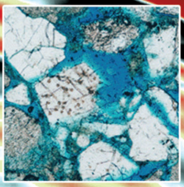

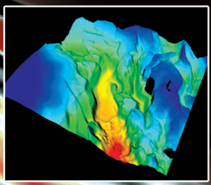

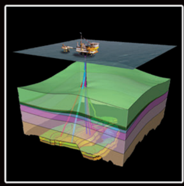

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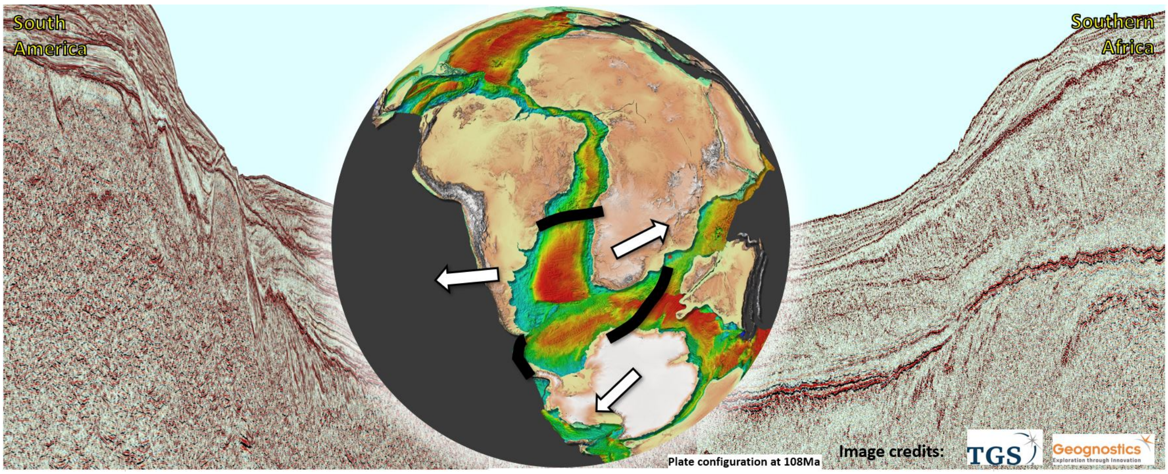

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Day One
6^{th} October 2021

Session One:
Tectonics

KEYNOTE: A new plate tectonic, basement and structural framework for understanding basins and plays in the Southern South Atlantic

Jon Teasdale and Tim Debacker
Geognostics

Introduction

In reconstructed space, the Southern South Atlantic province is intriguingly well-endowed with hydrocarbons. Major recent discoveries in South Africa and the Falklands, along with historic plays in Argentina and observations in Antarctica show significant prospectivity through time in a series of seemingly disparate, structurally complex Jurassic to Cretaceous basins. Using GEM, the Geognostics Earth Model, we have unravelled this complex tectonic story and built a spatially consistent regional framework in which to understand these basins and plays. GEM provides a new way of understanding basins from the bottom up, via basement terranes, plate tectonics, structural analysis and SEEBASE® depth to basement maps.

Plate Tectonics

The Southern South Atlantic is tectonically complex; far from a simple two-plate system implied by the Cretaceous to Recent separation of South America and Africa. Using the GEM plate model, we identify at least six key tectonic events that translate into spatially variable basin phases:

(i) Early-Mid Jurassic rifting and slow sea floor spreading between East and West Gondwana, forming the East Africa-Southern South America and Antarctic passive margin basins.

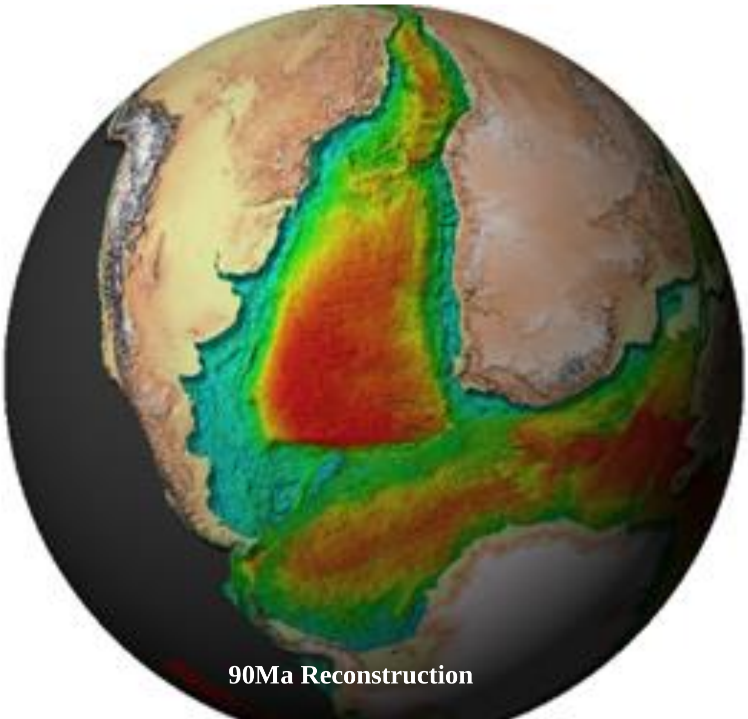
(ii) Late Jurassic-Berriasian transform movement between East and West Gondwana, forming the Davie and Mozambique-East Weddell transforms, significantly modifying earlier basins.

(iii) Valanginian-Aptian separation of South America, Africa and Antarctica via a triple junction in the proto-Weddell Sea, invoking the Falklands-Agulhas Fault. Dextral strike-slip causes differential movement and basin formation between the Maurice Ewing Bank, Falklands and South America.

(iv) Stable Late Cretaceous three-plate spreading system, passive margin basin evolution

(v) Acceleration of South America at end Cretaceous time causes ridge jump and change in spreading regime (sigmoidal transforms in Weddell Sea). This is related to Andean tectonics.

(vi) Neogene evolution of the Scotia Arc significantly modifies the southern South American margin as the northern proto-Weddell Sea is subducted with progressive west to east suturing of the Scotia accretionary wedge onto the extended margin.


90Ma Reconstruction

The influence of the Bouvet Plume on all of these tectonic events and on basin evolution is significant, both thermally and structurally. Onshore volcanics in southern Africa and Antarctica show that this plume has been active since the onset of rifting in the

Early Jurassic, and large oceanic plateau and hotspot volcano trails lead to the present-day plume expression at Bouvet Island.

SEEBASE® basement framework and basin control

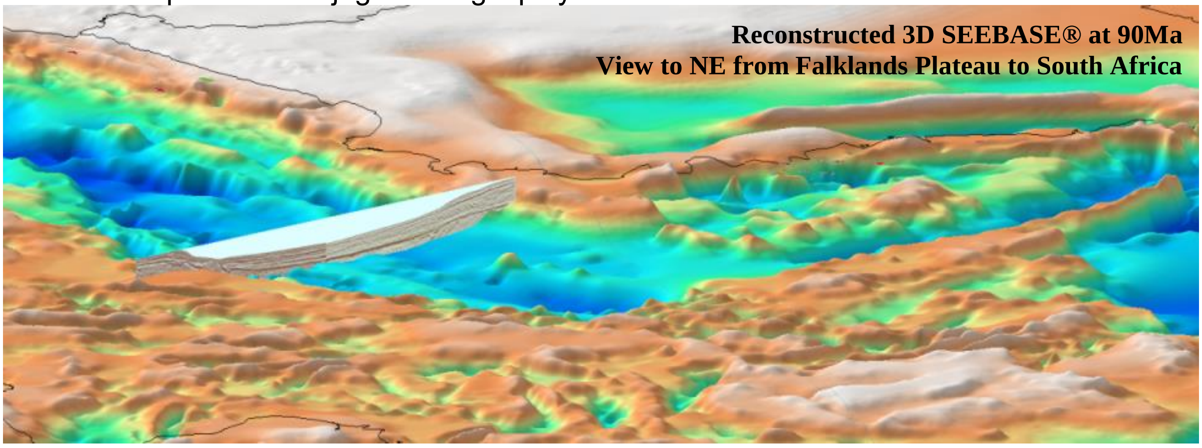
The complex basement terrane evolution of the southern South Atlantic can only be unravelled in reconstructed space – disparate geology and sparse outcrop have historically been difficult to correlate. We have interpreted structural fabrics and depth-to-basement across the region using the SEEBASE® workflow and have reconstructed the GEM Global SEEBASE® to correlate basins through time.

Our integrated interpretation shows a complex series of Neoproterozoic to Palaeozoic accreted terranes adjacent to the Archaean to Mesoproterozoic 'core' of Gondwana. These younger terranes can be correlated between South America, South Africa and NW Antarctica, and exerted a strong influence on Jurassic and Cretaceous basin formation.

The South African Jurassic Gamtoos and Algoa rift basins show a prominent change in trend. Analysis of potential field data and depth to basement mapping shows that these rift basins developed along the fabric of the eastern part of the Cape Fold Belt, and that the change in rift basin orientation is inherited from an oroclinal bend in the basement terranes. In reconstructed space using potential field data, the fabric of this oroclinal bend can be continued toward the Falklands where this basement fabric controlled the WNW-ESE trending Jurassic rift basins of the southern North Falkland Basin. As such, South Africa and the Falklands represent opposite limbs of the same East verging orocline of Late Palaeozoic (?Permian) age. In addition, we interpret the Falkland Islands themselves to be situated at a second oroclinal bend, with its shape mimicked by the ENE-WSW trending San Julian basin, and the N-S trending curved Malvinas Basin in Argentina. From there, and interrupted by the Neogene Scotia Sea, the Cape Fold Belt continues to the Ellsworth Mountains of Antarctica.

The origins of the Falklands-Agulhas transform, the world's longest structure, remain poorly understood. The only plausible explanation we see for such a long structure that originated in continental crust, crosscutting all older basement terrane boundaries and structures is that it represents a reactivation of a Late Triassic Karoo dyke swarm.

These new findings have important implications for regional and inter-continental correlations of new discoveries and plays across the southern South Atlantic, and provides a framework in which to open new conjugate margin plays.



The southern South Atlantic Ocean in the context of a holistic Gondwana dispersal model

Colin Reeves & Pricilla Souza
Earthworks, The Netherlands

***Figure 1**. The Bouvet plume and early separation between East and West Gondwana, 170 Ma.*

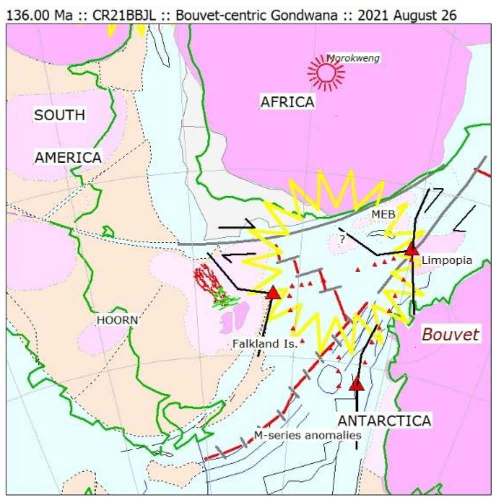


***Figure 2A**. 136 Ma: MEB still part of Africa plate.*

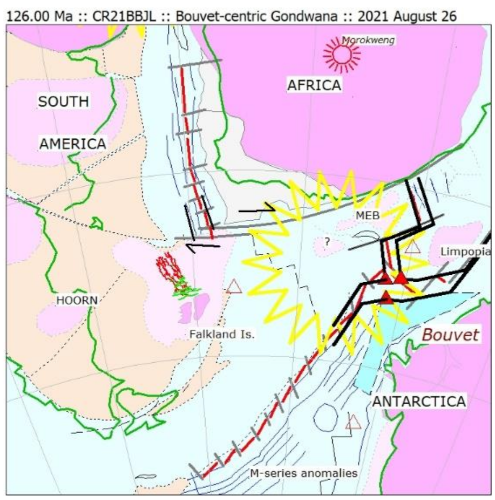


Figure 2B. *126 Ma: New TJ; MEB has joined Hoorn.*

Global tectonics within Gondwana is not so much about continents moving as about oceans – or at least their mid-ocean ridges – staying in the same place. A constellation of plume locations, fixed with respect to the earth's rotation axis, appears to influence strongly the location of the mid-ocean ridges of the oceans that now separate the Gondwana continents. The Bouvet plume is not only central to this dispersal process but also the first to have become active (c 184 Ma, Toarcian) with the Karoo-Ferrar events (Fig. 1).

The evolution of a mid-ocean ridge linking Bouvet to the Tristan plume over a distance of about 2400 km - essentially the southern half of the South Atlantic – is not simple but has perhaps been overly obscured by confusing ideas. Until about 165 Ma (Callovian) Gondwana still existed as just two large fragments, East and West. At about this time, a large part of Patagonia (call it Hoorn) became a third fragment and started to move west with dextral strike-slip along the Agulhas FZ where it was in contact with Africa. The first triple junction was between Hoorn, Antarctica and the Maurice Ewing Bank (MEB) that remained (largely) attached to Africa for another 30 myr. The triple junction remained stable while almost 900 km of extension occurred between MEB and the Malvinas plateau surrounding the Falkland Is. There was an almost equal amount of dextral strike-slip within southern South America (Fig. 2A) with only modest rift extension in the proto-southern South Atlantic and that only after about 140 Ma.

A rejuvenation of the Bouvet plume, contemporaneous with the first outbreak of the Tristan and Kerguelen plumes, caused a reorganisation of the triple junction off southern Africa in the interval 135-129 Ma (Valanginian-Hauterivian boundary now placed at 132.6 Ma, GTS2020). From a situation with MEB (as part of Africa) and Limpopia (as part of Antarctica) closely adjacent (Fig 2A), the MEB started following Hoorn along the Agulhas FZ while Limpopia left Antarctica and became fixed to Africa as the southern tip of the Mozambique Rise, where it is today. The new triple junction was between Limpopia (now part of Africa), MEB (now part of Hoorn) and Antarctica (Fig. 2B). The triple point is clearly preserved in the ocean off Antarctica.

True ocean growth had started in the southern South Atlantic Ocean, north of the Falklands-Agulhas FZ (FAFZ), during the period of triple junction reorganisation, evidenced by the presence of M-series magnetic anomalies there. Remarkably, the transform offset of 1200 km, initiated in this mid-ocean ridge as the Agulhas FZ, was to persist there until about 50 Ma (Eocene).

Figure 3A. *121.4 Ma, M0, begin Aptian.*

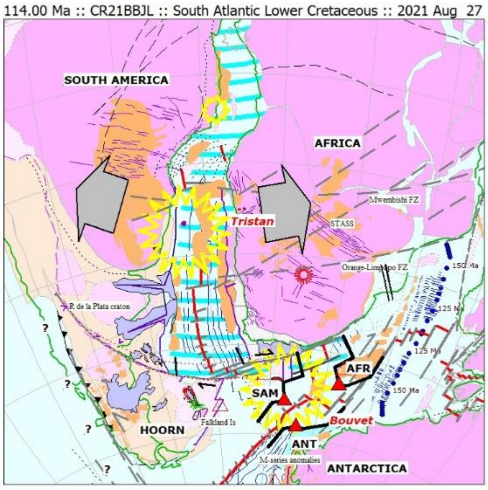


Figure 3B. *114 Ma, end Aptian*.

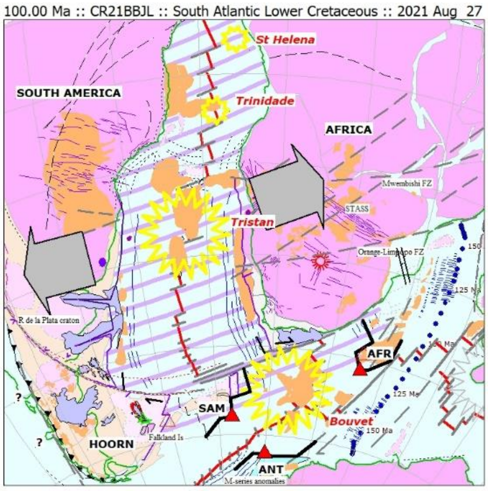


Figure 3C. *100 Ma, begin Cenomanian.*

The views shown in figure 3 are from model CR21BBJL which is also used in an animation for the interval 165-100 Ma that may be viewed and downloaded at:
www.reeves.nl/upload/ReevesAnimationLondon2021.gif

Continental separation south of the Tristan plume head was possible earlier than to its north since neither Africa nor South America was strictly rigid early in the Cretaceous. In Africa there is substantial evidence for a coast-to-coast Mwembishi FZ crossing Africa, moving dextrally by 70-80 km at about 130 Ma (Reeves, 2019) and a similar movement is also possible on an 'Orange-Limpopo FZ' sub-parallel to it (Fig. 3A). Both features are evident in offshore seismic surveys in South Africa and Namibia and the Mwembishi FZ links NE to the demise of the mid-ocean ridge between Africa and Madagascar and to what later became the Owen FZ.

On the South America side, the SW extrapolations of the known Permian-Triassic (Karoo) age strike-slip movements crossing the whole of Gondwana (STASS) are conceivable into Patagonia and southern Brazil (Fig. 3A). Cretaceous re-activation of (some of) these faults as scissor-like rifts (Salado and Colorado) is used in our model to add the extra length (about 150 km) to the South America margin that is evident in present-day geometry.

Scissor-like rigid opening of the South Atlantic north of Tristan, about a point near the Gulf of Guinea (Fig. 3B), gave way to coast-normal spreading at about 113 Ma (Aptian-Albian boundary, 113.2 Ma). This second rotation pole persisted until at least the end of the Cretaceous Quiet Zone (83.64 Ma, Campanian). This 30 myr period saw the development of the Walvis Ridge and Rio Grande Rise as products of Tristan plume activity at the mid-ocean ridge (Reeves and Souza, 2021) while a further outbreak of the Bouvet plume created the Agulhas Plateau at about 100 Ma (end Albian, Fig. 3C).

Southern Africa has tracked steadily NE, away from the Bouvet plume head, since the events described here for the Early Cretaceous. Even now the SW tip of the continent is displaced from it by no more than 2500 km. By contrast, the South America margin has moved almost 5000 km to the west in the same reference frame.

Related earlier work:

Reeves, C.V., 2019. The creation of the African margins and the Mesozoic demise of Gondwana. Abstract, PESGB Africa meeting, London, October 2019.

Reeves, C.V. & Souza, P., 2021. The lost 'continents' of the South Atlantic Ocean. Poster, Netherlands Earth Science Congress, April 2021.

