Regional Prospectivity, Offshore the Republic of the Congo*

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Abstract

The post stack merge of several 3D seismic surveys offshore the Republic of the Congo covers a total area of over 21,000 sq km showing geological features on a regional scale. Several plays and trends are revealed and leads have been identified within the survey-merge. This study provides an overview of the prospectivity of offshore Congo from a regional perspective and distinguishes four different play types: (1) Upper Miocene channel systems, (2) Lower Miocene turbidite channels, (3) Sendji Carbonates, and (4) Pre-salt sandstones. The geological development of all these plays here is associated with the separation of the African and South American plates during the Late Jurassic which can be subdivided into four distinct phases of deposition and deformation: Pre-Rift, Syn-Rift, Post-Rift deposition, and salt tectonic deformation. This article focuses on the last three phases of deposition and deformation since these are more relevant for the petroleum systems under discussion.

Geological Setting

Syn-Rift

Rifting of the African plate began in Late Jurassic with the formation of a series of asymmetrical horst-graben basins trending parallel to the present-day coastline (northwest-southeast). Initially the rift and associated basins were above sea level and isolated from the ocean. Thick sequences of fluvial and lacustrine rocks were deposited in the rift basins and these were organic-rich sediments. Some, deposited in oxygendeficient water, formed one of the source rocks for the hydrocarbons found today. Continued rifting widened the zone of normal faulting crustal extension through the Barremian.

Syn-rift offshore deposits of the northern (upper) part of the Congo Basin (Republic of the Congo) range in age from Neocomian to Barremian and consist of lacustrine and fluvial sediments. The Neocomian Vandji Sandstone overlies the Precambrian basement. The Sialivakou Shale and Djeno Sandstone are lacustrine shales and turbidite sandstones. The Barremian organic-rich lacustrine shales and marls and dolomitic black shales of the Pointe Noire Marl are up to 500 m thick. The Barremian Pointe Indienne Shale and the 300 m thick Toca Formation consist of lacustrine siliciclastic shales and carbonate rocks.

Post-Rift and Salt Tectonic Deformation

Post-rift rocks range from Aptian to Holocene in age and represent the opening of the Atlantic Ocean in equatorial West Africa. The initial post-rift sequences are of early to mid-Aptian age and consist of continental, fluvial, and lagoon sediments deposited as rifting ceased in the province. Periodic restricted circulation of the emerging basin, caused by volcanic activity to the south along the Walvis Ridge and the incomplete opening of the rift through Northern Africa, created conditions where extensive deposition of evaporite units, mainly salt, occurred. Early post-rift rocks were generally deposited in two distinct regimes - as transgressive units, consisting of shelf clastic and carbonate sediments, followed by progradational units along the continental margin, and as open-ocean, deep-water sequences.

In the Upper Congo Basin the oldest post-rift rocks are the Lower Aptian Chela Formation. The Chela consists of sandstone and shale deposited in a variety of environments including marine, lacustrine, and fluvial. The massive evaporite sequences are represented by the Aptian Loeme Salt which is at least 1,000 m thick and composed of halite, carnallite and minor anhydrite. As many as six evaporite cycles have been recognised within the unit. The thick salt in the basin acts as a décollement zone for the post-salt growth-fault structures in the Congo Basin. Near the top of the main evaporite section, thin beds of clastics are commonly found, and the salt grades upward into a regionally extensive, 50-metre thick dolomite unit representing the end of the Loeme evaporite cycle. Above the evaporites, the shelf-carbonate rocks are represented by the Albian Sendji Carbonate, consisting of dolomite, oolitic limestone and interbedded sandstone units; deposited in tidal channels in the lower part and as offshore bars and shore face units in the upper part.

Above the Sendji Formation are the Tchala Sandstone (proximal to the shore in the east) and the more distal/offshore siltstone of the Likouala Formation. These formations are overlain by the Turonian Loango Dolomite and the Madingo Marl and the Cretaceous Tertiary boundary is marked by an erosional event forming a widespread unconformity.

