COLORADO AND OTHER ARGENTINA OFFSHORE BASINS: COMPREHENSIVE 2D SEISMIC GRID HIGHLIGHTS ADDITIONAL PLAY TYPES AND UNLOCKS NEW TRAPS AND TRENDS - EXAMPLES FROM THE VENUS DISCOVERY OFFSHORE NAMIBIA

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ABSTRACT

Las cuencas de Colorado, Salado/ Punta del Este, Argentina y Oriental del Plata, forman parte del margen pasivo volcánico a lo largo de la costa oeste del océano Atlántico Sur, en Sudamérica. Estas cuencas se formaron en el Jurásico Tardío a Cretácico Temprano, cuando América y África del Sur empezaron a separarse, formando hemi grábenes rellenos de forma sin-tectónica, que eventualmente evolucionaron hacia cuencas de márgenes pasivos. Esta provincia del margen atlántico, situada entre la región sur de la Cuenca Argentina y la región norte de la Cuenca de Pelotas, se caracteriza por la presencia de flujos basálticos sub aéreos que vistos en secciones sísmicas forman Reflectores con Inclinación hacia el Mar (SDR's por su acrónimo de siglas en ingles).
La apertura asociada a la etapa de *rift* generó un ambiente de circulación marina restringida en el joven océano Atlántico sur, creando condiciones anóxicas desde el Barremiano hasta el Aptiano, lo cual habría permitido la deposición de sedimentos finos con facies de alto contenido orgánico y la formación de rocas generadoras con excelentes calidades bajo condiciones anaeróbicas.
Lamentablemente, ningún pozo exploratorio perforado ha confirmado el *play* profundo en esta región sub-explorada de las cuencas marinas de América del Sur. Sin embargo, el reciente descubrimiento de Venus en la Cuenca de Orange en Namibia, África del Sur, renueva las esperanzas para el margen conjugado de Argentina y Uruguay. La interpretación de datos sísmicos regionales sugiere que la roca madre Barremiana-Aptiana está ampliamente distribuida a lo largo de la costa de Namibia, variando en espesor y probablemente en contenido orgánico total.
Estas afirmaciones se basan en la evaluación de más de 78.000 km de sísmica 2D de offsets largos migrada en profundidad (PSDM en su acrónimo de siglas en inglés).

INTRODUCTION

Exploration activities of the offshore Colorado, Salado and Argentina basins has resulted in only 38 wells being drilled (26 wells in Colorado and 12 in Salado Basins respectively), with

none in water depths greater than 100 meters. These wells were drilled, mostly by major oil companies, without any commercial success. However, 4 wells with hydrocarbon shows suggested the presence of active petroleum systems.

Petroleum Systems include probable oil-generating source rocks in Paleozoic pre-rift, Jurassic to early Cretaceous syn-rift and Cretaceous sag and passive margin sediments. Reservoir rocks include Paleozoic, Jurassic, Cretaceous and Cenozoic sandstones.

A broader and more complete view of these basins provided by a comprehensive grid of 2D long offset seismic data (Fig. 1) expands the leads and prospects of the Colorado and Salado basins to include additional plays.

An additional play concept could be the syn-rift structures superimposed on the predominantly compressional pre-rift architecture.

Moreover, the stratigraphic/structural traps of Cretaceous drift sediments offer a new and highly prospective play systems still to be explored. Especially after the Venus discovery Offshore Namibia, Argentina and Uruguay's deep water conjugate margin.

