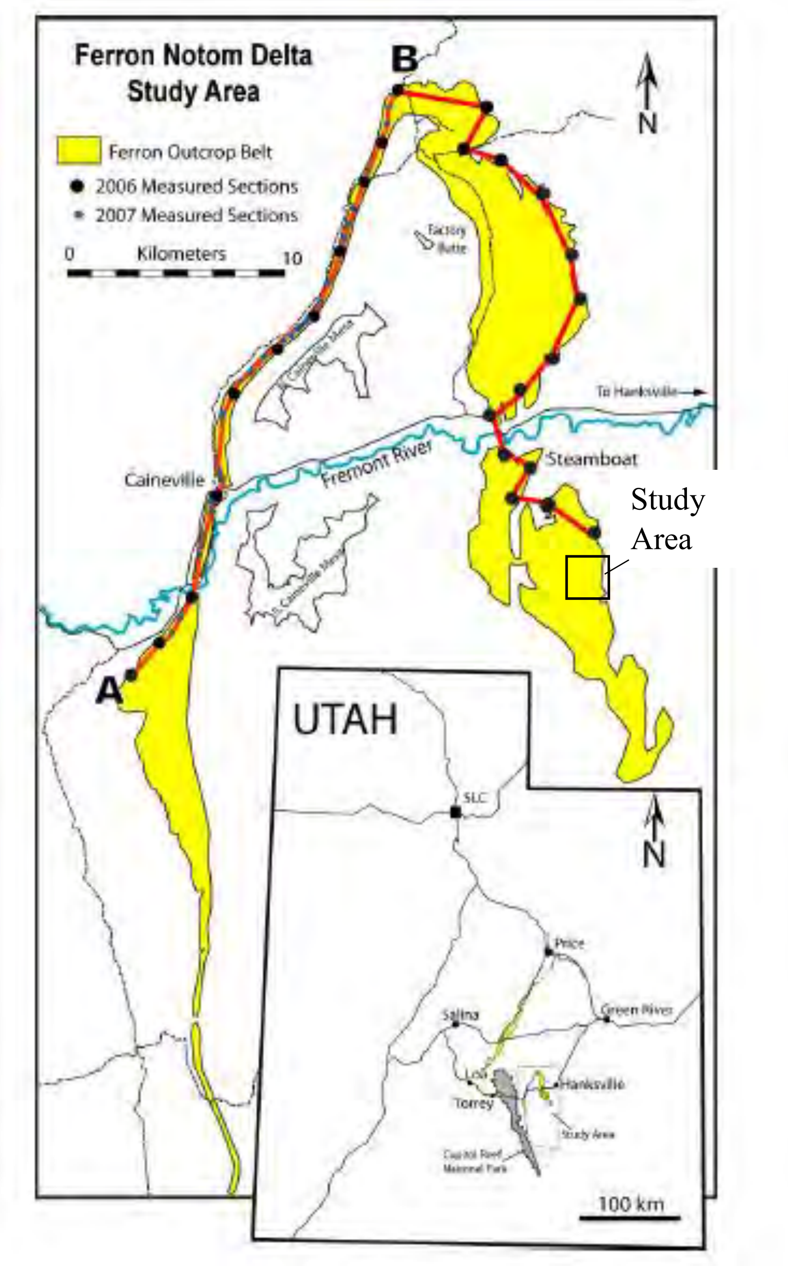

Figure 1: Study area in the Southern Ferron Sandstone, Hanksville, Utah.

