Derisking the frontier

A new study provides a clearer image of the Namibe salt basin.

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Dual-sensor broadband data have been used to identify significant presalt and post-salt potential in the Namibe Basin offshore southern Angola. The superior imaging offered by dual-sensor seismic data combined with geoscience evaluation work presents an understanding of the structural setting, reservoir facies and hydrocarbon charge of this frontier basin. Studies also seek to address some of the presalt exploration challenges in this basin that also have been encountered in the neighboring Kwanza Basin.

The Namibe Basin represents a significant unexplored hydrocarbon province located onshore and offshore southern Angola. During the Late Jurassic to Early Cretaceous the eastern Atlantic margin of this part of West Africa developed as the conjugate to the prolific hydrocarbon-bearing Santos and Campos basins offshore Brazil. Although recent research describes the conjugate basins of Brazil and Angola as asymmetrical, with each basin containing slightly different petroleum elements, discoveries of supergiant oil fields in the Santos and Campos basins have resulted in a wave of presalt exploration optimism in Angola, with some notable successes.

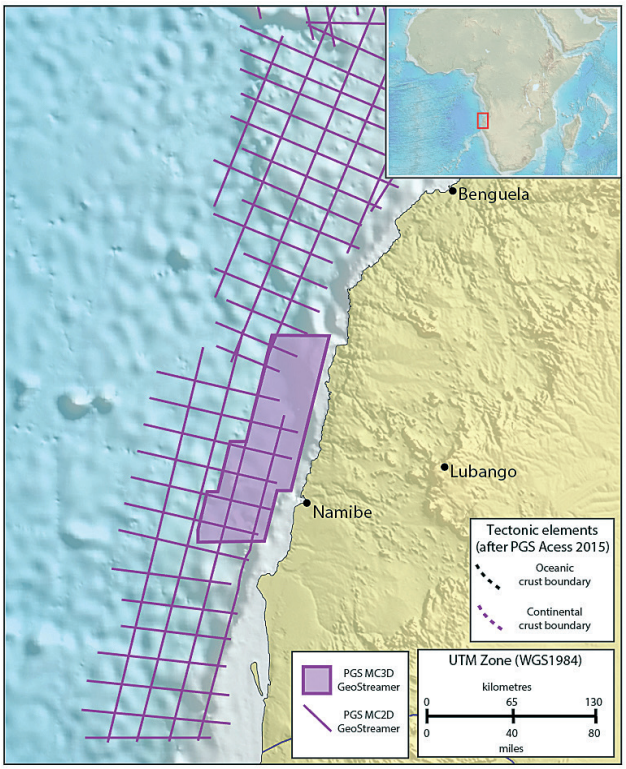

FIGURE 1. PGS acquired a regional 2-D dual-sensor broadband survey that was processed and migrated to a depth of 15 km (9 miles), allowing the basin architecture and presalt plays of the Angolan basins to be de-risked. (Source: PGS)

The recent exploration of the presalt plays in the Angolan Basin has been rapid, with significant discoveries made away from the present-day shelf in the Kwanza Basin such as Lontra, Orca and Bicuar, demonstrating the success of this play.

A large regional 2-D dual-sensor broadband survey was acquired by PGS in 2011 and was processed and migrated to a depth of 15 km (9 miles), allowing the basin architecture and presalt plays of the Angolan basins to be de-risked (Figure 1). Analysis and interpretation of this 2-D dataset, constrained by the PGS Access West Africa depositional sequence framework, highlighted the prospectivity potential of the Namibe Basin, and subsequently a multiclient 3-D dual-sensor survey was acquired to better illuminate it. This 3-D survey offers unrivaled imaging of the presalt section and allows more confident delineation of presalt reservoir facies.

Petroleum systems

Since the Namibe Basin is undrilled, the geological and hydrocarbon property information required to understand and de-risk the petroleum systems has been extrapolated from neighboring basins in Angola and Brazil, constrained by a sequence stratigraphic framework. In addition, geological knowledge has been collated from the onshore portion of the Namibe Basin, where the Cretaceous presalt stratigraphy outcrops and is exposed.

