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Rift Architecture And Its Control On Syn- Rift Sedimentation In Ahmedabad Block, Cambay Basin

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Summary

The present study integrates various surface and subsurface data using the evolving concepts on rift – tectonics and depositional environment to understand the interplay of rift architecture and sedimentation in Ahmedabad Block of Cambay failed rift.

Integrated study of seismic and other geoscientific data has been brought out that the synrift sediments fill can be divided into three major tectono- stratigraphic units: Early Rift, Rift Climax and Late Rift. The Early Rift is dominated by the deposition of slide and slump derived immature fluvial sandstone and conglomerate into the evolving half grabens. During rift Climax phase, the rate of tectonic subsidence exceeded the rate of sediment supply, causing the basinal lows to receive finer clastics which formed the source rock component of Syn- Rift phase. During the Late Rift period, the sediment supply outpaced the rate of tectonic/ fault controlled subsidence, indicating the deposition of well sorted coarse clastics- the potential reservoir rocks. The Rift Climax and Late Rift phase together constitute the source – reservoir couplets and therefore, form excellent areas for hydrocarbon exploration in Ahmedabad Block.

Introduction

Cambay basin –an on-land petroliferous basin, is situated in the western part of the Indian subcontinent in the state of Gujarat bordered by the Saurashtra uplift in the west and by the Aravalli – Delhi fold belt (NE-SW) on the east (Fig.1). Being an pericratonic aborted rift (Biswas, S.K., et. al., 1993), it provides an unparalleled natural laboratory for studying the processes and products of continental extension. The present study deals with the Ahmedabad Block of North Cambay Basin defined by Nandasan fault in the north, in south by Vatrak fault and Gulf of Cambay in the west and in the east by Sabarmati River. Rift architecture of this block and sedimentation pattern in tectono- stratigraphic framework (Fig.2) has been critically analysed.

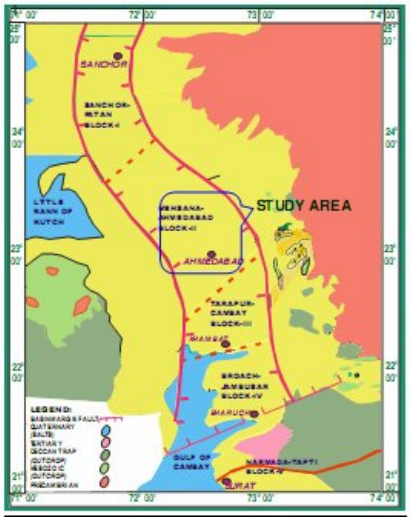

Figure.1. Map of Cambay Basin showing study area.

Regional Geology: An overview

The Cambay Basin is an intracratonic, NNW- SSE trending rift system situated in northwestern margin of the Indian Precambrian shield (Fig.3). This basin, like many other continental rifts, displays large-scale structural domains controlled by preexisting basement fault systems of Aravalli and Delhi trends. Magnetic and seismic data indicate that the rift geometry exhibits marked changes along the strike especially by alternations of half-graben asymmetry. These changes could be cross-faults, transfer/ accommodation zones which subdivide the basin into discrete sub-basins (Fig.3) with intrabasinal highs (Transfer zones). The different tectonic blocks are, i) Sanchor – Patan block, ii) Mehsana – Ahmedabad, iii) Tarapur – Cambay; iv) Jambusar- Broach and v) Narmada – Tapti block.

