Regional Prospectivity of Offshore Namibia and the Angolan Namibe Basin

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SUMMARY

The underexplored offshore deepwater basins of Angola and Namibia hold tremendous potential for hydrocarbons. Recently acquired broadband 2D seismic from the Namibe Basin (offshore Angola) and offshore Namibia has allowed a detailed imaging of syn-rift and post-rift structures, enabling more confident identification and mapping of prospects analogous to those so prolific in the South American conjugate margins.

Horst and graben structures that formed during rift phases are now visible in the depth-migrated seismic data beneath 3-6 km of post-rift sediments. Thick salt, which is well known to the north, extends into the northern Namibe basins. Post-rift channel and fan structures can be identified as high amplitude anomalies throughout the area.

Cobalt's recent discoveries in Angola have proven the great potential of pre-salt sediments and fuelled the search for prospects at this level in other nearby basins. In Namibia, a new phase of activity over the last few years includes wells by HRT and Chariot which have proven the existence of mature middle Cretaceous source rocks. Several further wells are planned for 2014

The improved imaging and resolution provided by modern broadband seismic significantly de-risk exploration in a frontier deepwater area where well costs are high.

Summary

Acquired broadband 2D seismic data shot in recent years in the Namibe Basin (offshore Angola) and offshore Namibia has allowed detailed imaging of syn-rift and post-rift structures and geology, enabling more confident identification and mapping of prospects analogous to those so prolific in the South American conjugate margins. The improved imaging and resolution provided by these data significantly de-risk exploration in a frontier deepwater area where well costs are high.

Introduction

The deepwater basins of Namibia and Angola hold tremendous hydrocarbon potential. These frontier areas of offshore West Africa have seen a demand for high quality, detailed and innovative seismic data which can be set in a regional context, in order to assist in the exploration, understanding and de-risking of these potentially prolific hydrocarbon provinces.

In an effort to better understand the petroleum systems of offshore Namibia and the Angolan Namibe Basin, PGS has recently acquired three 2D surveys using the GeoStreamer® and GeoStreamer GS® dual-sensor broadband towed streamer system, in association with Sonangol and Namcor (Figure 1). These surveys are: (1) In 2011, 12,700 kms regional 2D of the Angolan Namibe, Benguela and Kwanza basins; (2) In 2012, 5,000 line kms over Namibian blocks 2112B, 2113 A&B and 2413B, and (3) in 2013, 10,000 kms regional 2D focused in deep-water Namibia

These data give more accurate seismic imaging of structures, thus improving the regional understanding of tectonic evolution, structure and geology, providing new insights regarding the prospectivity of these basins, which will be summarised in this paper.

