7th International Conference & Exposition on Petroleum Geophysics

"HYDERABAD 2008"

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Siliciclastic Neogene Sediments of Saurashtra Offshore, with Special Reference to Depositional Environment of Miocene Sandstones in Growth Fault Controlled Sedimentation in Shelf Slope Complex

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Summary

The shelf-slope break in Saurashtra offshore has shifted westwards through time, most significantly from the Mid-Miocene to the present in the study area. The approximate location of the shelf break at Mid-Miocene and the present day demonstrates westwards progradation of the order of 100 km. This migration of the shelf break was in response to huge volumes of sediments shed from the rising Himalaya Mountains and transported out to the shelf edge. These prodelta deposits were mud-rich.To the east of the present

day shelf slope break, within the belt of Mid-Miocene to present day shelf migration, numerous coast-parallel listric faults have been mapped. These reflect the same mechanism as mapped in the seismic volumes and document the instability of the shelf during rapid sediment loading. However, a sealevel fall during lowstands offered the opportunity to breach through the carbonates by possible development of lowstand incisions, enabling the transportation of coarser-grained b edload from the east into the Saurashtra and Shelf Margin Basins. Thus sand deposition in the study area was conceptualized to be a shelf slope fan complex setting.

The abundance of claystone, with minor amounts of silt and very fine sand, encountered in a drilled well indicates that suspension was the primary means of deposition in the Saurashtra and Shelf Margin Basins. FMI study results supports the conceptualized model of shelf slope fan complex with presence of thick sandstone in Miocene section.

Introduction

The area under study lies offshore Veraval, Saurashtra Peninsula, on the western passive margin of India (Figure 1). Water depth across the block increases from 80 meters in the east to around 500 meters in the west. The shelf break occurs on the westernmost side of the block at a water depth of around 140 meters (Figure 2). Total Tertiary sediment thickness within the block exceeds 7,000 meters.

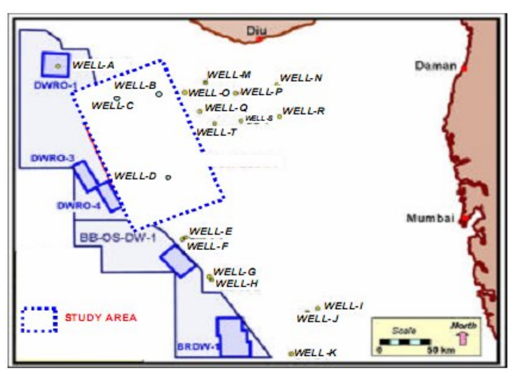

Figure 1. Location map of study area with two 3D seismic surveys within it.

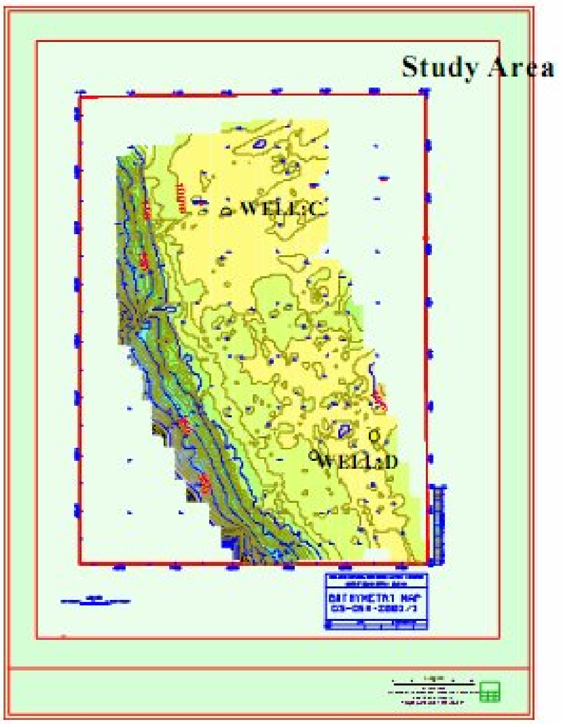

Figure 2. Bathymetry of Study area. Bathymetry varies from around 70 meters in the east to over 500 meters in the west. A prominent shelf break can be seen running along the western margin of the block. The seabed slope increases rapidly once a bathymetry of around 140 meters is met.

