A comparison of structural styles and prospectivity along the Atlantic margin from Senegal to Benin

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Overview

The structural style of the African Atlantic margin shows significant differences between the passive rifted Northwest African Atlantic Margin (offshore Senegal, Gambia, Guinea Bissau and Guinea) and the West African Transform Margin (from Sierra Leone to Benin). Recently acquired seismic data provides good quality imaging (down to the Moho in deepwater areas) that allows an understanding of the structural development since the initiation of the opening of the Atlantic Ocean at the end of the Jurassic and gives insights into the present day structural styles and how they developed.

The major difference between the Northwest Margin and the West African Margin is the presence of large salt structures north of Sierra Leone. North of Sierra Leone there are potentially three complete petroleum systems along the Atlantic margin: Lower Paleozoic, Lower Cretaceous Sub-salt and Upper Cretaceous-Tertiary. The presence of variably thick salt provides good seal in some areas and elsewhere it affects the thermal history making younger shales prospective for later hydrocarbon generation.

South of Guinea, the transform fault systems have controlled the basin shapes and delineate areas of increased prospectivity in deepwater Upper Cretaceous-Tertiary basins between the major fracture zones. There is no evidence of the presence of significant salt bodies between Benin and Sierra Leone. The two main petroleum systems present in this area are the: (1) Cenomanian-Turonian source with Upper Cretaceous – Tertiary deepwater turbiditic sands as reservoirs, (2) Lower Cretaceous source and reservoir.

Comparison of seismic data from the two areas highlights the structural differences and shows examples of the different types of traps from the two regions.

Introduction

This talk compares the structural styles of two adjacent areas offshore West Africa (West African Transform Margin and Northwest African Atlantic Margin) and how this affects the prospectivity of the two regions. The structures are illustrated by example seismic sections.

The two areas compared in this talk are shown on Figure 1. The West African Transform Margin (WATM) extends from the north of Sierra Leone around the coast of West Africa to Benin in the east. The extent of the Northwest African Atlantic Margin (NWAAM) considered in this talk is from Guinea Conakry in the south to the northern most border of Senegal. The two regions are separated by the Guinea Transfer Fault Zone (Guinea TFZ).

Figure 1: Map of WATM and NWAAM (created from Google Maps)

<u>WATM structure and prospectivity</u>

WATM structure and development has been controlled by transform movements initiated during a rifting phase in the Lower Cretaceous. The post rift section extends from mid Albian to Present and includes a period of thermal relaxation and then a passive margin drift phase. It is noted that no evidence of evaporate deposition has been found in this region.

WATM is characterised by a series of basins between transform fracture zones oriented approximately SW-NE terminating against the coast and forming embayments .The shallow shelf area of each basin tends to be narrow with relatively wide slope and rise extending out to over 300 km from shore (Figure 1).

This basin geometry has produced large turbidite slope fan and lobe systems throughout the Upper Cretaceous and Lower Tertiary. These turbidite channels together with source rocks laid down in periods of deepwater anoxic conditions in the Late Cretaceous (especially Cenomanian-Turonian) have produced a prolific Upper Cretaceous play along the present day mid-lower slope in water depths of over 1000 m. This system has been proven by drilling to extend from Ghana (Jubilee oilfield) to Sierra Leone (Mercury-1 and Jupiter-1 discovery wells). Figure 2 is a schematic of the WATM Upper Cretaceous slope play system.