Tectonic evolution of the Southern South Atlantic conjugate margins

Hans Morten Bjørnseth, Christopher Stadtler, Matthias Eugen Tischler and Sebastian Hinsken
Equinor ASA, Stavanger, Norway

Abstract
Transitional crust represented by a symmetric set of seaward dipping reflectors (SDR) has been mapped along the Southern South Atlantic conjugate margins. Integrated with interpretations of magnetic anomalies and fracture zones on the oceanic crust and major tectonomagmatic features on the continental crust this has been used to build a revised plate tectonic model. According to this model, the first continental breakup in the South Atlantic occurred in Valanginian along a segment north of the Agulhas fracture zone. The opening of the South Atlantic propagated northwards in Hauterivian by dissecting a prominent basement ridge (Rawson Ridge - Cape Ridge) marking the northern boundary of the Cape Sub-basin. The northward breakup propagation reached the linked North Pelotas – Walvis magmatic ridge in Late Barremian - Early Aptian.

Our conjugate margin analysis indicates a very asymmetric rifting and opening history in the Southern South Atlantic, with most of the lithospheric thinning and syn-rift magmatism preserved on the eastern (African) side. The outer part of the South American margin is narrow and steep, often lacking evidence of major rifting prior to the formation of the SDR wedges. In contrast, the African conjugate margin is wide, commonly associated with NNW-SSE oriented magmatic dominated syn-rift depocentres. A regional outer high was subsequently formed further west by excessive magmatism, followed by the formation of a symmetric set of SDR wedges on both margins and final continental breakup.

The breakup unconformity tied to the top of the SDR wedges have been mapped regionally on both margins. This is regarded a fundamental stratigraphic marker for basin analyses in the region, representing onset of seafloor spreading and consequently also the boundary between the syn-rift and drift megasequences. Furthermore, a pre-rift megasequence has been penetrated by several wells offshore Argentina but has not yet been proven offshore along the African margin. Three subunits within the drift megasequence have also been included in our tectonostratigraphic framework for Southern South Atlantic basin analyses. The three proven plays of the Orange basin on the African side plot quite differently within this framework. The A-J1 oil discovery proved up a syn-rift play charged by a lacustrine syn-rift source rock. Early drift petroleum systems and plays were proven by the discovery of the Kudu gas field, while the Albian fluvial – shallow marine sandstone play proven in the Ibhubesi gas field is placed within the middle drift subunit.

Timing of the Opening of the South Atlantic

Kyla Simons, Patricio Figueredo, Russell Mapes, Laurin Musso
ExxonMobil

Until recently, little modern seismic data existed over the Argentina portion of the deep-water South Atlantic, so the timing and nature of basin formation has been largely inferred from seafloor magnetic anomalies and areas of higher data density like Brazil and West Africa. The timing of opening of the southernmost Atlantic is of significance because during the earliest stages of basin opening, unique and previously unidentified conditions may have existed creating a substantial period of basin isolation prior to marine incursion. This period of isolation may have provided the possibility for deposition of organic-rich sediments and reservoirs that differ dramatically from those observed during later stages of the basin's evolution. New work indicates that the timing and sequence of breakup is more complex than previously interpreted, creating the crustal structure and paleogeography potentially conducive to play element deposition.

The breakup of the southern Atlantic margin was accompanied by the emplacement of a large volume of magmatic products in the form of basaltic seaward dipping reflectors (SDRs) that persist along the whole Argentina margin and represent subaerial conditions during early seafloor spreading. As the basin evolved, observation of magmatic morphologies allowed us to identify younging trends in the new crust, gradual and abrupt migrations of the spreading center, and spatial and temporal changes of paleogeography.

We present seismic interpretations from recently acquired TGS Argentina Deepwater Basin 2D seismic data, structures inherited from the early separation of South America from Africa, and magnetic anomalies. We combine these interpretations and observations with information from the conjugate margin in South Africa to fill in calibration gaps on the South America side, using the implied symmetry in the seafloor spreading process. Extrapolations of magnetic anomalies together with the implied younging direction of ocean crust, as seen by features in the Argentina seismic, enabled us to identify an area of oceanic crust that appears to be of early Cretaceous age, older than prior interpretations and what is currently published in the literature. In addition, some deeper areas in the south, nearing the Falkland Plateau, contain early sedimentary packages not present further north along the Argentina margin. The strata onlaps both the paleo-slope and the ocean crust, suggesting this may be the oldest crust in the area and, we speculate, the remnant of an isolated basin that existed during the earliest stages of southern Atlantic opening. These deposits exhibit relatively transparent seismic facies not observed elsewhere in the basin and could represent previously unrecognized lacustrine source and/or reservoir rocks. Additionally, this area is unique as our paleotectonic interpretations suggest this seems to be the only area along the South Atlantic margin where a piece of oceanic crust was captured from the African side.

The Agulhas Transform Margin: A long lived structural history on the road to South Atlantic connection

Sapin, F.[1] and Sany, F.[2]
[1] TOTAL, avenue Larribau, 64000 Pau, FRANCE
[2] CVA Engineering, 2 rue Myron Kinley, 64000 Pau, FRANCE

The Austral South Atlantic opened during the Lower Cretaceous in the frame of the breakup between South America and Africa. This opening has the peculiarity to be supported by a strong magmatic input usually linked to the presence of the Etendeka-Parana Hotspot located at the northern tip of this austral segment of the Atlantic forming volcanic passive margins. Magnetic data acquired during the last decades also suggest a northward propagation of the oceanisation from 135 Myr (M10-M11 anomalies) to 126 Myr (M0 anomaly).

The acquisition of new seismic data at the southern tip of Africa allowed us to revise the structural scheme and more precisely map the transform margin domains along the Agulhas-Falkland Transform Zone. This work resulted with an updated and more precise history of the transform margin. This also implied the revision of the geodynamic history of the Austral South Atlantic.
Indeed, a better mapping of the area offers the possibility to better position the Falkland-Malvinas Plateau and Maurice Ewing Bank along the African side. Therefore, the best fit position between South America and Africa Plates is revised.

Using these new positions, the recent magnetic data acquired off coast South Africa and up to date world gravimetric map, we propose a new evolution for the opening of the Austral South Atlantic. This new geodynamical evolution, using a limited number of subplates in South America, suggests that the main pole of rotation for this South Atlantic segment is located in Angola, quite close from the northern tip of this ocean.
We also show that the propagation of the oceanisation is stepped and 3 episodes can be identified. First, the opening of the southernmost segment (135-131 Myr) buffered in the ancient Cape-Ventana Foldbelt. A second, more brutal, event saw the oceanisation of the longest segment of the Austral South Atlantic almost synchronously around 130 Myr. The last step ended around 126 Myr in the Santos Basin prior to the breakup of the Central South Atlantic (113-112 Myr). This part is also buffered by the presence of the Etendeka-Parana Hotspot that was still strongly active in the area.

This evolution reveals that the Falkland-Malvinas Plateau was already present prior to this opening and its structuration was mainly related to the southern oceans (Antarctic, Weddel, etc.). It also emphases the importance of inheritance and large lithospheric events in the propagation of the breakup even when largely supported by magmatic input.

Session Two:
Inherited Structural Grain

KEYNOTE: Mesozoic Rifting in SW Gondwana: influence of preceding rifting in the opening of the Southern South Atlantic Ocean, Geodynamic and Paleogeographic implications

Juan Pablo Lovecchio[1], Sebastien Rohais[2], Victor A. Ramos[3], Ignacio Brisson[1], Néstor Bolatti[1]

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2 IFP Energies nouvelles, Rueil-Malmaison, France.
3 Instituto de Estudios Andinos Don Pablo Groeber, UBA-CONICET, Buenos Aires, Argentina.

The opening of the South Atlantic in the Early Cretaceous was the final stage of the complex rifting history of SW Gondwana. In this presentation we reassess the chronology of Mesozoic basin formation in southern South America and Africa and integrate it in the long-term breakup history of SW Gondwana. The amalgamation of cratons in the Neoproterozoic (during the Brasiliano-Panafrican orogeny) was followed by terrane accretion to the active SW Gondwana margin throughout the Paleozoic and the development of the Gondwanides orogeny in the Late Paleozoic, with the collision of the Patagonia terrane (Ramos, 2008) forming the Ventania-Cape fold belt system in the Late Permian-Early Triassic.

Since the end of the Gondwanides orogeny, intracontinental rifting dominates central-southern Africa (Karoo I phase, see Frizon de Lamotte et al., 2015), while retro-arc extension in the SW Gondwana margin triggered the formation of the Cuyo and Bermejo rift systems in western-central Argentina and the Late Triassic Precuyano depocenters of the Neuquén Basin. In Patagonia, extensional depocenters in the Deseado Massif and the Malvinas basin (Lovecchio et al., 2019) are also of Late Triassic age. Extensional reactivation of the Late Paleozoic Ventania fold and thrust belt and its offshore extension towards the South African Cape fold belt, is interpreted to have occurred at this time (Lovecchio et al., 2018).

In the Early Jurassic, the impingement of the Karoo plume triggered rifting in Eastern Africa, producing the Karoo II basins (*sensu* Frizon de Lamotte et al., 2015). The Colorado and Salado basins on the Argentinean shelf, oriented orthogonally to the margin, together with the Liassic E-W oriented depocenters of the Neuquén basin are interpreted to have formed at this time, as part of the reactivation of the northern boundary of Patagonia. A marine ingression of the Panthalassa ocean is recorded in the Neuquén basin at this time (with deposition of the Los Molles Fm source rock).

East African rifting ultimately lead the breakup of Eastern from Western Gondwana in the Middle Jurassic. In the Patagonian retroarc, trenchward volcanic arc migration is observed, from the Early Jurassic NNW-directed Subcordilleran Batholith to the Late Jurassic N-S oriented Patagonian Batholith (Echaúrren et al., 2017). Retroarc extension is also evidenced by the development of the Liassic Chubut basin (marine, Panthalassic) and the Cañadón Asfalto continental basin (lacustrine). In southern Patagonia, the Austral and Malvinas and other related basins formed in the Early-Mid Jurassic in association with the synextensional retroarc emplacement of the Chon Aike magmatic province. Extension in southern Patagonia continued through the Late Jurassic recorded by the subduction-related, bimodal volcanism of the El Quemado complex and the opening of the Rocas Verdes back-arc basin (Pankhurst et al., 2000).

Oblique rifting in the core of the Late Paleozoic Gondwanides orogen was responsible for the formation of the Outeniqua and Rawson/Valdés basins. Recent works in the southern portion of the Malvinas (Falkland) Plateau (Eagles and Eisermann, 2020) allowed the identification of Late Jurassic oceanic crust, under a regional stress field consistent with the one interpreted for the Rawson/Valdes/Outeniqua basins. Late Jurassic is a key moment in the evolution of the South Atlantic realm as it marks the first Tethyan marine transgression. This transgression, recorded in the Outeniqua basin by Tithonian marine sediments (Broad et al., 2015), should have flooded this intracontinental region across the Malvinas (Falkland) Plateau. Further west, this transgression is also recorded in the Malvinas basin (Galeazzi et al., 1998) and the western Austral basin (Malkowski et al., 2015).

Following a rotation of the stress regime to a more present-day E-W oriented extension, the South Atlantic Rift initiated in the Early Cretaceous. The northern rift of the North Malvinas (North Falkland) basin was probably the southernmost branch of this system (Lohr and Underhill, 2015) but the system is best developed north of the Agulhas-Malvinas (Falkland) fracture zone, which soon started acting as a major strike-slip border allowing the decoupling of Africa from South America. Rifting and breakup advanced diachronically from south to north, initiating in the previously thinned Rawson/Valdés-Outeniqua segment. A precursor oblique rift system affecting the core of the Gondwanides orogen, and a larger degree of extension in this segment might be responsible for the magma-poor character of the margins between the Agulhas-Malvinas (Falkland) fracture zone and the Colorado-Cape fracture zone. A mid-Valanginian age for the onset of oceanic crust accretion is consistent with a strong unconformity of this age observed in the Outeniqua basin (Broad et al., 2015) and the interpreted magnetic anomalies on oceanic crust (Collier et al., 2017).
Rifting and SDR (Seaward Dipping Reflectors) emplacement advanced progressively north of the Colorado-Cape fracture zone along different rift segments bounded by fracture zones and producing strongly asymmetric conjugate margins. Evidence support a passive rifting model for the South Atlantic rifting (dal Zilio et al., 2018) with rifting and breakup advancing to the north, towards the Paraná LIP (Franke, 2013). Barremian and particularly Early Aptian marine shales related to the OAE1 are present in the Southern South Atlantic (Dummann et al., 2021) and constitute the main source rock for the Cretaceous plays in these conjugate margins.

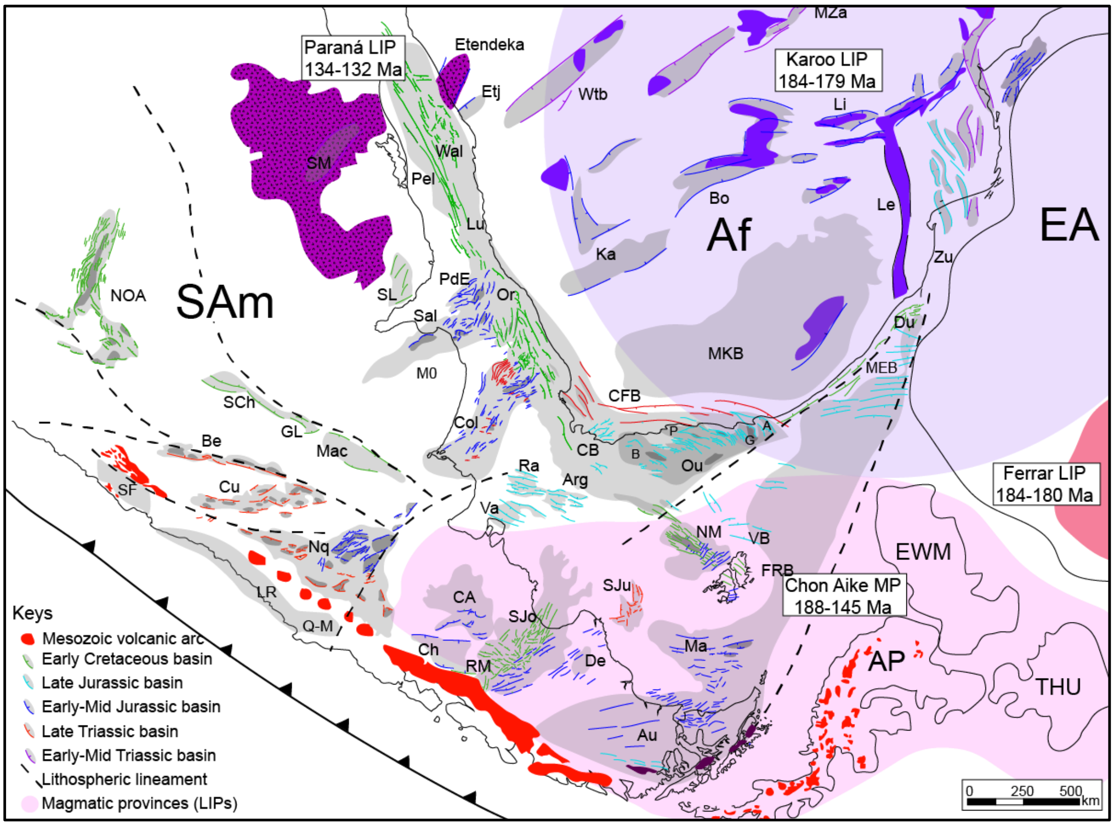

Fig. 1. Mesozoic basins of SW Gondwana displayed on a prerift Late Paleozoic setting.

The structural and crustal architecture of the Falkland Plateau Basin

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Unravelling transform margin initiation and evolution poses numerous challenges because these settings are associated with complex structural and crustal architectures. Here, we consider the tectonic evolution of the Falkland Plateau Basin (FPB) in the South Atlantic which is part of a transform margin that displays a wide range of structural styles affecting a highly heterogeneous crust. The present-day configuration of the FPB is controlled by its original location at the triple junction between South America, Antarctica, and Africa and against one of the longest offset transform faults on Earth – the Agulhas-Falkland Fracture Zone.
The elusive nature of the of the FPB crustal architecture, along with its debatable tectonic evolution, has led to significant uncertainties in assessing its hydrocarbon potential, and understanding the tectonic evolution of the southern South Atlantic. Here, we address this by integrating potential fields and seismic reflection data to delineate crustal domains and map fault networks, and 2D gravity forward modelling and 3D inversion to better constrain the crustal architecture based on the density distribution along the FPB to provide insight into its role in the regional evolution.
Our results define three distinct structural domains in the FPB, separated by NNE-SSW trending lineaments, interpreted as fracture zones based on their gravimetric and magnetic signatures. The westernmost domain lies east of the Falkland Islands shelf and comprises the Fitzroy and Volunteer sub-basins. This region is underlain by extended continental crust with a significant volume of magmatic and volcanic additions in the form of N-S trending dykes, sill complexes, and lava flows, and is predominantly affected by WNW-ESE and NNE-SSW to N-S striking normal faults with geometries that support sinistral wrenching superimposed on orthogonal extension. The central domain is a 100-150 km wide sliver of highly faulted continental crust with densities indicative of magmatic enrichment and potential underplating. The easternmost domain lies west of the Maurice Ewing Bank and comprises a triangular area underlain by a heterogeneous crust. The northern part displays high reflectivity and elevation, interpreted as attenuated and underplated continental crust, and the south-central part is associated with NW-SE trending magnetic lineaments/stripes, interpreted as oceanic crust. These findings document the structural and crustal complexity of a basin that initiated at a triple junction, which was strongly affected by wrenching. Our results point to a more complicated thermal and structural evolution of the plateau than previously envisaged, which has implications for its hydrocarbon prospectivity, maturation and exploration.

