Introduction

2018 saw a series of major discoveries in what is conventionally classified as deep water, including Ranger and Longtail (part of the Liza complex) in Guyana, Guanxuma in Brazil and Calypso in Cyprus. These discoveries accounted for the biggest proportion of resources discovered in 2018. Exploration efforts should clearly be heading in this direction, targeting significant remaining potential. Most of the deep water environment is considered as frontier exploration ground where long offset 2D seismic data is proving to form an integral part of taking the first steps in identifying both proven and new play fairways.

In this deep water setting, drift (or coast parallel bottom currents) and turbidite (or gravity) processes are common along continental margins. The interaction of these processes can build large mixed / hybrid (turbiditic-contouritic) depositional systems. These have only been recently recognized and are only now being studied in more detail. One of the leading research groups is part of a joint industry project (JIP) led by Royal Holloway under Javier Hernandez Molina and supported by a group of major oil companies. This initiative has led to the start of widespread recognition of these systems at a global scale by integrating outcrop, well and seismic data and should make an important contribution in our understanding of contourite-influenced areas.

Several prolific discoveries have been associated with hybrid turbidite-contourite systems, of which the most notable is in the Rovuma Basin offshore Mozambique (Maba Complex 85 TCF) (Palermo et al., 2014). Another significant hydrocarbon accumulation associated with a mixed system, though not published as this type of depositional system but with clear seismic indications, is the deep water confined channel Barra complex (3 BBOIP) in the Sergipe Basin, Brazil. This study focuses on recognizing and evaluating these mixed systems on seismic data using several examples from a comprehensive global long offset 2D seismic dataset (Figure 1). The work aims to contribute to the understanding of these depositional systems which have already proven to contain significant potential and as indicated by this study, have clear signs of being associated with huge hydrocarbon potential.

