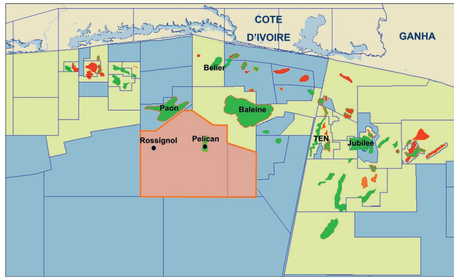
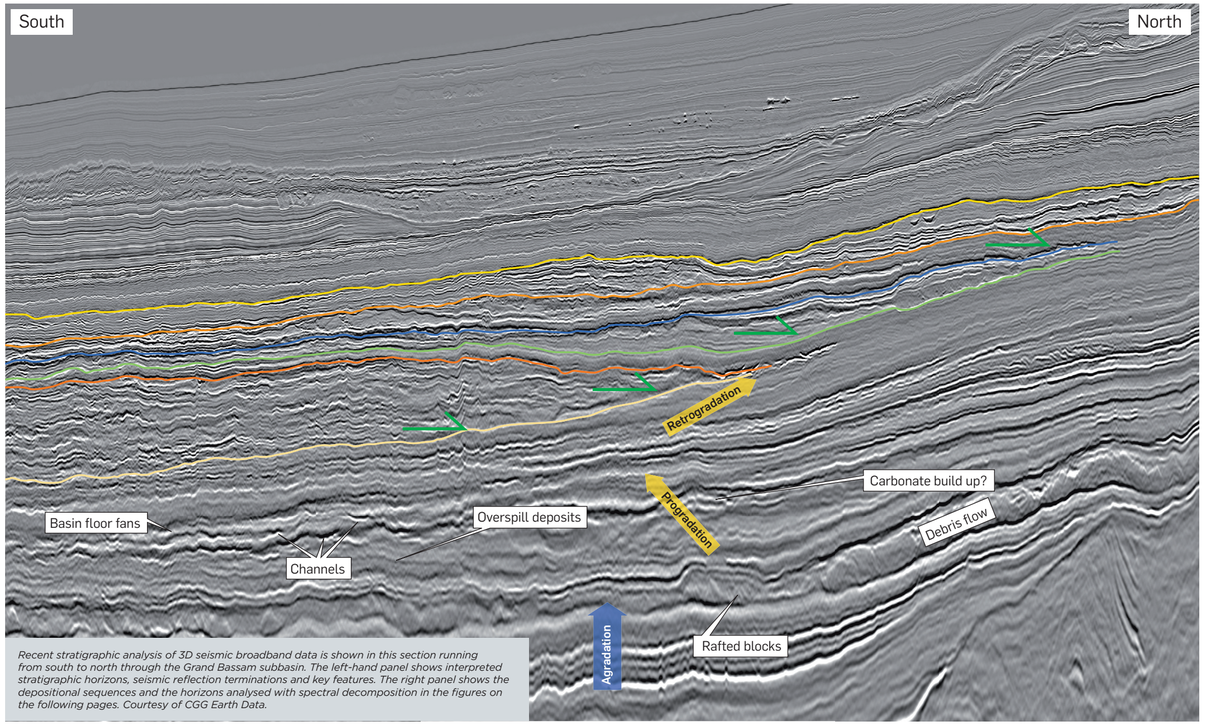
Baleine Discovery: Cote D'Ivoire's Exploration "Black Swan"

Broadband seismic data unlocks new play potential.