The upper section of Cenozoic sedimentation is dominated by progradational sandstone and siltstone (proximal to shore) and more distal turbidite and deep-marine shale units that originated from the Congo River. Uplift and associated erosion and non-deposition occurred during both the Oligocene and Miocene, forming regional unconformities. Fans, turbidites and stacked channel systems dominate the Oligocene and Miocene and provide numerous potential hydrocarbon reservoirs.

Prospectivity

The study area is subdivided into two structural domains: a margin-ward extensional domain in the shallower part of the survey and a compressive domain in the deeper part of the survey. The structural difference between these two domains is caused by the salt movement. With continuing and rapid loading of terrigenous material the initially horizontal layered Aptian Salt migrated from the shallower extensional domain towards the deeper compressive domain where it is found in compressional salt walls.

The area shows four different play types: (1) Upper Miocene channel systems, (2) Lower Miocene turbidite channels, (3) Sendji Carbonates, and (4) Pre-salt sandstones.

Play Type 1: Top Miocene Play Type

The Miocene plays are associated with channels where sedimentation geometry is controlled by the topographic basins situated between the anticlinal structures above the salt walls. An amplitude extraction shows the details of multiple "meander-form" channel systems traversing the deep basin and terminating in fan shaped morphology. Figure 3 shows "meander-form" channels and fan systems trending roughly southeast to northwest across the image. The regional view seen in Figure 3 uses amplitude anomalies between Top Miocene + 0.1 s and Top Miocene +0.2 s to reveal fans and turbidite systems at the base of the slope to the west. The regional map provides paleocurrent trends that can be used to interpret the sediment source location(s) and flow direction(s) of the complex systems. In addition to identifying flow direction and flow changes, the displacement of channel systems by faulting and salt domes can be seen. The source of the sediments for these 1 to 2 km wide channel systems is the Congo River Delta. The significance of these meandering systems is enhanced by several discoveries in this unit. Figure 4 shows the Elephant discovery, a recent discovery by CNOOC, which lies in a Miocene turbidite channel (highlighted as an amplitude anomaly in the RMS extraction in Figure 3). The regional scale of this RMS map allows the identification of analogue leads within the same channel system. Examples of these leads are the two flat spots in Figure 4. The flat spots are located in Upper Miocene strata in the same interval as the Elephant discovery. Both the leads and the Elephant discovery are located in the channel system.

Play Type 2: Lower Miocene Play Type

The Lower Miocene play occurs in a similar geological setting to the Top Miocene play, but stratigraphically deeper and further offshore. Whereas the Top Miocene play can also be a stratigraphic trap, the Lower Miocene play is a structural trap. All leads identified within this play fairway consist of sand-prone channel sequences trapped within local structural closures. These are analogous to the Azurite Field which is located on a neighboring structural high along the same channel fairway feature as the lead in Figure 5. Both the lead and the Azurite Field are sitting on a structural high and are in the same channel complex.

Play Type 3: Albian Carbonate Play

The Albian Carbonate play (Sendji Formation) is controlled by the movement of salt in the current shelf area which created traps within turtle back and anticlinal structures. Other traps are related to fault blocks or paleotopography. Potential reservoirs are sealed by lacustrine and marine shales and sourced by pre-salt shales. The migration pathway is fault related. Albian Carbonate plays are found in shelf areas, which make targets economically more prospective than, for example, deep sea Miocene plays.

Play Type 4: Pre-Salt Play

The pre-salt plays (sandstones) are either trapped structurally by the salt and normal faults or stratigraphically by pinching out updip towards the basement and the salt. Pre-salt reservoirs typically follow a shallow water to onshore trend along the margin. However, it is important to realize that wells do not target pre-salt in the deeper offshore area, thus the deepwater pre-salt remains untested. With recent deepwater pre-salt success along the Angolan margin, and the Diaman discovery by Total proving a working hydrocarbon system in the deepwater offshore Gabon, it will only be a matter of time before deepwater pre-salt exploration extends into Congo.

Conclusion

The regional coverage of the Congo Mega-Survey allows the interpreter to identify and locate prospects over a wide area. These play types present excellent hydrocarbon potential. Additionally, discoveries from adjacent Gabon and Angola can be considered as analogues and can provide further information about the hydrocarbon potential in the less-explored Republic of Congo.

