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Sequence depositional model of the Cretaceous sedimentary succession of the Cauvery Basin in Ariyalur area, Tamil Nadu

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Abstract: The vertical and lateral relationships of rock facies, macro- and microfossil assemblages, sedimentary textural characteristics, and diagenetic changes of the lithologic units were investigated in the Albian- Maastrichtian mixed carbonate and siliciclastic deposits outcropped at the Cauvery basin margin in the Ariyalur area. Dalmiapuram, Garudamangalam, Sillakkudi, and Kallankurichchi are the four Transgressive-Regressive cycles shown by combining field and laboratory data. Major sea level variations in outcrops during the Late Turonian and Late Maastrichtian are connected with worldwide sea level changes, according to Haq et al. (1987) and Miller et al (2005). The seven sequence surfaces outcropped in the Ariyalur region are presented progressively in this work, with the confidence of extending the outcrop deposition model into subsurface linking with biozone processes. The prevalence of sandstone reservoirs in the deep basin and the degree of relative sea level changes are closely related, according to the sequence depositional model.
Keywords: Cauvery Basin, Cretaceous, Sequence model.

Introduction

The Cauvery Basin is located on India's south-eastern coast. During the Late Jurassic-Early Cretaceous breakup of Gondwana, this pericratonic rift basin emerged (Rangaraju et al., 1993; Lal et al., 2009; Raju et al., 2017). The basin covers 37825 km^2 on land, 43723 km^2 in shallow water, and 158452 km^2 in the Bay of Bengal's deep seas (DGH, 2020). The deposition of a large sedimentary pile spanning the late Permian to Recent epochs has been exposed through deep drilling for oil exploration (Nallapa Reddy et al., 2013; Raju and Reddy, 2016). The basin's western margin, at Ariyalur and Preambular, has well-preserved Aptian to Early Paleocene deposits (Fig. 1). Major and minor unconformities cut across the thick sedimentary sequence. Along road cuttings, river channels, badland topography, mine and quarry sections, the full architecture of the sediment strata is visible. The Cauvery Basin's Cretaceous succession has attracted geoscientists' interest due to its paleoeographical location in the Indo-Pacific area. It's also a treasure trove of rich and diverse fauna, allowing for easier inter-regional correlation of different Cretaceous strata around the world. Researchers studied the pioneering work on several facets of the geology of the Cauvery basin from 1862 to 2021.

Spatial Distribution of Outcrops

The Cauvery Basin is India's most extensive epicontinental Mesozoic basin. The basin is divided into multiple grabens, with inter-basinal horsts in between. The enechelon grabens are orientated northeast-southwest, according to Bouguer gravity data (Venkatarengan et al., 1993). Precambrian crystallines, such as granite gneiss/diorites and charnockites, make up the basement rock. In sections of the Ariyalur, Vridhachalam, and Pondicherry regions, Cretaceous to early Paleocene strata crop out intermittently. In the TamilNadu districts of Ariyalur and Preambular, a complete sequence of syn-rift and post-rift Cretaceous deposits has been revealed (Fig. 1). The basin's deposition began with fluvial and lacustrine rift-fill sediments, which were followed by shelf carbonates, shale, and clastics. Road cuttings, river beds, bad-land terrain, mines, and quarries all show signs of the Late Aptian to Late Maastrichtian/Early Paleocene sedimentary periods. These outcrops have less deformation and are easier to map. The unconformity surfaces are well-defined and aid in lithological formation classification. Diverse macrofossils from the Phylum Mollusca, Brachiopod, Echinodermata, Bryozoa, vertebrates, dinosaur eggs, and plant fossils can be found in the outcrops. Furthermore, microfossils abound in the strata of the Cauvery basin. The Ariyalur outcrops provide a museum-like setting for palaeontology, sedimentary facies, and stratigraphic characteristics research. For geoscience beginners, this area is regarded as the field museum of palaeontology, and it is an ideal place for Cretaceous research. At Terani, Teranipalyam, Neykulam, and Kalpadi, the syn-rift strata are spread in four patches. Dalmiapuram/ Karai Formations exposed at Uttatur, Olaipadi, Melarasur, Kallakkudi, KVC, Varagurpet, Maruvattur limestone mines, and stream drainage channels belong to the post-rift Albian- Cenomanian-Turonian strata of the Uttatur Group. The Karai Formation is best exposed 2 kilometres west of Karai village, with bad land topography, Kulakkalnattam hamlet, and abandoned quarries in the villages of Maruvattur, Kunnam, Odhiyam, and Veppur. The Trichinopoly Group's Coniacian-Santonian succession, known as the Garudamangalam Formation, is divided into three members: Kulakkalnattam, Anaipadi, and Saturbhugam. The outcrop at Sattanur village is notable for exposing a fossil wood that is 18 metres long. A spectacular ammonite colony may be seen on a sandstone outcrop near

