

RMS Amplitude extraction in the Upper Cretaceous overlain on a Bouguer Corrected Gravity (200 km high pass filter) map, offshore Côte d'Ivoire. The deep-water play is highlighted with potential turbidite channel and fan reservoirs charged by underlying Cenomanian/Turonian source rocks deposited over oceanic crust. RMS extraction derived from horizon interpretation of the full-stack PSTM Côte d'Ivoire MegaSurvey.

Go West: Deepwater Prospectivity in the Côte d'Ivoire Basin

Mapping of Upper Cretaceous reservoirs and source rocks across the deep-water area of Côte d'Ivoire suggests exciting exploration potential.

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The **Tano Basin** has been the location of several high-profile discoveries made in recent years with the drilling of the **Afina-1X well** in **Ghana** and the discovery and subsequent expansion of the **Baleine** structure offshore **Côte d'Ivoire** (see map above).

These large accumulations have shown that there are significant volumes of hydrocarbons being found in Cretaceous-aged plays over continental crust in this well-explored basin. Using insights gained from extensive **PGS MultiClient** seismic data coverage, new play

concepts from recent discoveries offshore Namibia can be applied directly to Côte d'Ivoire.

This enhanced regional scale understanding of petroleum systems highlights the remaining opportunities over oceanic crust in the western area of the Côte d'Ivoire offshore, allowing exploration potential to be extended from analogs and existing in-basin discoveries into underexplored areas.

TECTONIC HISTORY KEY TO PETROLEUM SYSTEM DEVELOPMENT

Offshore Côte d'Ivoire can be split into two main basins, the **Tano Basin** in the east and



Côte d'Ivoire Basin in the west. Both depocenters developed during the opening of the Atlantic, with transtensional rifting beginning in the Early Cretaceous and finishing at the end of the Albian with the formation of oceanic crust.

The Tano Basin developed in an area of relative tectonic quiescence between the Saint Paul's and Romanche Fracture Zones, resulting in pull-apart grabens with a thick clastic fill. This created a broad shelf to deep water profile with the basin underpinned by thick continental crust, gradually thinning towards the continental to oceanic crustal transition.

In comparison, the Cote d'Ivoire Basin has a narrow shelf to deep water profile, characterized by transtensional faulting and initial graben development orientated sub-parallel to the present-day coastline. The continental to oceanic crustal transition is also more abrupt here due to the underlying Saint Paul's Fracture Zone.

The stratigraphic section of both areas can be divided into the pre-, syn- and post-transform tectonic phases, each with a distinct depositional history and related petroleum systems. The pre-transform stage has not been penetrated by drilling in the Côte d'Ivoire Basin and so we will focus on the syn- and post-transform stages due to their contribution to proven petroleum systems.

The syn-transform phase of trans-tensional opening in the Gulf of Guinea

began around the Berriasian and ceased at the end of the Albian. A thick section of continental to marginal marine clastics was deposited during this period, providing potential reservoir units in the form of fluvial to marginal marine sandstones. Source rocks transition from deeper Aptian lacustrine shales to shallower Mid-Albian marginal marine shales through the stratigraphic section as rifting progressed.

Extensional opening of the Transform Margin basins ceased at the end of the Albian and was followed by wide-spread deposition of Cenomanian-Turonian marine shales. The area formed a continuous anoxic seaway from the late Albian to Turonian, which resulted in a high total organic carbon content (TOC) oil-prone source rock in the region.

REGIONAL DATA COVERAGE FOR ENHANCED UNDERSTANDING OF PROSPECTIVITY

In partnership with **PetroCi** and **Direction Générale des Hydrocarbures, PGS** has a large footprint of MultiClient seismic data available offshore Côte d'Ivoire (see map below). The recently expanded **CDI MegaSurvey** offers almost complete west to east coverage of the Ivorian offshore with 33,861 sq. km of 3D and 31,743 line km of 2D.

