

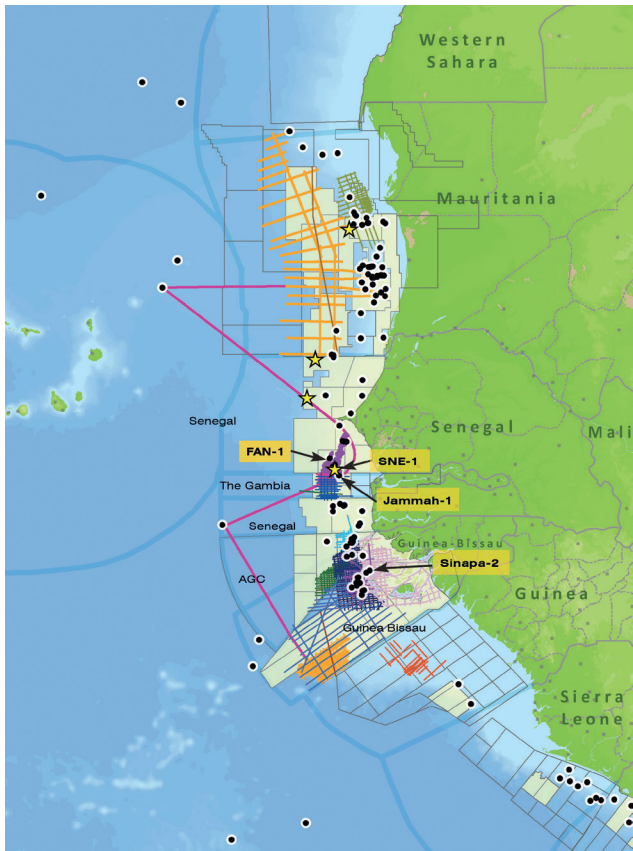
# Claiming a place for Guinea Bissau on the hottest shelf margin on planet Earth

Neil Hodgson<sup>1</sup> and Karyna Rodriguez<sup>2</sup> present an analysis of the prospectivity of the region which shows that the next big play is offshore Guinea Bissau.

## Introduction

The recent glut of giant oil and gas hydrocarbon discoveries on the North West African coast (Figure 1) began in 2014 with the SNE-1 discovery by Cairn in Senegal. This play-making well targeted Albian sandstones and Aptian carbonates in a structural trap, at the eroded edge of the Early Cretaceous platform margin.

There are a number of interesting play elements at work in this play that require definition so that a model can be extracted and reused elsewhere along the margin in the chase for analogue traps. Where we will end up is Guinea Bissau, Senegal's southern neighbour, where the plays is as yet unexplored yet appears to have an even more promising potential, but first – SNE.



**Figure 1** location map of SNE Discovery, Senegal amid recent discoveries on the NW Margin (The Mauritania, Senegal, The Gambia, Guinea Bissau 'MSGGB' Basin).

The SNE discovery has been presented to the industry by operator and partners several times over the last few years, including a presentation at the recent HGS PESGB African conference by Wytze de Boer et al. of Cairn Energy (Geophysics of the SNE Field, Senegal, HGS PESGB 16<sup>th</sup> African Conference, 2017). It is hardly surprising that industry is interested in this discovery as, with current resource estimates exceeding 500mmbbls, this was the biggest discovery in the world in 2014 and a truly ground-breaking, basin opening innovation. Most remarkable was that the discovery was oil –

bucking the global trend of discoveries that was otherwise suggesting we have fine tools to explore for big gas resources but struggle to find big oil. The Liza-1 (>2bn bbls oil) discovery in Guyana in 2016 put this concept firmly to bed, yet the SNE discovery is still one of the few giant oil resource additions drilled this century.