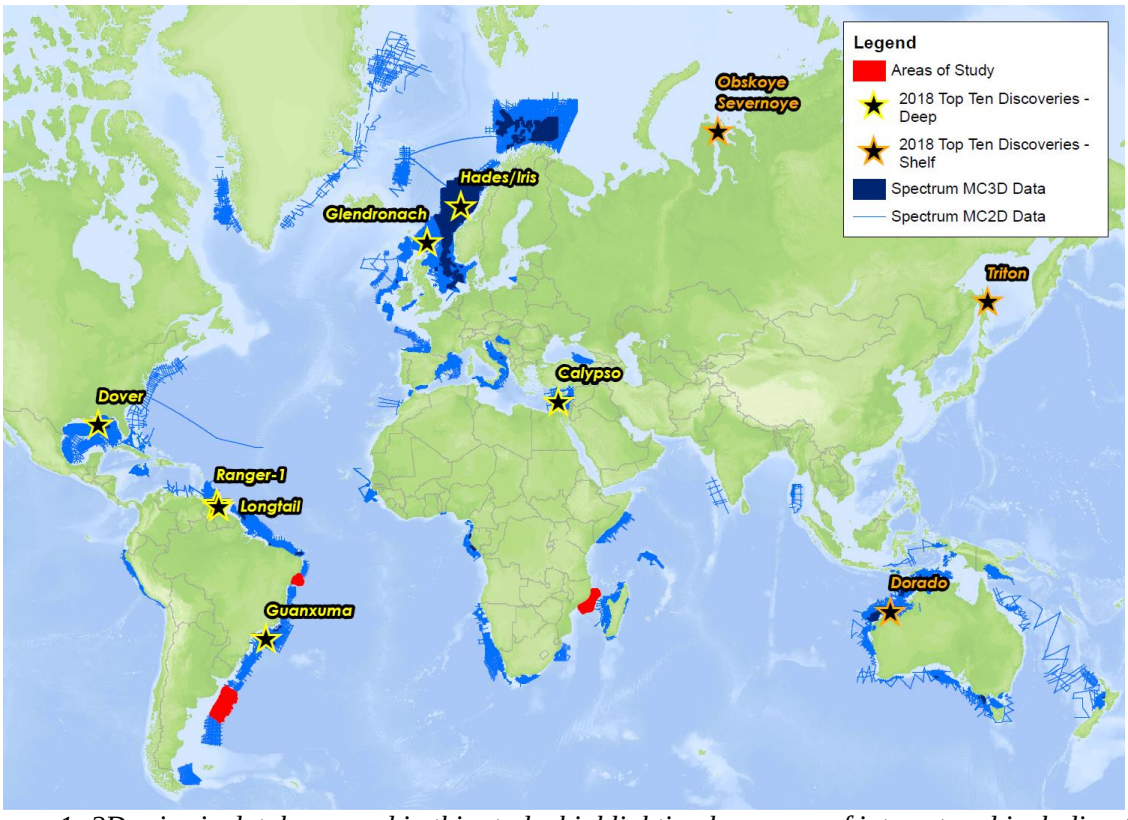

Figure 1: 2D seismic database used in this study, highlighting key areas of interest and including top 10 discoveries of 2018 according to IHS

Seismic Identification of Mixed turbiditic-contouritic depositional systems

The approach used was to integrate available understanding of these mixed systems (Sansom P., 2018) and to identify similar seismic features in slope to basin settings over selected areas including Sergipe Basin offshore Brazil, Argentina Basin offshore Argentina and Angoche/Southern Zambezi Basins offshore Mozambique. This analysis was enabled by imaging obtained from long offset modern 2D seismic data processed through a deghosting sequence with thorough demultiple and denoise processes applied resulting in a high resolution image which allowed high confidence identification of hybrid systems. The identification relied on the recognition of a series of diagnostic criteria and further tests such as flattening horizons to restore the section to its original depositional geometry,

For hydrocarbon potential evaluation, a full petroleum system elements analysis was performed in which probable source rocks, reservoir and traps were identified. Potential source rocks were identified using a systematic frontier basin methodology which looks at tectonic reconstruction, palaeographic setting, seismic character, any well and outcrop data available and includes source rock characterization (Eastwell et al, 2018), based on criteria published in 2011 (Loseth et al., 2011) and expanded to include additional criteria such as frequency response. Present day thermal maturity modelling using average geothermal gradient was performed. To de-risk reservoir presence and quality, both depositional system features and seismic character were used. The trapping mechanism is usually provided by the associated characteristics of the hybrid system.

Angoche Basin Offshore Mozambique

To the south of the 2014 Palermo study over the 85 TCF ENI Mamba Complex, lies the Angoche Basin in which long offset 2D seismic data acquired in 2017/2018 has revealed a series of hybrid turbidite-contourite systems with confined to more weakly confined channels flanked by impressive drift mounds (Figure 2). A series of migrating channel complexes is also observed (Figure2) which is very similar to the system described by Palermo. The model put together by Fonnesu F., 2013 illustrates how the gravity flow moves sediment down the turbidite cahnnel while the drift current winnows the channel in a perpendicular direction, depositing a unilateral drift mound on the flank of the channel. Counterintuitively, the channels migrate against the current direction. This might be a characteristic of more contourite-dominated systems. This process results in enhanced reservoir quality (Net/Gross up to 90%) in the channels and an overlying effective seal provided by the fine-grained drift mounds.

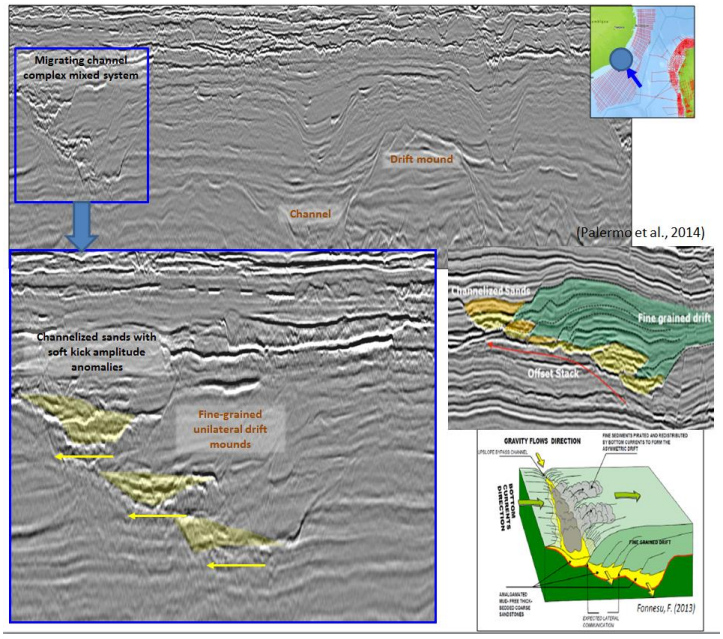

Figure 2: Strike line from the MOZ2D-17 survey showing different styles of hybrid systems.

