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Sequence Stratigraphy of the Bombay Basin – An Overview

A. Sadangi
DGM, Nuvoco, Mumbai- 400 070, India

Abstract

The Bombay Basin, also referred to as the Mumbai Offshore Basin, represents one of India's most prolific hydrocarbon provinces and has been the subject of systematic sequence-stratigraphic investigation for over forty years. Progressive advancements in seismic interpretation, biostratigraphy, and wireline-log analysis have significantly enhanced the understanding of its depositional evolution and reservoir architecture (Chatterjee & Barai, 2020). Sequence stratigraphic research has enabled geoscientists to delineate major systems tracts, identify key stratigraphic surfaces, and evaluate the relative roles of tectonism and eustasy in controlling basin development (Biswas, 1987). The Paleocene to Quaternary succession of the basin reflects a complex interaction of syn-rift sedimentation, post-rift thermal subsidence, carbonate platform evolution, clastic progradation, and basin-scale accommodation changes (Prabhakar & Zutshi, 1993). Integrative studies combining 3D seismic attributes, sedimentological observations, well-log signatures, and geochemical markers have considerably refined models of reservoir distribution, stratigraphic trapping, and migration pathways (Rao & Talukdar, 2021). This review synthesizes findings from four decades of research—restricted to literature up to 2021 to provide an expanded overview of the basin's tectono-stratigraphic history, the sequence stratigraphy of the major depositional intervals, and the technological advancements that continue to influence hydrocarbon exploration and reservoir prediction in the basin.

Introduction

The Bombay Basin forms an integral part of the western continental margin of India and represents one of the best-studied passive-margin basins in the northern Indian Ocean (Kunte & Wagle, 2001). Its tectonic and stratigraphic architecture is intricately linked to the Late Cretaceous rifting of the Indian plate from the Seychelles microcontinent, a process associated with extensive Deccan volcanic activity that emplaced the basaltic basement over which younger sediments accumulated (Biswas, 1987). The early Paleocene sediments were deposited over an uneven volcanic topography, where basement highs acted as localized structural controls influencing early accommodation and sediment dispersal patterns (Khadri, 2016).

Initial geological investigations into the basin were dominated by lithostratigraphic approaches that, while foundational, lacked the resolution necessary to predict subtle depositional patterns or stratigraphic trapping mechanisms (Fuloria, 1993). The emergence of sequence stratigraphy in the late 20th century revolutionized basin interpretation by introducing concepts such as systems tracts, key bounding surfaces, relative sea-level fluctuations, and the importance of sediment supply–accommodation interactions (Prabhakar & Zutshi, 1993). These developments enabled the reconstruction of basin-wide chronostratigraphic frameworks, improved reservoir delineation, and allowed integration of eustatic and tectonic drivers into basin models.

The introduction of 2D and later 3D seismic data significantly improved the resolution of subsurface interpretations, allowing mappers to identify seismic facies, clinoform geometries, platform margins, and deep-water depositional elements with greater confidence (Chatterjee & Barai, 2020). Combined with enhanced biostratigraphic dating, seismic attributes, log-motif interpretation, and geochemical correlation, these tools have transformed the Bombay Basin into a model setting for studying passive-margin sequence stratigraphy.

This expanded review integrates developments from 1980–2021, outlining the major depositional phases of the basin, elucidating the sequence-stratigraphic significance of key stratigraphic intervals, and examining technological and conceptual advances that continue to shape research and exploration strategies.

Sequence Stratigraphy and Basin Evolution

Early Syn-Rift and Post-Rift Transition

The syn-rift to early post-rift phase of the basin is captured predominantly in the Paleocene–Early Eocene Panna and Bassein formations. The Panna Formation is characterized by fluvio-deltaic to shallow-marine clastic wedges that formed in response to extensional tectonics and the development of half-graben depocenters (Fuloria, 1993). These deposits commonly exhibit block-fault-controlled geometries, variable thickness, and facies distributions that reflect local accommodation generated by fault activity (Prabhakar & Zutshi, 1993).

Early lowstand wedges in the Panna Formation record coarse clastic influx into structurally confined depocenters, while subsequent transgressive phases resulted in widespread marine flooding and deposition of finer-grained shales. This shift corresponds to the transition from syn-rift fault-controlled subsidence to broader post-rift thermal subsidence.

The overlying Bassein Formation marks the onset of regionally extensive carbonate deposition during a post-rift highstand phase characterized by reduced clastic supply, stable subsidence, and the development of broad carbonate platforms (Govindan et al., 2014). These carbonates host several hydrocarbon reservoirs and exhibit complex internal architectures controlled by antecedent basement topography, differential subsidence, platform-margin progradation, and episodic sea-level oscillations (Chatterjee & Barai, 2020).

This interval highlights the changing interplay between tectonic accommodation and global eustatic controls as the basin evolved from an active extensional setting to a more thermally subsiding passive margin.

Middle–Late Eocene Clastic–Carbonate Interplay

During the middle to late Eocene, sedimentation was dominated by alternating carbonate and siliciclastic systems represented by the Mukta and Daman formations. These units reveal one of the most dynamic depositional intervals in the basin's history, characterized by lateral shifts between carbonate platform development, clastic progradation, and episodic relative sea-level changes (Fuloria, 1993).

