Rifts from the Offshore North-East Coast Basin in East Coast Passive Margin of India

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Abstract

The east coast basins of India have developed during rifting between India and Antarctica in Early Cretaceous. The rift architecture is well established in the Cauvery, Krishna-Godavari and Mahanadi basins from various literatures (e.g., Rao, 2001; Nemčok et al, 2007, 2012; Sinha et al., 2010). However, the offshore North-East Coast (NEC) Basin seems to be devoid of any rifting, the commonly held reason being the strike slip fault activity shifting the entire basin landward. Earlier publications (e.g., Fuloria et. al., 1992) have shown the presence of rifts in the Mahanadi Basin, which have not been correlated throughout the NEC Basin due to poor seismic imaging. The present work shows the presence of rift architecture entirely in the offshore NEC basin. The study area lies within the shelf to slope break at less than 100 m bathymetry. Presence of good quality 3D, regional GXT 2D and some other regional 2D deep-profiling seismic lines enable us to identify the presence of at least six isolated, NE-SW trending synrift grabens in the offshore NEC basin, conforming the continuation of the east coast graben system. The rifts lie below a massive thickness of Early Cretaceous volcanics, making their identification in earlier data difficult. 3-D seismic data have been useful in inferring the sedimentation pattern below the hard basalt top, while seismic velocity have been used to differentiate between the grabenal sedimentary fill and the basement. Three first order reflectors are identified, marking the top of the cratonic basement, synrift and early post-rift sag phase. Second order reflectors are present in some of the sections, which have been inferred as unconformity surfaces between Early and Late synrift phase. Two-way-time thickness maps have been prepared for the different sedimentary packs to infer the depositional setup and transport direction. Amplitude maps have also been used to identify possible synrift facies distribution. Absence of nearby wells penetrating the synrift restricts us in direct age correlation, hence relative chronology with respect to the Early Cretaceous volcanics have been used to infer the age of the sediments.

Introduction

North-East Coast (NEC) basin in the northern-most part of East Coast of India is a present day passive margin basin and the study area is part of the offshore NEC basin, as shown in figure 1. Like Cauvery (CY) and Krishna-Godavari (KG) basins, this basin is a pericratonic basin along the east coast formed during rifting between India and Antarctica in Early Cretaceous. The NEC offshore basin gets major sediments from the Ganga-Brahmaputra rivers in the north and lesser volume of sediments from rivers like Brahmani and Subarnarekha in the west. The present day tectonic and structural configuration of the East Coast (EC) of India, shown in figure 2, is a series of synrift basins linked by transfer faults that give rise to the passive margin setting. Earlier publications (e.g., Fuloria et al., 1992) have established the presence of rift grabens in Mahanadi basin, which was later affected by Early Cretaceous volcanism. However, no prominent rift system has been identified in the NEC basin. The main challenge in this work is to interpret the rift grabens in the offshore area and establish the structural and tectonic continuation of the basin with other East Coast basins. The study area is well covered by 2D and 3D seismic data including long cable length deep seismic data. Few wells have been drilled in the shallow part of the basin, and are correlated by Fuloria et al. (1992). Satellite gravity anomaly maps are available to analyse broad basement and crustal features.

Observations

The main criterion to be a rift-related sequence is to have growth sequence of sediments towards the bounding fault above a basement surface, known as a rift-indicator. The initial observation of the rift grabens in offshore NEC basin came from the 2D regional line shown in figure 3. Further observations have been made in 3D seismic data, and mapped in detail, as shown in figure 4. Three major unconformity surfaces have been observed within the rift fill, marked as “b”, “c” and “d” horizons, and shown in green dotted lines in figure 4, apart from the basement, marled as horizon “a”. Some channel systems have been observed at the top of the reflection package “c”, above which lies a chaotic reflection package with some high amplitude parallel reflections, marking the “d” horizon.