Regional Setting

The study area lies on the continental shelf of the western volcanic rifted passive margin of India. The basin extends from continental crust, Archean granitic basement, through probable Mesozoic sediments on the Continental slope, across modified and attenuated continental crust in the "East Laxmi Basin", to true oceanic crust, of mid-Cretaceous or younger age, which underlies the abyssal plain of the Arabian Sea west of the Laxmi Ridge (Figure 3). The area is expected to be underlain by thick Deccan Trap basalts overlying granitic basement with or without sub-Trappean Mesozoic sediments. The Deccan Trap basalts form the effective economic basement in the study area for petroleum exploration.

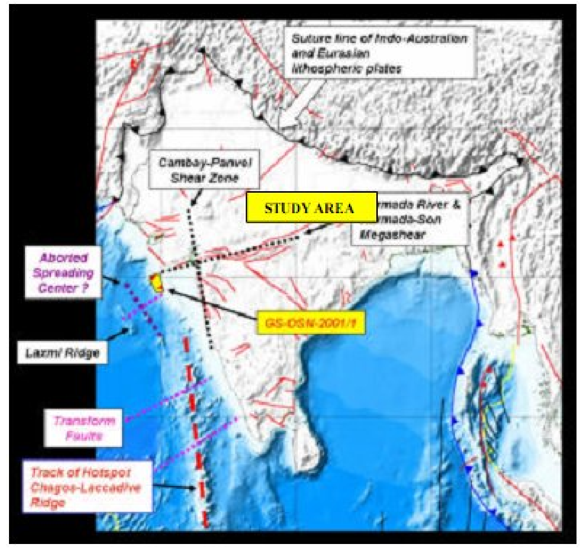

Figure 3: Main tectonic elements of the Indian subcontinent and location of study area. The area is bounded to the immediate north by the extension of the Narmada-Son megashear. The track of the Deccan hotspot passes to the east of the study area.

The simplified tectonic elements map of the Indian sub-continent shown above (Figure 3) illustrates a few key regional points. The area is affected by a number of crustal scale shears and lineaments including the ENE-WSW Narmada Son line and the NNW-SSE trend of the rift margin. More SW-NE trending shears are present related to old transform faults originating from the paleo- spreading ridge.

The N-S track of the lithospheric plate over the "hot spot", remained after Deccan Trap flood basalt extrusion at a mantle plume in NW India, forming the Chagos-Laccadive Ridge.

The smaller Laxmi Ridge to the northwest may be a sliver of continental crust. The Narmada River exploits the crustal scale Narmada -Son megashear. The Narmada and nearby Tapti rivers are the only significant rivers supplying quartz-rich sand size siliciclastics to the West Indian passive margin continental shelf.

To the north, the Indus supplies a vast deepwater siliciclastic turbidite fan complex that onlaps the lower part of the western Indian continental slope. Indus sediments will not occur within the area.

The area was effectively a starved moderately deepwater basin during the Paleogene. Carbonates thrived where local bathymetric highs favoured growth, while limited clastic input was recieved in basinal areas. Major tectonic reorientation, tilting and relative sea level deepening took place following the

Oligocene-Miocene collisionthat created the Himalayas, resulting in the introduction of clastics into the area and, for the most part, to the cessation of carbonate growth.

The Indus river system does not appear to have contributed reservoir-quality sands to the study area, while Narmada-Tapti fluvial systems are expected to have contributed significantly. The Indus turbidite system is restricted entirely to an area down slope of study area , while well control from the shelf indicates that Narmada-Tapti derived sediments are dominated by mudstones with silts, and sands.

Significant Geologic and Tectonic Events

"Crustal scale" tectonic events effecting the passive margin in the study area include:

1. Long period of stable emergent craton from Pre-Cambrian to early Mesozoic.Initial rifting and separation of India from Africa in the mid-Jurassic
2. Continued rifting, separation of Madagascar from west India in the mid-Cretaceous
3. Northward drift of western India over a mantle plume at K/T boundary
4. Outpouring of Deccan Trap flood basalts over a large area between 66 and 65 Ma
5. Last major rift as Seychelles moves away from western India in the Early Tertiary. Deposition of Paleocene-Eocene source rocks in accommodation caused by rifting
6. Continued igneous activity along southward moving track of hotspot. Thermal cooling and subsidence after rifting event & movement away from plume
7. Localized wrench tectonics and intrusive & extrusive igneous activity in the Eocene
8. Initial contact of Indo-Australian and Eurasian plate in mid-Eocene
9. Significant subduction and first major Himalayan orogenic event in mid-Oligocene
10. Extension & block faulting in some areas of western Indian margin in Late Paleogene
11. Thermal-isostatic subsidence of margin appears to accelerate around mid-Miocene
12. A geo-chronological chart showing some of the above events and a global sea level curve is shown in Figure 4. A discussion of the various stratigraphic units follows.