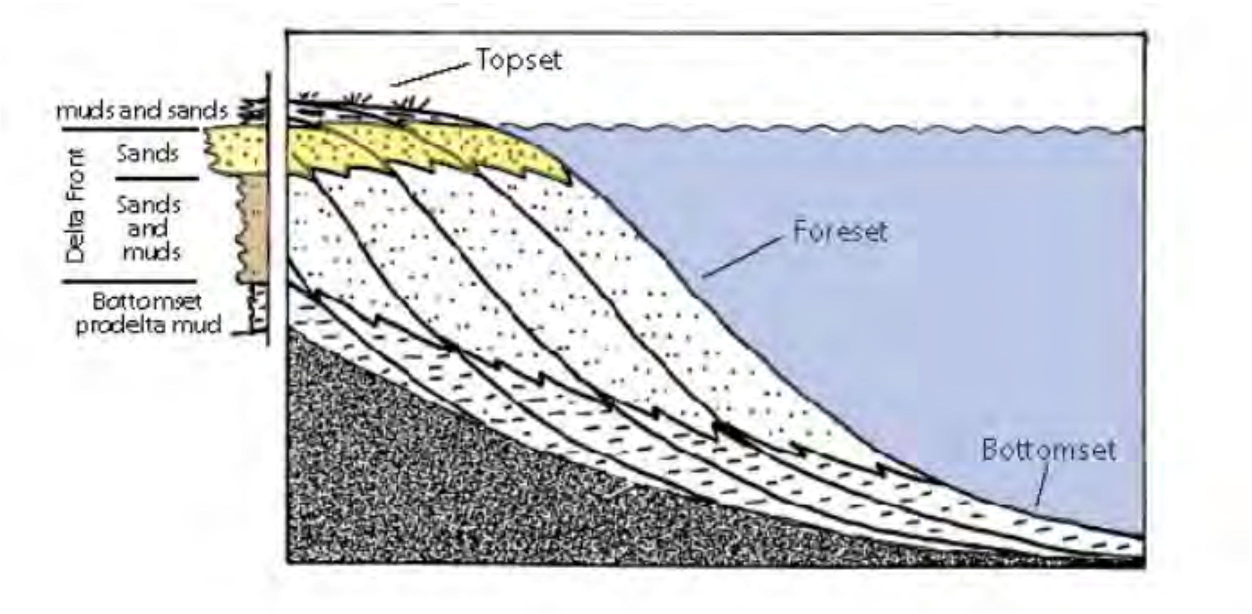

Figure 2: Stratigraphic body classification of various beds in a delta (Gani & Bhattacharya,

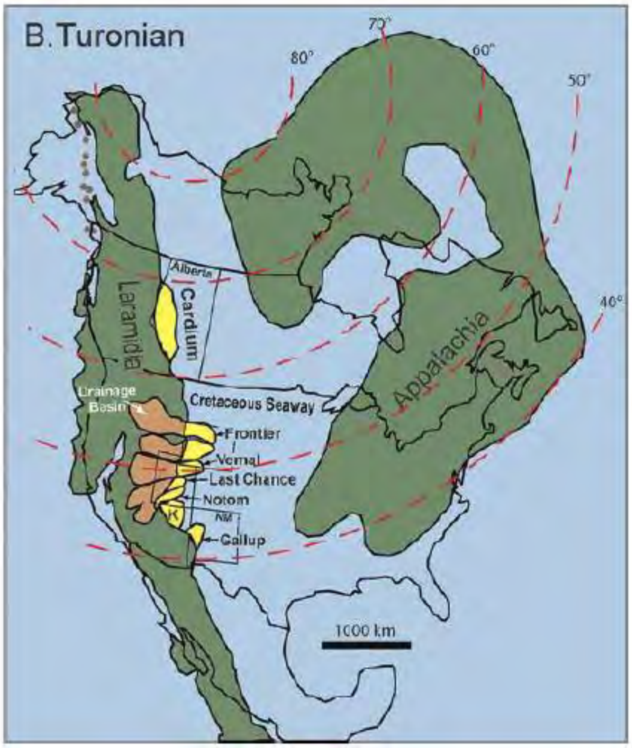

Figure 3: Map of Cretaceous Western Interior Seaway depicting the Ferron Deltaic Complex, which includes the Notom Delta which is the primary focus of study and contains the Ferron Sandstone Member. (Bhattacharya & MacEacheran, 2009)

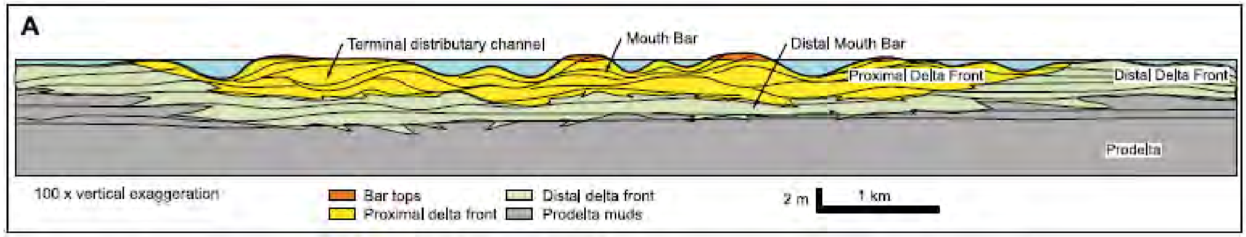

Figure 4: Terminal Distributary Channel in Shallow Deltaic Environment (Olariu and Bhattacharya, 2006)

