City and wadi: exploring the environs of Jerash

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Archaeological excavations of urban sites in the Mediterranean have a long history, but only recently are geoarchaeology-based landscape studies beginning to provide insight into the complex and dynamic relationships between cities and their hinterlands. Such studies are becoming increasingly important as archaeologists seek to understand how cities sustained themselves, demonstrating resilience to both external shocks and long-term environmental changes, and, conversely, how cities contributed to their own demise through the over-exploitation of environmental resources (Barthel & Isendahl 2013; Butzer *et al.* 2013; Kintigh *et al.* 2014; Nelson *et al.* 2016).

The site of Jerash, Jordan (Figure 1), occupied from the Hellenistic to the Islamic period, is one of the major cities of the Roman Decapolis. The longevity of the classical city came to an end in AD 749 as a consequence of major seismic activity along the Jordan Valley's strike-slip fault (Lichtenberger & Raja 2015). Bisected by the River Chrysorrhoas ('the river of gold', now Wadi Suf), the city's wider significance is also tied to its location in one of the fertile areas of the northern highlands of Jordan, with a good water supply and a number of spring lines.

A geoarchaeological survey of the urban area and its surrounding watershed demonstrates that the underlying soils comprise Cambisols (red Mediterranean soils), which were formed primarily as a result of aeolian deposition during the late Pleistocene, and Fluvisols adjacent to the wadi (Lucke *et al.* 2014; Figure 2). More critically, these surveys have identified spatial and temporal series of late Holocene colluvial and fluvial deposits on lower slopes within the city and along the Wadi Suf. The purpose of our research programme is to determine the possible factors, such as land use or climate change, that caused the movement of these sediments, and how this reflects sustainability or mismanagement of this urban centre. The geoarchaeological results are related to the archaeological and historical information about

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ANTIQUITY 91 358, e7 (2017): 1–6 doi:10.15184/aqy.2017.123

Figure 1. Overview of ancient Jerash. The city was continuously occupied from the Hellenistic to the Ummayad period (first to eighth centuries AD) (Lichtenberger & Raja 2015).

the urban development of the site. Within a context of climate change, our competing hypotheses are that, as the city grew and developed, land-resource demands contributed to enhanced sediment movement; alternatively, city-resource demands enhanced landscape management, and it was only with the demise of the city that sediment movement accelerated.

Fundamental to our study is the development of robust chrono-stratigraphies within and outside the ancient city, which entail constraining short-term events and identifying long-term change. We have identified, described and sampled three profiles in the upper, middle and lower sections of Wadi Suf (Figure 3). Three profiles have also been examined in the north-west quarter of Jerash, which offer contrasting colluvial, alluvial and anthropogenic sedimentary sequences for analysis (Figure 4).

Establishing absolute and relative geochronologies for these profiles in this landscape is challenging. For example, charcoal radiocarbon dates are inherently older than the sediments in which they are deposited, and the limestone geology does not contain feldspar and quartz grains, which are needed to produce optically stimulated luminescence (OSL) dates. Therefore, our application of OSL as a dating tool is critically dependent on the late Pleistocene aeolian-deposited quartz grains, together with source contributions from local sandstone outcrops. Despite these potential limitations, our pilot work has established that luminescence is evident in the colluvial and alluvial

https://doi.org/10.15184/aqy.2017.123 Published online by Cambridge University Press