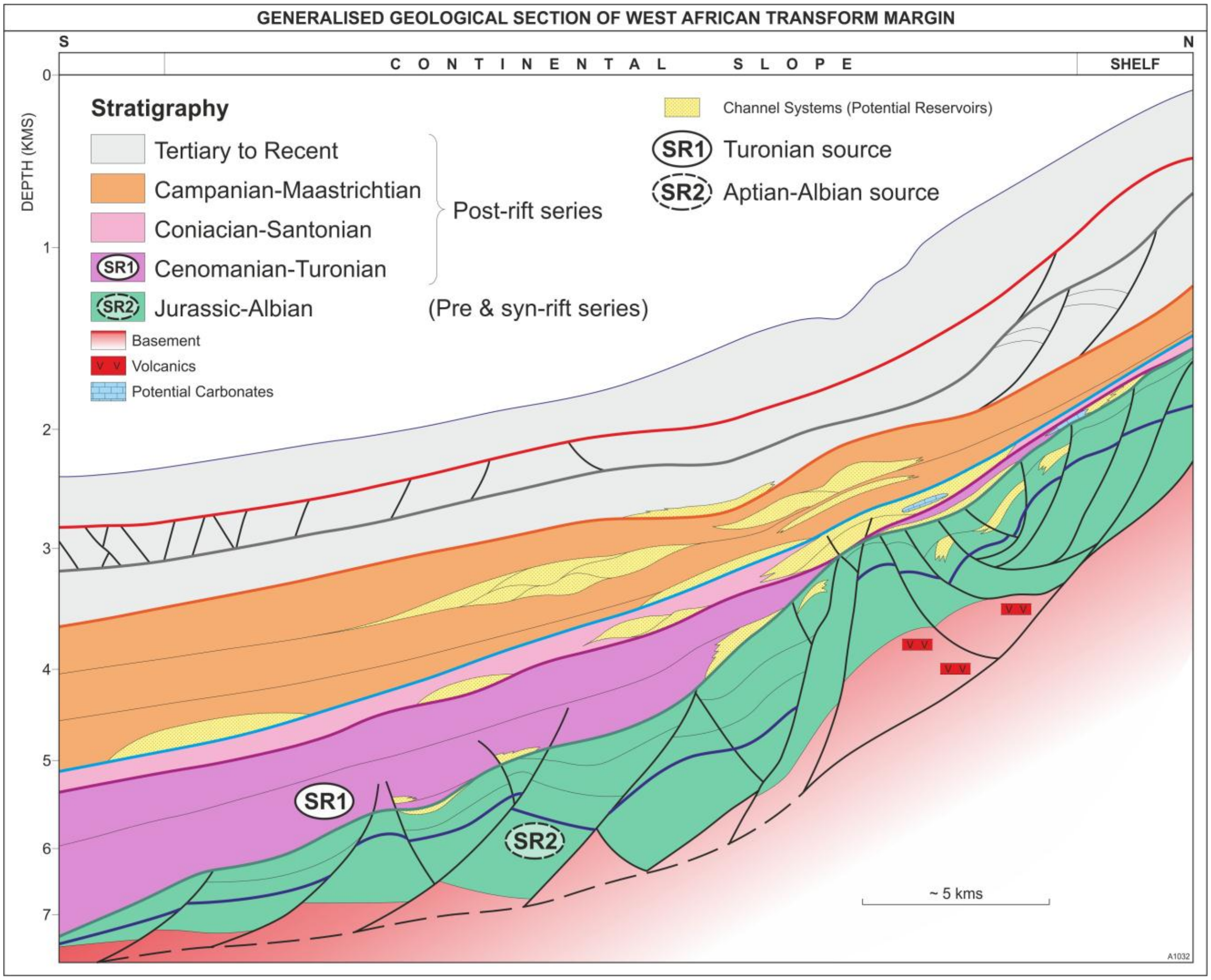

Figure 2: Schematic diagram of main play types along WATM

A secondary play exists within the Lower Cretaceous synrift section (e.g. Tano North and South, offshore Ghana) with lacustrine source rocks and shallow water sands or carbonates forming the reservoirs. However, this play has produced only small oil fields to date. A possible extension of this play into deep water has not been tested.

A minor play exists in the Saltpond area (offshore Ghana) where transform movements have created a wider platform area that has preserved a small Paleozoic system (Devonian source rock and reservoir).

The Keta Basin and Dahomey Embayment (eastern Ghana to Benin) have been affected by the Niger Prodelta since very Late Cretaceous and the thick Tertiary section in the deep water areas offers the possibility of reservoirs in the Paleogene.

NWAAM structure and prospectivity

NWAAM is identified as a more typical Atlantic Margin syn- and post-rift system. In the study area the major structures were created during the rifting phase from late Triassic until late Jurassic and the following thermal sag phase. Since early Cretaceous the region has been a passive margin.

