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# Pedology of archaeological soils in tells of the Judean foothills, Israel

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ABSTRACT

Tells (archaeological mounds) predominantly consist of poorly consolidated to unconsolidated sediments, and soils that are highly anthropogenic. This study examines pedogenic processes related to carbonate mobilization in tells in comparison with their peripheral soils (reference soil profiles). The key objective of this study is to test the hypothesis that tell deposits evolve through concurrent processes of sedimentation and pedogenesis (synlithogenic pedogenesis), and further explain it. Case studies are presented from three tells in semi-arid and Mediterranean climatic zones of the Levant. The methods applied included field survey, analyses of particle size distribution, pH, %$CaCO_3$ and organic carbon content, and soil micromorphology. Soils of the tells contain miscellaneous cultural materials that derive mainly from degraded mud bricks, pottery and burnt wood. Chemical data show basic pH values, high $CaCO_3$ content, and minor amounts of organic carbon. Field observations and lab analyses both indicate high similarity amongst the tells and their reference soil profiles. Buried tell soils show same characteristics as near-surface soils. However, the reference soil profiles show incipient horizonation, slightly darker colours, and more developed structure. Micromorphology of both the tells and the reference profiles show cohesively welded peds in a vughy microstructure, groundmass with an open porphyric c/f-related distribution, and discontinuous carbonate recrystallization. Relative rates of soil formation in the tells can be estimated when archaeological records are established. Contrary to the tells, the reference soil profiles show lower porosity and only minor remnants related to earth construction materials. We classify the soils of the studied tells as archaeological Calcareous Anthraltic Xerorthents. The correlative WRB classification would be Calcic Urbic Technosols (Archaic). The anthropogenic materials are as calcareous as the natural soils, but due to human action, carbonates in the tells are distributed differently. Based on these observations, ancient human actions and the dry climate have led to very little mobilization and accumulation of carbonates. The information provided in this study adds to the pedological understanding of archaeological environments. Specifically, it can be useful for the study of site formation processes of tells.

## 1. Introduction

The evolution of tells involves repeated human occupation of sites that built-up as a result of deposition and erosion processes of cultural materials (Davidson, 1976; Butzer, 1982, p.77–97; Rosen, 1986; Wilkinson, 2003, p. 100–127; Matthews, 2017). Tells etymologize from the Semitic language of Akkadian (Tillu; *tēlu*, meaning mound, ruin heap; Sokoloff, 2002). The occurrence of tells is abundant in western Asia, southeastern Europe and North Africa (Matthews, 2017). The characteristic composition of many tells is either calcareous or gypsiferous (e.g., Matthews et al., 1994; Beach and Luzzadder-Beach, 2008; Pustovoytov et al., 2011; Love, 2012; Benz et al., 2015; Riehl et al., 2015; Ackermann et al., 2017a), indicating that tells commonly form under arid to temperate (Mediterranean) climatic conditions. Apparently, pedogenesis in tells occur simultaneously with sedimentation (Sedov et al., 2017). Different from the classic (gradual) pathways of soil forming processes (Schaetzl and Anderson, 2005, pp. 347–461; Blume et al., 2016, pp. 285–316), soil formation that is associated with concurrent sedimentation is regarded as "synlithogenic pedogenesis" (Khokhlova et al., 2001; Targulian and Goryachkin, 2004; Shishov et al., 2005).

Recently, Sedov et al. (2017) added a new pedo-archaeological approach to the study of tell formation processes by considering synlithogenic pedogenesis as having a key role in the formation and

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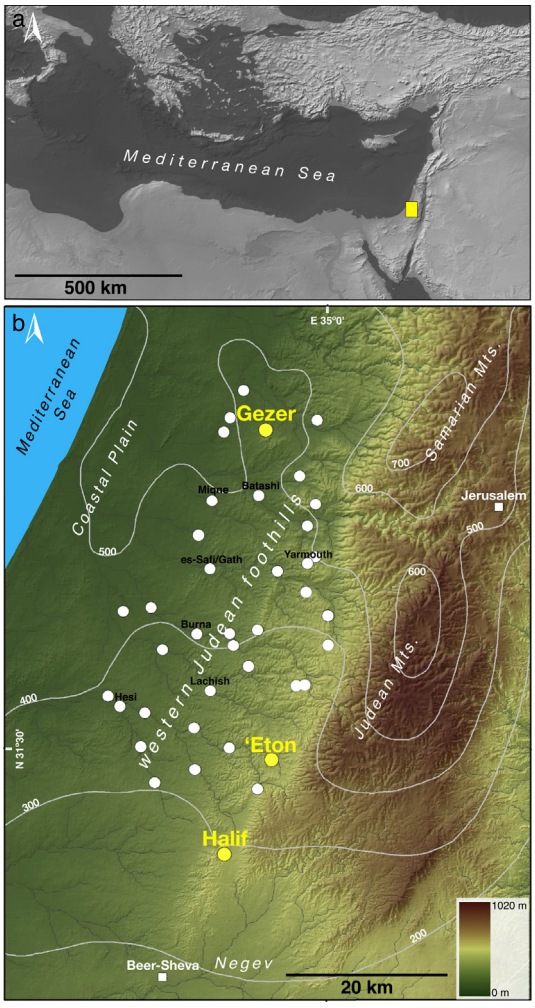