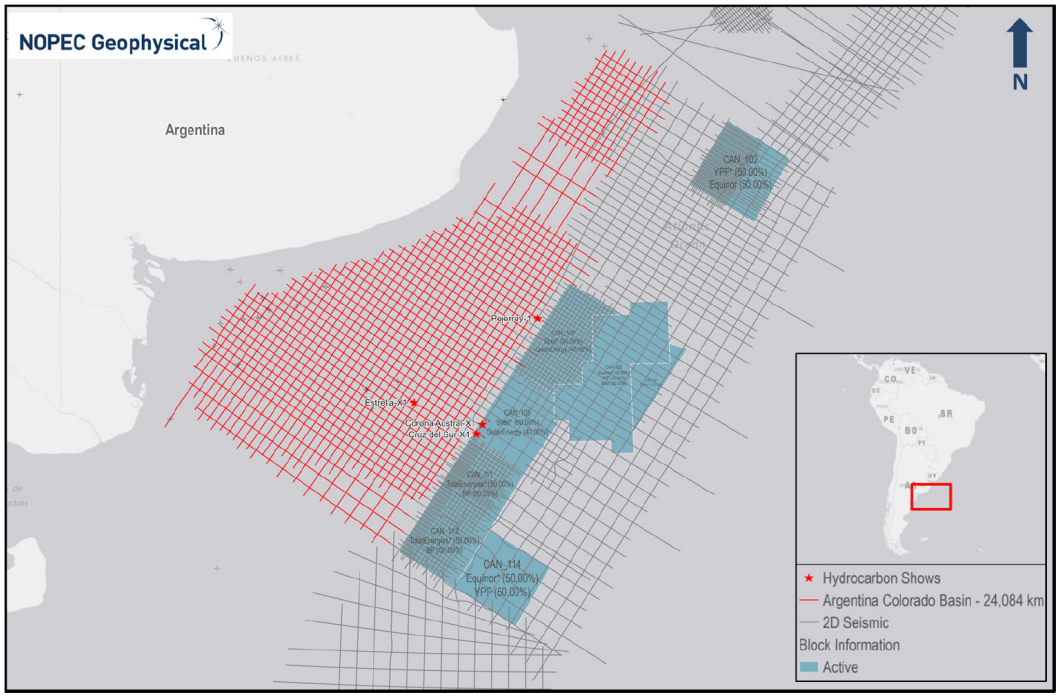

Figure 1. Colorado and Salado Basins Seismic Base Map. The 2D seismic in red corresponds to the latest Colorado Basin acquisition, whereas the grey outline corresponds to the legacy 2D seismic. The wells with hydrocarbon shows are highlighted with red stars.

The Colorado and Salado Basins

The Colorado and Salado (Punta del Este in Uruguay) are underexplored basins; traditionally the main exploration target has been the pre-rift structural trap play of Paleozoic age.

The individual rift basins along this margin initially formed from intra-cratonic rifting within the paleo-continent of Gondwana during the Mesozoic. The Colorado and Salado Basins, that formed following north-west/south-east extension prior to the east/west extension that resulted in the opening of the South Atlantic, can be clearly seen superimposed on the predominantly compressional pre-rift architecture.

As evidenced by the Colorado and Salado Basin 2D survey, many structures have been eroded at the break-up unconformity level, but the forelimbs and back limbs of the Paleozoic folds are still present. This truncated stratigraphic relationship as well as the uneroded anticlines may act as hydrocarbon traps sourced by Paleozoic pre-rift and early cretaceous syn-rift source rocks (Fig. 2).