Acknowledgements

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Reference Cited

Brownfield, M.E., and R.R.Charpentier, 2006, Geology and total petroleum systems of the West-Central Coastal Province (7203), West Africa: U.S. Geological Survey Bulletin 2207-B, 52 p.

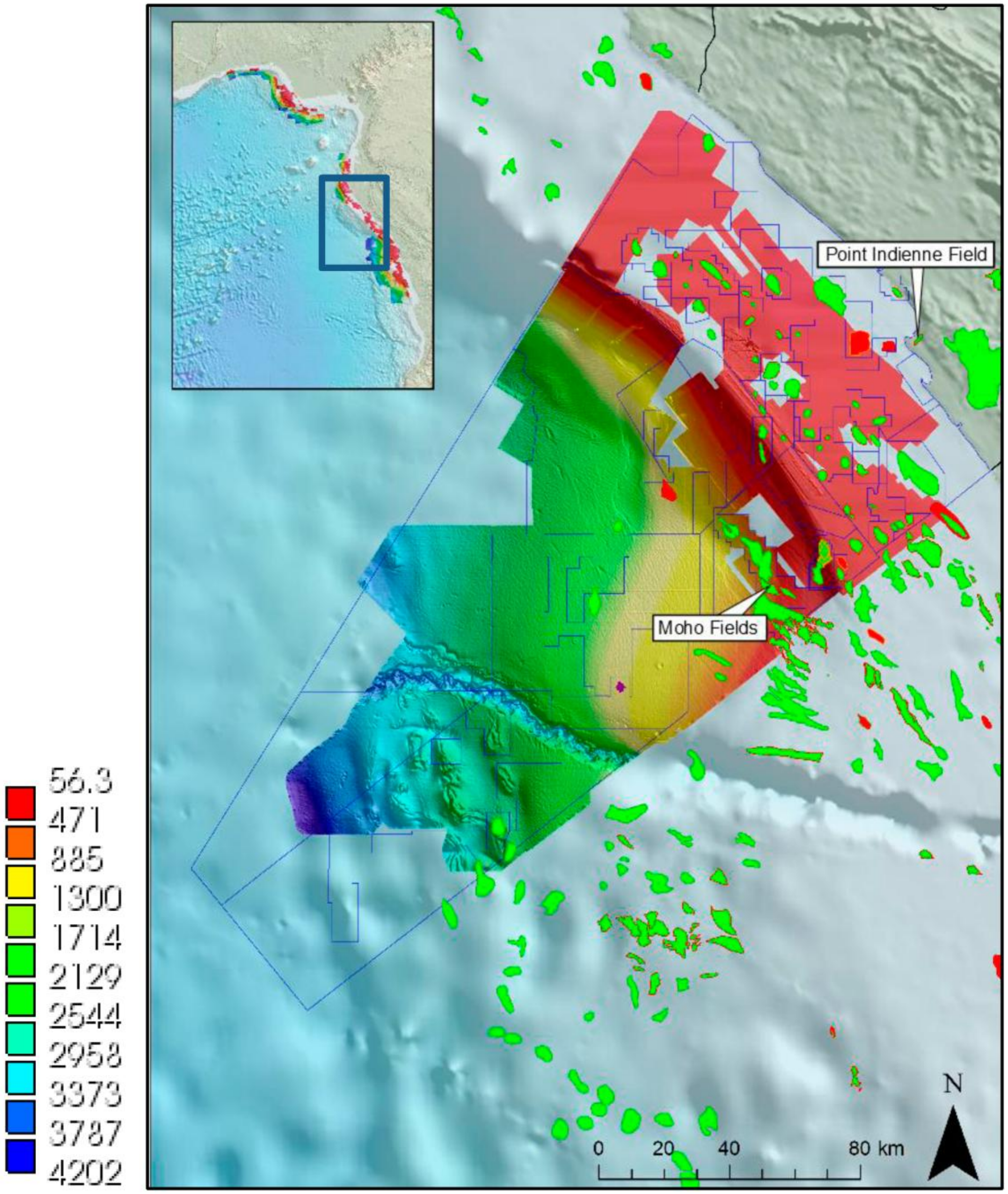

Figure 1. The PGS/SNPC Congo Mega-Survey with areas of interest discussed in this study.