Karambiyam hamlet. Although the Campanian strata are widely accessible in the Ariyalur area, alluvium has buried most of it. The best-exposed Campanian sandstone can be found in Mettol and Nochikulam village road cuttings. TANCEM Limestone mines in Kallankurichchi, Srinivasapuram, Dalmia mines in Srinivasapuram, Periyanagalur, Velliperinjium- GRASIM mines in Periyanagalur, VISCOS/Malabar limestone mines in Reddipalyam, and around Ariyalur districts have Maastrichtian outcrops. Around the settlements of Ottakovil and Kallamedu, terminal Cretaceous outcrops can be found. The Kallankurichchi limestone mine is a classic example of a fossil bank, exposing the Maastrichtian section's best maximum flooding surface (MFS) in the Ariyalur area. In the Dalmia limestone mines at Kallankurichchi village, the unconformity surface between the Campanian and Maastrichtian successions is represented by a well-preserved conglomerate deposit (Kallar Conglomerate). These outcrops on the Cauvery Basin's western margin are shallow marine deposits incorporating sequence stratigraphic surfaces.

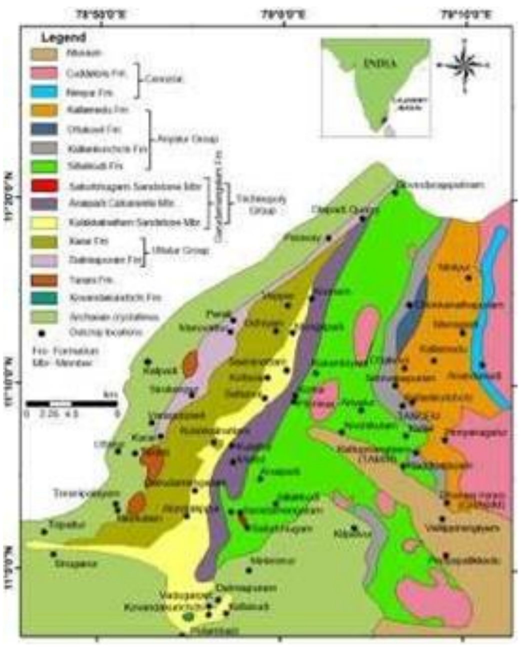

Fig. 1. Cretaceous outcrops of the Cauvery Basin in the districts of Ariyalur and Preambular, Tamil Nadu.

