Taking an integrated approach to seismic exploration

Getting as much information from the seismic data as possible leads to better decisions.

Patrick Coole, PGS

In 2014 Petroleum Geo-Services (PGS) began a large, integrated 2-D geosciences project with the aim of increasing the geological understanding of the Angolan and Namibian offshore margins (red lines, Figure 1). The project employed an integrated approach using regional 2-D interpretation, gravity and magnetics, and quantitative seismic interpretation to achieve this aim.

Seismic acquisition took place offshore Angola in 2011 and offshore Namibia in 2013. Both datasets were acquired using PGS' dual-source GeoStreamer and GeoStreamer with GeoSource, respectively. The true broadband nature of this type of acquisition system allows a superior seismic image, providing broader frequencies across the amplitude spectrum and making it ideal for reservoir characterization/quantitative interpretation and geological interpretation.

While shooting the seismic data, PGS also acquired gravity and magnetics data along the same lines. As such, the PGS Access project combines regional 2-D geological interpretation, quantitative interpretation, and gravity and magnetics. It also ties to important pre- and post-salt wells and discoveries, providing an integrated geoscience project targeted specifically at exploration and aiding geoscientists in understanding this prolific yet geologically complex margin.

Geology

Both the Angolan and Namibian offshore basins were formed during the Late Jurassic to Early Cretaceous due to the rift and subsequent drift and separation of the South American and African plates. The major stage of rifting occurred from the early Jurassic to early Cretaceous (Neocomian) from south to north. The basins that formed during this rifting phase are stratigraphically divided up into pre-rift, syn-rift, sag-phase and post-rift successions.

The main reservoir targets offshore Angola are in syn-rift sandstones, sag-phase lacustrine carbonates (the focus for exploration over the past five years) and post-rift shallow marine carbonates and channel and turbidite systems. In Namibia, targets are typically in post-rift channel sandstones and shelf carbonates but also are chasing the pre-rift basin potential. However, in terms of exploratory wells drilled, Namibia remains far more

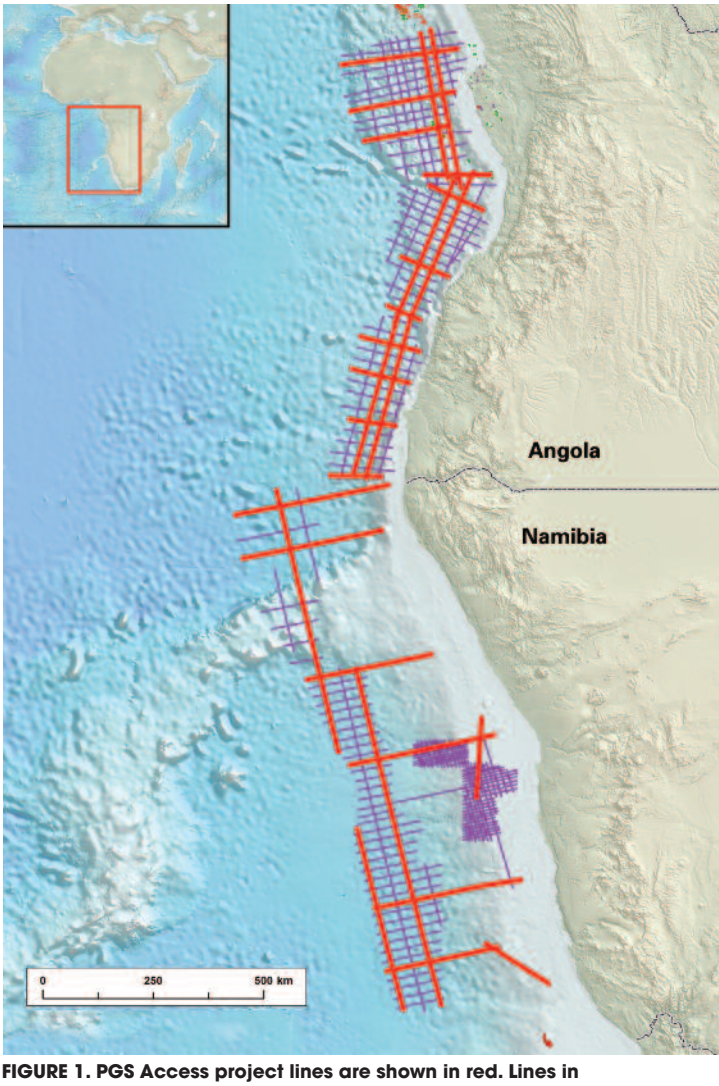

FIGURE 1. PGS Access project lines are shown in red. Lines in magenta are the additional 2-D dataset that runs across Angola and Namibia. (Source: PGS)

immature than Angola and, as a consequence, less is understood about its petroleum system.