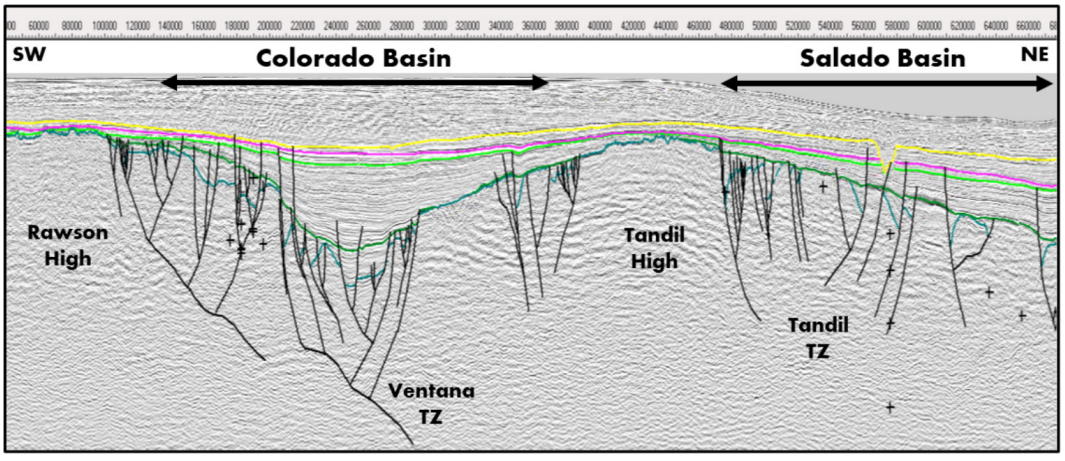

Figure 2. Colorado and Salado Basins representative seismic line, showing key features such as structural highs and transfer zones (referenced as TZ). NE-SW notional orientation from Fig. 1, parallel to the coastline.

Exploration activities of the offshore Colorado and Salado Basin has resulted in only 38 wells being drilled, in water depths less than 100 meters, and without commercial success.

A broader and more complete view provided by the interpretation of a comprehensive grid of 2D long offset seismic data (Fig. 1) will expand the leads and prospects by including additional plays. Rift and syn-rift structures superimposed on the predominantly compressional pre-rift architecture could create an additional play type on these basins.

The Argentina and Oriental del Plata Basins

The Argentina Basin (Argentina) and Oriental del Plata Basin (Uruguay) are also part of the volcanic-rifted margin along the southern South Atlantic coast of South America. The basins formed in the Late Jurassic to Early Cretaceous period, as South America and Africa started to drift apart, forming continental syn-rift half-grabens which subsequently evolved towards passive marginal basins (Lovecchio, 2018).

No wells have been drilled to confirm the hydrocarbon play concepts of this part of the underexplored South American deep-water basins, but the recent Venus discovery in the Orange

Basin of Namibia, South Africa provides great hope for the conjugate counterpart basins of Argentina and Uruguay and its extension into southern Brazil.

Interpretation of regional seismic data suggests that the Barremian-Aptian source rock is distributed over a wide range of offshore Namibia and varies in thickness and probably in Total Organic Carbon (TOC).

The Venus discovery indicates favorable burial history for oil expulsion in the Orange Basin, which may also imply the same for the conjugate basins of South America. Mapping the Aptian turbidite channel and fan complexes may identity many Venus´s lookalike leads and prospects of the Argentina and Oriental del Plata basins.

The Relevance of the Venus Discovery Offshore Namibia

An annotated 2D seismic line near the Venus discovery shows remarkable resemblance and comparison to 2D seismic lines of the deep-water Argentina and Oriental del Plata basins. Seismic attributes of the South American 2D data helps identify and enhance potential leads and prospects of the Aptian/Albian turbidite Play. In addition, a comprehensive grid of 2D long offset seismic data expands our view of the deep-water and helps to identify and map the Cretaceous turbidite channel and fan complexes.

These remarks are based on the evaluation of more than 78,000 km long offset 2D depth (PSDM) seismic data (Fig. 3).