The Rawson rift system: pre-breakup extensional tectonics underneath the Argentine shelf

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Ofelia Silio (YPF SA, Offshore Exploration) Federico Späth (YPF, SA Geophysical Department) and Nestor Bolatti (Offshore Exploration)

The Rawson basin comprises a rift system located underneath the continental shelf of the Southwest Atlantic Ocean, between 41°S and 43 °S latitude. The main bounding faults are NNW-SSE oriented and the rift system extends from the San Matías Gulf on the northwest, to the continental slope on the southeast. These half-grabens remained landlocked during most of its history and preserve a continental pre-breakup record as their development is prior to the opening of the South Atlantic.
Rift related depocenters are NNW-SSE oriented, alike to the early rift systems of Outeniqua on the conjugate African margin. They were identified by regional reflection seismics and gravimetry in the mid-1960s. However, it was not until 1977 that YPF drilled the PV.es-1 (Valdés) well onshore. The well found Tertiary and Cretaceous sediments with some traces of hydrocarbons in the cutting record, overlying a basement of Paleozoic age, comparable to the Fm. Sierra Grande outcropping on the onshore. In 1988, Exxon and Chevron recorded 10,000 km of 2D seismic, covering the main grabens identified. This project culminated in the drilling of the Tayra.x-1 well (1990), which targeted a horst structure. Although the well encountered wet gas shows, it was abandoned as a dry hole.
Based on the structural style of the Rawson Basin, two distinct rift systems were recognized. The northwest segment, known as the Ameghino sub-basin, is the area where the Tayra.x-1 well is located. It shows several asymmetric extensional grabens with a width of 60km on average, which are separated by horst structures and linked to a common detachment. On the southern segment, grabens are more elongated and isolated and follow a symmetrical pattern. They are narrower (~10 km wide) and located in the southeast limit of the basin, nearly reaching the continental slope. This segment was named South Rawson sub-basin.
The link zone between the northwest and the southeast segments is marked by a possible NW-SE oriented strike slip zone, with several features interpreted as volcanoes. Onshore to the northwest, this zone can be related to the Jagüelito fault system, a basement rooted structure associated to Pb Ag Zn mineralizations. U/Pb ages on fault gauge and coeval andesitic dykes indicate a Middle Triassic age (243,6 ± 1.7 My) which would suggest that this strike slip fault controlled the Rawson rift development as an inherited feature. In addition, the southeast end of this strike slip fault zone links up with the Colorado Fracture zone, that separated distinct segments of SDRs during the earliest opening of the South Atlantic. Thus, this lineament seemed to have acted as an inherited feature controlling the later breakup process at a regional scale.
This strike-slip segmentation implies that the structural evolution would not have been homogeneous throughout the Rawson Basin. Therefore, the Tayra x-1 well results would only be representative for the drilled northwestern basin segment, different from the grabens further Southeast. A review of existing information and new reprocessed seismic data, together with a gravity modeling of the rift system supports the existence of its segmentation.

Hot Spots, inversion, strike-slip, canyons and magmatism – unravelling the complexity of the Diaz Marginal Ridge, South Africa: does it matter for prospectivity?

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Transform margins are increasingly active areas of exploration. Yet, our understanding of them lags behind that of magmatic and non-magmatic margins and too often we assume a simple strike-slip dominated system with little appreciation of the superimposed complexity. In this study, we investigate the structural configuration and associated hydrocarbon prospectivity of the globally significant Diaz Marginal Ridge (DMR). The DMR is a bathymetrically elevated feature that is orientated parallel to the Agulhas Falkland Fracture Zone (AFFZ) on the southern margin of South Africa. Although it has long been recognised as an important feature, and intimately associated with the development of the AFFZ transform system, its origin and evolution remains unconstrained. Whilst this has received academic attention over the past few decades, recent exploration interest has highlighted the importance of understanding the impact of the DMR's evolution on prospectivity of both southern South Africa and the southern South Atlantic more widely.

In this study, we use recently acquired seismic data across the DMR to derive a new structural interpretation of the ridge and its association with the evolution of both the AFFZ and the Southern Outeniqua Basin. The DMR is characterised by a significant stratal onlap of latest Valanginian- and Hauterivian-aged stratigraphy in the southernmost Outeniqua Basin. Whilst this onlap forms the basis of recent exploration success in the Brulpadda well, the genesis of the rotation of the surface onto which the onlap occurs is poorly constrained.

Our new structural interpretation documents the presence of an inverted Jurassic (?) rift basin that is controlled by the reverse reactivation of a south-west dipping basin bounding fault. This structural inversion results in the uplift of the footwall onto which the progressively rotated stratal onlap occurs. It also accounts for a classic hanging-wall inverted harpoon geometry, a smaller antithetic north-east dipping fault, and north verging footwall short-cut faults. These structures result in the progressive uplift and inversion of the southern flank of the Southern Outeniqua Basin during the Hauterivian.

This compressional event runs counter to the basin evolution at the same time interval immediately to the north. The basin controlling faults (Plettenberg, Gamtoos, St Croix) within the Outeniqua Basin were synchronously active as extensional structures. By considering the strain ellipses across the basins in the context of our structural database, we explain this dichotomy by invoking horizontal strain partitioning whereby the regional extension dominant during the Jurassic and earliest Cretaceous switches to shear dominated system as the AFFZ becomes active. The strain ellipse associated with the shear results in east-west orientated maximum stress and north-south orientated minimum stress. Superimposing this onto the change in orientation of the Cape Foldbelt crustal fabric allowed the same crustal detachment to accommodate both compression and extension.

This interplay of contemporaneous compression and extension has a significant influence on the potential of multiple sediment input locations, but also localised source rock deposition associated with the significant reactivation of the rift basin systems.

Whilst this interplay of compression and extension is observed on other margins that undergo structural inversion, what is noticeable along the DMR is the overprinting of later stage tectonic and magmatic overprinting. Although much of the DMR, and corresponding AFFZ is dry with very little magmatism, our regional mapping, coupled with the reflection seismic interpretation, demonstrates significant but localised magmatism. The margin is further complicated by the occurrence of a significant uplift and erosion event, most noticeably manifested by the Aloga

Canyon and Gamtoos peneplanation. We attribute this event to the potential tracking of a mid-Cretaceous hotspot across the margin that results in a transient uplift and erosion event.
The DMR, therefore, is anything but a simple transform margin dominated by strike-slip faulting. Rather, it has a complex structural configuration that is the consequence of the interplay of transform margin processes, pre-existing crustal heterogeneity, magmatism and a potential hot-spot track. Prediction of the hydrocarbon system within the margin requires an appreciation of how these components interact and impact both source rock and reservoir distribution.

Session Three: Rifting

Paleotectonic and paleogeographic mapping of southern Africa and its conjugate margins

Duncan Macgregor, *MacGeology Ltd, Reading, UK,* and **Colin Reeves**, *Earthworks, Delft, Netherlands*

We present 20 open access palinspastic maps reconstructing southern Africa and its conjugate margins between the Permian and Recent, on which basin development, active tectonic lineaments, paleoclimate and paleogeography are plotted. The plate model over which these are compiled can be accessed at www.reeves.nl , while a full set of paleotectonic and paleogeographic maps plus legend, covering the whole of Africa, can be accessed at www.macgeology.co.uk . In both sets of maps and in the selection attached here, the African Plate is held in a fixed position, while other plates plus paleolatitude and climatic belts, move relative to it. Most interpretations in Argentinian basins are taken from Lovecchio et al. (2020). The main uncertainties in plate reconstruction lie on the current South American plate, relating to whether there is oceanic crust between the Falklands and Maurice Ewing Bank (MEB) and the extent of transform movements at various times in northern Patagonia. The former uncertainty has a significant impact on our paleogeographic reconstructions and we favour models similar to those of Eagles and Eisermann (2020), which have a Kimmeridgian onset for stretching between the Falklands and the MEB, as this provides a means for deep oceanic waters to penetrate to the Algoa and Gamtoos Basins of South Africa, as is observed in the stratigraphic record (Mcmillan et al, 1997). The latter uncertainty has little impact on paleogeographic interpretations.

The Cape orogenesis of South Africa is here related to the closure of an oceanic back arc basin (Fig 1) that originally lay between South Africa and southern Patagonia (Linol and de Wit, 2016). The paroxysm of the orogeny lies close to the Permian-Triassic boundary and effects are seen well into Africa, including the development of a wide foreland basin (the Great Karroo Basin), the triggering of Permian rifts along extensive transforms and inversions as far as the Congo Basin. Collapse of this tectonic belt at some time in the Triassic or Jurassic is the most likely model for the initiation of the Colorado Basin (Fig 2) of Argentina (Lovecchio et al, 2020). Repeated activity of the Bouvet plume affects the region. The first, in the Pleinsbachian and Toarcian (Fig. 2), precedes the formation of the Indian ocean. First oceanic crust is emplaced in the Oxfordian off Mozambique, in the Kimmeridgian on the Falklands Plateau and from Valanginian to Aptian (propagating northwards) in the southern South Atlantic (Figs. 3-5), each pulse associated with its own volcanic event. Consistent with the frequency of these pulses, a very high proportion of the margins developed are magmatic, with some of the thickest seaward dipping reflectors observed anywhere in the world: others are transforms. These trends undoubtedly play a role controlling the thermal history of each of the margins and the regions current relative coolness (Macgregor, 2020). This paper highlights the effects of this clockwise unzipping around the African Plate in introducing marine waters at different times in different basins, and the impact this has on source rock potential. For instance, the age of the first marine transgressions youngs from east to west across the South African Outeniqua set of basins (Figures 3-4) and is nearly 100 MMyr earlier here than in many of the conjugate basins on the South American plate.

Once the African and South American plates move apart, any similarity between them is lost, unlike many conjugate Atlantic margins further north, which continue to show close tectonic and stratigraphic correlations. The key difference is the large scale uplift of southern Africa in the Late Cretaceous (Fig. 6) (with continuing Tertiary pulses), events which have no parallel in Argentina. Sedimentation offshore, including the development of turbidite reservoirs, responds heavily to these uplifts (Baby et al, 2018), though a progressive drying out of the southern Africa climate from the Late Cretaceous onwards plays an equally important role.

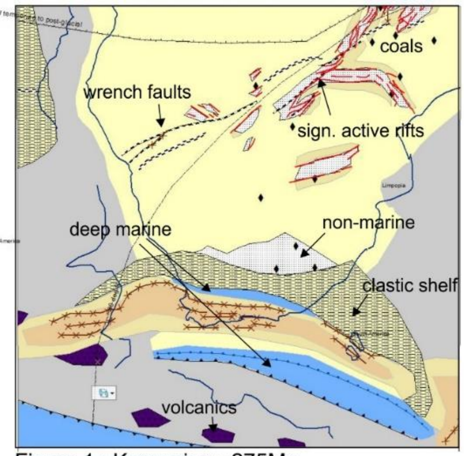

Figure 1 : Kungurian ~275Ma

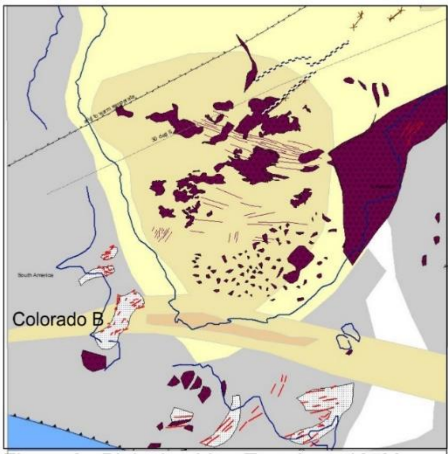

Figure 2 : Pleinsbachian-Toarcian ~185Ma

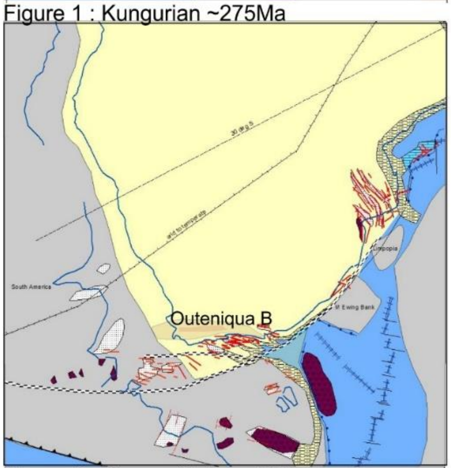

Figure 3 : Kimmeridgian ~155Ma

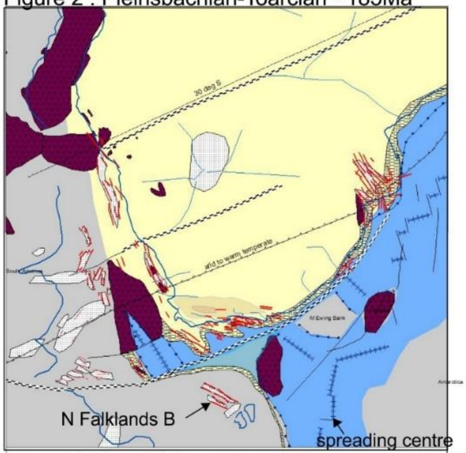

Figure 4 : Late Valanginian-Hauterivian ~135Ma

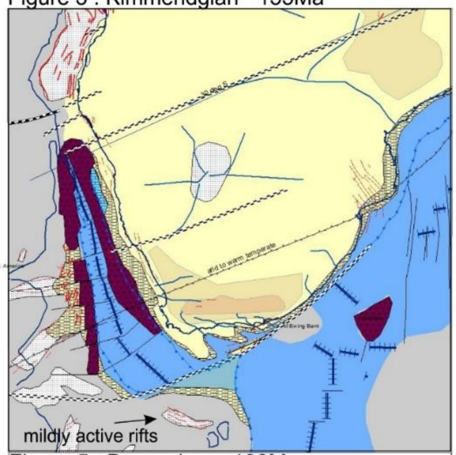

Figure 5 : Barremian ~ 130Ma

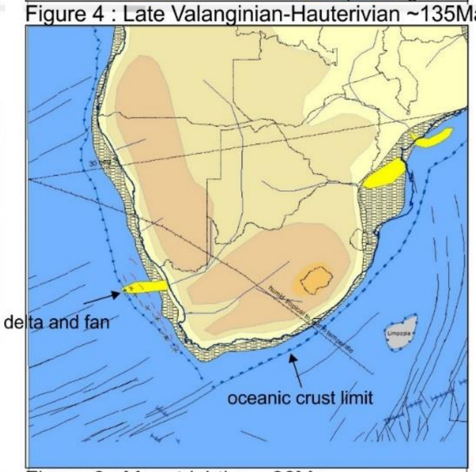

Figure 6 : Maastrichtian ~66Ma

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Maldonado Triple-Junction Rifting Structure Offshore Uruguay: Characteristics and Petroleum Implications

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Abstract

The processes of continental rifting generally begin with the development of triple joint structures. Usually, in the development of these structures, two of the arms continue the extension process developing oceanic crust, while in the remaining arm, the extension does not continue, generating thus an aulacogen.

The fragmentation of the southern Gondwana supercontinent, during the Upper Jurassic to Early Cretaceous, developed in this way from several triple joint rift structures that merged and eventually generated the Atlantic Ocean.

In offshore Uruguay two main basins are recognized (Punta del Este and Pelotas) that are part of the continental fragmentation and separation process that continues up to this day.

Punta del Este Basin, interpreted as an aborted rift, develops in the west segment of the Uruguayan offshore. It is characterized by NW-SE trending half-graben structures and NE-SW seaward dipping reflectors (SDRs) wedges in the distal part.

Pelotas Basin develops in the Eastern segment of the Uruguayan offshore and continues through southern offshore Brazil. It is the portion of the margin that continued its extension and evolved into a passive margin. Unlike Punta del Este, Pelotas Basin does not have large graben structures, instead it develops a thick NE-SW trending SDRs sequence in its central part.

In the shallower region, both basins, are separated by a basement high (Polonio High) which was active during the Cretaceous. The limit between these basins in the central and distal part of the offshore is not so clear. No SDRs wedges were developed in the transition zone between these basins.

Soto et al. (2011) proposed that a set of NW-SE trending faults, which develop in this transition zone, constitute a transfer system called Rio de la Plata Transfer System (RPTS). According to these authors the RPTS would have generated the interruption and/or sinistral displacement of the SDR wedges of Punta del Este and Pelotas basins.

Later, Thompson et al. (2018) proposed the development of a triple joint rift structure called Maldonado Triple Junction (MTJ). Several evidences show that the MTJ operated and controlled the continental fragmentation in the region of offshore Uruguay during the Early Cretaceous.

The consequent geometry associated with the MTJ would be defined by the SDR packages of Punta del Este and Pelotas basins, which represent the rift arms that evolved, and an aborted central rift that represents the aulacogen structure (Figure 1).

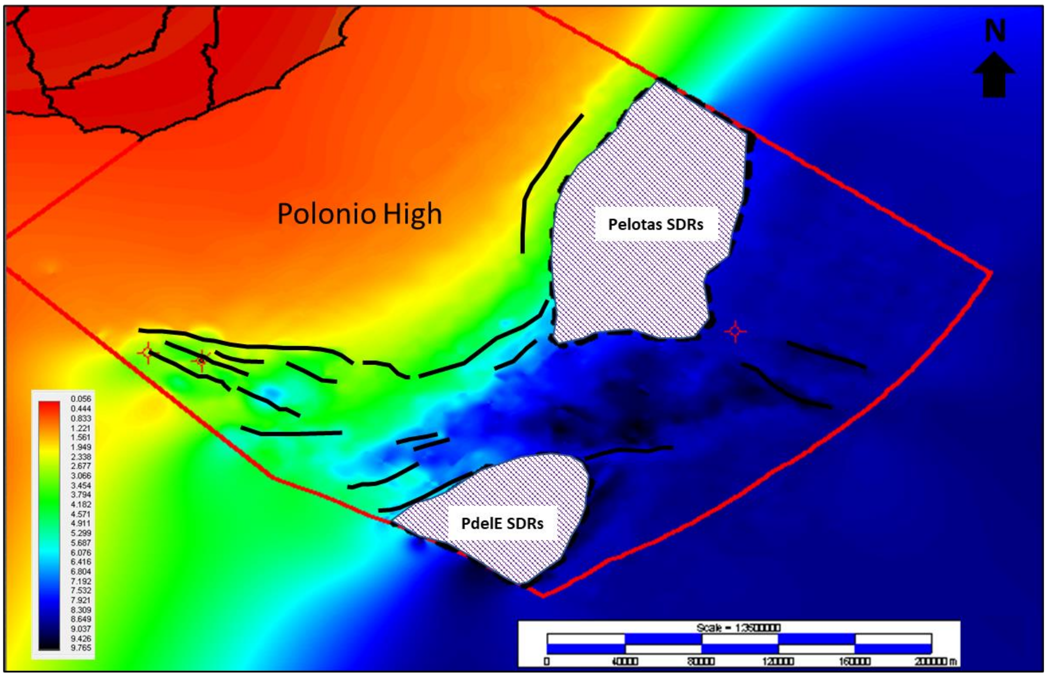

Figure 1: Top basement structural map (TWT) offshore Uruguay with location of Punta del Este and
Pelotas basins SDR wedges and main synrift and early postrift faults

It is postulated in this work that the presence of this central aborted rift structure is the reason why SDRs in the offshore Uruguay are segmented, since conditions for SDRs formation were not developed in the aulacogen structure.
Through the integration and analysis of geophysical data, including 3D seismic and gravity, we analyzed this area in the central offshore Uruguay region from a Petroleum System perspective. The aulacogen structure developed unique structural and sedimentary characteristics for the Early Cretaceous that are different from the surrounding areas of the offshore. These distinctive features had important implications in the deposition of source rocks, maturation, generation, expulsion and accumulation of hydrocarbons.

Key words: Triple Junction, Offshore Uruguay, Petroleum Systems.