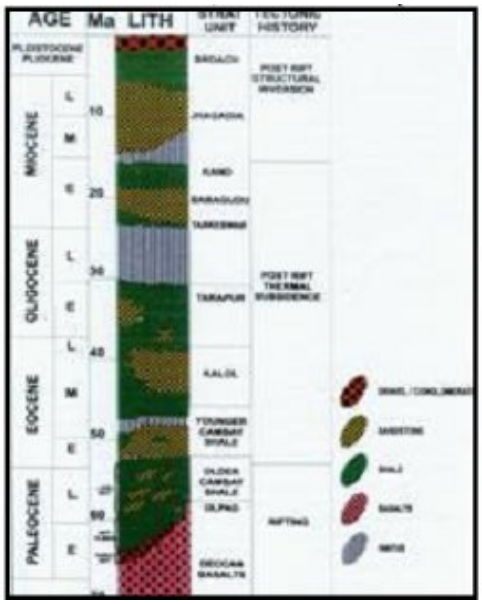

Figure.2. Generalised tectono-stratigraphy of cambay Basin.

Figure.3. Tectonic map of Cambay Basin in relation to tectonic setting of Western India Showing Saurashtra, Kutch & Bombay Basins.

Generalized stratigraphic column of Ahmedabad Block is given in Figure.4.

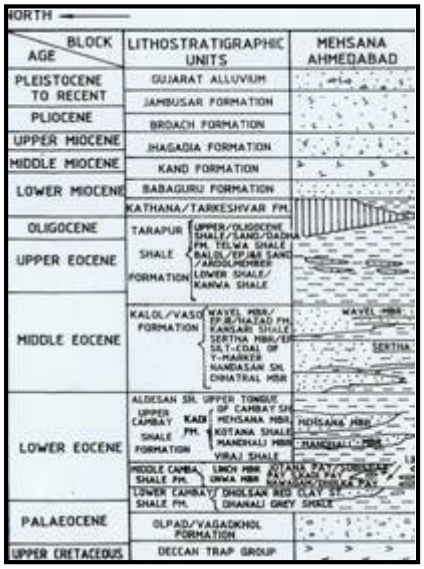

Figure.4. Generalised stratigraphy of Cambay Basin.

Deccan basalts of Upper Cretaceous to Lower Paleocene age forms the technical basement and is overlain unconformably by Trap wash, Trap conglomerate, claystones and siltstones of Olpad Formation accumulated in the rift-related asymmetric half grabens. The Cambay Shale overlies the Olpad Formation and marks the first major marine transgression in the basin during Early-Middle Eocene. The present study is limited to the alluvial to lacustrine rift fill sediments of Olpad and Older Cambay Shale Formation. Recent alluvium covers the entire basinal area except the outcrops along the eastern margin.

Geodynamics of Cambay Aborted Rift basin

The Cambay Basin originated by rifting and drifting of the Indian plate from the Madagascar marked by outpouring of huge Deccan Basalt during Late Cretaceous time. The rifting subsequently failed and evolved as a post rift interior basin (Aborted Rift) synchronous with the evolution of the Arabian Sea (Fig.5). During Late Cretaceous period, widespread basin formation occurred due to crustal subsidence that followed the Deccan volcanism. The crust around Cambay and Narmada rifted during Cretaceous phase due to widespread crustal tension. Located over rising columns of hot mantle, these rifts ('failed arms') never became oceans. Compressions originating in the plate collisions that produced the Indo- Beluchistan orogeny and upliftment of Western Himalaya caused erosion (inversion) of rift basin contents.

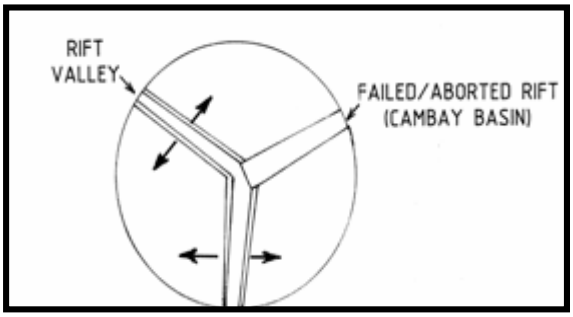

Figure.5. Schematic diagram showing a failed/ aborted rift.

Methodology

The present study is based on the integration of various surface and subsurface data. The detailed sedimentological and stratigraphic analysis of the lateral variation in depositional geometries, stacking patterns and facies of the syn-rift package was undertaken. Subsurface geophysical data coupled with information from outcrop sample cuttings and cores are used as the basic data.