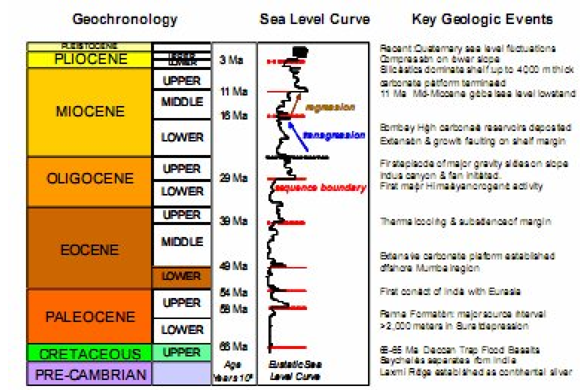

Figure 4. Geo-chronological chart, Sea Level Curve and Key Geologic Events

Oligocene–Recent Siliciclastics

The setting of the study area was basically that of a starved basin from early thermal subsidence in the Paleocene, until shelf progradation from the east reached the area in the Early to Mid Miocene.

The Oligocene through Recent siliciclastic sediments deposited over the Paleogene carbonates and interbank mudstones were initially fine grained, and significant sands only being seen in the Mid- Late Miocene and Pliocene.

In the study area, almost the entire Neogene section is heavily cut by west hading growth faults and associated smaller counter - regional antithetic faults (Figure 5). The growth faults sole out into a decollment within the Oligocene.

A major concern for the Miocene play in the area was presence of reservoir quality sands. The study area lies at a considerable distance from the mouths of the present day Narmada and Tapti Rivers which are the only significant source of siliciclastics to the area. Any sands from these rivers should presumably be expected to reach the area during sea level lowstands, and should be present in features such as incised valleys, shelf -edge deltas, and low stand slope wedges.

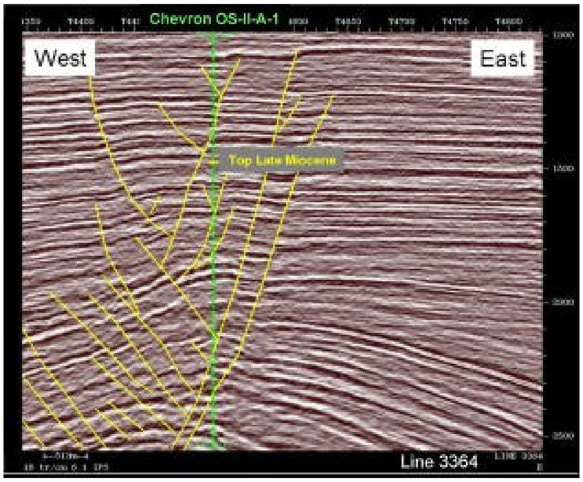

Figure 6. Fault interpretation through the well-C

Neogene clastics and their depositional system conceptualised

1. The study area lies in the East of present day shelf slope break.
2. Present satellite image and well data indicates alignment of coarser clastics due to tides dominantly along the Saurashtra Craton.
3. The Paleo shelf break during Paleogene period was on the east of study area. This is manifested by isolated carbonate build ups at Eocene level. During Neogene period due to surplus clastic supply from east-north-east shelf edge prograded westwards for about 100kms upto present day shelf slope break.
4. Progradation of Miocene shelf to present day position was due to to abundant sediment deposition between Miocene shelf slope break and Present day shelf-slope break.
5. The enormous clastic supply was due to Regression , Himalayan Orogeny, basin tilting towards west and shift of depocentre from Surat depression to the study area.
6. This shift of shelf-slope break led to the generation of listric faults and and generated accommodation for sediment. (Fig-7,8&9)
7. The Coasrer clastics supplied through subsea channels from the North–East are perpendicular to Listric faults. The coarser clastics were getting aligned along the listric faults parallel to Paleo shelf break as fan deposit.