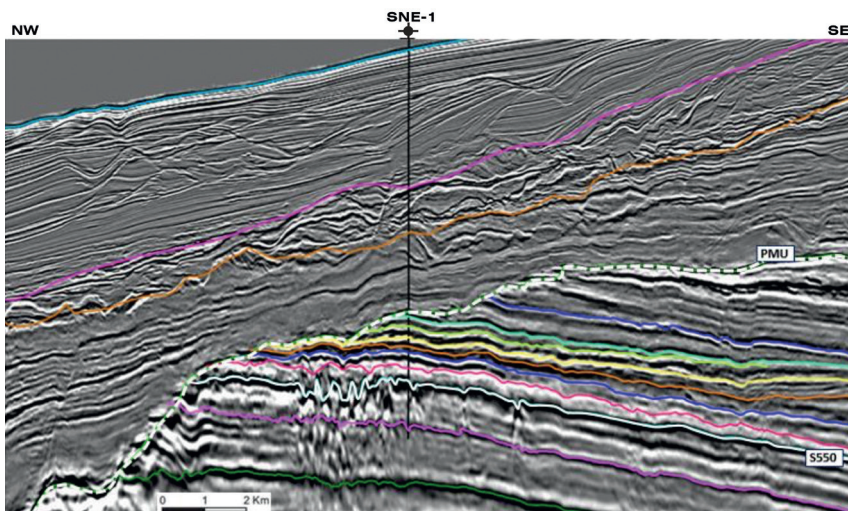
## SNE giant oil discovery play elements

The SNE play as we now understand it (taking source from these industry presentations) comprises a three-way structural one way unconformity bound trap (Figure 2). The structure is provided by the Early Cretaceous carbonate platform dipping east. The timing of this dip is considered to be early Tertiary, associated with the pronounced unconformity labelled PMU in Figure 2. The sea-ward margin of the carbonate platform is partly lost to erosion by unconformity, but appears to have been some 5-6km west of the SNE-1 well. However, the interaction of the overlying Albian clastic delta with the Aptian carbonate platform edge is missing. On the platform, the vertical seal for the trap is provided by Late Albian mudstones, while the seal across the unconformity (previously known as the Senonian Unconformity and now known as the Pre-Miocene Unconformity (PMU in Figure 2)) is provided by both seismically quiet parallel layered deepwater mudstones and a chaotically canyonized and filled mudstone sequence of Miocene and younger ages.

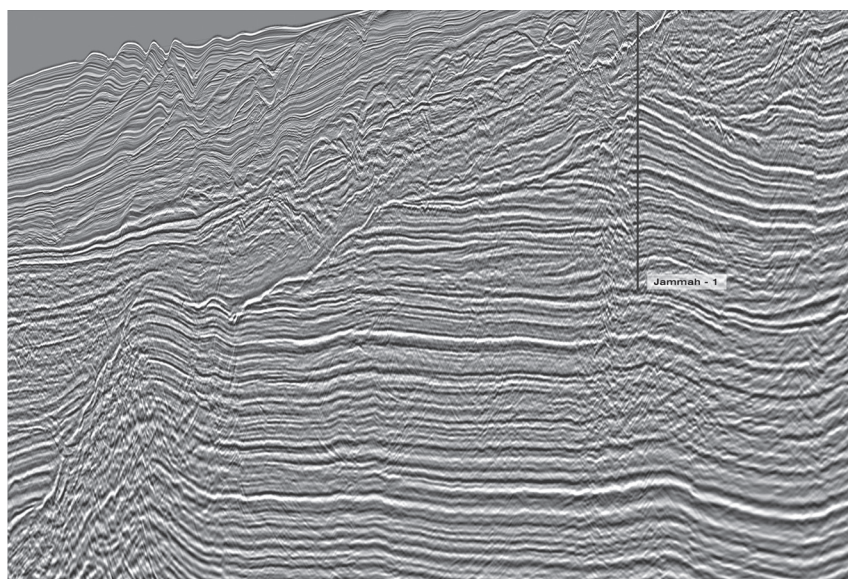
The primary reservoir in the SNE play is provided by Albian deltaic clastics. As interpreted by Cairn Energy and visible on Figure 2, the reservoirs are represented in the lower parts of prograding clinofolds, in at least two stacked sequences that display clear progradation from east to west. Owing to the way the PMU interacts with these sets, any top-sets or shoreface/coastal plain sands that may have been deposited this close to the carbonate

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**Figure 2** West East PSDM seismic line through SNE-1 well (De Boer et al., 2017).



