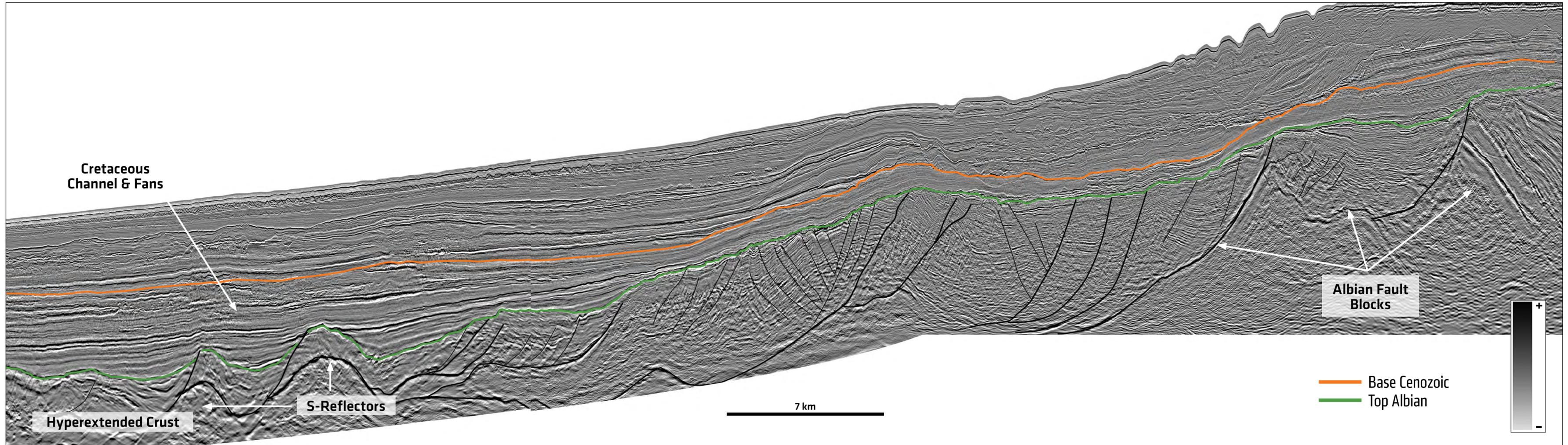
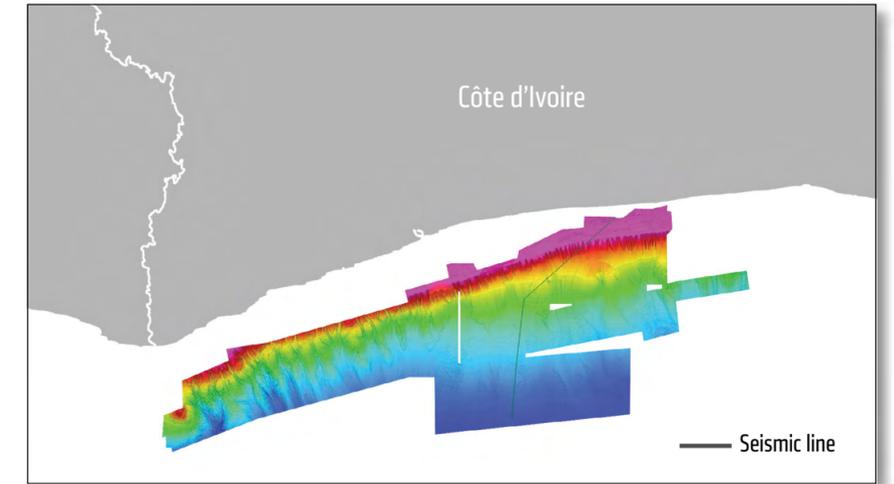


# Côte d'Ivoire

## Regional Understanding to Unlock Potential

Offshore Côte d'Ivoire is a well-established petroleum province, particularly in the eastern areas. Exploration is now moving into the more frontier region of the western Côte d'Ivoire Basin. To support these efforts PGS, in partnership with Petroci and Direction Générale des Hydrocarbures, has created a fully matched and merged contiguous dataset comprising full stack GeoStreamer 3D, conventional 3D and accompanying 2D across 23,000 km<sup>2</sup> offshore Côte d'Ivoire. The PGS Côte d'Ivoire MegaSurvey now allows exploration and detailed regional evaluation for the first time, allowing plays to be effectively developed and risked.



# Extending Exploration Potential to Western Côte d'Ivoire

Regional seismic data allows plays to be interpreted in full for the first time across the Côte d'Ivoire.

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Exploration in Côte d'Ivoire has historically been focused on the central and eastern areas where numerous hydrocarbon discoveries have been made. These include a trend of gas discoveries in Upper Cretaceous stratigraphic traps (Foxtrot, Panther and Marlin fields) and oil discoveries in Lower Cretaceous structural traps (Lion, Espoir, Acajou, Baobab and Kossipo fields). The Capitaine East-1X (Lukoil) and Paon (Anadarko) discoveries have proven the prospectivity of Upper Cretaceous oil-bearing stratigraphic plays in the deep water.