Results and Discussions

Each of the four unconformity surfaces has been mapped in 3D seismic data as shown in figure 5, taking example from a single graben. The four horizons have been correlated with, a - the synrift base or the basement top, b - top of syn-tectonic or early syn-rift phase, c - top of late syn-rift phase and d - top of post-rift sag phase, respectively. In figure 4, the fault trends are observed to be prominent and linear, with extensional basins truncating against them. The base of the basin shows a high positive amplitude reflection, which indicates the presence of a hard bed beneath the basin. It is interpreted as the basement top, based on regional extent and high impedance contrast, and marked as horizon a, as mapped in figure 5a. Above this horizon, the reflection patterns shows one thick pack of sediments, those have been interpreted as the early syn-rift phase. This kind of reflection indicates a sudden flow of sediments into the basin. Above it is an unconformity surface that has been mapped as horizon “b” and shown in figure 5b. Above this horizon, parallel reflectors are observed, indicating a lacustrine environment, which is likely to be the last phase of syn-rift activity. Above this sequence lies another unconformity surface, horizon c, which forms the downlapping surface for the reflectors above it. Horizon c has been mapped in the graben B and B’, shown in figure 5c. In this map, no such rift basin architecture is seen. Above the downlapping sediment package lies another unconformity surface, horizon d, whose map is shown in figure 5d.The reflections below the horizon d, shows some concave upward reflections, indicating the presence of marine channel systems. Above horizon d lie the Early Cretaceous volcanics, related to 85°E Ridge activity.

Conclusions

Based on the above interpretations and discussions we can conclude the following;

1. The presence of well-developed rift systems in the NEC basin puts it in continuation with the crustal architecture of the other East Coast basins
2. The present interpretation puts a doubt in the actual presence of a strike slip fault shifting the rift systems
3. Well-developed sedimentary sequences within the synrift succession points towards a long lived synrift stem in the northern part of the East Coast of India
4. The presence of a sedimentary succession below the Early Cretaceous volcanics puts forward a new play possibility in this basin.

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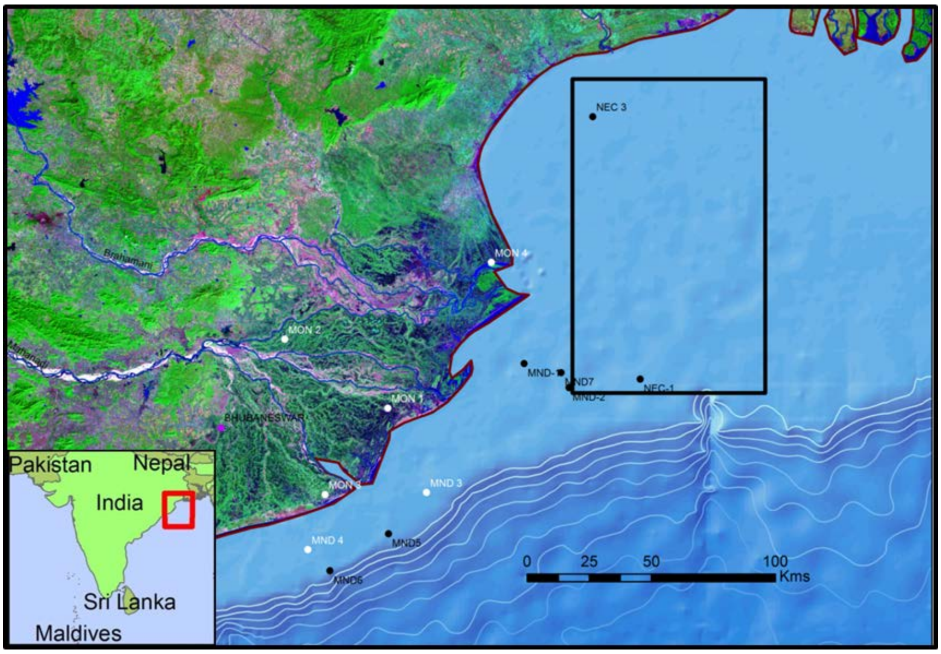

Figure 1: Figure showing the location of the study area in the NEC basin. Inset: Position of NEC basin in the East Coast of India