Rift architecture and its control on sedimentation

a) Early Rift phase

Many geoscientists conclude that the basic structural unit of continental rifts is the half-graben (Fig. 6). These half- grabens (Fig.7) were isolated, of sub- regional scale and were not connected during the initial stage of rifting. The Early Syn- Rift sequence display variable facies and is highly asymmetrical. This sequence is confined by an unconformity at the top (contact with underlying Deccan trap) and an erosional unconformity at

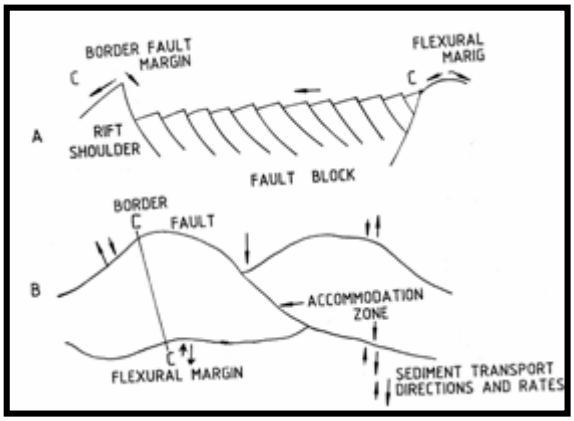

Figure.6. Diagrammatic section (A) and map view (B) of generalized structural geometry of a continental rift (After Lambiase, J.J., 1990).

the top (contact with Rift climax sequence). The basal unit of the Olpad Formation is dominated by mafic volcanic rock fragments, derived from volcanic rocks in the footwall of the graben bounding normal faults. The sediment supply to the sub- basins from adjacent highs (Fig.8) is dependent on basin architecture during rift initiation phase. The sediment (mostly trap conglomerate and trapwackes) transport routes being steep gradients and the sedimentation mechanism was dominantly slides and slumps. The resultant sediments were texturally immature, matrix dominated and prone to extensive later diagenesis.

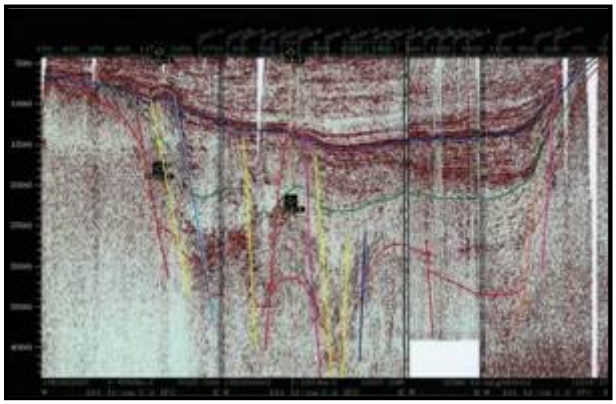

Figure.7. E- W seismic sections in the southern part of the study area representing horsts, grabens and basin margin faults.

b) Rift- Climax Phase

The rapid subsidence of the hanging wall and uplift of the footwall causes the drainage system to incise during Rift climax time. The rate of sediment supply was greatly exceeded in comparison to the rate of tectonic subsidence during this time (Fig.9). As the rate of tectonic subsidence increases, the basin is flooded with coarser

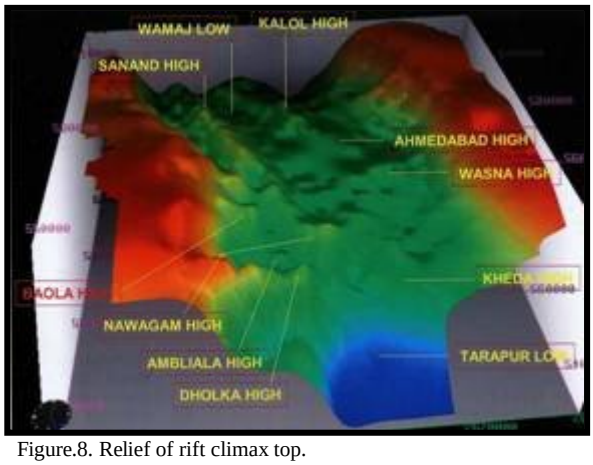

Figure.8. Relief of rift climax top.