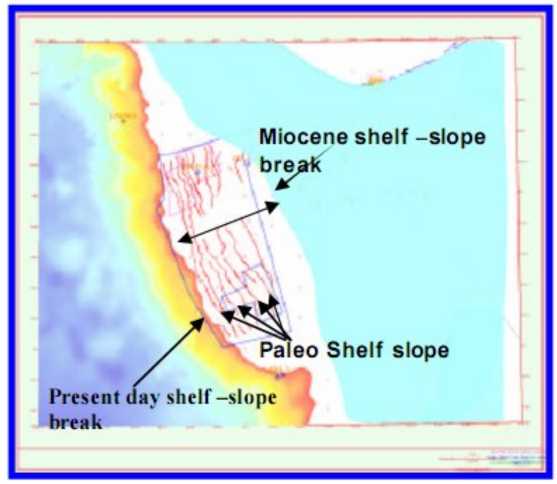

Figure 7. Miocene shelf prograded to present day depicting generation of listric growth faults as their footprint.

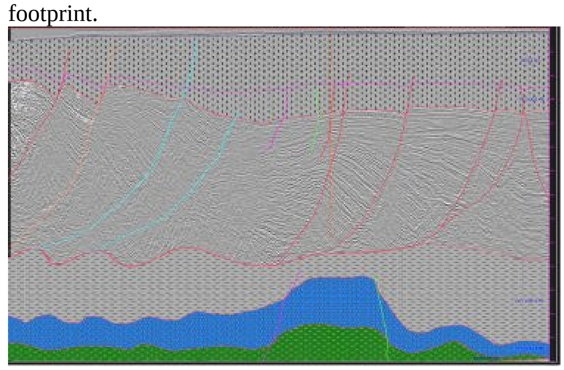

Figure 8:Seismogeological cross section along the Well -A, showing growth faults.

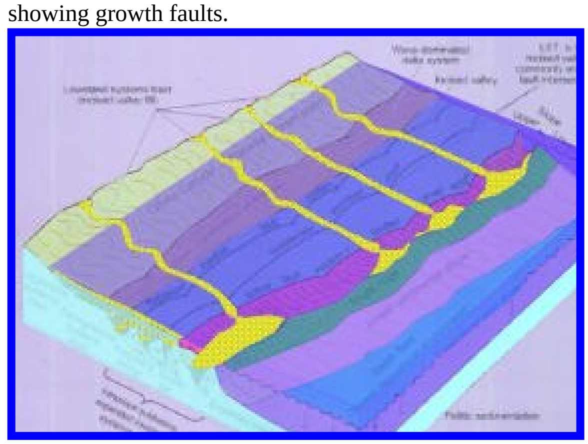

Figure 9:Conceptualised sand deposition model in the study area

Miocene Sandstones and shelf slope fan complex:

The results of FMI studies in one of the wells in the southern part are summarized below:

Stack of gravity differentiated grain flows are observed. Loading effects are seen at top of flows. The debris is angular fragment rich. It is expected to be proximal part of distal fan.

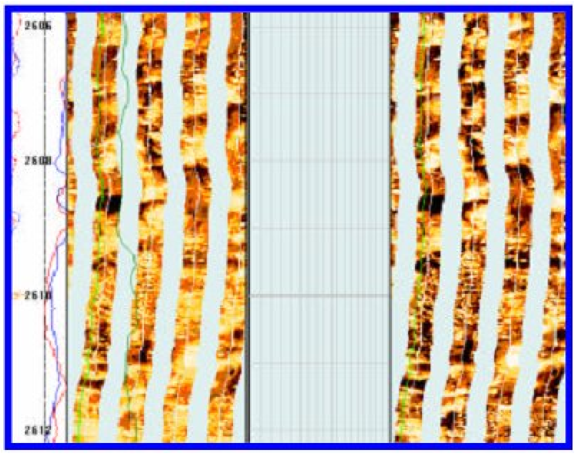

Figure10: Gravity flows (grain flows) down slope differentiating density of turbid mass

Calcified (Post deposition) settle of coarser clastic material brought in by turbid currents, which probably came in as a turbid pulse.

