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The internal grabens of the Levant Rifts and their geodynamic significance

Yossi Mart [a,*], Dina Vachtman [b]

[a] Leon Recanati Institute for Marine Studies, University of Haifa, Mount Carmel, 31905 Haifa, Israel
[b] Statoil ASA, 9414 Harstad, Norway

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ABSTRACT

The Levant Rift system is a linear assemblage of rifts and their mountainous flanks that comprise three structural distinct sections. The southern Jordan Rift is built of series of secondary axial grabens that diminish in length northwards and are separated from each other by poorly rifted threshold zones. The central section of the rift system is the Lebanese Baqa'a embedded between mountainous flanks, and a splay of faults that scatter to the north-northeast; the northern section comprises the SW-trending Karasu–Hatay Rifts from which the Ghab graben branches southwards. It is suggested that the rifting of the Jordan Rift is the northern extension of the Red Sea continental break-up, while the Karasu–Tatay section correlates geodynamically with the migration of Anatolia westwards. The Baqa'a, its mountainous flanks and the fault splay mark the termination of the crustal break-up from the south, but rejuvenation of some faults indicate the effects of the Anatolian migration.

1. Introduction

The geodynamic setting of the Levant Rift system is commonly considered to be a prime example of a large transform fault exposed on land (e.g., Freund, 1970; Garfunkel, 1981), where its post-Eocene age and its transform characteristics are commonly taken for granted (e.g., Gvirtzman and Steinberg, 2012; Hartman et al., 2015). Evidence for left-lateral displacement during the Late Quaternary at a rate of ca. 5 mm/yr (Klinger et al., 2000) is considered representative. However, the tectonic regime of that rift system has been highly debated, and Dubertret (1970), Mart and Horowitz (1981), Picard (1987) and Horowitz (2001) emphasized the extensional structural features of the rift, indicated by its normal boundary faults and large dip-slip throws. The latter interpretation presumed that the rift system was generated primarily by oblique tectonic extension, and that it was initiated in the Late Miocene; it serves as a prime example of early continental break-up (Mart and Dauteuil, 2000; Mart et al., 2005).

The Levant Rift system is a 1100-km-long, north–south-trending series of structural and morphological depressions bounded by structurally uplifted mountainous terrains along its flanks, where large normal faults constrain the mountain-to-valley transitions in many places. The system comprises two segments of distinct tectonic patterns. The southern segment of the rift system extends from the Red Sea through the Gulf of Elat, the Dead Sea and the Sea of Galilee, to the Lebanese Baqa'a (Fig. 1). This rifted segment is built of a series of axial downthrown grabens and uplifted mountainous flanks, with vertical throw of several kilometers, separated from each other by thresholds of subdued structures, where the downthrow of the rifts and the uplift of their flanks are reduced. In addition to vertical displacement, sinistral strike-slip displacement was observed along the southern segment of the system (e.g., Ben-Avraham et al., 2010; Freund et al.,

* Corresponding author.
E-mail address: yossimart@gmail.com (Y. Mart).

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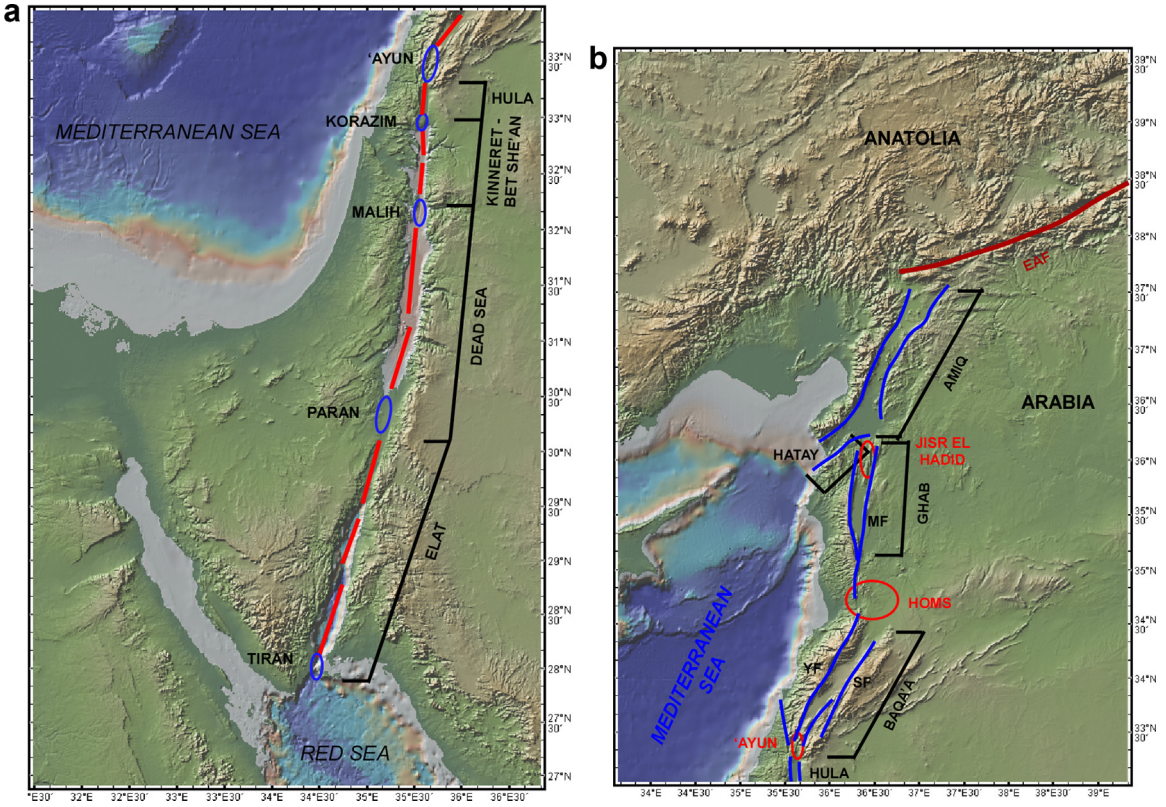

