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Age and structure of the Levant basin, Eastern Mediterranean

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ABSTRACT

Large parts of the Mediterranean were formed during the Mesotethys Ocean opening and subsequently became land-locked in the midst of the Africa-Eurasia plate convergence. Since the Neogene, this convergence has concealed key sections of the original basins. Previous studies widely agree that the easternmost part of the Mediterranean, the Levant Basin, opened during the Permian to Early Jurassic (PJ) and accordingly explain the architecture of the basin and its margins. However, since the PJ model was suggested in the late 1990's a flood of new evidence has arrived since the hydrocarbon exploration, some of which do not fit in with the PJ model, and some remain unexplained. The current research re-examines the old and new evidence from the Levant basin, its margins, the surrounding landmass, the adjacent Eratosthenes Seamount and the eastern part of the Herodotus Basin. The integration of geological and geophysical data suggests that the Levant Basin formed ~100 Myr later than previously thought, i.e., during the Cretaceous. Its opening was triggered by the 'Levant-Nubia' mantle plume that induced a sequence of wide-spread Ocean Island Basalt volcanism. The resulting crustal updoming and stretching led to the breakup of the Levant landmass since ~141 Ma, and drifting of the Eratosthenes Seamount since ~125 Ma. Back-arc extension shaped the Levant Basin as a hybrid crust comprising continental slivers intervened by oceanic patches. The basin opened during the Long Normal Cretaceous Polarity Chrons between ~122 and ~84 Ma, and therefore it does not show any magnetic lineation. The opening of the Levant basin occurred while the Herodotus basin floor subducted eastward under the Eratosthenes Seamount. The subduction hinge did a roll-back and facilitated the Seamount drifting. The Seamount absorbed intensive volcanism while chasing the subduction roll-back and sliding between two Subduction-Transform Edge Propagator (STEP) faults that bounded the stretching Levant back-arc basin. The Turonian-Maastrichtian compression stress regime, or inversion, halted the extension of the Levant Basin, stagnated its hybrid fabric, and prevented the development of a spreading center. The evolutionary scenario suggested here is a game changer for future exploration in the Levant and may serve as a global analog for the formation of marginal seas.

1. Introduction

Marginal seas are formed in conjunction with the tectonic processes shaping their surrounding landmass (Zhou, 2014). Some seas develop through a continental breakup, crustal thinning and drifting of platelets (e.g., back-arc basins). Others form while converging plates close to a remnant ocean floor. The constructive nature of the marine environment makes these seas a central information source for reconstructing the regional tectonics, understanding the source-to-sink processes, and predicting the hydrocarbon maturation history. These Earth-system processes are inherently inter-linked. Hence only when a synchronized understanding of their dynamics is reached, will a comprehensive scenario of the basin formation be achieved.

The formation and degeneration of the eastern Mediterranean represent both scenarios of marginal seas. It was originally formed during the breakup of Gondwana and subsequently became trapped between the converging Afro-Arabian and Eurasian plates. The eastern Mediterranean comprises two major basins, the Herodotus and Levant-Phoenician (Fig. 1). Schattner and Ben-Avraham (2007) and Schattner and Lazar (2014) suggested that the Phoenician and Herodotus basins are remnants of the Mesotethys and in between, the Levant basin is regarded as being younger. The concept of the Permian to Early Jurassic (PJ) opening of the Levant basin, its crustal fabric and structural architecture developed through several prominent studies (e.g. Garfunkel and Derin, 1984; Garfunkel, 1998; Robertson, 1998; Walley, 1998; Ben-Avraham et al., 2002; Gardosh et al., 2010). Since the 1990's unprecedented exploration has flourished in the basin, massive gas reservoirs were discovered, and a flood of high-quality data was

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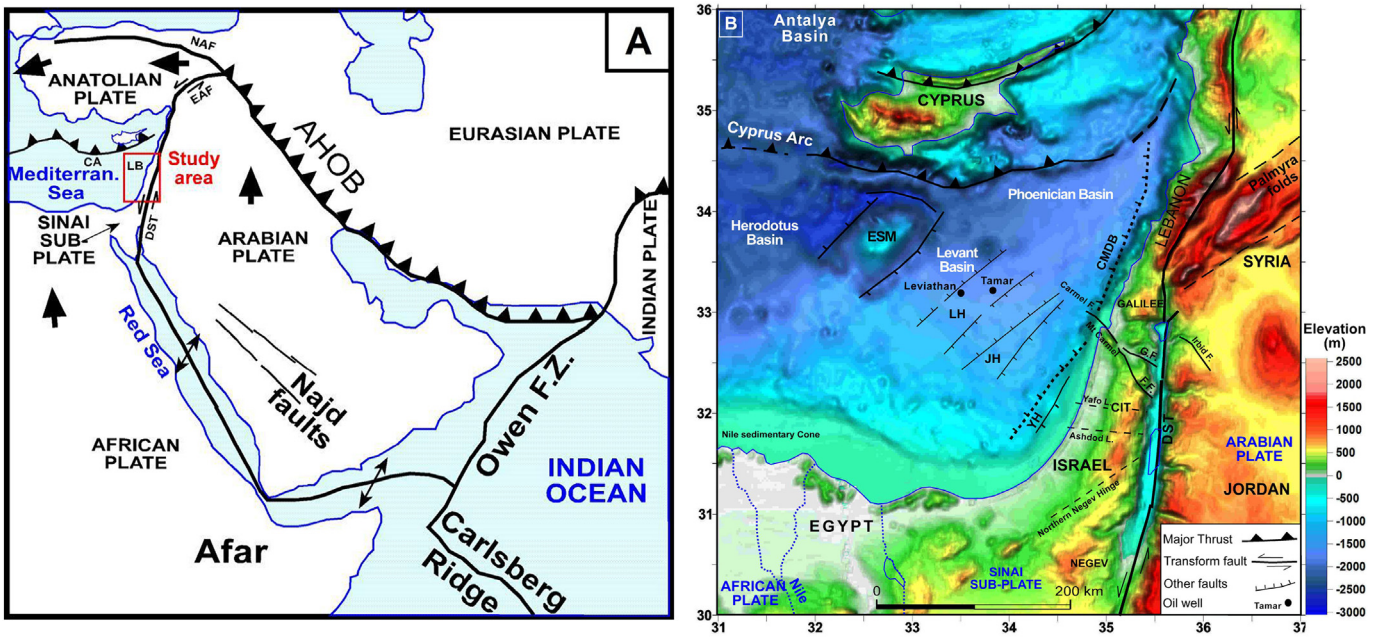

