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Integrating seep geochemistry and 2D seismic for 3D basin Petroleum Systems Modelling in the MSGBC Basin

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Summary

We utilise a large database of regional 2D seismic, integrated with detailed geochemistry of surface (micro)seeps, to build a 3D Basin & Petroleum Systems Model for the MSGBC Basin, NW Africa. The study indicates that at least 2 oil groups can be distinguished based on facies indicators; 1) marine carbonate and 2) more clastic origins. Integrated with 1-D, 2-D & 3-D thermal-burial modelling in the different segments of the basin, we demonstrate that some industry preconceptions around the lack of source presence and maturity are unfounded, with mature mid-Cretaceous and Jurassic source rocks predicted in both the basin (where many discoveries exist), but also in the deep offshore (a source for the FAN-1 discovery).

Introduction

The Mauritania, Senegal, Guinea Bissau & Republic of Guinea (MSGBC) Basin has yielded multiple commercial gas discoveries, such as Tortue-1, Yakaar-1 and Orca-1, as well as oil discoveries such as FAN-1 and SNE-1 (now Sangomar field). There is however a general perception that source presence and maturity may be a critical risk in the offshore area, largely due to several dry wells, despite their failures being attributed to a variety of factors (e.g., missed structures due to drilling on vintage seismic, poor reservoir quality).

Source rock intervals have been proven by the drill bit in the MSGBC offshore basins in both exploration and Deep Sea Drilling Project (DSDP) wells. Early to mid-Cretaceous palaeo-tectonic reconstructions indicate that the deepwater MSGBC and Guyana-Suriname basins formed an axis where marine circulation was restricted, which is likely to have enabled preservation of organic matter on the seafloor to form world-class marine source rock intervals from the Barremian to the Turonian. Early Jurassic syn-rift lacustrine and late Jurassic carbonate source rocks are also likely to be present in the MSGBC platform areas based on biomarker and isotopic compositions of discovered oils and gases.

In this study we utilised geochemistry results obtained from 313 gravity and piston cores from a regional campaign in 2020, in conjunction with regional structural mapping, borehole information and heat flow measurements. The study showcases an integrated 3D Basin and Petroleum Systems Model (BPSM) which allows the explorer to better understand lateral and temporal variations in source rock quality, maturity and ultimate expulsion potential.

Method

Seabed sampling of sediments stained with hydrocarbons is a direct indicator of the presence of migrating petroleum in the subsurface, whether expelled by active sources or re-migrated from traps. Two major factors can interfere with the identification of oil stains in sediment extracts: co-extraction of sedimentary organic matter and contamination by petroleum from anthropogenic sources. In both cases, “non-seep related” organic compounds tend to overprint the weaker signal of the quantitatively minor oil stains. Our study comprised a rigorous Quality-Check (QC) of the potential oil stain samples to exclude samples which were non-seep related.

This geochemical study adjoined to the TGS seismic data builds on initial work conducted by TDI-Brooks and Geomark (Geomark, 2020). High-resolution geochemical data from seabed cores have been assessed for traces of migrated fluids and placed into the regional context of rock and gas samples from the wider MSGBC (Figure 1a). Integrating this assessment with a thermally calibrated regional 3D Basin and Petroleum Systems Modelling study (BPSM) enabled us to map an estimated distribution of distinct fluid families based on source facies, maturity, and age.

Our study led to the identification of several potential oil seeps throughout the survey area. An initial geochemical screening of the samples suggested that petroleum micro-seeps might be present in several locations across the survey area. In addition, several independent maturity- and source-related parameters consistently showed the candidate samples to be oils (mature) with two distinct source types of; 1) marine carbonate and 2) more clastic origins.

A grid-based 3-D BPSM has been built utilising regional depth surfaces compiled by TGS. The thermal-burial history in the different segments of the basin was constrained using 2-D thermo-tectono-stratigraphic basin reconstruction modelling techniques (Figures 1b & 1c), calibrated to temperature, surface heat flow and vitrinite reflectance data, where available. The results demonstrated the likely widespread maturity of early to mid-Cretaceous source rocks across the platform, but also in the deep basin oceanward of the shelf break. This suggests oil/gas charge is not limited to just the platform, but deep-water provinces are also likely to contain oil mature kitchens. Overlying the regional shale caprock isopach and the locations of potential microseeps showed a relationship between surface hydrocarbon and areas with thin or absent top seal, suggesting this may be a critical risk for hydrocarbon exploration.

