Palaeogeographical and Morpho-Depositional Reconstruction of Deep water Saurashtra Offshore Using 2D Seismic Data

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Summary

Depositional history off Saurashtra shelf span from Mesozoic to recent times with bulk of deep water sedimentation happening in late Miocene to recent times. The presently studied interval initiates with several sea mounts characterized by high amplitude mounded configuration with internally chaotic reflectors, associated with SDR wedges at several places. These sea mounts are of volcanic origin and are linked to Deccan volcanism that initiated in Cretaceous times. Seismo facies characteristics and mutual arrangement these mounts and wedges led to their identification as volcano stratigraphic units such as landward flows, inner SDRs, outer highs, and outer SDRs. Their identification helped in understanding land sea interfaces in eruption times spanning from cretaceous to early palaeocene. Moreover arrangement of sea mounts and their spatial relationship with inner SDR wedges also suggest that the area was under early stage of oceanic crust formation processes. Sea incurred from south-west of the area, slowly engulfing upper reaches till Eocene times. Identification of retrograding packages associated and topped by aggrading ones over the southern limb of the arch bears the testimony of the above. Several reef built over volcanic mounts belong to this period. These reefs weren’t very extensive and presumably got drowned with rapid increase in bathymetry under rising sea level condition. A rapid rise in relative sea level is presumed; which gets support from the occurrence of sediments essentially belonging to deep water realm. It is in this time period the first deep water channels of Indus were found to be deposited over the older deposits. These deep water channel levee system starts to appear from the western end of the area. Upwards channels appear more frequently. However, a drastic increase in channel width, its sandiness and amalgamation is noticed, above a regionally correlatable surface (H1), reflecting an abrupt and large increase in sand budget. Pleistocene sea level fall and/or rapid uplift of western Himalayan ranges vis-a-vis draining of Indus and tributaries resulted this surface. Mass wasting products such as debris flows, are seen to occur near the slope in greater quantities. Debris flows from the slope area contributed sediments to channel levee system of Indus, thus increasing the sediment input. Toe of slope show a slight movement towards east from Mid Miocene to recent times.

Keywords: palaeogeography, deep water, SDR, volcanostratigraphy, stratigraphic evolution, Indus fan, transitional crust

Introduction

Saurashtra offshore basin is one of the four offshore basins in the Indian west coast. Towards north separated from Kutch basin by Saurashtra arch and southwards it extends into Mumbai offshore basin, Narmada son lineament being a divide. Categorised as a pericratonic rift basin, present basin underwent a lot of volcanism in cretaceous palaeocene times. Thus the status of a volcanic passive margin basin is now given to it equivocally. The basin has a proven record of geological history for over 100 my from early Cretaceous to recent times with still older mesozoic deposits speculated to be present. Present
data shows an evolving volcanic passive margin basin that houses essentially a mixed carbono clastic succession over the volcanics, carbonates being less developed than clastics. The study area is located in the deep water parts off the present shelf break, immediate south of Saurashtra arch, covering approximately 35000 Sq Km area. (Fig: 1) Toward south water is found to be more than 3000m, towards west about 2500. Present work aspires to reconstruct essential palaeogeographic elements of the evolving basin from cretaceous to recent times, as seen in 2D seismic data.

Data & Methods

The 2D seismic data acquired in more than two vintages. Both conventional and long offset data is used for interpretation. Long offset data shows much better resolution with least noise. The present study employs method of seismic facies analysis to decipher depositional characteristics, volcano sedimentary morphologies and deep water depositional processes to arrive at possible conclusions about the stratigraphic history and reconstruct palaeogeographical elements. Entire section is divided into Six stratigraphic intervals. For each interval morpho - depositional characteristics recognised and their frequency of occurrence is noted. Thus with passage of time evolution of stratigraphic record is reconstructed with referred palaeogeographic maps.

Regional Geology and Previous Studies

Indian subcontinent was a part of greater Gondwanaland with its west coast attached with African continent, before it starts a break up process in Early to Mid Jurassic, approximately 180-170 Ma. Other continental masses which were the part of the Gondwanaland, are Australia, Africa, Antarctica, Madagascar, Arabian and South America plates. The area is believed have separated from Seychelles / Laxmi ridge in upper Cretaceous times after which a marine transgression may have rendered the area into a shallow arm of sea. Deccan volcanism taken place during this time which covered the area with thick volcanics. The area with a moderate gravity high considered to be a transitional crust continues down south to Laxmi basin (prominent gravity high) and the adjacent rifted terrain (gravity low) towards the continental side. GOP rift lies towards south west of the area. (Fig 1) By Upper cretaceous the spreading from GOP rift is believed to have ceased, later on the spreading centre have shifted westward in between Mascarene plateau and Lakshmi ridge forming the proto Carlsberg Ridge. Evolution of Saurashtra Arch which runs ENE – WSE north of the study area is formed during cretaceous volcanism times. A phase of tilting (Lr – Mid Miocene) is associated with its southern limb. (Kunduri et al 2006)

Saurashtra basin recorded pre – syn and post volcanic deposits. Post and syn volcanic deposits and features being recognisable on seismic data, can be correlated and mapped . Pre volcanic deposits are not very frequently observed in seismics and in many areas of west coast their existence is still model driven, though some are reported (Carmichael et al, 2009). Volcano stratigraphic intervals (syn volcanics) are scantily studied in the area since most of the wells only penetrate the upper part of the formation, their seismic expression being understood only lately in the last decade. On the other hand post volcanics are fairly well understood in the area, wells drilled encountered a late palaeocene to Eocene limestones overlain by Indus Fan clastics. In one well viz GS DW 1- 1A late Palaeocene to early Eocene are also found to be Karsed.

