

# Issues in the study of palaeoclimate and palaeoenvironment in the early Holocene of the central Zagros, Iran

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**Abstract:** This paper reviews some of the key issues in the study of palaeoclimate and palaeoenvironment in the early Holocene of the Central Zagros. It also considers palaeocological research in this and other regions of the Near East, as well as preliminary results from new collaborative excavation and research at the early Neolithic sites of Sheikh-e Abad and Jani in Kermanshah province. The paper concludes with an outline of issues and directions for future research on Holocene palaeoclimate and palaeoenvironment in the Central Zagros. The three key issues in the study of the early Holocene climate and environment examined in this paper are (1) local and regional variation in the nature and rate of climatic change after the end of the Ice Age (2) responses by plant and animal populations to these changes, and (3) and human settlement patterns and ecological strategies.

**Keywords:** Iran, Palaeoclimate, Holocene, Central Zagros

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## 1. Introduction

The Central Zagros region is of major importance in studies of the origins of agriculture as it is one of the key natural habitats of wild plants and animals that were domesticated between 12,000-9,000 CAL B.P. The importance of climate and environment in these ecological and social changes have been re-emphasised in recent research on the Neolithic as significant factors in the viability and histories of early sedentism and the inter-relationships between humans, plants and animals (Conolly *et al.* 2011). Many researchers highlight the importance of climatic improvement and the spread of plants and animals out of restricted refugia in providing sufficiently predictable resources to support more widespread and longer-term increasingly sedentary communities, especially during the Bølling/Allerød 15,000-13,000 B.P., and the Early Holocene from 11,600 BP (Zeder 2009).

It is generally argued, however, that during the period of rapid warming in the Early Holocene the Zagros was colder, drier and less habitable than other regions of Southwest Asia such as the Levant, which recent research has confirmed was wetter than today (Mithen and Black 2011). This argument was based on an apparent absence of sites in the Zagros from *ca.* 12,000-10700 B.P. (Hole 1996), and on vegetation and climate proxies from Lake Zeribar in the central Zagros, which suggest that there were few trees (van Zeist and Bottema 1977) and a reduction in spring rains in the Early Holocene (Stevens *et al.* 2001). This paper critically reviews this evidence in the light of recent palaeoenvironmental and archaeological research in the Central Zagros and south-west Asia more widely.

## 2. Palaeoclimate

The Central Zagros region is located on the boundary of three major climatic zones and is therefore sensitive to

climate change. Analyses of a range of multi-proxy indicators from Lake Zeribar sediment cores enable the study of climatic and environmental variation over the last 40,000 years (Van Zeist and Bottema 1977; Snyder *et al.* 2001; Stevens *et al.* 2001; Wasylkowa 2005). Lake Zeribar lies 160 km northwest of the city of Kermanshah at an altitude of *ca.* 1,300 m.

Mean monthly temperatures in Kermanshah vary between 2° C in January and 27° C in July. Mean annual precipitation is 480 mm, and is highly concentrated in winter. Rainfall is subject to considerable inter-annual variation “depending upon the numbers and trajectories of Mediterranean cyclonic storms reaching the Zagros Mountains” (Brookes *et al.* 1982).

Multi-proxy indicators from Zeribar analyzed to date include: pollen, diatoms, plant macrofossils and  $\delta^{18}\text{O}_c$  and  $\delta^{13}\text{C}$  stable-isotopes of carbonate-rich sediments. This data has been examined in light of climatic models of atmospheric responses to deglaciation and changing patterns of insulation (Stevens *et al.* 2001).

The multi-proxy climate data from Lake Zeribar suggest that during the Younger Dryas, *ca.* 13,000– 11,500 CAL B.P., this region was cold and arid with semi-desert vegetation of *Artemisia* and shrubs. During the period of rapid warming which followed this, Stevens *et al.* (2001) argue that the Central Zagros was drier than other regions of the Near East, including southeastern Turkey and Jordan, where there are pre-pottery Neolithic A settlement sites from *ca.* 11,600 CAL B.P.

Pollen records suggest that there may have been delays in the development of both the current Zagros oak dominated forest and of grasses (van Zeist and Bottema 1977). The earliest woodland pollen is of pistachio (10–15%) and oak (<2–10%). The greater abundance of pistachio, which is under-represented in pollen records, in comparison to oak suggests moderately arid conditions as pistachio is more drought tolerant than oak (Djamaliet *al.* 2010).