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Structural evolution of the South African Transform Margin and implications for deepwater oil plays in the Natal Trough

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Impact Oil & Gas

Africa's south-eastern continental margin is dominated by the Agulhas-Falkland Fault Zone (AFFZ), which was initiated during the Early Cretaceous (at 142Ma) as a southern transform boundary to the nascent South Atlantic Ocean. Across this major fault zone, strain was transferred from active sea-floor-spreading in the South Atlantic to spreading within the Natal Trough, a small parasitic ocean basin that formed between the AFFZ and the Mozambique Ridge. As a result, the Natal Trough is underlain by oceanic crust, which youngs in age in a NE-SW direction.

Interpretation of different geophysical datasets along this margin highlights a wide variety of structural styles, implying that the region has been subjected to a number of stress regimes since the margin formed. This study aims to address these structural observations and place them in context with the complex, multi-stage tectonostratigraphic framework of Southern Africa, working towards a better understanding of the offshore prospectivity of the Natal Trough.

The first major tectonic event occurred during the Permo-Triassic formation of the Gondwana supercontinent, when collision between the South American and African plates formed the WNW-ESE Cape Fold Belt (CFB), the accompanying Karoo Foreland Basin, and the NNE-SSW trending Durban Arch (Tankard, 2009). During the Jurassic (approximately 183Ma), the earliest stages of break-up of East and West Gondwana involved the entire study area undergoing extension. Thrust segments within the CFB underwent gravity collapse to form half-grabens within the greater Outeniqua Basin, and basic volcanism gave rise to the Lesotho plateau basalts.

The transition from extensional to transform tectonics along the AFFZ was first recorded in the Berriasian (142 Ma), with initial dextral movement between the South African Transkei Margin and the Maurice-Ewing Bank (east of the present-day Falkland/Malvinas Plateau). Earliest movement of the AFFZ and the sub-parallel South Outeniqua Fault involved a southerly dip-slip component, resulting in the development of flanking monoclines, and the subsequent rapid deposition of early erosive products into the newly formed South Outeniqua and Maurice Ewing Basins.

Whilst no appreciable strike-slip movement subsequently took place along the South Outeniqua Fault, strike-slip movement along the AFFZ throughout the Lower Cretaceous resulted in the accretion of oceanic crust across the Natal Trough and the formation of an oceanic depocentre for offshore clastic deposition, the Natal Trough. As the mid-ocean ridge migrated orthogonally along the AFFZ continent-ocean boundary, a time-transgressive thermal uplift of the continental margin propagated along the margin over time. This uplift resulted in clastic starvation of the early oceanic basin, creating a perfect environment for the deposition of Valanginian-Aptian marine oil-prone source rocks. Coeval erosive products from the African hinterland were deflected westwards, along the frontal thrusts of the Cape Fold Belt, and ultimately into the proto-Olifants fan lobes of the South Atlantic.

Thermal collapse of the uplifted continental margin and accompanying footwall subsidence occurred in the Early Albian, resulting in rapid influx of coarse clastic material into the Natal Trough, leading to the development of large-scale basin floor fan systems. Sedimentation was controlled by the Cape

Fold Belt and Durban Arch structural highs, acting as important drainage divides, which funnelled Lower Cretaceous clastics into the offshore Natal Trough. Sediments were further guided by a series of synthetic E-W trending Riedel shears that developed between the major transform faults, both on the narrow continental shelf and in the oceanic domain. These Riedel shears originated within the principal displacement zone (PDZ) of the large-scale dextral transforms: the South Outeniqua Fault, the AFFZ, and the outboard Natal Transform. Sediment entry points at multiple stratigraphic levels along the margin are located at structural intersections between the AFFZ and the continental Riedel shears.

Furthermore, structural interpretation of 2D seismic data across the AFFZ shows evidence of at least two phases of inversion and associated folding. During the Albian period, continued dextral AFFZ transform movement facilitated local transpression around the offshore extension of the Durban Arch. This inversion resulted in the disconnection of Aptian feeder channels from their down-dip basin floor fan lobes, and the subsequent triggering of mass transport complexes (MTCs) from an unstable shelf provided an effective top seal to these beheaded fans.

An additional episode of uplift, erosion and slope failure is also recognised in the Campanian, resulting in a thick package of MTCs overlying the Upper Cretaceous fan sequences. The latter event occurs in response to large-scale drainage reorganisation of the South African hinterland which ultimately results in the cessation of large-scale clastic drainage along the South African transform margin.

This talk will detail how discrete tectonic episodes have resulted in the deposition of thick source rocks, large volumes of stacked coarse clastic reservoirs, and structural geometries which generate, and enhance, hydrocarbon traps in this frontier deepwater basin.

Feedbacks of sedimentation and lithosphere deformation on thermal evolution of rifted margins

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Abstract
The thermal evolution of continental rifted margins is key to understand the rift processes and the maturity of sedimentary basins, but it does not always comply with classic rifting models. Here we use 2D numerical models which couple surface processes, i.e. sedimentation and erosion, to plate deformation to investigate the relationship between rifting processes, sedimentation and thermal history of passive margins. We show that top basement heat-flow and temperature are strongly related to the rift deformation pattern: peak basement temperatures and heat-flows occur much earlier than break-up time for locations in the proximal margin and decay progressively as deformation migrates towards the future basin center. When sediments are considered, top basement temperature depends as much on stretching factor as on the thickness of overlying sediment pile. In the postrift, the lithosphere should have relaxed to its original thermal state at 60 Myr after break-up, for typical lithosphere thicknesses, according to classical models. However, in our models the magnitudes of heat flow and temperature still increase from the proximal towards the distal margin at this time. In this presentation we discuss these results, show how they can explain some anomalous observations in distal Mid Norway and South China sea margins, and discuss the implications for the thermal and basin maturity histories of passive margins in general.

It's a bit of a squash and squeeze; revised timings of rifting, uplift and erosion in the Gamtoos Basin, South Africa from biostratigraphic analysis

Gavin Elliott
NewAge (African Global Energy) Ltd
Janice Weston (Weston Stratigraphic Ltd)

The Gamtoos Basin is an enigmatic rift basin, located predominantly offshore southern Africa, with rapid rifting followed by structural inversion that led to a complex uplift and erosion history. Rifting occurred from the Oxfordian to Late Valanginian with crustal heterogeneities inherited from the Late Paleozoic Cape Fold Belt controlling basin size, location and structural evolution. From the Late Valanginian to the Albian, the Agulhas-Falklands Fracture Zone (AFFZ) to the south of the Gamtoos Basin was an active transform margin as the Falklands Plateau passed by triggering inversion, uplift and erosion of the earlier rift basins. Understanding the timing, duration and extent of these events is key to unravelling not only the petroleum potential of the basin but also the wider understanding of how southern Africa separated from the Falklands Plateau.

Dates presented in scientific literature for these events are derived from the original biostratigraphic analyses carried out on wells drilled in the 1970's and 1980's. NewAge currently operate a licence over the Gamtoos Basin and carried out a biostratigraphic study of five key wells to refine the chronostratigraphic framework and gain insight into paleo-environments. The results of the study, when combined with those from recently reprocessed 2D seismic data and well logs, have revealed a number of insights into the evolution of the Gamtoos Basin that will challenge the perceived wisdom.

Five wells were selected for the study spread across the basin with two in the immediate hangingwall of the main basin bounding fault, two in the basin fringes and one on a structural high. Micropaleontological slides were provided by Petroleum Agency SA and in total 1209 slides were examined over 10,050 m of section covering the Late Jurassic to Early Cretaceous. The study has shown that the Upper Jurassic section is much thicker than previously thought, with a Top Jurassic pick moved upwards by at least 1 km in most wells. The Top Jurassic is marked by an unconformity with duration of ~ 10 - 13 Ma across the five wells. Seismically, this surface is a prominent reflection event but with little indication of erosional truncation and could potentially represent a basinwide hiatus. The lowermost Cretaceous section, Berriasian and Lower Valanginian, is largely absent with a thick Upper Valanginian to Hauterivian section overlying the Jurassic strata. This is capped by the regional Late Albian erosional unconformity which is considered to represent the end of the active transform motion on the AFFZ.

These new dates indicate the Jurassic rifting may have been more rapid than previously thought leading to high sedimentation rates in rapidly subsiding marine basins. The Top Jurassic event may represent a structural hiatus between rifting and transform motion on the AFFZ. The impact of this revised basin chronology on the petroleum system will be discussed in the paper along with comparisons to structural evolution models for the southern Africa transform margin.

Session Four:
Volcanism & SDRs and Mantle Processes

KEYNOTE: **Relationships between heatflow, stratigraphic architecture, residual depth anomalies, and mantle convection at South Atlantic margins**

Nicky White
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The outstanding success of quantitative rifting models conditions the way in which we analyze large-scale structural and thermal characteristics of deep-water margins throughout the South Atlantic region. For example, generation of subsidence and/or uplift is usually linked to the isostatic interplay of crustal and lithospheric thinning, which are ultimately controlled by horizontal plate motions. Despite this success, there is ample evidence that both vertical movements and thermal anomalies at these margins are influenced by sub-lithospheric mantle processes. The clearest evidence comes from analysis of residual depth anomalies measured on oceanic crust that abuts deep-water margins. Seismic reflection and legacy seismic wide-angle profiles are used to measure these anomalies which represent positive and negative deviations from the well-known oceanic age-depth relationship. Along the South Atlantic margins, residual depth anomalies have amplitudes of +/- 1 km and wavelengths of 100-10000 km. The largest anomaly occurs in the Argentine abyssal plain which is more than 1 km deeper than it should be. The spatial pattern of anomalies is consistent with long-wavelength gravity anomalies and with upper mantle seismic tomographic imagery. There is compelling evidence that this mantle-controlled dynamic topography has had a profound influence upon adjacent continental shelves. For example, along the Brazil, Argentine and West African margins, a series of broad structural domes and swells straddle these continental shelves. Uplifted marine terraces, offshore stratigraphic geometries, and fluvial drainage patterns all suggest that these domes developed during Cenozoic times. In summary, it is becoming clear that mantle convection plays a significant, and hitherto underestimated, role in moderating vertical movements, stratigraphic architecture and organic maturation at deep-water margins.

Ridge/rift jumps and margin asymmetry at magma-rich margins: Some implications for the formation of the Austral South Atlantic and its petroleum systems

Ken McDermott (1), Christian Heine (1), Philip Thompson (2)

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The Lower Cretaceous breakup of Gondwana that resulted in the formation of the South Atlantic Ocean varied in its magmatic budget from North to South. The austral segment of the South Atlantic (ASA), between the Florianopolis and Falkland – Aghulas Fracture Zones represents the archetypal conjugate magma-rich continental margin pair composed of stretched continental crust separated from oceanic crust by a continent-ocean transition zone (COTZ) that containing all of the tectonomagmatic elements typically observed at magma-rich margins: seaward-dipping reflectors (SDRs); landward-dipping faults; volcanic outer-highs; lava deltas; and high-velocity lower crust/underplated zones.
While the process of SDR formation is largely a symmetric, it is apparently at odds with observations across the ASA's conjugate margins where the distribution of magmatic crust on the Southwest African margin is consistently wider than that of the South American margin. Many authors explain this asymmetry through lithospheric-scale plume – rift centre interactions with some more recent observations suggesting ridge/rift jumping may have a role. Asymmetry in oceanic accretion (s.s) is also observed in oceanic magnetic striping leading some workers to suggest variable spreading velocities across the mid-ocean ridge with significant implications for global plate modelling.
We present results from an integrated mega-regional conjugate study defining the crustal structure of the South Atlantic conjugate margins, here focussing on the distribution of three identified crustal types across the ASA: continental; magmatic; and oceanic crust. These crustal domains are separated by the Oceanward Limit of Continental Crust (OLCC) and Landward Limit of Oceanic Crust (LALOC) boundaries, and describe the composition, and formation processes of the magmatic crust.
We demonstrate that while accretion of magmatic crust is indeed strongly diachronous (oceanward younging), there are areas where SDR geometries suggest landward younging, delineating abandoned ridge/rift-centres (ARCs). ARCs are dominantly preserved along the SW African margin and we suggest are the cause of the observed margin asymmetry.
Additionally, we recognise two end-member rift modes within the South Atlantic that differ significantly due to their relative magmatic budget during rifting ranging from mechanical (shear dominated, low magma budget) to magmatic (dominated by crustal dilation and accretional; high-magma budget). Considering rifted margins in the context of these endmembers leads us to propose refinements to how magma-rich margins should be interpreted and analysed in order to integrate with basin modelling workflows. For the strongly magmatic ASA calculating continental crustal stretching (β-factors) is not of particular use since continental breakup occurs though crustal dilation and accretion rather than stretching. A more appropriate analysis of crustal composition for basin modelling purposes may be to consider continental thinning (γ-factor) together with magmatic additions with reference to departures from typical oceanic thickness (Ω-factor).
Finally, we consider the implications magmatic crust, margin asymmetry and the impact of igneous additions may have on conjugate margin prospectivity within the ASA.

Dynamic topography and Crustal Architecture

Neil Hodgson
Searcher

As all continents that rift and part with the creation of new, ocean crust is by definition a volcanic event, it may be a surprise that precisely half the world's passive margins are described as magma poor and half are magma rich. So what do we mean by rich or poor? - The transition from continental to oceanic crust on magma-rich passive margins is adorned by volcanic seaward dipping reflectors (VSDR's) - flood basalts in fan-stack terrains. Other continental - oceanic crust transitions either show very abrupt, or very extended crustal stretching yet no sub areal flood basalts (VSDR's). These then are the magma poor margins. Both magma poor and magma rich margins can be extensive laterally on the scale of 1000's km - the implication is that two very different processes are at work on a grand scale and somehow complicated machinery dictates the fight for supremacy of either. Yet on another scale, these two end member crustal architectures styles can speak of a rift to drift transition that is just either sub areal (magma rich), or subaqueous (magma poor). And so the question becomes not whether the margin is magma rich or magma poor - but why the beginning of volcanic eruption during rift to drift transition was above or below free water level. Convection within the earths upper mantle below an active rift could provide a simple answer. The dynamic topography of the oceanic crust in the southern Atlantic will be discussed as a proxy for mantle convection and the possible consequences of this discussed in terms of the dominant rifting and drifting process.

Magmatic margin processes – the importance of understanding along and across margin variability on exploration

Douglas Paton[1], Estelle Mortimer[2], James Norcliffe[2], Paul Markwick[3], Jonathon Salomo[4] Chantell Van Bloemenstein[4]

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The southern South Atlantic is regarded as an archetype magmatic margin in which exceptionally well imaged Seaward Dipping Reflectors (SDRs) have been identified. In this contribution, we present the most recent models of SDR and magmatic margin formation and apply them to the Orange Basin. The models invoke crustal attenuation with magmatic addition during the formation of Inner SDRs followed by a period of Outer SDRs formation. This second phase, which is best understood through sequential section restorations, is entirely driven by magmatic processes and involves the interaction of lateral flows and magmatic dyke interactions. We use these concepts and identify the lateral variability of the magmatic system from our regional mapping to consider how the interaction of pre-breakup configuration and the along-margin changes in magmatic plumbing system impacts margin evolution. Whilst these concepts are globally applicable, we make two significant observations in the Orange Basin that not only require further consideration but have a significant impact on the application to the associated hydrocarbon system.

Firstly, a detailed magmatic-seismic interpretation of the Orange Basin, coupled with analysis of the magnetic spreading chrons, questions the long-held assumption that the basin was dominated by a progressive northward unzipping event.

Secondly, despite the abundance of SDRs throughout the Orange Basin and its conjugate, the SDRs are noticeably absent in the southern portion of the margin. This apparent “switching off” of the magma system is poorly documented.

Both of these observations force us to re-evaluate the processes that were active during the period of lithospheric break up in the South Atlantic. Furthermore, as the nature of the magmatic margin evolution has a fundamental control on paleobathymetry at the point of break-up, the observations require us to also re-evaluate the current understanding of source rock and clastic versus carbonate reservoir distribution models.

Day Two
7th October 2021

KEYNOTE: Frontier exploration in the Southern South Atlantic – can it defy the odds?

Bryan Gill
Westwood Global Energy

Southern South Atlantic Activity and Performance

Since 2010, 20 frontier play exploration wells have been drilled offshore in five countries across both margins of the Southern South Atlantic, half offshore South America and half offshore Africa. These wells have tested 15 different plays (as defined by basin, reservoir age and lithology) in eight different basins, and have resulted in commercial discoveries in just two cases, a frontier well success rate of 10% and a frontier basin success rate of 25%.

The Sea Lion field was discovered in 2010 by Rockhopper Exploration in Lower Cretaceous sandstone in the North Falkland Basin. The discovery was made in the second well of a 2010 campaign and followed six unsuccessful wells drilled in the basin in 1998. Since the initial discovery well a further 12 exploration wells have been drilled with potentially commercial discoveries at Casper and Zebedee. In total, around 500mmboe has been found in the basin, but 11 years after discovery the Sea Lion project is still awaiting FID.

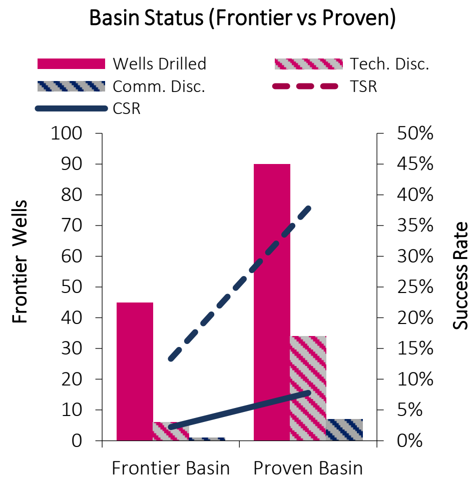
The Brulpadda discovery was made in 2019 by Total in the Outeniqua Basin in South Africa. The discovery well encountered 57m net gas condensate pay in two Mid to Lower Cretaceous reservoirs, ~~including~~ and a thin oil leg. A second discovery was made in the play at Luiperd in 2020. The discoveries are in ~1400 m and ~1800m water depth with extremely challenging metocean conditions.

Elsewhere in the Southern South Atlantic exploration has been disappointing. Eight wells have been drilled in Namibia since 2010 with no commercial success, and one frontier test each in Argentina and Uruguay.

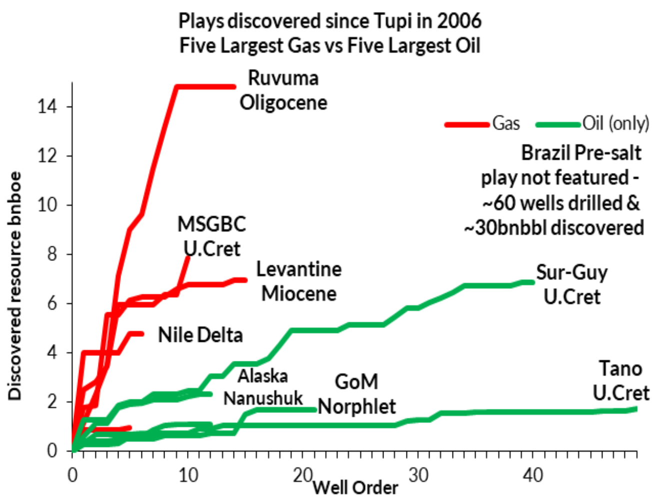
Global Frontier and Emerging Play Exploration

Frontier exploration carries significant risk. Since 2010 the global commercial success rate for frontier exploration wells has been 6%, with frontier play wells in unproven basins delivering a commercial success rate of only 2%, versus frontier plays in proven basins at 8%.