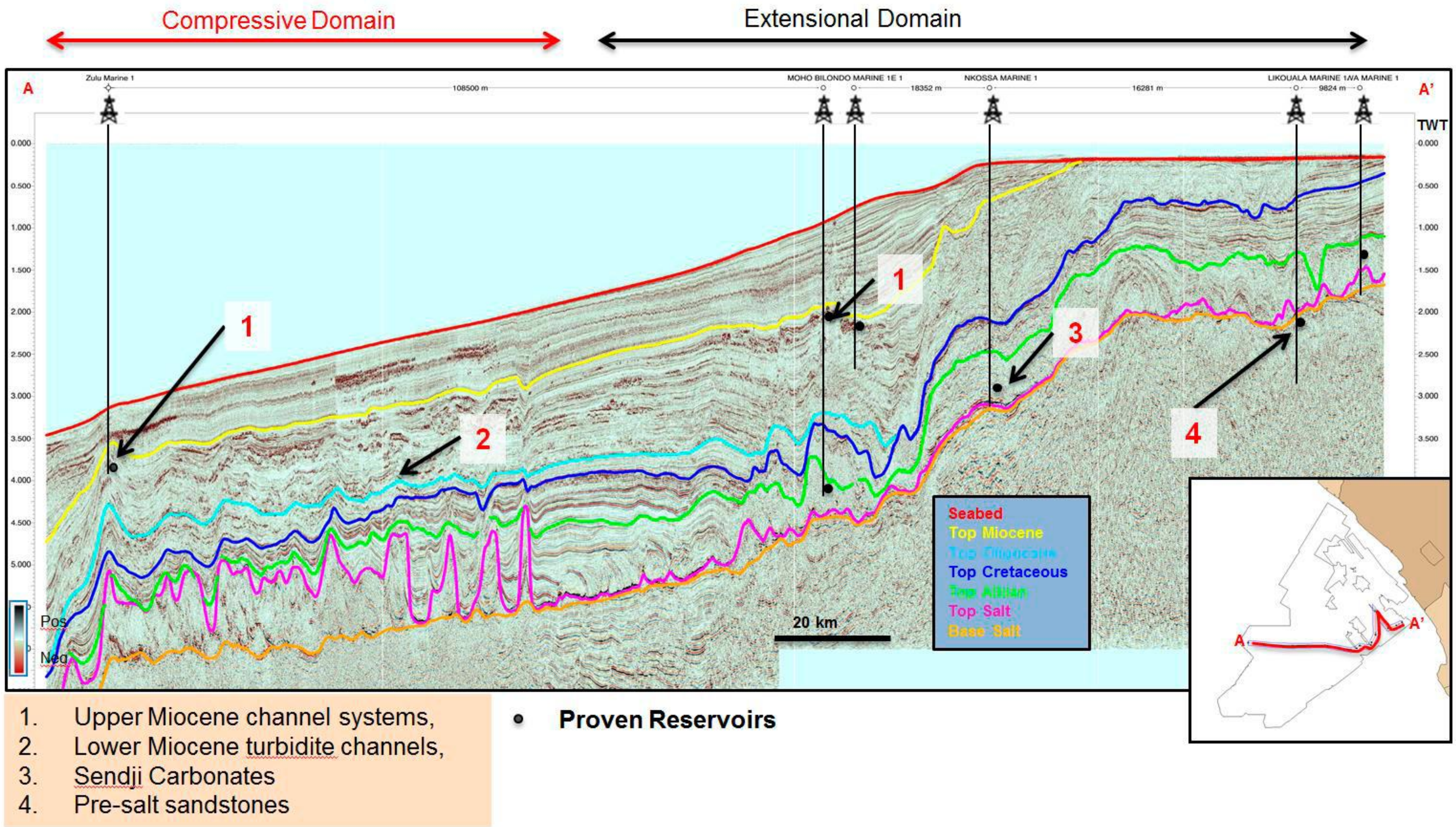

Figure 2. East-west seismic cross section with major interpretation horizons and proven reservoirs representing four different play types.