Seismic interpretation of this interval highlights well-preserved clinoform geometries that document repeated cycles of shelf-margin progradation, topset–foreset–bottomset transitions, and the formation of widespread shelf-edge delta systems (Rao & Talukdar, 2021). These patterns suggest alternating highstand and forced-regressive phases driven by subtle tectonic adjustments, differential subsidence, and changes in sediment supply.

This interval contains numerous stratigraphic traps, including pinch-outs of clinoform foresets, shale-draped margins, and downlap terminations. These traps have proven commercially significant, underscoring the importance of high-resolution sequence-stratigraphic mapping across the Eocene section.

Oligocene–Miocene Siliciclastic Progradation

The Oligocene–Miocene marks a pronounced shift toward siliciclastic-dominated sedimentation driven by increased hinterland uplift, intensified monsoonal weathering, and enhanced riverine discharge

(Kunte & Wagle, 2001). This interval is marked by large-scale basinward progradation of deltaic and shallow-marine systems. High-quality 3D seismic data reveal a series of progradational clinoform complexes that represent successive highstand systems tracts (Chatterjee & Barai, 2020). These clinoforms display clear patterns of toplapping onto transgressive surfaces and downlap onto maximum flooding surfaces (MFS). The mapping of several basin-wide MFS horizons has been central to refining the chronostratigraphic correlation of this interval (Rao & Talukdar, 2021).

Maximum flooding surfaces—characterized by high-continuity, low-amplitude reflections and associated condensed marine shales—act as reliable correlation markers and regional seals. Their continuity across the basin also provides insights into the interplay of global eustatic signals and regional tectonics. For example, subtle thickening and thinning of transgressive systems tracts across structural lineaments reflect periodic tectonic reactivation consistent with earlier models of basement-involved inversion (Biswas, 1987; Prabhakar & Zutshi, 1993).

From a petroleum perspective, this interval contains multiple highstand deltaic sand bodies that form key reservoirs, while MFS-related shales serve as seals. Slope-channel systems, turbidite aprons, and deep-water fans exhibiting significant geomorphological variation offer additional exploration opportunities.

Miocene to Quaternary: Post-Rift Thermal Subsidence and Deep-Water Systems

The Late Miocene to Quaternary represents a fully established passive-margin phase dominated by thermal subsidence and the development of extensive deep-water depositional systems (Khadri, 2016). This interval exhibits stacked channel–levee complexes, mass-transport deposits, submarine fans, and fault-controlled mini-basins.

Seismic geomorphology—within the scope of pre-2021 literature—has been instrumental in mapping these systems, revealing complex channel patterns, slope-fan architectures, and sediment-gravity-flow processes. Although these younger successions contribute less to conventional hydrocarbon systems, they are important for assessing shallow gas accumulations and geohazard risks, particularly slope instabilities and seafloor failure zones.

Themes in Recent Research

Improvements in Carbonate System Characterization

Research up to 2021 has significantly advanced the understanding of carbonate reservoir analogs within the Bassein and Mukta formations. High-resolution seismic attribute analysis, porosity mapping, and diagenetic studies have clarified controls on reservoir development, including early marine cementation, meteoric diagenesis, and karstification patterns (Govindan et al., 2014). Sequence stratigraphy provides a predictive framework for understanding platform-margin evolution and identifying reservoir-prone facies belts.

Advances in Seismic Geomorphology

Seismic geomorphology has increasingly been applied to map deep-water systems in the basin. Studies with data available up to 2021 demonstrate detailed mapping of submarine channels, levee complexes, fan lobes, and mass-transport deposits (Rao & Talukdar, 2021). These insights support improved facies modelling, reservoir property prediction, and stratigraphic trap identification.

Tectonic Reactivation and Stratigraphic Implications

Several studies underscore the role of reactivated basement structures in influencing sedimentation patterns, accommodation, and stratigraphic architecture. Subtle inversion events have produced angular unconformities, localized forced regression surfaces, and compartmentalized depocenters, especially in the northern basin (Biswas, 1987; Prabhakar & Zutshi, 1993).

Emerging Pre-2021 Technologies

Prior to 2021, technologies such as early machine-learning–based facies classification, chemostratigraphy, and rock-physics modelling began gaining traction. These methods improved the ability to:

- automate seismic facies prediction
- enhance chronostratigraphic resolution where biostratigraphy is limited
- correlate lithofacies across structurally complex areas
- predict reservoir heterogeneity and fluid pathways (Rao & Talukdar, 2021)

Conclusion

Sequence stratigraphy has profoundly shaped the geological understanding of the Bombay Basin. Over the last four decades, integrated seismic interpretation, high-resolution stratigraphic mapping, and multiproxy datasets have enabled reconstruction of the complex interplay between tectonism, thermal subsidence, carbonate platform evolution, clastic progradation, and eustatic sea-level changes (Chatterjee & Barai, 2020). While the basin is now relatively mature from an exploration standpoint, emerging analytical techniques within the boundary of technologies established prior to 2021 continue to open new avenues for refining reservoir characterization, improving structural and stratigraphic trap prediction, and enhancing basin modelling workflows. The Bombay Basin will thus remain a benchmark for passive-margin sequence-stratigraphic research and a key hydrocarbon province within the Indian offshore domain.

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