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Increased sedimentation following the Neolithic Revolution in the Southern Levant

Yin Lu[a,b,*], Nicolas Waldmann[b], Dani Nadel[c], Shmuel Marco[a]

[a] Department of Geophysics, Tel Aviv University, Tel Aviv 6997801, Israel
[b] Dr. Moses Strauss Department of Marine Geosciences, Leon H. Charney School of Marine Sciences, University of Haifa, Mount Carmel 3498838, Israel
[c] The Zinman Institute of Archaeology, University of Haifa, Mount Carmel 3498838, Israel

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ABSTRACT

The Dead Sea drainage basin offers a rare combination of well-documented substantial climate change, intense tectonics and abundant archaeological evidence for past human activity in the Southern Levant. It serves as a natural laboratory for understanding how sedimentation rates in a deep basin are related to climate change, tectonics, and anthropogenic impacts on the landscape. Here we show how basin-wide erosion rates are recorded by thicknesses of rhythmic detritus laminae and clastic sediment accumulation rates in a long core retrieved by the Dead Sea Deep Drilling Project in the Dead Sea depocenter. During the last ~11.5 kyr the average detrital accumulation rate is ~3-4 times that during the last two glacial cycles (MIS 7c-2), and the average thickness of detritus laminae in the last ~11.6 kyr is ~4.5 times that between ~21.7 and 11.6 ka, implying an increased erosion rate on the surrounding slopes during the Holocene. We estimate that this intensified erosion is incompatible with tectonic and climatic regimes during the corresponding time interval and further propose a close association with the Neolithic Revolution in the Levant (beginning at ~11.5 ka). We thus suggest that human impact on the landscape was the primary driver causing the intensified erosion and that the Dead Sea sedimentary record serves as a reliable recorder of this impact since the Neolithic Revolution.

1. Introduction

In addition to tectonics (e.g., Zheng et al., 2000; Dadson et al., 2003; Molnar et al., 2007; Wang et al., 2014) and climatic change (e.g., Molnar, 2001, 2004; Zhang et al., 2001; Clift et al., 2008), humans have also exerted a significant impact on surface erosion over timescales ranging from years to centuries (e.g., Hooke, 2000; Syvitski et al., 2005; Wilkinson, 2005; Montgomery, 2007; Wilkinson and McElroy, 2007; Reusser et al., 2015). However, large-scale anthropogenic impact over millennial timescales remains elusive and unclear. Therefore, there is a need to analyze longer reliable continental records that provide important evidence of the human imprint on landscape evolution. Here, we offer geological evidence for increased sedimentation in the Dead Sea drainage basin, Southern Levant, already at ~11.5 ka. This increase is associated with the establishment of large villages and the concomitant domestication of plants and animals that formed the basis of the Neolithic lifeways. These life styles forever changed the trajectory of human history (Bar-Yosef, 1991; Bar-Yosef, 1998a).

The abundant pre-Neolithic, Neolithic and post-Neolithic archaeological sites in the basin provide unique information on the association between tectonics, climate change, and increasing human impact on the landscape at the basin-scale. In this study, the clastic sediment accumulation rates (SARs) and the thicknesses of seasonally deposited detritus laminae (Neugebauer et al., 2014, 2015) in a core from the Dead Sea depocenter are used as relative measures of basin erosion. The continuous and well-dated sedimentary record retrieved from the Dead Sea depocenter provides an excellent opportunity for analyzing the response of erosion to climate change, tectonics and anthropogenic activity through time.

2. Geological background

The Dead Sea is an endorheic lake bordered by the Jordanian Plateau to the east and the Judean Mountains to the west (Fig. 1A, B). The lake surface is presently ~429 m below sea level. The lake occupies a pull-apart structure (the Dead Sea Basin) that has developed along the Dead Sea Transform since the Miocene (Ben-Avraham et al., 2008). Climatic zones in its drainage basin range from Mediterranean (warm dry summers and mild winters with up to ~1000 mm mean annual precipitation) to hyperarid; these zones fluctuated substantially during

* Corresponding author at: Department of Geophysics, Tel Aviv University, Tel Aviv 6997801, Israel.
E-mail addresses: yinlu@post.tau.ac.il, yinlusedimentology@yeah.net (Y. Lu).