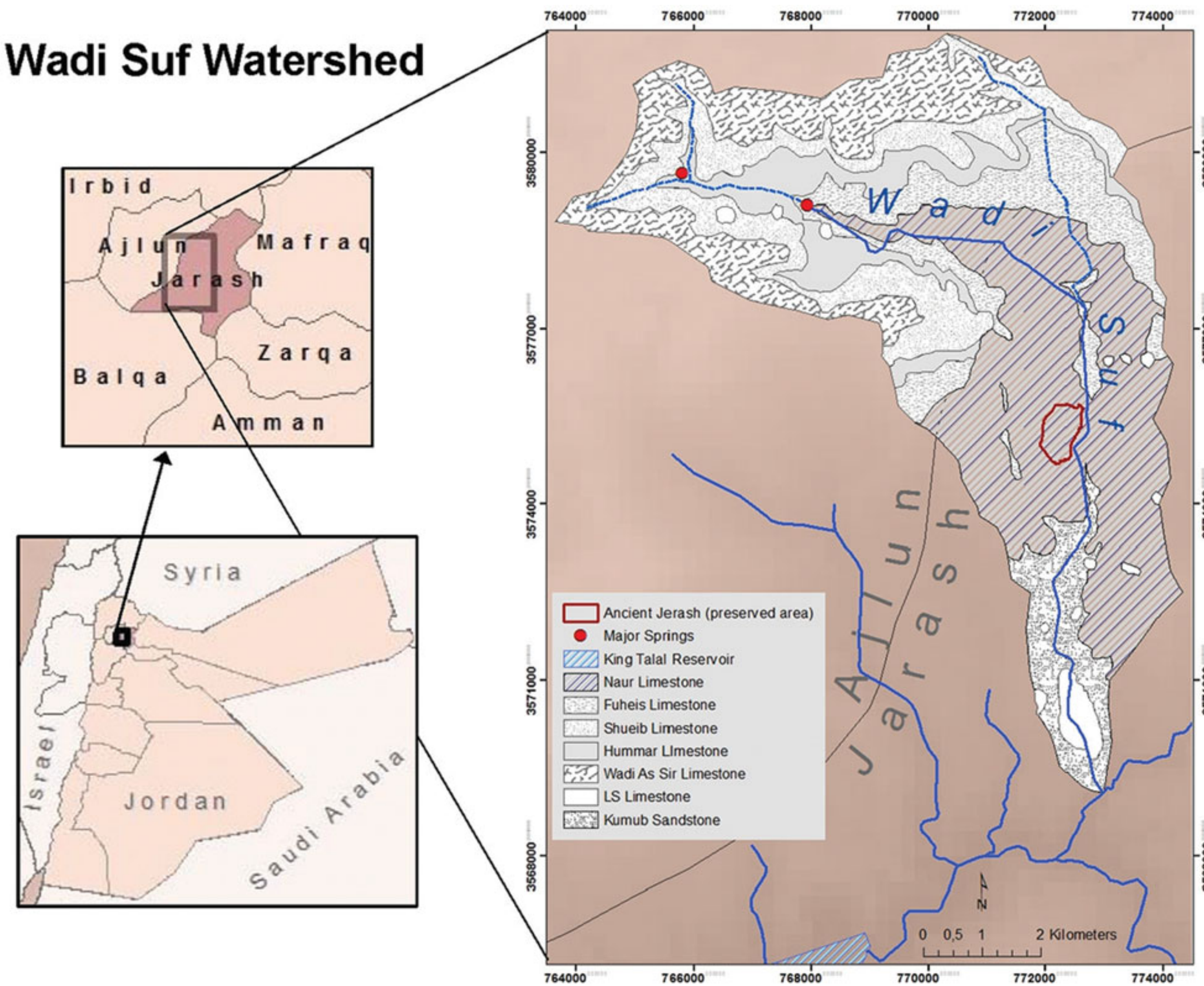

Figure 2. The watershed of Wadi Suf and the ancient and present city of Jerash, Jordan (modified from Hammouri & El-Naqa 2008; DEM from USGS, 2011).

Figure 3. Off-site investigations of the Wadi Suf (left). Lower wadi section (right).

material (Figure 5). The calendar year age estimate for the juxtaposition between bedrock and fluvial deposition in the upper Wadi Suf is AD 605±107 (SUTL2878), and perhaps gives an early indication that major movement of sediments in this part of the landscape occurred before the earthquake that destroyed the city in AD 749. It coincides with desiccating climatic conditions that occurred *c.* AD 100–700 (Orland *et al.* 2009).

Figure 4. On-site sediment stratigraphy showing two sequences of introduced red soils. Our hypothesis is that these were for small garden plots, a practice still evident today.

Our analytical work includes quantifying particle size distribution to characterise the nature of past water- and slope-flow regimes, which reflect the spatial and temporal variation of stability, deposition and erosion (Figure 5). We also examine land-use modification such as the anthropogenic transportation of soils to create stable growing mediums for gardens and urban farming. Preliminary integrated geochemical and micromorphological characterisation of these anthrosols within the city has demonstrated enhanced lead and copper levels (based on XRF analyses), and high fine black carbon frequencies, which suggest enhanced air pollution levels resulting from metallurgy (Figure 6). By analysing upstream and downstream sediments, we will establish the spatial extent of pollution in the wider surroundings of the city.

