Deepwater Exploration In The NW Niger Delta: Are There Parallels For Indian Exploration?

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Summary

The findings of the interpretation of High Density 3D (HD3D) seismic in the deepwater North Western Niger Delta are summarized in this paper. The geology of the area discussed herein has similarities with the Krishna-Godavari Basin. Water depths in the Niger Delta areas discussed are between 1000 – 2000 m. The shoot was completed in 2004. The data has facilitated spectacular imaging of structural and stratigraphic features. This has led to an improved understanding of the geology and has thus reduced exploration risk.

Introduction

In an exploration context, the geology of the Krishna-Godavari Basin of India has some similarities with that of the deepwater Niger Delta: Both are on passive continental margins and contain thick deposits of Tertiary rocks with clastic inputs. The Akata shale of the Niger Delta is a diachronous mobile shale; mudrocks with diapiric structures have developed in parts of the Krishna-Godavri Basin. Fault bounded mini-basins occur in both provinces. However, based on 2D data, the consensus view was that the area of the NW Niger Delta discussed here had one main structural lead. This view has been revolutionised by a much improved understanding of not only mobile shale deformation in the block, but also of the architecture of Tertiary deepwater depositional features.

The Niger Delta is one of the world's largest Cenozoic delta systems and contains prolific hydrocarbon reserves. The total sedimentary prism contains a clastic fill up to 12 km thick (e.g., Doust and Omatsola 1990; Reijers et. al., 1997). The incipient site of the origin of the delta is associated with the plate tectonic rift framework of continental separation. The province can be sub-divided into the Western Niger Delta and the Eastern Niger Delta, with the line of division being the Charcot Fracture Zone (Fig 1) . The area of the study lies northwest of the Chain/Benue Fracture Zone. In the outer western part of the deepwater region, the underlying structural framework has influenced the location of transfer fault systems, which in turn may have influenced toe-thrust trends (Morgan 2003, 2004).

Methodology

The seismic data was acquired by MV Ramform Valiant using dual source shooting, 8 and 10 streamer configuration and 12.5 m x 18.75 m bin dimensions. HD3D seismic data has closer subsurface CMP line separation obtained through high trace density recordings, along with superior wavefield sampling (e.g., Long 2003; Long and Buchan 2004; Ramsden et. al., 2005). Record length was 8.5 s. The migration technique was Bending Ray Kirchoff Pre-Stack Time Migration. The seismic data consists of a 1600 sq. km volume, that was loaded with 37.5 x 50 metre inline and crossline spacing. The interpretation used 'Seisworks' software on Unix workstations. No well data was available from adjoining blocks for well-to-seismic ties.

Results and Discussion

Six regionally extensive horizons have been identified and mapped. Five of these seismic markers are within the Akata, Agbada and Benin Formations (see Figures 2 and 3). The contacts of these horizons (Fig 3) are gradational and of a wide age range, and hence are used informally as formation names (Doust and Omatsola 1990). The Akata Shale is largely composed of marine mudstones, but it is known that this unit has interbedded silts and sands. The shales of this formation are overpressurized, and are an excellent source rock. The Akata is overlain by the Agbada Formation, which has the majority of hydrocarbon reservoirs in the Niger Delta. The Agbada rocks originate from paralic, brackish to marine, coastal and fluvio-marine sediments. The uppermost unit is the

