Exploring the Last Frontier: Offshore South Gabon

JAKE BERRYMAN and GREGOR DUVAL, CGG

A new seismic survey and integrated study reveals potential in the ultra-deep offshore petroleum systems.

Historically, the focus of exploration in Gabon has been on the pre-salt plays of the interior sub-basin and the pre- and post-salt plays of the north and south sub-basins on the continental shelf. However, with these areas considered mature, and given the recent Ivela-1 and Boudji-1 discoveries, the announcement of Gabon's 12th licensing round, low drilling costs and more favourable production-sharing contract terms, explorationists are now looking further offshore.

In 2015 CGG acquired 25,168 km^2 of high-quality BroadSeis™ broadband 3D seismic, gravity and magnetic data in the Gabon South Basin and conducted an extensive two-year geological study for the Direction Générale des Hydrocarbures. State-of-the-art seismic imaging applied to this huge survey revealed the deepwater and pre-salt geology in unprecedented detail, and indicated the considerable potential of the basin, as well as that of the ultra-deep water.

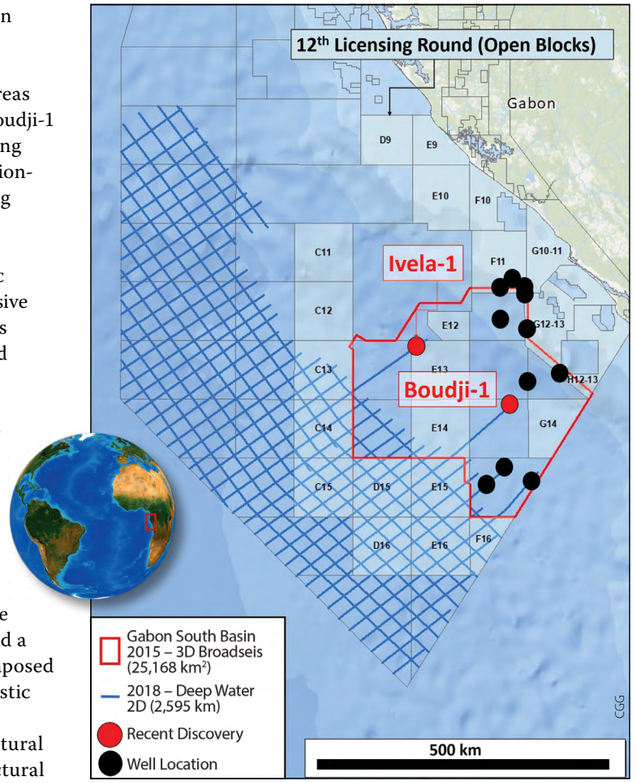


Figure 1: Map of South Gabon showing seismic coverage, locations of wells mentioned in the text and open blocks available in the 12th licensing round.

Active Petroleum Systems

The offshore Gabon basins have sedimentary fill typical of a passive margin setting, starting with syn-rift continental clastic deposits from Berriasian to Middle Aptian, a sag sequence made of transgressive Middle-Upper Aptian sands, shales and evaporates, and a post-rift series of Upper Aptian to Pleistocene age composed of shallow-water carbonates followed by deepwater clastic rocks, as illustrated in Figure 2.

Explorers have traditionally targeted combined structural and stratigraphic traps in the post-rift section and structural traps in the syn-rift and sag section in the offshore Gabon basins, as shown in Figure 3. In the Gabon North Basin, including the Ogooué Delta, the post-rift traps have been shown to be charged by a series of source rocks ranging from syn-rift lacustrine deposits to post-rift marine and deltaic deposits. In the Gabon South Basin, however, the only proven source rocks exist in the syn-rift lacustrine deposits of the Melania and Kissenda Formations, as illustrated in Figure 2, while there are questions over the distribution and maturity of post-rift source rocks.