The various 3D input datasets have been matched, merged and re-binned

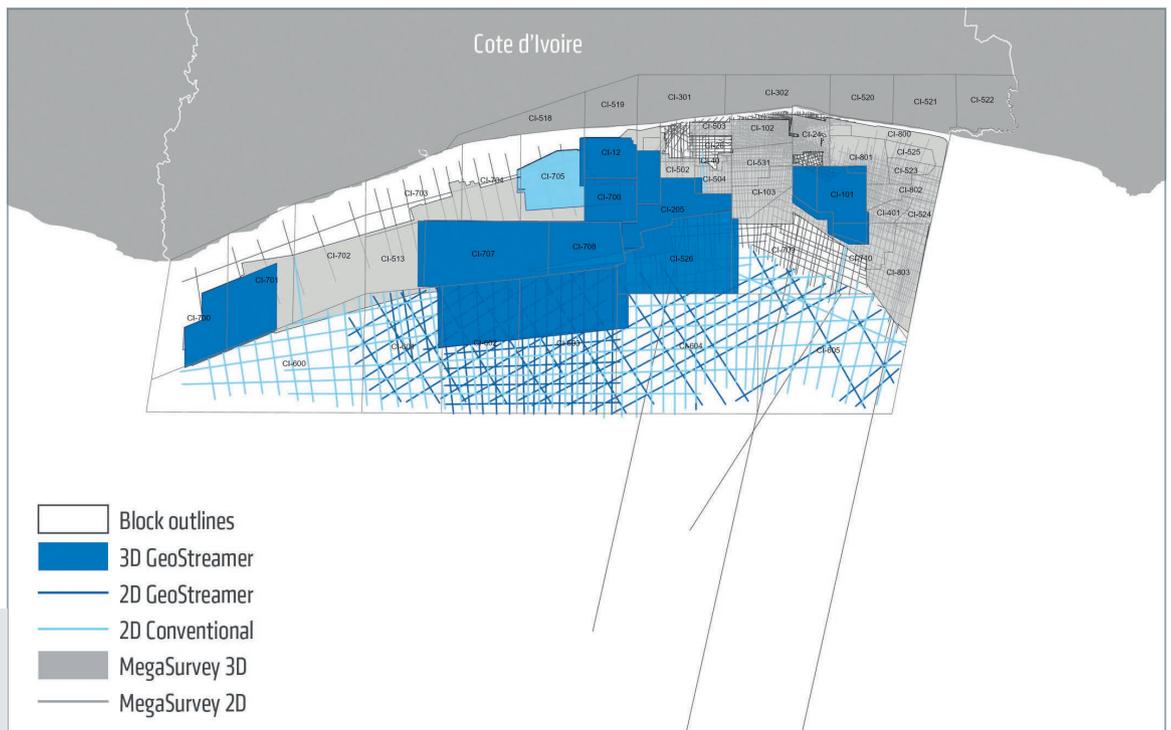
onto a common grid resulting in a single, continuous volume of full-stack seismic data in the time domain, allowing for regional scale play analysis. Overlying the western portion of this dataset are several broadband **GeoStreamer** surveys where pre-stack data has been used to perform AVA analysis, enhancing the understanding of the prospectivity in the region (see next page).

EXPLORATION HISTORY OF THE TWO KEY PLAYS

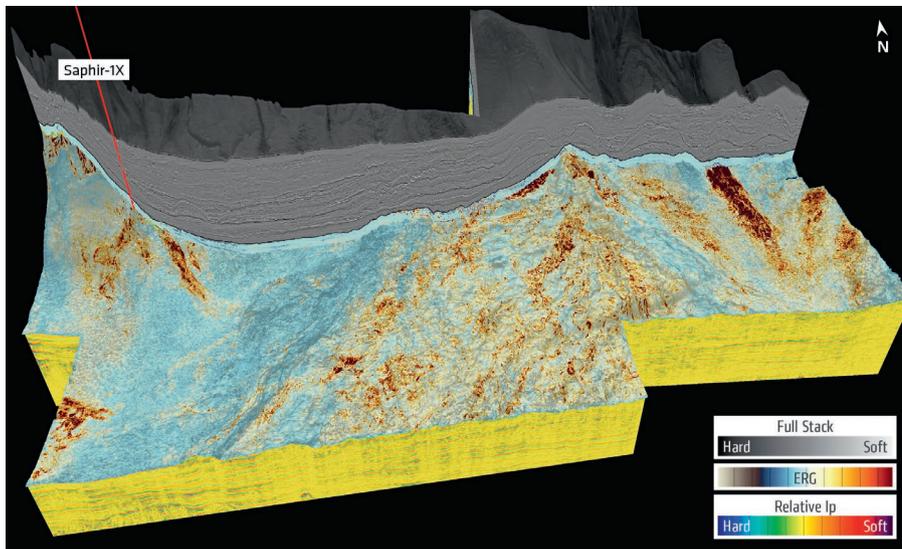
Two main plays have been the focus for exploration in the Ivorian offshore; the syn-transform Lower Cretaceous and the post-transform Upper Cretaceous. The Lower Cretaceous play dominates the area around the shelf edge in both the Tano and Côte d'Ivoire Basins. A contributing factor in this inboard dominance is the source rock maturation history.

Berriasian to Albian source rocks sit within the gas maturity window around the shelf due to a relatively thinner overburden, whereas they are likely to be over-mature in more distal syn-transform basins where depth of burial is greater. These source rocks are paired with Albian aged fluvial to shallow marine syn-transform sandstones, as proven in the Baobab Field.

The Upper Cretaceous system is most successful around and outboard of the present-day shelf edge due to the thick



The regionally extensive PGS MultiClient Data Library Offshore Côte d'Ivoire.



