Tectonophysics 665 (2015) 186–198

Contents lists available at ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

The enigma of the Jonah high in the middle of the Levant basin and its significance to the history of rifting

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A R T I C L E   I N F O

Article history:
Received 18 March 2015
Received in revised form 27 August 2015
Accepted 30 September 2015
Available online 17 October 2015

Keywords:
Levant basin
Mesozoic horst
Seamount
Paleo-height
Pre-stack depth migration
Horizon interpretation

A B S T R A C T

Recent giant gas discoveries within deeply buried structural highs in the middle of the Levant basin have attracted the attention of the industrial and academic communities striving to understand the origin of such structures, their relations to the tectonic history of the basin, and their evolution through time. Here we focus on the Jonah high, which is one of the largest structures in the basin and is particularly enigmatic in its geometry, dimensions and location compared to nearby structures. It is buried under more than 3 km of Late Tertiary sediments, and is associated with one of the largest magnetic anomalies in the basin, though no significant gravity anomaly is observed. Previous studies raised several possibilities explaining its origin: an ancient horst related to the early stage of basin formation (Late Paleozoic or early Mesozoic); a Syrian Arc fold (Late Cretaceous to Neogene); a giant volcanic seamount; and an intrusive magmatic body.

A reconstruction of the evolution of this structure is proposed here based on newly produced pre-stack depth migration of five selected seismic reflection lines crossing the Jonah high combined with a basin-wide interpretation of more than 500 2-D time-migrated lines. We suggest that the Jonah high is a horst bounded by grabens, most probably formed during continental breakup related to the Neo-Tethys formation. However, unlike other extensional structures that were reactivated and inverted during the Syrian Arc deformation, the Jonah high was never reactivated. Rather, it formed a prominent seamount that persisted for 120–140 Ma until the Early Miocene, when it was finally buried. In a wider perspective the Jonah horst is similar to the Eratosthenes seamount, a fragment of continental crust between the Levant and Herodotus basins.

1. Introduction

The thick (>10 km) sedimentary cover in the Levant basin (easternmost corner of the Mediterranean Sea; Fig. 1) hides several structures not expressed in the present-day bathymetry. A series of narrow and elongated anticlines and monoclines are prominent in the shallow part of the basin (Figs. 1 and 2). These folds are quite similar in their geometry to the well-known Syrian Arc folds, ~1000 km-long fold belt extending from Sinai through Israel to Syria, originally defined by Krenkel (1924). The deeper part of the basin hosts fewer structures. Some of them, such as the Tamar and Dalit gas bearing anticlines, are narrow and long, resembling the folds in the shallow part of the basin. Others, such as the Leviathan and Jonah highs, are larger and different in their geometry and extent (Fig. 1).

This study focuses on the Jonah high, located 80 km west of the Israeli coastline in the southeastern part of the Mediterranean Sea (Figs. 1 and 2). Seismic reflection surveys reveal a triangular, ~18 km-wide structure, buried under more than 3 km of Late Tertiary sediments and a mound topped by sub-horizontal bundles of reflectors (Folkman and Ben-Gai, 2004; Gardosh et al., 2008). The Jonah high, one of the most prominent structures in this basin, is quite enigmatic and attractive both for tectonic research and for hydrocarbon exploration. Its dome shape, as displayed on seismic sections, reveals a non-reflective internal structure that does not show folded beds (Fig. 2). In addition, it is associated with one of the largest magnetic anomalies in the Levant basin. Interestingly, only a small positive gravity anomaly is observed (Gardosh et al., 2008; Rybakov et al., 1997) and extrusive or intrusive boundaries typical to magmatic bodies are not identified in seismic images (Fig. 2). Finally, the difference between its non-reflective internal structure and its reflector-rich surrounding is prominent, but distinct faults were not recognized (Fig. 2).

Several suggestions for the origin of the Jonah high, with different profound implications for our understanding of the regional tectonics, were offered in the literature, without providing a detailed analysis. Folkman and Ben-Gai (2004) suggested that the Jonah high is a deep-