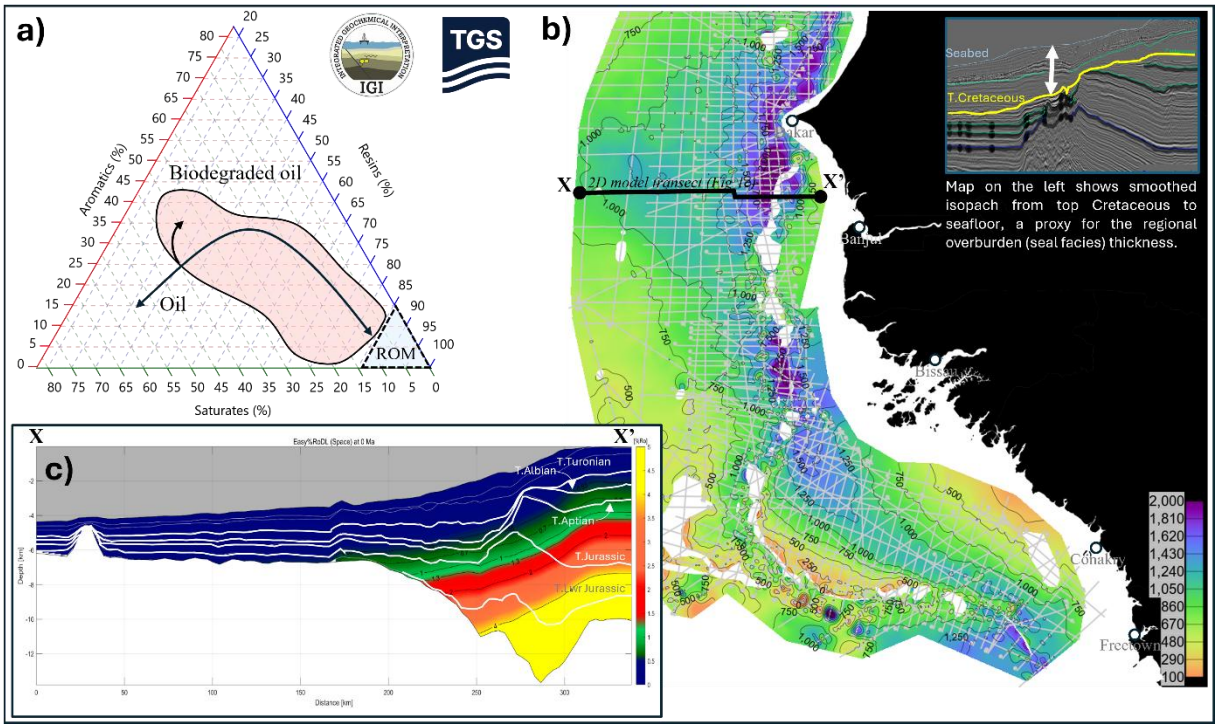

Figure 1 *a) geochemical composition of surface organic extracts (following rigorous QC) showing how samples likely to represent petroleum hydrocarbons can be separated from ROM (Recent Organic Matter); b) Isopach from the seafloor to top Cretaceous showing the presence/absence and thickness of overburden above the Mesozoic petroleum system(s). The absence of this top seal often coincides with the presence of migrated hydrocarbons (microseeps) in shallow sediments; c) present day vitrinite reflectance (as a proxy for source rock maturity) from a regional 2-D transect model showing Cretaceous source rocks are likely mature in both the platform and deep basin oceanward of the shelf break.*

Conclusions

The BPSM combined with the surface seep geochemistry survey aimed to produce a comprehensive understanding of the regional petroleum systems, complementing structural and stratigraphic mapping from an extensive seismic data coverage. We provided insights into the thermal and structural history, source maturity, hydrocarbon charge timing and retention along the margin, to further comprehend oil migration in a region currently assumed to be a gas province. The MSGBC basin has good regional seals and hydrocarbon samples are thus rare to come by. Hence, maximising our understanding from the existing data provides the most cost-effective way to de-risk source rock presence and maturity, to better target areas of opportunity.

Acknowledgements

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