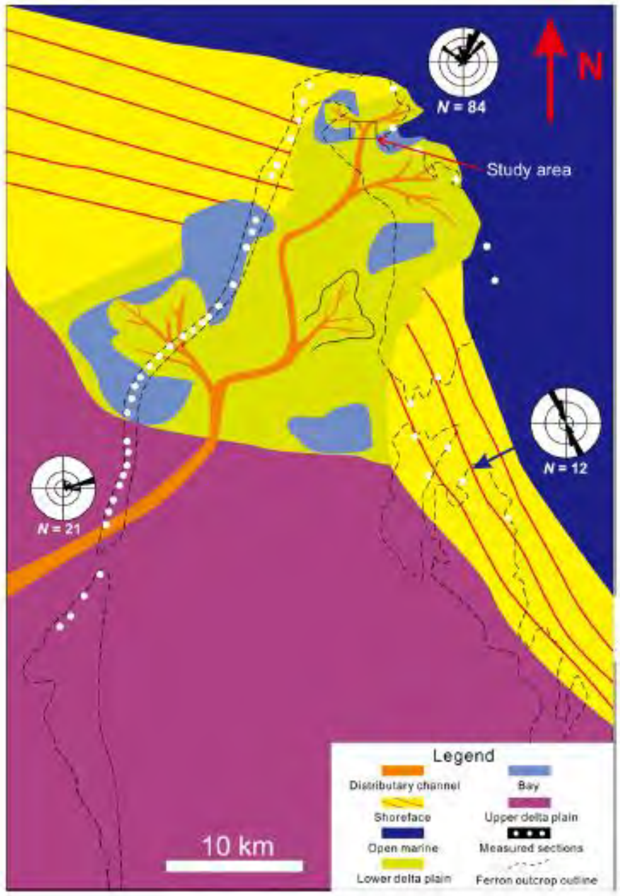

Figure 5: Paleogeographic reconstruction of parasequence 5a (Li et. al, 2014)