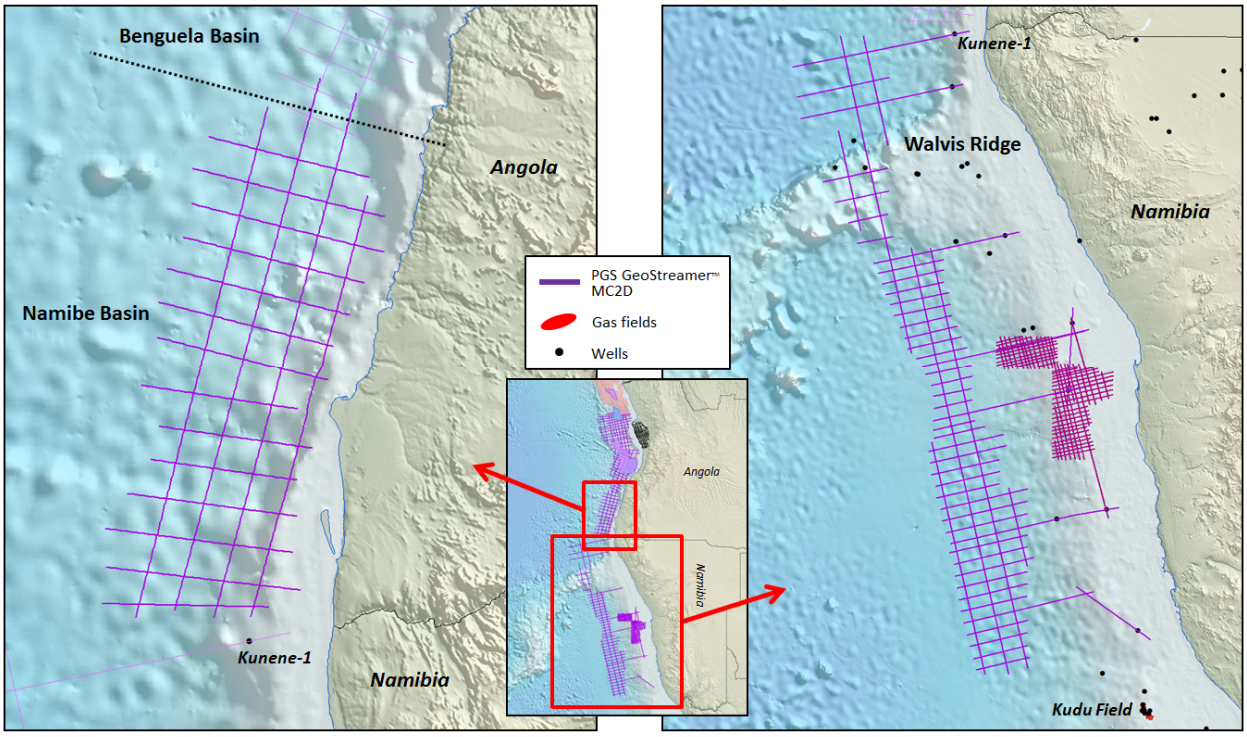

Figure 1 *Location of the Namibe and Namibian basins showing PGS 2D data coverage.*

Seismic Acquisition and Processing

Namibe, Benguela and Kwanza Survey

A 10 km dual-sensor streamer was deployed with a tuned source array with a volume of 4130 cu.in. The data were acquired with a 15 second record length in combination with the long-offset streamer

configuration. Broadband acquisition, and subsequent Pre-stack Depth Migration (PSDM) data processing, has allowed for a much more precise seismic image of the pre-salt / syn-rift section, permitting better geological understanding, lead identification and prospect delineation.

Namibian blocks 2112B, 2113 A&B and 2413B survey
In 2012, 5,000 km of dense 2D broadband data was shot in the shallow water offshore Namibia, in blocks 2112B, 2113 A&B and 2413B. The data were acquired with a cable length of 10,050 m and a 12 second record length. The processing workflow was designed to optimise the full bandwidth of the broadband data. By using Pre-stack Time Migration (PSTM) on the broadband data, PGS have been able to enhance the subsurface image at both shallow and deep intervals, helping to improve geological understanding along this frontier margin.

Deep water Namibia Survey
In 2013, 10,000 km of 2D broadband data was shot in deep water offshore Namibia. The data were acquired with a cable length of 8100 m and a 12 second record length. Data processing includes 2D Surface Related Multiple Elimination (SRME), High Resolution Time Domain Radon De-Multiple and Anisotropic Kirchoff Pre-Stack Time Migration. As in the Namibian blocks 2112B, 2113 A&B and 2413B survey, the processing workflow has been designed to work with the broadband seismic data to give an enhanced image of the subsurface.

Regional & Petroleum Geology

Namibia and the Namibe Basin have similar geological histories and potential hydrocarbon plays (Table 1), controlled largely by the opening of the South Atlantic in the Early Cretaceous. The volcanic Walvis Ridge separates the two regions and controlled sedimentation to the north during rifting.

	Namibe Basin	**Namibia**
Source	Syn-rift lacustrine and shallow marine shales, early post-rift deep marine shales	Syn-rift lacustrine and shallow marine shales, early post-rift deep marine shales
Reservoir	Syn-rift continental and marine sands, sag phase carbonate banks, post rift deep marine sandstones	Syn-rift continental and shallow marine sandstones, sag phase carbonate banks, post rift deep marine sands
Seal	Syn-rift salt in the northern Namibe, deep marine shales across the area	Intraformational shales in both the syn-rift and post-rift
Trap	Multiple traps, including salt related, pinch outs on volcanos and basement highs, channels and fans	Pinch outs on basement highs and slopes, channels and fans, shelf edge related carbonate build ups

Table 1 *Overview of the main play elements of the Namibe Basin.*

The syn-rift stage of both areas is typified by a series of asymmetrical horst and graben basins, in which thick sequences of fluvial and lacustrine sediments were deposited in narrow deep lakes. In analogous formations in the conjugate margins of South America, burial of algal blooms and plant detritus, along with anoxic bottom waters lead to the formation of high quality source rock. Reservoir rocks range from conglomerates and sandstones, shed locally from uplifted horst blocks.