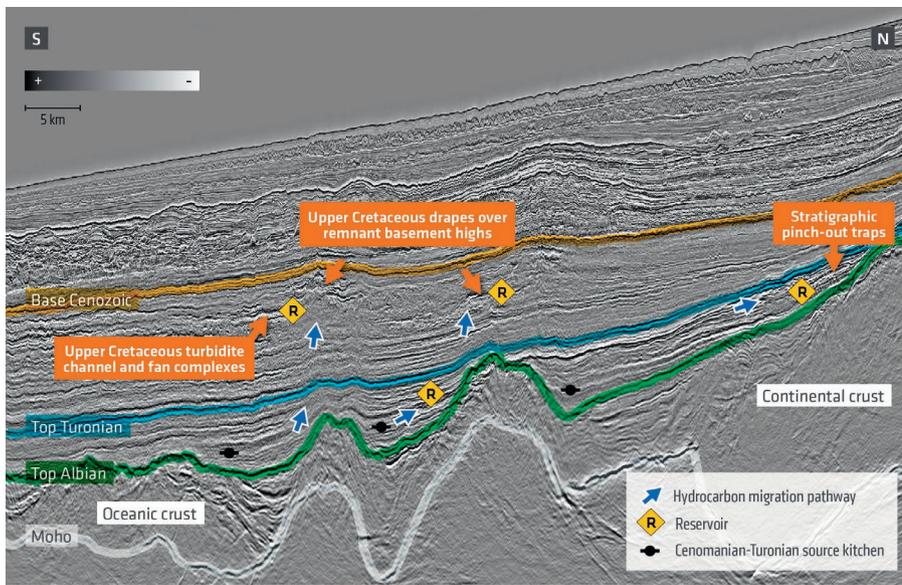
AVA anomalies across the deep-water offshore Côte d'Ivoire highlighted using an Enhanced Restricted Gradient (ERG) attribute from above the Base Senonian horizon. This has been draped over a relative acoustic impedance volume from various merged GeoStreamer MC3D surveys. Full Stack and Angle stacks were conditioned and matched cross-vintage to bring data into a common amplitude and bandwidth. AVA spectral balancing was also applied to match bandwidths of the near and far angle stacks to produce a consistent Enhanced Restricted Gradient (ERG) attribute. Relative Impedance attribute was also generated following a trace integration method.

clastic section allowing for sufficient burial of shallower Cenomanian-Turonian aged source rocks. These type II source rocks have mixed oil and gas potential. Complementing this widespread source kitchen are Albian to Santonian aged shallow to deep marine sandstone reservoirs.

The largest discovery in this play is contained within the **Baleine** shelf-edge structure which is reported by Eni to contain **2.5 billion barrels** of oil and **3.3**

trillion cubic feet (TCF) of associated gas over two main reservoir levels. This discovery has also expanded the Upper Cretaceous play to include carbonate shelf edge reservoirs.

The Paon discovery by Anadarko has proven that the Upper Cretaceous play extends into the deep water Tano Basin, with the Saphir-1X well drilled by Total illustrating that the play is present to the west in the Côte d'Ivoire Basin too.



Full-stack PSTM dip line from the Deepwater 2018 GeoStreamer MC3D survey, highlighting play concepts directly related to recent Namibian discoveries.

As shown by the RMS amplitude extraction from the Upper Cretaceous on the first image of this article, turbidite channel and fan complexes, annotated by the orange arrows, are widely deposited across the entire Ivorian offshore. Multiple sediment input points (blue arrows) are observed in both the Tano and Côte d'Ivoire Basins, highlighting the promising reservoir potential to the west of the Tano Basin. These features are also highlighted using pre-stack data (left), which indicate AVA anomalies in the deep-water area.

DEEP WATER PLAY CONCEPTS FROM NAMIBIA

Recent 2022 exploration success offshore **Namibia** with **TotalEnergies' Venus-1** and **Shell's Graff-1** and **La Rona-1** discoveries have suggested that Cretaceous-aged source rocks deposited over transitional to oceanic crust are oil mature in outboard areas, expanding the Cretaceous play into the deep-water in the Orange Basin.

The concept for hydrocarbon generation and expulsion from source rocks subjected to increased heat flow due to a shallow aesthenosphere may also be applied to the deep water offshore of Côte d'Ivoire, expanding prospectivity beyond the area underpinned by continental crust in both the Tano and Côte d'Ivoire Basins.

Applying seismic facies analysis to the section shown here (bottom left), Cenomanian-Turonian-aged source rocks are hypothesized to have been deposited directly over transitional to oceanic crust. These deposits are characterized by their low amplitude, planar response typical of deep-water shale deposits. The Cenomanian-Turonian-aged shales are a proven source rock offshore Côte d'Ivoire, containing high TOCs.

Similarities can be drawn between the location of the Namibian discoveries over transitional to oceanic crust and the extension of potential Upper Cretaceous reservoirs into the deep-water offshore of Côte d'Ivoire. Using Bouguer Corrected Gravity data and through mapping of the Moho on the seismic, these turbidite channel and fan complexes are observed to extend beyond the continental-oceanic crustal transition. These reservoirs, where draped over oceanic crustal highs and paired with underlying Cenomanian-Turonian potential source rocks, hint at exciting further exploration opportunities in the Côte d'Ivoire Basin (left). ■

Images courtesy of PGS