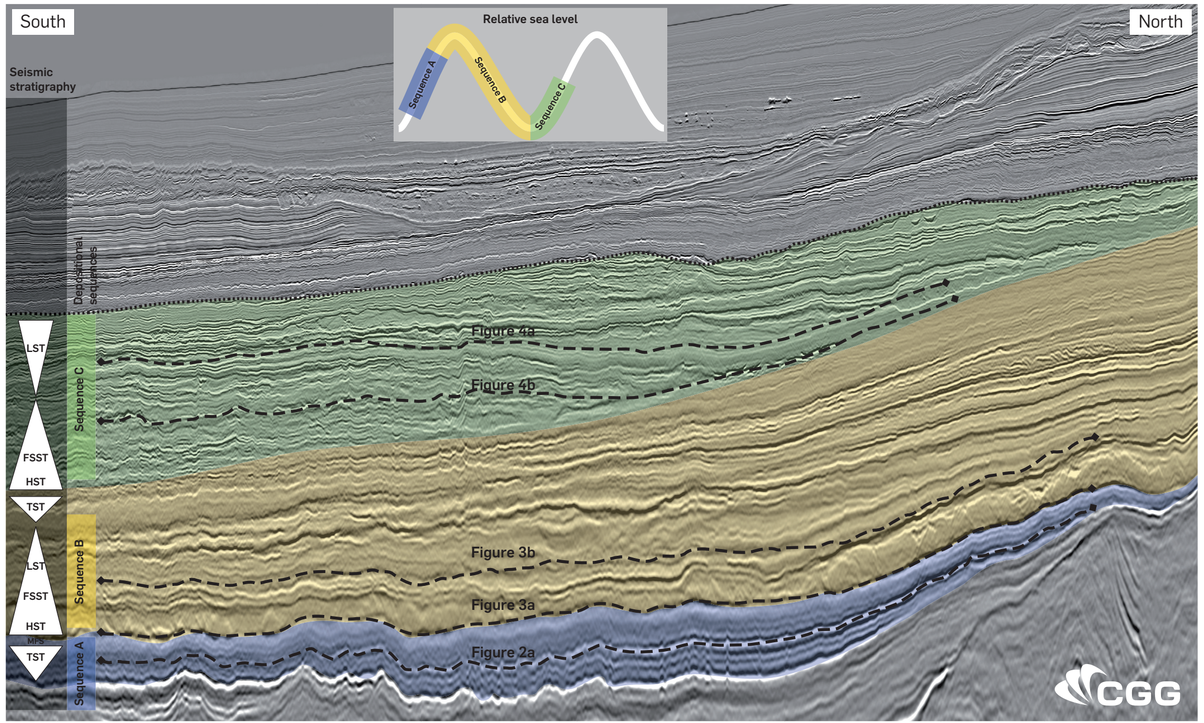
The recent world-class **Baleine** discovery within the **Deep Tano Basin** has attracted renewed exploration interest for the offshore **Côte d'Ivoire**. Its structural complexity and depositional stratigraphy, resulting from multiphase rifting of this basin, require high-quality seismic data to develop detailed geological models. To achieve this, **CGG** recently conducted a seismic stratigraphic analysis using the **CDI-14 broadband multi-client 3D seismic dataset** over the **Grand Bassam** subbasin. The goal was to develop new insights into **Late Cretaceous** depositional mechanisms and key facies distribution to shed light on the potential prospectivity of this basin.



Location and coverage of the CGG broadband 3D seismic survey (4,400 km²) acquired in 2014 and the distribution of hydrocarbon fields across the Tano Basin.



Recent stratigraphic analysis of 3D seismic broadband data is shown in this section running from south to north through the Grand Bassam subbasin. The left-hand panel shows interpreted stratigraphic horizons, seismic reflection terminations and key features. The right panel shows the depositional sequences and the horizons analysed with spectral decomposition in the figures on the following pages. Courtesy of CGG Earth Data.



The Tano Basin - Revealing Late Cretaceous Depositional Styles in a Frontier Basin

A recent seismic stratigraphic analysis demonstrates the presence of key petroleum system elements and the potential to develop new, high-impact prospects.

Text: Javier Martin, formerly CGG

Over the last few years, the industry's focus on hydrocarbon exploration has dramatically declined. Transforming resources into reserves has become a challenge for most African regions that have seen their production profiles shrinking substantially (Martin, 2022).

Despite this decline in exploration, there has been a high number of recent world-class discoveries in Africa. Among them, **Baleine** (Eni, 2021), offshore **Côte d'Ivoire**, is recognised as one of the biggest discoveries in recent history. A facies distribution model has been derived from seismic stratigraphic analysis, using CGG's multi-client 3D broadband seismic data from its **Earth Data Library** over the **Grand Bassam subbasin**, to help predict high-potential leads for further exploration.

CÔTE D'IVOIRE - CGG DATA COVERAGE

Over the last two decades, CGG has gained extensive insight into the acquisition, processing and interpretation of data sets in Côte d'Ivoire. Our first survey in 1999, comprising approximately 814 km² of 3D seismic data, was acquired to provide an understanding of basin structure and prospectivity and enable the mapping of clastic and carbonate systems within the **Tano Basin**.