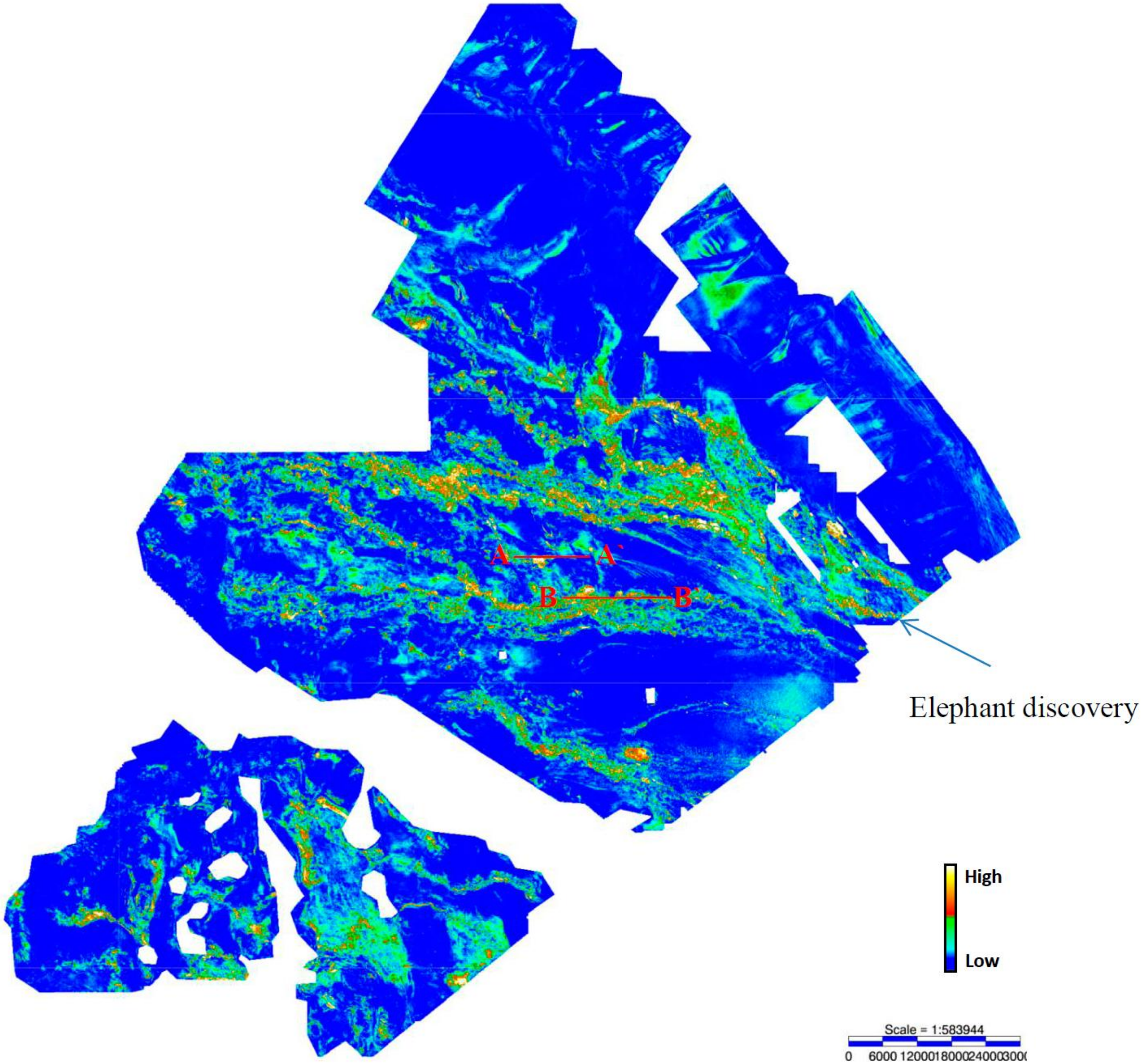

Figure 3. RMS between Top Miocene + 0.1 s and Top Miocene +0.2 s surfaces. Seismic lines A-A' and B-B' showing leads in Upper Miocene are illustrated in Figure 4.