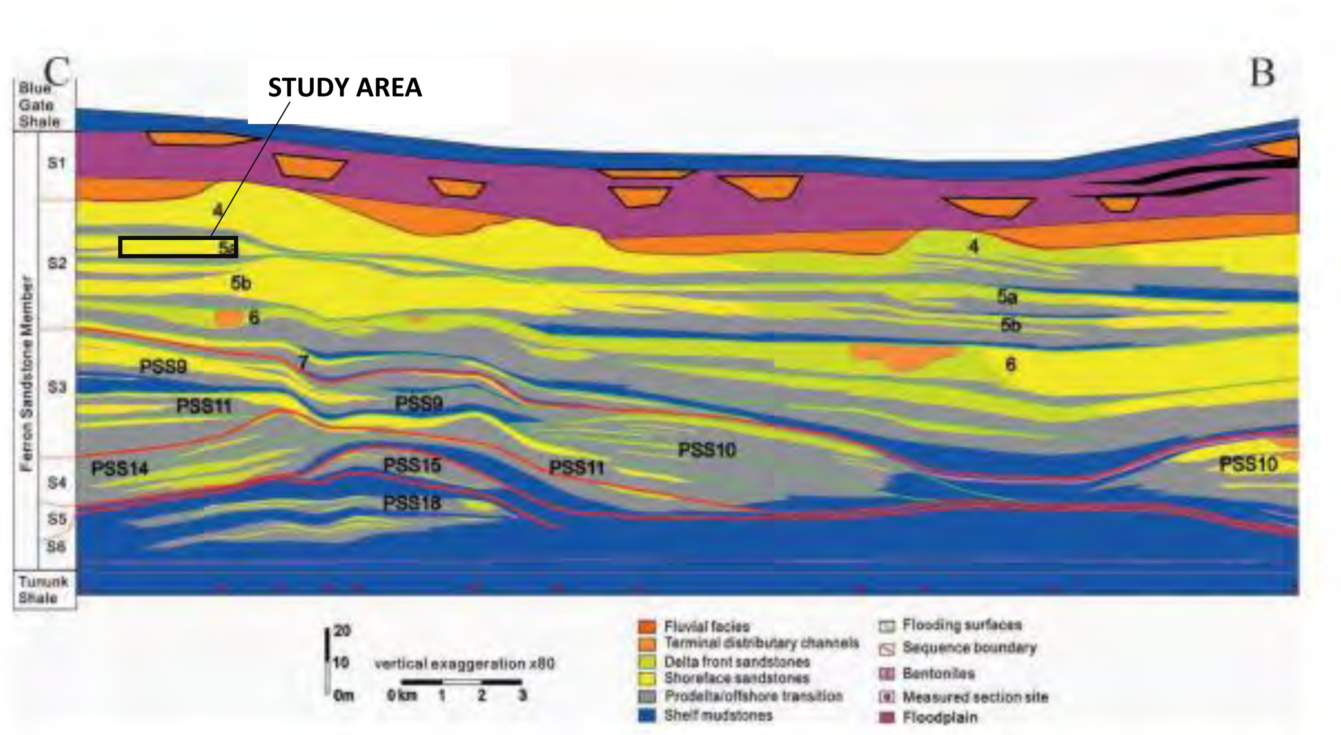

Figure 6: Strike oriented regional stratigraphic cross section of the Ferron Notom deltaic complex (Li et al., 2011). This also illustrates the study area of interest in Parasequence 5a.

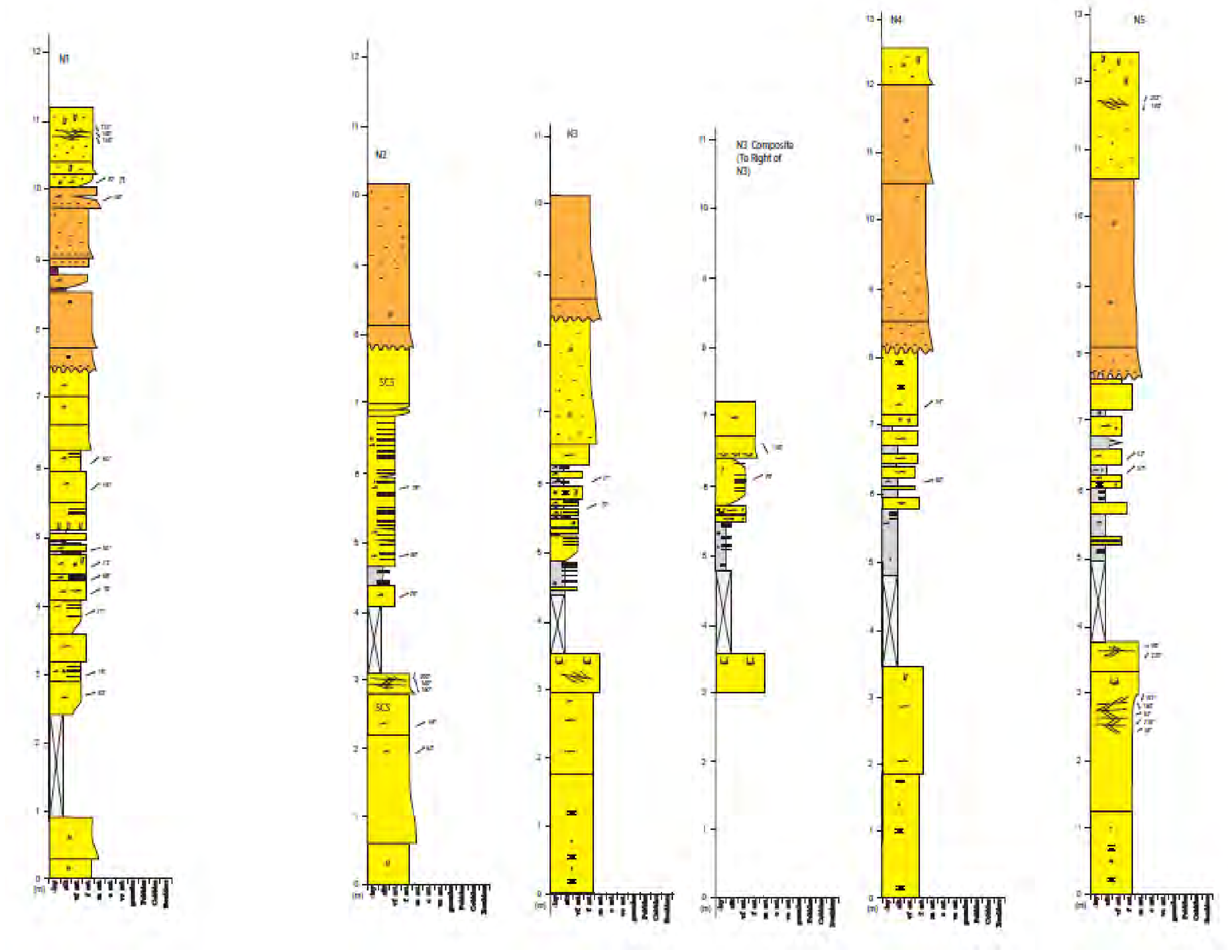

Figure 7: Six of the ten stratigraphic sections (N1-N5) measured and subsequently digitized in Adobe Illustrator.