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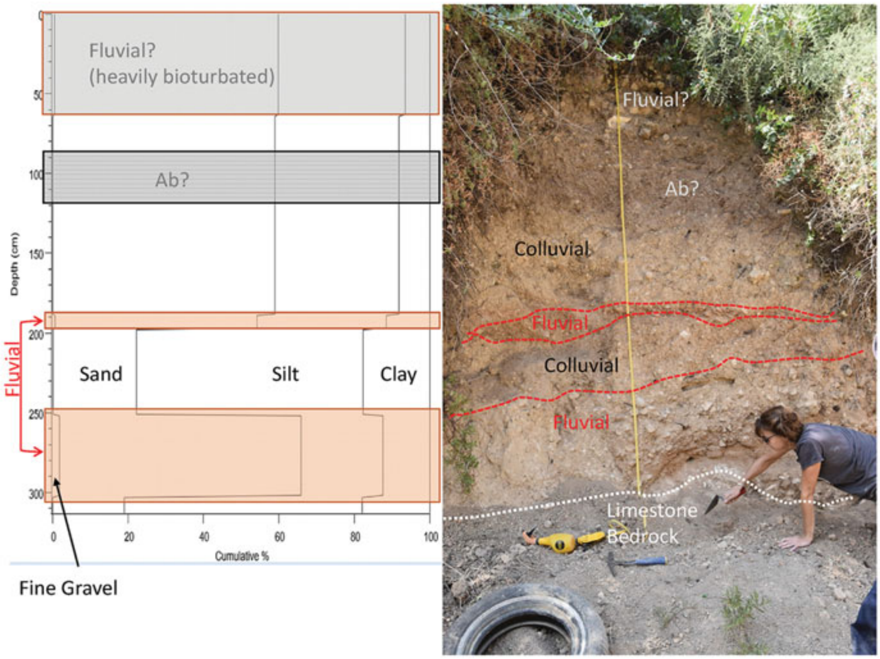

Figure 5. Particle size distribution ranges from a profile located in the headwaters of Wadi Suf.

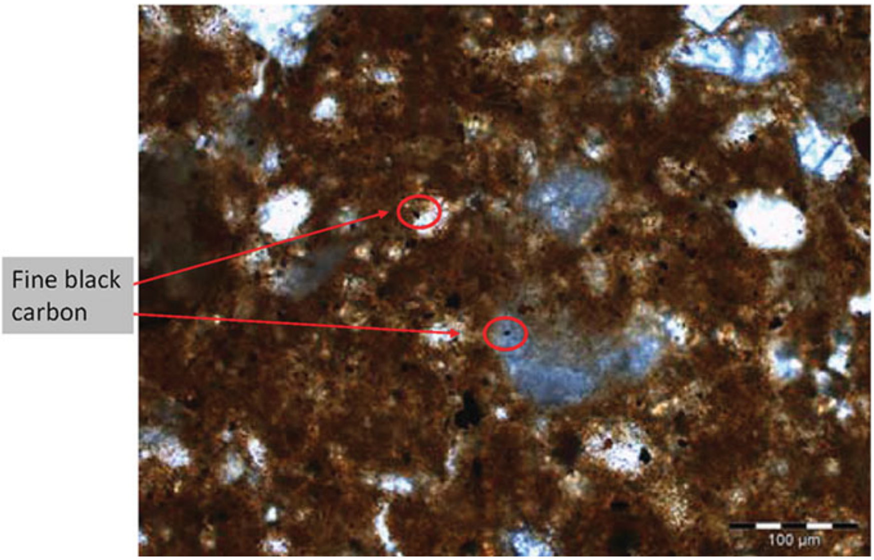

Figure 6. Thin-section micromorphology image of on-site red Mediterranean soil showing enhanced frequencies of fine black carbon. This and associated enhanced lead (up to 22ppm) and copper levels (up to 48ppm) indicate air pollution within the city.

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By developing detailed chrono-stratigraphies for on- and off-site locations at Jerash, we anticipate gaining a new understanding of both the beneficial and adverse environmental effects of early urban centres in the classical world (Butzer *et al.* 2013), and how urban areas and their immediate hinterlands were sometimes sustained and managed, and sometimes damaged and abandoned.

Acknowledgements

The work was done within the framework of the Danish-German Jerash Northwest Quarter Project of the Universities of Aarhus and Münster. We thank the Department of Antiquities in Amman and Jerash for their permission and support. Thanks are also due to the funding bodies that have supported the project: the Carlsberg Foundation, the Danish National Research Foundation (grant 119), Deutsche Forschungsgemeinschaft, the EliteForsk Prize (Danish Ministry of Education and Research) and the H.P. Hjerl Hansens Mindefondet for Dansk Palæstinaforskning.

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https://doi.org/10.15184/aqy.2017.123 Published online by Cambridge University Press