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Primary carbonates and Ca-chloride brines as monitors of a paleo-hydrological regime in the Dead Sea basin

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Abstract

Lakes Samra, Lisan and the Dead Sea occupied the Dead Sea basin during the Last Interglacial (~140–75 ka BP), last glacial (~70–14 ka BP) and Holocene periods, respectively. The age of Lake Lisan and Samra was determined by U–Th dating of primary aragonites comprising parts of the lacustrine sedimentary sequences. The lakes have periodically deposited sequences of layered calcitic marls (Lake Samra) or laminated primary aragonite (Lake Lisan). The deposition of aragonite as the primary carbonate phase reflects the contribution of the incoming freshwater (loaded with bi-carbonate) and high Mg-, Ca-chloride brine that originated from the subsurface vicinity of the Dead Sea basin. Deposition of calcitic marls suggests a minor effect of the brines. The Ca-chloride subsurface brine has been migrating in and out of the wall rocks of the Dead Sea basin, reflecting the regional hydrological conditions. During most of the last glacial period and during the late Holocene, sufficient precipitation above the Judea Mountains pushed the subsurface Ca-chloride brines into the lakes causing the deposition of aragonite. During the Last Interglacial period the rain that precipitated above the Judea Mountains was insufficient to induce brine flow toward Lake Samra. It appears that sporadic floods provided calcium, bicarbonate and detritus to produce the Samra calcitic marls. Travertines deposited at the Samra–Lisan boundary indicate the early stage in the resumption of groundwater (springs) activity that led to the resurgence of Ca-chloride brine and rise of Lake Lisan. Similar variations in the regional rain precipitation and hydrological activity probably characterized the long-term geochemical evolution of Pleistocene lacustrine water-bodies in the Dead Sea basin, enabling the use of the carbonates as paleo-hydrological monitors.

1. Introduction

The Dead Sea basin (DSB) is located in the desert fringe between the sub-tropic and Mediterranean climatic zones. Its Quaternary sedimentary record reflects the tectonic and climatic history of the region, which fluctuated between arid and wet periods (cf Neev and Emery, 1967; Stein, 2001). Currently, the deep depression of the DSB is occupied by the hypersaline Dead Sea, which evolved from ancient brines that existed in the DSB and its surrounding since the late Neogene (Zak, 1967; Starinsky, 1974). These ancient brines originated from evaporated seawater that intruded the early DSB, interacted with the surrounding Cretaceous carbonates, dolomitized them and returned as Ca-Chloride brines to the lagoon, depositing the thick sequence of Sedom salts (Zak, 1967; Starinsky, 1974; Stein et al., 2000, 2002). After the disconnection of the Sedom lagoon from the open sea, several hypersaline to freshwater lakes occupied the tectonic depressions along the Jordan–Arava valley (e.g. the Pleistocene lakes of Amora, Samra, Lisan and the Holocene Dead Sea). The size and composition (salinity) of these lakes have changed in time, reflecting the interaction between the ancient brines and freshwater flushing from the drainage area (e.g. paleo-Jordan River and runoff from the basin shoulders). This interaction, in turn, reflects the climatic conditions in the region that fluctuated between wet and hyper-arid periods (Neev and Emery, 1967; Stein, 2001). During the last glacial period (~70–14 ka MIS 4, 3 and 2) the basin was occupied by Lake Lisan, which extended over large distance from the Sea of Galilee in the north to the Arava

