Deepwater Hydrocarbon Potentialof Orange Basin, South Africa: An Untested Oil Play

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Keywords

Late Cretaceous Orange river delta, untested deep water play

Summary

Orange Basin is located in South Atlantic Ocean offshore west coast of South Africa. The basin is under explored especially in the deep water areas. This study demonstrates huge undrilled exploration potential in different plays. This untested play in deeper water outboard area within the growth fault domain has very high hydrocarbon resource potential.

Introduction

Orange Basin, the largest of South Africa's offshore basins is extending from the Luedritz Arch in Namibia to the Agulhas Fracture Zone in the south of South Africa covering an area of about 160,000 km^2. More than 7kms of sediments derived from the Orange River and Olifants River were dumped into the Orange basin throughout the Cretaceous. Orange Basin is relatively underexplored with nearly 38 exploration and appraisal wells drilled all within the ~400m water depth line. Several petroleum systems are proven to be working in this basin. A-J-1 well drilled in the synrift graben near to coast is the only oil discovery in this basin; Kudu field in north and Ibhubesi field in south are the commercial gas discoveries so far. However the deep water late cretaceous growth fault area remains untested.

Regional Geological Understanding

Orange Basin is a typical rifted-volcanic passive margin and was created with breakup of the South American and African continental plates during Late Jurassic/Early Cretaceous, followed by rifting and drifting lead to the opening of the South Atlantic Ocean. Regional seismic profiles and drilled well data indicate different play types in the outboard in comparison to the inboard proven plays. Margin tilting as a response to the post rift thermal subsidence coupled with progressive hinterland upliftment followed by huge denudation of the hinterland and previously deposited inboard sequence sourced the sediments in the outboard. The latest 3D seismic interpretation indicates at least two major extensional episodes in the outboard. First extension was related to the destabilization of the Santonian(?)outer shelf which was aggrading with little progradation in a stable margin, and lead to the gravity collapse like "tilted book shelf" of the sequences deposited before this tectonic event, and faulted down detaching over Albian prodeltaic shale. However the next phase of upliftment during late cretaceous and early Tertiary caused huge margin instability resulting in development of series of growth faults and toe thrust system in the outboard which becomes younger with westerly moving depocentre filled by substantial sediment thickness by prograding Orange River delta in an unstable margin. This substantial sediment thickness provided the necessary and sufficient burial for the source rock deposited during Cenomanian/Turonian which found to be immature in the inboard wells. The immature CT source rock proves the source potential however gas prone in some of the inboard wells, but in key outboard wells with two high HI samples indicate the improvement of the source quality in the offshore. Integrating the depositional history supported by the 3D and 2D seismic interpretation and incorporating the gross depositional maps petroleum system modeling was carried out and the results shows CT source is oil matured and started expelling oil since KT in the outboard and likely to feed the outboard structures that formed before the migration from the source rock took place. Many structural leads have been identified in the new 3D seismic in the outboard area. Integrating the regional interpretation, isopachs, seismic attributes some of these leads upgraded and matured to prospects based on the ranking exercise considering the resource size and geological risking.

Methodology

The Study area is covered with various vintages of 2D seismic data of poor to moderate quality especially in the deep water areas. The growth fault is so structurally complex that the 2D seismic couldn't image well. Cairn India acquired a 1981 sq km of full fold 3D seismic data in the deep water area. This improved the subsurface imagesignificantly. The PSTM and PSDM processing appreciably brought out the several structural closures which are comparable to other proven growth fault dominated areas analogous to Niger delta or Gulf coast Lusiana Frio.

Integrated approach has been used here to understand the development of the key tectonic events and there overall implication to the petroleum system.
The regional vintage 2D seismic data were tied with the inboard wells to constrain the stratigraphy. Mapping of the mega sequences extended to the new 3D data to understand the tectonic phases and its implication on the structure development from inboard to outboard. Regional well data and literature helped to build up the stratigraphic concept which then incorporated with the seismic facies and geomorphologies to develop the stratigraphic framework.