The NWAAM area is separated from the WATM by the Guinea TFZ which is oriented NW-SE. Major transform ridges occur along the southern edge of the area and these are associated with increased subsidence locally and more complicated structure in places, see Figure 3. Several sub-basins and structural highs (igneous intrusions, ridges along transform zones, uplifted basement) are found beneath the present day carbonate shelf, Salt layers of Triassic age have mobilised and provide structures for traps and affect temperature distribution. Recently acquired seismic data indicates that the salt structures of the NWAAM region may exist further to the west than generally accepted. Igneous intrusions of similar age form prominent highs in the north of the area.

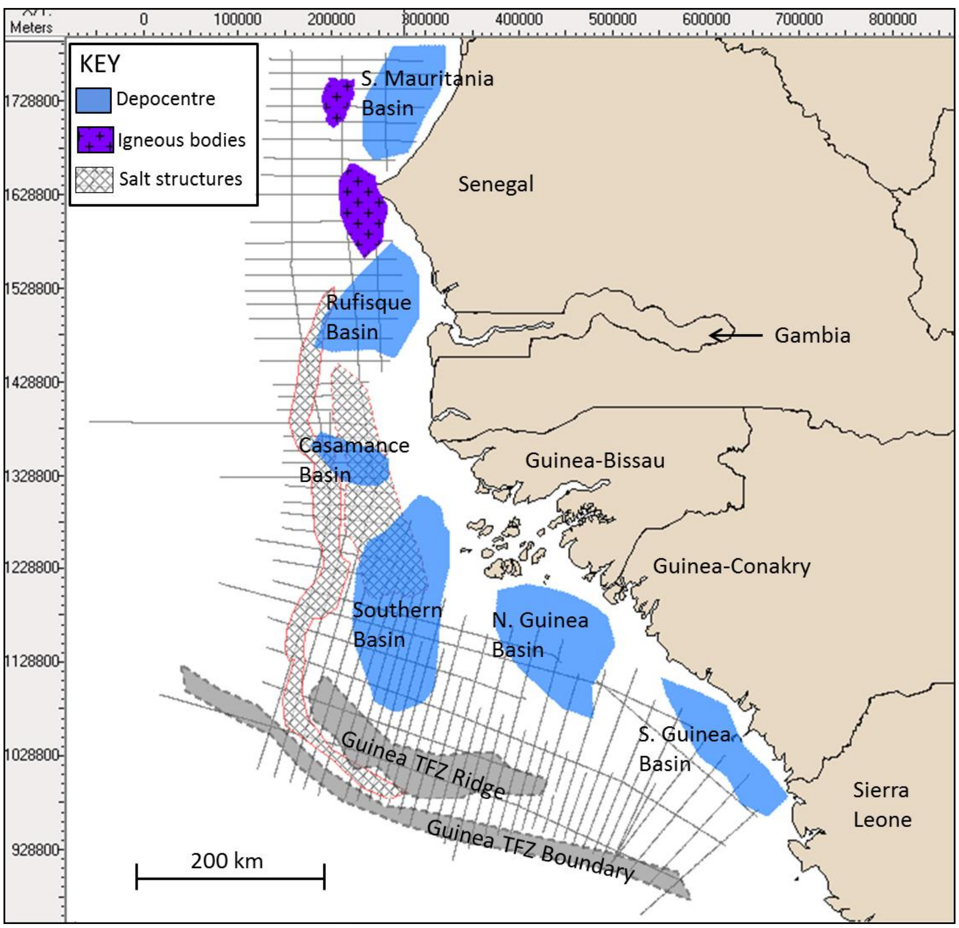

Figure 3: Map of major structures and sediment depocentres in NWAAM

Extensive carbonate sedimentation occurred from Jurassic-Albian over much of the region extending from near coast to deep water with thickness up to over 2000 m. Large platform areas are seen on the shelf with total sediment thickness (syn- and post-rift) up to 12000 m in places. Examples of different traps associated with structures created by the tectonic history of the area can be seen in Figure 4.