Sergipe – A Proven Multibillion Barrel Hybrid System

On the North Eastern coast of Brazil lies the Sergipe Basin which in recent years has seen an astonishing rejuvenation in exploration effort and oil success. In 2010 Petrobras discovered the Barra Field and subsequently several more significant discoveries in Upper Cretaceous to Lower Tertiary turbidite channel sandstones in the deeper water of the basin, that have turned the tide of exploration towards the deep water targets with total reserves > 3 BBO. Despite clear seismic indications of contourite drift features, these have received little attention and yet seem to play a key role in the success of this petroleum system. A depth seismic section through one of the Barra wells shows a clear contourite drift downdip of the confined channel (Figure 3) indicating the presence of drift currents during the deposition of this mixed system. It is possible that the winnowing of this channel by perpendicular drift currents is largely responsible for the excellent reservoir quality associated with these sands.

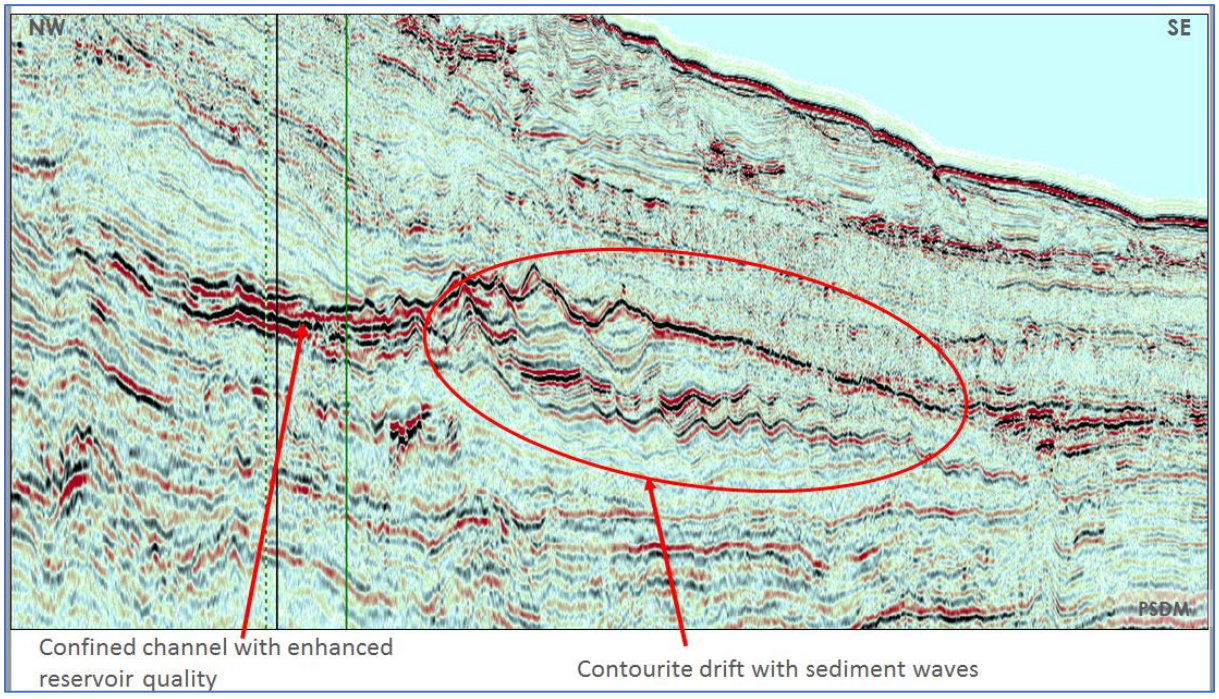

Figure 3: PSDM through a Barra well showing clear evidence for contourite drifts.