Recent frontier success has generally offered relatively modest rewards to the industry. Plays have either turned out to be limited in scale or have proven difficult to commercialise in a reasonable timeframe. Significant gas volumes have been found in Oligocene play of the Ruvuma Basin in East Africa but much of the resource remains stalled due to above ground challenges. In the MSGBC progress is being made on Tortue, but there is a significant risk that the gas at Yakaar and Orca may remain stranded. The Upper Cretaceous Liza play in the Suriname-Guyana Basin is the only oil play opened since the pre-salt of Brazil in 2006 to exceed 2.5bnbbl of oil resource.



Frontier basin and play activity and success rates 2016-2020

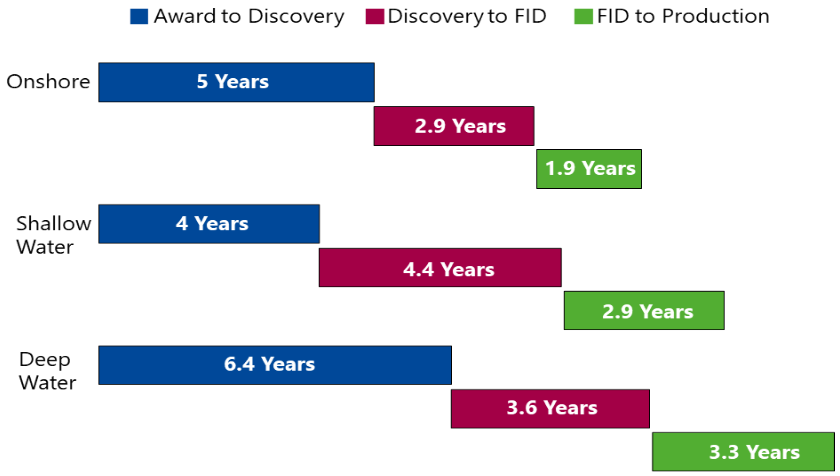


Creaming curves for emerging plays opened since 2006

Westwood has identified five to seven frontier wells in Namibia, South Africa, and Argentina to be drilled in the next two years. Statistically, the chance of success of this programme is very low and even the success case the resource that could be opened up may be limited.

As governments and companies respond to the energy transition away from hydrocarbons, the time taken to bring a hydrocarbon discovery onstream, with potentially net zero emissions, is becoming more important. In the median case, deep water discoveries take around six years from initial licence award to discovery and a further seven years from licence award to first production. A frontier discovery made in 2021 may not be onstream before 2030 and payback may not occur before global demand for hydrocarbons is reduced by growing energy supply from renewables. A well planned on a recently awarded exploration licence may not be in production until well into the 2030's.

So will these wells beat the odds and what does the future hold for frontier exploration in the Southern South Atlantic and globally?



Time from Licence Award to Discovery, Discovery to FID and FID to first production for High Impact wells

Session Five: Reservoir Systems/Source-to-sink

KEYNOTE: Contourites and Mixed Depositional Systems along the southern south Atlantic and its economic implications

Hernández-Molina, F. J.[1]; Rodrigues, S.[1]; Kirby, A.[1]; Thompson, P.[2], Badalini, G.[3], Viana, A. R.[4]; Rodriguez, K.[5], Hodgson, N.[5], Conti, B.[6], Went, D.[7], Miramontes, E.[8], Wilckens, H.[8]

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Sediment gravity flows and along-slope bottom currents (contour currents) are the two main deep-water sedimentary processes that shape and modify submarine sedimentary successions along modern and ancient continental margins. Over the last decade, numerous marine bottom current-controlled depositional, erosional and mixed features have been recognized along continental margins and within abyssal plain regions across the world's oceans (Fig. 1).

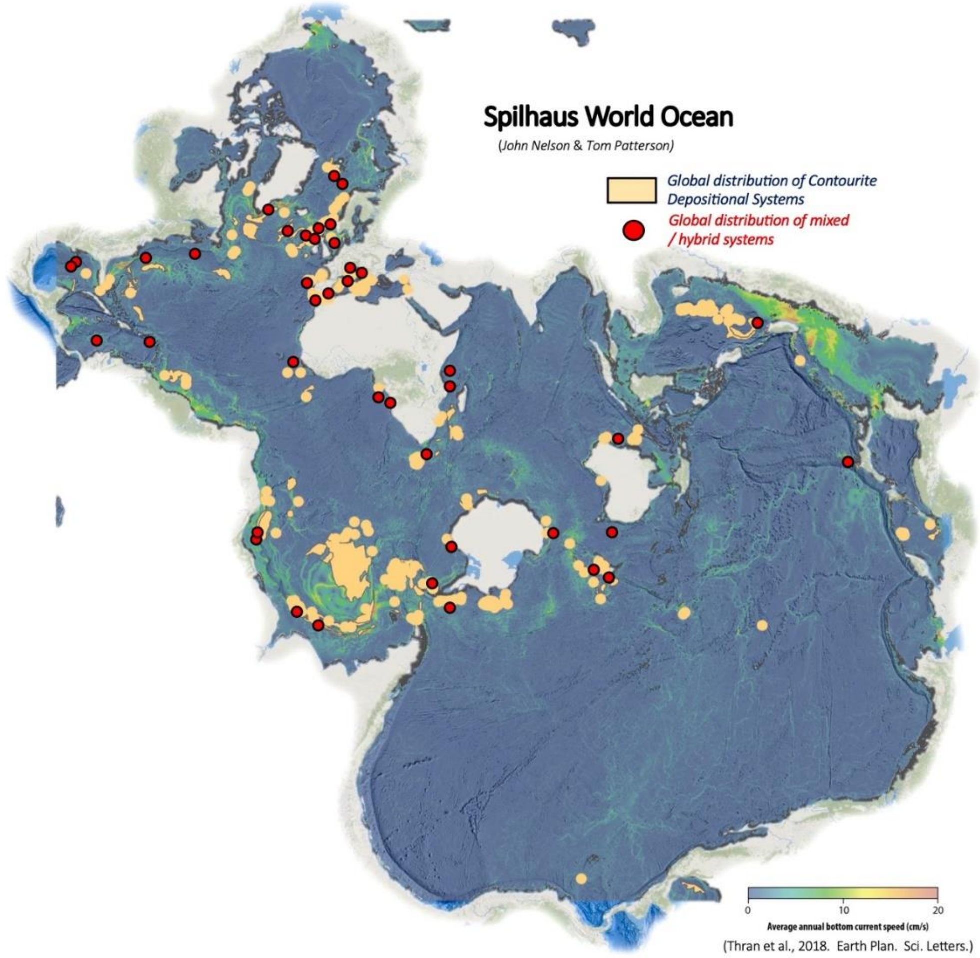

Figure 1. Compilation map for the global distribution of contourites and mixed systems on deep-water environment, with a projection. It can be noticed that the southern south

Atlantic represents a hot spot for the formation of these systems. Global average bottom current speed on the background from Thran et al. (2018).

At the current time, there is an explosion of examples of *Contourites* and *Mixed Depositional Systems* described through academic and industry research. New models are being proposed and there is a growing interest in these systems, in their origins, their deposits and evolution, their relationship with deep-sea ecosystems, geological hazards, and even their economic potential. The continental margins along the South Atlantic are not an exception to that (Fig. 1). In the 1970s research began to show the influence of deep-water bottom currents along the South Atlantic margin with more intense research in the 1990s providing more detailed observations and analysis of water masses, their associated oceanographic processes (e.g., eddies, deep sea storms, internal waves, etc), and their influence on deep-marine sedimentation.

Research has shown that the long-term evolution of regional water masses exerts a first order control on continental margins, including controls on sediment input points and sedimentary stacking patterns of deep-water sedimentary successions. However, the local-scale processes and facies variations, which are more difficult to analyse, are fundamental to the understanding of contourite facies development, including sandy contourite deposits in deep-water settings, which represent an entirely different deep-water sand deposit from the classic turbidite sands. Sandy contourites are documented from many margins – both modern and ancient - including those along the South Atlantic with sand-rich facies typically found along contourite terraces, channels and at the exit (or relatively close to the exits) of straits/gateways. As a result, the value of understanding *Contourites* and *Mixed Depositional Systems* has increased dramatically in recent years with research investment from the energy industry to better understand turbidite-contourite systems and their potential to form a key part of the future exploration strategy which has often only focussed on classic turbidite reservoirs.

This work summarises those finding along the South Atlantic which shows clear evidence of bottom current influence on sedimentation through the Mesozoic, Cenozoic to present-day. large basin-scale depositional, erosional and mixed features are described showing examples of *Contourites* and *Mixed Depositional Systems*, based on 2D and 3D seismic profiles and to the sedimentary facies scale. Their implication in energy geosciences are highlighted and discussed, especially in the occurrence of reservoirs, seals and source rocks. Moving forward, a closer collaboration between industry and academia is needed to better understand these sedimentary systems, especially how, and when, deep-water environments are shaped by bottom-current dynamics. While these systems have become a target for deep-water exploration, reservoir evaluation and development, uncertainty persists as to how these specific features are formed. In particular the understanding the sedimentology of these systems will allow us to better understand all aspects of the mechanism for hydrocarbon entrapment. We discuss new plays that are unique to hybrid systems, new reservoir and seal distribution models and new approaches to hydrocarbon charging. Whilst pertinent for exploration, a re-evaluation of observations on fields and discoveries on the slope of many passive margins may yield new insights into their formation and improve our understanding. Therefore, new conceptual models are needed to evaluate specific questions of how they could contribute to Energy Geosciences and the Low Carbon Energy Transition.

This project is funded by the Joint Industry Project supported by TOTAL, BP, ENI, ExxonMobil, Wintershall Dea and TGS within the framework of “The Drifters Research Group” at Royal Holloway, University of London (RHUL).

The timing and importance of contour current activity in the Southern South Atlantic

Jochem Bijkerk[1], Philip Thompson[1], Piet Lambregts[1]
[1] *Shell International Exploration and Production*

Theme:
Day 2: Play Elements - Reservoir systems (inc. DW clastics; carbonates; contourites)

In areas with (paleo-)contouritic currents such as the South Atlantic, sedimentological models that focus solely on turbidity or contour currents are insufficient to explain observations on modern 3D seismic data sets. With past and present Deepwater acreage positions in the Pelotas, Orange and Cape Basins, Shell has excellent 3D seismic coverage to assess the timing and importance of contour current activity for hydrocarbon exploration.
Contour current activity in this area is intermittent which is related to variations in e.g. the overall state of oceanic circulation and tectonic events such as the opening of sea straits. Shortly after open ocean circulation was established during the Albian observations asymmetric drifts developed along turbiditic deposits in the Orange Basin, whilst Middle Cretaceous to Upper Cretaceous sediments on the conjugate in the Pelotas Basin record similar features orientated in an opposite direction suggesting the presence of deep water currents. Evidence for strong northward shallow water currents affecting the upper slope are observed in Cenozoic of Namibia, while the Cenozoic contouritic record of Uruguay has been widely published and related to various oceanographic events and variations in a highly stratified water column.
Although most interest has been aimed at the effect of contour currents on reservoir, they can affect all play elements, ie. charge through their effect on source rock distributions, or provide a sealing facies, while the ability to strongly affect slope morphology provides the opportunity to develop additional stratigraphic traps. The current challenge for hydrocarbon exploration regarding contour currents is how these currents contributed to the stratigraphic records, as well as when and where they did so. A good understanding of these questions can strongly benefit frontier hydrocarbon exploration in this area.

The Tale of Two Rivers: Effect of Southern African Uplift on Reservoir Distribution in the South Atlantic

Abbey Hunt[1], Tony Younis, Philip Birch
Impact Oil & Gas Limited

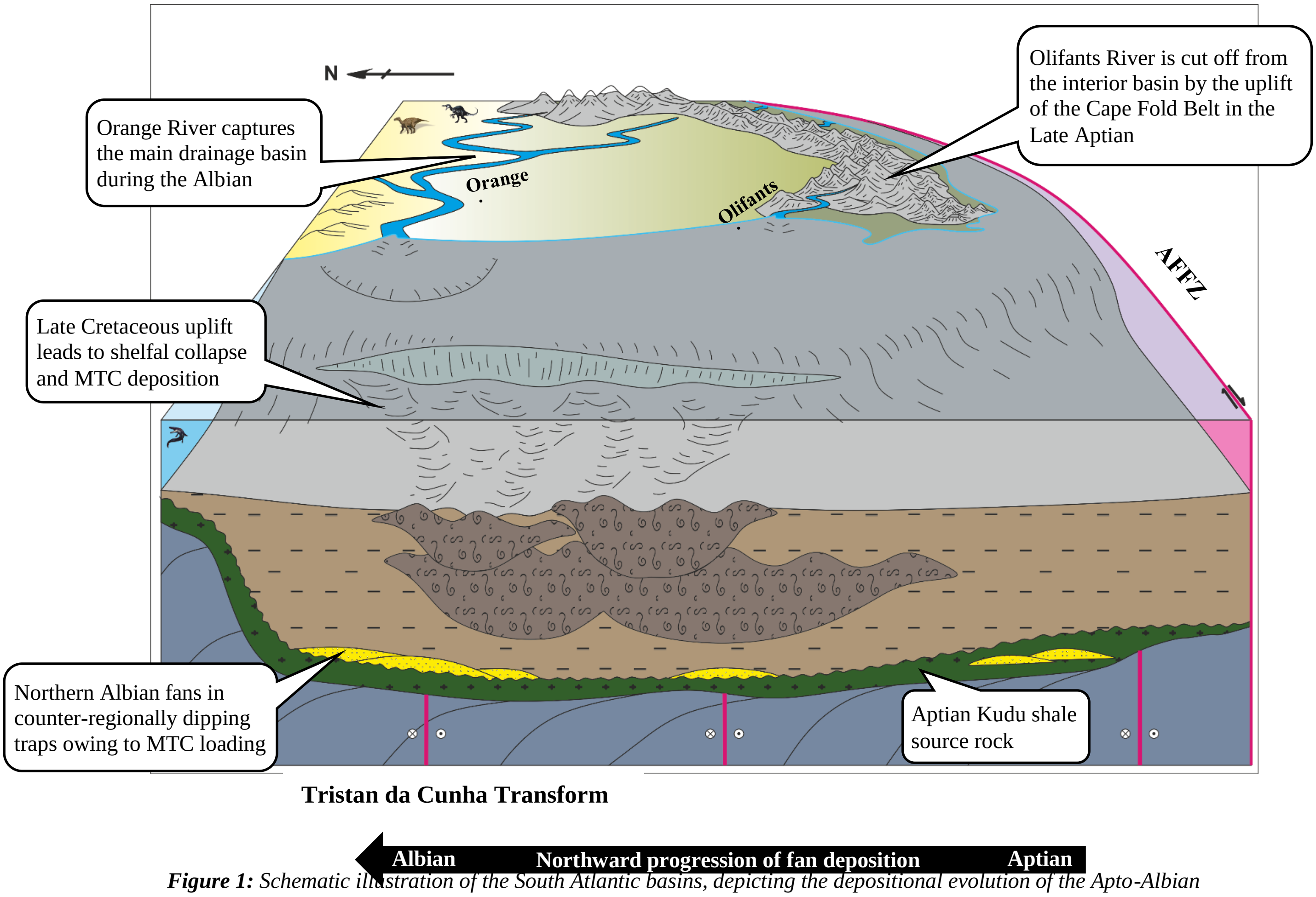

***Figure 1:** Schematic illustration of the South Atlantic basins, depicting the depositional evolution of the Apto-Albian sedimentary fairways within the Outer Basin due to regional tectonic processes.*

Not only did the opening of the South Atlantic provide optimum conditions for the deposition of the proven, 'Kudu' shale source rock during the Apto-Barremian, it led to the deposition of extensive Apto-Albian basin floor fans across large parts of the deepwater Orange and Cape Basins.

Since the early Cretaceous, Southern Africa has experienced an estimated 6km of erosion, calculated by a combination of borehole data and outcrop data (Tinker, de Wit and Brown, 2008), resulting in high volumes of sediments being deposited in the offshore Orange and Cape Basins, principally via two major rivers: the Olifants and Orange Rivers. The evolution of these river systems can be linked to an early Cretaceous uplift between 140Ma and 115Ma, evidenced by AFTA data and shifting offshore depocentres mapped using seismic data across the entire SW Atlantic margin.

A question remains regarding the cause of this uplift, with the opening of the South Atlantic and coeval onset of the Agulhas-Falkland Fault Zone (AFFZ) in the Berriasian (142Ma) seemingly being the driving mechanism for a time transgressive, early Cretaceous uplift across the Palaeozoic Cape Fold Belt (CFB) and into its adjacent Karoo foreland. Dating of extensive kimberlite intrusions within Southern Africa suggests that a second mechanism may have also contributed to the denudation of over 3.5km in this region. A notable cluster of kimberlite intrusions within the Kalahari craton were emplaced between 135Ma and 120Ma, aligned with NW-SE and NE-SW trending lineament corridors that controlled the early opening of the South Atlantic. These potentially contributed a thermal element to the uplift. On a localised scale, thermal effects were also experienced along the transform of South Africa as the mid-ocean ridge migrated along the margin during break-up of Africa and South America.

As the Southern Africa uplift story begins to unfold, the link between its timing and the spatial and chronostratigraphic distribution of reservoirs within the Orange and Cape Basins becomes clearer. The early Cretaceous uplift resulted in the deposition of Apto-Albian basin floor fans, that can be mapped clearly on seismic data, and extend as far as 450km offshore, depositing reworked CFB and Karoo sediments into the nascent South Atlantic. The time transgressive nature of the uplift created a diachroneity in fan deposition as onshore drainage patterns evolved – seismic interpretation and resulting isopach maps (e.g. Baby et al., 2018) indicate the oldest fans exist in the southern Cape basin and young northwards into the Orange Basin. During the Aptian, a huge volume of sediment was deposited by the proto-Olifants river, the dominant river at the time. However by Albian times, the uplift and consequent re-emergence of the Cape Fold Belt (CFB), following earlier orogenic collapse, resulted in the severance of the proto-Oliphants from its pre-established drainage basin, which was then subsequently captured by the Orange river on the western coast and the Mzimvubu and Groot Kei rivers on the eastern coast. In the South Atlantic, this resulted in the deposition of extensive basin floor fans at the front of the Orange River delta, covering an area over 15,000 km^2, and straddling the maritime boundary between Namibia and South Africa.