Sequence Stratigraphic Surfaces in Outcrops

Following the sequence stratigraphic concepts of Vail et al. (1977) and Van Wagoner et al. (1980), seven 2nd/3rd order sequences are found (Fig. 2) in the outcrop succession in the Cauvery basin near Ariyalur area. The Kovandankurichchi Formation, which is typified by fanglomerate facies, is the oldest sedimentary unit overlying the Precambrian crystalline basement (Govindan et al., 1998). (Fig. 2a and b). The Terani Formation, which has river to littoral origins, lies on top of this layer (Banerji, 1982). The sequence boundary-1 (SB1) is formed by the contact between the Precambrian crystalline basement and the Kovandankurichchi Formation, whereas the sequence boundary-2 (SB2) is formed by the higher contact with the Terani Formation (Sarkar et al., 2014). The Terani Gritty Ferruginous Sandstone Member conformably overlies the Ptilophyllum acutifolium-bearing Terani Claystone with sandstone intercalations. Its highest section, which contains foraminifera and ammonite shells, marks the beginning of the first marine intrusion (Fig. 3a). The sequence boundary-3 (SB3), which merges with the transgression surface (TS), separates marine and non-marine facies. SB- 3 closely correlates with the Aptian/Albian boundary (Reddy et al., 2013). During the Albian to middle Turonian, the Uttatur Group's Dalmiapuram and Karai formations evolved in a marine environment, overlaying the Terani Formation. The Terani Formation and the Dalmiapuram Formation's Coral Algal Limestone Member form a para-conformable contact (Fig. 3b). The abrupt conclusion of the Coral Algal Limestone is thought to reflect a drowning surface created by clastic input and a rise in sea level (Nagendra et al., 2002a). The sequence boundary-4 (SB4) is defined by an unconformable link between the upper surface of the Karai Formation (Fig. 4a and b) and the Garudamangalam Formation (Fig. 5a) (Nagendra et al., 2002b; Nagendra et al., 2011). Because of basin uplift related with the Marion hot mantle plume during the late Turonian, SB4 is linked to a 2.10 Ma hiatus (Nagendra et al., 2002a, 2011; Raju et al., 2005). The Garudamangalam Formation overlies SB4. The Saturbhugam Sandstone indicates the relative sea level (RSL) decline during the late Santonian, which created fluvial channel deposits as part of the highstand system tract (HST); the erosion surface at the top of this sandstone defines the sequence boundary-5 (SB5) (Nagendra et al., 2011; Reddy et al., 2013).

The sequence boundary-6 is marked by an unconformity surface at the foot of the Kallar Conglomerate, which overlies the Saturbhugam Sandstone (SB6). Weathering and erosion of the exposed Sillakkudi Sandstones resulted in the formation of the conglomerate (Fig. 5b). At the foot of the Kallankurichchi Formation, the Ferruginous Limestone has a transgression surface indicated by the occurrence of smaller benthic foraminifera, indicating marine inundation. The Ferruginous Limestone, Lower Arenaceous Limestone, and Gryphaea Limestone make up the transgressive systems tract. These three members' stacking patterns match to a retrogradational parasequence corresponding to intermittent flooding occurrences (Nagendra et al., 2002b). The frequency and preservation of microfossil tests, as well as macro- and microfossil assemblages, show that the water depth in up section is deepening. One of the best developed maximum flooding surfaces (MFS) in the area is found in the Gryphaea Limestone Member, which is rich in macrofossils. The MFS is sharp, and it correlates to the upper surface of the Gryphaea shell bed. It is found between the Gryphaea Limestone and the Upper Arenaceous Limestone. A calm atmosphere is suggested by the abundance of huge Gryphaea shells (Fig. 6a). A shallowing tendency towards the top of the Upper Arenaceous Limestone, which constitutes the HST, is suggested by high silica concentration and reduced micro- and macrofossil abundance. The shallowing upward trend continues into the Ottakovil Formation (Fig. 6b), which marks the conclusion of the marine phase, which was brought to a close by a massive sea-level drop induced by the basin's eastward tilt (Fig. 6c). The emergence of the Reunion hot mantle plume and the Deccan volcanic eruptions, which caused uplift in central India, are thought to be responsible for this tilt (Raju et al., 1993; Jaiprakash et al., 2016; Nagendra and Reddy, 2017). The top of the Ottakovil Formation is interpreted as sequence boundary-7 (SB-7) (Fig. 7)

Sequence Depositional Model

The following diagrams express the sequence of sedimentation records with time frames and sea-level changes.

