Sedimentary and Stratigraphic Analysis of the Viking Sand in the Edgerton/Wainwright Area, Central Alberta*

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Abstract

The Viking Formation was deposited within the Western Canadian foreland basin during Albian time, Early Cretaceous. This study examines the lithology, sedimentary facies, and stratigraphy of the Viking Formation in the Edgerton/ Wainwright area (NW corner 45-5W4 to SE corner 44-4W4) of central Alberta. The studied section is comprised of, in ascending order, marine offshore shales of the Joli Fou Formation, marine sandstones of the Viking Formation, marine shales of the Westgate Formation, to the Base Fish Scales Marker. within the Viking Formation. The Viking Sand unit was deposited as a thin sand sheet in a shoreface environment during a lowstand, related to a forced regression. In cores, the Viking Sand unit is demarcated by burrows in-filled with coarse-grained sediments beds of rip-up clasts and structureless sands lenses (up to 5cm). The base of the Viking Sand unit can be interpreted as a Regressive Surface of Marine Erosion (RSME) as coarse shoreface sands overlie offshore transitional sediments with a sharp contact between the two facies. During a following transgression, parts of the lowstand shoreface deposits became subsequently reworked and redistributed to form linear sand bodies (i.e., Viking Sand unit) trending NW-SE, creating a Transgressive Surface of Erosion (TSE). The TSE is overlain by offshore transitional sediments, which where deposited during a subsequent sea level stillstand. The upper boundary of the Viking Formation is a basin-wide Transgressive Surface of Erosion (TSE), marking the end of Viking deposition and onset of deposition of marine shales of the Westgate Formation.

Introduction

The Viking Formation was deposited within the Western Canadian foreland basin during Albian time, Early Cretaceous. The Viking Formation consists of the lower offshore transitional sediments, the Viking sand unit and the upper offshore transitional sediments. The Viking sand unit was deposited as a thin sand sheet in a shoreface environment during a lowstand, related to a forced regression. The base of the Viking Sand unit can be interpreted as a Regressive Surface of Marine Erosion (RSME) as coarse shoreface sands overlie the lower offshore transitional sediments. A transgression took place to end the deposition of the Viking Sand unit and consequently parts of the lowstand shoreface deposits (i.e., Viking Sand unit) were reworked and redistributed to form linear sand bodies trending NW-SE, creating a Transgressive Surface of Erosion (TSE). The TSE is overlain by upper offshore transitional sediments, which were deposited during a subsequent sea level stillstand. The upper boundary of the Viking Formation is

distinguished by a basin-wide Transgressive Surface of Erosion (TSE), marking the end of Viking deposition and onset of deposition of marine shales of the Westgate Formation.

Study Area

The study area is located in the Edgerton/Wainwright area in east-central Alberta from NW 45-5W4 to SE 44-4W4 (Figure 1). The study consists of data that have been collected from 397 well logs as well as core logs from 2 cored intervals from within the study area and 4 cored intervals from the immediately surrounding townships.