Regional interpretation

The first stage of the project was to complete a large-scale 2-D seismic interpretation. Total line coverage used for PGS Access covers almost 8,000 km (4,970 miles), so having the best regional interpretation to carry forward into quantitative interpretation is crucial for gaining accurate insight. The lines cover a variety of basins, from the Kwanza Basin in the north of Angola to the Orange Basin in the south of Namibia, each with both large-scale and subtle differences in structure and stratigraphy. A number of horizons have been interpreted, from basement through the syn-rift, sag-phase, Top and Base Aptian Salt and into the post-salt (Figure 2).

The 2-D grid chosen for PGS Access specifically covers a number of presalt discoveries, including Baleia/Orca, Cameia, Azul and Denden. Interpreting the seismic data across these discoveries has provided a better understanding of them as well as enabling the development of viable presalt leads through the Kwanza, Benguela and Namibe basins.

Gravity and magnetics

The gravity and magnetics interpretation project was completed in conjunction with the regional 2-D interpretation. A two-stage approach was taken. The first stage entailed making a regional qualitative interpretation using gridded gravity and magnetics data, drawing from both PGS' acquired 2-D and public domain data sources. The second stage entailed 2-D gravity modeling, whereby an iterative process was used to modify 2-D density models until the synthetic gravity response matched the high-resolution gravity data recorded by PGS during acquisition (Figure 3).

Densities used in the 2-D modeling were constrained using a combination of density logs derived from well data and literature available in the public domain. Horizons were taken from the 2-D interpretation to help con-

