Synrift depositional set up and reservoir characteristics on active ridge flank; A pseudo shelf-slope regime. A Case study from Kali-Kuthalam area, Cauvery Basin, India

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Keywords

Shelf, aggradation, bitumen, wacke, syn sedimentary, convolutions, diagenesis

Abstract

Kali and Kuthalam fields are located on the sloping part of eastern flank (footwall) of the Kumbakonam ridge in Cauvery basin. During synrift marine transgression, Aptian-Barremian shale is the earliest sediment to deposit on the basement in this area. Arenaceous sediments of Albian-Aptian age of Upper Andimadam Formation marks the rift climax. The location being in the proximity of boundary faults, rapid rate of sedimentation has created strong syn sedimentary deformation structures (sediment failure) during synrift and later on, east ward tilt of the basin and rapid burial of this area has given rise to pseudo shelf-slope appearance on present day regional seismic. But these synrift sediments are deposited in shallow marine environment probably under fluctuating foreshore-shore face conditions with strong terrestrial input contrary to the general outlook of the deep marine. This makes great difference in geological modelling. Coupling of active sea level rise and rapid rate of sedimentation has created higher order fining up sequences with overall aggradational stacking pattern and small scale Syn-sedimentary soft deformations. This is evident from conventional cores and electrologs. Overall diagenesis is dominant mechanical compaction with moderate clay matrix (kaolinite + chlorite) with patchy carbonate cementation and terrigenous coal streaks.

Introduction

Cauvery basin is a commercially proved hydrocarbon basin in India. As a result of rift-drift phenomenon of the Indian plate from Gondwana land in M-Late Jurassic - Early Cretaceous, taphrogenic fragmentation of the Archaean-Proterozoic basement occurred (Nagendra et.al, 2017, Basavaraju et, al, 2016) and a number of the existing basement faults/lineaments got reactivated during the evolution of the basin. This basin constitutes alternating horsts and grabens trending NE-SW. From north to south, the grabens/depressions are named as Ariyalur-Pondicheny, Trauquebar-Tanjore, Nagapattinam, Palk Bay - Ramnad and Mannar sub-basins. The horsts separating the sub-basins are likewise designated as Kumbakonam - Madanam, Karaikal, Pattukotai – Mannargudi, Vedaranyam and Mandapam-Delft ridges. The basement tectonics was very active during synrift and post rift causing tectonically induced slopes. A series of NE-SW trending active normal faults parallel to and in enechelon with bounding fault were responsible for creating slopes in all the sub-basins. Series of N-S, E-W and NNW - SSE faults are responsible for segmenting the ridges and aided in the development of saddles. Major E-W/NW-SE transform fault are pathways for drainage in to the basin.

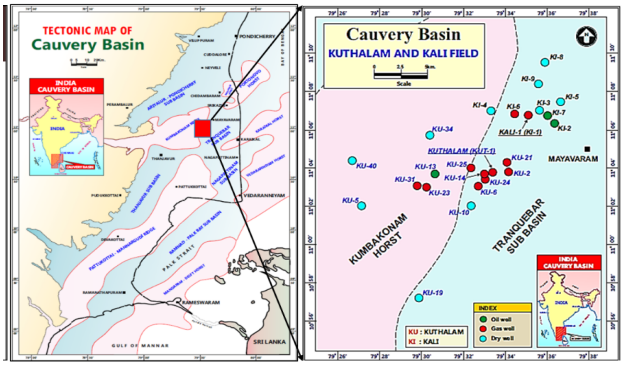

Figure 1: Above plate displays Horst and graben sturucture of Cauvery basin following the overall general trend NE-SW, transected by transform faults in NW-SE direction. Alternating ridges and depressions can be seen. Location of Kali and Kuthalam fields can be seen.

Objective and Methodology

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Objective of this paper is to understand the tectonically active ridge flanks areas in the rift set up. Overall geological evaluations based on seismic and litho-bio stratigraphic studies in better understanding of evolution of ridge flank areas thus better delineation of petroleum systems. Kali-Kuthalam area on the eastern ridge flank of Kumbakonam-Madanam, Cauvery basin is a best example of such location. Sedimentological studies are carried out on conventional cores for lithology, depositional environment and reservoir characterization in biostratigraphic set up. Electrolog evaluations are carried out to identify the nature of sediment sequencing. Litho-Bio-Electrolog evaluations are integrated with seismic profiles to infer the overall geological set up of the area.