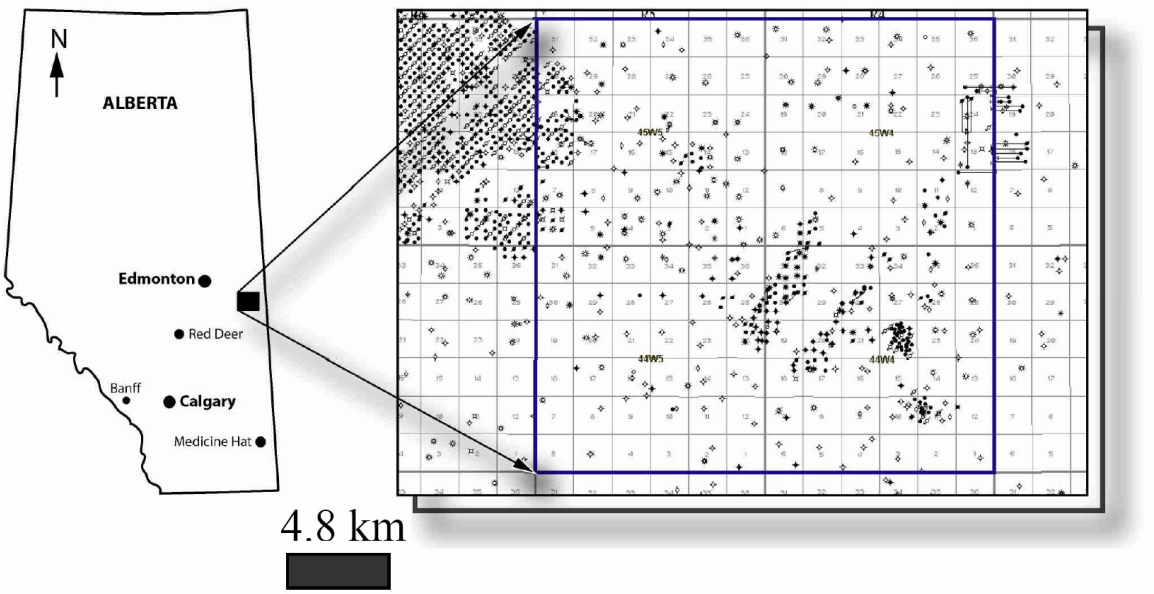

Figure 1. Location map of the study area.

Facies and Facies Associations

Five facies have been defined for the regional study area T44 to T45 and R4W4 and R5W4. These facies have been grouped into four facies associations, on the basis of dominant lithology.

Facies 1A: (Figure 2) Shales that are usually black or grey with abundant fish scales and minor plant debris near the top (Hein, 1986). Within the study area the shales range in thickness from 37m to 70m and average approximately 48m from the base of Fish Scales to the top of the Viking Formation. Intensive burrowing has lead to marine offshore shale that has the presence of very fine grained to silty quartz grains (Figure 2). Small rippled, very fine grained sandstones are sporadically interbedded within the shale. Sideritized units up to 12cm thick can also occur throughout this facies.

Facies 1B: (Figure 3) Offshore transitional shales that occupy the Viking Formation above and below the Viking Sand unit. Within the study area these shales average 14m in total thickness. There is sporadic pyritized plant debris, with moderate burrowing and an increase in the quartz amount found within the shale. The presence of small <2cm sized sand lenses with cross stratified bedding increase in abundance up in the succession, towards the Viking Sand unit.

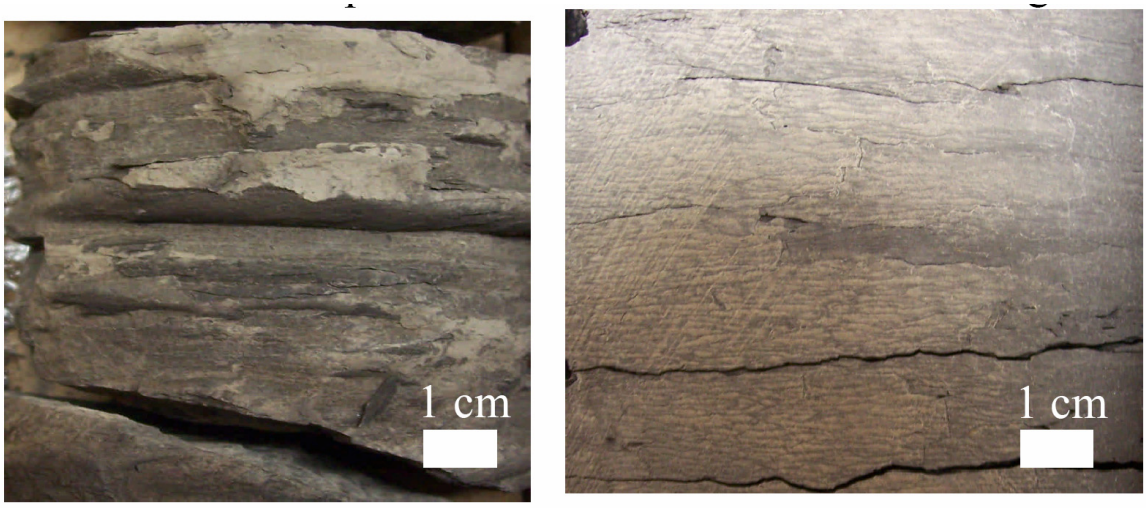

Figure 2. Left, black shale. Well: 11-35-44-6W4 @ 590.85m. Right, cross-sectional view of black shale, showing silty sediments in highly burrowed facies 1A. Well: 11-4-46-4W4 @ 572m.