As in the present, grasses represented 15–20% of the pollen record in the early Holocene, but expanded rapidly from *ca.* 11,800 CAL B.P. to reach a peak *ca.* 10,500 CAL B.P. of 50%. This increase in grasses coincides with an increase in settlement in the Central Zagros region, at sites such as Tepe Asiab from *ca.* 11,000 CAL B.P., followed by Ganj Dareh and Tepe Abdul Hosein, *ca.* 10,000 CAL B.P., as re-dated by Zeder (2005). Oak woodland does not reach its peak in the Holocene until *ca.* 6,000 CAL B.P.

A rapid and sustained reduction in  $\delta^{18}\text{O}_c$  values in the lake sediments suggest that there was a decrease in spring rains and protracted drought throughout much of the year in the early Holocene, with most of the available moisture provided by winter snows (Stevens *et al.* 2001).

Stevens *et al.* 2001 suggest that this reduction in spring rains may relate to changes in atmospheric circulation patterns, perhaps related to displacement of northern storm tracks, which penetrated Turkey but veered north of the

Caspian Sea. This hypothesis, however, is difficult to model based on current circulation patterns.

Jones and Roberts (2008), question whether the isotope record from Lake Zeribar necessarily represents a period of low, predominantly winter precipitation during the Early Holocene in the Central Zagros. The negative isotope records, -7‰, which are below those of today and those further west in Turkey, could be explained by a number of other factors that influence oxygen isotope values in precipitated lake carbonates, including the greater distance of Zeribar from westerly source areas, with the heavier isotope  $\delta^{18}\text{O}$  preferentially rained out, and/or a change in storm tracks, which can result in up to 6‰ variation in  $\delta^{18}\text{O}$  values. In addition, lake system water residence times in the small relatively shallow and probably seasonally closed system of Lake Zeribar, are likely to differ from those in larger or open systems, such as at Lake Van, making comparisons difficult.

Early Holocene increases in both temperature and precipitation are likely to have counter-balanced the effects of each other on isotope values. Further research is needed on current water balance and isotopic records to provide comparative models for interpretation of palaeoclimate records.

Jones and Roberts (2008) therefore suggest that the low negative oxygen isotope values may be due to the greater distance between Lake Zeribar and westerly source areas and/or a different set of storm tracks, relative to lakes in central and southeast Turkey, rather than due to lower and predominantly winter precipitation, as suggested by Stevens *et al.* (2001).

Other discrepancies include Lake Zeribar plant macrofossil and diatom data (Wasylkowa *et al.* 2008, 316) as well as on site Neolithic bioarchaeological plant and animal data that suggest there may have been higher water-tables and more woodland and wet/marsh lands in the Zagros in the Early Holocene than pollen records from Zeribar indicate (Matthews *in press*; a & b).

### 3. Methodology and Study Area

This paper explores how these lake core data and interpretations of climatic and environmental change relate to evidence for human settlement and ecology and processes of Neolithization in the Central Zagros in the Early Holocene. It compares and contrasts multi-proxy data from lake cores with evidence for human-environment inter-relationships from stratified settlement sites in the Central Zagros. It includes consideration of preliminary results from new collaborative excavation and research by the Central Zagros Archaeological Project (CZAP) at two early Neolithic sites in Kermanshah province directed by Dr. Mohammadifar, Dr. Motarjem, Prof. Roger Matthews and Dr. Wendy Matthews, with other researchers from Hamedan, Tehran, University College London, Reading University and the Iranian Center for Archaeological Research (ICAR) (R. Matthews *et al.* *in press*).

Sheikh-e Abad, 38 km north of the city of Kermanshah, is situated on a fertile plain at an elevation of 1,430 meters above sea level (Figure 1). It is surrounded by mountain peaks over 3,000 meters high. The site is 35 km north of the site of GanjDareh – where there is evidence of some of the earliest domesticated goat in the world, *ca.* 10,000 CAL B.P. (Zeder 2005).