In 2014, driven by in-house geological models and prospectivity predictions, CGG acquired a further 4,400 km² of 3D broadband seismic data (**CDI-14**) in the deep water offshore area of Côte d'Ivoire. The aim was to enhance imaging of **Late Cretaceous plays** that remained highly speculative and poorly understood at the time. Since the survey was acquired, the **Pelican** and **Rossignol** wells, drilled by Anadarko in 2016, confirmed CGG's predictive models, and Eni's **Baleine** discovery in 2021 put the Ivorian offshore basins at the forefront of exploration in West Africa.

MULTIPLE PROVEN HYDROCARBON PLAYS

With a total number of 137 exploration wells drilled since 1954 and 22 discoveries since 1974, the Côte d'Ivoire offshore territory has attained the status of a proven hydrocarbon province. Two main exploration phases have identified two major working petroleum systems (Martin et al., 2018):

1. The **Mid-to-Late Albian coastal syn-rift play**. Formed during the Late Albian continental break-up (Scarselli et al., 2017), when a series of syn-rift rotated fault blocks developed during a divergent tectonic cycle (Morrison et al., 2000).
2. The **Late Cretaceous deep marine post-rift play**. Well known along the Ghanaian side of the Tano basin, and identified more recently within the Grand Bassam sub-basin. This play is defined by the productive Cenomanian class II source rocks and the stratigraphic Turonian to Maastrichtian deep marine clastic reservoirs.

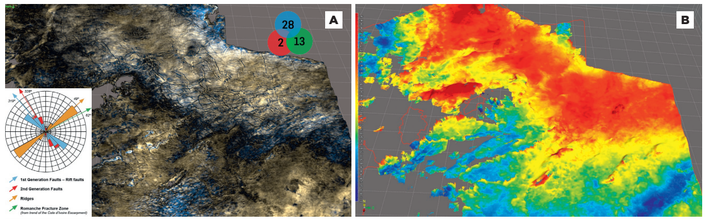


Figure 2. (A) Spectral decomposition attribute on a stratal slice from Sequence A (see seismic foldout). The complex basin architecture is formed by NW-SE normal faults related to divergence and transpressional ridges related to transform displacement. Colour key indicates spectral decomposition frequencies. (B) Isopach map of Cenomanian source rock showing the location of the depocenter in red colours. Images courtesy of CGG Earth Data. Rose diagram of fault orientation is taken from Scarselli et al., 2018.

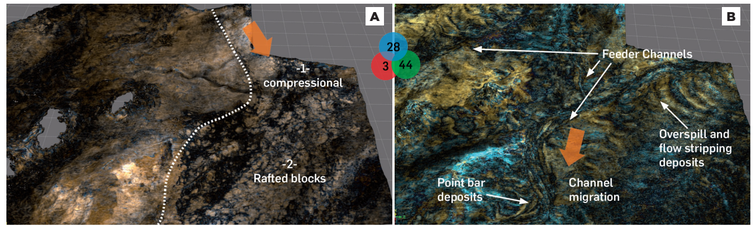


Figure 3. Spectral decomposition attribute over two different stratal slices from Sequence B (see seismic foldout). (A) Architecture and transport orientation of the MTC: 1 - Compressional domain and 2 - rafted blocks and debrites. (B) Feeder turbiditic channels with migration bars and flow stripping overbank deposits.

SEISMIC STRATIGRAPHY AND DEPOSITIONAL PATTERNS

From a geodynamic standpoint, the deep Ivorian basin has traditionally been described as a classic and well-known example of a divergent basin. The basin is bounded by transform faults that segment the African Equatorial margin into several transform margins (Mascle et al., 1995, Basile, 2015). Throughout its development, the basin has undergone multiphase rifting, tectonic reactivation, and volcanism, which have strong implications for sediment distribution and petroleum system development.

CGG's recent seismic stratigraphic analysis has provided new insights into the Late Cretaceous depositional mechanisms and facies distribution, through the identification and analysis of three main depositional sequences (seismic foldout).

SEQUENCE A

Overlies the Late Albian unconformity and is observed across the survey as a continuous, sub-horizontal and aggradational interval that displays a post-kinematic accommodation to the paleo-relief. Stacking patterns observed within this sequence suggest deposition occurred during a marine transgressive cycle sag phase, related to thermal relaxation after the continental breakup. The top of this sequence has been interpreted as a maximum flooding surface during maximum marine transgression.