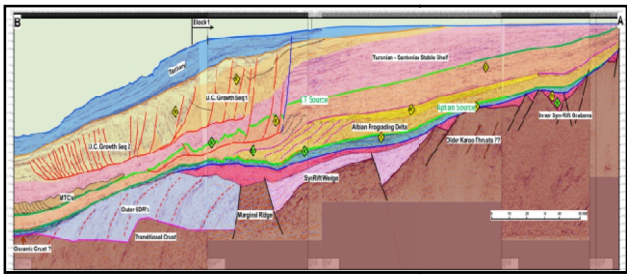

Figure 1: Regional geo-seismic section of Orange Basin

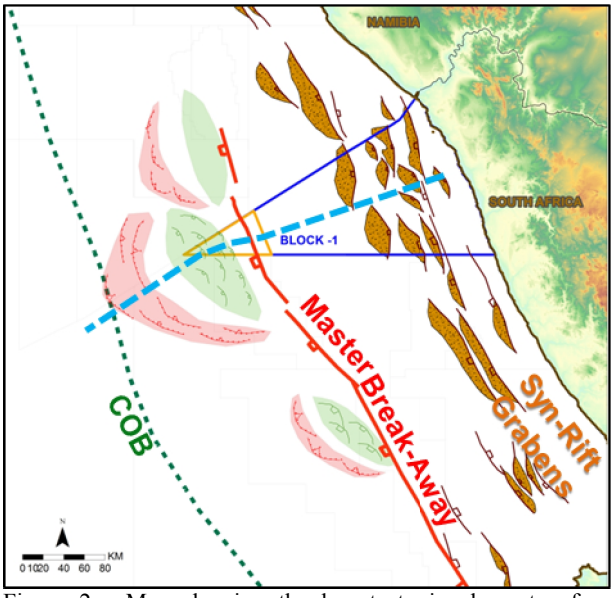

Figure 2: Map showing the key tectonic elements of Orange Basin

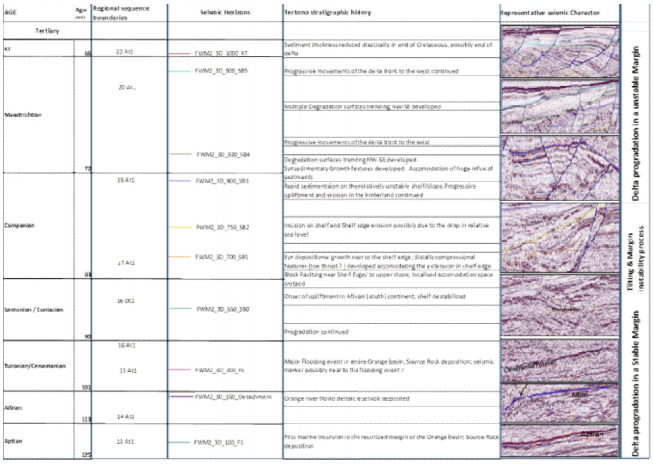

Figure 3: Tectono-stratigraphic event chart of deep water Orange Basin

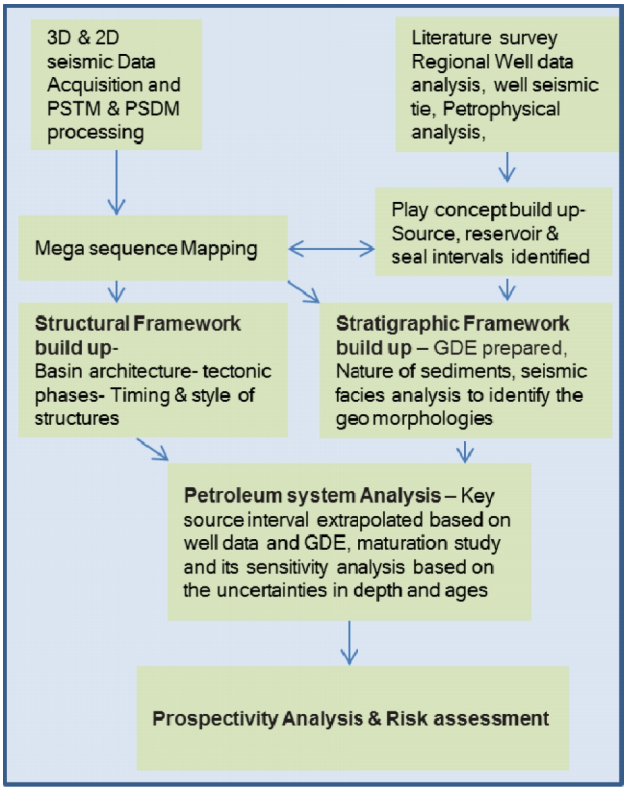

Figure 4: Flow chart depicting the methodology adapted to assess the hydrocarbon potential of the deep water orange basin

Structures and Reservoirs prediction from 3D seismic: Outboard 3D seismic clearly definesthe large faulted antiformal structure in Cenomanian to Albian interval near to the master break away fault extending much beyond the 3D area. Cenomanian-Albian sequence tapers towards west. Several faults cut through the structure with throws ranging from 20-80m. These are observable on variance attribute extracted on mapped Cenomanian surface. RMS seismic amplitude extracted within window of +/-80ms with respect to Cenomanian surface shows there are bright amplitude package trending north south parallel to shelf edge which is interpreted as possible signature of shore face sand deposits. Further deep water channelized features observed in the attribute maps and in the seismic which suggests possible slope channels.