time progress, the shallower flank areas of the ridges also becomes part of the sea/ocean and exhibits distribution of sediments. There exists multiple coast lines almost parallel to each other following the same general trend of horst & grabens. During final phases of Syn-rift, these flank areas receives greater amounts of sediments as drainage pattern gets stronger. As sea takes over, all intercontinental basins get connected by one ocean and becomes part of a single open marine system. Kali and Kuthalam fields are adjacent areas located in Tranquebar sub basin (fig 1). All the wells are located on the eastern flank of the Kumbakonam ridge. Kuthalam and Kali field both are closely spaced and shared same geological setting and sedimentation history. This part of the basement came under mean sea level after Barremian sea level rise and started to accommodate sediments.

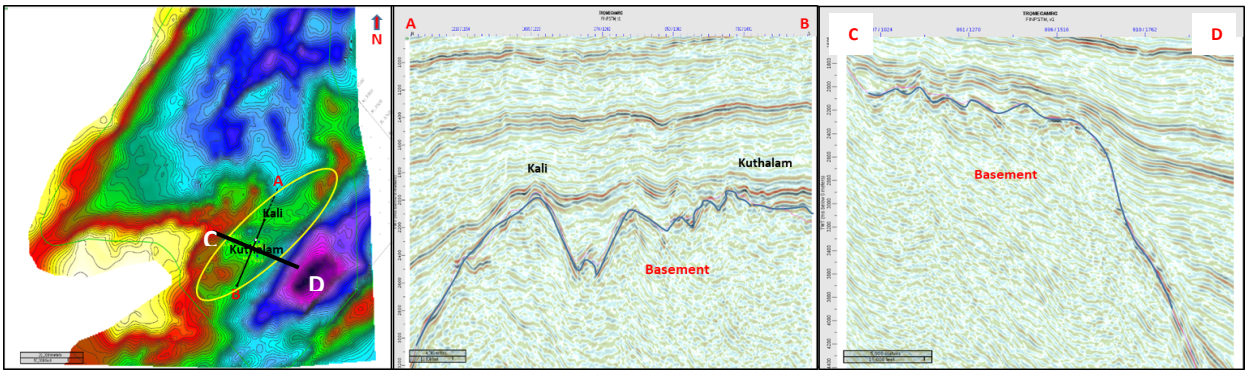

Figure 2: Seismic sections AB and CD along with time relief map of the area depicting nature of basement and overlying sediments. Cross section AB in NE-SW direction almost parallel to the general trend of the basement. Saddles within the basement can be seen. Cross section (CD) in NW-SE direction on time relief map. From Kuthalam flank to the deeper area, a sudden drop in basement depth as pseudo shelf-slope can be seen. It was not that steep as it is today.

Pseudo Shelf-slope

In continental rift basins, as rift is progressing and new sea is originating, each intercontinental graben or depression behaves like an independent lake or sea. Initially, the central and deeper parts of the depressions get connected and displays relatively wider distribution of contemporaneous sediments. As

This area being in the proximity of boundary faults, rapid rate of sedimentation during synrift, and later on east ward tilt of the basin and rapid burial of this area has given rise to pseudo shelf-slope appearance on present day regional seismics. Besides, the sedimentary structures from conventional cores of this area has shown deformational structures like sand-shale admixing, micro faulting, micro slides and slumps and gives rise to the misled interpretation of deep marine slope failure and related mass flows & turbidities. But the geological environment of that time is entirely different and is of shallow marine.

Sedimentation and depositional set up

Lithofacies identification is done by integrating conventional core studies and electrologs. During Albian-Aptian time when active marine transgression

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is happening, there is enough accommodation space and the rate of sedimentation is also high and rapid. This has created aggradational stacking of the sediment with fining up nature. Megascopic and electrolog interpretations of CC-1 and CC-2 (2560-2578m) of well Kali-C is present below.

