

T-R Sequence Model for the Bakken Formation in Southeast Alberta, Southwest Saskatchewan

Tarig Ib. Mohamed and Charles Henderson
Department of Geoscience, University of Calgary

Summary

Sedimentologic analysis of cores and well logs from the Bakken Formation in southeast Alberta allowed identification of Bakken sedimentary facies, as well as interpretation of the influence of sea level fluctuations and sediment supply on deposition of Bakken deposits. These findings are used to generate a transgressive-regressive T-R sequence model for Bakken deposits that highlights previously overlooked surfaces and system tracts. This interpretation offers more comprehensive understanding of the lateral distribution of middle Bakken lithofacies within a high-frequency sequence framework.

Introduction

Bakken deposition has been linked to changes in base level in response to sea level cyclicity (Richards, 1989; Caplan and Bustin, 1998; Smith and Bustin, 2000; Angulo and Buatois, 2011). Changes of base level in the sedimentary record are recognized by employing sequence stratigraphic principles (Posamentier, 1988; Van Wagoner et al., 1988; Embry and Johannessen, 1992). Previous workers (Richards, 1989; Caplan and Bustin, 1998; Smith and Bustin, 2000; Angulo and Buatois, 2012) have demonstrated that the Bakken black shale members were deposited during a marine transgression, with the lower black shale member being correlative with only the lowest portion of the Exshaw black shale member to the west (Mohamed, in review). However, controversy still exists over the base level changes that shaped the Bakken middle sandstone member. Previous interpretations include transgressive shallow marine (Christopher, 1961), forced regression systems tract, regressive incised estuary (Angulo et al., 2008), low stand systems tract (Smith and Bustin, 2000; Kohlruss and Nickel, 2009) and high stand systems tracts (Angulo and Buatois, 2012). Understanding of the lateral continuity and stratigraphic framework of Bakken lithofacies is essential for commercial potential and risk analysis, which may be addressed by constructing a sequence stratigraphic model that outlines base

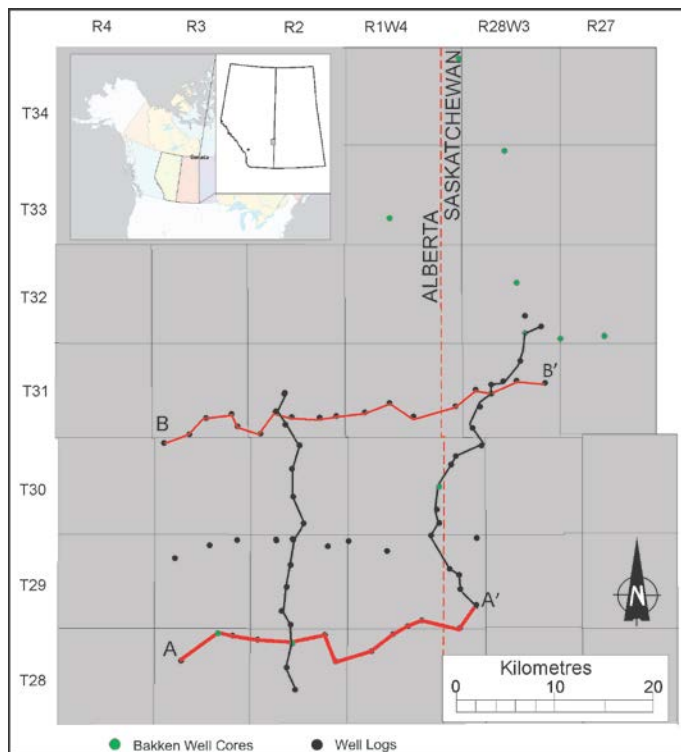


Fig.1. Study area, the lines demonstrate cross section locations and green circles indicate location of cores analyzed in this study.

level changes as demonstrated by lithofacies of the Bakken Formation.

Theory and/or Method

This study utilized 11 cores and more than 150 well logs from the Bakken Formation in southeast Alberta and southwest Saskatchewan (Fig. 1). Sedimentologic analysis of cores was integrated with gamma ray logs to correlate Bakken lithofacies, as well as to generate cross sections and subsurface isopach maps throughout the study area. Sequence stratigraphic concepts and terminology in this paper are heavily based on the transgressive-regressive T-R sequence model (Embry, 2002), as well as Exxon model (Vail *et al.*, 1977; Posamentier, 1988). The T-R model is based on recognizable, low diachroneity surfaces as “quasi-chronostratigraphic” markers for facies correlation (Embry *et al.*, 2007); T-R sequence model is very applicable in ramp setting basins.