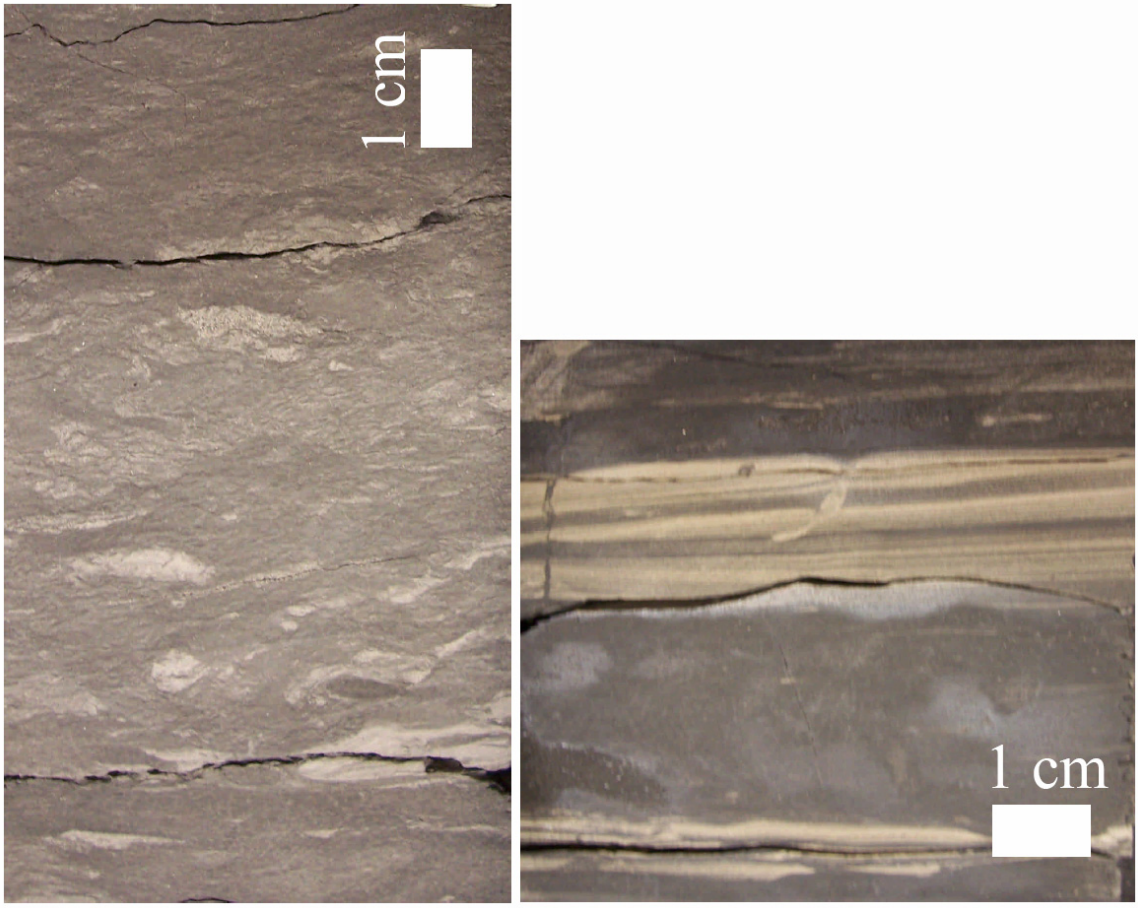

Figure 3. Facies 1B, Well ; 6-11-44-6W4. Left, (601.7m), shale intermixed with very fine sandstone. Right, (605.2m) showing 2-cm sand lens, interbedded sand and mud with presence of trace fossils.

Facies 1C: Joli Fou shale, lying below Viking Formation. Black to grey with massive texture, completely homogenous.