**Figure 3** The Gambia West-East 2017 reprocessed broadband data, seawater compensated.

platform margin have been eroded. Therefore, the reservoir in the field comprises an upper sequence of lower slope sands (the 400 series, proven to have reservoir continuity across the field by DST test of the SNE-6 well), that lie over blocky, ‘base of slope’ sands in the lower sequence (the 500 series sands). We interpret the ‘base of slope’ blocky sands as classic low stand fan deposits.

Charge for SNE’s 32oAPI oil may be provided by generation off the platform in the western basin from Turonian source rocks. The migration pathway may be through Albian and younger Cretaceous slope clastics, and/or the shelf edge carbonate talus slope into the trap. Indeed it was the FAN-1 well that preceded SNE-1 by two months, which was to demonstrate that the NW African Margin was particularly special as the FAN-1 well revealed not only 29 m of net 29-41oAPI oil-bearing Cretaceous age sandstone (Cairn Energy investor announcement dated 07/10/2014), but also a considerable thickness of Turonian age mudstone. This unit will be deposited along the margin where mature areas will be a major oil source for future exploration efforts on the margin. This thick Turonian source rock interval penetrated by FAN-1, with its potential to charge the shelf edge play through on-lapping slope channels and clastic fans opens up a charging system

applicable farther south on the margin. Of course this is just one of the potential source rocks on the margin of NW Africa that may be charging plays in at the shelf margin, slope or basin floor setting. To the north in Mauritania the source rocks for Kosmos’s Tortue-1, Teranga-1 and Yakaar-1 gas discoveries are reported to be Albian and Barremian/ Neocomian-Valanginian in age, with the Cenomanian-Turonian providing the source for the Chinguetti, Tevet and Tiof oil discoveries. To the south in Guinea Bissau thick Albian Mudstones with high TOC have been reported in the platform location, and the Dome-Flore and Sinapa-2 discoveries demonstrate that an intra-platform source (of Turonian, Albian, Aptian, or even Jurassic) associated with the diapir play fairway is also effective.

### Seeking analogy play configuration on the NW African Margin

Having identified the main controls on structure, source, seal, and reservoir for SNE, we can now examine the margin to the south through the lens of these play elements to identify analogue features. Indeed, less than 20 km south from SNE across the border in The Gambia, a similar trapping configuration is presented.

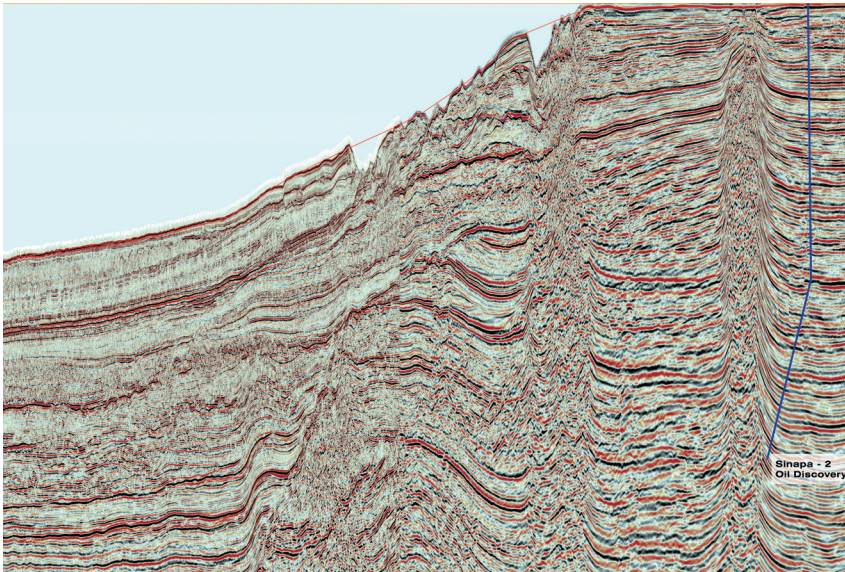
On Spectrum's sea-water compensated 2017 broadband reprocessed data, the Albian clastics penetrated near TD by the Jammah-1 well, inboard but down dip at Albian level due to the Tertiary dip generated in the platform, are again truncated at the PMU in a trapping configuration. Here the PMU erosion has taken the deltaics farther back from Aptian carbonate platform margin, generating an additional carbonate platform margin play (Figure 3).