It is thought that three post-rift source rock intervals may be found in the Gabon South Basin blocks offered in the 12th licensing round:

- A potential Turonian source rock (Azile Formation), which is proven to generate hydrocarbons in the offshore Gabon North Basin and has been drilled by several wells in the shallow waters of the Gabon South Basin. This source rock interval is the result of a deep marine anoxic event during the early Turonian (see Figures 2 and 4).
- A possible Cenomanian source rock (Cap Lopez Formation) from another global sea level high stand and deep marine anoxic event (see Figures 2 and 4).
- A potential Albian source rock (distal Madiela Formation) which has been shown to generate hydrocarbons and charge fields in the Lower Congo Basin to the south-east of the Gabon South Basin (see Figure 2).

Highlights from 2015 Data

Based on previous studies, the Gabon South Basin area is interpreted to include continental, transitional and oceanic crustal domains, as illustrated in Figure 5. Understanding the crustal types is important because they have different heat flows that can have an impact on source rock maturity.

In the early seismic images, the oceanic crust is jagged in nature and is displayed by a high-amplitude increase in acoustic impedance throughout.

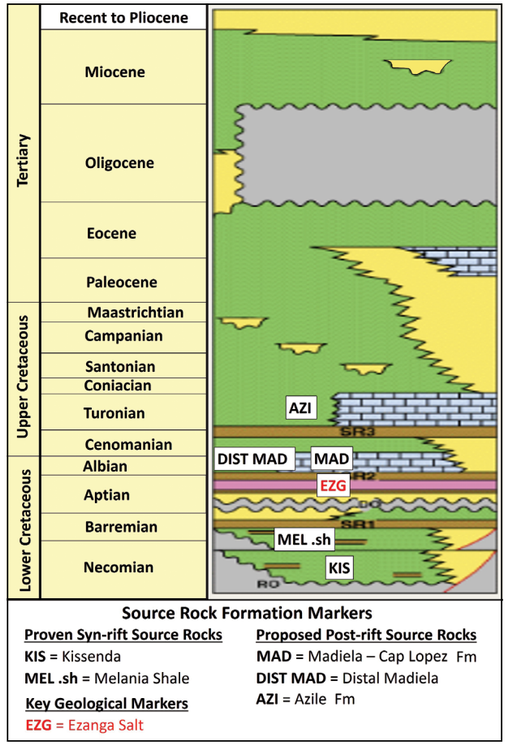
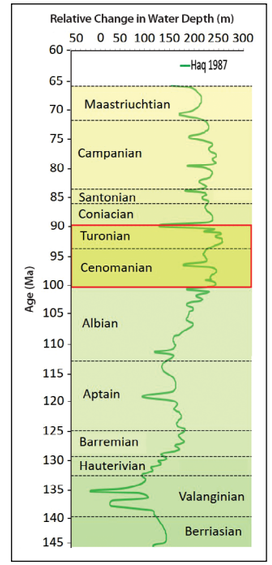


Figure 2: Chronostratigraphic chart of southern Gabon, modified from Bray and Lawrence, 1999.

Directly overlying the oceanic crust are a series of continuous, opaque, undulating parallel marine sediment beds that on-lap against a prominent unconformity surface. Drawing from previous studies in the area, from the stratigraphic relationship of this package with the surrounding sediments and from correlation of the seismic to the nearby wells that drilled through the Cenomanian-Turonian section, it is concluded that this is the interval where the post-rift source rocks are found.

