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# Pliocene-Pleistocene waterbodies and associated deposits in southern Israel and southern Jordan

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ABSTRACT

This paper provides an in-depth review of evidence for the presence of twelve waterbodies spanning the Late Pliocene through Late Pleistocene in southern Israel and southern Jordan. A comprehensive description of these waterbodies is presented, combined with new field, paleontological and numerical age data, along with a discussion of their implications for paleohydrology and paleoclimate. The region is currently hyper-arid and there are no permanent rivers, wetlands or lakes in the area. Nevertheless, during the time-frame examined, continuous layers of limestones and mudstones were deposited in wetlands and shallow lakes. According to their location, the waterbodies were classified into either resulting from local tectonic depressions or in wide natural depressions at base levels. Following the types of sediments and fauna associated with these waterbodies, it is suggested that four wetter periods occurred: Late Pliocene/Early Pleistocene, Middle Pleistocene, Middle Late Pleistocene and terminal Late Pleistocene. This resulted in the deposition of limestone, chalk, travertine, calcrete, mudstone, marl, clay, silt and sandstone. For several waterbodies, vertical and lateral transitions between white limestone and fine clastic sediments rich in carbonate, indicate changes in depositional conditions from a shallow lake to a wetland, both associated with wetter hydrological settings compared to current climatic conditions.


## 1. Introduction

Since the transition from the Pliocene to Pleistocene, the climate of the southern parts of Jordan and Israel (Fig. 1) fluctuated between hyper-arid and arid conditions (e.g. Enzel et al., 2008; Amit et al., 2011; Frumkin et al., 2011). Fluvial terraces in the Negev, Arava (or Araba) Valley and the Jordanian Plateau (Fig. 2) attest to cycles of wet and dry periods in this region during the Quaternary (Shaw, 1947; Bentor and Vorman, 1954; Garfunkel and Horowitz, 1966; Shahar et al., 1966; Bartov, 1974; Eidelman, 1979; Gerson, 1982; Eyal, 1984; Amit and Gerson, 1986; Amit et al., 1993, 2011; Ginat et al., 1994, 2003; Ginat, 1997; Avni, 1998; Abed and Yaghan, 2000b; Issar et al., 2011) whereas today the area receives less than 50 mm of rainfall annually (Mithen and Black, 2011).

A total of twelve Pliocene and Pleistocene waterbodies in southern Israel and Jordan have been previously described (Table 1). The aim of this paper is hence 1) to assemble data from previous studies augmented with new results to present evidence for the presence of Pliocene-Pleistocene waterbodies in the currently arid parts of the southern Levant that are today devoid of such features; 2) to analyse paleoenvironmental conditions that led to the formation of sediments found in the field; 3) to present a classification of different types of waterbodies based on differing geological settings; and 4) to provide a spatial and temporal reconstruction of waterbodies in the southern Levant during the Late Pliocene and the Pleistocene. These are combined to obtain a new picture of the climatic history of the region.