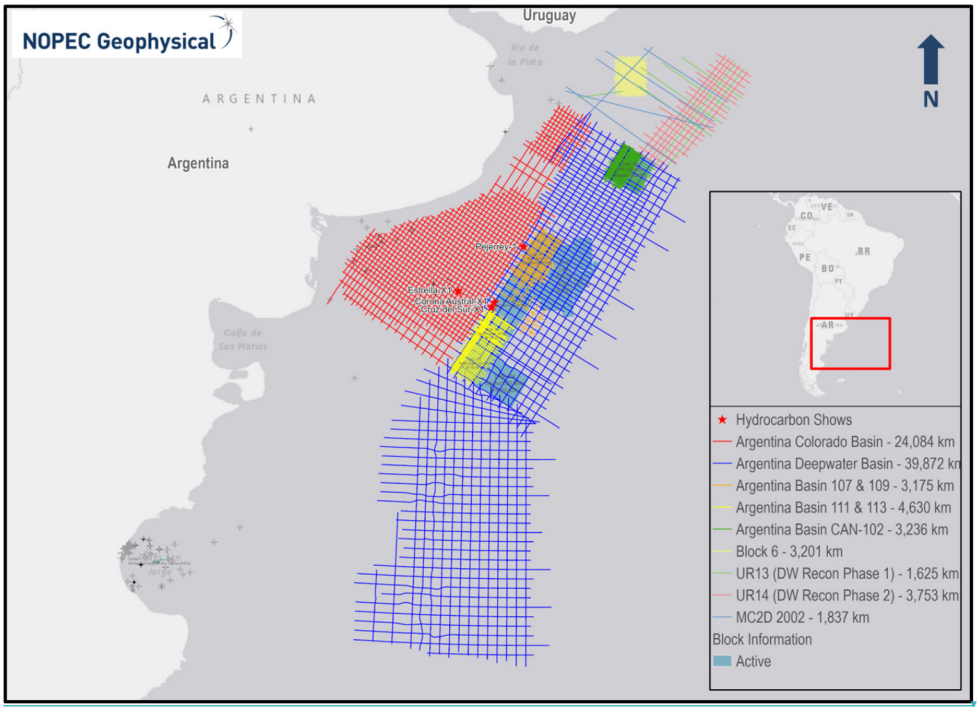

Figure 3. Seismic Index of 2D depth (PSDM) of offshore Argentina and Uruguay.

Regional Setting

The Argentina Basin has a continental volcanic rifted margin, segmented by major fracture zones which reflect the pre-existing Gondwanan structural fabric. The individual rift basins, the Colorado Basin being the largest, along this margin initially formed from intra-cratonic rifting within the paleo-continent of Gondwana during the middle Mesozoic and evolved into a true passive margin following the separation of the South American plate from the African plate in the early Cretaceous (Lovecchio, 2018). The focus of this presentation is the drift plays of this volcanic passive margin.

Long-offset seismic data acquired with a 12 km cable helps image and define the offshore crustal architecture (Fig. 4) significantly.

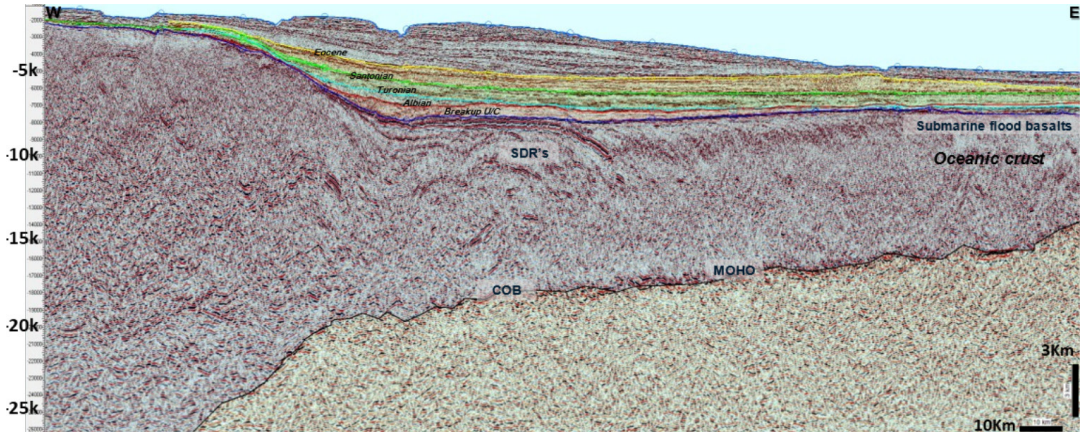

Figure 4. Long-offset seismic data acquired with a 12 km cable helps image and define the offshore crustal architecture significantly. NW-SE example seismic line from Fig. 3.

Interpretation of the Moho has allowed us to develop conclusions about the nature of the crust and the position of the Continent Ocean Boundary zone (COB). Seaward Dipping Reflectors (SDRs) are easy to distinguish on the high-quality seismic dataset and the varying acoustic signature and thickness of different SDR packages allow us to make inferences about the volume of magmatism at the time of rifting (Rosello *et al.* 2019). Transfer zones observed on strike lines cut by numerous strike-slip faults appear to correlate with thinning and offsetting of these volcanic SDR packages. The imaging at depth outboard in the deep basin is of high quality, allowing clear identification of SDRs quenched by first flooding and the onset of oceanic crust.