In deep water south of the Walvis Ridge, Seaward Dipping Reflectors (SDRs) are clearly visible on the seismic and are interpreted to be thick, stacked, sub-aerial basalt flows interspersed with non-volcanic sediments. These were deposited towards the end of the syn-rift period and mark the transition between continental and oceanic crust (Figure 2). SDRs seem to be absent from the Namibe Basin. As active rifting ceased in the Early Cretaceous, the early post-rift, or sag phase was characterised by the deposition of continental, fluvial, lagoonal and finally transgressive to deep

marine sediments. This includes several potential source rock horizons related to Oceanic Anoxic Events in the Aptian and Cenomanian/Turonian. The Walvis Ridge controlled sedimentation to the north during this period; repeated cycles of marine incursions across the ridge into a restricted basin led to the development of a thick evaporite sequence. Although this salt is widespread throughout the West African margin, it thins into the Namibe Basin (Figure 3) and is absent from Namibia, where open marine conditions prevailed earlier than to the north.

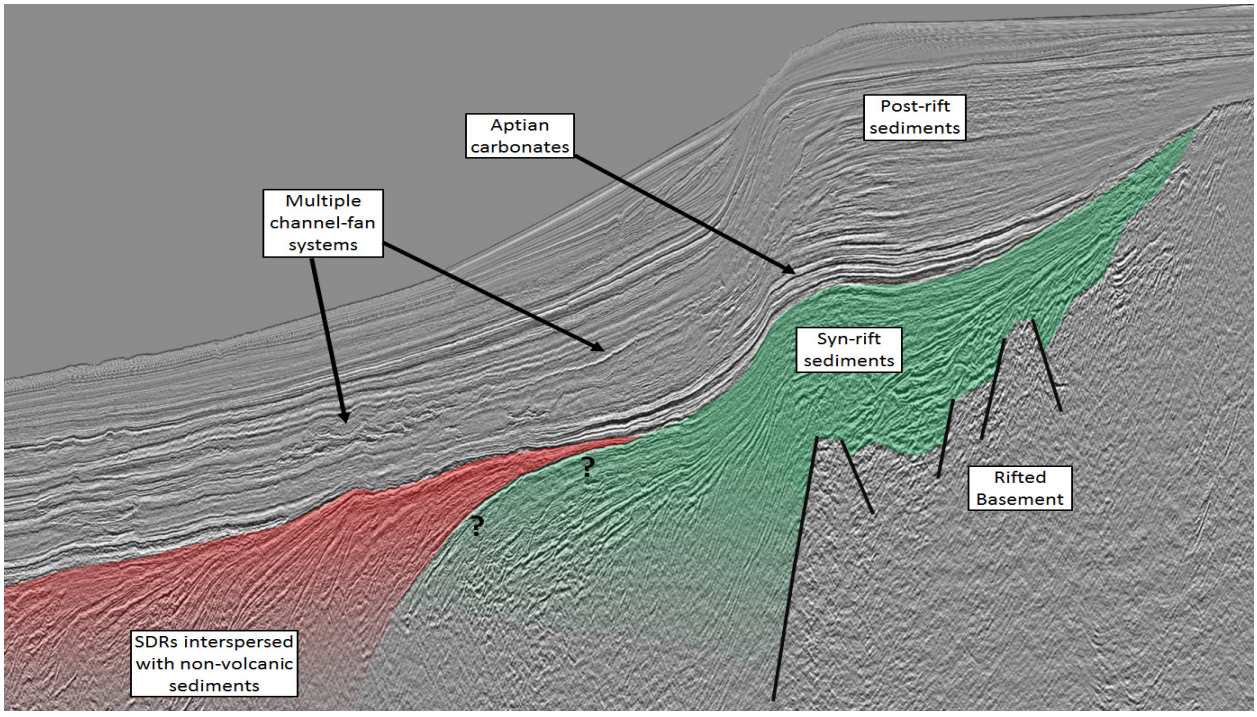

Figure 2 *Dual-sensor streamer 2D dip line, Namibia (fast track time migration, 2013).*