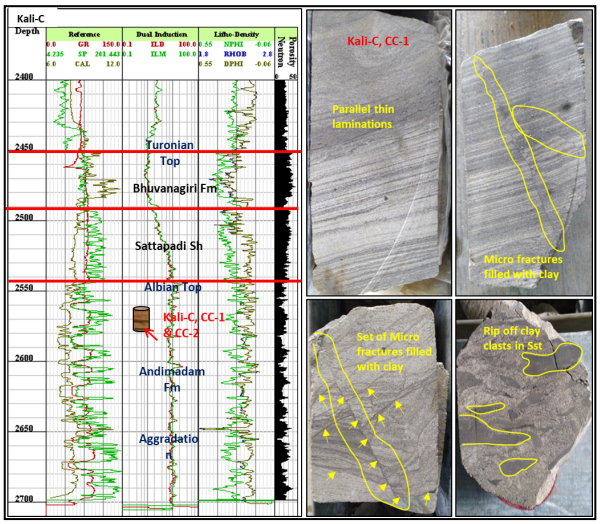

Figure 3: Well log with ages and formation boundaries of well Kali-C. Stratigraphic position of CC-1&CC-2 is displayed. Albian top is the top of Andimadam Formation and end of synrift. Vertical aggradation with Andimadam can be seen. Micro photographs are displaying parallel even regular laminations with micro fractures filled with soft clay (syn sedimentary) and rip off clay clasts.

Megascopic studies of conventional cores

Megascopic studies of Kali-C, CC-1 and CC-2 (Fig 4) of Albian age concludes that overall lithology is dominantly sandstone with minor shale alternating laminae. Massive structureless coarse sandstone grading into scarcely laminated fine sandstone. Fining up sequences are roughly 2m's thick. Primary sedimentary structures present are parallel even laminae and flaser bedding. Soft syn-sedimentary deformation structures like sand-shale infusions, convolutions, small scale flame structures, parallel micro fractures those are filled by clay, micro slips are visible. Vertical water escape structures are present. Terrigenous plant debris are present along with Shaly matter.

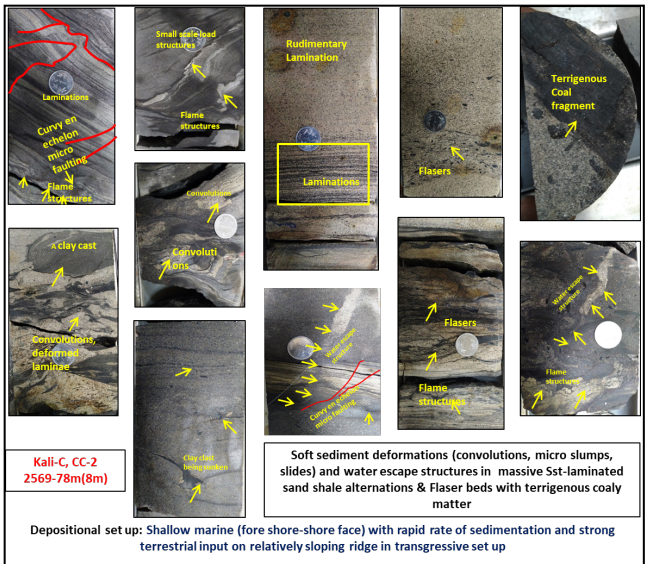

Fig 4: Megascopic observations of CC-1 and CC-2 of Kali-C well.

Megascopic studies of Kuthalam-A, CC-1 (fig 5) of Albian age indicates that major lithology is massive structureless coarse sandstone grading into laminated fine sandstone-shale alternations and then to shale.

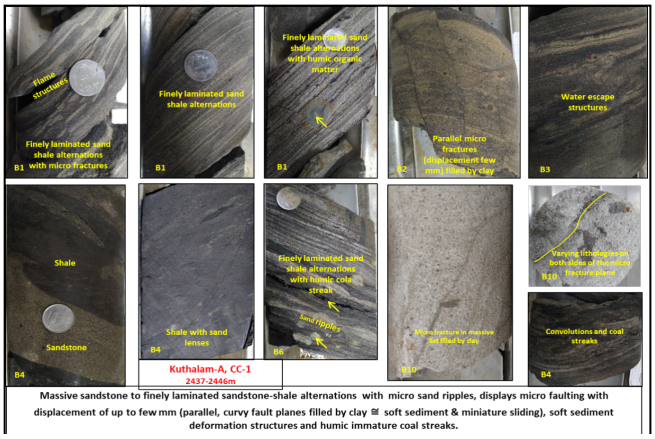

Fig 5: Megascopic observations of CC-1 and CC-2 of Kuthalam-A well. Environment of deposition is shallow marine (mostly foreshore) with strong terrestrial input.

Coarse sandstone signatures of sand flow. Fine laminated sandstone exhibiting even parallel regular

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laminations. Sand shale infusions, small scale convolutions, water escape structures, flame structures, small scale sand ripples, small sand lenses in shale are indicative of soft sediment deformation (ductile deformation). Parallel small scale micro fractures with displacement of few cm are also present. These fault planes are filled with soft clay by fluid movement indicative of soft sediment deformation. Terrestrial plant streaks are also seen along fine laminae.