Indus fan clastics are well studied in especially in northern Indus basin. Spectacular channel levee systems are mapped and correlated.

Discussion

Cretaceous – Early Palaeocene

Indus- Kutch-Saurashtra basins records voluminous Deccan volcanism in deep water parts. In the area a number of sea mounts are found south of the Saurashtra Arch. These sea mounts arranged in NE- SW direction, showing parallelism with the arch. (Fig 2) Top of these mounts show high amplitude reflectors that are further up grades into carbonate built ups. Reflectors within these mounts are chaotic without a visible base. (Fig 3) They seem to be similar to “Outer High” facies of Plank et al (2000). On both north and south of these mounts there occur SDR wedges that interpreted to represent volcanostratigraphic intervals. These prismatic set of reflectors dips towards outer highs. They show a diverging pattern of reflections with large out flow lengths and are interpreted as inner SDRs (Fig 4). Possibly they represent subaerial, synrift volcano-sedimentary intervals. Northern wedges are bigger than
their southern counterparts. Southern packages show a shorter outflow length but they are fairly straight and are included in Inner SDRs. Outer SDRs facies further south is identified. They show a curved reflector with fairly diminished flow lengths. (Fig 7 a , 7 b ). Their identification helped in understanding the position of sea during the period. Further north of inner SDRs (northern set) occurs another set reflectors that dip northward but their dip is much less than the inner SDRs. They are probably landward flows facies that are later faulted during the formation the Saurashtra Arch.

Saurashtra Arch

Saurashtra arch which is essentially a horst graben complex is thought to have a synvocanic history. It enters the area in NW (Fig 2). It is southerm limb and northern limb dip opposite with respect to each other, southern limb being more steeper than the northern limb. Present study suggest that northern limb, is built over “landward flow” facies and southern limb is interpreted to be over Inner SDR facies. Later on rifting occurred at the junction of landward flows and inner SDRs leading to formation of arch.

Upper Palaeocene–Eocene

After volcano tectonic quiescence is attained in late Palaeocene, area was witnessing incursion of sea. Low lying areas were flooded followed by upper reaches.

This is manifested well in the southern limb of the Saurashtra arch which shows retrograding packages over basalts layers, further up topped by aggrading packages (carbonate built up?) (Fig 6a , 6b). This observation indicates that rate of relative sea level rise varied during this period, a relatively faster rise is followed by a slower rise. Thus both a transgressive tract and a high stand tracts are visible here. Built ups show mounded geomorphology with well-defined horizontal reflectors within. Base of these built ups are visible. The incursion of sea must have occurred from south west as cretaceous land-sea interface was seen there.
Fig 5: Late Palaeocene to Eocene time palaeogeography.

Fig 6a: Southern limb of the Saurashtra arch seen to be built over the Inner SDRs.

Fig 6b: Interpretation of Fig 6a. It shows retrograding packages topped by aggrading ones.

Fig 7a: section showing a volcanic plateau (right) and outer SDRs (left).

Fig 7b: Interpretation of section in fig 7a. volcanic plateau (towards right) shows a rather mounded configuration with visible internal reflections. Outer SDRs show dipping reflectors. A prograding package is shown within the red rectangle that may possibly be a lava delta?

**Post Eocene – Recent**

Post Eocene witnessed a major unconformity in Oligo-Miocene times after which the area got drowned to deep waters under rising sea level conditions. This is supported by the fact that deep water sedimentation features such as debris flows and deep water channel levee systems are observed. (Fig 10) It is in this time period the first deep water channels of Indus were found to over the older deposits. (Fig 8) Spectacular channel levee systems are most prominent features of the area and are found to be correlatable across 2D lines. These deep water channel levee system starts to appear from the western end of the area. Upwards channels appear more frequently. This was possibly due to presence of Saurashtra arch which has acted as a barrier to flow of sediments from north. With passage of time as the arch got filled up, channels are seen to have moved eastward. However, a drastic increase in channel width, its sandiness and amalgamation is noticed above a regionally correlatable surface (H1), reflecting an abrupt and large increase in
sand budget. Pleistocene sea level fall and/ rapid uplift of western Himalayan ranges vis-a-vis draining of Indus and tributaries resulted this surface.

Fig 8: Post Mid – Miocene Pliocene time evolution of Indus deep water channel levee systems.

Fig 9: Pleistocene to recent time reconstruction of Indus Channel systems vis a vis deep water mass flow processes.

Fig 10: A section showing a channel levee systems, contributed with sediments from mass flow deposits (marked with arrows).

Fig 11: section showing the marker (H1 marked with red) above which an increase in sediment budget is noted. Red arrows indicate individual channel levee systems.

Conclusions

Deep water parts of Saurashtra basin records proven history from cretaceous to recent times. From the foregoing discussions following conclusions are made.

An extensive Cretaceous system is visualised and differentiated into volcanic sea mounts associated with SDRs as per classification proposed by plank et al 2000. Saurashtra arch is evolved over SDR packages, its southern limb is built on inner SDRs while it is northern limb is over landward flow facies. Land sea interface was possibly located SW of the area.

Sea started encroaching in the area in late Palaeocene times and occupied low lying areas. Retrograding packages and shallow carbonate reef bears the testimony of this time period. Rate of sea level rise was variable as concluded from Retrograding packages which are topped by aggrading ones.

Subsequent history belongs to deep water. Channel levee systems started appearing from the western end, upwards their frequency of occurrence increased. Entire system seem to move more towards the toe of slope and then subsequently moved away. Channels which were nearer the slope were contributed with sediments from mass flow deposits.

A major increase in sand budget is observed towards upper end of the record. Extensive, high relief channel levee systems are developed in this period. This is possibly linked with either a sea level fall in pleistocene or may be rapid rise of western Himalayan ranges.
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