The Atlantic margin province between the southern Argentina Basin to the south and the northern Pelotas Basin to the north is characterized by these thick subaerial flood basalts. The rifting provided an environment for the young South Atlantic Ocean where circulation was restricted to create anoxic marine conditions in the Barremian to Aptian times, allowing good quality source rock facies to develop and deposit under anaerobic conditions. The interpreted top of the SDRs/basement provides the base of the Aptian source rocks.

No wells have been drilled to confirm the hydrocarbon play concepts of this part of the underexplored South American deep-water basins, but the recent Venus discovery in the Orange Basin of Namibia and South Africa provides great hope for the conjugate counterpart basins of Argentina and Uruguay. Interpretation of regional seismic data suggests that the Barremian-Aptian source rock is distributed over a wide range of offshore Namibia (Fig. 5) and varies in thickness and probably in Total Organic Carbon.

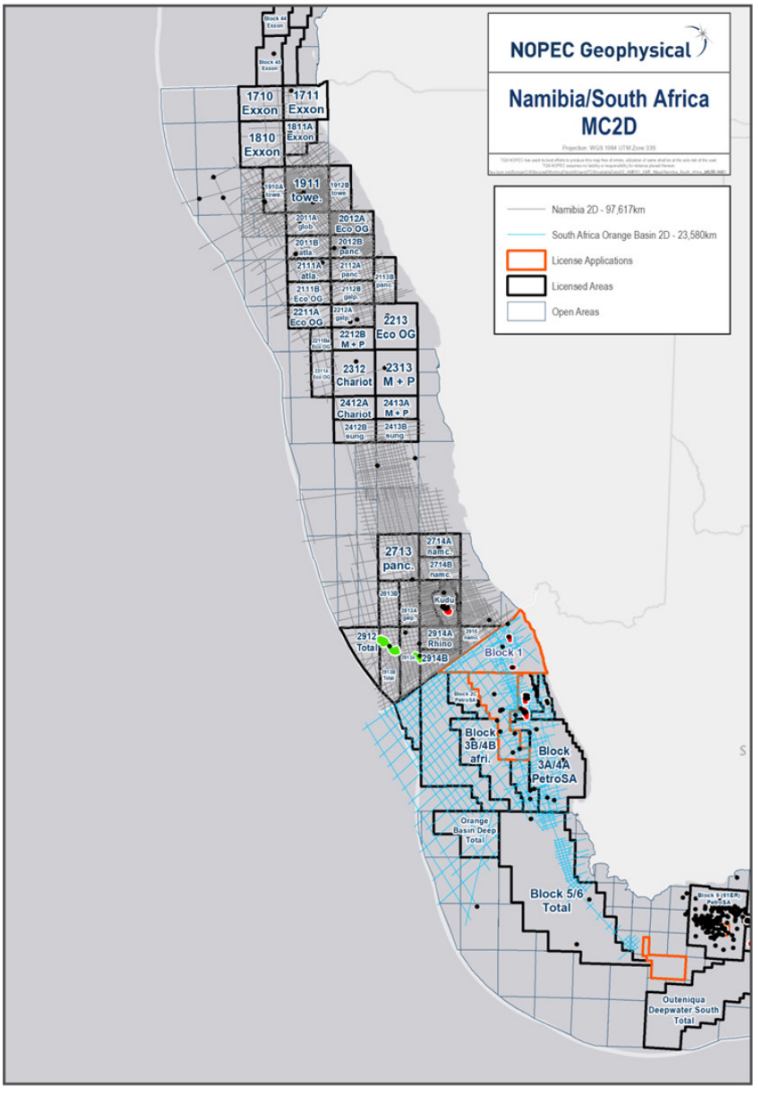

Figure 5. Regional seismic data and well information along the Namibia margin suggests that the Barremian-Aptian source rock is distributed over wide parts of offshore Namibia.

A 2D representative seismic line near the Venus discovery is a great illustration of the working petroleum system (Fig. 6).