In terms of SNE play analogue, the charge, timing and trap/seal systematics are identical or rather carry similar uncertainties as SNE pre-drill. However, it is the Albian clastics that are particularly interesting here, as it appears that the top-sets of the two prograding clastic sequences are both present with intriguing possibility for good quality shallow marine shore face or coastal plain sands rather than lower slope and base of slope reservoirs.

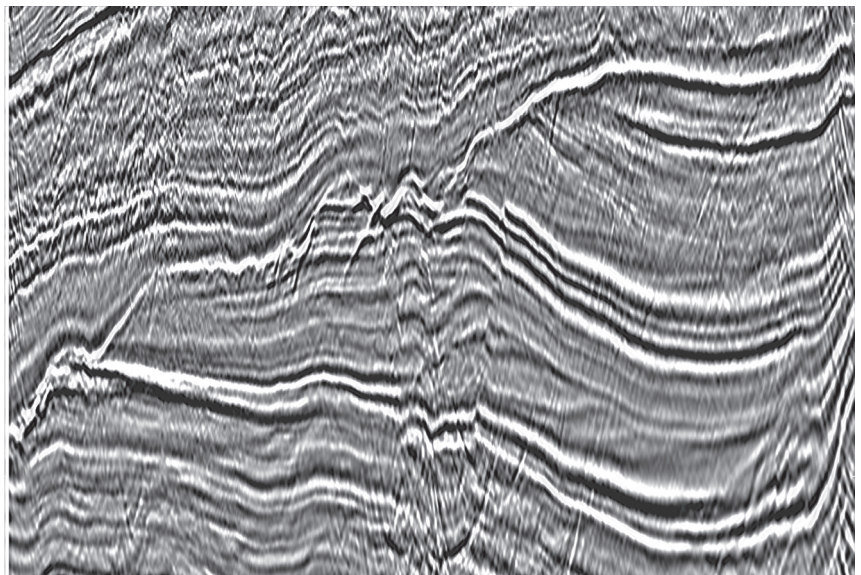
Farther south than The Gambia lies the AGC area of shared licencing with Guinea Bissau and Guinea Bissau itself (Figure 1). The Albian Delta- PMU play can be followed here and again looks remarkably similar (Figure 4).

On the 100km-long regional line of Figure 4 the configuration of play elements offshore Guinea Bissau can be seen to be very similar to those identified for SNE and The Gambia. In the deep basin a thick Cretaceous section (up to 4 sec TWT) overlies against the Early Cretaceous carbonate platform. Additionally, a small fold seen on this line against the platform edge looks similar to an antiform in the same structural location in The Gambia. Here in Guinea Bissau this antiform appears to be related to, or cored by, salt diapirism.