These exploration successes have encouraged explorers to look further afield in tectonically complex areas of the western transform area controlled by the St. Paul's Fracture Zone. The Morue-1X well (Anadarko and Total) and Saphir-1X well (Total) have shown a working hydrocarbon system in the previously underexplored western portion of the basin.

## Development of the Ivorian Transform Margin

Côte d'Ivoire is part of the West African transform margin, a large tectonically constrained area bounded by a series of major fracture zones which formed during the separation of the African and American continents in the late Jurassic to Cretaceous.

An overview of the tectonic framework using Bouguer corrected Smith and Sandwell gravity data (right) outlines the key structural features of the Côte d'Ivoire Basin. The development of the Ivorian embayment was controlled by a segment of the Atlantic rift delineated by the St. Paul's fracture zone in the north and the Romanche fracture zone to the south. From east to west the crust transits from continental material with a low gravity response into increasingly dense oceanic crust. Along the northern margin this transition occurs more rapidly due to the area's proximity to the transform fracture zone. Using the PGS Côte d'Ivoire MegaSurvey seismic data, hyperextended crust can be delineated in the transitional area, providing potential for new play concepts and increased understanding of basin development.

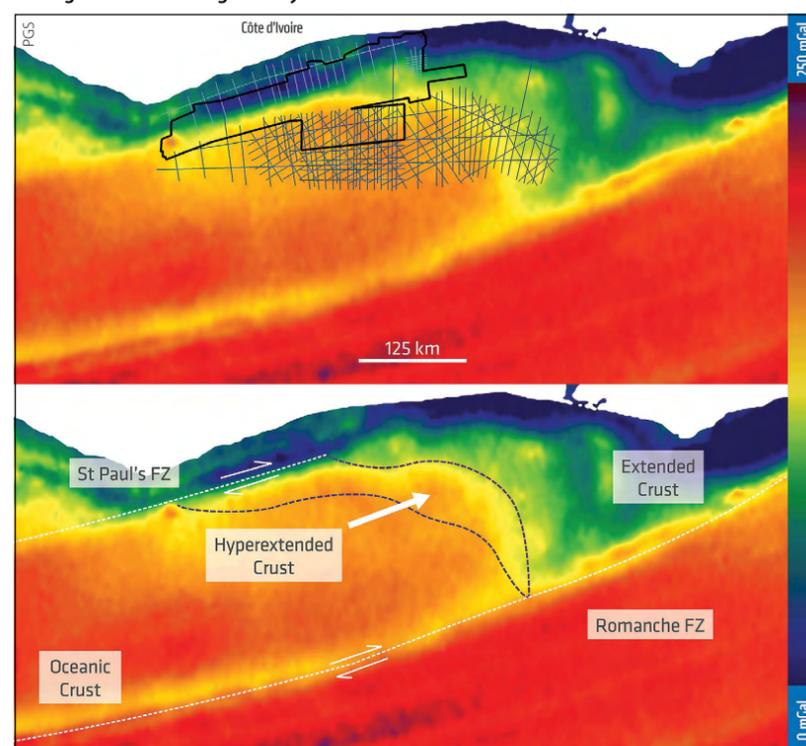
The western area of the Côte d'Ivoire Basin developed as a typically steep transform shelf margin characterised by transtensional faulting with local transpressional features likely to be controlled by pre-existing structure. Using the merged seismic data, the development of the margin can be broken into three fundamental periods of tectonic activity:

**Pre-transform – Untapped Deep Potential:** The pre-transform stage has not been penetrated by drilling in the central Côte d'Ivoire Basin, although outcrops of rocks from Precambrian to Triassic age do exist in the Tano Basin to the east in Ghana. Pre-transform Jurassic rocks have also been found in the neighbouring Tano Basin. These consist of conglomerates and shales deposited in a continental setting.

The pre-transform stratigraphy has been deformed and tilted by subsequent transform faulting, creating excellent trapping geometries.

**Syn-transform – Development of Petroleum System Elements:** During the syn-transform stage (Berriasian

Bouguer gravity maps across the offshore Ivorian Basin with the MegaSurvey data coverage overlaid (top) and a tectonic interpretation (bottom) showing the tectonic setting in which the MegaSurvey sits.



to Albian), sediments were deposited in a continental and marginal marine setting in the Côte d'Ivoire Basin (Chierici, 1996), allowing for the accumulation of Middle Aptian source rocks. The environment became progressively marine during the Albian as rifting continued, leading to the deposition of sands, shales, calcareous deposits and conglomerates.

