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in Wiebke Bebermeier – Robert Hebenstreit – Elke Kaiser – Jan Krause (eds.), Landscape Archaeology. Proceedings of the International Conference Held in Berlin, 6th – 8th June 2012

Edited by Gerd Graßhoff and Michael Meyer,  
Excellence Cluster Topoi, Berlin

eTopoi ISSN 2192-2608  
<http://journal.topoi.org>



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# A Preliminary Model of Upper Pleistocene Landscape Evolution in the Wadi Sabra (Jordan) Based on Geoarchaeological Investigations

Geoarchaeology; Levant; Upper Pleistocene; fluvial deposits; modern humans.

## Introduction and Study Area

While there is almost no doubt about the African origin of modern humans,<sup>1</sup> the path of dispersal and final immigration into Europe is still under debate.<sup>2</sup> Our project focuses on the Levant as a potential main corridor for human migrations from Africa to Europe during the Middle and Upper Palaeolithic. It is embedded in the multi-disciplinary CRC 806 “Our Way to Europe,” also investigating other regions including the source areas in North-East Africa, the North-African/Southern-European-Corridor, the Balkans and Central Europe.

The timeframe of the Marine Isotope Stage (MIS) 4–2 (74–12 ka) is very important for geoarchaeological research, especially in Jordan, where sites and palaeoclimatic evidence are still lacking. We focus on the reconstruction of the Upper Pleistocene landscape evolution around archaeological sites in the presently arid environment of the Wadi Sabra (South-Central Jordan). The study is based on sedimentological and geochemical analysis of terrestrial sedimentary deposits. The study area is situated in the Greater Petra area in the eastern escarpment of the Dead Sea Rift. In this region, the Wadi Sabra valley system developed along a NE-SW striking tectonic fault line and recently drains the Jordanian plateau towards the west (Fig. 1). In altitudes from 600 to 800m a.s.l., up to 30m of stratified wadi deposits have been preserved from modern erosion. Determined by the nature of the local bedrock (Palaeozoic sandstones), the wadi fills are mostly of sandy composition. The association with archaeological finds of the Middle to the Final Palaeolithic (~50–18 ka) allows a reconstruction of palaeoenvironmental conditions during and after the time of the initial human occupation. Here we intend to present a preliminary model of landscape development in the Wadi Sabra based on field work impressions and laboratory data analyzed to date.

## Materials and Methods

During field campaigns from 2008–2011, the complete local sediment stratigraphy of the wadi was captured in different geomorphological positions. In addition to the chronological evidence from radiometric dating (OSL), the sediment sequences in the Wadi Sabra

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Fig. 1, upper left.