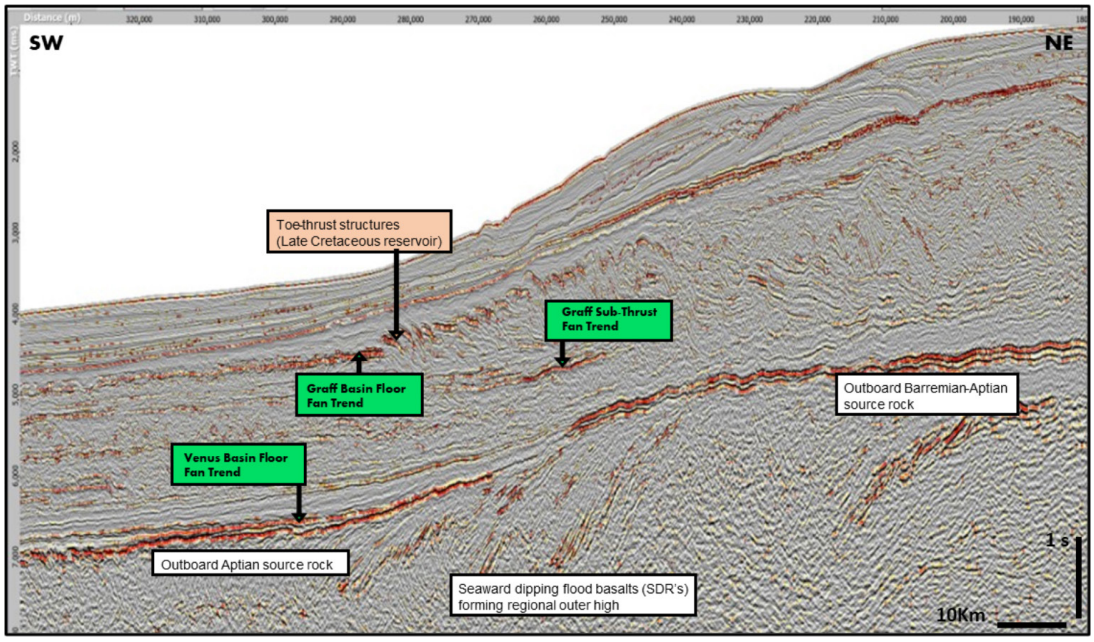

Figure 6. Representative 2D Seismic dip line near the Venus discovery, illustrating some elements of the turbidite play and working petroleum system. NE-SW example seismic line from Fig. 5.

The Venus discovery indicates favorable burial history for oil expulsion for the Orange Basin which may also imply the same for the conjugate basins of South America. Mapping the Aptian turbidite channel and fan complexes may identity many Venus's lookalike leads and prospects of the Argentina and Oriental del Plata basins. The Venus discovery is a great analog for the Argentina Basin Cretaceous turbidite basin floor fan play (Fig. 7).