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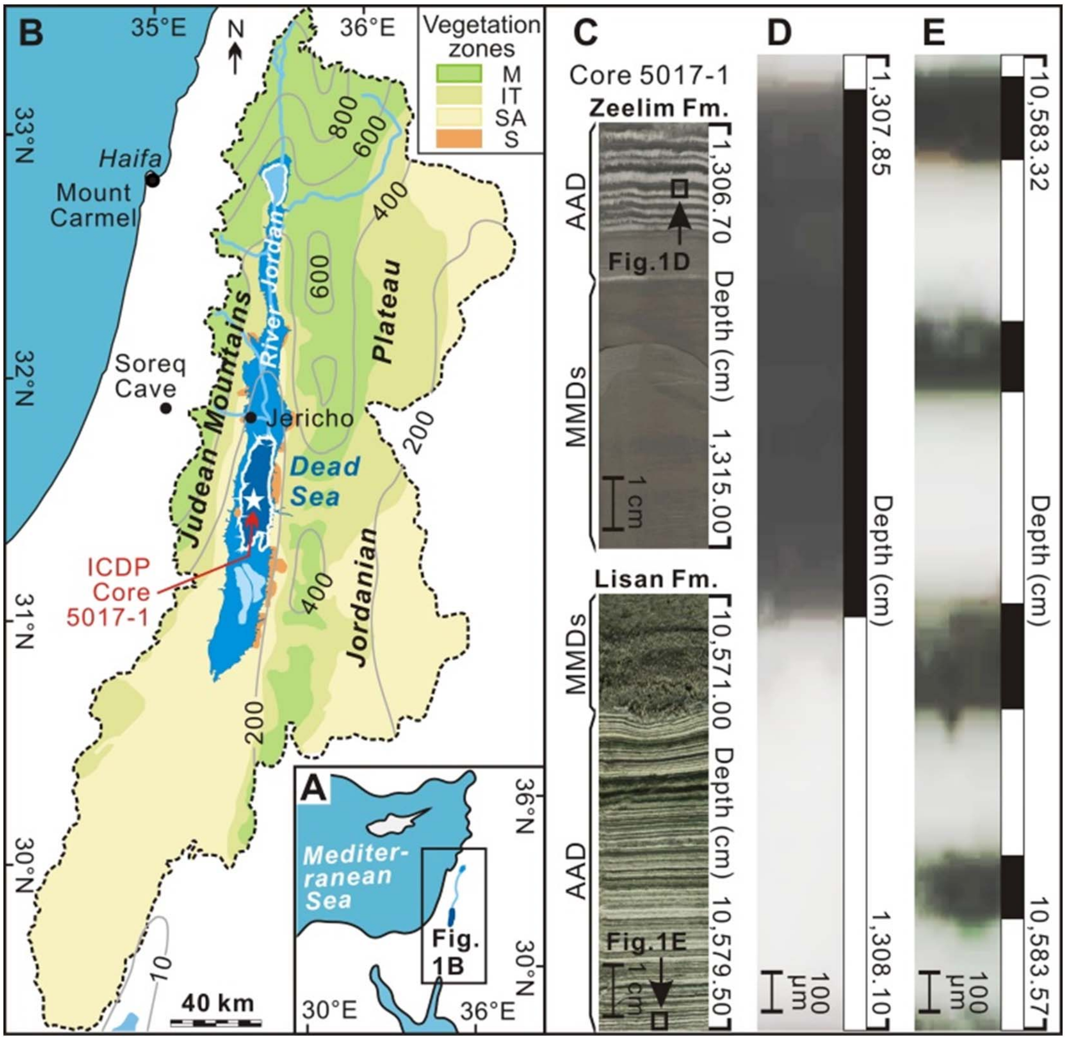

Fig. 1. Location and climate of the Dead Sea drainage basin and basic facies of sediments in the Dead Sea depocenter. A: Location of the studied area in the Southern Levant. B: The Dead Sea drainage basin (enclosed by a black dashed line) with the location of composite core 5017-1 (white star). Current precipitation in mm yr^{-1} is marked by gray lines (Enzel et al., 2003) superimposed on vegetation zones (shaded areas) (Langgut et al., 2014) and maximum extent of Lake Lisan (blue area) during the Last Glacial Maximum (LGM) (Bartov et al., 2002). The vegetation zones are divided into M (Mediterranean(humid to semi-humid)), IT (Irano-Turanian (semi-desert)), SA (Saharo-Arabian (desert)), and S (Sudanian (tropical)). Black points mark places referred to this study. C: Core images showing alternating laminae of aragonite and detritus (AAD), and mass movement deposits (MMDs) in the formations (Fms.) studied. D and E: High resolution digital images of the AAD packages showing the thicknesses differences. Black and white bars indicate detritus and aragonite laminae, respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

the Quaternary glacial cycles. During the Quaternary, the basin was consecutively occupied by a sequence of terminal water-bodies: Lake Amora (MIS ~6), Lake Samra (MIS 5), Lake Lisan (MIS 2-4) and the Dead Sea (MIS 1) (Stein, 2001). In accord with these limnological variations, the Quaternary stratigraphy of the basin infill has been divided into four respective formations: Amora, Samra, Lisan, and Zeelim formations.

3. Materials, chronology and methods

3.1. Materials

Between November 2010 and March 2011, a ~456.7 m-deep composite core (Core 5017-1) was extracted from ~297.5 m water depth in the Dead Sea depocenter (31°30′29″ N, 35°28′16″ E) during a drilling campaign under the umbrella of the International Continental Scientific Drilling Program (ICDP) (Stein et al., 2011). The average recovery rate was ~84.5%. The core penetrated the entire Zeelim Fm. (~89.3–0 m), Lisan Fm. (~177.0–89.3 m), Samra Fm. (~328.0–177.0 m) and the upper part of the Amora Fm. (~456.7–328.0 m) (Torfstein et al., 2015).

Lacustrine facies in the core are characterized by sequences of alternating laminae of aragonite and detritus (Fig. 1C) (Neugebauer et al., 2014). In addition, there are thicker layers of detritus (mud, sand and gravel) inferred to be mass movement deposits (Fig. 1C). Thicknesses of aragonite and detritus laminae in the upper ~110 m of the core were carefully measured, and clastic SARs in the upper ~110 m and in the entire core were calculated. As aragonite, gypsum, and halite in Core 5017-1 are chemical precipitates, only the detritus laminae and detrital layers are included in calculations of clastic SARs.

3.2. Chronology

Detailed ^{14}C and U–Th dating published by the Dead Sea Deep Drilling Project (DSDDP) Scientific Team (a complete list of the scientists is available at www.icdp-online.org) show that the core spans the time period from ~220 ka to the present (Neugebauer et al., 2014; Neugebauer et al., 2015; Torfstein et al., 2015) (Fig. 2). The upper ~110 m of the core, were deposited since the Last Glacial Maximum (LGM, ~22 ka). Ages (at 109.1 m and 456.7 m) between dated horizons were calculated by linear interpolation. Age points used for age-depth plot and clastic SAR calculation are listed in Table 1.