1 White et al. 2003; McDougall, Brown, and Fleagle 2005.

2 Oppenheimer 2009.

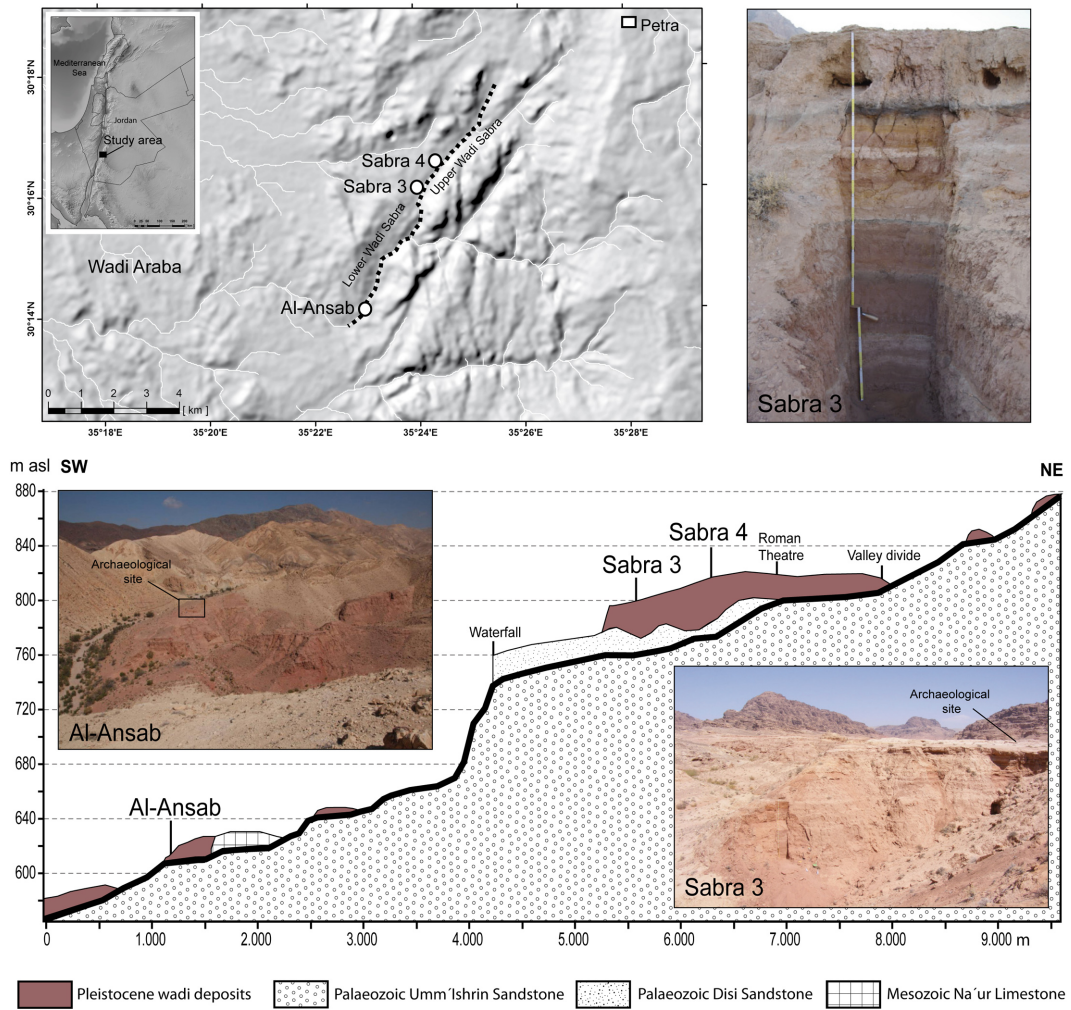


Fig. 1 | Geomorphological characterization of the Wadi Sabra valley system. Upper left: Digital elevation model ASTER GDEM 2010 showing the location of the study area and investigated sites. The dashed line indicates the recent valley bottom of the wadi. Upper right: Picture of the upper part of the sediment stratigraphy at Sabra 3 showing ancient palaeosol sequences and the recent calcareous duricrust at the top. Bottom: Longitudinal section along the recent valley bottom with pictures of investigated sediments and sites.

are accompanied by several lithic assemblages left by *homo sapiens sapiens* ranging in time from the Initial Upper Palaeolithic to the Early Epipalaeolithic Age. All periods of the Palaeolithic sequence are represented at least by single surface sites.

To decipher the depositional processes and environmental conditions, we initially performed grain size analysis (laser diffraction), carbon fractionation and statistical measurements on selected sediment sections. These first sedimentological investigations showed that aeolian processes had only a minor influence on the deposition of the sediments. The material is primarily of fluvial and colluvial origin.<sup>3</sup> Consequently, we further investigated the interrelation between fluvial and colluvial processes in sediment deposition and tried to define the major topographic influences and positions in which the diverse sediment layers were deposited. Additional geochemical analysis is currently under evaluation to testify whether pedogenetic processes can be evaluated and linked to past climatic conditions.

3 Folk and Ward 1957; Bertrams et al. 2012.

## Results

In the southern part of the study area at the Al-Ansab (Fig. 1) site, the sediment stratigraphy contains diverse alternating sequences of gravels, homogenous sands and calcrete deposits. They indicate phases of fluctuating environmental conditions with both high energy discharge events and phases of stable surfaces of unknown age. These deposits are discordantly overlain by a more homogenous progression of sands evidencing a continuous phase of fluvial aggradation which probably dates to MIS 4 and 3 according to the stratigraphy (OSL data are under evaluation). The deposition of these sediments is interpreted as being induced by higher weathering intensities and potentially a more balanced seasonal precipitation than today, inducing a higher sediment production. At the top of this sediment remnant, the occupation of this area is attested by the Early Upper Palaeolithic Ahmarian site of Al-Ansab. First OSL samples have already dated the sediments to the Upper Pleistocene.<sup>4</sup> However, the sand deposits are challenging for OSL dating as they show overall weak luminescence sensitivity and partial bleaching prior to deposition. Recent elaborations finally suggest the related sections to be ~38–28 ka in age, which corresponds to the age obtained for Ahmarian finds elsewhere in the Levant.<sup>5</sup> Due to erosional processes in the Holocene and recent times, subsequent phases of sedimentation are not preserved in this part of the study area.

In the northern part of the wadi (Sites Sabra 3 and 4), comparable sequences of homogenous sands are again overlain by a 3m thick progression of intercalated calcrete and sand deposits covered by a 60cm thick calcareous duricrust on the recent surface which has preserved them from erosion (Site Sabra 3, Fig. 1). The sediments in this part of the study area contain several archaeological find-spots of the Later Upper Palaeolithic (~25 ka) until the beginning of the Neolithic (10,5 ka<sup>6</sup>) including the first Levantine Aurignacian assemblage from Jordan (Sabra 4). At sites dated archaeologically to the Last Glacial Maximum (Final Upper Palaeolithic, Early Epipalaeolithic; ~24–18 ka), numerous small bone fragments were excavated. To date, identified species include gazelle, wild sheep, equids, fallow deer, aurochs, brown bear and wild boar (Dr. Hubert Berke, personal communication).