**Fig. 1.** (a) Map of the Eastern Mediterranean, showing the location of the study area (yellow rectangle). (b) Study area, showing locations of recognized tells (white dots) and sites of case studies (yellow dots). Names of other sites that are mentioned in the text are indicated in black. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

stratigraphical development of tells. By inspecting deposits of two tells in northern Thrace (Bulgaria) and southeastern Anatolia (Turkey), Sedov et al. (2017) concluded that contrary to natural soils, soils in tells form in a synlithogenic manner and could be classified as Urbic Technosols. However, despite these advances, several knowledge gaps remain in our understanding of pedogenesis of tells, such as: 1) What are the dominant processes of synlithogenic pedogenesis in tells? 2) What pedogenic properties and processes control the composition and structure of tells? 3) Can synlithogenic soils of tells be further classified and mapped? To address these knowledge gaps we investigated three tells in the Judean foothills, Israel (Fig. 1). The goals of this study are to: 1) Provide new insights on pedogenesis of near-surface calcareous deposits of tells, 2) Examine the possible pedogenetic relations between tells and their peripheral soils, 3) Assess the extent by which pedogenic properties influence the morphology and preservation of tells, 4) Further classify tell soils, 5) Raise implications for pedological and (geo) archaeological research of tells.

Tells are commonly distributed in the western Judean foothills (also known as the Shephelah; Fig. 1). The first geoarchaeological studies of tells in the Judean foothills started in the late 20th century (Bullard, 1970; Goldberg, 1979; Rosen, 1986). Here we examine three tells from this region: Gezer, 'Eton and Halif (Fig. 1). As a result of previous excavations (Ortiz and Wolff, 2012; Faust, 2013; Sapir, 2016; Borowski, 2017) a large area is exposed in the three tells. The examination of these specific sites enables us to observe hundreds of square metres of open profiles with no need for further excavations. While most of this study refers to the upper 1–2 m of the studied tells, a large excavation space in Tell Gezer (> 10 m deep, 20 × 20 m wide), and the detailed work of Sapir (2016) at Tell 'Eton, provide us with a view and a reference to large portions of soil that could not be inspected in this study. The available archaeological records of the three tells (Ortiz and Wolff, 2012; Faust, 2013; Sapir, 2016; Borowski, 2017) enable to assess the maximum age boundaries for the formation time of the studied profiles. A combination of field survey, particle size distribution (PSD), pH, $CaCO_3$ content, and organic carbon (OC) content has been applied in order to explore the nature of the groundmass of the tells and compare them with soils from their proximity. Soil micromorphology, that was proved to be most efficient for studies of tell soils (Stoops and Nijs, 1986; Matthews, 1995; Courty and Coqueugniot, 2013; Maghsoudi et al., 2014; Sedov et al., 2017) is taken as our main method. It is, however, accentuated that soil micromorphology is applied here as a tool for interpreting pedogenic features, rather than cultural materials. As opposed to the intense study of anthropogenic effects on soils in modern times (Howard, 2017), this study sheds light on a rarely discussed topic - the influence of humans on soil forming processes in history.

## 2. Background and previous studies

Early studies that described cultural mounds did not refer to their geoarchaeological features (Warren and Conder, 1884; Clermont-Ganneau, 1896; Rassam, 1897; Hilprecht, 1903, p.17). Such reference came only in the second half of the 20th century (Lloyd, 1963; Davidson, 1973, 1976; Liebowitz and Folk, 1980; Butzer, 1982, p.77–97), with the molding of geoarchaeology (Davidson and Shackley, 1976; Shahack-Gross, 2017). Further on, a milestone in the study of tells has been achieved with Rosen's (1986) seminal book “Cities of Clay: The Geoarchaeology of Tells”. Since then, marked efforts have been conducted in exploring various (geoarchaeological) materials and properties of tells (Albert et al., 2008; Matthews, 2010; Love, 2012; Maghsoudi et al., 2014; Regev et al., 2015; Sapir et al., 2016; Shahack-Gross et al., 2018), whereas only scarce studies focused on pedological processes in tells (Stoops and Nijs, 1986; Ryan et al., 2009), and not a much higher number of studies present a more holistic view on tell formation processes (Matthews et al., 1997; Davidson et al., 2010; Sapir, 2016; Sedov et al., 2017). Inspecting site formation processes is usually performed in the scope of ethnoarchaeological studies, mainly for the purpose of reconstructing past human activities (Schiffer, 1987; Weiss et al., 1993; Stein, 2001; Shahack-Gross et al., 2005; Matthews, 2010; Davidson et al., 2010; Riehl et al., 2015). Here, however, the terminology of “tell formation process” is discussed in a pedological context.

Tells are amongst the most outstanding archaeological landforms of the Judean foothills (Fig. 1). Located in the southwestern area of the Fertile Crescent (Lev-Yadun et al., 2000), since prehistoric times this part of the Levant has attracted many civilizations (Stern and Urman, 1988; Dagan, 2000, 2011), as inferred from the dense distribution and distinctive appearance of tells across the landscapes of this region. As shown in previous studies (Khalaily and Marder, 2010; Marder et al., 2011; Zaidner et al., 2018) the earliest prehistoric sites known so far in the Judean foothills are related to the Lower Palaeolithic (Late Acheulean culture). The cultural peaks in this region occurred during the Late Bronze (1550–1200 BCE) and Iron ages (1200–586 BCE; Koch, 2017; Maeir and Lipschits, 2017), and later, during the Byzantine period (324–638 CE; Bar, 2004). The youngest finds are attributed to the Ottoman period (20th century CE; e.g., Dagan, 2011).

Archaeological excavations of tells in the Judean foothills initiated in 1890 with an expedition to Tell el-Hesi (Hesi in Fig. 1; Bliss, 1894,