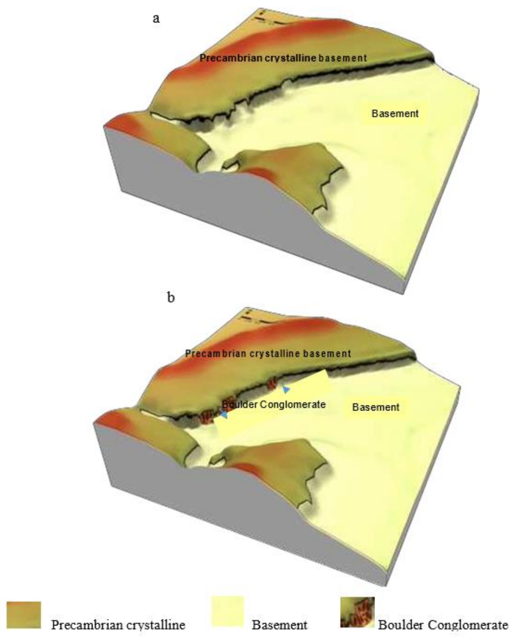

Fig. 2. Three-dimensional block diagrams showing a) The structural highs and lows of the Precambrian crystalline basement. b) Mappable boulder Conglomerate of the Cretaceous system. It's found at the Kovandankurichchi limestone quarry-II, where it's found underlying the basement rocks. The clasts are made up of buff-grey feldspar, sub-angular to sub-rounded quartz, boulders, cobbles, and pebbles originating from Precambrian crystalline rocks, and the conglomerate has inverse grading.

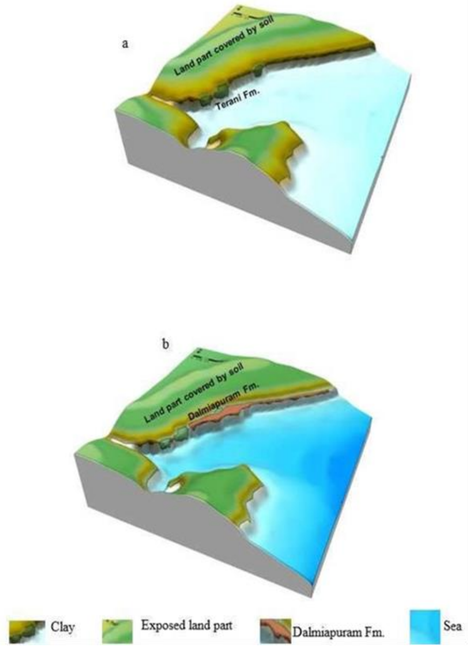

Fig. 3. Three-dimensional block diagrams showing (a) the Terani Claystone Member at the base with sandstone intercalations and the Terani Gritty Ferruginous Sandstone Member at the top. Quartzo-feldspathic and ferruginous gritty sandstones with intercalated claystone make up these deposits. (b) The Dalmiapuram Fm is formed by the CAL, MBL, Greyshale intercalations, and ML (CAL= Coral Algal Limestone, MBL=Marl Bedded Limestone).

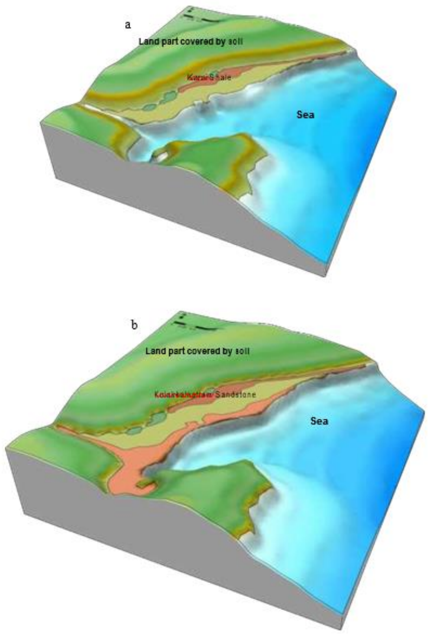

Fig. 4. Three-dimensional block diagrams illustrating a) Karai shale exposure due to basinal uplift, possibly induced by the Marion hot mantle plume rising. With respect to the Dalmiapuram Formation, this shale is a deeper-water deposit. b) The Kulakkalnattam sandstone is a strongly burrowed shore face facies unit.