clastics and the sediment gets deposited at the basin margin on the fault block highs and the rift axis was sediment starved. The bodies of water probably lakes that developed in the rift grabens, received deposition of a sequence consisting of siltstone and shale. These bodies of water were apparently rich in algae and fungi, which created organic – rich sediments.

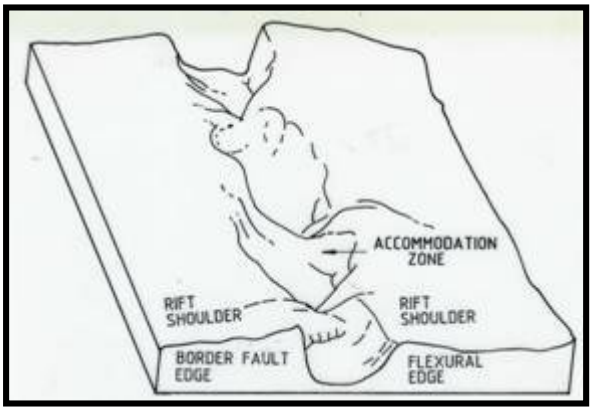

Fig.9. A continental rift following rapid initial subsidence (After Lambiase, J.J., 1990).

c) Late Rift Phase

The rift graben system was filled up by the higher energy systems and resulted in deposition of coarser clastics derived from channels during Late Rift phase. The channels were from both flexural margin and axial drainage system. The sediments are preserved on the footwall as well as hanging wall to active faults during this time. The rate of sediment influx kept pace with and commonly exceeded the rate of accommodation generation. Many isolated small basins were in existence during early rift time. This phase is characterized by the complex stacking patterns, different stages of tectonic unrest, rapid transgressions and variations in the rates and directions of sediment influx and generation of accommodation space. Deposits of this phase are extremely heterolithic and are interpreted as nonmarine lacustrine to parallic environments (Fig.10). In general, the basin was sediment filled during this time and achieved a near peneplanation at the concluding part of Sysnrift phase. Cambay Basin rifting came to an end in the Early Lower Eocene, with the cessation of further continental spreading.

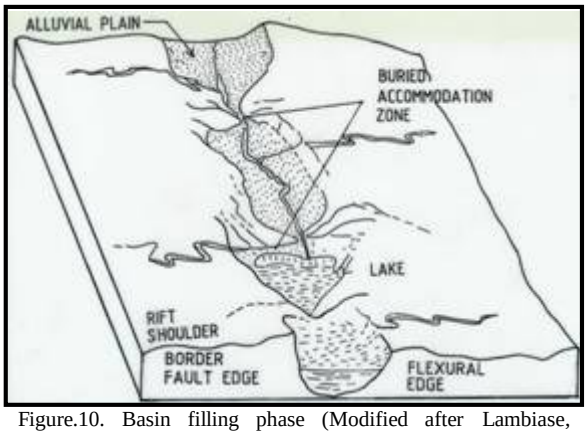

Figure.10. Basin filling phase (Modified after Lambiase, J.J., 1990).

Observation and interpretation

The most significant period of syn-rift deposition in Ahmedabad Block, occurred during Late Cretaceous to Upper Paleocene time. The component parts of the syn-rift succession are known as the Olpad Formation which was fluvial to lacustrine dominated and characterized by the presence of large, low angle extensional faults, distinct half-graben morphology with polarity reversal and rapid facies variation. The Older Cambay Shale is a late syn-rift sequence. It is thick in the Half-graben areas and onlaps the preexisting highs and accommodation zones.