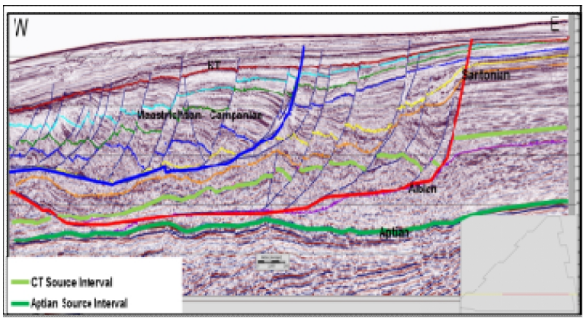

Figure 6: 3D PSTM section showing the structural elements in the deep water orange basin

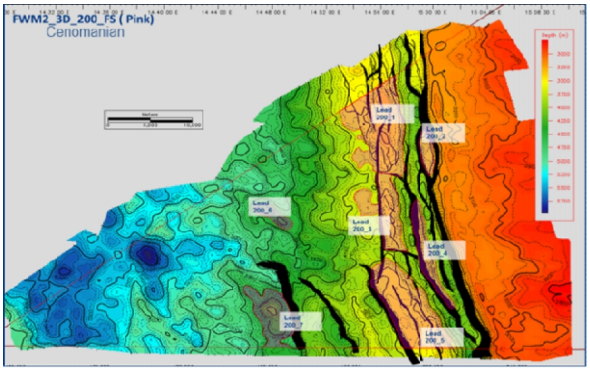

Figure 7: Depth structure map of Cenomanian surface showing the major structural trend in outboard areas

Delta progradation commenced in Orange basin in Albian and well established by Cenomanian. Progdational geometry shows a change from strongly progradational to aggradation up to Santonian, before the destabilization took place.

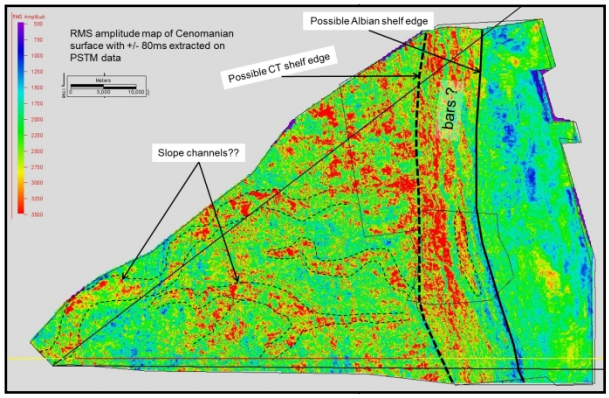

Figure 8: Seismic attribute (windowed RMS 80ms +/-) showing the geomorphologies in the Cenomanian to Albian time in the deep water areas

Regional understanding and the 3D seismic clearly highlights the two phases of extensional event in the deep water. First extension during Santonian (?) destabilized the aggrading outer shelf and leads to the gravity collapse and faulted down and detached over Albian prodeltaic shale. However the next phase of upliftment during late cretaceous and early Tertiary caused huge margin instability resulting in development of series of growth faults and toe thrust system in the deep water which becomes younger with westerly moving depocentre filled by substantial sediment thickness by prograding Orange River delta in an unstable margin. So the major Growth sequences developed in Campanian to Maastrichtian.

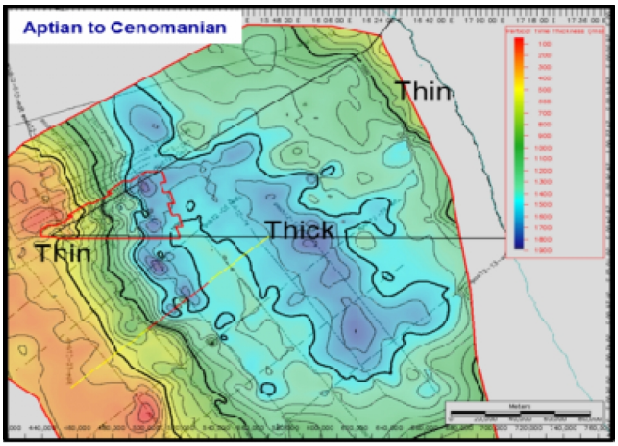

Figure 9: Time thickness map between Aptian to Cenomanian interval showing the major depocenter in the inboard areas

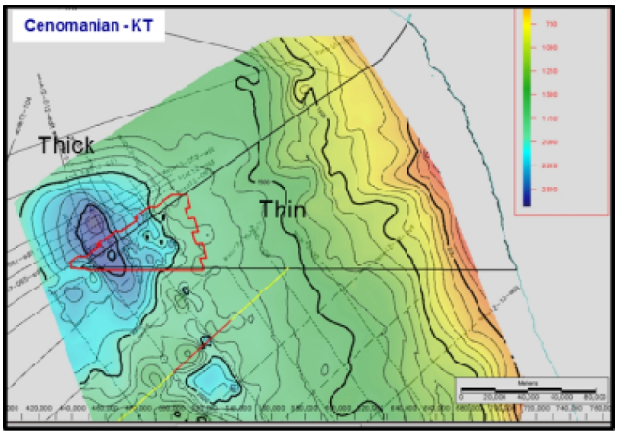

Figure 10: Time thickness map between Cenomanian to KT interval showing the major depocenter in the outboard areas clearly highlighting the shift in depocenter during the Late creatceous