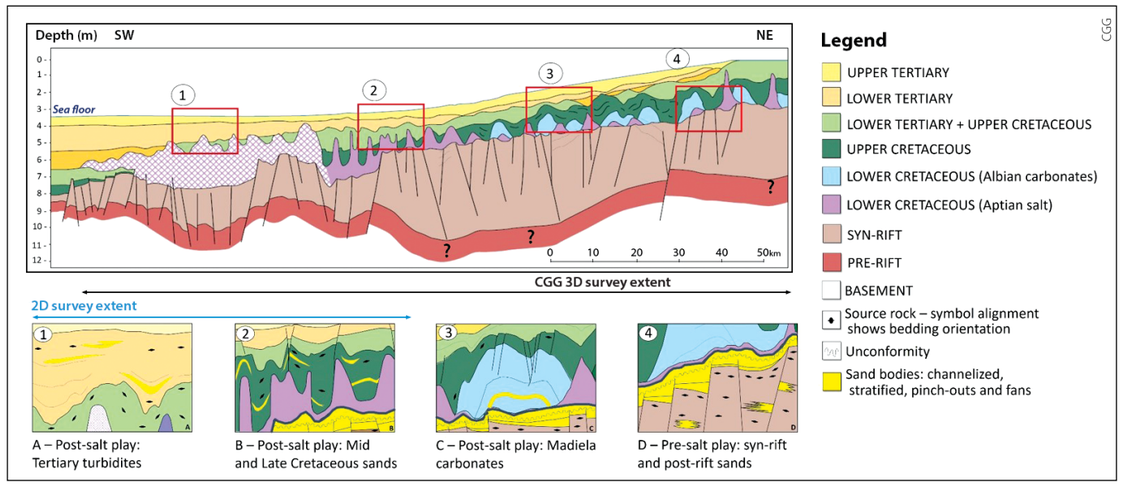
Further up in the section, the seismic reflectors are regularly interrupted by bright amplitude patches, which indicate the presence of numerous sand-filled turbidite channels. From previous studies, it is thought that these are fed from the Congo Delta to the south-east and that they form good-quality reservoir targets (Figure 5). This turbiditic system has been active and depositing silici-clastic reservoir facies in the area since the Oligocene (Figure 6) when the West Africa plate margin was tilted by major tectonic events. These turbidites may interact with the Ogooué Delta input from the north-east. The Ogooué Delta is older than the Congo Delta, with onset of turbidite deposits in the Late Cretaceous, which have provided good reservoirs for most of the fields in the Ogooué Delta Basin.

Figure 4: Sea level curve highlighting high stands related to the Cenomanian to Turonian anoxic event, modified from Haq et al., 1987.



On the images from the 2015 3D broadband data (Figure 5), the shallow subsurface is marked by a prominent seismic reflector that crosses the sedimentary structures at about 600 ms TWT below the seabed and mimics the bathymetry throughout the area of interest. This Bottom Simulating Reflector (BSR) is an indicator of the presence of large quantities of gas in the shallow sediments. At those depths, near the seabed, so-called gas hydrates can form. As the temperature increases again below the seabed, there is a point where the gas returns to its free state. The BSR observed on seismic data represents the boundary

Figure 3: Simplified cross-section highlighting the play types offshore south Gabon.



between gas hydrates above and free gas below. Understanding the depth at which the BSR appears below the seabed is important because it provides an indirect measurement of the geothermal gradient and heat flow from the underlying crust, and hence provides information about the potential maturity of the hydrocarbon source rock. In fact, the potential gas chimney observed in the central part of the seismic section and connected to a deeper migration focal point is an interesting observation to support the maturity of Albian-Turonian source rocks.

On the north-east side of the seismic section in Figure 5, we observe the presence of the Aptian evaporates (i.e. Ezanga Salt Formation) and syn-rift fault blocks.