Fig. 1. A. Inset of Geodynamic setting surrounding the Arabian plate. LB, Levant Basin; DST, Dead Sea Transform; AHOB, the Alpine Himalaya orogenic belt; EAF, East Anatolia Fault; NAF, North Anatolia Fault; F.Z., Fracture Zone. B. Location and elevation map of Eastern Mediterranean-Levant study area illustrating the location and major faults (black dashed line marks subsurface fault). DST, Dead Sea Transform; F.F., Faria Fault; G.F., Gilboa Fault; CMDB, Continental Margin Deformation Belt (after Schattner et al., 2006a,b); ESM, Eratosthenes Seamount; JH, Jonah High; YH, Yam High; LH, Leviathan High.

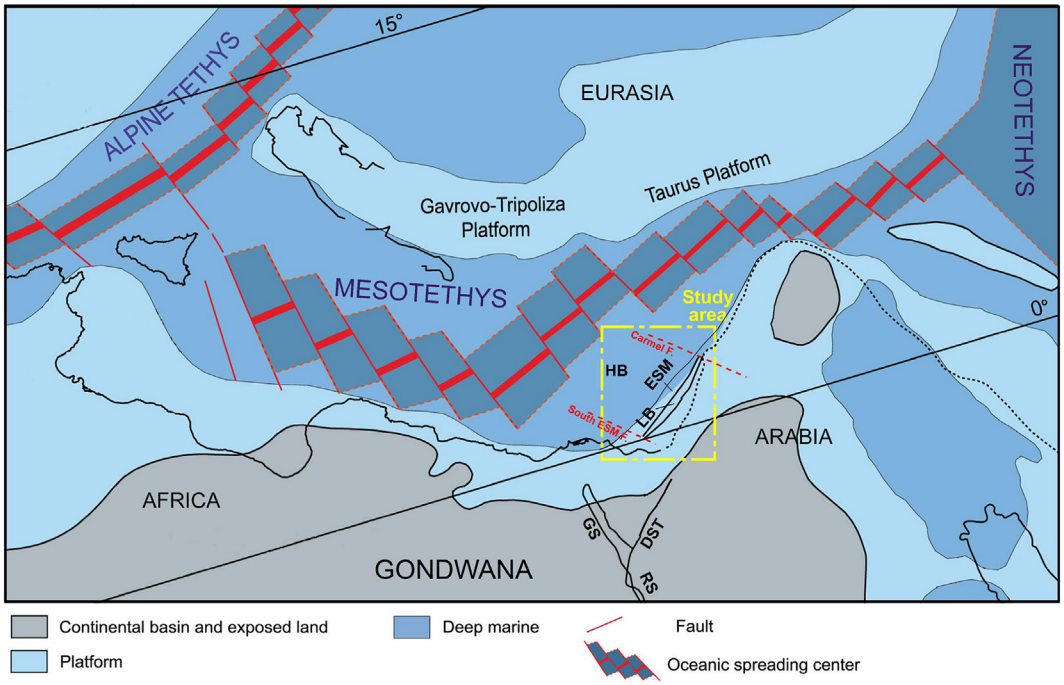

Fig. 2. A. Middle Jurassic paleo-reconstruction of North Gondwana showing opening of the various Tethyan Ocean branches (modified after Frizon de Lamotte et al., 2011), as well as outlines of structures that developed in future tectonic events. LB, Levant Basin; ESM, Eratosthenes Seamount; HB, Herodotus Basin; DST, Dead Sea Transform; GS, Gulf of Suez; RS, Red Sea; F, Fault. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

released for research. Some of the new evidence coincides with the PJ model (Figs. 1, 2), while other evidence does not fit well with this prevailing model. For example, the oldest strata revealed by deep wells reach Tertiary units. Nonetheless, the PJ model has been widely accepted and with time became a confirmation bias for many studies that presented their interpretations accordingly.

The present study challenges the prevailing PJ model. Unlike the common research approach that focusses on the basin only, our study examines geological evidence and various geophysical methods that have accumulated across the Levant basin and its margins to establish a unifying and consistent tectonic scenario for the formation of the Levant basin. Data is presented from key locations, extending from the Herodotus basin, through Eratosthenes Seamount, and particularly the Levant basin and its eastern continental terrain.