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Hydrocarbon Potential of the Gentle Flank of the Rift Graben - A Study on Cauvery Basin, India

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Summary

Cauvery Basin is the southernmost among the Mesozoic rift basins of India lying along its east coast. The basin came into existence due to separation of Indian plate from Antarctica during the fragmentation of Gondwanaland. In rift basins, hydrocarbons generated from pre rift/ syn rift sources have a tendency to accumulate on the gentle slope both in syn rift and in immediate post rift sediments. Present study established that in Cauvery basin most of the established hydrocarbon accumulations occur on the gentle flanks of the syn rift half grabens. Similar phenomenon of preferential hydrocarbon accumulation has been observed in prominent petroliferous basins, viz., Reconcavo (Tequipe and Aqua Grande Field, Brazil) and Gulf of Suez (Middle East). In the present study, the preferential proclivity of hydrocarbons on gentle flanks has been examined from Generation-Migration-Entrapment point of view. The reactivated NNE-SSW set of faults and the transfer faults have been the conduits for vertical migration. The stratal up dips towards the gentle flank is the guiding factor during migration of hydrocarbons to the gentle flanks.

Introduction

In Cauvery Basin rift related extensional faulting (along Eastern Ghat trend) that spanned from Late Jurassic (~160 Ma) till late Albian (~101.5Ma) resulted in formation of a number of en echelon horst and half grabens (sub basins) of varying polarity and tilt viz., Ariyalur-Pondicherry, Tranqueber, Nagapattinam, Tanjore, Gulf of Mannar-Ramnad-Palk-bay and Pamban (between India and Sri Lanka). The basement high trends that separate these Cretaceous half grabens are Kumbakonam-Madanam-Portonovo Pattukottai-Mannargudi-Vedaranyam-Karaikal and Mandapam-Delft ridges (Fig. 1). The major graben bounding NNE-SSW normal faults were dissected by two conjugate transfer zones in WNW-ESE and WSW-ESE directions (Fig. 2).

Cauvery Basin comprises more than 8000 m thick sedimentary sequence ranging in age from Late Jurassic to Recent deposited over Precambrian granite-gneiss basement. Oldest sediments encountered in drilled wells are

dated as Oxfordian age (Upper Jurassic) based on palynology. However, the oldest sediments studied in the outcrops are of Neocomian-Barremian age (Lower Cretaceous) deposited in non-marine to marginal marine conditions. Initial depositional environment was probably lacustrine and with the incursion of sea during rifting, shallow marine condition had prevailed. Gradual deepening of basin during active rifting resulted in deeper bathymetry.

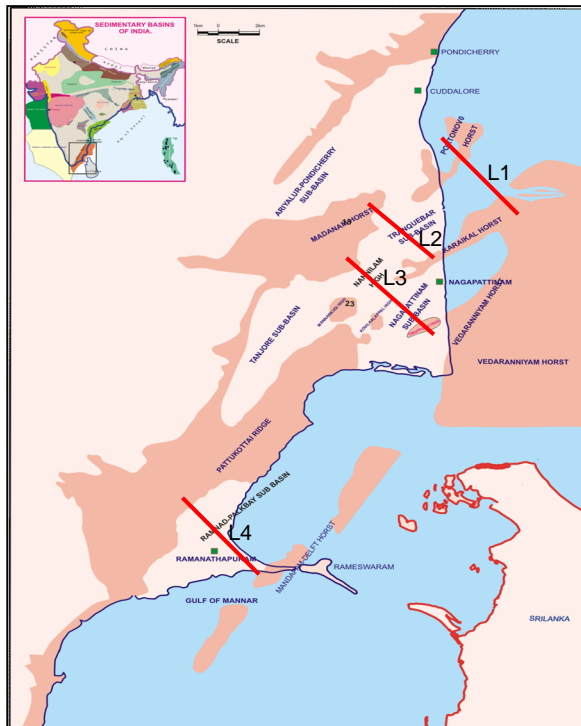


Figure 1: Tectonic Map of Cauvery Basin

The pre/syn rift sediments comprising sandstones and shales of Andimadam Formation range over 4000m in thickness. The post rift sediments dominated by clastics with considerable limestone development in the Tertiary also ranges over 4000m. The generalized lithostratigraphy of Cauvery basin is shown in Fig. 3. Five major unconformities were observed within Albian, Turonian, Campanian, Maastrichtian and Miocene in the outcrops. The widespread unconformities at the top of Turonian and Cretaceous have probably been caused by basal exhumation due to uplift and contraction. Initial shelf-slope system started emerging during late Cretaceous and gradually typical shelf-slope system had emerged by Early Eocene.

Method

Seismic, well log and laboratory data were integrated for analysing the structural elements of rift segments, stratigraphic framework and depositional setting. Four representative seismic profiles from different sub basins covering boundary fault margin to flexural margin are shown along with the drilled wells (Fig. 4, 7, 8, 9). The emerging trend clearly shows preferential hydrocarbon accumulations on the gentle flanks of the half grabens.

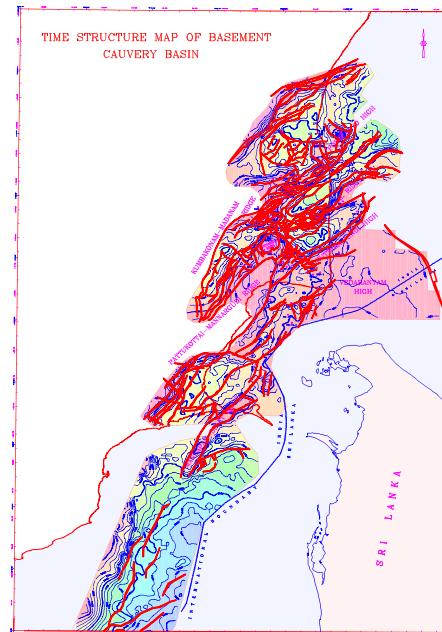


Fig. 2: Time Structure Map of Basement showing major fault trends.