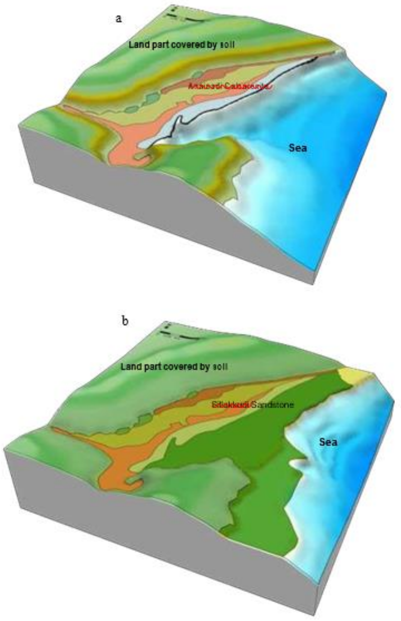

Fig. 5. Three-dimensional block diagrams of the same sandstone exhibiting (a) Kulakkalnattam sandstone and (b) Anaipadi Calcarenite as facies variants. (b) Inoceramus, Echinoids mega fossil, and Thalassinoides burrows are found in the Sillakkudi sandstone, which is dominated by quartz. The deposits are formed in a trangressive environment.

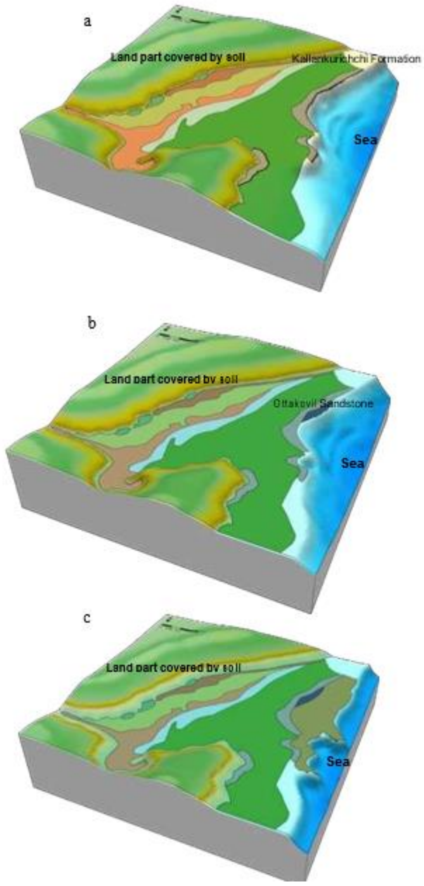

Fig. 6. (a) Three-dimensional block diagrams depicting Kallankurchchi Fm comprising of Ferrugenous limestone, aranaceous limestone, and Graphyea limestone are sandwiched between them. (b) Mega fossils are found in the Ottakovil sandstone, which has deeply burrowed formations. (c) Fluvial channel deposits are shown by the cross-lamination structures in the Kallamedu Formation.