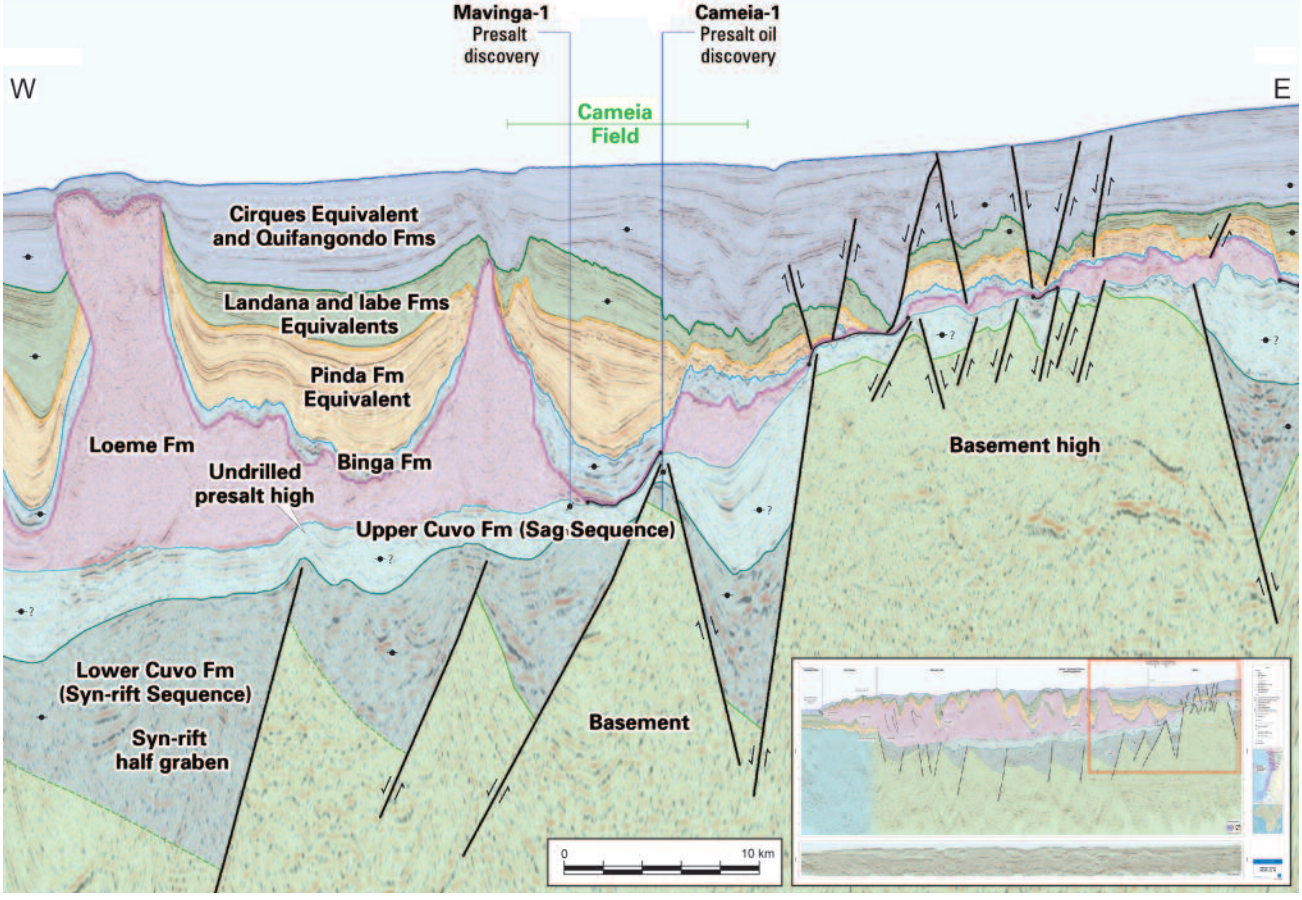

FIGURE 2. This example shows an interpreted PGS Access zoomed profile over the Cameia Field. The image to the bottom right shows the whole interpreted PGS Access profile line. (Source: PGS)

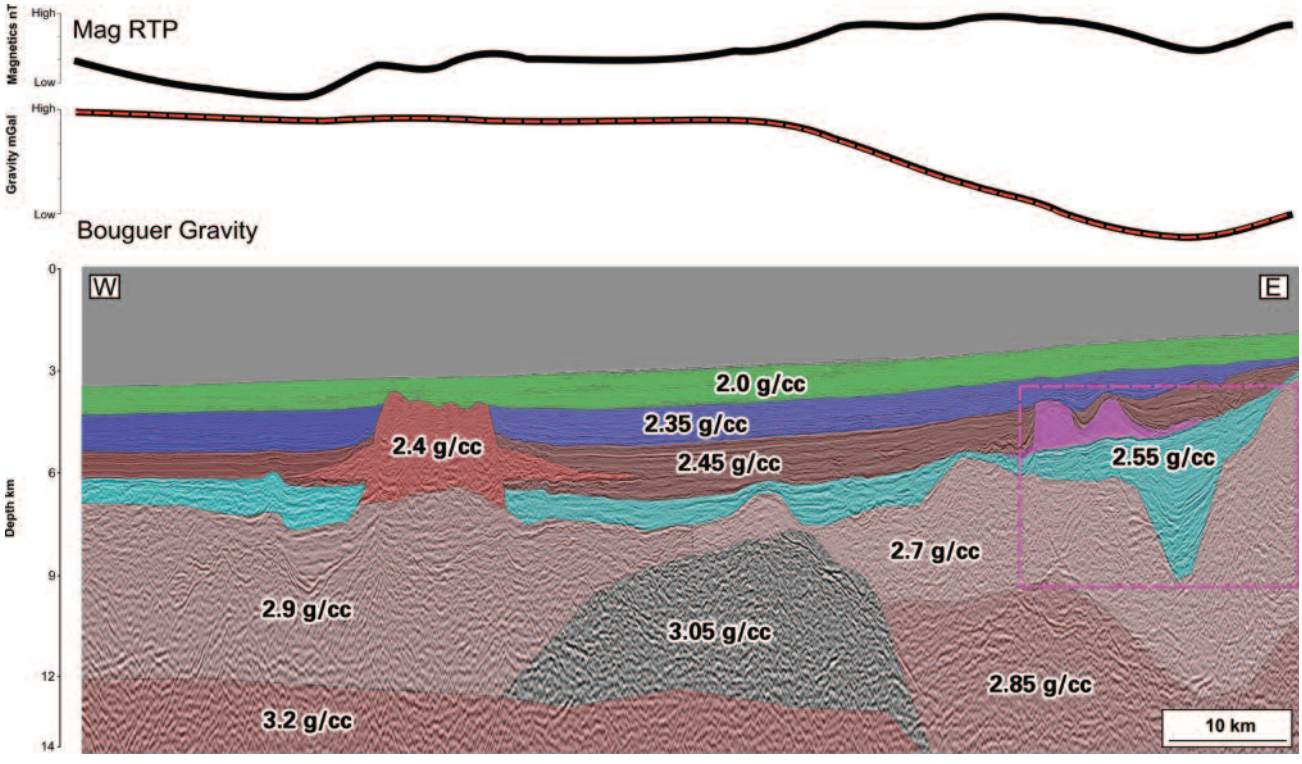

FIGURE 3. The density model is overlain on the seismic, with the synthetic gravity response (red dashed line) matching the recorded data (black line, recorded Bouguer gravity response). This interpretation shows a clear syn-rift basin (fuschia dashed box) on the east of the seismic line with salt and a thick post-rift sedimentary sequence overlying. This syn-rift basin is a highly prospective area in the Namibe Basin. (Source: PGS)

strain the initial stages of the model build and were modified until a good fit was made between observed and modeled data. This process meant that various competing seismic interpretations could be tested.

