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Middle to late Pleistocene shift in eolian silts contribution into Mediterranean soils at the fringe of the Negev loess, Israel

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ABSTRACT

A common spatial feature within loess deposits worldwide is a downwind decrease in thickness and grain size, trends that are powerful tools for reconstructing paleowinds and past atmospheric circulation. Although such trends have been identified, there is limited knowledge of similar trends farther downwind from the loess region, where eolian influx can influence soil formation and hydrological processes. To examine these impacts we studied Quaternary sequences in prehistoric sites in Jerusalem, located only ~50 km downwind from the edge of the Negev loess. All sequences are composed of two units separated by an unconformity. The lower unit is of middle Pleistocene age, it is composed of unimodal clay to silty clay dust deposits with chert clasts and Lower-Middle Paleolithic artifacts. A non-deposition interval characterized the middle to late Pleistocene transition, when dust accumulation rates were low. The upper unit age is late Pleistocene to Holocene; it is composed of bimodal silty clay to silty clay loam. Quartz, K-feldspars, and plagioclase contents together with the location and amplitude of grain-size coarse mode increase up-sequence. The addition of coarse silts to the upper unit of the sequences was coeval with episodes of loess accretion in the Negev. These silts were generated most likely by eolian abrasion of sand grains in the upwind dunes. Similar to the Negev, the addition of silts resulted in burial of the drainage network and reduced runoff and soil erosion rates. We stress the importance of desert loess in determining soil composition and surficial hydrology in wetter areas located in adjacent downwind regions.

1. Introduction

Loess is an eolian sediment, dominated by silt-sized particles, that is identifiable in the field as a distinct sedimentary body; it covers a significant portion of land surface of Earth and as such constitutes one of the most important archives of long-term dust deposition (Muhs et al., 2015). Loess covers vast areas worldwide, including Europe, Asia, South America, and North America, Africa, the Middle East, New Zealand, and Australia. Loess thickness, particle size and carbonate content tend to decrease downwind from sources, and these trends are powerful tools for reconstructing paleowind characteristics (Muhs et al., 2015). Although such trends have been well identified within loess deposits, there is limited knowledge of similar trends farther downwind from the loess accretion area. Coarse dust deposited beyond loess regions, usually in increasingly wetter areas, has the potential to influence soil formation and alter hydrological properties.

The formation of the Negev loess represents one of the major sedimentologic and hydrologic changes that occurred in the Negev desert and across its fringes during the Quaternary. The loess accreted mainly between 95 and 10 ka, following changes in the Nile Delta and the advance of the Sinai sand dunes starting at ca 180 ka (Crouvi et al., 2008, 2009; Amit et al., 2011). This appearance of loess in the Negev induced a major hydrological change due to filling and even burying of fluvial systems by these dust particles, thus altering slope and stream hydrology (Yair, 1987; Yair and Enzel,

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1987). The particle size distribution (PSD) of the loess is bimodal, with modes in the coarse silt fraction (36–65 μm) and in the fine silt to clay fractions (2.5–10 μm) (Crouvi et al., 2017). Recognizing the bimodality of the Negev loess indicates that the loess had two different sources that supplied sediments through two different transport mechanisms (Yaalon, 1969; Yaalon and Ganor, 1973, 1979; Yaalon and Dan, 1974): (1) distal sources in the Sahara and Arabia supplying fine silts and clays transported by winds (long-term suspension) over thousands of kilometers; (2) proximal sources in Sinai, supplying fine sands and coarse silts, transported by short-term suspension and modified saltation. An additional proximal source was later suggested, in the form of the Mediterranean shelf exposed during eustatically low sea levels (Gerson and Amit, 1987; Crouvi et al., 2008; Enzel et al., 2008). Recently, it has been shown that the adjacent, upwind sand dunes that advanced into the Sinai and Negev during the late Pleistocene were the major source of the coarse silts in the loess, based on spatial, temporal, sedimentological and mineralogical associations between the dunes and the loess (Crouvi et al., 2008, 2009) (Fig. 1). The source of the fine mode (<20 μm) is a mixture of proximal and distal sources, including adjacent sand dunes, wadis in Sinai, the exposed Israeli and Sinai shelves, and the Sahara and Arabia (Crouvi et al., 2009; Ben Israel et al., 2015). The particle size distribution of the loess varies in space and time, mainly as a function of distance and direction from the Negev sand dunes (Crouvi et al., 2017): (a) grain size decreases away from the sand dunes to the north, east and south directions (Ravikovitch, 1952; Ginzbourg and Yaalon, 1963) (Fig. 1); (b) grain size becomes coarser with time due to the northeastward propagation of the dunes from Sinai into the Negev during the late Pleistocene (Crouvi et al., 2008). However, the relation between loess formation in the Negev and downwind accumulation of sediment (and soil formation) along the mountainous backbone of Israel, farther north and northeast, remains unclear. This is mainly due to the lack of well-defined sequences of such eolian contributions in the mountains and the difficulty to date soils. Despite reports on addition of eolian coarse silt grains to the mountainous soils around Jerusalem, only tens of kilometers downwind from the loess region (e.g., Dan et al., 2007; Sandler et al., 2015), the timing and pattern of these inputs are not yet established. In addition, it is unclear whether the addition of these silts to the mountainous soils altered the surface hydrology of the region.