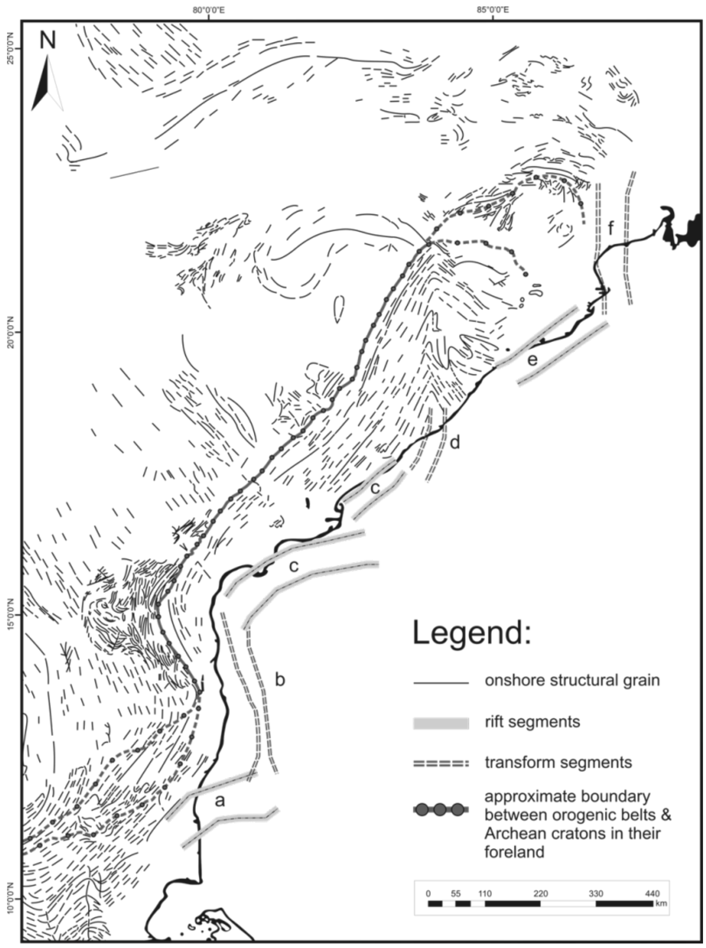

Figure 2: Figure showing the major structural elements of the East Coast of India (Nemčok et al., 2012). There are six major segments:(a) Cauvery Rift zone; (b) Coromondol transfer zone; (c) KG rift zone (d) North Vizag transfer zone; (e) Mahanadi Rift zone and (f) Konark transfer zone.

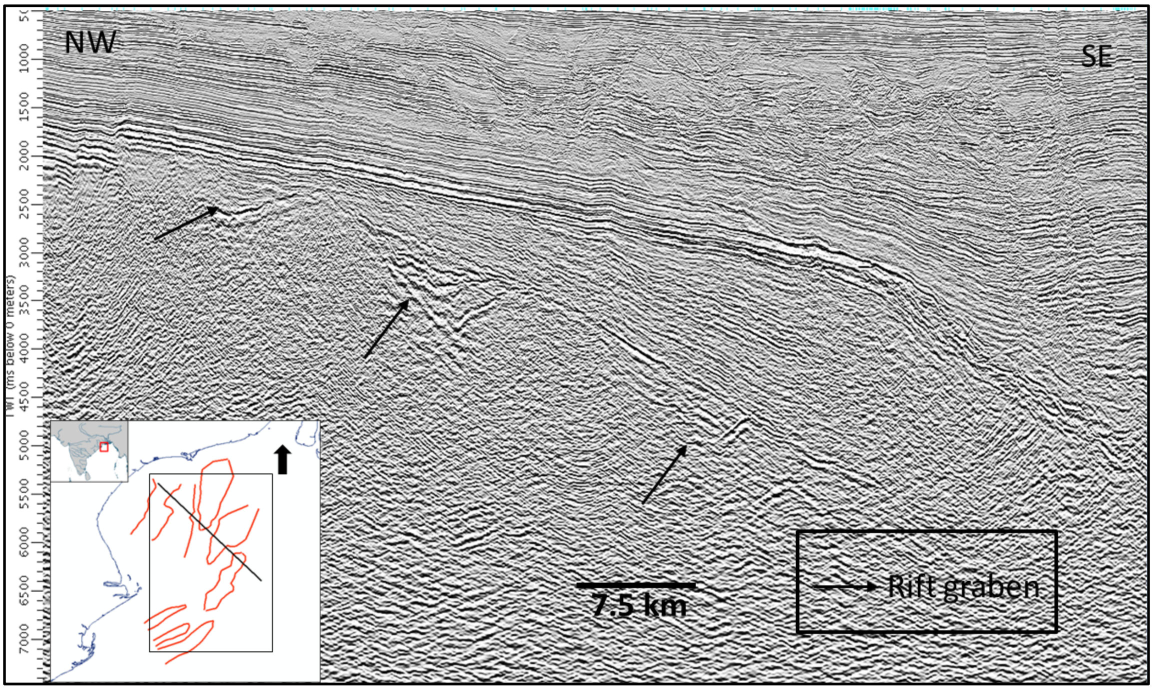

Figure 3: Figure showing the regional 2D seismic reflection profile across the three rift basins within the study area. The black arrow in the inset shows the north orientation. The vertical scale is in two-way time milliseconds, and the horizontal scale is in kilometers.