Facies 2: (Figure 4) Interbedded shale and fine grained sandstone. Contains argillaceous laminations with wavy to low angle sandstone lenses, with minor burrowing. Lenses range from 2 – 5cm in thickness. Sandstones are fine grained and contain a variety of low angle cross stratified sandstone lenses.

Figure 4. Facies 2 (well 6-11-44-6W4), indicating the fine-grained low-angle argillaceous cross-stratified sandstone lens @ depth of 606.3m.

Facies 3: (Figure 5) Muddy sandstone facies is characterized by laminated to structureless beds with fine to medium grained sandstones. Thinner sandstones are more heavily bioturbated while thicker sandstones have preserved low-angle cross-stratification. Thickness ranges from 0.8m to 2.5m, moving SE to NW respectively. In core samples the Viking sand unit can be demarcated by moderately bioturbated, upper very fine- to medium-grained sands, with porosities ranging from 5 - 30%.

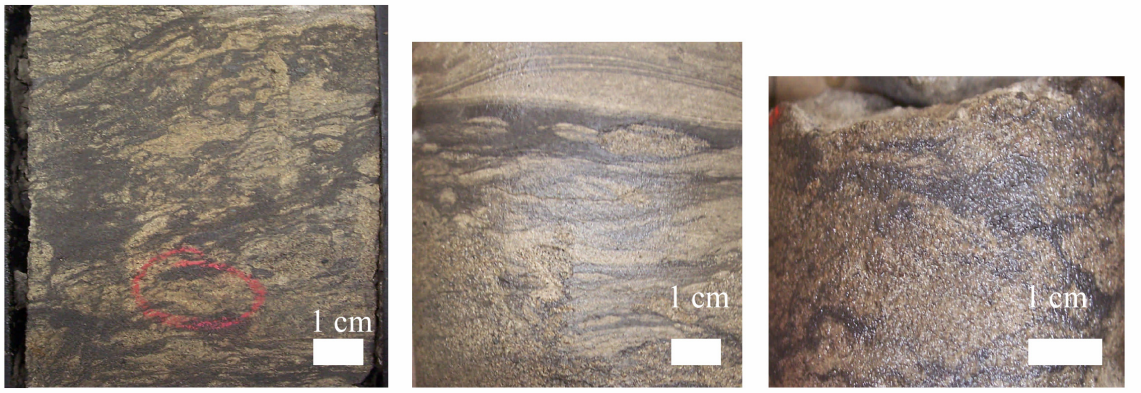

Figure 5. Facies 3, Viking Sand unit. Left, well: 6-11-44-6W4 @ 607.2m. Middle, well: 7-8-45-5W4 @ 539.3m. Right, well: 11-35-44-6W4 @ 596m. Thinner sandstones are bioturbated; thicker sandstones have preserved low-angle cross-stratification and lenticular bedding.

Facies Associations

Facies Association 1: Shale (Westgate Shale) contains subfacies 1A.
Facies Association 2: Fine-Grained Sandstone contains subfacies 1B and Facies 2.
Facies Association 3: Interbedded Sandstone and Shale contains facies 3.
Facies Association 4: Bioturbated Shale contains subfacies 1C.

These facies associations form a consistent vertical stacking pattern within the study area and follow the following general sequence:

4 → 3 → 2 → 1

Petrography

Four samples were taken for petrographic analysis. Three of the four were plotted in a triplot QFL diagram for classification (Figure 6) and are from the Viking Sand interval. Each sample was normalized using quartz, lithics, and feldspar content. The fourth sample analyzed was a mudstone that contained over 75% mud matrix and is found in Facies 1A. Sample RW-2 (Facies 3) normalized contains 59% Quartz, 39% Lithics, and 2% Feldspars, with 4% porosity. Mud matrix comprises 35% of sample RW-2. RW-3 (Facies 3) normalized contains 63% Quartz, 36% Lithics, and 1% Feldspars with 8% porosity, while the mud matrix comprises 28% of this sample. RW-4 (Facies 3) normalized contains 65% Quartz, 32% Lithics, and 3% Feldspars with 4% porosity. Mud matrix on the order of 40% comprises sample RW-4.