The aim of this paper is therefore to document the sedimentologic and pedologic properties of Quaternary deposits in the Judean Mountains in an attempt to reconstruct temporal changes in dust properties and influx. As any chronology is difficult to establish using absolute dating techniques in these thin soils and sediments, we directed our efforts toward archeological sites containing such soils and sediments that can constrain the radiometric dating. The properties of sediments and soils associated with such buried sites, and their chronology, can shed light on when silt arrival from the desert became important in (a) increasing dust accretion, and thereby, (b) altering surface properties and exerting a significant impact on the regional hydrology.

Here we integrate mineralogy, PSD and luminescence analyses of eolian, fluvial and archaeological deposits from hilltop and headwater locations of Paleolithic sites in southern Jerusalem (Figs. 2, 3). Preliminary results of the archeological excavations were reported by Barzilai et al. (2009, 2010). Hilltop, eolian deposits provide a reliable source for reconstructing regional paleoenvironments as they were not affected by the fluvial system (Crouvi et al., 2009). Dust deposits transported and deposited in headwaters, especially in first order streams, can also be regarded as representative of primary eolian dust due to their limited transport distance in the fluvial system; this is opposed to dust deposits that change their PSD characteristics through long fluvial transport (kilometers and longer) (Vandenberghe, 2013; Vandenberghe et al., 2018).

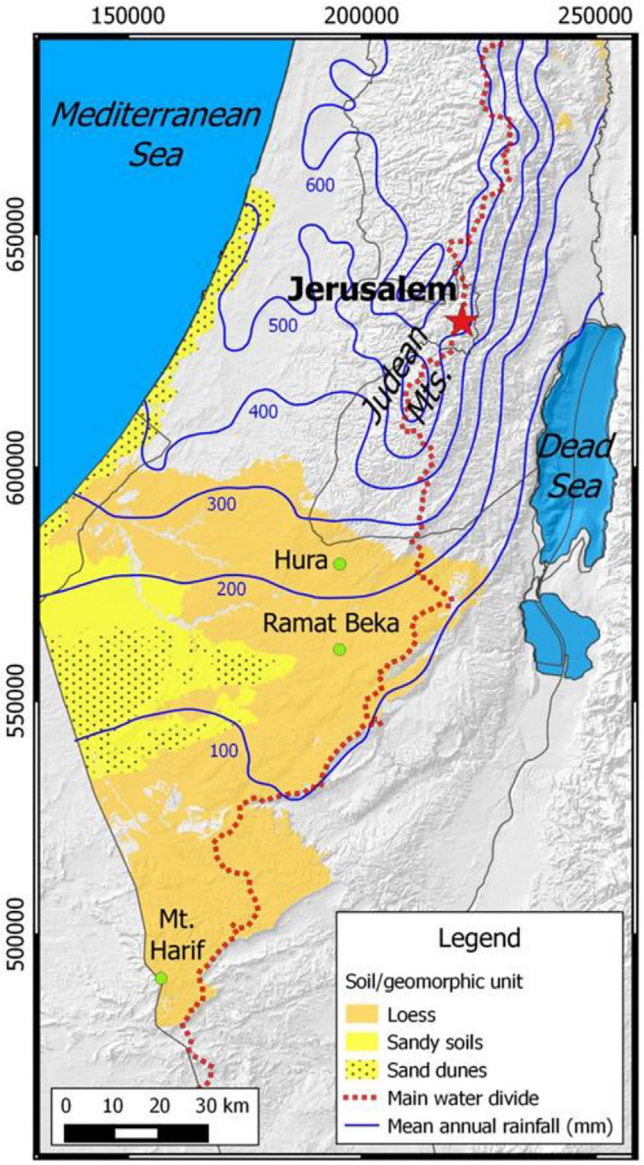

Fig. 1. Map of central and southern Israel with the main geomorphic units/soils in the Negev (see Crouvi et al. (2008) for more details). The study site (Jerusalem) is marked by a large red star. The location of the three loess sequences studied by Crouvi et al. (2008) that are mentioned in the text are marked by green dots. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

These sites therefore offer a rare opportunity to study temporal changes in eolian (and to lesser extent, fluvial) regimes, as they are located at and near the main water divide of the mountainous backbone of Israel, only ~50 km downwind from the northern edge of the Negev loess (Fig. 1). Thus, these deposits are indicators of (a) eolian additions to soils at the far end of a regional source to sink eolian system, and (b) interactions between eolian and fluvial headwaters systems under a Mediterranean climate. The archeological findings contributed to the geomorphologic interpretations by (a) providing time constraints that can be further corroborated by radiometric ages, and (b) estimating the depositional history of the artifacts (i.e., whether they are *in-situ* or have been redeposited over time).