The Wamaj low, a major low trending NNW- SSE lies in the northen part of the study area and the thickness of Rift climax sediments is around 2500 ms (Fig.11). The low has become deeper due to reactivation of low margin faults to accommodate more sediment. Oil fields viz. South Viraj, Sanand, Kalol and Indrora are producing from rift sediments. The well Kalol- A, drilled in the eastern margin of the Wamaj low, has shown well developed source potential in rift climax sediments. The increased percentage of methane gas with depth was observed in Olpad section I well Kalol-A during drilling indicates the generation of gas in the deeper section of synrift sediments (Fig.11). The main producing sands in the Dholka and Nawagaon fields are from this set of sediments. Development of arenaceous facies in the lower half of the Rift Climax phase indicates that initially these highs were the accommodation zones or the sands are of in situ origin formed by winnowing action. In the southern part, the major trend of low is almost N- S to NE- SW (Fig.12). The lows are separated by Dhloka & Ambliala high to the west and Mehmedabad high to the east. The transition from Rift climax sequence to late rift sequence is marked by change in sedimentation pattern

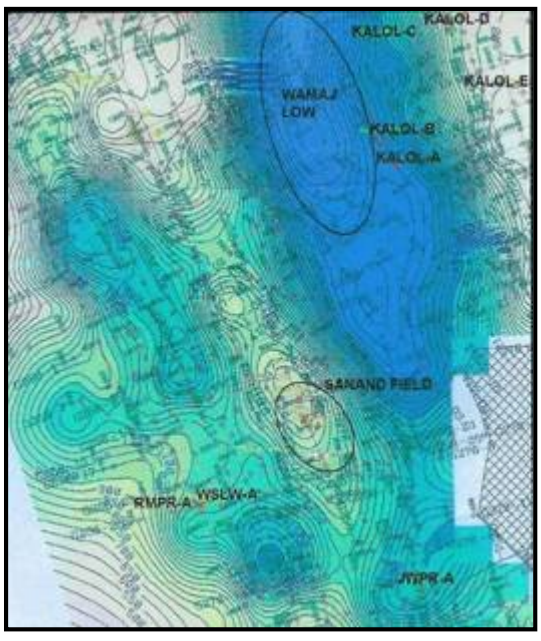

Figure.11. Time thickness map of Rift Climax sequence.

from fine grained lacustrine to coarse grained fluvial and shallow marine deposits. During this period, inversion structures were developed due to transpressional tectonics (e.g. Baola structure). The

sediment supply outpaced the rate of subsidence indicating deposition of coarser clasties during this phase.

The sediments deposited during late rift period are having good reservoir potential owing to the high energy condition prevailing at that time and lower deposition gradient. Wamoj low has been identified as the major generation kitchen for the Rift Climax sediments depending on source potential, thermal history and maturation history (Banerjee, A., et.al. 2000) (Fig.13). Olpad Formation attained maximum maturity 2.0 (Vro) in the central part of the major lows. The Cambay shale attained maturity level of about 0.4 – 0.55% Vro in all the depocentres at 36 MYBP (Ray, G.K., et.al. 2000) (Fig.14).

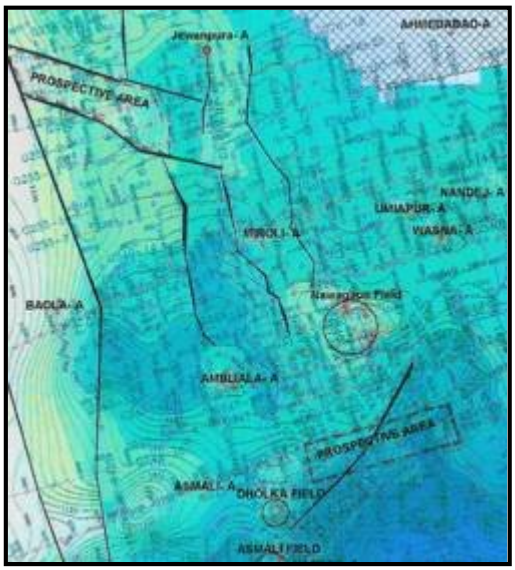

Figure.12. Time structure map on Rift Climax top.