Findings

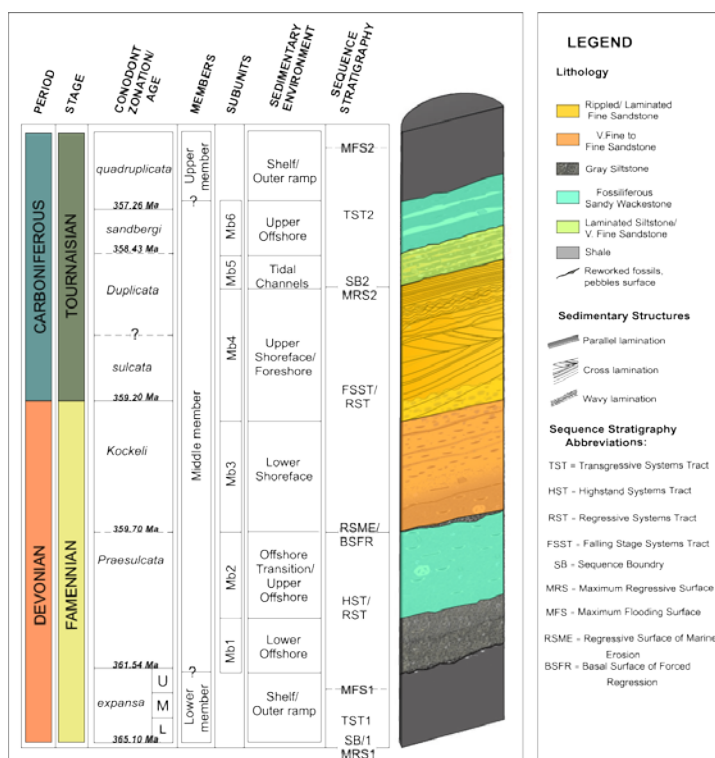


Fig. 2. Generalized core log depicting sedimentologic and biostratigraphic characteristics, depositional environments and sequence stratigraphic surfaces of the Bakken Formation. Conodont zonation from Johnston *et al.* (2010), core log modified from Angulo and Buatois (2012).

systems tract (HST) bounded by a maximum flooding surface and a basal surface of forced regression (BSFR), and (b) a falling stage systems tract (FSST) overlying the BSFR and capped by a sequence boundary (SB2) and a distal maximum regressive surface (MRS2). Finally, (3) an upper transgressive systems tract (TST2) that consists of tidal channel deposits (Mb5), upper wackestone (Mb6) and lower portion of upper Bakken shale (Fig. 2, Fig.3).

Examination of Bakken cores revealed eight distinct and correlatable lithofacies (Fig. 2): (1) outer shelf shale (lower Bakken shale), (2) lower offshore siltstone Mb1, (3) upper offshore to offshore transition fossil-rich wackestone Mb2, (4) lower shoreface sandstone Mb3, (5) upper shoreface to foreshore sandstone Mb4, (6) tidal channel fill Mb5, (7) upper offshore wackestone Mb6 and (8) outer ramp shale (upper Bakken shale). Gradational stacking pattern of lower Bakken shale, lithofacies Mb1 and Mb2 (Fig. 2) indicate shallowing upward succession that resembles deposition during an episode of normal marine regression. Sharp transition to shoreface deposits of Mb3 and Mb4 suggest enhanced sediment supply and development of conditions associated with forced marine regression. Several flooding surface are observed within shoreface deposits of Mb3 and Mb4, these surfaces are demonstrated by black mudstone beds embedded within the sandstone deposits.

Stacking patterns and stratigraphic surfaces of Bakken lithofacies allow definition of three systems tracts that include (1) a transgressive systems tract (TST1) that consists of lower part of lower Bakken shale, (2) regressive systems tract (RST) that consists of middle Bakken lower shale; this regressive systems tract can be further subdivided into (a) lower high stand

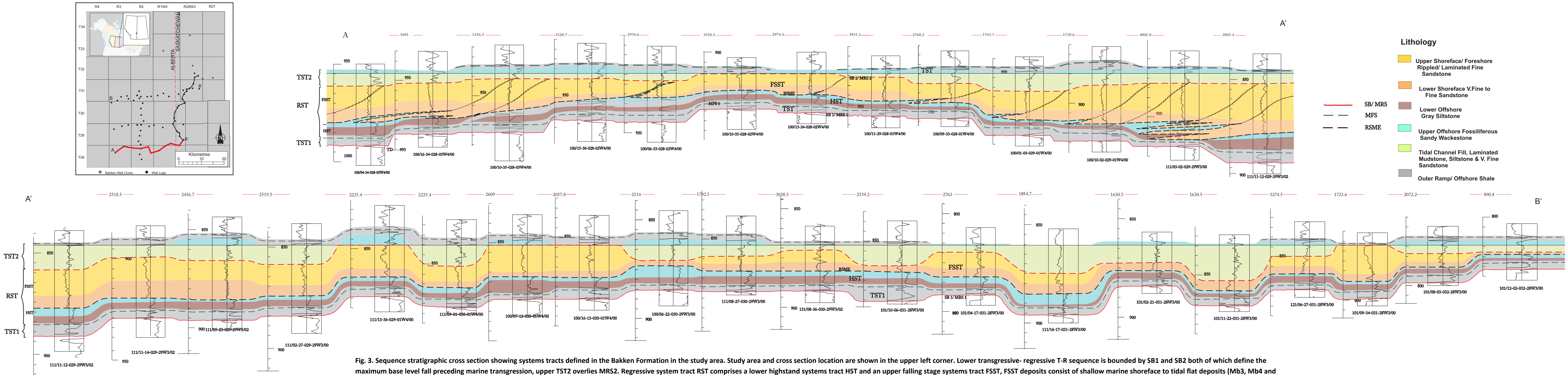


Fig. 3. Sequence stratigraphic cross section showing systems tracts defined in the Bakken Formation in the study area. Study area and cross section location are shown in the upper left corner. Lower transgressive- regressive T-R sequence is bounded by SB1 and SB2 both of which define the maximum base level fall preceding marine transgression, upper TST2 overlies MRS2. Regressive system tract RST comprises a lower highstand systems tract HST and an upper falling stage systems tract FSST, FSST deposits consist of shallow marine shoreface to tidal flat deposits (Mb3, Mb4 and Mb5). RSME separates HST from FSST. Several marine flooding events are demonstrated by offshore deposits overlying FSST strata. Upper cross section is attempting to depict the prograding character of FSST as stacked shoreface successions that prograde westward with ongoing marine regression, shazam lines indicate that shallow marine Mb1, Mb2 and Mb3 might be time-synchronous within a shoreface parasequence. The size and extent of shoreface parasequences is based on models of modern shoreface parasequences (Stive and Vriend, 1995; Charvin et al., 2011).