**Figure 1.** Aceramic Neolithic mound of Sheikh-e Abad, Kermanshah province, Iran. Looking SW

Jani lies 90 km to the southwest of Sheikh-e Abad, at 1,280 m (Figure 2). These two sites are important to debates on the nature of climate and environment in the Early Holocene and processes of sedentism and Neolithization. They enable comparative study of local meso- and micro-scale variations in environment, between the upper cooler Zagros at Sheikh-e Abad, and lower warmer Zagros at Jani, which currently receives up to twice as much precipitation from westerly storm tracks. Geologically, Sheikh-e Abad is in the high karstic limestone zone, Jani is in the lower folded zone, as mapped by Heydari (2007).



**Figure 2.** Aceramic and Ceramic Neolithic mound of Jani, Kermanshah province, Iran. Looking E

These two sites enable comparative study of human settlement and ecology and the nature and spread of Neolithic plants, animals, and practices along one of the most important trade routes in the ancient world, later known as the Silk Road and the Great Khorassan highway. Dr. Mohamadifar and Dr. Motarjem discovered the site of Sheikh-e Abad during their surveys in the region, and

DrKamirAbdi discovered Jani in his survey of the Islamabad plain (Abdi 2003, 414: site 117)

Preliminary results indicate that these sites are comparatively large and were occupied for some time. They are each approximately 1 hectare in size and 8-10 meters high. Sheikh-e Abad dates to the Aceramic Neolithic.  $^{14}\text{C}$  dates indicate that the site spans *ca.* 13,800-11,600 CAL B.P. (R. Matthews *et al.* in press). The earliest levels exposed in Trenches 1-2, are of midden and open-area deposits, with traces of architecture in the upper levels in Trench 2 (Figures 3-4). Trench 1 spans 11,810-11,240 CAL B.P. The base of Trench 2 dates to 9,590 CAL B.P.

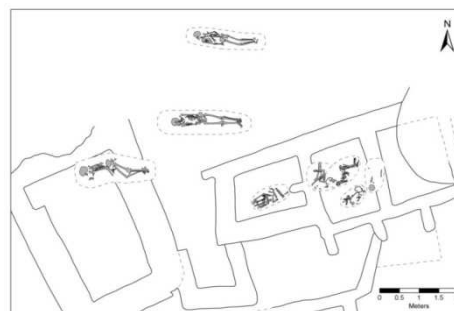


**Figure 3.** Excavations in Trench 1, Sheikh-e Abad, showing bands of ash. Looking NW. Scales = 2 m and 50 cm.



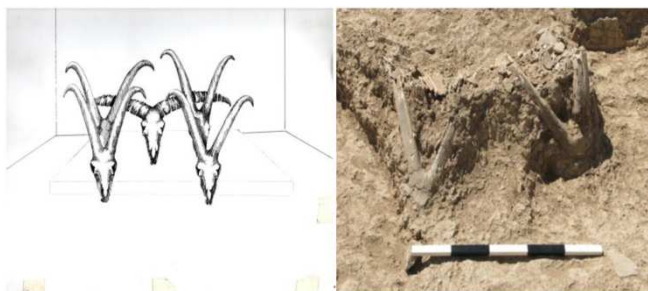
**Figure 4.** Trench 2, Sheikh-e Abad, Scales = 2 m and 50 cm.

Trench 3 on top of the mound dates to 9,950 CAL B.P. (Figure 5). Here complex architecture and a possible shrine with a wild sheep skull and four wild goat skulls, one of which was covered in red ochre, were investigated (Figure 6).



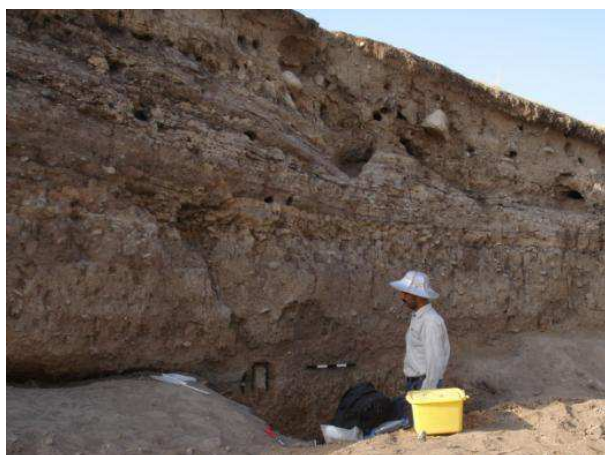
**Figure 5.** Excavations in Trench 3, Sheikh-e Abad, showing Building 2 (west/left) and Building 1 (east, right). Looking N. Scale = 2 m.