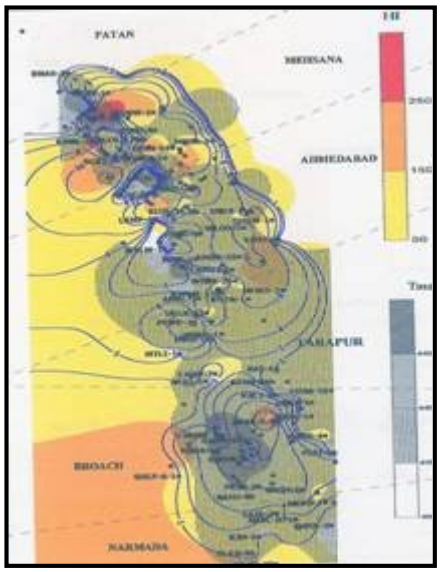

Figure.13. Average Source Potential Index, Tmax and HI for Cambay Shale formation in Cambay Basin. SPI (MT hydrocarbons/m^2) in solid lines. Areas with Tmax more than 435^0 C and HI (mg/ hydrocarbons/ g TOC). More than 50 are shaded.

Two prospective areas have been identified within synrift sediments, one is structural in nature located to the west of Jiwanpura- 1 and the other to the east of Dholka field is stratigraphic High amplitude event has been observed in seismic sections are interpreted as arenaceous facies and are good locales for hydrocarbon entrapment (Fig.12).

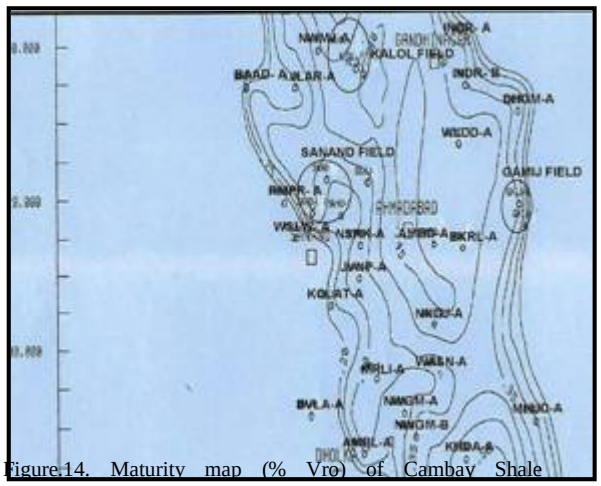

Figure.14. Maturity map (% Vro) of Cambay Shale layer (36 MYBP), Ahmedabad Block (After ray, G.K., 2000).

Play types of these Late Rift reservoirs are both stratigraphic and stratistructural in nature. Inversion structures form important stratistructural prospects. Both reactivated and newly created rift forming faults acted as conduits for hydrocarbons. The faults along with rift climax and Late rift source-reservoir couplets form existing synrift GME component.

Conclusion

- The stratigraphy of the Cambay Rift Basin spans all stages from Pre- rift, Syn- rift continental to lacustrine environments through the rift to drift transition to post- rift
- The component parts of the syn-rift succession are known as the Olpad Formation which was fluvial to lacustrine dominated and characterized by the presence of distinct half-graben morphology and rapid facies variation. The Older Cambay Shale is a late syn-rift sequence and is thick in the Half-graben areas and onlaps the preexisting highs and accommodation zones.
- Wamoj low has been identified as the major generation kitchen for the Rift Climax sediments.
- The volumetrically significant plays include both stratigraphic and stratistructural. These features are well placed with respect to closure, reservoir, timing and charge.

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