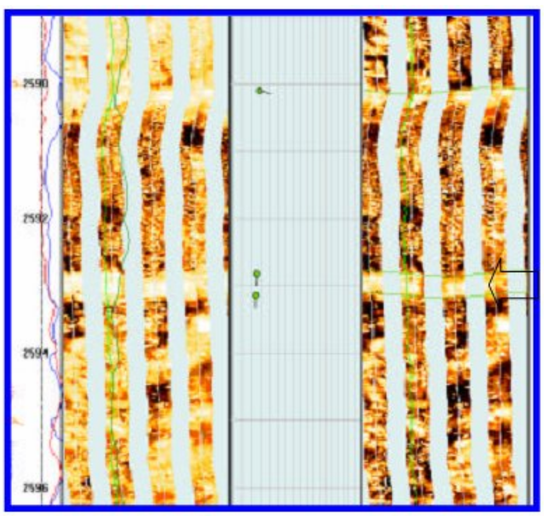

Figure 11: Debris flow of angular fragments in a clayey ground mass-above 2593.0 m level

Deposition locale may be a table like break on the shelf slope. The deposition is interpreted to be the proximal part of distal fan to distal fan and deposition on the shelf slope table type break.

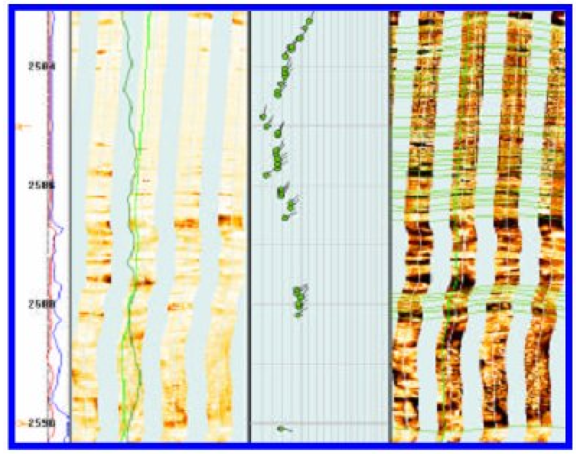

Figure 12: Bottom current reworked accretory above 2585 m levelBottom current reworked erosive below 2585 m levelClear cross beds-orthogonal to basinal dip direction

Erode-cut fill entering into deeper bathymetry with stack of three cut fills, Multiple sub cycles of traction load – dominated cut fills , transporting sediments N-S are observed.

Two conjugate directions N-s and S-N of sediment transport at the locale are indicative of parallel to shore bottom currents, moving the sediments as they are deposited and post deposition.

The fluid escape structures are also observed

The cut fill channels are traction load dominated. Interpretation of the channels is that there are switching currents orthrogonal to basinal dip direction (contour currents or thermal origin bottom currents)

Some hole break outs are also observed The reservoirs are expected to have poor to moderate permeability. (Fig:10,12,13 and 13)

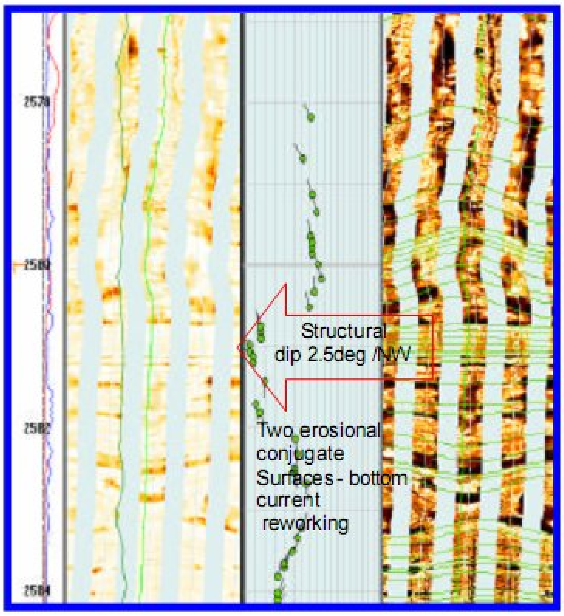

Figure 8: Cross beds parallel to structur dip above 2581 m level. Shelf bypasse traction load dominated eposition

Conclusion

Shelf slope complex of the Saurashtra offshore covers huge area as well as sediment thickness. Insufficient well data and limitations of seismic data were the impediments for confidently conceptualising the depositional system within the area. However on the basis of seismic responses, high energy influx characterized by fan morphology w as identified . The drilling results followed by FMI studies resulted in the confirmation of hypothecated Miocene sand deposition system.

Acknowledgement

The authors are thankful to Oil and Natural Gas Corporation Ltd. for providing the opportunity to complete this work. The views expressed in this paper are of the authors and not necessarily be of the organisation to which they belong.

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