A tectonically quiet period from the Late Albian to Early Cenomanian allowed for the deposition of a widespread sealing shale above these basin floor fans. AFTA data, together with well and seismic data, indicates a second period of uplift during the late Cretaceous, from the Cenomanian (100Ma) to the Campanian (80Ma). An associated rapid increase in sediment load to the Orange Delta triggered the formation of a thick sequence of mass transport deposits (MTCs) in the Orange Basin, providing not only an ultimate seal, but the necessary overburden required to place the Aptian 'Kudu' source rock on the abyssal plain into oil maturity. Another notable consequence of MTC loading has been the creation of counter-dipping trapping styles.

With an improved understanding of the onshore uplift of Southern Africa and its aforementioned consequences on sedimentary processes, new and exciting opportunities are being developed that may unlock a new era in ultra-deepwater exploration.

Session Six:
Reservoir Systems/Source-to-sink continued

High-resolution sedimentary budget quantification from the Cenozoic deposits in the Pelotas Basin, South Atlantic: workflow and implications for Source-to-Sink studies

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2 YPF S.A. Exploration, Buenos Aires, Argentina
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4 Pampa Energía –Maipú 1, Buenos Aires, Argentina
5 TOTAL E&P, CSTJF, Pau Cedex, France

Source-to-sink (S2S) studies give a new breath for basin analyses, both in (i) understanding the sedimentary basin deformation and (ii) identifying new plays and prospects. S2S studies are commonly based on the quantification of sediment supply, often deduced from sedimentary budgets.
In this contribution, we propose a high-resolution sedimentary budget quantification method that has been applied at basin-scale for the Cenozoic deposits of the Pelotas Basin (offshore southern Brasil and Uruguay, South Atlantic). A new workflow is implemented including five main steps: (1) basin-scale analysis and characterization, (2) quality control and selection of reference 2D dip-sections, (3) HR seismic stratigraphy analysis, (4) sediment supply estimation taking into account lithology and porosity corrections and then (5) the estimation of the sedimentary budget curve including 41 time-intervals for the last 65 Myr. Variance ranges were determined considering the parameters of the method on the case study. The main uncertainties are related to the seismic velocities for the time-to-depth conversion (5%–22%), the method for lithological parameters quantification and associated porosity correction (4.4%–14.3%), the absolute ages of stratigraphic markers (1%–25%), and the proportion of in-situ sediment production (0.3%–0.5%).
This workflow allows the identification of several cycles from an entire sedimentary basin fill characterized by pulses of sediment supply (Qs) whose growth phase lasts less than 1 Myr, followed by a constant phase lasting 1–2 Myr, and finally an exponentially decreasing phase lasting 2–5 Myr. These pulses alternate with phases where the sediment supply was very low for intervals of ca. 1–5 Myr.
Ten major pulses were recognized for the Cenozoic. At the end of the Eocene and up to the Middle Oligocene, Pulses 1, 2 and 3 are organized in an overall increase of their maximum value, ca. 41,000; 121,000 and 247,000 km3/Myr respectively. These three pulses are about 4-6 Myr of duration and mark the first clear pulses following a 28 Myr-long period (Paleogene) characterized by very low sediment supply, ranging from 26,000 to 30,000 km3/Myr (half of the mean value of the Cenozoic). Just after pulse 3 (ca. 27-23 Ma), the sediment supply was very low, with about 10% of the mean value for the Cenozoic (ca. 5,000 km3/Myr). This period corresponds to a large portion of the Upper Oligocene. At the base of the Miocene, Pulse 4 was organized as the previous ones, with similar duration and amplitude (ca. 142,000 km3/Myr). Similarly to Pulse 3, Pulse 4 is followed by a 4-5 Myr-long period (ca. 19-14 Ma) of very low sediment supply (ca. 6,500-14,000 km3/Myr). Pulse 5 (ca. 14-10 Ma in the Middle Miocene) was the most important sedimentary pulse of the Cenozoic, about 15 times larger than the average value for the era (of ca. 800,000 km3/Myr). The Qs decrease is very rapid, in less than 4 Myr. Pulse 6 lasted for ca. 3 Myr with a maximum of about 66,000 km3/Myr during the Upper Miocene. During the uppermost Miocene, Pulse 7 lasted for ca. 4 Myr and is characterized by a longer plateau with a maximum Qs value of ca. 105,000 km3/Myr. It is followed by a 1 Myr-long period (ca. 4.5-3.5 Ma) with very low sedimentation rate (ca. 8,000 km3/Myr). During the Plio-Quaternary, Pulses 8, 9 and 10 had shorter duration (cycles of 0.3-0.5 Myr) than the previous ones. Pulses 9 and 10 have maximum Qs values about 5 times higher than the mean Cenozoic rates, with 262,000 and 225,000 km3/Myr respectively.
We propose that the sediment supply dynamic in the Pelotas basin records the orogenic phases of the Andes located more than 2,000 km upstream (Fig. 1), and that the recorded Qs

pulses in the basin are out of phase with respect to the active tectonic phases of the Central Andes. Finally, by comparing the volume of preserved sediment and the production capacity of the catchment, we suggest that an additional source of sediment besides the Brazilian craton and the Andes should be envisaged, potentially associated with deep-water oceanic circulation.

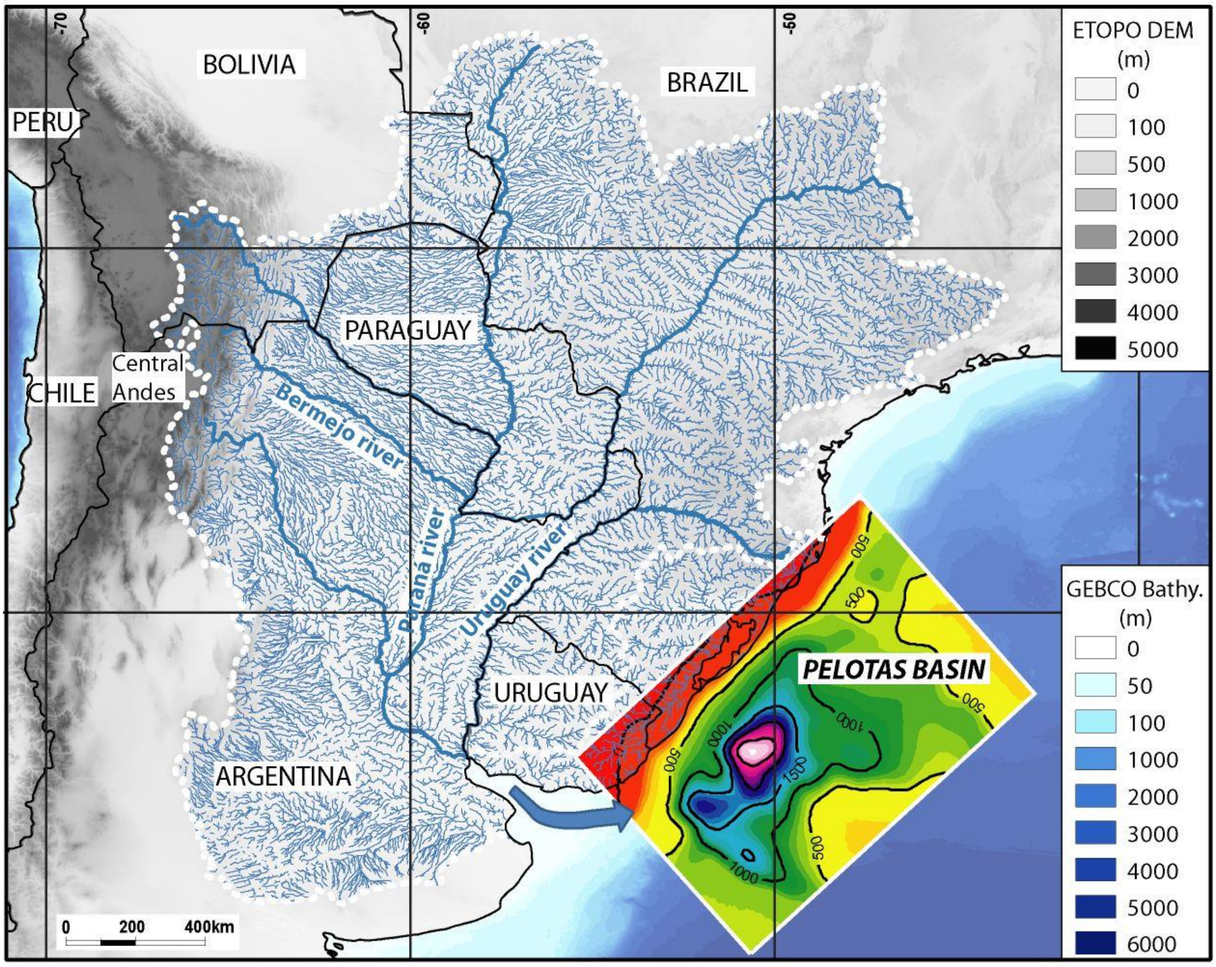

Figure 1. Paraná to Pelotas source-to-sink system located along the South Atlantic South American passive margin. Hydrographic system of the Paraná river presented in blue. Thickness map of the Plio-Quaternary deposits from the Pelotas basin in meters (modified from Rohais et al., 2021).

Late Cretaceous mixed (turbidite-contourite) systems along the Argentine and Uruguayan margins: onset, depositional evolution and conceptual implications

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Along- and down-slope processes are two key sedimentary processes in shaping most continental margins. Their interactions can build large mixed or hybrid turbidite-contourite systems, characterized by a wide range of features and deposits. Globally, several mixed systems have been identified in the Cenozoic record, however their representation in the Mesozoic remains severely understated.

A significant example has been recently discovered across the Cretaceous record of the Argentine and Uruguayan margins, over 280,000 km^2 (Fig. 1). This mixed depositional system was studied using new 2D broadband seismic reflection data, 3D seismic cubes, and chronostratigraphic well data (Fig. 1A). This system developed along the middle continental slope to upper rise, between 3500 and 6500 m depth, with nineteen 300-500 m thick mounded drifts, separated by sixteen 2-5 km wide submarine channels (Fig. 1B).

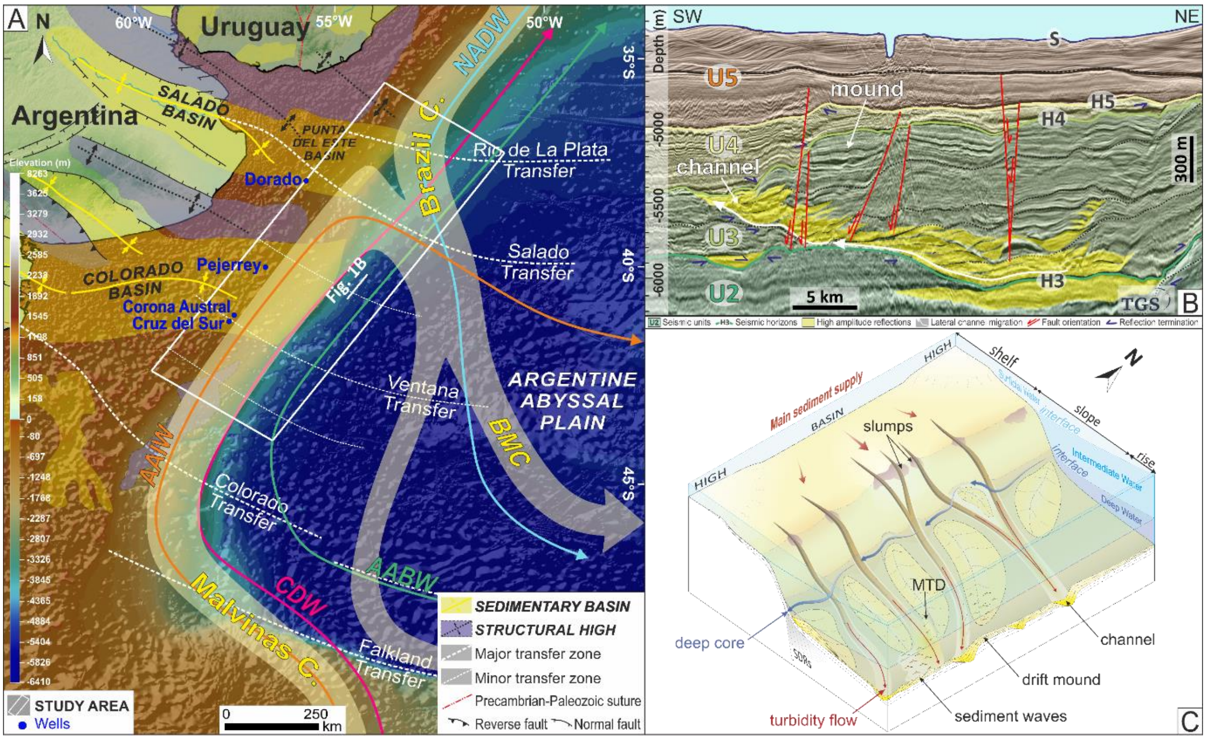

Figure 1. A) Bathymetric map of the Argentine and Uruguayan margins, depicting the past structural configuration, present-day oceanic circulation, and location of the main study area; B) Interpreted seismic profile along the Argentine margin, presenting the main seismic units (U1 to U5) and discontinuities (H1 to H5), as well as the key morphological features of the mixed depositional systems; and C) Depositional model for the Cretaceous mixed systems, formed by synchronous interactions between down-slope turbidity flows and along-slope bottom currents. AABW – Antarctic Bottom Water; AAIW – Antarctic Intermediate Water; BMC – Brazil-Malvinas Confluence; CDW – Circumpolar Deep Water; NADW – North Atlantic Deep Water; S – Seafloor; SDRs – Seaward dipping reflectors.

A detailed seismic stratigraphic interpretation revealed four distinct stages of evolution: i) a *pre-drift stage* (~125 – 89.8 Ma) from the Aptian to the Coniacian, characterized by the formation of initial turbidite systems during thermal subsidence of the Argentine and Uruguayan margins; ii) an *onset stage* (~89.8 – 81 Ma) developed between the Coniacian and Campanian, which recorded the first exchange between SE-oriented turbidity flows and weak SW-flowing bottom currents; iii) a *growth stage* (~81 – 66 Ma) from the Campanian to the Maastrichtian, characterized by maximum drift and channel growth, with progradation and expansion of the mixed systems towards SW due to frequent, synchronous interactions between the along-slope bottom currents and the down-slope turbidity flows (Fig. 1C); and iv) a *burial stage* (~66 Ma) in the Paleocene, where the mixed depositional systems were preserved below an extensive contourite system, due to a persistent bottom current intensification (which has continued until the present-day) and a gradual reduction of the down-slope gravity-driven processes. These evolutionary stages recorded the Mesozoic to Cenozoic paleoceanographic circulation and the formation of intermediate- and deep-water regimes after the breakup of Gondwana (~125 Ma ago) and the northward opening of the South Atlantic Ocean. Other control factors have shaped the evolution of these systems, such as inherited morphological structures (Fig. 1A), regional tectonic events and recurrent gravitational processes (Fig. 1C).

The present results were compared to other mixed depositional systems, to better understand these complex morphological features and their stratigraphic stacking patterns. This comparison allowed us to differentiate two end members of drift and channel migration (e.g., up-current versus down-current systems) and identify synchronous to asynchronous interactions between along-slope bottom currents and down-slope turbidity flows. The distribution of the different morphological elements and their lateral migration reflects the imprint of the most influential process, as well as the changing energy, velocity, frequency, and timing between the two processes. The inferred interactions result in unconventional plays, where sand-rich reservoirs, deposited across channels and channel margins, are sealed by the laterally migrating, mounded drifts. These results reveal a significant exploration potential and present a new target for the exploration industry.

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Session Seven: Source & Thermal Modelling

Integrated basin modelling on the Argentinian Slope

Sebastian Hinsken
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Anne Sofie Andersen, Hans Morten Bjørnseth, Christopher Stadtler (Equinor IOF) and Stephen Anthony Clark (Equinor R&T)

Integrated Basin modelling has been applied offshore Argentina. The method is based on tectonic forward modelling of carefully chosen basin scale cross sections. The modelling was developed and calibrated with wells for the South Atlantic with focus on the outer tectonic domains. On the Argentinian Slope rifting commenced in the Jurassic (≈ 175Ma) and continental breakup happened in the Early Cretaceous (Valanginian/Hauterivian) involving major SDR-Wedge formation. Syn-rift sedimentation was limited, and deep erosion of the pre-rift sequence indicate major uplift and erosion during the syn-rift to break up stage. Today the Argentina Slope is at lower elevation than the conjugate South African side (ca. 1km) and infill patterns indicate young subsidence. Dynamic topography is seen to account for the present and past topographic anomalies and needs to be added into the equation in order to obtain realistic beta-factor and paleo water depth results. Heat flow and paleo water depths derived from the tectonic forward modelling were successfully used for basin modelling allowing the delineation of potential sweet spots in this frontier area .

An alternative to : "*Tectonic and palaeogeographic evolution of the Southern South Atlantic: Implications for source facies distribution*"

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Abstract
The hydrocarbon prospectivity of the southern South Atlantic remains less developed? compared to the margins to the north of the Walvis Ridge. In part, this may reflect geological differences - variations in basin evolution, hinterland development, and climate. This can be seen in the documented depositional differences of pre-break-up source facies. The deep-water freshwater lakes of the northern West African margin (e.g. Kwanza Basin), compared with the shallower, saline, and hyper-saline lacustrine source systems in the Campos and Santos basins. South of the Walvis Ridge, the earlier opening of the margins and interaction with the proto-Southern Ocean marine incursions may partly explain the lesser development of major lacustrine source rocks. But this is further complicated by contemporary volcanism. For example, on the Namibian and South Africa margins, volcanic and volcaniclastic fill appears to restrict the development of deep water lacustrine facies, which are currently known only from the A-J 1 graben, which shows limited volcanics.

To understand how these processes interact and dictate depositional play systems, especially source facies, we need to map each process and assess which are important, how, and why. The results also have implications for better understanding the carbon cycle through geological time.

In this paper, we use a selection of palaeogeographic, palaeodrainage, and palaeoclimate reconstructions of the South Atlantic to illustrate how these processes operate and interact in the region. This includes reconstructing the underlying crustal architecture (the crustal geometry and composition; the structural framework), the geodynamic processes that act on the crustal architecture to build and evolve the landscape and accommodation space, and then the landscape itself processes acting upon it. This latter also includes the restoration of source-to-sink relationships.

