Carbonate reefs as a new play in the Northern Egypt Red Sea rift basin - unveiled by elastic full-waveform inversion

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ABSTRACT

The Northern Egyptian Red Sea rift basin is attracting the attention of exploration companies as it lies at the triple junction of the Gulf of Suez, Gulf of Aqaba, and Red Sea rift basins. The Egyptian Red Sea is currently largely underexplored, yet contrarily, holds an estimated mean volume of 5 bn bbl of undiscovered but recoverable oil and 112 tcf of natural gas (Schenk, n.d., 2010).

Despite its proximity to the well-explored Gulf of Suez region, the Red Sea basin remains enigmatic. Previous exploration phases yielded limited success, but gradually advanced basin knowledge has affirmed the presence of an active petroleum system, which proven by numerous oil and gas shows encountered in the drilling of 14 wells within the basin.

The complexity of the Red Sea's geology, characterized by an active rift system and intricate salt tectonics along with layered evaporites, poses numerous challenges to acquiring high-quality seismic images. Over the years, various local and regional 2D/3D surveys have been conducted, spanning from 1970 to 2018. However, the potential for ground-breaking insights lies in the integrated interpretation of the most recent seismic data acquisitions.

This study focuses on the integrated interpretation of a long-offset, dual-source narrow azimuth towed streamer seismic survey acquired in 2022 and processed with elastic full--waveform inversion (EFWI) workflows in 2023, in conjunction with shipborne high-resolution gravity and magnetic surveys. Leveraging this advanced technology, we focused on the concept of a lately observed play type for the Red Sea: Middle Miocene carbonate buildups. This ideas draws support from onshore surface geology, an in-depth examination of well data, and analogues found in reservoirs and fields within the Gulf of Suez basin.

Carbonate reef buildup plays stands out as the most abundant type of hydrocarbon reservoir globally, holding over half of the world's total hydrocarbon resources (Greenlee & Lehmann, 1993). A notable occurrence of the carbonate field within the area is the Ras Gharib Field discovered in 1938, situated in the Gulf of Suez basin and produced oil from Pre-Miocene and Middle-Miocene Belayim reefal limestones buildups (Momtaz, 1976).

Integrations of subsurface data, including the newly acquired 3D seismic data, velocity model, well data, gravity, and magnetic data, enabled the identification of similar carbonate reef buildup play concepts in the Northern Red Sea rift basin. Seismic data analysis has revealed intriguing features within the Middle-Miocene Belayim Formation, indicative of possible carbonate buildups. Some notable characteristics include strong top-positive reflections with internal seismic reflectors and clear continuous base reflectors (Figure 1). Additionally, map views of the Belayim Formation suggest sub-circular to elongated morphology with greater thickness compared to basinal sediments (Figure 2). The identified potential carbonate plays exhibit moderate gravity values without corresponding magnetic anomalies. Moreover, proposed carbonate buildup bodies are also delineated in higher velocity ranges if compared to surrounding regions.

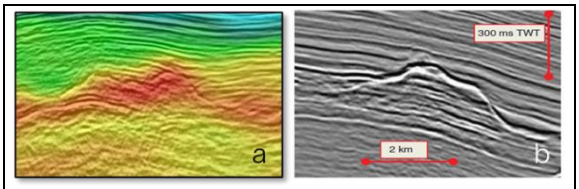

Figure 1: Comparison of geological body in the Red Sea (a) with known carbonate buildup in Luconia, Malaysia (b) (Koša et al., 2015)

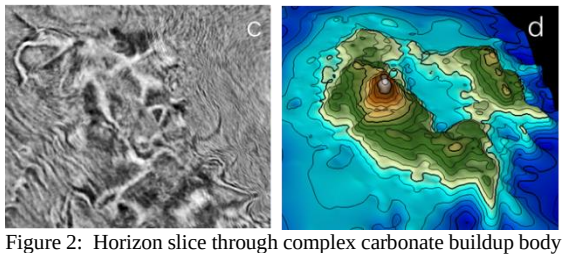

Figure 2: Horizon slice through complex carbonate buildup body (c) and thickness map of exploration lead (d).

These new ideas, along with the revisited interpretation and understanding of the basement structure and the salt geometry have been incorporated into a 2D petroleum systems model covering the most promising exploration leads. Model assessments affirm the Belayim Formation as the youngest source rock with significant expulsion potential across the studied area. Various modeling scenarios suggest that postulated Belayim carbonate reef buildups, with interpreted thickness in the range of 400 to 900 meters, could be self-charged or charged from underlying faulted Early Syn-rift (Early-Miocene Kareem and Rudeis Formations), proven oil/gas source rocks in the Gulf of Suez basin.

The Belayim Formation carbonate buildups lay directly beneath the salt and evaporites section, making it well sealed, therefore, our analysis suggests that the Middle Miocene-Belayim Formation could represent a promising and significant exploration target.