Inboard, the faulting associated with the transform superficially shows the appearance of typical rift normal faulting; however, secondary fault patterns and the tectonic setting indicate dextral oblique movements. Outboard there is clear evidence of hyperextended crust demonstrated by classic S-reflector (very low angle detachment faults) geometries.

This period corresponds to the syn-rift phase discussed in the literature covering the eastern passive margin setting of the Côte d'Ivoire Basin (Scarselli et al., 2018).

**Post-transform – Stratigraphic Trapping Potential:** The end of oblique transform movement was superseded by thermal subsidence in the post-transform stage (Cenomanian–Holocene). This phase almost entirely comprises clastic marine sandstones and shale deposition, with minor carbonate sediments. Potential reservoir rocks include ponded and channelised turbidite systems and basin floor channel and fan systems. The organic rich black shales deposited within topographic lows provide source rock potential.

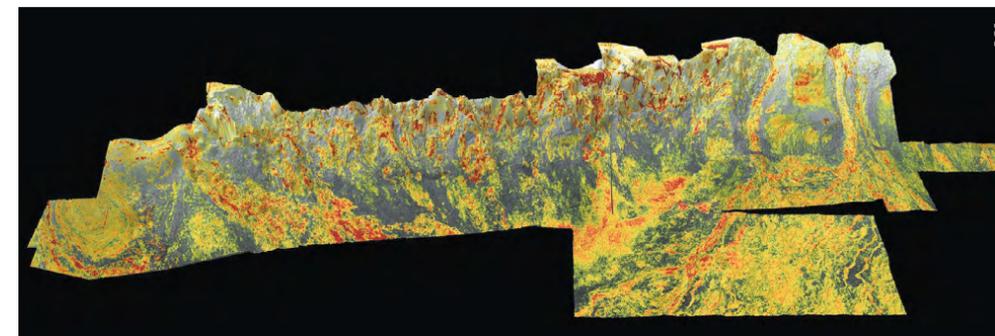
## Regional Data Allows Broad Assessment

The key to evaluating a relatively underexplored region (with respect to the rest of the offshore Côte d'Ivoire) such as the Ivorian Transform Margin is the availability of regional datasets. The PGS Côte d'Ivoire MegaSurvey offers a regional perspective of the tectonic activity and basin development, leading to a greater understanding of existing and potential petroleum systems. This covers both existing discoveries and open blocks available for licensing, so analogues can be drawn and a regional evaluation of existing successes and failures can be made.

In the following sections some key examples show the advantage that a regional dataset can have in understanding the geology and its implications for further exploration.

## Hyperextended Crust Exploration Opportunity

The foldout seismic section shows that the crust dramatically thins towards the offshore with evidence of hyperextension and S-reflectors across the base of the syn-kinematic packages providing potential for increased heat flux and source rock maturation. Distal areas are often dismissed as unprospective due to the limited maturation of source rocks through low levels of heat flux from radiogenic elements within remaining



RMS amplitude extraction of Cretaceous turbidites (yellow/red) using the Base Cenozoic horizon (see foldout), illustrating the distribution of channels and fans across the transform area extending the play from the east (view to north).

continental rocks (Doran and Manatschal, 2017). However, given recent advances in the understanding of margin development from seismic data and well results, it is becoming clear that this assumption is increasingly invalid (Doran and Manatschal, 2017). In magma-poor environments where the crust is able to extend significantly, the shallowing of the mantle controls increased heat flux. This can prolong the extension and drift phase of increased heat flux allowing for source rock maturation.

These distal areas of the Côte d'Ivoire could be productive with syn-kinematic stratigraphy being charged from a mature Aptian source. Another possible scenario is for a prevalent Cenomanian source rock to be matured allowing for the charge of the deepwater Cretaceous fan sandstones.

Results from the Kosmos exploration campaign across this terrain (deepwater part of the foldout) will provide valuable insight into the potential of these plays.

## Regional Mapping of Cretaceous Turbidite Plays

The successful Cretaceous turbidite play is ubiquitous across the Côte d'Ivoire Basin. The regional nature of the PGS MegaSurvey 3D data provides an unprecedented ability to understand the distribution of the turbiditic sands. RMS amplitudes extracted through an interval of Cretaceous turbidite deposits clearly delineate the drilled channel systems to the east of the MegaSurvey and highlight that sediments were also sourced from the west. Basin-wide understanding provided by MegaSurvey seismic data allows for reliable regional depositional models to be built both spatially and temporally through geological time, allowing for the best potential targets to be identified for future exploration.

## A Promising Area

The Ivorian Transform Margin is an exciting prospective area that now can be evaluated in detail in a regional context using the MegaSurvey. The initial results presented from this study show that plays in the well-established areas of the Côte d'Ivoire extend west, with new play potential also present. This opens the opportunity for operators to extend existing plays such as the Cretaceous turbiditic sandstones and to develop new plays in open acreage utilising new thinking of heat flux over hyperextended crust to exploit new potential source kitchens.

References available online. ■