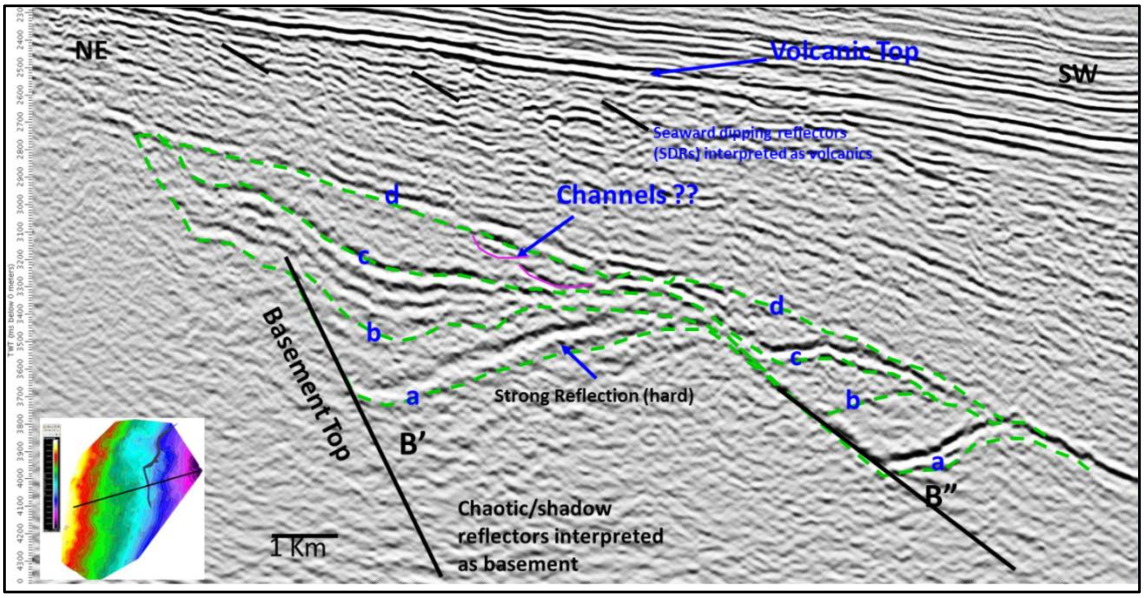

Figure 4: 3-D seismic reflection profile showing the different unconformity surfaces interpreted and mapped, shown in green dashed lines, in one of the grabens (in figure 3). The vertical scale is in two-way time milliseconds, and the horizontal scale is in kilometers.

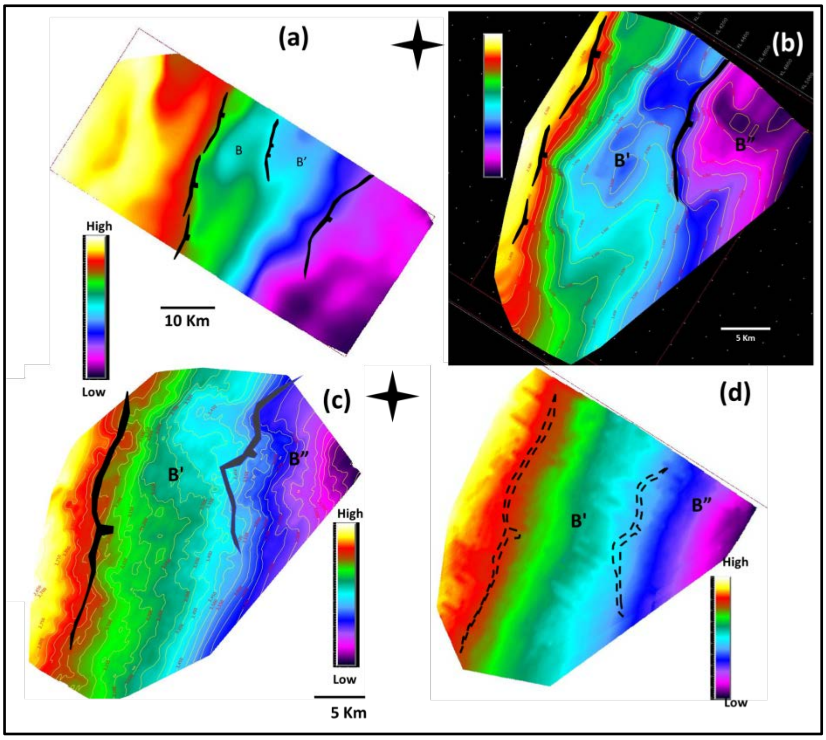

Figure 5: Map view of the four unconformity surfaces interpreted (as shown in in figure 4). a) interpreted basemnet, b) early syn-rift phase, c) late syn-rift phase, and d) top of post rift sag phase.