Source rock story

From a regional understanding of the source rocks of the Angolan and Brazilian margins, those for the Namibe Basin are expected to occur predominantly in the presalt syn-rift (Lower Cuvo equivalent) and sag phase (Bucomazi equivalent) lacustrine sections, with

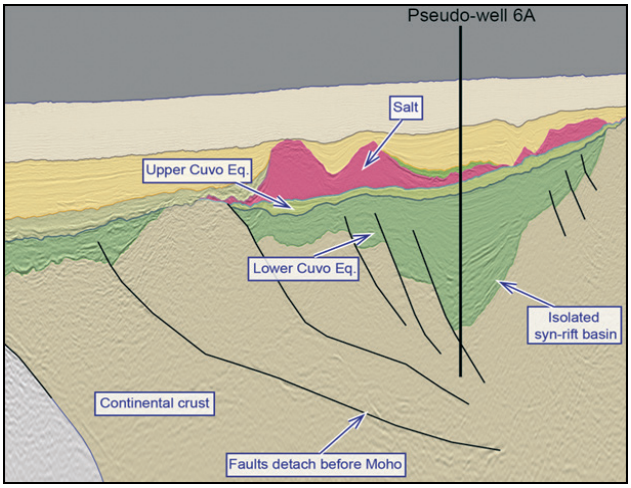

FIGURE 2. Basin modeling work conducted on pseudo well locations in the Namibe Basin exhibits encouraging maturation profiles. (Source: PGS)

potential for a secondary early post-rift source rock (Iabe equivalent) in the deeper water.

Regional temperature and geochemical information has been taken from well data in Angola and Namibia, and appropriate ranges were selected as input for the modeling of source rocks. The results of this basin modeling work, conducted on pseudo well locations in the Namibe Basin, exhibit encouraging maturation profiles, with the Lower Cuvo Formation equivalent reaching early oil generation in the Eocene and Bucomazi Formation equivalent in the Miocene (Figure 2).

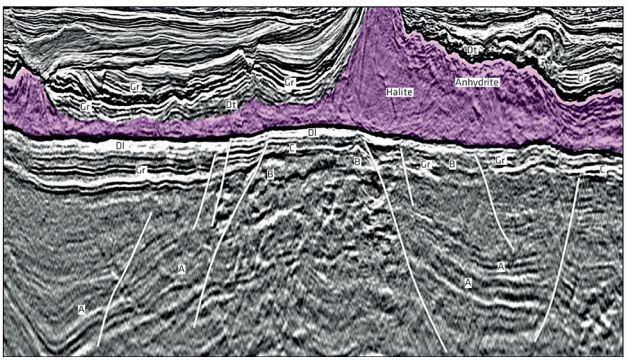

FIGURE 3. The resolution of the dual-sensor broadband survey has allowed seismic facies to be characterized and delineated with greater confidence in the presalt section. (Source: PGS)

Reservoir facies analysis

An understanding of the likely reservoirs of the Namibe Basin and their stratigraphic and spatial distribution can be established by comparing equivalent depositional packages between the conjugate basins of Angola and Brazil.

In the Namibe Basin, syn-rift reservoirs are expected to exist as formation equivalents to the Lower Cuvo Formation continental sandstones and the Upper Cuvo Formation fluvial to lagoonal. Post-rift reservoirs are expected to comprise shallow marine sandstones of the Iabe Formation, Pinda Formation (Binga Member) carbonates and deep marine sandstones of the Landana Formation.

The resolution of this 3-D dual-sensor broadband survey has allowed seismic facies to be characterized and delineated with greater confidence in the presalt section. These facies could then be compared to drilled analogs seen in equivalent dual-sensor broadband data in the Kwanza, Santos, Campos and Espirito Santo basins (Figure 3).

In the early syn-rift section equivalents of the Lower Cuvo Formation continental sandstones from Kwanza and the Lower Guaratibe sandstones of Santos can be interpreted, characterized by higher amplitude seismic facies with possible fan-like geometries. Above these, equivalents of the shallow marine sandstones of the Upper Cuvo Formation (Kwanza) and Upper Guaratibe (Santos) also can be delineated.

In the sag-phase section, seismic resolution allows the description of multiple facies characters and their spatial distribution to be mapped in relation to the rift structures. Here, depositional facies such as grainstone shoals, microbial buildups, coquinas and tidal dolomites can be inferred based on matching their seismic reflector amplitude, frequency and continuity characters to equivalent facies in the Kwanza and offshore Brazilian basins.

In the post-rift section, facies distribution is noticeably influenced by salt movement. Here grainstone shoals and sand-dominated mass flow deposits can be interpreted with numerous plays provided by salt withdrawal collapse features and ponding of sands in palaeo-lows.

Sealed by salt

Aptian salt deposits are well known in the Kwanza, Santos and Campos basins, where they act as the main seal for multiple fields and discoveries. Interpretation and mapping on the new 3-D dataset has shown that the salt deposits are far more extensive in the Namibe Basin than previously identified in conjugate margin reconstructions or in 2-D data. Within the salt itself different seismic reflector characteristics are recorded, suggesting the presence of massive halite as well as bedded anhydrite layers.

