Sedimentology, Ichnology and Stratigraphic Architecture of the Viking Formation in the Chedderville Field and Surrounding Area, Alberta, Canada

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Introduction

The Viking Formation of Alberta and Saskatchewan is a Lower Cretaceous siliciclastic unit with a complex depositional history and multiple internal discontinuities (Stelck, 1958; Boreen and Walker 1991; MacEachern et al. 1999). Sediment was sourced from the southwest in response to the uplift of the Cordillera, during which the paleo-shoreline prograded northeast into the Western Interior foreland basin (Glaister 1959; Boreen and Walker 1991; Pattison 1991; MacEachern et al. 1999). Oil and gas production from the Viking Formation of central Alberta has been a noteworthy play in the basin since the early 1930's and dramatically expanded in 1978 with the discovery of the Crystal Field (Reinson et al. 1988). Current exploration of the Viking Formation in Alberta and Saskatchewan has evolved towards unconventional hydrocarbon recovery within mature fields possessing relatively low-permeability sandstones and bioturbated muddy sandstones. Facies characterization based on the lithology, sedimentology and ichnology is crucial in determining a reliable depositional interpretation, and evaluating the quality of potential hydrocarbon reservoirs.

The Viking Formation overlies and grades out of shales of the Joli Fou Formation. Multiple, regionally extensive parasequence sets overlie the Joli Fou Formation and are characterized by coarsening upwards siltstones and very fine-grained sandstones, bound by shale deposits. These deposits are informally referred to as the "Regional Viking" and correspond to Viking Allomembers A and B as defined by Boreen and Walker (1991). Within the Chedderville Field, lithologies grade out of or erosively overlay the Regional Viking. These deposits can be broadly characterized as sandier-upwards successions of interbedded very fine- to fine-grained sandstones and mudstones. Hummocky cross stratification, oscillation ripples and combined flow ripples are abundant. Bioturbation is moderate to abundant (BI 3-5) and dominated by *Planolites*, *Phycosiphon*, *Chondrites*, *Schaubcylindrichnus freyi*, *Teichichnus, Asterosoma* and *Zoophycos,* with accessory *Rosselia*, *Cylindrichnus*, *Thalassinoides*, *Ophiomorpha*, *Rhizocorallium, Diplocraterion* and *Skolithos*. The sedimentological and ichnological characteristics give rise to a fully marine interpretation suggestive of upper offshore to lower and middle shoreface deposits. In contrast, other examples within the study area contain current ripples, syneresis cracks, convolute bedding, siderite cement, phytodetrital deposits (wood fragments, coal and carbonaceous detritus) and mm- to cm-scale discrete mud beds (hyperpycnal and fluid muds deposits) may also be present. Bioturbation intensity is generally lower (BI 1-2) and trace fossils are dominated by diminutive *Planolites*, *Chondrites* and *Phycosiphon*. These deposits are interpreted to be a result of opportunistic faunal colonization, reflected by facies-crossing elements of the *Cruziana* Ichnofacies within a marine setting prone to periodic salinity variations (i.e., deltaic deposits). Stratigraphically upwards, very fine- to fine-grained, hummocky cross-stratified sandstone beds thicken up to meter-scale beds. Bioturbation intensities are reduced (BI 0-2), inferred to be due to elevated water turbidity, defaunation and decreased preservation of ambient (fair-weather) deposits. In fully marine, shoreface environments, elements of the *Skolithos* Ichnofacies reflect the recolonization of tempestites and are inferred to be structures of suspension-feeders (e.g., *Skolithos* and *Cylindrichnus*; MacEachern et al. 2005). By contrast, tempestites within storm-influenced and storm-dominated delta complexes tend to show recolonization by structures of deposit-feeders (e.g., *Chondrites* and *Planolites*) and grazers (e.g., *Phycosiphon* and *Helminthopsis*), corresponding to the *Cruziana* Ichnofacies (MacEachern et al. 2005). The upper contact of tempestites are commonly eroded and overlain by medium-grained, trough cross-bedded sandstones or granule to pebble conglomerates. These deposits are interpreted to be the result of prograding foreshore deposits, commonly with abundant phytodetritus. Centimetre- to dm-scale transgressive lag deposits mantle these coarse clastic successions, and are sharply overlain by black shales of the Westgate Formation. This sharp contact marks a marine flooding surface.

Method

The study area encompasses Townships 37-41, Ranges 3-8 West of the 5^{th} Meridian in Alberta, Canada. It is approximately 2 890 km^2 and includes the Chedderville, Willesden Green and Farrier oil fields and western portions of the Gilby, Medicine River and Sylvan Lake oil fields. The study area contains in excess of 5 900 wells penetrating the Viking Formation, 410 of which have associated Viking Formation core samples. Fifty-six core samples were logged in detail for this study and an additional 13 core lithologs employed from a previous study. Sedimentology, ichnology and stratigraphic stacking patterns are carefully integrated to form sound interpretations. Emphasis is placed on the Chedderville Field in Township 37, Ranges 6-8 West of the 5^{th} Meridian. High-resolution analysis of the Chedderville Field was undertaken and subsequently, tied into the stratigraphic architecture of the surrounding region. Geophysical well logs were analyzed in conjunction with core lithologs and used to extrapolate interpretations beyond that of the available core data.

Conclusions

Within the study area, the dominant facies within the Viking Formation can be interpreted as offshore to shoreface and prodelta to delta-front deposits, with spectrum of deltaic influence recognized across the paleo-shoreline and extending into the basin. Increased occurrences of unidirectional bedforms, discrete mud beds (hyperpycnal and fluid mud deposits), syneresis cracks, phytodetrital deposits and convolute bedding, in association with the low intensity and low diversity of diminutive trace fossils are evidence of proximity to deltaic distributary channels. Furthermore, tempestites commonly associated with shoreface deposits are also common in prodelta and delta-front deposits (MacEachern et al. 2005). Several amalgamated storm deposits have been identified as storm-influenced deltaic deposits, based on the ichnological assemblages associated with post-defaunation recolonization.

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