The preliminary results suggest that basin architecture in the southern South Atlantic may have been of most significance in dictating the prospectivity of syn-rift. North of the Walvis Ridge source facies are dictated by basin geometry, hydrology, and clastic input. Post-rift source facies reflect a range of factors, including the location of deep-water bathymetric barriers, coastal oceanic upwelling, oceanic anoxic events, and the location of major river deltas

The Southern Toe - A Closer (Zoom) Look

Schiefelbein, C.F.; Urien, C.M.; Dickson, W.G.; and Zumberge, J.

Twenty years into our teamwork, a super-regional view of South Atlantic conjugate basins continues to develop, even as our set of crude oils has nearly doubled to almost 1700 from the initial selection. Detailed geochemical data from these representative samples is tested against their tectono-structural setting, comparing paleo- reconstructions of the region against the paleo-depositional settings inferred from the oils data.

The tectono-structural interpretation now uses vintage-2020 compilations of geophysical data (bathymetry, gravity, magnetics, basement depth, sediment thickness) to direct and refine mapping of tectonic elements and basin features. We review the continental terraces from Southern Brazil across Argentina. The northern segment, influenced by a Proterozoic craton, contains relatively shallow margin basins extending from Pelotas to the Salado-Colorado Mesozoic aulacogens. The southern segment, Patagonia, extends from the Colorado Anomaly to the Malvinas (Falkland) Plateau. This region benefits from a newly-developed magnetics RTP (reduction to pole) algorithm which greatly improves imaging of Triassic and Jurassic volcanism (LIPs) and related features.

In this presentation, we examine southern South Atlantic conjugate basins of Uruguay, Argentina and Chile for plays related to Upper Jurassic-Neocomian syn-rift lacustrine source rocks. The geochemical point control has iterated through an expanding data volume (Schiefelbein & Dickson 2014) using a combination of multivariate statistical analysis (MSA) and spatial comparisons to tecto-structural mapping (Dickson et al., 2016). We discuss examples of MSA significance, matching rift basin and sub-basin containers with inferred paleo-geographies and associated ages derived from the oils analysis.

Mapping the Kudu Source Rock in the Walvis and Orange Basins, Offshore Namibia – Integration of Seismic Inversion and Petroleum Systems modelling

Christian Niño[1], Teresa Martins[1], Astrid Fernandez[1], Sergio Cersosimo[1], Sara Pestana[1], Daniel Rodrigues[1], & Martin Zubiri[1],
[1] *GALP*

Hydrocarbon exploration in frontier and emerging basins rarely count with data from source rock penetrations in the basin. Therefore, there are many uncertainties regarding the source rock geochemical properties (e.g. %TOC, HI), thickness, organofacies and overall, their Ultimate Expulsion Potential (UEP). So, when a Petroleum System Model is built the source rock properties are generally assumed after seeps, shows or basin analogs.

In like manner, mapping of the source rocks has not always been a priority for seismic interpreters or exploration teams in small or mid-size companies. But, when the source rock has been drilled and geochemically characterized, mapping of the source rock should be a priority to track their areal extension, and variations in thickness and UEP. During the last decade the use of seismic inversion has proven to be of great help in this effort (Løseth *et al*, 2011; Broadhead *et al*. 2016; Niño-Guiza *et al*. 2016; Davison *et al*. 2018).

Offshore Namibia, in the Walvis and Orange basins, the Wingat-1, Murombe-1 and Moosehead-1 wells drilled the whole section of the Aptian/Barremian Kudu source rock, providing an opportunity to study its regional changes in organofacies, UEP and maturity.

Sampled %TOC values were plotted against P-Impedance values from wireline logs evidencing a relationship between high %TOC and low P-Impedance values (third degree inverse relationship), as reported in other basins by Løseth *et al*. (2011). On 3D data, the source rock signature can be clearly traced across the Walvis and Orange basins. A constrained sparse spike inversion was run, and the inverted P-Impedance volume was used as input for generating %TOC distribution maps within the area covered by 3D data.

In the Walvis basin, the map reproduces the decrease in %TOC observed between Murombe-1 and Wingat-1 (from distal to more proximal basin positions), but interestingly it also suggests the continuity of very good %TOC values and thickness towards the north, where the basin depocenter is located.

In the Orange basin, the results allow to tract the excellent source rock facies drilled at Moosehead-1 and shows a region where it has been partially eroded. It was also observed an increase in P-Impedance than seems to be related more with a change in lithology (more marls and carbonates) than with a decrease in %TOC.

The thickness and %TOC map obtained were integrated into the petroleum systems modeling to estimate the original UEP of the Kudu source rock, its present-day maturity and to define the areas where more oil should have been expelled. The workflow allowed identifying basin sweet spots where the risk of encountering a rich and mature source rock expelling hydrocarbon has been significantly reduced.

Seismic characterization of source rocks: Why should it be assessed on a site-by-site basis?

Antoine Thiéblemont[1, 2], Anne-Claire Chaboureau[2], Carolina Castano-Uribe[2], Benoit Paternoster[3], and Ekaterina Shipilova[4]

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Seismic characterization of source rocks (SR) became widely used to de-risk for petroleum systems evaluation during exploration. Generally, rock-physics combined with seismic amplitude versus offset (AVO) and inversion data are used to detect SR presence and to assess SR lateral and vertical variations measured in total organic carbon (TOC) content (in weight percent -wt%). Despite its great potential, this method suffers from a wide range of pitfalls and many uncertainties. In this study, we demonstrate the variability of seismic responses of SR. Rock property studies of SR show that the relation between acoustic impedance (AI), which is the product of density and P-wave velocity, and TOC turned out not to be representative in SR with TOC contents less than ~4-5 wt%. In the screening phase of rock-physics data, SR also reveal a large range of Poisson's ratio values, which relates to P-wave and S-wave velocities. Moreover, the seismic AVO analysis gave support for this complex behavior, highlighting AVO Class I, III and IV anomalies. Therefore, the expectation from which the top of SR intervals would feature a "*clear dimming with offset*" (AVO Class IV) should not be generalized for SR identification in frontier areas, as suggest by results of this study.

Session Eight:
Basin Case Studies

Tectonostratigraphic evolution of the Malvinas Basin and main play families, an illustrated review

Sebastian Galeazzi
Yonathan Quintero (Pluspetrol)
Pluspetrol SA - Virtual presentation confirmed. In-person presentation to be confirmed.

The Malvinas Basin is one of many basins on the southernmost South American continental shelf that have a proven petroleum system that for various reasons remain at frontier exploration status. This could soon change, as the area attracted the industry's attention with a very positive response to the 2019 Argentine Offshore Exploration round. Using an expanded dataset, as compared with previous publications, we revisit here the description of the main tectonostratigraphic units of the basin, as a basis to better interpret petroleum systems and exploration plays.
The basin formed during the Triassic-Late Jurassic rifting, evolved into a sag-phase passive margin in the Late Jurassic-Cretaceous, and finally became a foreland basin in the Cenozoic, in response to the formation of the Fueguian Orocline and the North Scotia Transform Margin. It shows today a NNW-oriented Mesozoic depocenter over which an EW-oriented foredeep developed in the Cenozoic, with strong impact on its petroleum systems.
The syn-rift unit, Megasequence 1 (Triassic-Late Jurassic), reaches over 3000 m in thickness in the basin center. It consists of continental volcanic and pyroclastic rocks (Tobífera Fm) lying over pre-rift Late Paleozoic sedimentary and low-grade metamorphic rocks and granites. Lacustrine facies are expected but not evident from seismic facies nor well data. Tobifera volcanoclastics fill NNW-oriented grabens and half grabens. Two major faulted depocenters controlled the basin center location throughout the Mesozoic.
Rift deposits are covered in basin center locations by a 1000 m-thick "early-sag" unit, Megasequence 2a (Late Jurassic-Early Valanginian). It is in turn covered by up to 400 m-thick Megasequence 2b (mid Valanginian-Aptian). The first includes open marine clastic facies, with a probably structurally controlled shelf break, directly overlying shallow marine and continental syn-rift series. Seismic facies suggest the presence of a possible Tithonian marine source rock interval. Megasequence 2b records the generalized flooding of the basin, particularly over the explored, western, Dungeness High, with the deposition of the transgressive clastic shoreline wedge of the Springhill Fm. Oil discoveries show a successful play but relatively poor-quality, thin, lithic sandstone reservoirs. Thicker, time- equivalent shoreline facies are expected farther north and east, as per Nautilus-1 well results.
Megasequence 3 (Albian-Maastrichtian), represents the "passive-margin" series of the basin with some 900 m-thick, shale-prone marine facies, characterized by a conspicuous Turonian-Cenomanian sigmoidal offlap geometry from the east. This is an undrilled reservoir and play in the basin, with shoreline reservoirs in NNW-oriented growth-fault systems. Type II and II-III source rocks were deposited in all pre-Albian distal marine intervals.
Megasequences 4 (Paleogene) and 5 (Neogene), record the change to a foreland basin stage in the early Cenozoic. This depositional wedge reaches over 4000-m in thickness and includes Paleogene shallow water, glauconitic sandstones, deposited in a starved, southerly tilted platform, covered by a Neogene clastic wedge that developed progressively, from west to east, with deep-water slope and basin-floor reservoirs in the southern foredeep.
Two main play families are proposed: a northern "Platform Family", dominated by Late Jurassic and Cretaceous targets in structural and stratigraphic traps, and a southern "Foredeep-FTB Family", comprising Cretaceous tilted blocks and Oligocene-Miocene deep water sandstones in stratigraphic traps and minor fold-fault related traps.

Pelotas Basin – Exploration of the last great play of the Southern Atlantic

Neil Hodgson and Karyna Rodriguez,
Searcher

Cretaceous clastic slope and basin floor plays on Southern Atlantic passive margins have provided an industry focus for exploration for the last 15 years. Yet despite dramatic success in the Sergipe Basin of Brazil, this play remains untested from the Santos Basin to the Malvinas Basins.

1 Hydrocarbon play elements; source, reservoir and trap are examined from the perspective of presence, effectiveness, uncertainty and dogma. The margins of the southern South Atlantic are seen to have abundant opportunities where the gods of hydrocarbon trapping could have brought all the play elements together. However, in terms of access and do-ability we propose that the best place to prove this play is actually the much over-looked Pelotas Basin of Southern Brazil (Dias et al., 1994; Stica et al., 2014; Zalan, 2017).

Source Presence and Effectiveness

Plate tectonic reconstructions, show that up until the Latest Aptian the southern Atlantic remained a restricted seaway which together with the global anoxic event during this period (Schlanger and Jenkyns, 1976; Jenkyns 2010) created the ideal conditions for widespread source rock deposition.

These source rocks are proven on the conjugate margin, DSDP well 361 in South Africa (Bray et al., 1998) and wells Wingat-1, Moosehead-1 and Morombe-1 in Namibia (Petrorio, a, b, c 2015).

Seismic data along the southern Atlantic margin shows strong indications of an Aptian age source rock interval deposited above oceanic crust with an observed consistent low frequency, semi-transparent low amplitude character, interpreted to be associated with source rock presence (Hodgson et al., 2017). Source rock characterization studies of this interval (Loseth et al., 2011; Eastwell et al., 2018) show a strong amplitude anomaly with an expected decrease in acoustic impedance, due to the velocity and density decrease associated with Kerogen presence, as well as an AVO Type IV anomaly with the amplitude dimming with increasing angle due to the strong anisotropy generated by the horizontally aligned clay minerals.

This character has been observed on original legacy data in the Pelotas Basin (*Figure 1*) and may be mapped regionally to demonstrate the sedimentologic and loading controls on richness and maturity.

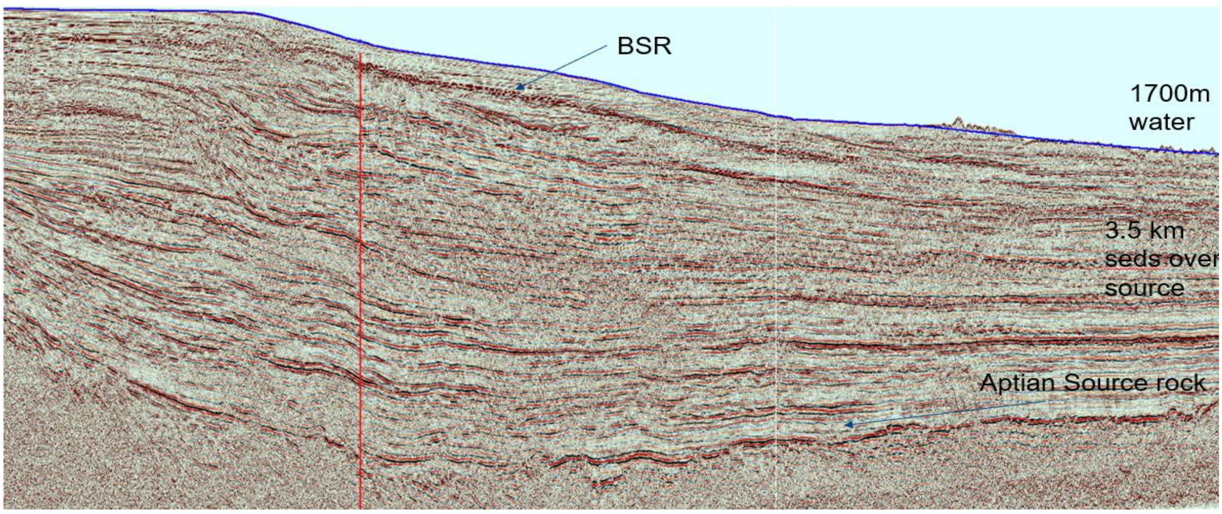

***Figure 1** – Original legacy dip line, in time but water depth compensated, in the Pelotas Basin showing the typical Aptian source rock character observed along the southern Atlantic margin as well as a clear BSR.*

Determining the geothermal gradient in undrilled regions remains one of the largest areas of uncertainty in frontier basin exploration. Bottom Simulating Reflectors (BSR's) occur at the base of a shallow gas hydrate layer in many of the world's deep-water basins and by calculating the geothermal gradient from the sea floor to the base of the hydrate, quantitative and qualitative inference of the deeper heat flow can be made, ultimately assisting basin modelers in their work.

In the Pelotas Basin the clear and extensive BSR (*Figure 1*), can be mapped over 20,000 sqkm. Here we have used Pressure-Temperature phase stability for gas hydrates in a saline medium to estimate the geothermal gradient in the hydrate layer (Vohat et al., 2003; Hodgson and Intawong, 2013; Kvenvolden and Claypool, 1988).

In the area where a BSR can be confidently picked, the hydrate geothermal gradient for the Pelotas Basin is seen to vary between 28 to 32°C/km (*Figure 2*), with a relatively small variation in the dip direction a slightly greater variation along strike.

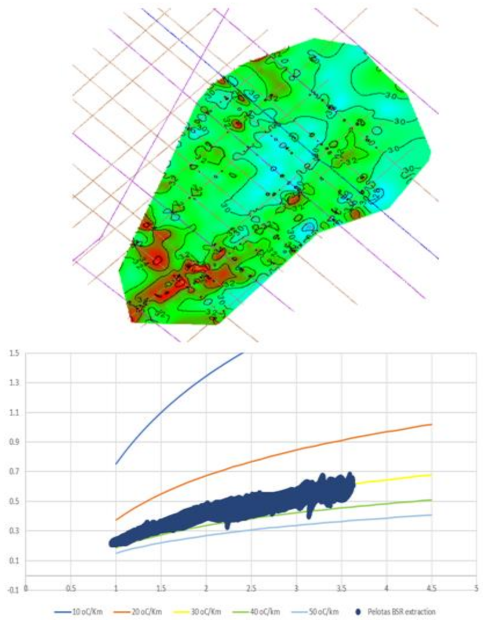

***Figure 2** – Upper Map: BSR-derived geothermal gradient grid over the southern Pelotas Basin. Contours are °C/Km. Low values blue/green 28-30°C/km, higher values to south brown/red 34°C/km. Area 20,000 sqkm.*

Lower Chart: Depth to BSR vs thickness of hydrate layer, where the lines are geothermal gradients in °C/km. 288,000 data points were extracted from a 2D mapped 20,000 sqkm BSR in the Pelotas Basin

This is perhaps a surprising observation as the crustal architecture is observed to change in the dip direction.

Using the hydrate geothermal gradient as an upper indicator of geothermal gradient, we calculate that under the thickest part of the Pelotas delta cone the Aptian source rock is likely to be gas and gas condensate generative. However, as the sedimentary column thins radially around the cone, the Aptian source rock is modelled to be in the oil window in the area of the Cretaceous basin floor play in the Pelotas Basin.

2 Reservoir Presence and Effectiveness

Traditional turbidite-centric slope and basin floor depositional models, predict that turbidite currents comprising a mixture of sand, silts and clays sands will transport materials through a confined slope system to the break of slope at the basin floor.

The slope systems typically have internal meandering channel amplitude character and may be incised or constructional. At the basin floor a reduction in flow velocity of the turbidite allows the coarsest fraction of the entrained load to be deposited. With time and channel avulsion, large, anastomosed fans may develop. On seismic, these are represented as laterally extensive and continuous amplitude with chaotic internal character.

Recently another factor at play in developing traps for hydrocarbons has been recognized on the Argentina to Pelotas Basin margin, which are strong coast parallel bottom currents (Mutti et al., 2014; Hernandez-Molina et al., 2008). The presence of such currents makes this a "hybrid" system – a mix of gravity driven turbidite currents interacting with orthogonal contourite currents. These systems have a number of unique characteristics pertinent to every aspect of the entrapment of hydrocarbons (Fonnesu et al., 2020). This is observable on seismic in diverse features – from the way that turbidite flows interact with contourite drifts, and in the "fines stripping" of turbidite currents by contourite currents (Mutti et al., 1980). Several examples of the plays both in slope setting and basin floor setting will be demonstrated on seismic.

Trap Presence and Effectiveness

For the basin floor plays the simple apron fan model can only create hydrocarbon trapping when faulting or a lack of sand in the feeder channel prevents hydrocarbon migration back to the shelf. Bypass may be caused by the steepness of the channel system preventing coarse clastics depositing or a change of sediment entry point to the basin. However, such bypass events are not ubiquitous and at best hard to prove ahead of drilling, as the thief horizons may be sub seismic scale. Of course, DHI and seismic attribute work can guide explorers towards the traps that have worked, yet these methods just reduce risk, and do not obviate it, and will skew exploration towards gas, and away from valid DHI-free traps.