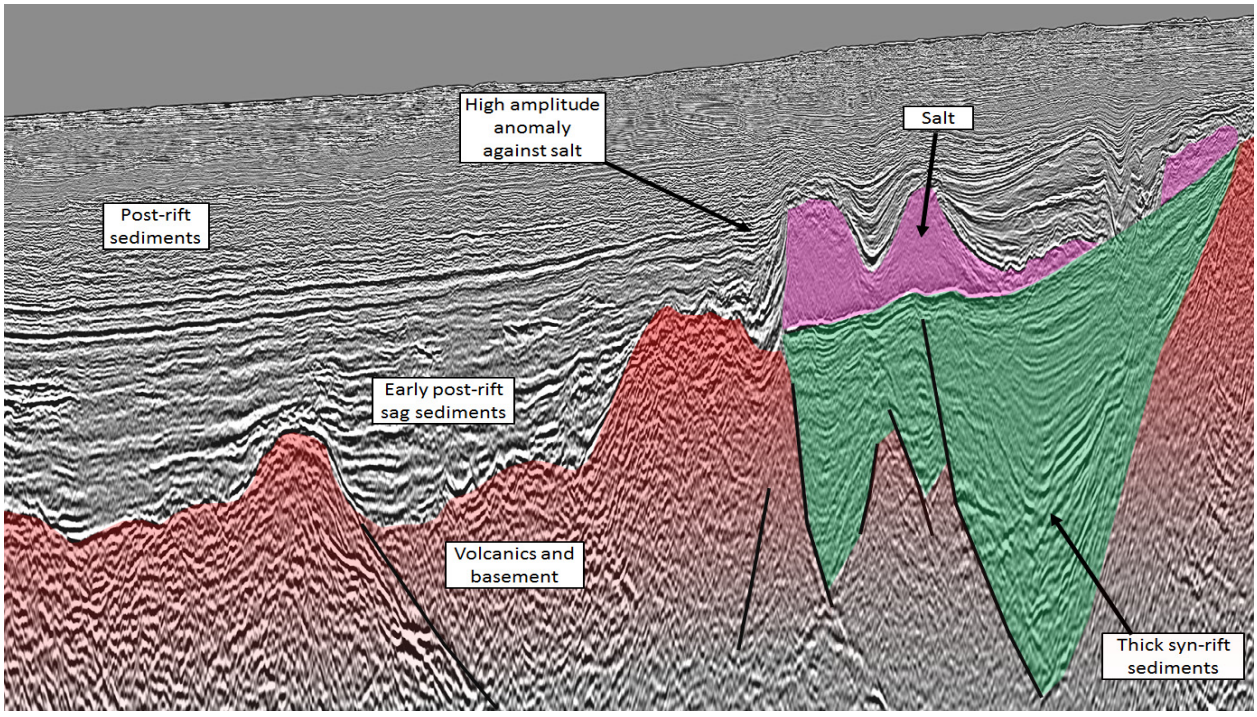

Figure 3 *Dual-sensor streamer 2D dip line over the Namibe Basin (final depth-migrated).*

2-5 kms of post-rift sediments overlay the syn-rift sections along this margin (Figure 2), while volcanic centres are common in the Namibe Basin and are associated with the early post-rift stage, some of which are still presently exposed at the sea bed.

Recent Activity

Kunene-1, the Namibe Basin's only exploration well, was drilled by Sintezneftegaz in Namibia block 1711 in 2008 and discovered gas in post-salt sediments. However, just to the north of the Namibe Basin in 1992, the Falcao-1 well penetrated the pre-salt section, encountering ~600 m of organic-rich lacustrine shales, and reservoir-quality carbonates. In 1996, the Baleia-1 well also drilled into the pre-salt and encountered a 300 foot oil column in a dolomitic reservoir with estimated in-place volumes reported to exceed 1 billion barrels (Henry *et al*., 2010). Finally, Cobalt's recent discoveries in Angola Blocks 20 and 21 have proven the great potential of pre-salt sediments fuelling the search for prospects at this level in other nearby basins.

In Namibia, a flurry of exploration in the mid-1990s led to several dry wells being drilled and the gas discovery of Kudu Field. This has been followed in the last few years by a new phase of activity, which includes wells by Petrobras, HRT and Chariot which proved the existence of mature middle Cretaceous source rocks. More wells are planned for 2014, including Welwitschia-1 by Repsol and Tower in northern Namibia.

Conclusions

Broadband seismic has improved the imaging of syn-rift and post-rift structures, enabling more confident identification and mapping of prospects. These data clearly demonstrate the presence of thick syn- and post-rift packages, thick sediment in deep water, as well as salt in the northern Namibe Basin. The improved imaging and resolution provided by this type of seismic acquisition significantly de-risks exploration in frontier areas, something that is of significant importance where well costs are extremely high.

References

Henry, S.G., Sebastio, L., Kumar, N., Sebastio, A. and Venkatramen, S. [2010] Tupi's Conjugate: New Pre-salt Plays in the Angolan Offshore. *AAPG Search and Discover Article*, #90104.