Observation and Analysis

Almost all the sub basins are NNE-SSW oriented half grabens either with gentle eastern flanks i.e. Tanjore, Ramnad, or gentle western flanks i.e. Tranquebar, Nagapattinam.

The sediments deposited during initial rift were probably nearly flat-lying. Continued rifting and deepening of high angle graben-bounding normal fault gave rise to typical wedge shaped facies. The syn rift wedges rotated and tilted towards the graben binding faults till end of rift (late Albian). Consequently strata up dip directions point towards the gentle flanks (Fig. 4). Geological section along the representative seismic line L4 passing through Ramnad sub basin (Fig. 5) clearly depicts the half graben architecture, fault patterns, strata wedging and inversion structures on the gentle flank of the half graben

Reservoirs- syn rift and post rift: During rifting, major sediment supply comes through

- Longitudinal (axial) drainage from the shoulders of the rifted grabens (Fig. 6).
- Transverse drainage from the gentle flanks (hanging Wall) and.
- Transverse drainage from the (steep flank) footwall along transfer zones



dissected by reactivated/ younger faults the hydrocarbons are routed up into younger reservoirs with predominant gentle flank bias in Cauvery basin (Fig. 5). Major fault trends are synthetic and antithetic to the graben bounding fault and more in number relatively towards the flexural margin than fault bounding margin of the half graben.

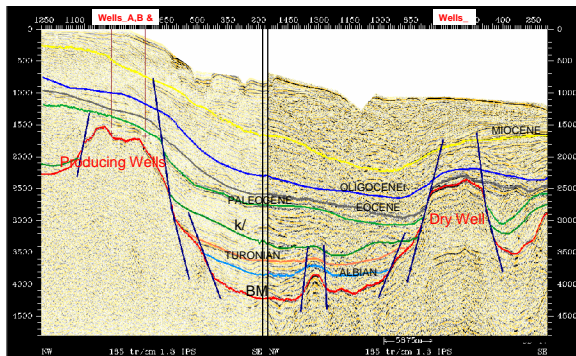


Fig. 7 Seismic section passing through Offshore (L1) – North Cauvery

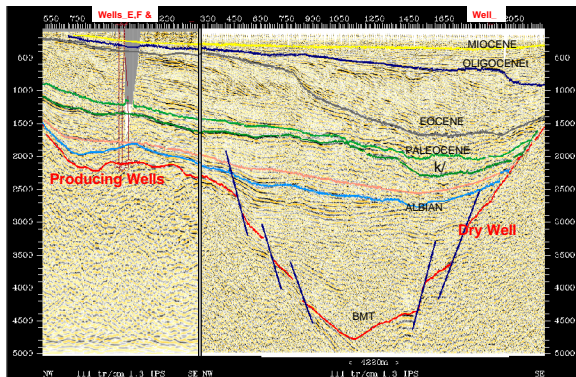


Fig. 8: Seismic section passing through Tranquerbar sub basin (L3) – Central Cauvery

Sub basin wise hydrocarbon proclivity on the gentle flanks in Cauvery basin is demonstrated on seismic and geological sections (Fig. 4,5,7,8&9). The typical geological cross section in Fig. 5 passing through the representative seismic line L4 in Fig. 6 of Ramnad sub basin shows the graben bounding fault to the west and the discovered hydrocarbon pools (wells R-3 & R-4) to the east on the gentle flank to the east.

Several stages of reactivation of the synrift extensional faults are noticeable. Inversion of the faults responsible for hanging wall antiforms are observed near the Cretaceous

top (Campanian-Maastrichtian) in North and South Cauvery whereas, in Central Cauvery such activity continues further into Eocene and Oligocene.

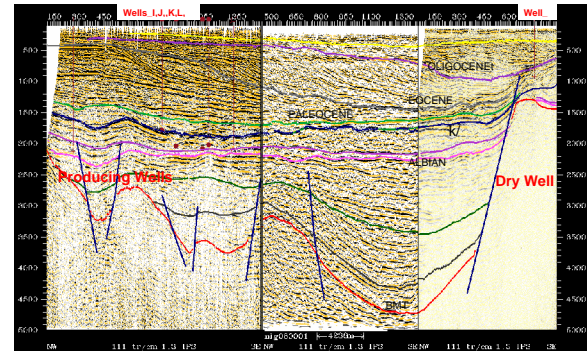


Fig. 9: Seismic section passing through Nagapattinam sub basin (L2) – Central Cauvery

Occurrence of mature source facies is largely restricted within the syn rift sequence. Extension of the rifted graben into the present deep offshore areas enhance the possibility of considerable hydrocarbon generation in the offshore part of Cauvery basin, wherein already a medium size oil field, a small gas field and recent oil and gas strikes establishes the potential of offshore sub basins. Future exploration in deep offshore Blocks of Cauvery would be rewarding if it's focused on probing the gentle flanks of the half grabens.

Conclusions:

- Based on a detailed study of Cauvery basin and worldwide analogues, it is propounded that hydrocarbons generated from pre rift and syn rift sources would preferentially migrate to the gentle flanks of the rifted half grabens.
- This case study in Cauvery basin clearly brings out the higher prospectivity of the gentle flank in all sub basins.
- The vertical migration through the transfer faults were and also the reactivated NNE-SSW faults has carried the hydrocarbons into the post rift sediments without altering the gentle flank bias in Cauvery basin.

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