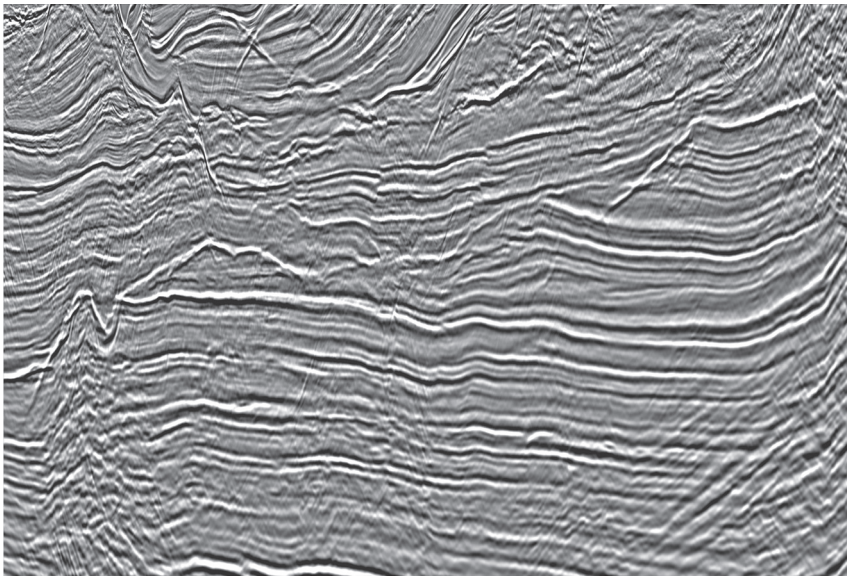
The strongly dipping Aptian carbonate platform is observed to be eroded to create a stepped surface forming a number of structural traps three way dip closed and one way sealed by mudstones above the PMU. This unconformity has significant relief and is not thought to represent sub-areal exposure as one would have to propose a drawdown of several kilometres of the Atlantic in the Early Tertiary or mysteriously an inversion of similar magnitude of the margin and rapid subsidence thereafter. Rather it is proposed that the unconformity represents a more modest margin tilting, rebasing and submarine erosion event,



**Figure 4** Guinea Bissau: West-East Sea water compensated 2D conventional PSTM line (TWT).



**Figure 5** Guinea Bissau detail of West-East 2017 reprocessed broadband data, seawater compensated.



**Figure 6** Guinea Bissau detail of West-East 2017 reprocessed broadband data, seawater compensated.

which correlates to mass transport deposits in the basin at end Cretaceous level. Following the PMU out of the basin from early Tertiary conformable sequences, several erosional platform margin carbonate structures are identifiable. Additionally, in the upper part of the PMU, Albian sandstones again are brought into trapping geometry. These can be seen in more detail on the 2017 broadband processing of this Guinea Bissau data (Figure 5). However, an advantage of this regional line is that it also crosses two of Guinea Bissau's salt diapir structures, the eastern of which being the Sinapa-2 diapir flank oil discovery.

### Sinapa-2 oil discovery

Sinapa-2 was drilled by Premier Oil in 2004 to test the Albian reservoir in the flanks of the Sinapa salt dome. Two sand units were penetrated: an upper one of poor quality sands 90m thick and, below an intervening mudstone interval, a second sequence with excellent quality sands 250 m thick. 35oAPI Oil was recovered in an MDT sample from the upper sequence of sands. The well was side-tracked up-dip and a similar pair of Albian sand sequences penetrated. Again oil was sampled from the upper sand, defining a 500 m oil column. This well tie has been used to correlate both the upper and lower sands into the two prograding sequences in the platform /unconformity play (Figure 5).

### SNE+ a look-alike play

Figure 5 shows a detailed 20-km section of this regional line that has now been reprocessed to broadband. The deghosting has brought out significant details of the prograding Albian sandstones. The upper sequence is slightly thinner but comprises full clinoforms prograding east to west until terminating at the PMU. The unconformity has cut back significantly from the Aptian carbonate platform margin at this upper level. Below this unit is a parallel layered package (presumed to be equivalent to the inter sandstone mudstone unit in Sinapa-2, 2ST. The lower sequence again progrades strongly west to east. In the east progrades show the full clinoform. However, in the west the clinoforms appear stacked lower slope and base of slope deposits – not unlike the SNE sequences approaching the platform margin edge.