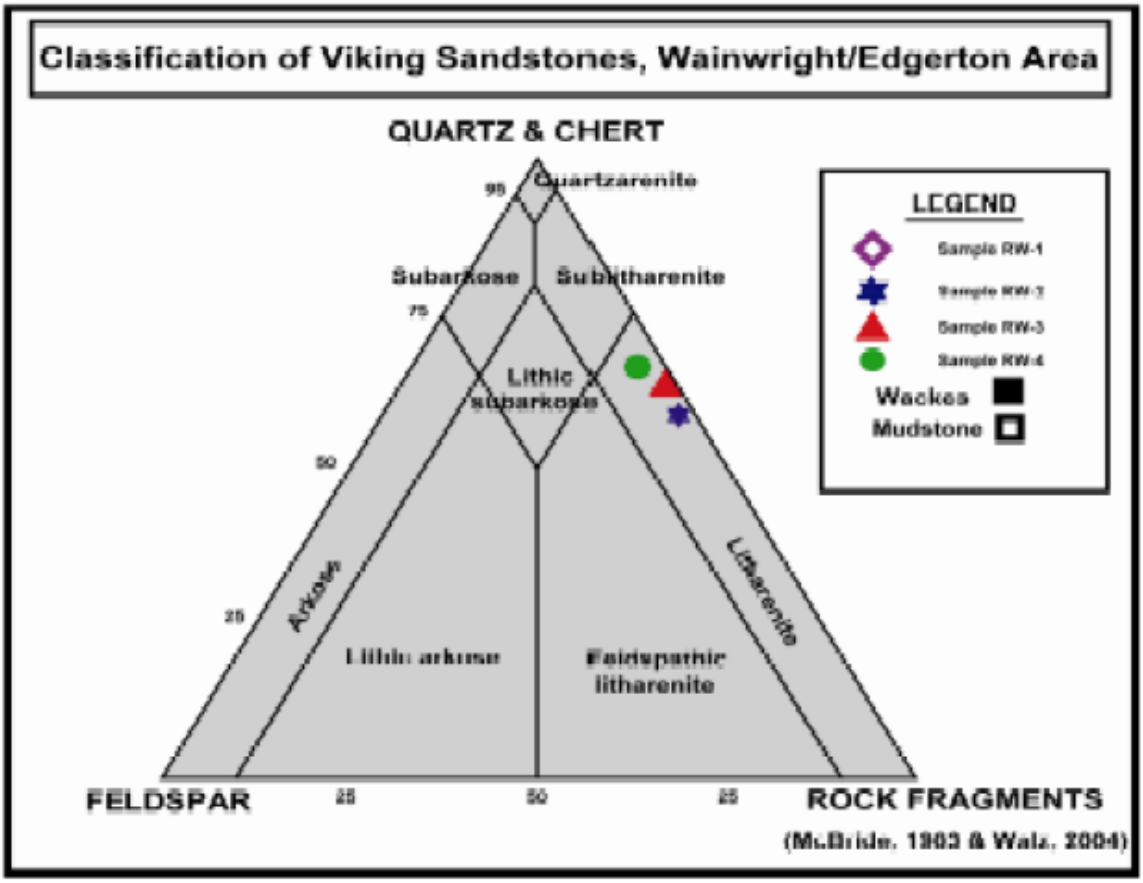

Figure 6. QFL diagram representing three Viking Sand samples. RW-1 (570.85 m) and RW-2 (584.5 m) from well 11-4-46-4W4, RW-3 (605.25 m) and RW-4 (604 m) from 10-3-45-6W4.

Stratigraphy

The Viking Formation represents an overall regressive package that is overlying the regional highstand and transgressive (Leckie, 1986) Joli Fou Shales (Facies 1C) and underlying the transgressive Westgate Shales (Facies 1A) and has been termed a regional shelf-to-shoreface sequence by Reinson et al (1988). The overall facies succession that is present consists of offshore marine shales (Joli Fou and Westgate Shales, Facies 1B and 1A), transitional sandy mudstones (Viking, Facies 1C & 2) and the lower shoreface muddy sandstones (Viking Sand unit, Facies 3) (Figure 8).