**Figure 6.** Goat skulls in Building 2, Trench 3, Sheikh-e Abad. Looking SE. Scale = 50 cm.

At Jani, survey, cleaning, recording, and sampling of a 60 meter long section revealed that the earliest levels of the site are Neolithic, comprising open areas and middens with fire-cracked stones, pits, and architecture and have been dated by  $^{14}\text{C}$  to ca. 10,000 CAL B.P., at ca. 1m above natural (Figure 7). The upper levels belong to the ceramic Neolithic and later.



**Figure 7.** Tepe Jani, showing micromorphology block sample at the base of the mound at the interface with natural sediments. Scale = 50 cm.

## 4. Human-Environment Inter-Relationships

This paper examines preliminary on-site evidence for the presence and use of materials from woodlands, wet and dry grasslands, and animal dung, which provides an independent marker of early animal management, as changes in bone morphology may be delayed by up to 500-1,000 years (Zeder 2005). A range of analytical approaches is being applied in these studies, including archaeobotany, phytoliths, micro-morphological study of sediments in large resin-impregnated thin-sections, and geochemistry (R. Matthews *et al.* in press).

As Asouti (2003, 2005) has observed, on-site palaeoenvironmental data can provide vital information on species that are under-represented in off-site sequences, including trees such as *Pistachio*, which is a poor pollen disperser, or insect-pollinated taxa. On-site sequences can also provide well-stratified high-resolution information on

human-environment inter-relationships that are key to understanding the significance of palaeoclimatic and palaeoenvironmental data from off-site sequences, which may be difficult to correlate with settlement data.

Roberts (2002) has observed that the delayed spread in oak-woodland and parkland is in fact widespread in interior regions across the Near East. Oak woodland does not peak in many regions until ca. 6,000 CAL B.P.

Roberts (2002) suggests that, in addition to consideration of climatic and environmental factors, the delay in the spread of woodland in the Early Holocene may be due to the presence of other competing demands on potential woodland and parkland landscape-ecological zones/habitats. These factors include grazing and browsing by animals (goat, sheep, deer and gazelle), and woodland clearance and management of vegetation composition and structure by humans for hunting, gathering, livestock grazing and cultivation. This is likely to have included selective cutting of trees for fuel and timber, whilst selectively leaving fruit and nut bearing trees.

Studies of micro-charcoal in lake-core sediments, have identified an increase in the intensity in burning perhaps for land clearance in the Early Holocene (Roberts 2002; Turner *et al.* 2008 although distinguishing between vegetation fires from deliberate, accidental or natural causes is problematic. In the Lake Zeribar region, (Wasylikowa *et al.* 2006; Wasylikowa and Witkowski 2008; Wasylikowa 2005), observe an increase in the occurrence of charred grass awns around 12,000 CAL B.P. from dry-land fires surrounding the lake. In addition, there is an increase in grass pollen and *Plantagolanceolata* type from 10,000 CAL B.P., which may be associated with disturbance of vegetation by hunters/herders.

At Sheikh-e Abad and Jani, HengamehIlkhani has established that wood charcoal is present in charred plant assemblages attesting the presence of at least some trees. Shells from pistachio (a poor pollen disperser) and almond (insect-pollinated) are also present in archaeobotanical assemblages from both of these sites. We are examining which specific tree species were selected for fuel and timber (Asouti 2003, 2005; Roberts 2002).

Preliminary analyses of both charred plant remains and phytolith assemblages suggest that there were some cereals (Whitlam *et al.* in press; Shillito and Elliott in press). Both wetland and dry land grasses were present in the environs of both sites, including sedges and reeds. Other charred plant remains identified by HengamehIlkhani include wild legumes, including lentils. Therefore, the palaeobotanical, archaeozoological, and environmental data suggest these sites were located close to a rich range of ecological zones including plains, wetlands and mountains.

