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Subsidence and conversion of the Dead Sea basin to an inland erosion base level in the early middle Miocene as inferred from geomorphological analysis of its ancient western fluvial outlet

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ABSTRACT

The first major subsidence of the Dead Sea pull-apart basin (DSB) is evidenced by the thick Hufeira Member of the terrestrial Hazeva Formation. The age of the Hufeira Member and the conversion of the DSB to an inland erosion base level are not well constrained. For this purpose we studied the effect of the evolving basin on its ancient fluvial outlet to the Arad-Be'er Sheva Valley (ABSV), which served as a Miocene corridor between the embryonic DSB region in the east and the Mediterranean Sea in the west. We mapped and analyzed the morphostratigraphy of four series of rock-cut erosion surfaces (from top to bottom: the Barir, Kuseifa, Ar'ara, and Shemen surfaces). They are manifested in the east as fluvial erosion surfaces, capped by conglomerates, passing laterally westward to marine wave-cut surfaces, capped by a shallow marine limestone of the early middle Miocene Ziqlag Formation. The age of these surfaces is constrained to the early middle Miocene (Langhian) based on morphostratigraphy correlation with the Ziqlag Formation. Paleogeographic reconstruction of the two higher and older surfaces reveals transverse valleys, which drained the DSB region and crossed the present route of the regional water divide. These transverse valleys were presumably the western outlets to the Mediterranean Sea of the newly subsiding basin. Precambrian components in the assemblage of the clasts that cover the Kuseifa surface were not found in the Hufeira Member and thus reflect an ongoing post-Hufeira exumation of the DSB drainage basin. Hence, this early middle Miocene surface postdates the Hufeira Member, assigning an age of late early Miocene to the first major subsidence of the DSB. The two lower and younger surfaces represent local drainage systems confined to the ABSV. This transition from regional to local drainage system marks the establishment of the present regional water divide and the conversion of the DSB to an inland erosion base level during the early middle Miocene.

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1. Introduction

The Dead Sea pull-apart basin (DSB), the lowest place on earth (425 bmsl), is served today as a regional inland erosion base level. The DSB is about 150 km long, composed of several subbasins separated by diagonal faults. It was formed between two left-stepped segments of the sinistral Dead Sea Transform (DST), (Fig. 1). A sequence of fluvial, lacustrine, and evaporite sediments more than 10 km thick was encountered under its northern part, just south of the present Dead Sea (Quennell, 1958; Garfunkel, 1981; Garfunkel and Ben-Avraham, 1996, Garfunkel and Ban-Avraham, 2001; Ben-Avraham, 2014; Garfunkel, 2014). Following the model of Garfunkel (1981), which suggested coupling of the DST and DSB, a similar age would be expected for both of them. Yet, it is not clear when the embryonic DSB was converted into an inland erosion base level, disconnected from the Mediterranean Sea in the west.

Tectonics along the trace of the DST started south of the DSB as early as the Oligocene (e.g., Garfunkel, 1970; Avni et al., 2012), but no evidence is available for horizontal displacement or development of a deep structural depression in the DSB area during this phase. The first displacement along the DST was inferred from dating of magnetic anomalies along the spreading center of the Red Sea, ranging between 18 and 16 Ma (Garfunkel, 1981; Joffe and Garfunkel, 1987) and 14 Ma (Bosworth et al., 2005).

The initiation of the DSB is demonstrated by the accumulation pattern of the early Miocene terrestrial Hazeve Formation (Calvo and Bartov, 2001; Zilberman and Calvo, 2013). A subsidence of ~150 m occurred after the deposition of the lower part of the Hazeva Formation, sheltering this sequence from sequential erosion (Calvo and Bartov, 2001). The tectonics ceased during the deposition of the overlying Rotem Member, more than 1 km thick, which exhibits a similar thickness inside and outside the DSB. This unit was deposited upon a wide regional subsiding basin prior to the DSB formation, extending far beyond its borders to the east and west (Calvo and Bartov, 2001; Zilberman and Calvo, 2013).