Much of Viking deposition in central Alberta is the result of a lowering of relative sea level that corresponds to the worldwide event that occurred around 97 m.y. (Vail et al, 1977). Figure 7 shows this shoreface stacking model with locations 2-4 being correlative to the area in this study.

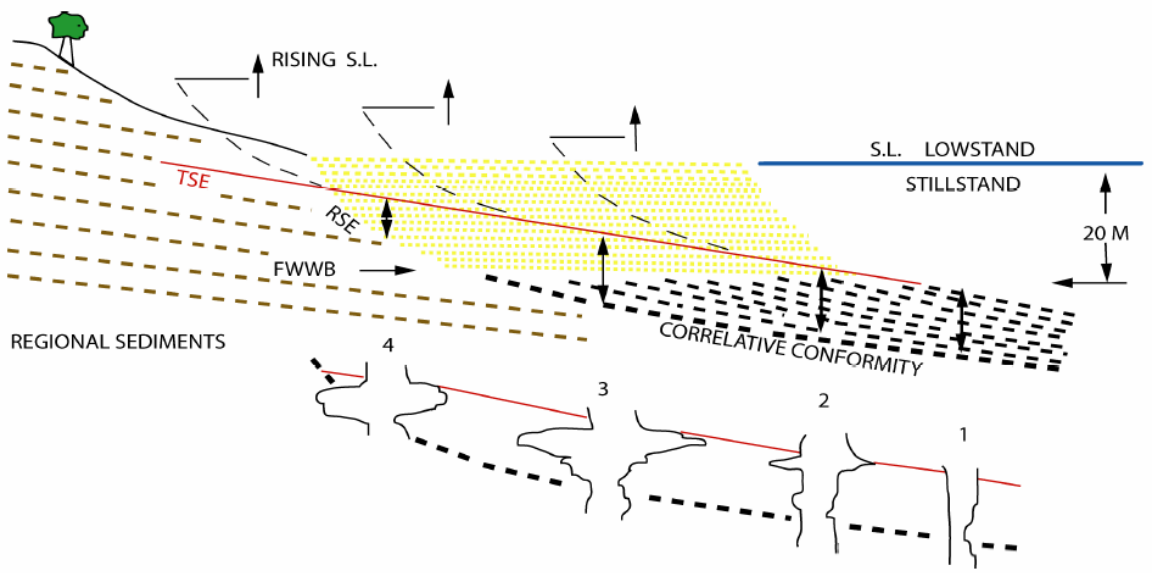

Figure 7. Lowstand prograding shoreface creating a RSE which is then followed by subsequent sea level rise creating a TSE and erosion of some lowstand shoreface sediments (modified after Walker, 1995).

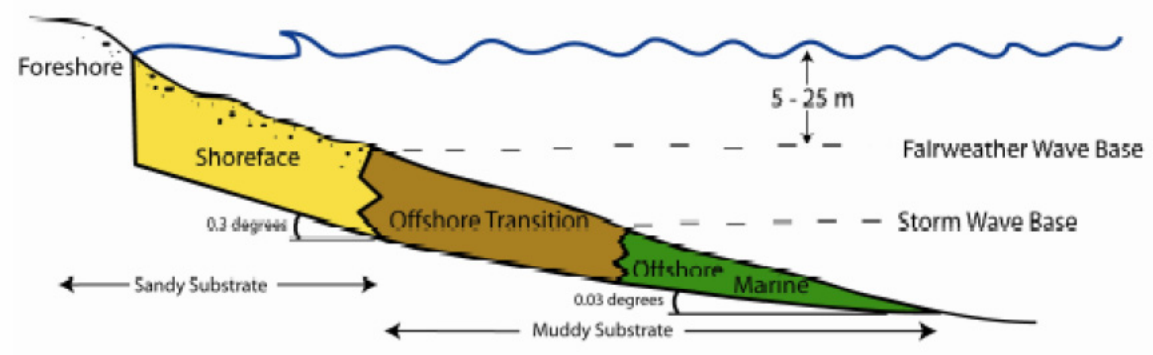

Figure 8. Depositional environment under which Viking sediments were deposited.