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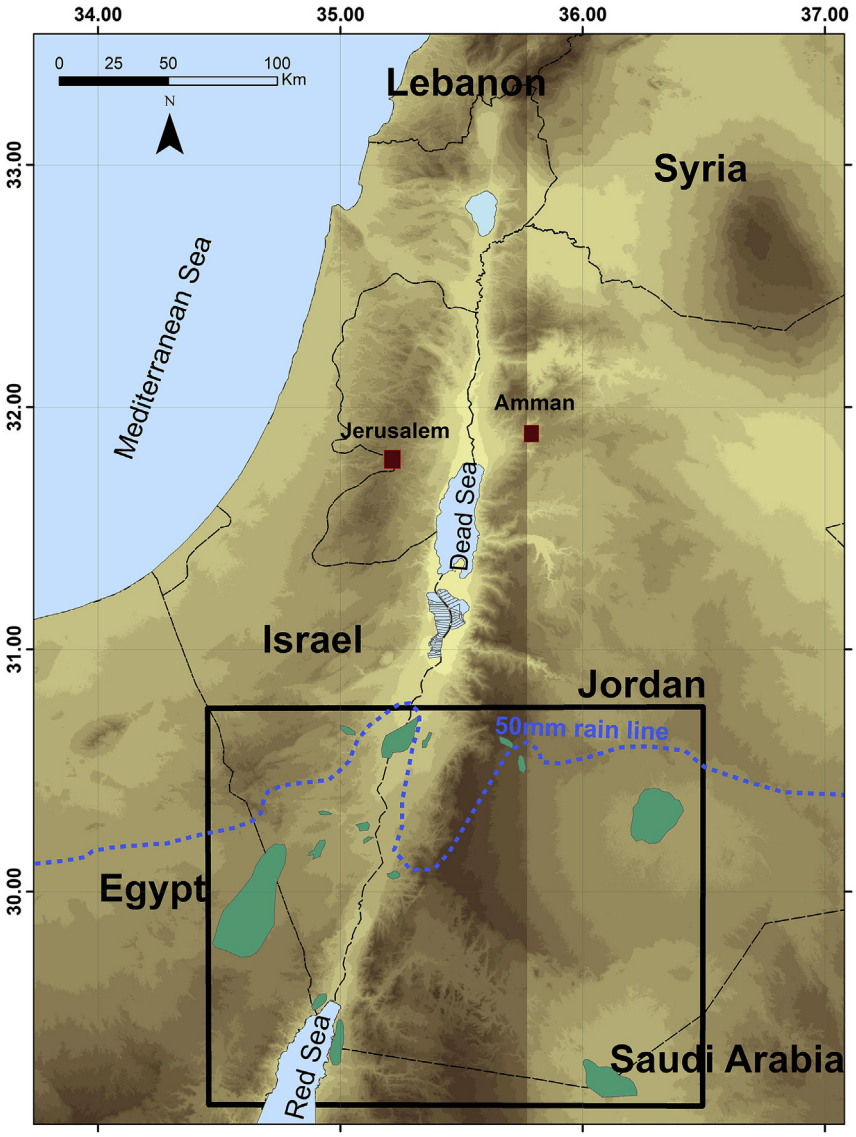


**Fig. 1.** The southern Levant and location of study area (rectangle) with the 50 mm precipitation isohyet (dashed blue line) following Shtern et al. (1986). The studied waterbodies are shown in green. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

## 2. Background

### 2.1. Geological setting

The study area, located in southern Israel and Jordan, spans an area of 150 km by 200 km (Figs. 1 and 2) and is situated along the southern part of the Dead Sea Fault (DSF) rift valley and its margins, between Sinai and the Jordanian Plateau. Landscape ranges from large flat basins, such as Al Jafr and Mudawwara, to tectonic graben escarpments in the Arava Valley, inselberg topography with steeply incised desert streams (locally termed wadi meaning ephemeral river/stream) in Wadi Rum, and moderate relief in the southern Negev, west of the Arava Valley (Fig. 2; Bender, 1974; Avni, 1998). The Jordanian Plateau is characterized by upper Cretaceous to Paleocene limestone and marls. Lower Cambrian sandstone typically occurs in the desert of southernmost Jordan and Precambrian magmatic and metamorphic rocks are exposed along the Edom Mountains in south-western Jordan (Bender, 1968, 1974). These rocks can also be found in the Eilat Mountains along the north-western margin of the Gulf of Aqaba (Eyal et al., 1981; Beyth et al., 2012). Upper Cretaceous marine carbonates are exposed along the western margin of the Arava Valley in the Negev (Ginat, 1997). Tilted Cretaceous marine carbonate rocks occur near Jabal-Khureij in the central Arava Valley (Fig. 2) and in the wadis nearby.

The Neogene landscape of southern Israel and Jordan is closely linked to the establishment of the DSF and the Dead Sea as a closed inland basin with a deep base level of erosion (Picard, 1951; Garfunkel and Avraham, 1996; Avni et al., 2012a,b; Garfunkel, 2014). The DSF represents the plate boundary between the Arabian plate and the Sinai sub-plate. Motion along the DSF, left-lateral strike-slip movement combined with transversal extension, led to the formation of this long depression (Freund et al., 1970; Garfunkel, 1981, 2014). Uplift of the eastern margins of the valley since the Late Oligocene-Miocene led to the formation of the Edom Mountains, which became the water divide between the Jordanian Plateau and the Arava Valley (Fig. 2). N-E striking faults formed the water divide between the southern Negev and the southern Arava Valley during the Miocene (Avni, 1998, Fig. 2). This period was followed by a phase of intense denudation that shaped most of the prominent features seen today in the landscape of the

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