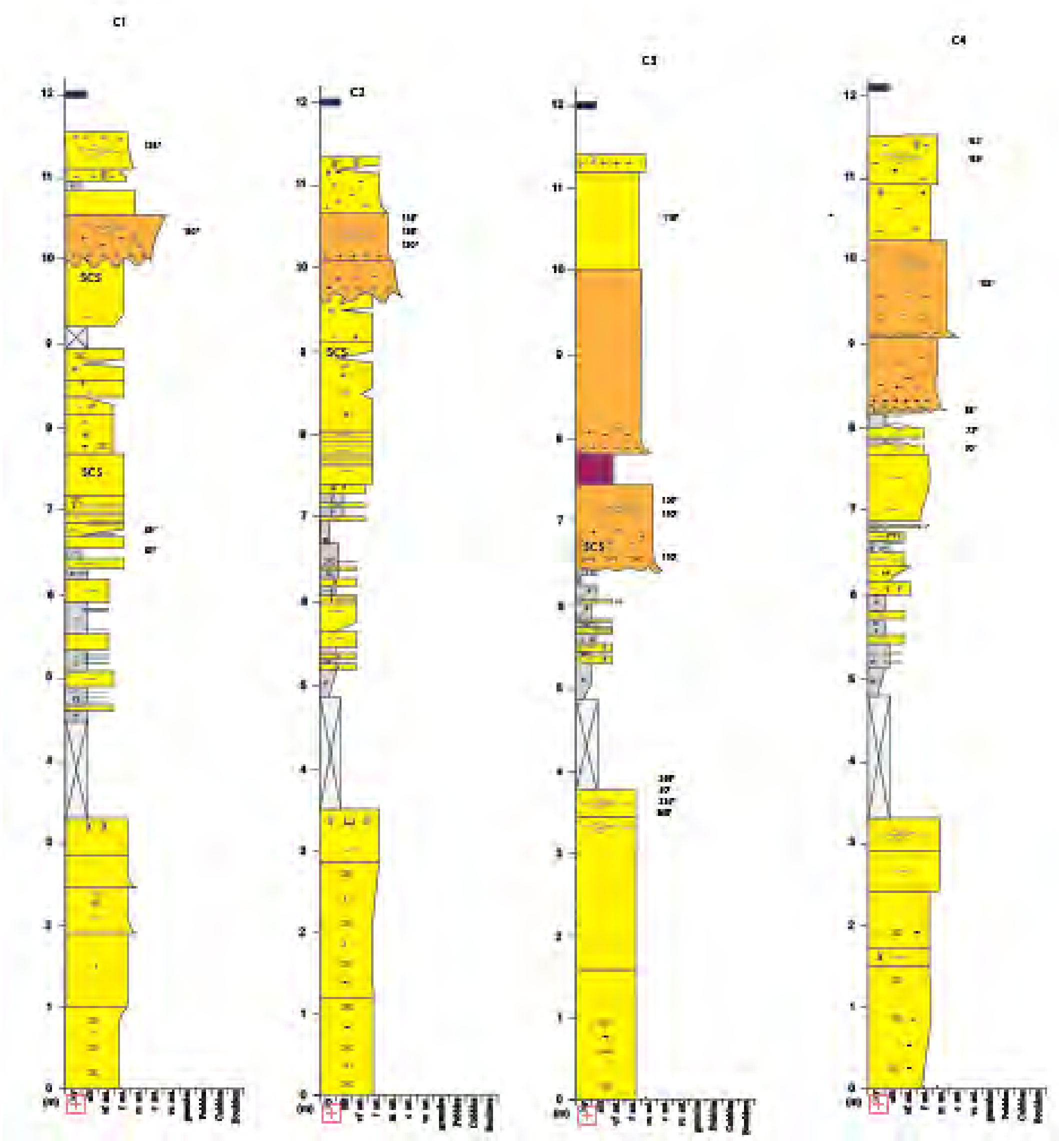

Figure 8: Four of the ten stratigraphic sections (C1-C4) measured on opposing size of the other six measured sections above; also digitized in Adobe Illustrator.

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