This couplet of Albian sands appears in this SNE style trapping configuration elsewhere along the platform margin in Guinea Bissau. Another example, Figure 6, shows both prograding units. However, the PMU unconformity has eroded down through the Lower Albian unit creating a 'buried hill' feature at the shelf margin. Again the clinoform geometry suggests lower slope/base of slope sediments in this closure, while to the east of this the lower sand appears to have an upper slope, shore face part of the clinoform in the trap – not unlike the geometry in The Gambia in this unit.

As the Albian deltas prograded across the shelf, they approached the precipitous platform margin edge. On reaching this, facies belts stopped prograding and started to aggrade (Figure 6), as the slope sediments began to pour over the platform edge, and in all probability sediment drainage began to be channelled into off-shelf canyons taking sand to the basin floor (as discovered by the Fan-1 and fan South-1 wells). Thus the amount of erosion of the Albian clastic sequence by the PMU drastically changes the expected facies in the trap. Deep erosion back from the Aptian carbonate platform margin edge places the shore face and delta top clinoforms under the unconformity, while minimal erosion means that the depositional clinoforms that run up to the platform edge and therefore lower slope and base of slope sediments are represented in the trap.

It is striking that two Albian sand units behaving in this way appear both at SNE and Guinea Bissau at apparently the same geological moment. There is no obvious dip divergence on the platform, suggesting that the basin began to subside rapidly at end Aptian bringing facies belts out across a dipping platform, and so we suggest that the appearance of the clastic delta relates to changes in sediment supply. While this margin is generally passive, tectonically the end of the Aptian coincides with the real development of the transform margin to the south east of Guinea Bissau that changes an extensional rift into a strike slip transform margin. This may have caused inversion and faulting in the interior drainage of North West Africa (fetch piracy etc.) that brought a large drainage system to the Senegal-Guinea Bissau margin at end Aptian that kills the carbonate platform and brings a clastic delta to

both the SNE and Guinea Bissau. The couplet of two prograding sequences separated by a flooding event suggest that from Senegal to Guinea Bissau sediment supply twice exceeded accommodation space generation during episodic but steady basin subsidence. After the deposition of the upper sand, sand facies belts moved back into the shelf and the area is covered by pro-delta muds, suggesting either increased subsidence or reduction in sediment supply.

### Summary

An analysis of the play elements, which have come together so elegantly in the giant SNE discovery, suggests that these elements are also present south of the SNE area through The Gambia and into Guinea Bissau.

The section in the deep basin is likely to contain thick Turonian source rock, in addition to other (Early Cretaceous and older) potential source rocks from The Gambia to Guinea Bissau. The migration pathways are analogous and the tectonic tilting generates the landward dipping carbonate platform, and therefore the structural dip of the trap, is also present from Senegal to Guinea Bissau.

Lastly the appearance at the beginning of the Albian of clastic deltas that then dominate this previously clastic starved carbonate platform margin is likewise correlated and indeed the same sequence stratigraphic processes appear to have controlled deposition from north to south along this margin. However, variation in the submarine erosion that generated the PMU, would appear to dramatically change the prognosis of the facies of Albian deltaics that one might encounter in the trap.

Putting the play elements together to find the analogue prospects to the giant SNE discovery on this margin requires a regional approach focused on play systematics. Yet this is still explorers' country –

high-quality broadband data is illuminating such a play in Guinea Bissau of comparable giant size to SNE, and now this must be followed by the drill-bit to open up the southern part of the basin and reveal the true oil potential of the margin.

### Reference

De Boer [2017]. HGS-PESGB HGS PESGB, 16th African Conference, Abstracts.

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