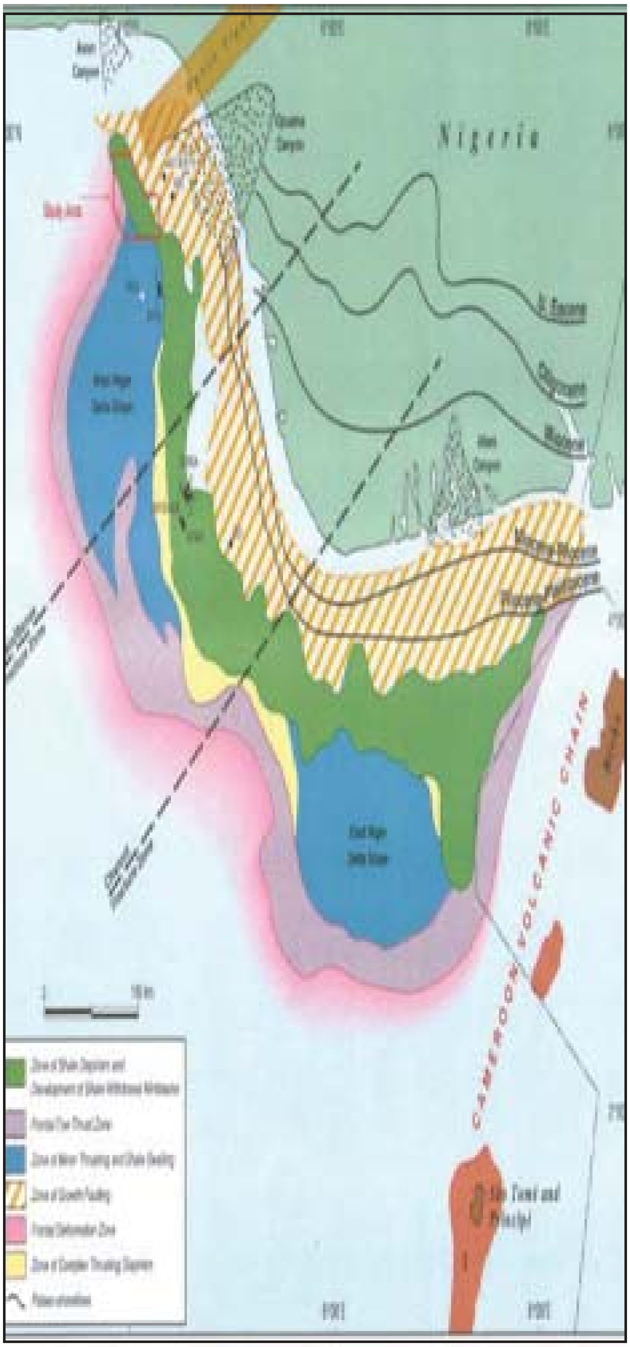

Fig.1: Regional geologic elements and location of the study area.

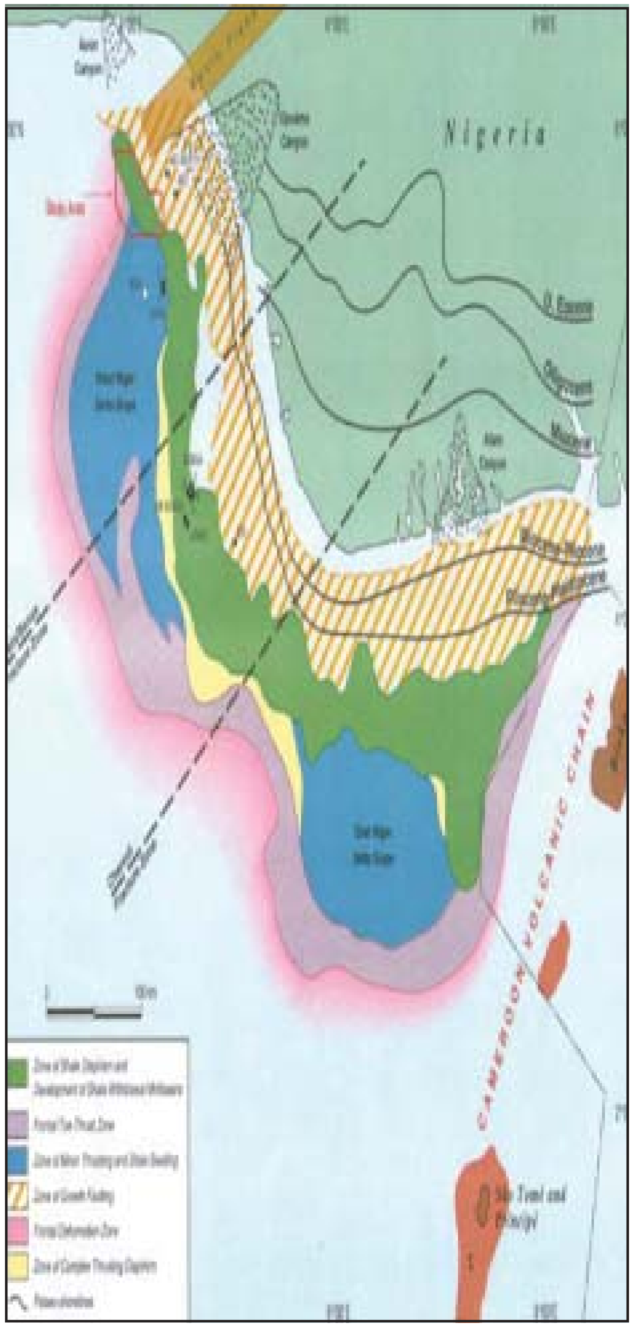

Fig 2: General stratigrphy of the Niger Delta.