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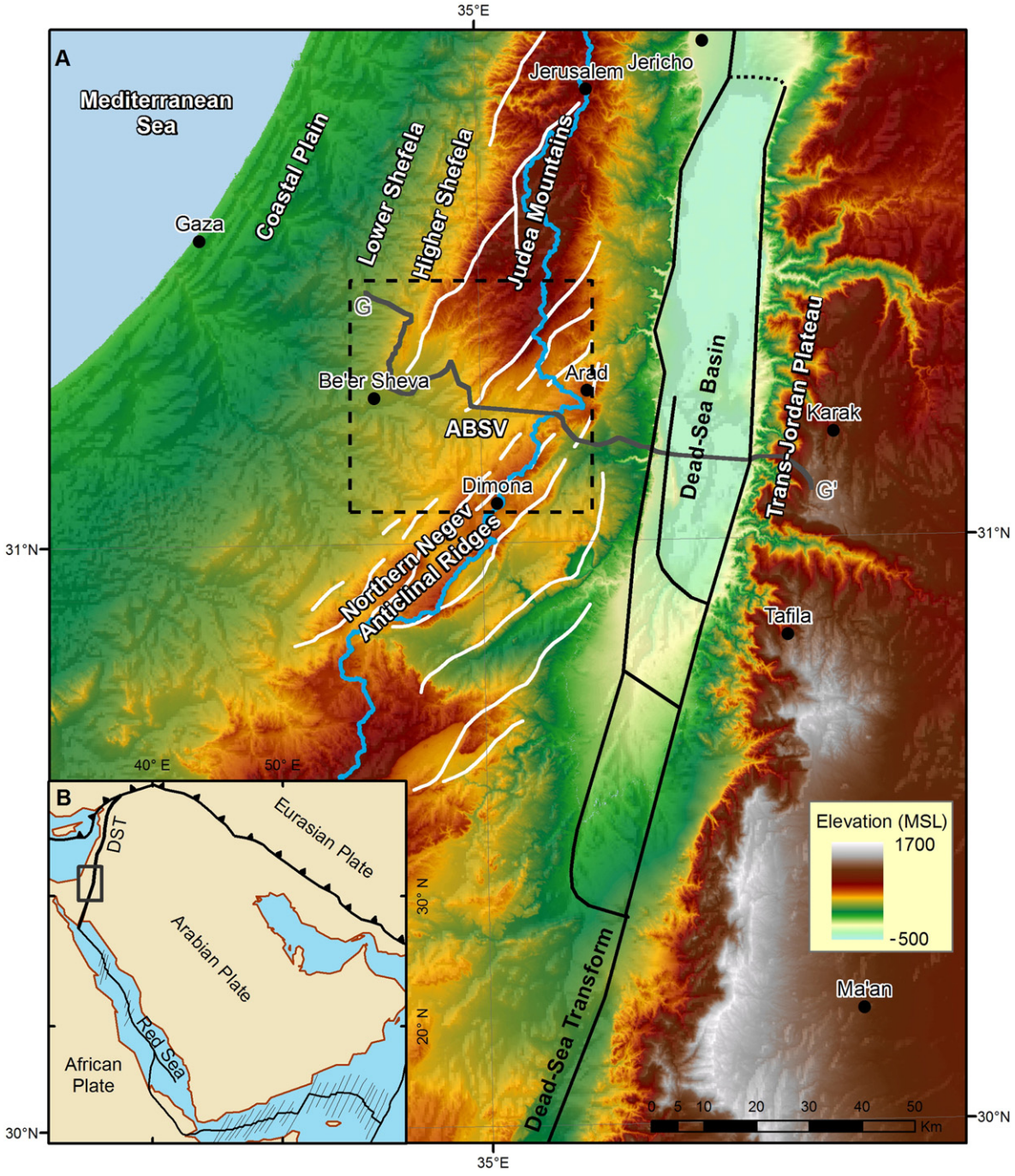

Fig. 1. (A) Location map. The general tectonic boundaries of the DSB are illustrated. Black lines mark the main faults of the DST. Anticline axes are marked by white lines, after Sneh and Weinberger (2014). Blue line outlines the course of the regional water divide separating between the DSB to the east and the Mediterranean Sea to the west. Locations of geological cross sections G–G′ of Fig. 7 are marked by gray line. (B) Map of the regional tectonic setting of the Middle East. Gray rectangle outlines the study area.

The first prominent subsidence of the DSB is reflected by the >1650-m-thick Hufeira Member (the uppermost member of the Hazeva Formation), which is confined to the DSB and contains clasts derived from its exposed shoulders (Calvo and Bartov, 2001; Zilberman and Calvo, 2013). The age of the Hufeira Member is not well constrained. Zilberman and Calvo (2013) suggested that the deposition of the underlying regional Rotem Member ended before the uplift of the entire region during the early middle Miocene (e.g., Buchbinder et al., 1986; Buchbinder and Zilberman, 1997; Bar et al., 2013). However, it is not clear if the subsidence of the DSB and accumulation of the syntectonic Hufeira Member were contemporaneous with this uplift.

While efforts were made to date the tectonic history of the DSB, its ancient geomorphologic evolution is poorly investigated. Specifically, it is not clear when the DSB turned from an open basin that drained westward to the Mediterranean Sea into an inland erosion base level. This ancient drainage system, that drained the Arabian plate toward the Mediterranean Sea across the evolving DSB and through the Arad-Be'er Sheva valley (ABSV), was already active in the early Miocene (e.g., Neev, 1960; Gvirtzman and Buchbinder, 1969; Zilberman and Avni, 2007). The ABSV served as a fluvial corridor between the DSB and the Mediterranean Sea owing to its low structural position. The base level of these streams that drained the Arabian Plateau and the DSB was the sea that invaded into the ABSV several times during the

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