Interpretation of Depositional Environment

The Joli Fou (Facies 1C) is a basin wide formation that disconformably overlies the continental sands of the Mannville Formation while disconformably underlying the Viking Formation. To mark the end of deposition a major sea level regression took place, creating the erosional discontinuity defined as a RSE (Figure 9.2).

The transitional sandy mudstones of the Viking Formation (Facies 2 and 1B) were deposited between the fair weather wave base and the storm wave base (Fig 8). This lower portion of the offshore transitional sediments within the Viking are overlain by the Viking Sand unit (Facies 3) and underlain by the Joli Fou marine shales. The contact between the Viking and the Viking Sand is denoted as a RSME that was caused by the continued regression or fall of relative sea level (Figure 9.3) and is denoted by a sharp increase in gamma ray and resistivity on logs which can be defined in core by a increase in sand and grain size. This RSME marks the beginning of Viking Sand deposition.

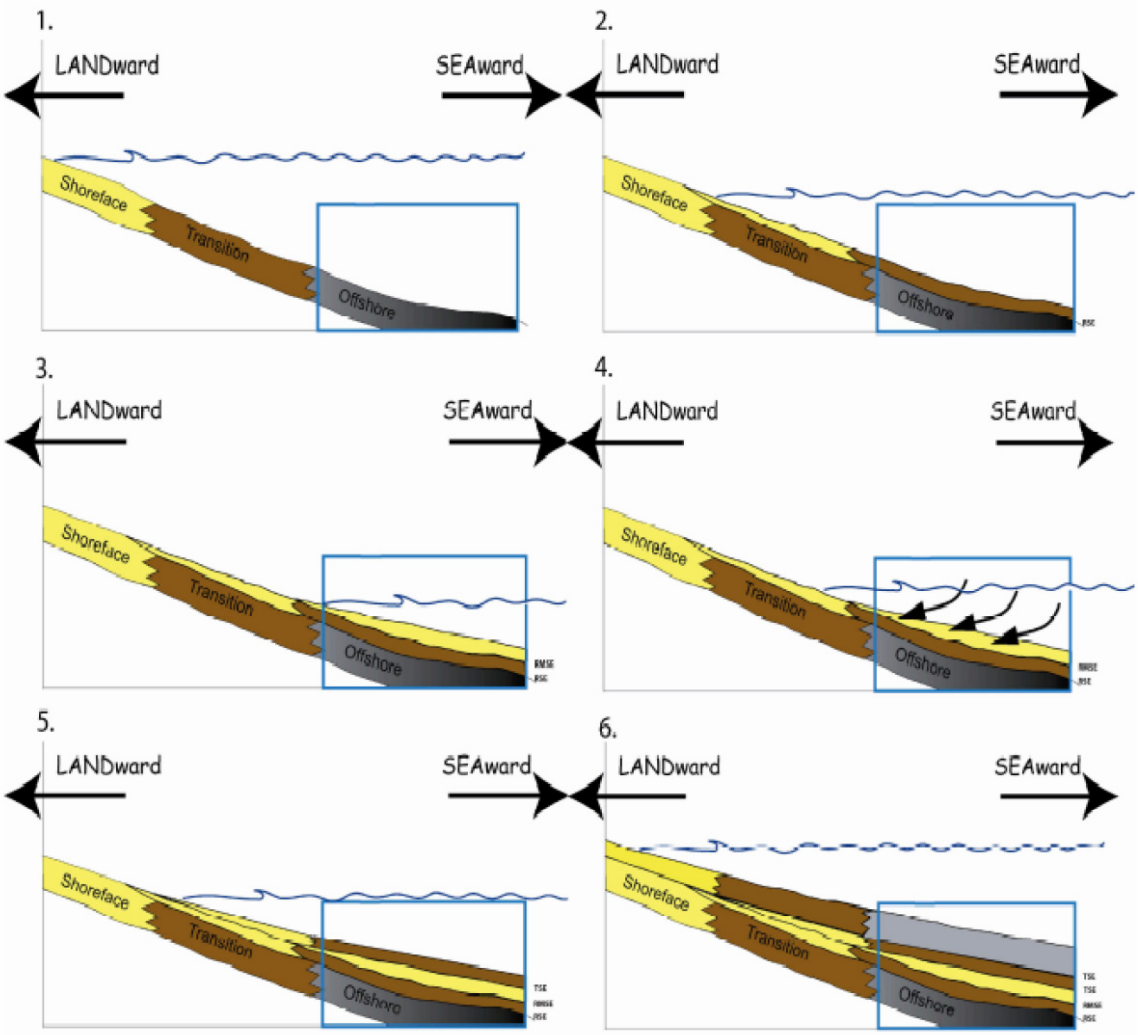

Figure 9. Schematic diagram showing surfaces and representative depositional environments of Joli Fou (1), Viking Transitional sediments (2), Viking Sand (3), Viking Sand erosion (4), and subsequent seaward transportation by the storms and waves, Viking Transitional sediments (5), and the Westgate Shale (6).

Following a time of lowstand progradation, transgression was reactivated creating a TSE (Figure 9.4). This surface is defined by a sharp decrease in gamma ray and resistivity on logs while in core it is denoted by the change in shoreface sands (Facies 3) to a mud dominated sand (Facies 2 and 1B). These lower shoreface sediments (Facies 3) were consequently redistributed as large linear NW-SE trending sand bodies.

A time of sea level stand still commenced and the thick 8-10m Viking offshore transitional sediments (Facies 2 and 1B) were deposited (Figure 9.5) between the fair weather wave base and the storm wave base (Figure 8). A basin wide TSE occurred as sea level rose and the shoreface moved proximally to the west, thus beginning the deposition of offshore sediments (Facies 1A). This TSE is characterized by a decrease in gamma ray and resistivity, while in core is represented by a decrease in sand content by abundance of sand lenses. Strikingly absent is the characteristic transgressive pebble lag

that typically denotes the contact between the Viking Formation and the Westgate Shales above.