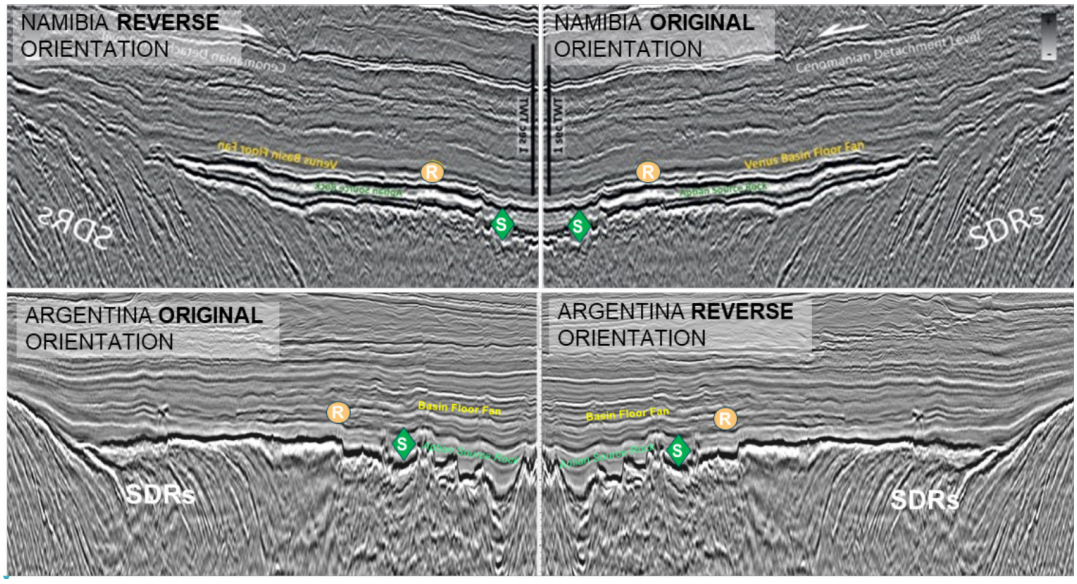

Figure 7. Notional seismic dip lines comparison between Argentina and Namibia conjugate margins. The Venus discovery is a great analog for the Argentina Basin Cretaceous turbidite basin floor fan play.

The annotated 2D seismic line near the Venus discovery shows remarkable resemblance and comparison to 2D seismic lines of the Argentina Basin and the deep-water of Uruguay. Seismic attributes of the South American 2D data helps identify and enhance potential leads and prospects of the Aptian turbidites. In addition, a comprehensive grid of 2D long offset seismic data expands our view of the deep-water and helps to identify and map the Cretaceous turbidite channel and fan complexes.

Mapping the seismic attributes such as Amplitude Versus Offset (AVO) and "sweetness" anomalies is important for understanding the play fairways and how each play concept works but also helps identify the turbidite channel and fan complexes (Fig. 8).

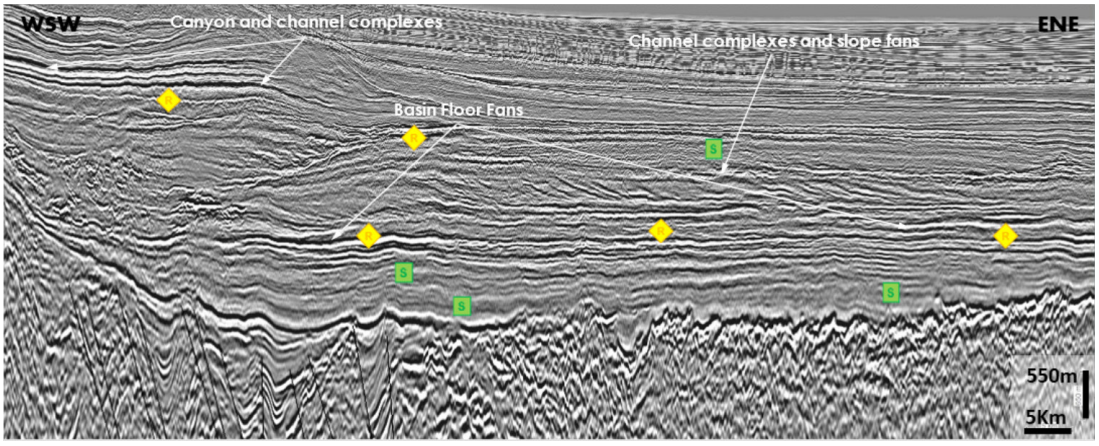

Figure 8. Representative 2D seismic amplitude section from the Argentina Basin highlighting source, reservoir and turbidite play types. Notional orientation ENE-WSW, parallel to the coastline of Argentina as per Fig. 1 and 3.

The sweetness attribute is often used as a quick-look technique to highlight thick, clean reservoir (sandstones), and/or hydrocarbons filled reservoir. It is simply derived by dividing reflection strength by the square root of instantaneous frequency (Fig. 9).

