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Aggradation–incision transition in arid environments at the end of the Pleistocene: An example from the Negev Highlands, southern Israel

Galina Faershtein [a,b,*], Naomi Porat [a], Yoav Avni [a], Ari Matmon [b]

[a] Geological Survey of Israel, 30 Malkhe Israel St., Jerusalem 95501, Israel
[b] Institute of Earth Sciences, The Hebrew University of Jerusalem, Jerusalem 91904,Israel

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ABSTRACT

One of the most significant environmental processes that occurred at the transition from the last glacial phase into the present inter-glacial phase in arid regions was the shift from aggradation to incision in the drainage systems. This is evident by the sharp transition from a fluvial regime depositing fine-grained sediment within the wadis to intensive incision which formed gullies and narrow channels that dissected the late Pleistocene sediments. In order to investigate this transition, we studied three small-scale basins in the arid region of the Negev Highlands, southern Israel. Although the selected basins drain toward different base levels, their geomorphological parameters, particle size distribution of alluvial units and their OSL ages are similar. Sediments from the penultimate glacial cycle are found in patches in the bigger catchments. Fluvial loess was widely deposited since at least 67 ka until after 28 ka, covering valleys and slopes. Between ~28 and ~24 ka, loess was washed from the slopes into the channels, exposing the underlying colluvium. At ~24 ka erosion began with the transport of slope colluvium as gravels into the valleys that eroded the underlying loess sediments. Incision became dominant at ~12 ka and is still ongoing and intensifying. Dust and reworked loess continued to be deposited during the main incision stages. It is proposed that the transition from aggradation to incision was controlled by rates of loess supply and removal. Until ~24 ka dust choked the drainage system and only after reduction in dust supply was erosion and incision possible. It began first on the slopes and then in the channels. Our results show that an increase in precipitation is not a prerequisite for initiation of incision as is often assumed. Similar processes are described in other arid zones around the world.

1. Introduction

In arid and semi-arid environments, such as the Middle East, Australia, and Inner Mongolia (China), aggradation of alluvial sediments during the last glacial cycle is well-documented (e.g., Williams et al., 2001; Avni et al., 2006, 2010; Haberlah et al., 2010). Most of these sediments originated from aeolian desert dust, accumulating as fine-grained loess sediments combined with clasts originating from the local geological units (Avni et al., 2006). The pattern of aggradation gave way to erosion and incision which continues to the present. This shift in the deposition/erosion sediment budget can be seen in arid and semi-arid environments worldwide (e.g., Botha et al., 1994; Eitel et al., 2001; Waters and Haynes, 2001; Williams et al., 2001; Avni et al., 2006, 2010; Walker and Fattahi, 2011). In some regions this happened toward the last glacial maximum (LGM, 24–18 ka; Mix et al., 2001; e.g., Haberlah et al., 2010; Avni et al., 2012), while in others it happened later in the early Holocene (~9 ka; e.g., Waters and Haynes, 2001; Avni et al., 2010; Walker and Fattahi, 2011).

Previous studies that investigated the late Pleistocene transition from aggradation to incision were mostly conducted in large drainage basins in several regions of both hemispheres: in the northern hemisphere at the northern edge of the Sahara Desert in Israel and Sinai (Ben-David, 2003), at the edge of the Gobi Desert (Avni et al., 2010), southwest USA (Waters, 1988; Bull, 1997; Waters and Haynes, 2001), and at several sites in eastern Iran (Walker and Fattahi, 2011 and references therein). In the southern hemisphere the shift from aggradation to incision was documented in Kwa-Zulu Natal in South Africa (Botha et al., 1994; Clarke et al., 2003), northern Namibia (Eitel et al., 2001), and South Australia (Williams et al., 2001; Haberlah et al., 2010). Most of those studies used optically stimulated luminescence (OSL) or ^{14}C as the main dating tool, and determined the timing of this transition mostly to 18–9 ka. The different researchers suggest general climate changes as responsible to the aggradation/incision transition. For example, increase in precipitation (Eitel et al., 2001, 2006; Walker and

* Corresponding author at: Geological Survey of Israel, 30 Malkhe Israel St., Jerusalem 95501, Israel.
E-mail address: galaf@gsi.gov.il (G. Faershtein).

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Fattahi, 2011) or, in contrast, desertification (e.g. Avni et al., 2006). In spite of the extensive research, there are still important knowledge gaps regarding the relationship between climate changes at the end of the Pleistocene and the widespread transition from aggradation to incision at that time.