The Westgate Shale (Facies 1A) is separated from the Viking formation by the previously mentioned major basin wide TSE (Figure 9.6). This erosional surface is the result of a reactivation in the relative sea level rise. Consequently, the deposition of the dark grey, non-calcareous offshore marine shales with rare centimeter sized interbedded sandstone lenses were deposited below the storm wave base (Figure 8).

Above the Westgate Shales is the Base of Fish Scales Zone. This zone is a basin wide marker bed that delineates the Albian/Cenomanian (lower/upper Cretaceous) boundary. This zone is identified by its abundant fish scales and shallow marine fauna within a finely laminated siltstone. Due to this zones continuous characteristics throughout the basin it will be used as the datum for this study.

Conclusions

There have been five facies defined within the study area along with four facies associations. The shale facies can be divided into three separate subfacies: 1a, 1b, and 1c. These represent the Westgate, Westgate-Viking Transition and the Joli Fou sediments, respectively. Facies 2 represents the Viking Formation and an increase in the physically structured sand lenses and preserved burrows. Finally, Facies 3 represents the Viking Sand unit which contains highly preserved burrows and fine- to medium-grained sands characteristic of lithic wackes (>15% matrix) according to a QFL diagram. The Viking Formation in central Alberta forms a lowstand prograding shoreface that follows a typical coarsening upward sequence. The formation varies in thickness throughout the study area, but shows an overall increase towards the sediment source in the NW.

Stratigraphically, following Joli Fou deposition a regression commenced that created a RSE, this surface marks the beginning of the Viking Formation. Within the Viking Formation a RSME was caused by an overall fall in relative sea level, it is this regression that marks the beginning of the Viking Sand unit's deposition within the Viking Formation. A prograding shoreface developed due to a sea level stand still and an influx of sediments from the west. This stand still ceased upon the reactivation of sea level rise and a TSE was created. This transgression eroded, reworked and redistributed much of the shoreface sediments that now comprise the Viking Sand unit. The shoreface was now located to the west and sea level was at a relative stand still for a time, allowing the remainder of the Viking sediments to be deposited. The end of Viking deposition is marked by a basin wide transgressive event that resulted in a final TSE that can be traced throughout the basin. Consequence of this basin wide transgression was the deposition of the Westgate Shales which reach thicknesses of 70m within the study area.

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