Benin Formation, which is composed of continental, fluvial and backswamp sediments.

The spectacular edge map of the sea-floor (Fig 4) illustrates aspects of the geomorphology of sea-bed channels systems that cross the region. Water depths are between 1000m to 2000 m. These channels indicate the direction and active nature of Holocene transportational and depositional systems of clastic material in the area.

The deformation of mobile shale of the Akata Shale (Fig 3) is of importance. The interplay of gravity sliding and mobilization of shale has led to structuration (e.g., Damuth 1994), with the Akata Shale acting as a decollment

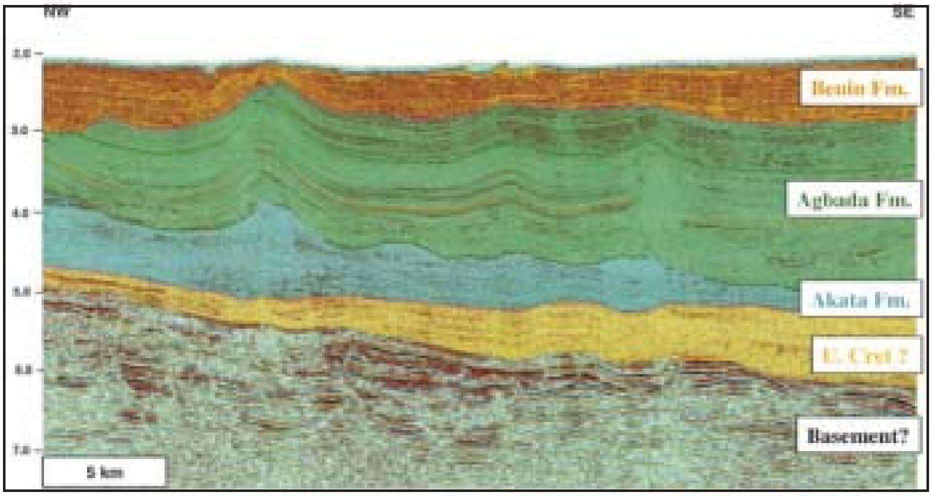

Fig 3: Example seismic section showing horizons interpreted and mapped in the present study.

Fig 4: Edge detection map of the sea-floor

surface, with extensive folding. The ductile and overpressured shales have moved as a mobile substrate in response to sediment loading, with shale withdrawal and growth of diapirs leading to hydrocarbon trapping configurations.

In the northwestern Niger Delta, the shale structures were established in Late Miocene time, with compressional uplift and folding of pro-delta strata, along with shale withdrawal from beneath the advancing data load (Cohen and McClay, 1996). In terms of understanding the structural geology of the area, a detailed fault interpretation is necessary in order to understand the timing of folding, faulting and diapirism. This is a time consuming task, but the HD3D data volume allows rapid fault characterisation by using Edge detection. This has proved to be a great aid in the rapid characterization of structural controls on play types.

The geomorphology of turbiditic and channel systems is of great importance in these deepwater provinces. Although many Tertiary channels systems have been compartmentalized by shale structuration, this is not ubiquitous. Figure 5 dramatically illustrates the geomorphology of an extensive channel system. The imaging was derived from a root-mean-square amplitude extraction within a gate of 100ms thickness from a Tertiary horizon. The channel length in this image is approximately 30 km in length. It is highly sinuous, and when interpreted in section, it has an amalgamated morphology.

Conclusions

Several of the main geological components of the NW Niger Delta have parallels with the Indian Krishna-Godavari Basin such as both having a thick sedimentary prism, mobile shales, fault bounded sub-basins and deepwater deposits. However, even though the deepwater Niger Delta is a world class petroleum province, there are significant exploration risks; The use of HD3D is a useful tool in reducing these. This study supports the view that the geology of deepwater continental margins is far from simple and dry wells are part of the equation.

Fig 5: Imaging of a deepwater Tertiary channel system using an RMS amplitude extraction from the HD3D volume.

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