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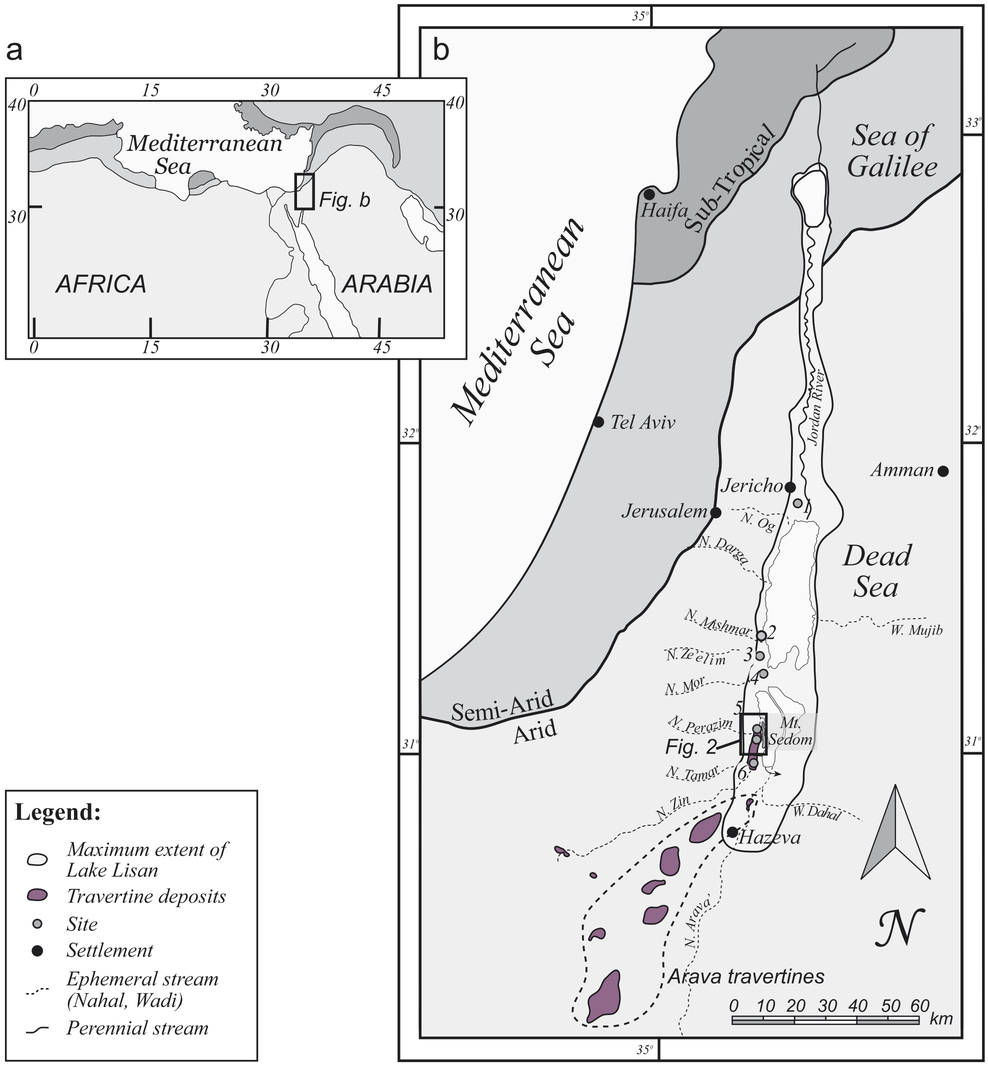

Fig. 1. (a) Main climatic zones in the East Mediterranean region, dark gray: subtropical dry summer, gray: semi arid, and light gray: arid (following Prasad and Negendank, 2004). (b) Map of the study area showing the geographical sites cited in this work and the main climatic belts. The sites are numbered 1: Bet Ha'Arava, 2: Mishmar, 3: Massada, 4: Mor, and 5: Perazim (the rectangle indicates the area of Fig. 2), 6: En Tamar.

valley in the south (Fig. 1). The high stand of Lake Lisan reached ~160 m below mean sea level (bmsl), which is ~250 m higher than the present Dead Sea level (currently standing at ~419 m bmsl). At ~13 ka BP, Lake Lisan dramatically declined to below 500 m bmsl and rose back at the beginning of the Holocene to an elevation of ~370 m bmsl (Stein, 2002). The dramatic lake-level change reflects abrupt fluctuations in the regional hydrological system, fluctuations that were accompanied by salinity and limnological (lake configuration) variations (e.g. layered vs. overturned lake). Prior to Lake Lisan and during the Last Interglacial period (MIS 5), the DSB was occupied by Lake Samra (Waldmann, 2002 and references therein). We found significant lithological and geochemical variations between the sedimentary sections of the two lakes (comprising the Lisan and Samra formations, respectively; Fig. 2). The Samra Formation consists mainly of layered calcitic marls or primary calcitic laminae while the Lisan Formation comprises mainly sequences of laminated primary aragonite alternating with silty-detritus laminae and sequences dominated by gypsum layers. The transition from a water body depositing mainly calcitic marls to that depositing mainly aragonite and gypsum is the main topic of this research. We suggest that this transition reflects a fundamental change in the behavior of the hydrological system feeding the lakes, which in turn mirrors the climatic conditions and rain distribution patterns in the region during interglacial or glacial periods.

2. The lithology, stratigraphy and chronology of the Samra Formation

The Samra Formation is defined as the chronostratigraphic unit that contains the sedimentary sequences which were deposited in the DSB and along the Jordan River during the Last Interglacial period, between ~135 and