The calcretes are probably the result of secondary relocation of carbonate by fluctuating ground-water or rainwater percolation.<sup>7</sup> These initial palaeosol horizons could be related to fluctuating climatic conditions<sup>8</sup> and temporary phases with more moisture availability at the end of the Pleistocene. This has been postulated by several Levantine studies, particularly for the MIS 2.<sup>9</sup> Some of the calcretic layers also contain high amounts of calcified root fragments (rhizoliths) indicating denser vegetation cover during the time of formation. This corresponds to the faunal remains from the sites suggesting a temporary wood or grass land environment which contrasts to the arid conditions that recently prevail during most of the year.

## Discussion

In the arid parts of the Near East, the availability of water is one basic precondition for human occupation.<sup>10</sup> Consequently, Palaeolithic sites are often located close to groundwater-fed springs, e.g. in wadis, as these locations were not strictly dependent on seasonal or

4 Klasen et al. (submitted).

5 Goring-Morris and Belfer-Cohen 2003.

6 Gebel 1983; Gebel 1988; Schyle and Uerpmann 1988; Bertrams et al. 2012.

7 Eitel 1994.

8 Robinson et al. 2006.

9 Goldberg 1986; Henry 1986; Bartov et al. 2002; Moumani, Alexander, and Bateman 2003; Davies 2005; Vaks et al. 2006.

10 Macumber 2008.

episodic rainfall events. Recently, we hypothesize that during the Upper and Epipalaeolithic, the Wadi Sabra might have been a particularly favorable settlement location, as a wide range of resources of different seasonality could be exploited within three main environmental zones: the Irano-Turanian steppe on the Jordanian plateau extending towards the east, the narrow N-S oriented strip of Mediterranean vegetation along the western edge of the plateau and finally the arid Arava valley.<sup>11</sup> Due to the abundant relief, these environmental zones have shifted both upwards and downwards in the past, depending on the available moisture. The available data indicate that the narrow strip of Mediterranean vegetation was probably extended during MIS 3 and particularly during MIS 2.

Several recent publications on palaeoclimatic conditions in the Near East assume colder and moister conditions in glacial periods compared to the modern interglacial.<sup>12</sup> On the one hand, these conditions could have extended the exploitable area from the Jordanian plateau down to the valley, creating an area where resources could be reached both from the plateau and the Mediterranean woodlands nearby. On the other hand, they should have increased the sediment production in an environment with limited sediment availability due to stabilized landscape conditions<sup>13</sup> resulting in a long term phase of fluvial aggradation in the study area. This aggradational phase corresponds to a time of reported high lake levels in the Dead Sea area (Lake Lisan<sup>14</sup>). In contrast, during most periods of the Holocene, the geomorphological processes were dominated by erosion which could have been induced by climate change or a lowering of the base-level in the Arava valley. Although the tectonic influence is poorly understood in this region, the absence of older sites is generally linked to climatic cooling events and increased aridity during MIS 4 and early MIS 3.<sup>15</sup> However, the climatic fingerprints from different archives are not distinct for this period.<sup>16</sup>

## Conclusion

Our sedimentological and geochemical investigations in the context of the Upper Palaeolithic sites in the Wadi Sabra indicate that the palaeoclimatic conditions at the end of the Pleistocene provided, at least temporarily, more favorable conditions for human settlements than today. A phase of continuous aggradation was active until the end of MIS 3 (Tab. 1). Faunal remains, rhizoliths and geochemical data of several calcretes and initial soil horizons indicate a presumable increase of moister climatic conditions during the LGM. Consequently, the study area might have been preferred by humans for occupation, indicating the landscape sensitivity of the Upper Palaeolithic culture during this time. During the Holocene, the geomorphological processes were then mostly dominated by erosion.

11 Al-Eisawi 1996.

12 Waldmann et al. 2009; Lisker et al. 2010; Frumkin, Bar-Yosef, and Schwarcz 2011.

13 Bullard and McTainsh 2003.

14 Bartov et al. 2002; Waldmann et al. 2009.

15 Goldberg 1986; Petraglia et al. 2010.

16 Henry 1986; Schuldenrein and Clark 1994; Moumani, Alexander, and Bateman 2003.

Age	Location/Site	Landscape evolution	Dating
MIS 4 (?) (74–59 ka)	Al-Ansab	Older phases of fluvial aggradation and stable surfaces (undated)	OSL (in progress)
MIS 3 (59–25 ka)	Al-Ansab, Sabra 3–4	Continuous fluvial aggradation and reworking of wadi deposits	OSL: ~ 38–28 ka Archaeology: Ahmarian (EUP), Aurignacian
MIS 2 (25–12 ka)	Sabra 3	Diverse phases of landscape stability, surface weathering and initial soil development, potentially denser vegetation cover	Archaeology: Qalkhan, Kebaran
MIS 1 (<12 ka)	Al-Ansab, Sabra 3–4	Predominantly erosion, potentially younger phases of aggradation (undated)	undated

Tab. 1 | Phases of landscape evolution in the Wadi Sabra during the Upper Pleistocene (MIS stages according to Martinson et al. 1987).

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