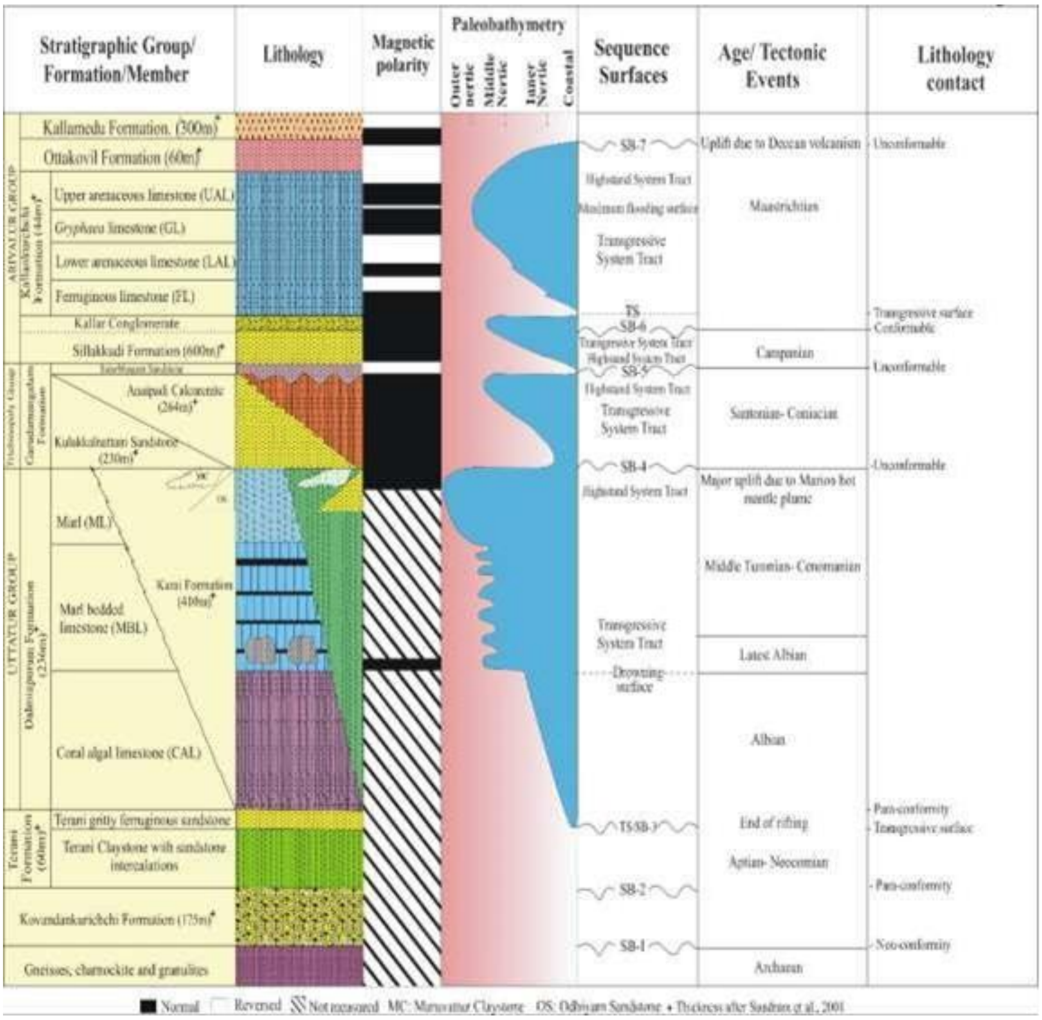

Fig. 7. Integrated data on lithology, sequence surfaces, age and tectonic events and lithology contact in the Cauvery basin outcrops in the Ariyalur area.

Conclusions

• The outcrop succession in the Cauvery basin in the Ariyalur area contains seven 2nd/3rd order sequences (Fig. 2).

• The topmost section of the Terani Gritty Ferruginous Sandstone Member, which contains foraminifera and ammonite shells, represents the first marine transgression at the basin margin.

• A drowning surface is inferred from the abrupt termination of the Coral Algal Limestone, which was created by clastic input and a relative rise in sea level.

• Due to basin uplift linked with the Marion hot mantle plume during the late Turonian, SB4 is associated with a 2.10 Ma hiatus.

• The macrofossil-rich Gryphaea Limestone Member represents one of the best-developed maximum flooding surfaces (MFS) in the outcrop area.

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