Argentina Basin – A Turbidite Dominated Hybrid System

Offshore northern Argentina has seen very little exploration activity in recent decades. A large 2D long offset seismic survey was acquired in 2017 to 2018 mainly to assist in the evaluation of the ongoing licence round. A detailed source rock analysis which included correlation to the proven Aptian source rock in the conjugate margin of Namibia, identified a high quality potential source rock with sufficient burial depth to generate hydrocarbons. This source rock is overlain by numerous stacked, mixed turbidite-contourite drift mounds and confined channel complexes throughout the Cretaceous and Cenozoic. These contourite drift mounds demonstrate the alternating dominant bottom current directions at the time of deposition. Drift mounds comprise predominantly muddy, fine-grained silty sediments, whereas intervening confined channel complexes may comprise coarse-grained well-sorted sands with high N:G – ideal reservoirs for hydrocarbon accumulations. One of these systems shows an AVO-supported high amplitude anomaly which can be mapped over a very large area. The system is extremely similar to Sergipe and indicates that there could be an accumulation three times the size of the Sergipe, i.e. 9 BBO (Figure 4).

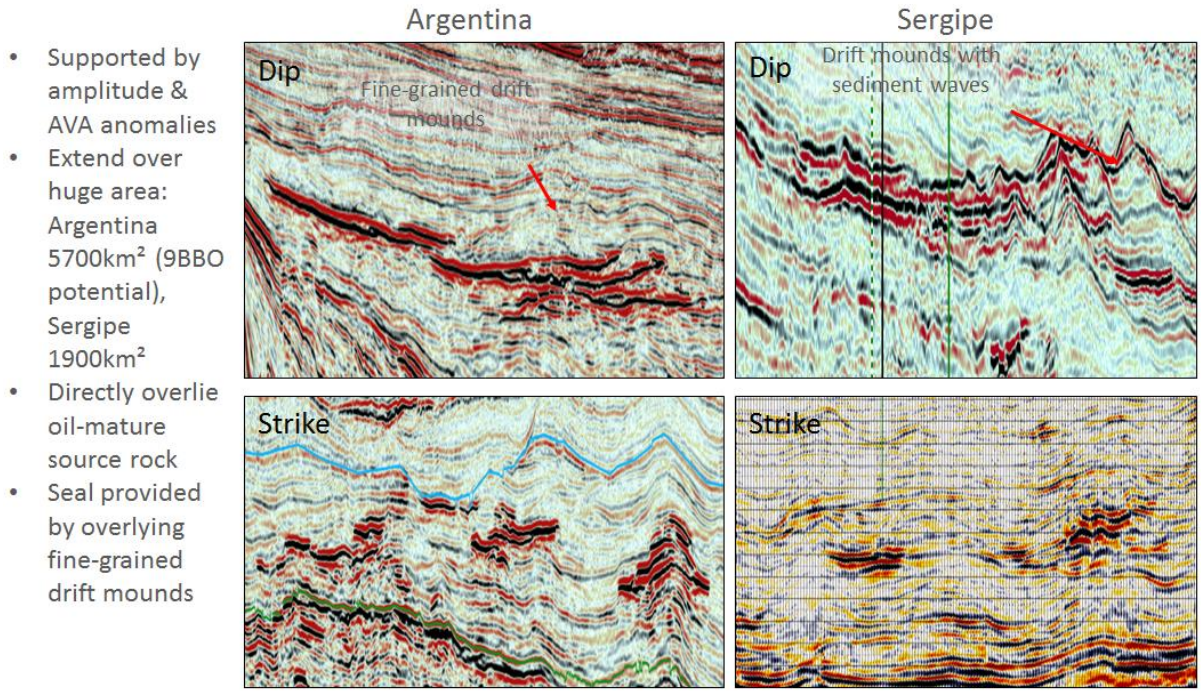

Figure 4: Comparison of the Sergipe and Argentina hybrid turbidite-contourite systems indicating huge potential in the Argentina Basin

Conclusions

Mixed/Hybrid turbiditic-contouritic systems are just beginning to be understood. These are deep water depositional systems located in relatively frontier basins. Modern 2D seismic is proving to be an essential tool in identifying these systems and performing a hydrocarbon potential evaluation, which must include a full petroleum systems review. The huge potential already proven offshore Mozambique and Sergipe indicates that this depositional system should be a main target in deep water exploration. The Argentina Basin has strong indications of a significant accumulation offering a very attractive opportunity in the ongoing licence round.

References

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