This sequence is believed to host the prolific regional and class II Cenomanian oil-prone type II source rock, deposited in a depocenter identified within the north-eastern area of the survey (Figure 2). Considering its proximity to the recent Baleine discovery, the source rock within this area could have the potential to generate significant commercial quantities of oil.

SEQUENCE B

This unit, developed between sequence A and overlain by the Senonian erosive unconformity (seismic foldout), displays a distinctive progradational pattern in connection with a relative fall in sea level.

The onset of this sequence is likely to have occurred during a high stand system tract (HST) cycle and an early falling stage system tract (FSST) cycle. An extensive mass transport complex (MTC), in the form of a debris flow, has been observed towards the bottom of the sequence and mapped along the eastern half of the survey. This suggests slope instability and limited sediment transport between the extensional and compressional domains (Figure 3a).

The upper section of the sequence is characterised by a system of NE-SW moderately sinusoidal turbiditic channels and basin floor fans (Figure 3b). These were likely deposited during the FSST and early low stand system tract (LST) cycles. Onlap terminations towards the top of the sequence indicate retrogradation during the last stages of the LST, in connection with the relative onset of rising sea levels. Overbank deposits associated with the observed turbidite channels are characterised by sediment waves from overspills and flow stripping.

SEQUENCE C

This sequence is observed on the seismic as three major, vertically stacked turbiditic complexes displaying a retrogradational depositional relationship (Figure 4). The sequence hosts a system of lenticular unconfined slope fans, deposited during the LST and the onset of the transgressive system tract (TST) cycles. The internal architecture and geometries of the terminal feeder sections and inner distributary channels are related to the depositional dynamics of deep marine turbidite deposition.

The turbidite channels described in Sequences B and C form potentially highly prospective reservoirs. Our seismic stratigraphic and attribute analysis indicates that within most channels there is a series of recurring features which provide an understanding of the observed reservoir facies and heterogeneities. An understanding of the sinuosity of channels in Sequence B and the stacked nature of turbiditic channels observed in Sequence C, along with an understanding of facies distribution, sheds great light on the reservoir distribution and potential in the deep waters of the Tano Basin.

IMPLICATIONS FOR PETROLEUM SYSTEMS

The seismic stratigraphic analysis presented here has been fundamental in understanding the prospective potential of the deep-water region of Côte d'Ivoire. This has been achieved through the observation and interpretation of Late Cretaceous depositional features and mechanisms described within Sequences A, B and C.

Based on the interpretation, distribution of hydrocarbon fields, and data from nearby wells, we determine that the maximum vertical thickness of the Cenomanian class II source rock occurs primarily within the northeastern area of the CDI-14 survey. Reservoir facies and distribution have been inferred from analysis of the stacking patterns observed in Sequences B and C, in which a prolific system of NE-SW turbiditic channels and fan-like architectures have been identified. Channels in Sequence B show "feeder-type" morphologies typical of upper to middle continental slope environments. By contrast, Sequence C exhibits geometries and orientations typical of lower slope to basin floor fans.

Fault interconnectivity between source rock and reservoir facies is likely to be related to crustal readjustments, as evidenced by volcanic structures and faults identified throughout the area. The seismic stratigraphic analysis and conclusions discussed herein demonstrate the presence of key petroleum system elements and the potential to develop new, high-impact prospects.

All images courtesy of CGG Earth Data.

References provided online. ■

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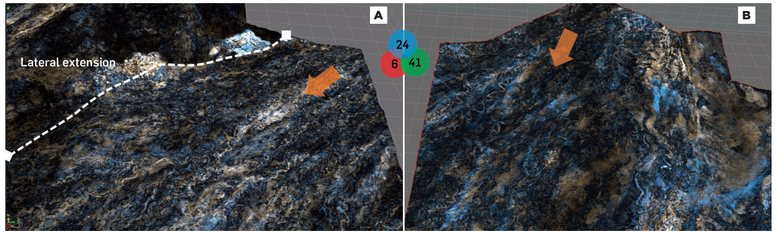

Figure 4. Spectral decomposition attribute over two different stratal slices within Sequence C (see seismic foldout) capturing the fan-like internal architectures. (A) Deepest fan complex with multiple terminal distributary channel segments active towards the eastern side of the area (B) Shallower fan active towards the central/western side of the area showing geometries typical from the inner fan system.