This study also highlights the Fourmajor prospective areas in the deep water:

1. Eastern deeper antiformal structure (close to the first fault) which should have predominantly upper shoreface/ shelf sands of possibly Cenomanian to Albian in age
2. Western deeper toe-thrust area involving Albian – Cenomanian sediment (deposited as fans in the deep water
3. Shallow first growth areas (mid of the survey) which possibly in the shelf edge are of upper Campanian
4. Western dominant growth area: possibly LST wedges of Campanian to Maastrichtian

Petroleum System Analysis:

There are at least two petroleum source systems available in the deep water area, Aptian marine source deposited in a restricted margin, and Cenomanian-Turonian marine shales deposited in open marine condition.

Aptian marine shale is proven in this margin as it is thought to charge Ibhubesi& Kudu gas field. This sequence was encountered in the inboard and offset wells with good TOC and HI values. Petroleum modelling suggest that in the outboard area the matured source rock is presently in gas window however it might have expelled oil in late Cretaceous to Paleocene.

Another source rock interval is Cenomanian-Turonian transgressive shales encountered in various inboard wells however immature and mostly oil and gas prone. Source rock quality is inferred to get better in the outboard area. The huge thickness of Maastrichtian / Campanian delta provides the necessary burial for oil maturity for CT source in the deep water areas.Basin modelling studies suggest that the generation from CT source postdates the late Cretaceous structuration. This structure can be charged by these source rocks vertically and laterally through faults and fractures.The immature CT source rock proves the source potential however gas prone in some of the inboard wells, but in key outboard wells with two high HI samples indicate the improvement of the source quality in the offshore. Integrating the depositional history supported by the 3D and 2D seismic interpretation and incorporating the gross depositional maps petroleum system modeling was carried out and the results shows CT source is oil matured and started expelling oil since KT in the outboard and likely to feed the outboard structures that formed before the migration from the source rock took place.

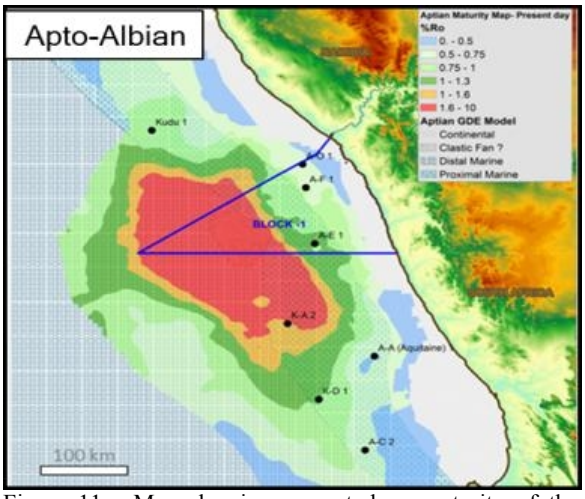

Figure 11: Map showing present day maturity of the Aptian source rock associated with Type II-III organic matter

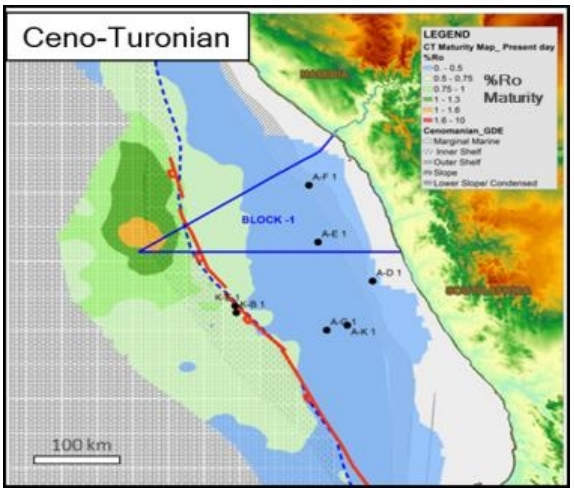

Figure 12: Map showing present day maturity of the CTsource rock associated with Type II-III organic matter

Conclusions

The current study reveals the deeper water Orange Basin has huge potential for discovering large oil and gas pools. Cairn identified multiple plays in a gravity driven extensional /compressional structural regime predating the migration from the deeper proven petroleum systems. Cairn intends to test these plays through the drill bit to unlock the value of this exciting petroleum province.

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