Trapping geometry and seal are considered to be the highest risk elements for basin floor fans. Fortunately, the base of slope play on passive margins also has a surprising twist derived from the architecture of continental and oceanic crust (Rodriguez et al., 2016). Whether the margin is magma poor or magma rich, close to the continent-oceanic boundary the older cooler volcanic crust that is subsequently loaded by sediment has subsided into the mantle more than the younger oceanic crust further offshore. The first sediments deposited onto this crust therefore now dip upwards out to sea (*Figure 1*). As such, basin floor fans that seal stratigraphically out to sea create large low risk traps, on a huge scale. Despite the difficulty of finding such plays in reasonable water depths, there have been discoveries of this style in the Atlantic in recent years as this geometry is observed along both sides of the Atlantic margin. Opportunity to explore this geometry play arises for two reasons. Firstly, because oceanic crust of a given age, and therefore a given thermal maturity, is not found at a consistent depth in the world's oceans due largely to the degree of support from underlying mantle convection cells (Hodgson and Rodriguez 2017, 2018, Hoggard et al., 2016). Secondly, in the world's great deltas where sediment input into a basin has been prolific and dominantly stable, these trapping geometries may be closer to the shore, such is the case with the Pelotas Delta. We use regional maps of play distribution and bathymetry to show that whilst the Cretaceous play south of Brazil may be in ultradeep water (>3km), in the Pelotas basin this play can be tested in water depths less than 2km.

Conclusions

In the Pelotas Basin of Southern Brazil, the combination of thick sedimentary cone above a strongly subsiding crustal architecture has created an opportunity to explore the Cretaceous basin floor play in relatively accessible and amenable water depths.

That there has been no exploration of Cretaceous basin floor fans south of the Santos Basin in Brazil, Uruguay and Argentina is itself remarkable. However, we suggest not as remarkable as the extraordinary potential of this play.

New insights into the petroleum geology, basin development and sediment transport mechanisms of the North Falkland Basin

Dave McCarthy
British Geological Survey
Thomas J.H. Dodd (British Geological Survey), Gayle E. Plenderleith (British Geological Survey), Darren J.R. Jones, (British Geological Survey) Thomas A. Randles (British Geological Survey)

The Falkland Islands are surrounded by five Mesozoic sedimentary basins that, despite significant successes are still be regarded as relatively frontier areas. In particular, the North Falkland Basin (NFB), and its early Cretaceous lacustrine petroleum system, has seen considerable exploration interest and, more importantly, success. The NFB can be divided into two structural elements: a north-south trending graben in the north; and a series of smaller grabens with a NW-SE trend in the south. The north-south trending main graben is divided into western and eastern depocentres, of which the eastern has been the focus of exploration. The initial exploration campaign in 1998, while not encountering any economically viable hydrocarbon accumulations, encountered an organic-rich sourced rock interval. In the last ten years, however, two separate drilling campaigns (2010–2012) yielded eight oil, gas and condensate discoveries (collectively) in 21 wells, across three distinct basins, providing an encouraging exploration success rate, especially in such a frontier area. The main highlight for exploration in the NFB being the discovery of the Sea Lion Main Complex, a sequence of oil-filled early post-rift lacustrine turbidite fans. The 2015 campaign added further appraisal as well as additional discoveries, including Isobel and Isobel Deep. This presentation draws upon high-quality 3D seismic and well data to discuss the geology and petroleum systems contained within the North Falkland Basin. The Lower Cretaceous early post-rift source rock is possibly one of the richest source rocks in the world, with TOC's up to 8.7% with an average of 4.5% and an average S2 value of 42 kg HC/tonne of rock. To-date, the main successful discoveries are within reservoirs composed of sand-rich, early post-rift, deep-lacustrine turbidite fan systems. Where intersected, these reservoirs have been proven to display up to 29% porosity, with c. 100s mD permeabilities. The turbidite fan systems were deposited along the basin margins, and within the centres, leading to relatively simple hydrocarbon migration and charge pathways out of the source kitchen. The successful traps are largely combined structural-stratigraphic traps, but structural traps and more subtle stratigraphic traps have also been identified. Recent studies by the BGS have evaluated basin structure but also reservoir architectures and facies distributions of the deep-lacustrine fan systems in which the discoveries have been made. These will be discussed in conjunction with an outline of the remaining exploration potential.

Deepwater prospects and discoveries of the Paddavissie Fairway in the Southern Outeniqua Basin

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Petroleum Agency SA
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The Paddavissie Fairway is an Albian deep marine basin floor fan located in block 11B/12B within the Southern Outeniqua Basin, off the south coast of South Africa. The Paddavissie fan (named for its tadpole shape) comprises 5 main prospects named after frogs: Platanna, Brulpadda, Woudboom, Luiperd and Blaasop. These stratigraphic and structural bound prospects were initially identified by DHIs within the 14A interval; these discoveries were also supported by AVO anomalies which are suggestive of hydrocarbons. The gigantic (over 1500 km2) Paddavissie basin floor fan complex is analogous to, but far larger than the neighbouring Oribi and Oryx oil fields in the Bredasdorp Basin that occur in the same stratigraphic interval and have a similar sedimentary source.
The fan complex is a deep-water play occurring in varying water depth from 1100 m to 1900 m. Two recently drilled wells have confirmed the occurrence of hydrocarbon saturated sandstones; BRU-1AX and LUI-1X drilled on the Brulpadda and Luiperd prospects respectively. Both wells tested positive for gas condensate where BRU-A1X encountered 57 m of net pay and LUI-1X encountered 73 m of net pay. The other prospects are expected to be charged, even though these remain untested thus far. However, the success of the two wells proves the existence of a world class petroleum province in the Southern Outeniqua Basin.

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The Geological Society of London is a professional and learned society, which, through its members, has a duty in the public interest to provide a safe, productive and welcoming environment for all participants and attendees of our meetings, workshops, and events regardless of age, gender, sexual orientation, gender identity, race, ethnicity, religion, disability, physical appearance, or career level.

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The Society values participation by all attendees at its events and wants to ensure that your experience is as constructive and professionally stimulating as possible.

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Harassment includes sustained disruption of talks or other events, inappropriate physical contact, sexual attention or innuendo, deliberate intimidation, stalking, and intrusive photography or recording of an individual without consent. It also includes discrimination or offensive comments related to age, gender identity, sexual orientation, disability, physical appearance, language, citizenship, ethnic origin, race or religion.

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Leave the building via the nearest and safest exit or the exit that you are advised to by the Fire Marshal on that floor.

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Lower Library:
Exit via main reception onto Piccadilly, or via staff entrance onto the courtyard.
Lecture Theatre
Exit at front of theatre (by screen) onto Courtyard or via side door out to Piccadilly entrance or via the doors that link to the Lower Library and to the staff entrance.
Main Piccadilly Entrance
Straight out door and walk around to the Courtyard.

Close the doors when leaving a room. **DO NOT SWITCH OFF THE LIGHTS**.

Assemble in the Courtyard in front of the Royal Academy, outside the Royal Astronomical Society. Event organizers should report as soon as possible to the nearest Fire Marshal on whether all event participants have been safely evacuated.

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First Aid

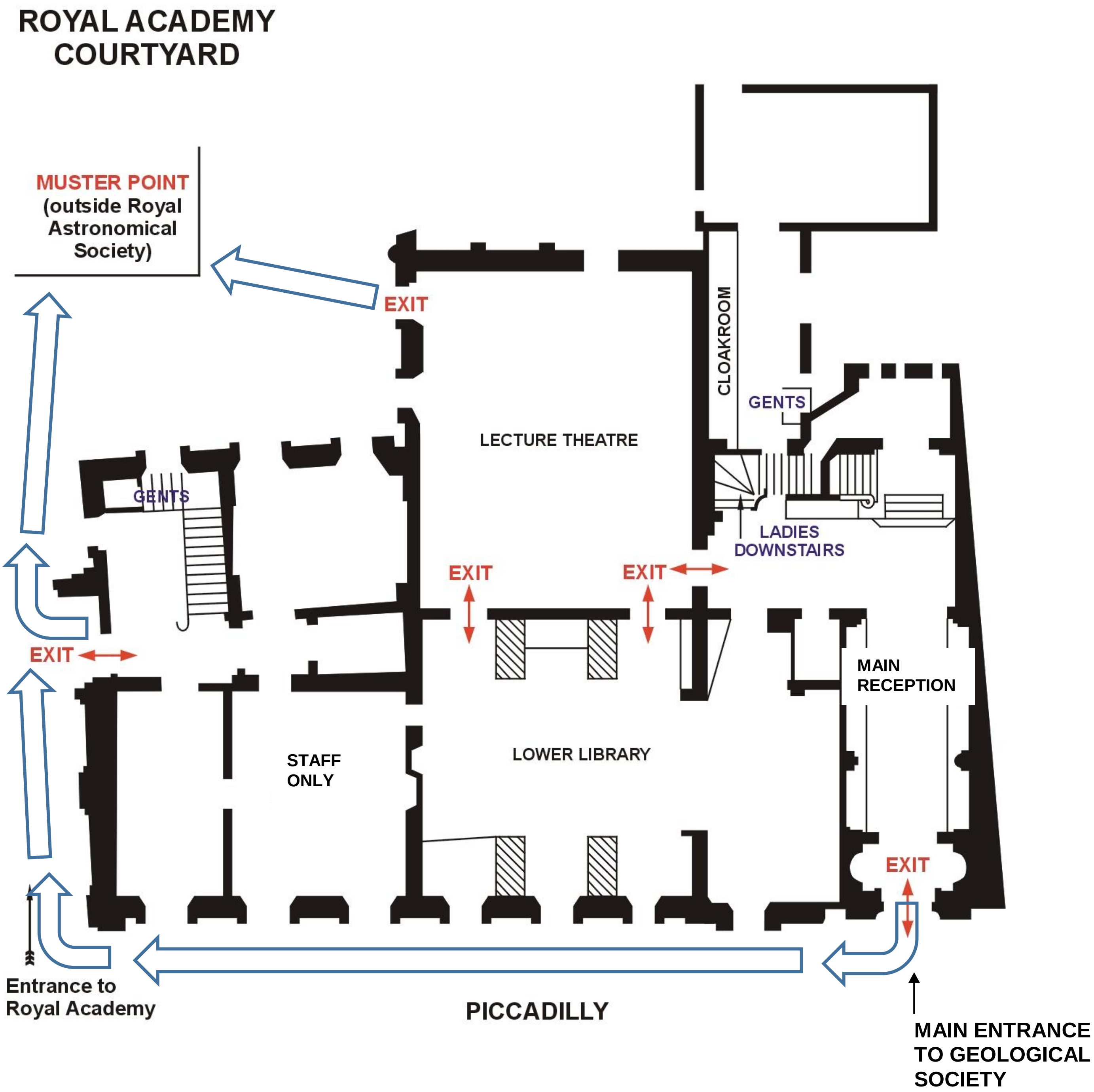
All accidents should be reported to Reception and First Aid assistance will be provided if necessary.

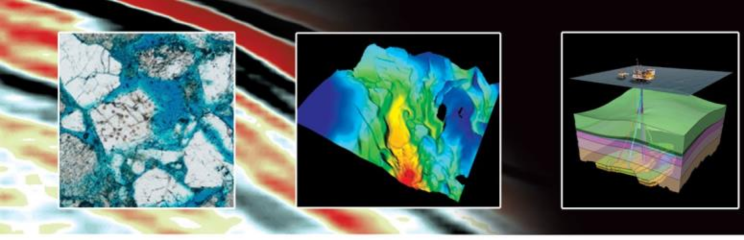
Facilities

The ladies toilets are situated in the basement at the bottom of the staircase outside the Lecture Theatre.

The Gents toilets are situated on the ground floor in the corridor leading to the Arthur Holmes Room.

Ground Floor Plan of the Geological Society, Burlington House, Piccadilly





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8th UK Geothermal Symposium

17th November 2021

The Geological Society, Burlington House, Piccadilly London and Virtual

Development of the UK's geothermal resources to provide heat and power is gaining pace in-line with demands for urgent climate action. Headlining from Cornwall, two much anticipated commercial **deep geothermal energy** projects are being developed following over a decade of preparation.

Mine water thermal energy is also gaining major traction across the former coal mining areas of the country with NE England taking the lead. The first mine water heating project is delivering MW's of low-carbon heat to Lanchester Wines in Gateshead and two more will be operational within 24 months. Innovation in repurposing of oil and gas industry assets is becoming a reality. Examples of **hot sedimentary aquifer** exploration and development in Ireland and Northern Ireland have been driven by a great example of linked up policy and research agendas.

The 8th UK Geothermal Symposium will showcase the latest developments in the UK's geothermal sector:

- **Theme one** will show-case four examples of the three main resource types: granites, sedimentary basins and flooded coal mines.
- **Theme two** will walk the audience through the de-risking processes related to geological uncertainty, drilling risk and commercial and financial risk in geothermal systems.
- **Theme three** will highlight the latest examples of pioneering research being carried out by industry-academic partnerships in the UK.
- **Theme four** will present an interactive discussion panel with leaders from the public sector to debate the current and future policy and regulatory landscape for the industry in the UK.

This Symposium is for everyone who wants an update on the latest and largest developments in the UK geothermal sector, and is aimed at investors, developers, industrial energy users, policy makers and geological researchers.

Registration: https://www.geolsoc.org.uk/11-EG-Geothermal

For further information please contact:

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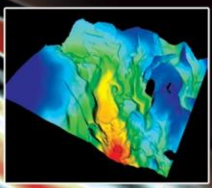
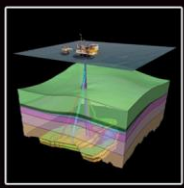

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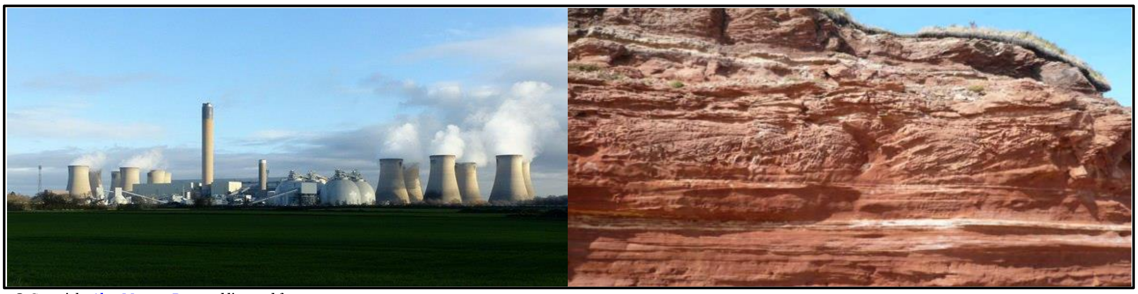
Call for abstracts – Deadline Monday 3 December 2021

Applicability of Hydrocarbon Subsurface Workflows to CCS

28-29 April 2022
The Geological Society, Burlington House, Piccadilly London



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The IPCC recommends large-scale carbon capture and storage programmes as part of the suite of measures taken to limit global warming in line with the Paris Agreement and subsequent more ambitious targets. It is widely recognised within the geological community that the successful implementation of carbon capture and storage programmes will be crucial to meeting global climate targets, and that geologists currently working within traditional hydrocarbon activities hold many of the key skills required. But **which** skills, and how are they applied?

This two-day meeting presents an opportunity to examine current and planned CCS projects and activities, and where well-established workflows in hydrocarbon production and exploration are helping to deliver them. Abstracts are invited on all elements of the E&P cycle, from basin screening to reservoir modelling and surveillance. These are likely to cover current projects under execution, as well as conceptual studies. Through a broad range of keynote speakers and session themes, the meeting will provide an opportunity to understand and share practical and focused examples of the value of skills built and lessons learned in oil and gas activities to the energy transition.

Session themes include:

- Managing-stakeholders
- Regional screening for CCS opportunities
- Petroleum systems applications
- Reservoir modelling
- Changes to the conventional subsurface risk and uncertainty framework
- Overburden studies
- Well integrity assessment
- Sedimentology and structural geology
- Long-term monitoring techniques

For further information please contact:

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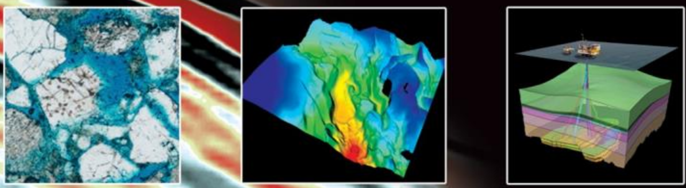

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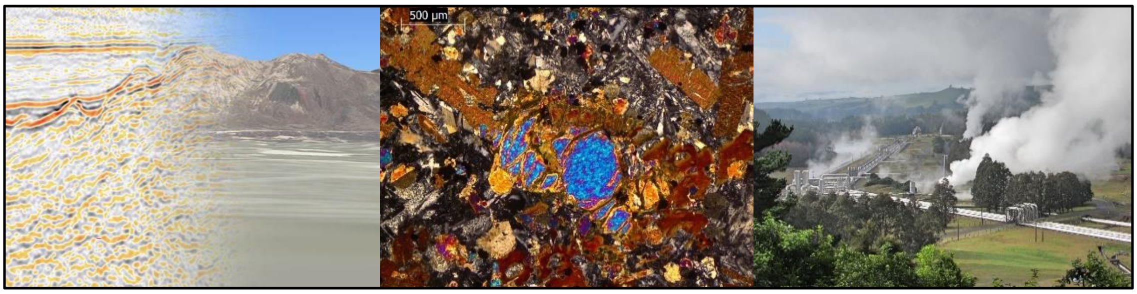
Call for abstracts – Deadline Friday 25 March 2022

The impacts of volcanism on sedimentary basins and their energy resources

8 - 9 September 2022

The Geological Society, Burlington House, Piccadilly London



A large number of global sedimentary basins are impacted by igneous systemsin the form of extrusives, intrusives and volcaniclastics. Considerable research regarding the impact of these volcanics on hydrocarbon plays has been completed in recent years including the role of intrusions in basinal heat flow and fluid migration, diversion of sediment pathways in volcanic terrains, and influence of igneous material on sealing units and reservoir quality. Sub-basalt stratigraphy also continues to be an enigma in many parts of the world both in terms of seismic imaging and play element definition. There is now an opportunity to disseminate and share learnings globally, which could unlock energy opportunities in in other hydrocarbon basins impacted by volcanism. Increasingly these concepts can also help to develop geothermal plays or delineate carbon capture and hydrogen storage. For example, the knowledge built up by the hydrocarbon industry on reservoir and seal characterisation in volcanically affected basins will have a strong influence on geothermal opportunities and gas storage site definition. The aim of the conference is to encourage global submissions to applied problems across the span of the energy transition. In particular the committee encourage expressions of interest for submissions regarding:

- Margin and basin-wide examples of volcanic systems and their impact on resource plays (hydrocarbons, geothermal, hydrogen, CCUS)
- Global examples of the impact of volcanics on reservoirs and seals from pore to basin-scale
- The influence of volcanics on basinal heat flow and our understanding of geothermal gradients, hydrocarbon charge and impact on geothermal systems.
- Examples of new tools to aid our understanding of volcanic impacted basins (at all scales from seismic imaging to diagenetic analysis).

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