Large presalt structures

The 3-D seismic dataset over the basin was acquired towing 12 dual-sensor streamers with a streamer length

of 8,100 m (26,575 ft). These acquisition parameters allowed the deep structures and faults to be successfully imaged and the architecture of the basin to be confidently interpreted.

Numerous syn-rift structures are seen within the presalt section associated with tilted fault blocks and subsequent inversion events. Overlying the syn-rift, the sag-phase similarly displays complex structural geometries with multiple subsalt closures in which hydrocarbons can be trapped.

Because of the resolution of the data in the sag-phase section, the relationship of the reservoir facies to these syn-rift structures can be understood. On the flanks of the structures, facies interpreted as grainstone shoals can be seen to be onlapping or pinching out against the highs, with the timing of rift activity clearly influencing the deposition of these facies. Toward the crests of the structures, facies interpreted as coquinas can be seen to be accruing along with possible microbial buildups, onlapped by grainstone shoals. Overlying these, in the late sag-phase, facies interpreted as shallow marine dolomites are interpreted in the central part of the basin immediately underneath the salt and likely associated with the onset of restricted basin circulation.

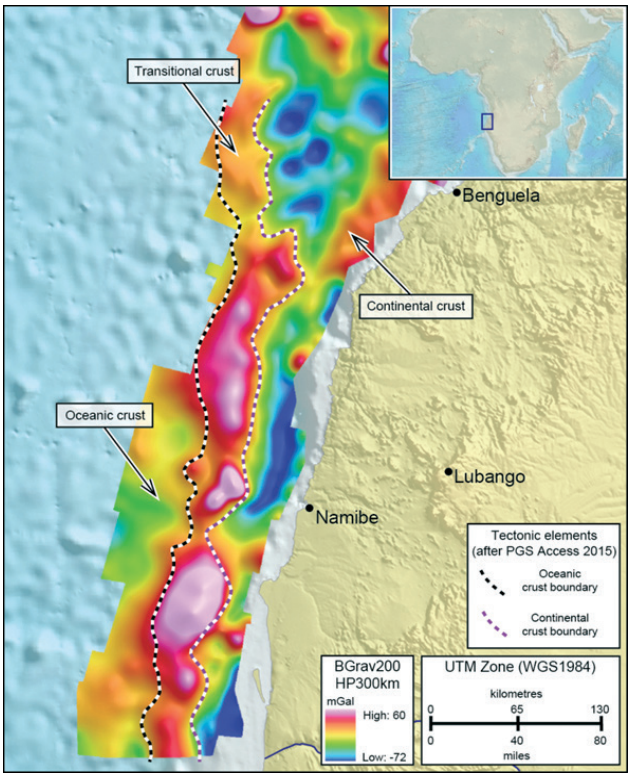

FIGURE 4. Shipborne gravity and magnetic data combined with GeoStreamer data have identified that CO_2 contamination can be de-risked through the interpretation of crustal types, mapping of volcanic hot spots and the interpretation of fault propagation depths. (Source: PGS)

Pull Quote

Challenges of CO_2 contamination

A number of recent exploration wells in the southern Kwanza Basin have encountered CO_2 contamination in presalt reservoirs, interpreted to have displaced an earlier oil charge. This CO_2 has been geochemically typed to mantle, either sourced via deep-seated faults penetrating the Moho or resulting from shallow exhumed mantle degasing.

A basin structure and architecture study of the Namibe Basin was undertaken as part of the PGS Access project using shipborne gravity and magnetic data combined with 2-D GeoStreamer data (Figure 4). This work has identified that CO_2 contamination can be de-risked through the interpretation of crustal types, mapping of volcanic hot spots and the interpretation of fault propagation depths. Similarly, areas of gravity highs can be assigned to areas of ridged lithosphere reducing the likelihood of the presence of exhumed mantle.

The Namibe Basin is an underexplored and undrilled province with considerable hydrocarbon potential. PGS dual-sensor broadband data combined with targeted geoscience work has identified the key elements of a working petroleum system while reducing the known exploration risks. Basin modeling results suggest the likely generation and expulsion of hydrocarbons from syn-rift source rocks, while gravity modeling work has predicted a reduced risk of CO_2 contamination.

The resolution and imaging of the seismic data permits the identification of numerous presalt reservoir facies analogous to those of conjugate and neighboring presalt basins and demonstrate the relationship and distribution of these facies to the syn-rift structures.

Open acreage, an anticipated license round and modern multiclient data make the Namibe Basin a highly attractive focus for frontier exploration. E&P

References available.