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http://dx.doi.org/10.1016/j.tecto.2015.09.037
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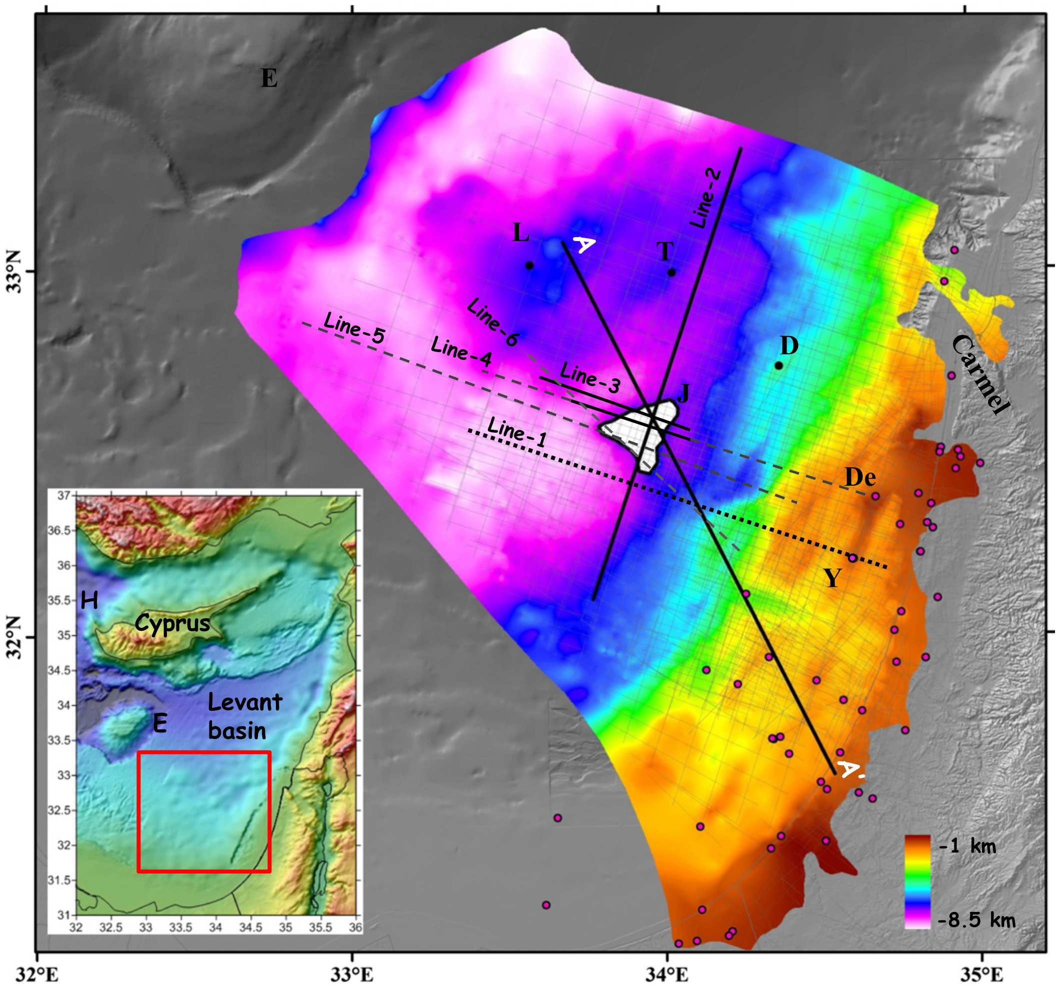

Fig. 1. Location map. Colored map is the Base Saqiye Group unconformity surface (modified after Steinberg et al., 2011). White polygon denotes the part of the Jonah high (J) where the lower Saqiye Gr. (Late Eocene–Oligocene) is missing. Gray background is bathymetry from Hall (1993). Regional bathymetry map (inset) is taken from ETOPO 11 (Amante and Eakins, 2009). Dashed lines are the depth-migrated seismic lines (this study). Doted black line is a representative time-migrated section (Fig. 2). Fine gray mesh represents all seismic lines used for interpretation. AA′ is a regional section used for gravity and magnetic modeling (Fig. 9). Dots are wells used for correlation. Abbreviation: L—Leviathan, T—Tamar, D—Dalit, De—Delta-1, Y—Yam-Yafo-1, E—Eatosthenes seamount, H—Herodotus Basin.

seated (8 km) igneous intrusion that was formed concurrently with the Syrian Arc structures. Considering its location tens of kilometers west of the main fold belt, the Jonah high has implications for the extent and nature of this deformation zone. Alternatively, Rybakov et al. (2011) suggested a Mesozoic and Cenozoic volcanic edifice that is located in the transition zone between the eastern Mediterranean oceanic crust and the continental crust of the Arabian plate. This alternative raises the question of the age of magmatic activity: is it related to the magmatism of Early Mesozoic rifting (Garfunkel, 1998; Robertson, 1998); to Early Cretaceous intra-plate magmatic activity previously identified in the hinterland (Garfunkel, 1989); or to Cenozoic magmatism related to the Arabia–Africa breakup? Gardosh et al. (2008) hypothesized that the Jonah high is an Early Jurassic horst, overlain by an extrusive volcanic cone of Late Cretaceous to Early Tertiary age. In respect to these contradicting scenarios we present a detailed analysis based on newly processed seismic data and interpretation of the Jonah high. The purpose of this paper is to explore its origin and evolution and to confirm or dismiss previously suggested explanations. For example, if the Jonah high is an ancient horst bounded by deep grabens, this would apparently prove that the Early Mesozoic rifting did not rupture the Levant lithosphere and did not produce an oceanic crust at that point. Such an alternative enables calculating the amount of extension during rifting and may provide important constraints for the thermal history of the basin and its ensuing subsidence.

Noteworthy, in light of the recent giant gas discoveries in the Levant basin within structural highs, such as Dalit, Tamar and Leviathan (Fig. 1), understanding the origin of the Jonah high (horst, fold or magmatic body), its age and rock composition, could have major implications for hydrocarbon exploration. The possibility that the Jonah structure rose above the ancient surrounding seafloor for tens or even a 100 m.y. and may have been covered by carbonate reefs further emphasizes its importance as a reservoir regardless of its origin.

The present research is based on a regional interpretation of more than 500 time-migrated seismic lines. Five selected seismic lines were reprocessed using the pre-stack depth migration procedure. This procedure is crucial for any structural analysis especially in the presence of lateral velocity variation, as it enables a closer representation of non-flat structures that are otherwise distorted in the time sections. The pre-stack depth migration procedure corrects for geometric distortions in and around the Jonah high and improves the internal imaging of the structure. We start with a brief description of the tectonic setting and methodology (Sections 2–3). In Section 4.1 we show that the depth-migrated section enables exploring whether internal folded layers or extrusive structures exist within the structure. We then examine the