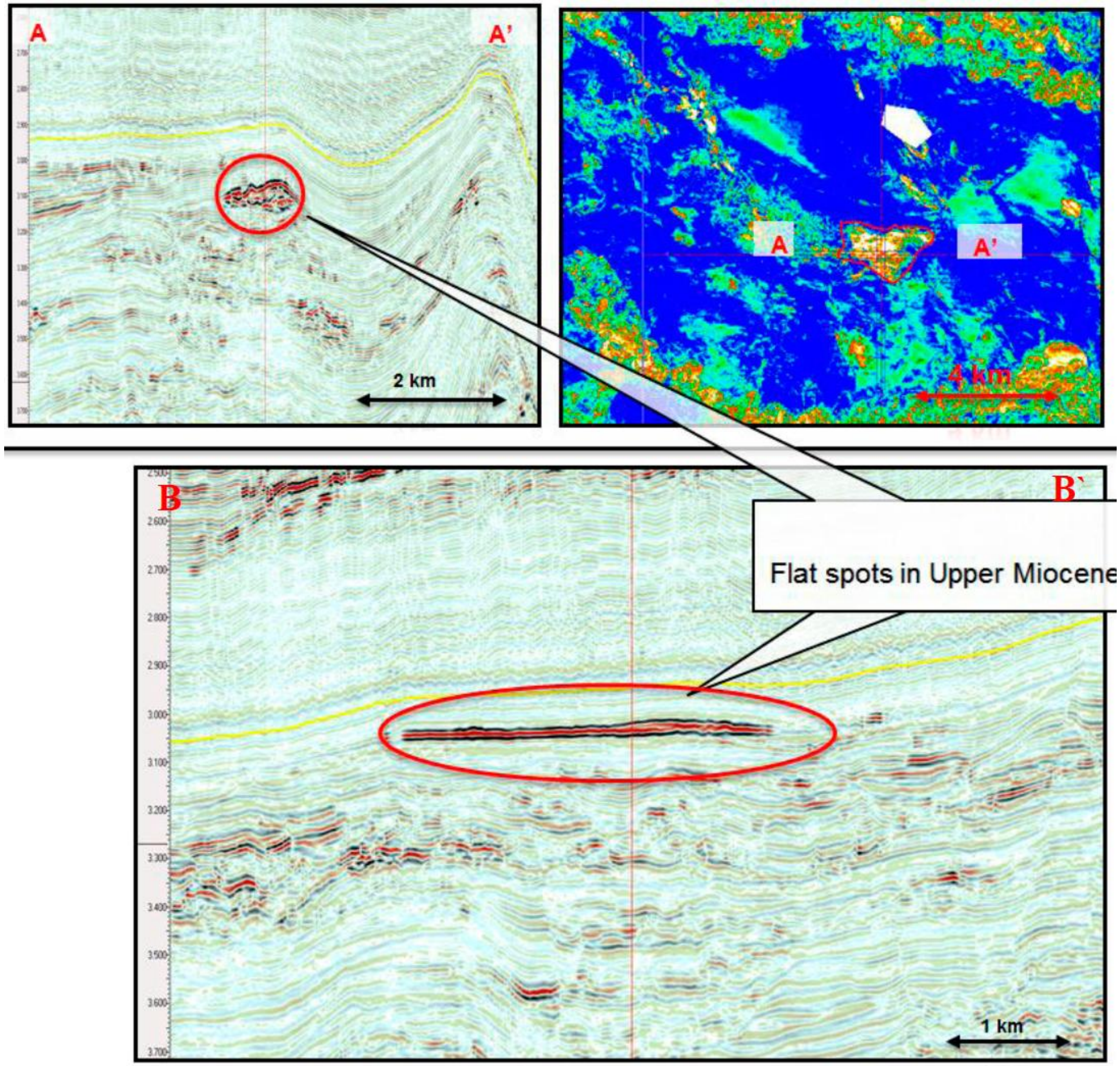

Figure 4. Flat spots in Upper Miocene within channel system.