This paper presents mapping, particle size distribution (PSD) analysis, and detailed OSL chronologies of three small-scale catchments in the Negev Highlands, southern Israel. The small basins best record the initiation of incision. Based on the morphological similarity between the basins and the sedimentological characteristics and ages of their alluvial

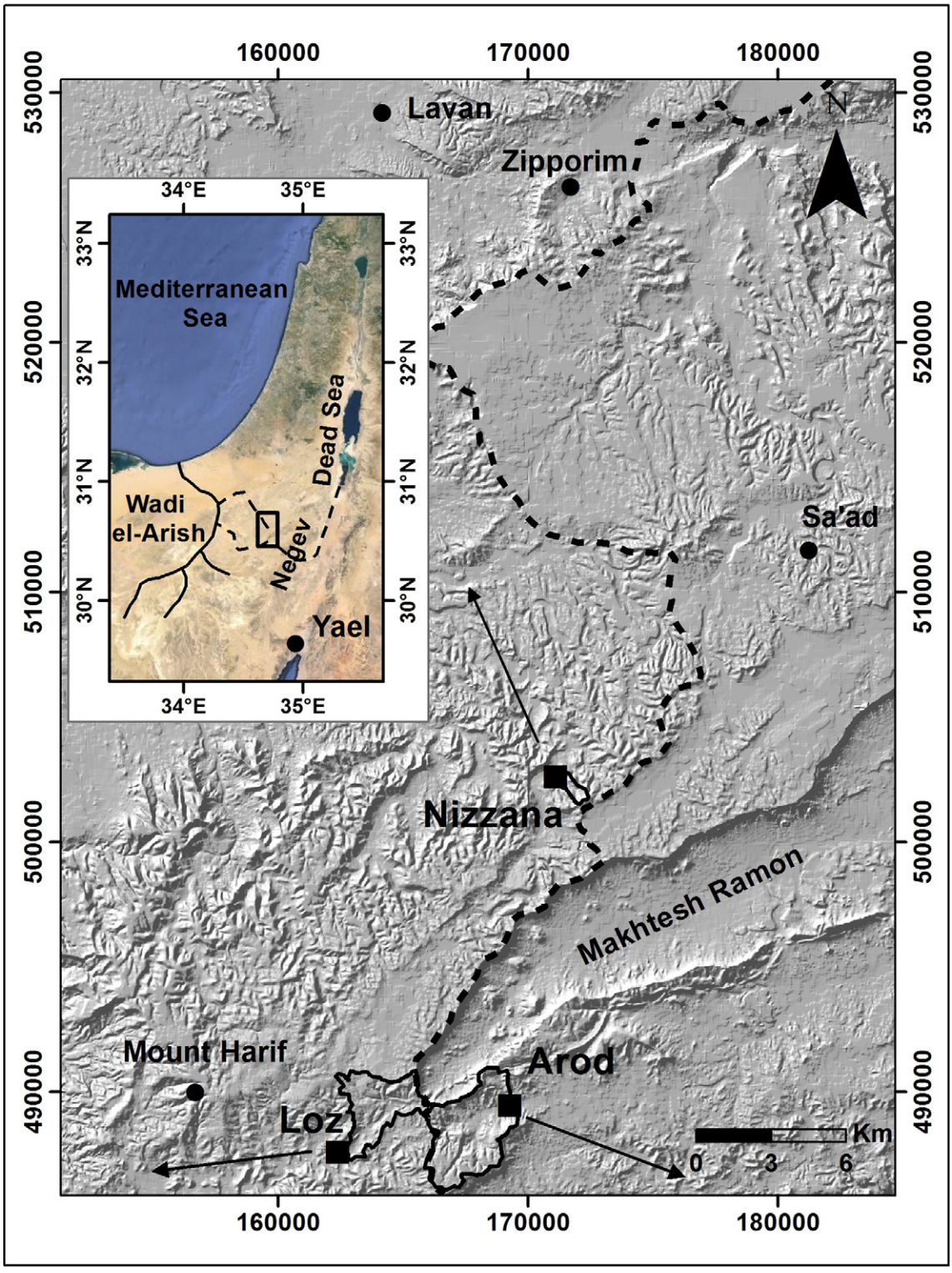

Fig. 1. Location map of the study sites within the Negev Highlands. Nizzana, Loz, and Arod sites are marked as squares. The catchments up to the study sites are marked. Previously studied areas are marked with a circle (Avni et al., 2006, 2012; Crouvi et al., 2008; Enzel et al., 2012). Arrows mark the general drainage direction. The thick dashed line shows the main water divide (DEM from Hall, 1997; ITM coordinate system). Inset — Location map of the Negev Highlands (marked in rectangle). The channels from the study sites to their base levels are marked with dashed lines. (Image from Google Earth 7.12.2041. "East Mediterranean", 31.395297N, 34.652278E, Image Landsat, 4/10/2013, February 18 2015.)