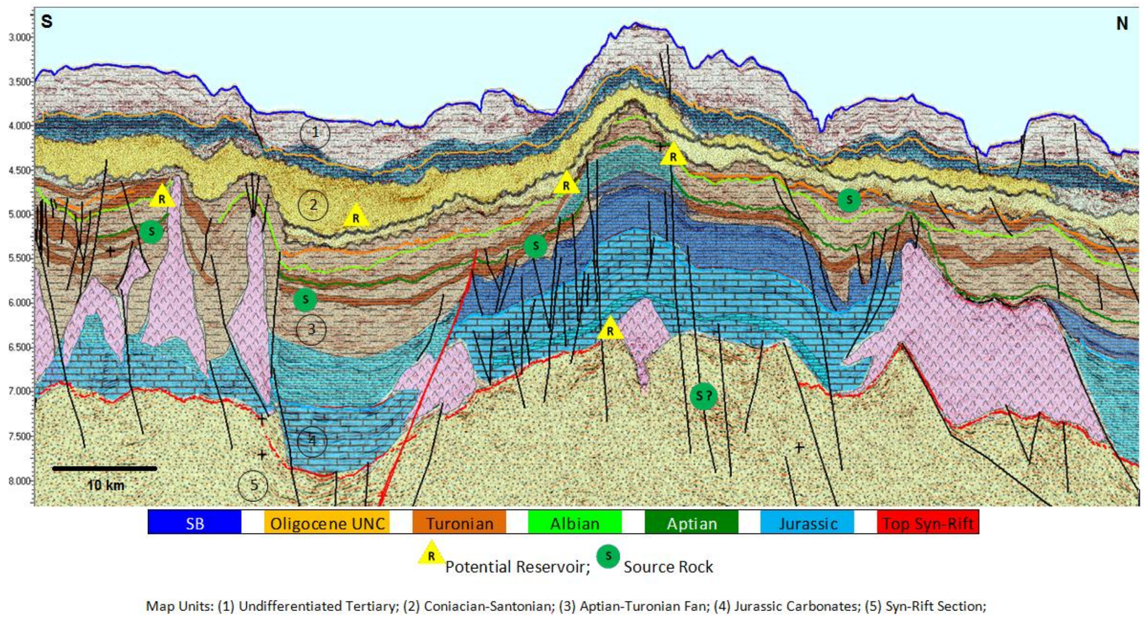

Figure 4: Interpreted seismic section illustrating NWAAM reservoir and source types

The following comments can be made regarding the hydrocarbon systems present:

- Turonian source rock is present, as indicated by DSDP wells, but is only in expulsion window in places where overburden thickness is sufficient.
- Lower Cretaceous source is expected to be mature over most of the region.
- Possible Triassic-Jurassic source rocks (syn-rift to early post-rift) are expected in the area, but would be overmature in the main depocentres.
- We cannot totally discount possibility of Paleozoic source near coast as seen further east onshore Senegal.

Conclusions

The two areas (WATM and NWAAM) have significantly different structural style and prospectivity. The NWAAM area shows much greater structural variation and trap types than the WATM. The new regional data set acquired in 2011 is particularly useful in providing a better understanding of the deep water areas.

The WATM prospectivity is dominated by the Upper Cretaceous slope fan and lobe systems but other plays (Lower Cretaceous, Paleozoic and Paleogene) exist in the region and have not been fully explored. Extensive 2D and 3D surveys have been recorded in this area and have indicated possible extension of the prospectivity zone into the ultra-deep water areas.

The NWAAM area contains several hydrocarbon systems that are found in different parts of the region depending on local tectonic and thermal history: Upper Cretaceous, Lower Cretaceous (widespread in the region), Jurassic-Cretaceous and Triassic-Jurassic. These systems are found in traps of different types including closures against salt bodies, syn-rift structural traps, carbonate reefs and siliciclastic slope fans. Considerable hydrocarbon exploration potential exists, with only a few areas tested by drilling and most wells in relatively shallow water on the platform area.