Sedimentary Architecture of the Bow Island Formation, Southwestern Alberta, Canada

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The Albian Bow Island Formation of southwestern Alberta has been a gas producer for decades but still contains significant unexplored reserves. To this date, only a few studies have been published on the Bow Island Formation (Cox, 1993; Reinson et al., 1994, Bradshaw, 2000, Langenberg et al., 2000, Vorobieva, 2000). We will here show how micropaleontology integrated with sedimentology and well logs contributed in unravelling the architecture of the Bow Island Formation. Our study are based on 54 cores, mainly within the upper Bow Island member, integrated with well logs. A total of approximately 400 well logs were used to produce cross-sections and structural and facies maps. Micropaleontological analysis was performed on 13 selected reference cores.

In southwestern Alberta marine deposits of the Late Albian Bow Island Formation unconformably overly non-marine deposits of the Mannville Group. The Bow Island Formation is here subdivided into three informal members; lower Bow Island member comprised of upward coarsening cycles of shelf to shoreface deposits, middle Bow Island member comprised of green and brown coastal plain deposits, and upper Bow Island member comprised of a complex succession of tidal flat, estuarine, lagoonal deposits intercalated with marine shoreface deposits. This threefold subdivision is in agreement with the work by Cox (1993) and Reinson et al (1994). Bradshaw (2000) included the coastal plain deposits within her upper unit. The overlying marine shales of the Westgate Formation thin gradually in westerly direction from 20 meters to being absent in the southwest where the Bow Island Formation unconformably is overlain by the Fish Scales Formation.

The Bow Island Formation is characterized by an overall progradational-retrogradational architecture. This architecture is similar to time-equivalent deposits of the Joli Fou and Viking formations further to the north and east (Reinson et al., 1994). Within the lower Bow Island member the two basal upward-coarsening shoreface cycles or para-sequences stack in a retrogradational para-sequence set. A thick shale interval above the two basal upward-coarsening shoreface cycles reflect the overall level of maximum flooding within the Bow Island Formation as the overlying cycles stack in a progradational para-sequence set. Within the upper part of the lower Bow Island member, detailed log correlations show shoreface deposits grading westward into coastal plain deposits of the middle Bow Island member implying a genetic relationship between the marine and non-marine deposits of the lower and middle Bow Island members, respectively. This interpretation is consistent with an eastward thinning of the coastal plain deposits of the middle Bow Island. A strong post depositional pedogenic overprint of the upper coastal plain deposits suggests these where sub-aerially exposed for a considerable time. We place a sequence boundary at the top of the middle Bow Island coastal plain succession. This sequence boundary is probably related to a major sea-level fall causing incision of a 60 m deep incised valley within the Viking Formation to the northeast (Reinson et al., 1988). In contrast, Bradshaw (2000) placed this major sequence boundary between the marine and coastal plain deposits of the lower and middle Bow Island members respectively.

The upper Bow Island member consists of lateral and vertical complex intercalations of marginal marine facies, e.g. shoreface, lagoon, tidal flat and soils. Although the member is only 20-m thick five transgressive surfaces and four sequence boundaries are identified. Sequence boundaries are in cores recognised by a basinward shift of facies and regionally as an unconformity characterized by erosion and valley incision. Transgressive surfaces, on the other hand, are characterised by a landward shift of facies and a change to more marine conditions. Lag deposits overlying the transgressive surfaces clearly show transgressions were associated with erosion and winnowing. Sequences are here simply subdivided into a lower and upper unit bounded by sequence boundaries and transgressive surfaces.

The transgressive surface at the base of the upper Bow Island member, with marginal marine sediments overlying coastal plain deposits marks the onset of transgression of the Mowry Sea and establishment of a new depositional era. The architecture of the upper Bow Island and overlying Westgate Formation are characterized by a stepwise change towards more open marine conditions following each transgression. This overall transgressive architecture is revealed by the facies directly overlying the five transgressive surfaces as a upward change from marginal marine tidal flat, shoreface and finally to offshore shelf settings. Foraminiferal assemblages reflect a similar change toward gradually more open marine conditions with increasing abundance and species diversity. Environmental stress of marginal marine deposits result in rare foraminiferal occurrences and fragile tests, whereas fully marine shoreface settings contain abundant specimens and species with robust tests to withstand increased energy.

Within the upper Bow Island member erosion associated with sequence boundaries and transgressive surfaces left a patchy distribution of facies and caused amalgamation of sequences. This complex framework together with the aggradational and slightly retrogradational architecture reflect deposition in a low accommodation setting during an overall rising relative sea level. Within the upper Bow Island member the depth of the incised valleys increases upward from a few meters to more than 10 m. This is probably related to the aggradational architecture and thereby increasing depositional relief. A gradual vertical increase in thickness of the transgressive lags from a few pebbles in the basal part of the upper Bow Island to 30 cm thick lags overlying the Westgate transgressive surface, reflect an increase in energy regime related to the stepwise change towards more open marine conditions.

Establishment of such a detailed sequence stratigraphic framework proved essential in order to distinguish between orientations of incised valleys of different generations. This is especially necessary in order to successfully offset proven reservoirs of incised valley fill in areas where these valleys are incised into each other.

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