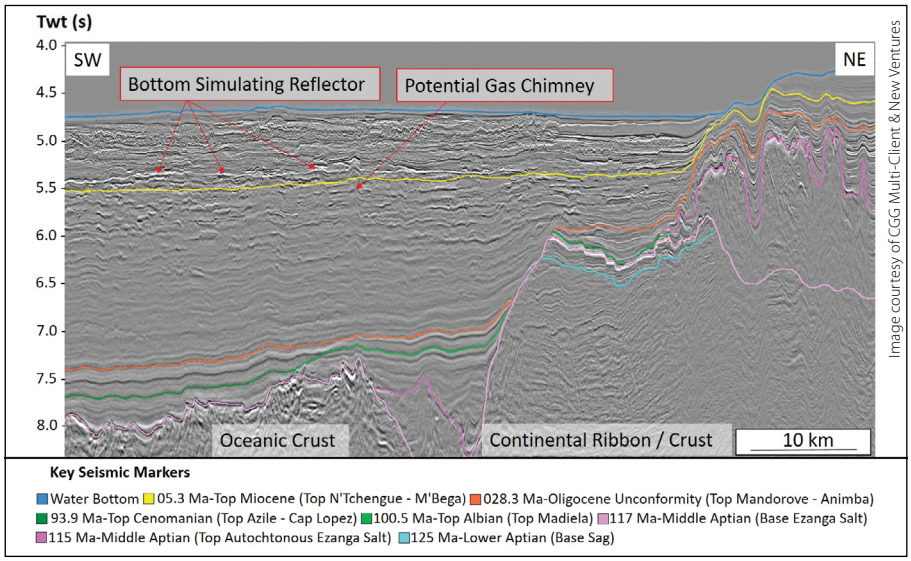


Figure 5: Seismic line highlighting key stratigraphic relationships, in the deepwater Gabon South Basin.

New Integrated Survey

As a consequence of the considerable potential revealed by the 2015 survey, CGG acquired a further 9,595 km of high-resolution 2D seismic data during 2018. This new 2D seismic covers the open blocks available in the upcoming licensing round (Figure 1) and is tied in to the 2015 3D broadband survey, the recent Ivela-1 and Boudi-1 discoveries, and the Judy-1, Genny-1 and Renee-1 exploration wells drilled in 2001. In addition, the westernmost extent of the survey covers new areas that have not previously benefitted from seismic data coverage. The survey was acquired in water depths between 2,000 and 4,140m using a 12-km streamer to provide ultra-long-offsets for deep imaging and velocity model building. It was towed at a depth of 12m in order to provide the wide seismic bandwidth necessary for optimum imaging throughout the entire seismic section, from water bottom to basement.

The new survey and an integrated study are looking at whether the source rock intervals outlined above can be mature in the ultra-deep offshore area where they have the benefit of a much thicker overburden, up to 4.5 km in places. They should also help us to understand how far the Congo Delta turbidite systems extend to the north and also how they interact with the Ogooué Delta input from the north-east, which may extend into the northern part of the new survey area.

A major objective of the new survey is to help understand how far the pre-salt petroleum systems may extend over the ultra-deepwater acreage of the Gabon South Basin. This is a successful exploration theme that has been proven by the recent Boudji-1 and Ivela-1 wells.

Deepwater Potential

The deepwater potential of Gabon has been established with a comprehensive geological study of the Gabon South Basin, backed by recent discoveries. To test how far into the ultra-deep water this proven play extends, the new 2D survey and integrated study that have been acquired and commissioned will address the key questions about the ultra-deep offshore petroleum systems, including reservoir distribution in the area and source rock maturity.

The main play anticipated for the ultra-deepwater Congo South Basin is within stratigraphic traps or combined low-relief structural traps formed within the Tertiary turbidites originating from the Congo Delta slope and possibly the Cretaceous-Tertiary turbidites from the Ogooué Delta slope to the north, which have both proved to be good reservoirs. These turbidite reservoirs are interpreted to be sealed by impermeable marine mudstone interbedded with sandstone, which have been encountered in all the wells drilled through the Cretaceous-Tertiary sections.

The new survey will help to de-risk this extensive play whilst also investigating the potential of the transform faults to form huge structural and stratigraphic closures within the subsurface.

References available online. ■

Figure 6: Simple GDE map highlighting the inboard extent of the Congo and Ogooué Delta turbidite deposits and the cross-cutting transfer zones/faults.