Fig. 1. (Color online.) General layout of the Levant Rift System and its two major components, the southern segment with its internal grabens (blue ovals) and thresholds (blue arrows), and the northern Amiq–Ghab–Hatay grabens (red ovals). Tectonically, the southern segment is connected with the Red Sea in the South and the Ghab–Amiq section with the East Anatolian Fault to the northeast. (a) The Elat, Dead Sea and Sea of Galilee graben components of the southern section. (b) The Lebanese Baqa'a (blue oval) and its fault splay (Black line) and the Ghab and Amiq grabens (red ovals). Hatay graben is the SW extension of Amiq graben. Note the linear offset between the Baqa'a and Ghab, and the diversion of the Yammouneh fault from a NNE–SSW trend in the south to a north–south one further northwards.
Charts: courtesy of https://www.geomapapp.org.

1970; Joffe and Garfunkel, 1987; Mart and Horowitz, 1981). Consequently, the oblique displacement along the Levant Rift system is commonly accepted (e.g., Joffe and Garfunkel, 1987; Mart et al., 2005), even though its quantitative details are debated (e.g., Mart, 2013; Mart and Rabinowitz, 1986; Sobolev et al., 2005).

The setting of axial grabens and intermittent thresholds is not unique to the Levant Rift: it was depicted also in the East African Rift (e.g., Bosworth, 1985; Ebinger et al., 1987; Gawthorpe and Hurst, 1993), and in the central and northern Red Sea (Bonatti, 1985; Le Pichon and Francheteau, 1978). And like the Red Sea, the northward diminishing size of the axial grabens was used to suggest the geodynamics of the early stages of continental break-up and the initiation of basaltic accretion in divergent plate boundaries as gradual ascent of punctiform magmatic diapirs (Bonatti, 1985). Analog models showed further that the punctiformic patterns of incipient rifting takes place only when the obliquity of the tectonic extension is 15°–30° from the normal to the axial zone of the rift (Agostini et al., 2009; Mart and Dauteuil, 2000).

The northern part of the southern segment of the Levant Rift system is the Lebanese Baqa'a and its mountainous flanks of Mt. Lebanon and Mt. Anti-Lebanon. The trend of the Baqa'a is NNE–SSW, off the north–south orientation of most of the southern segment of the rift. The Lebanese segment is also distinguished by its anomalous elevation, which rises some 1500 m above the rest of the southern section of the system, and by the distribution of fan-shaped series of fault splay, which constrain the rift and transect its margins (Fig. 1). These faults show both normal and strike-slip offsets (Brew et al., 2001; Walley, 1988, 1998). Well-known among the faults is the 150-km-long Yammouneh Fault that bounds the rifted Baqa'a from the west in its southern section, then transects Mt. Lebanon off the northern Baqa'a, to connect with the Zawiya Fault that bounds the Ghab graben. A sinistral offset of 11 km of Pliocene basalts along the Yammouneh Fault was reported by Dubertret (1970). Marine Middle Miocene deposits along the eastern flanks of the Baqa'a Rift suggest that the uplift of that segment occurred mainly in Plio-Quaternary times (Dubertret, 1975; Homberg et al., 2010; Walley, 1998).

The northern segment of the Levant Rift system includes the Ghab graben, which branches off southwards from the Amiq–Hatay Rift in southern Anatolia. The Amiq–Hatay graben emerged from the East Anatolian Fault (Fig. 1) and was probably generated under a predominantly extensional tectonic stress due to the westwards motion of Anatolia (Boulton and Robertson, 2008; Mart, 2013).