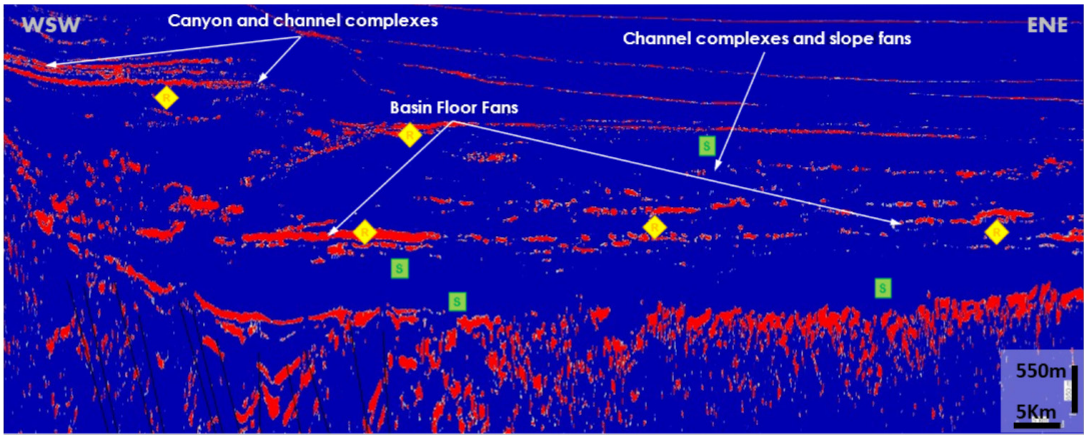

Figure 9. Same seismic section from the Argentina Basin with sweetness attribute derived by dividing reflection strength by the square root of instantaneous frequency.

Another technique to view amplitude versus offset is calculated using the far (F) and near (N) angle stacks in the following manner (F-N) *F (Fig. 10).

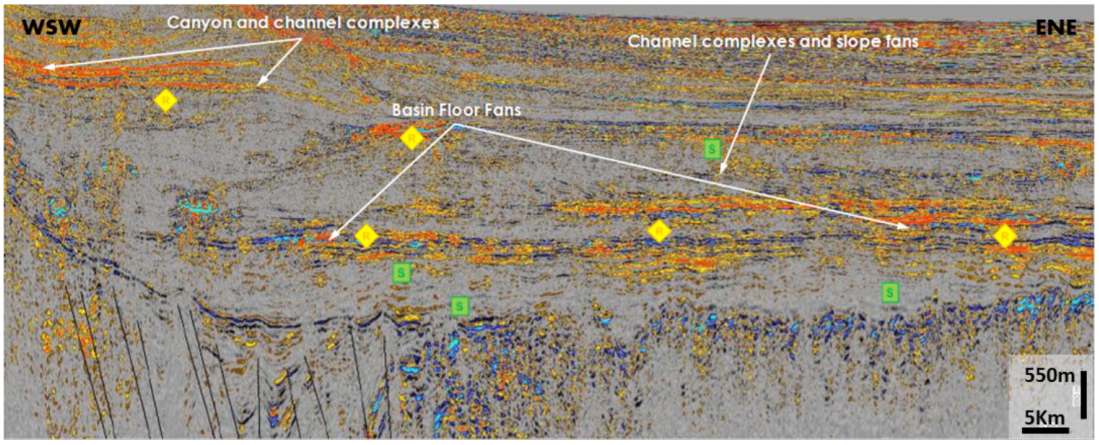

Figure 10. Same seismic section from the Argentina Basin with AVO attribute calculated from far (F) and near (N) angle stacks - (F-N) *F.

CONCLUSION

The Colorado, Salado and Argentina basins and their continuation into Uruguay and southern Brazil remain underexplored within the South American Western Atlantic margin. Many wells were drilled without economic success, nevertheless active petroleum systems are suspected.

The recent Venus discovery offshore Namibia opens the game for exploration in Argentina deep-water blocks by demonstrating the presence of an active petroleum systems at the conjugate margin.

There are many prospective ponded sand bodies equivalent to or lookalike to the Venus trap type throughout the Argentina to Pelotas basins fairway, surrounded by Aptian source rock, which is likely in the oil window. These remarks are based on the evaluation of more than 78,000 km of long offset 2D depth data (PSDM). This comprehensive seismic dataset provides the basis for regional interpretation to aid and de-risk exploration activities in Argentina.

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