Petrography and Reservoir Characteristics

Petrographic evaluations of Conventional cores of Kali and Kuthalam area revealed that, coarse sandstone is texturally mature and quartz rich and feldspathic up to 15% with subordinate mica. Coarse sandstone is quartz arenite to sub arkose and fine sandstone is wacke. Sediments have majorly undergone mechanical compaction with minor clay matrix of kaolinite, chlorite and secondary patchy calcareous cement.

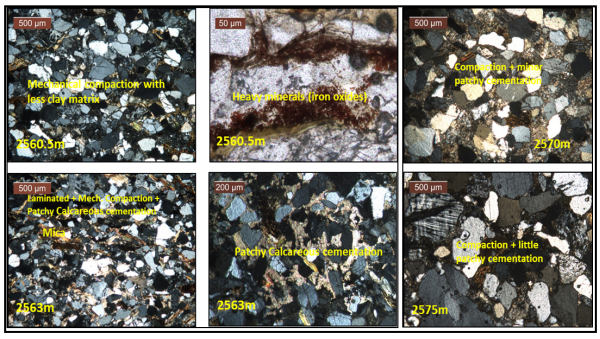

Fig 6: Petrography of CC-1 and CC-2 of Kali-C well. All images are under X-nicols. Mechanical compaction with sub ordinate clay matrix and patchy calcareous cementation.

Feldspar is altering to kaolinite clay. Dissolution of feldspar grains facilitated secondary porosity. Coarse sandstone is moderate to good reservoir with good textural maturity, little clay matrix, little patchy cementation and generation of secondary porosity. Petrography of conventional core CC-1 & CC-2 of Kali-C and CC-1 of Kuthalam-A is given below in fig 6 and fig 7 respectively.

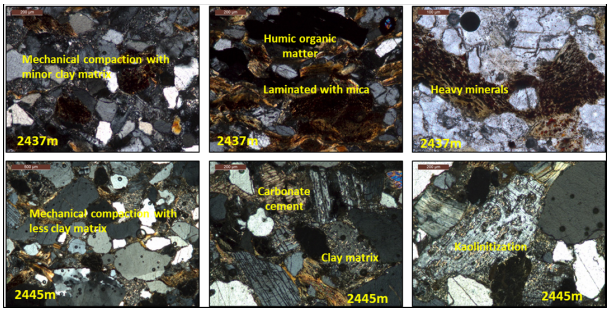

Fig 7: Petrography of CC-1 of Kuthalam-A well under X-nicols. Mechanical compaction with sub ordinate clay matrix and patchy calcareous cementation. Kaolinitization and calcite replacement can be seen.

Conclusions

Kali-Kuthalam area being in the proximity of boundary faults, rapid rate of sedimentation has created deformation structures (sediment failure) during synrift and later on, east ward tilt of the basin and rapid burial of this area has given rise to pseudo shelf-slope appearance on present day regional seismics. But synrift sediments are deposited in shallow marine environment probably under fluctuating foreshore-shoreface conditions with strong terrestrial input. Overall diagenesis is dominant mechanical compaction with moderate clay matrix (kaolinite + chlorite) with patchy carbonate cementation and terrigenous coal streaks.

References

Naresh Kollimarla and M. Malli Vijay (2019): Conventional core studies of Kali and Kuthalam area of Cauvery Basin, Internal project, RGL, Chennai.

Dr. B.Venkataraman and B. Bhaskaran (2003): Integrated Studies on Hydrocarbon Prospects of Kali-Kuthalam fields. Cauvery Basin, India.

R. Nagendra, A. Nallapa Reddy, 2017, Major geologic events of the Cauvery Basin, India and their correlation with global signatures – A review

M.H. Basavaraju, B. C. Jai Prakash et. al. 2016, Biostratigraphy and depositional environments of

subsurface sediments in well Arani-A, Palar basin, Tamil Nadu

J. Pandey and V. K. Rao (1991): Standard Laboratory Techniques & Procedures in
Geology, KDMIPE, ONGC, Dehradun, 1991.

Venkatarengan, R. et al (1993): Lithostratigraphy of Indian petroliferous basins. Document – VII; Cauvery Basin.

Reineck, H. E. and Singh, I. B. (1973): Depositional Sedimentary Environment, Springer.

Unpublished ONGC Internal reports.

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