The gravity and magnetics interpretation gave insight into the nature of the deeper structure, the basement and syn-rift graben structure and the volcanics across Angola and Namibia, which otherwise in just 2-D seismic interpretation may have been inconclusive.

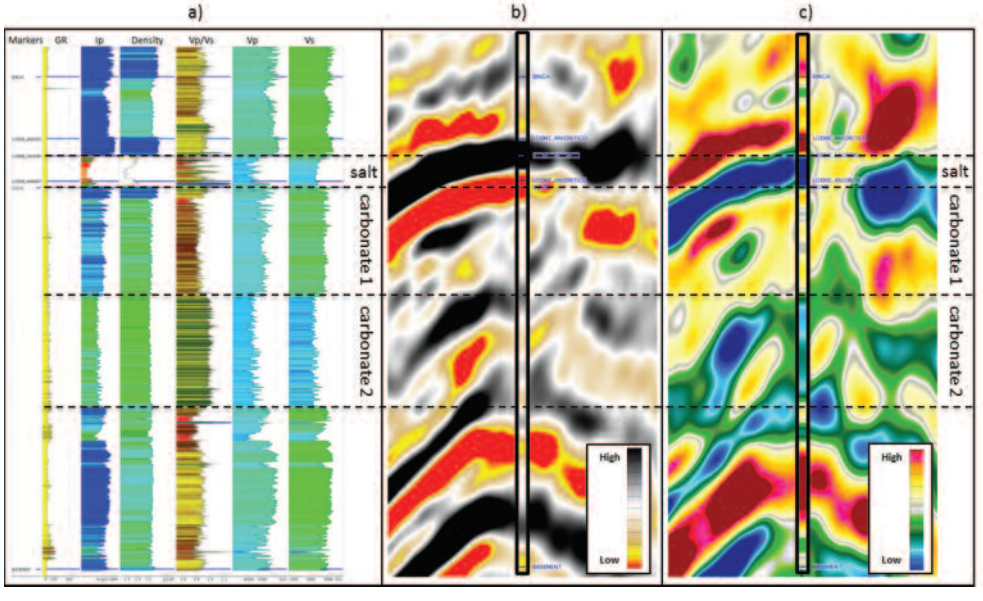

FIGURE 4. This figure shows a) the interpreted Baleia-1 logs, b) the well-to-seismic tie at the Baleia-1 location based on full-stack seismic data, and c) the interpreted induced polarization (Ip) inverted from Baleia-1 logs and Ip-relative from seismic data. (Source: PGS)

Rock physics and seismic inversion

Baleia-1 well (offshore Angola) was drilled in 1996, encountering a 91.4-m (300-ft) presalt oil column in a dolomitic reservoir. In-place hydrocarbon volumes are estimated to exceed 1 Bbbl of oil. To better understand the presalt dolomitic limestone reservoir, compressional- and shear-wave velocities, density and gamma ray logs were used from the Baleia-1 well for rock physics analysis.

Two carbonate intervals were discriminated. Carbonate 1 is an upper interval composed primarily of dolomitic limestone, and the lower interval is predominantly argillaceous limestone, referred to as Carbonate 2 (Figure 4a). The acoustic impedance volume (Figure 4c) shows a clear distinction between Carbonate 1 and 2, caused by a sharp decrease in velocity at the interface between the two intervals.

A very good well-to-seismic tie at Baleia-1 is observed both on the seismic (Figure 4b) and on the relative inversion version—acoustic impedance in this case (Figure 4c)—leading to a greater confidence and understanding of the presalt reservoir and its distribution.

Quantitative interpretation work performed on the PGS Access data in the Kwanza Basin is indicating a similar relative acoustic impedance response to that seen in the Santos Basin. This may begin to show that reservoir quality carbonates and dolomites deposited within the sag phase have similar elastic properties.

By performing an integrated reservoir approach, geoscientists at PGS have been able to gain insight into both the regional- and reservoir-scale geology. The PGS Access project shows how to get as much information from the seismic data as possible. This will in turn lead to better decisions on where to best invest time and resources along the Angolan and Namibian margin and therefore improve upon exploration success. E&P

Acknowledgment

The author would like to thank Sonangol, NAMCOR and PGS for permission to publish this work.