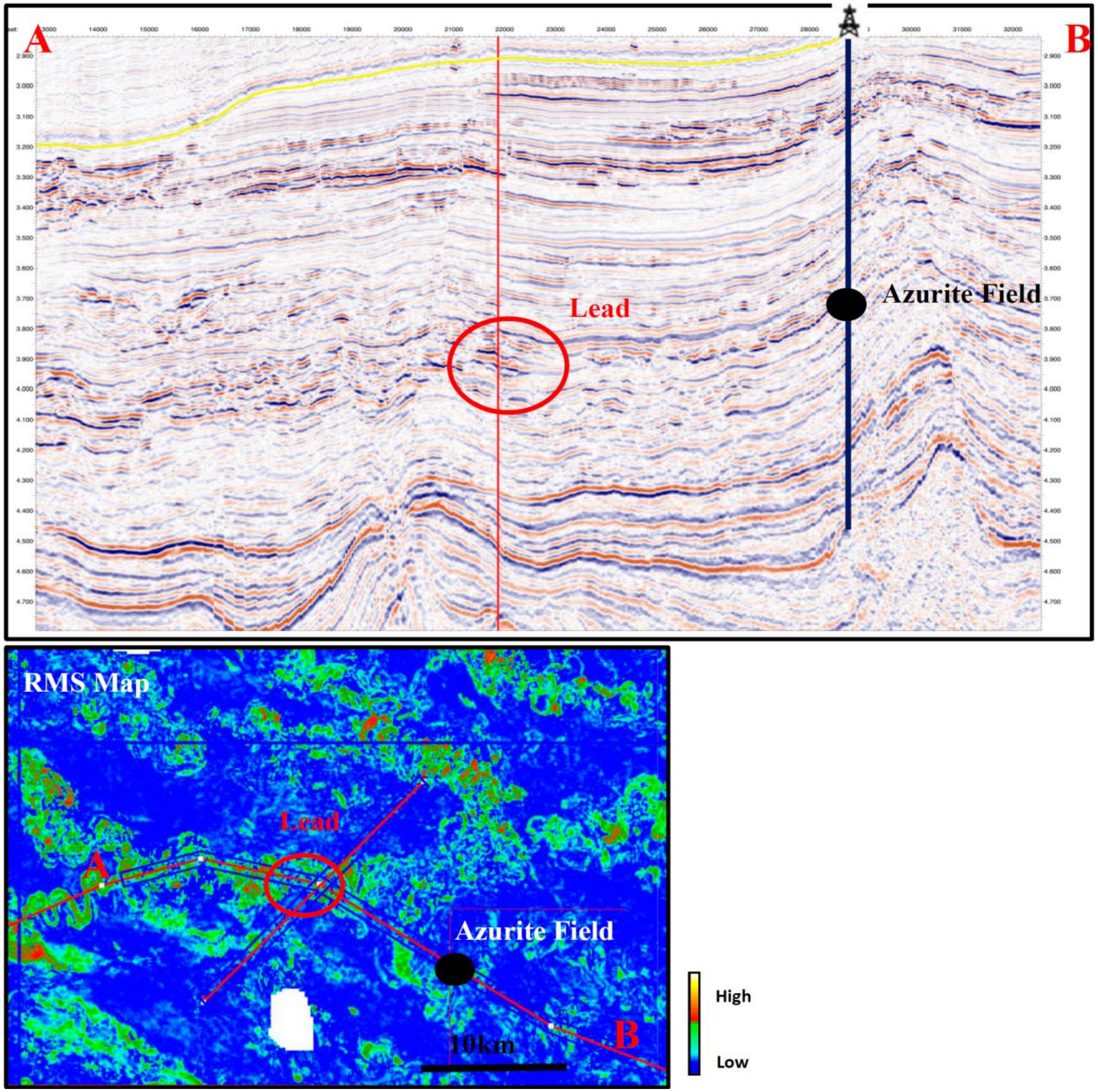

Figure 5. Lead of Lower Miocene Play Type sitting in the same channel as the Azurite Field (RMS Map). Both the lead and the Azurite Field are sitting on a structural high.