Wood charcoal dominated archaeological charred plant assemblages at other sites in the region from at least ca. 10,000 CAL B.P. including Tepe Abdul Hussein (90-98%) (Hubbard 1990) and GanjDareh (van Zeist *et al.* 1986). Hubbard (1990) and Willcox (1990) reconstruct the landscape of Tepe Abdul Hossein as parkland or savannah-

like with common small trees of pistachio and almond. The herbaceous cover was similar to that of the present day, with many small *Astragalus* bushes, thistles, grasses, medicks, fenugreeks and many other small herbs. Willcox (1990) observed that growth rings of woods tended to be narrow, reflecting aridity in the region where wood was collected. No oak was identified from Tepe Abdul Hossein, suggesting that it had not yet colonised this region, as suggested by the sparse representation of oak pollen in the Early Holocene sequence from Lake Zeribar. Willcox argues that this correlation between charred wood assemblages on archaeological sites and pollen record, supports the wider use of charred wood assemblages in reconstruction of both local and regional environments, as reliable pollen stratigraphy in these semi-arid to arid regions is largely restricted to lakebeds.

At GanjDareh the wood species identified include: *Pistacia*, *Celtis* (hackberry), *Prunus*, *Rhamnus* and *Salix/Populus*, which was selected for construction timbers (Van Zeist *et al.* 1986).

In contrast to all of these sites, no carbonized wood was recovered from Ali Kosh (Helbaek 1969, 387). Miller (1996) has convincingly argued that many seeds from Ali Kosh are derived from dung burnt as fuel, as at other sites in the Near East, including Çatalhöyük (Matthews 2005; 2008; 2010). Roberts (2002) suggests that this may have meant firewood was in short supply, although dung is known to have excellent burning properties (Sillar 2000) and may have been preferentially selected for fuel.

Calcareous spherulites from dung have been identified in microscopic analysis of spot samples of sediment from ashy deposits in an open area at

Sheikh-e Abad and in thin-sections from Trench 2 and 3 both as a source of fuel and evidence of the presence of animals within this settlement (Matthews *et al.* in press). We are currently investigating animal diet, fodder and grazing/browsing patterns as indicators of past vegetation and early animal management practices. This micromorphological analysis has the potential to identify early management of animals, up to 500 years prior to detectable changes in bone morphology related to domestication (Zeder 2005; Matthews 2010). This identification of dung also requires careful evaluation of the taphonomy of charred and non-charred plant remains assemblages from these sites (Miller 1996; Van der Veen 2007; Matthews 2010).

At Çatalhöyük, layers of compacted non-charred dung have been identified in animal pens (Matthews 2005). Here, the diet of these penned animals included reeds, preserved as phytoliths, within dung pellets. At both Çatalhöyük and Sheikh-e Abad, the source of dung rich in phytoliths has been identified as ruminant using GC/MS (Shillito *et al.* 2011; Shillito *et al.* in press). Isotope analysis of animal bone from Sheikh-e Abad and Jani is providing more information on animal diet and potential grazing or management, in the eastern and western Central Zagros (R. Matthews *et al.* in press).

## 5. Soils and Sediments

The implications of alluvial and colluvial sequences for archaeological survey in Central West Iran have been studied by Brookes *et al.* (1982). In examination of exposed sections in the Mahidasht, they identified five major depositional units, in a sequence 6 meters thick. The Early Holocene sediments comprise reddish-brown blocky silty clays – silt loams, which are less sandy than later alluvia and have calcium carbonate concretions 2-3 cm in diameter. They propose that these sediments are a product of erosion of terra rossa soils from interfluvies by sheet wash.

Current calcareous soils in intermontane valleys in the Kermanshah region have been examined by Heidari *et al.* (2005), through fieldwork and analysis of micromorphology, particle-size, mineralogy and chemistry (carbonate content, organic carbon, electrolytic conductivity, pH and cation exchange capacity, COLE and XRD). These fertile vertisols are currently used for dry and irrigation farming, pasture and meadow. They are yellowish brown in colour and have high clay content, at 54-79%, dominated by the clay mineral smectite (with varying amounts of vermiculite, illite, chlorite and kaolinite clay minerals). These soils have a blocky microstructure, and are susceptible to shrink-swell with alternate wetting and drying. The calcium carbonate content is 18-43% (some as secondary sparite infilling channels). The pH is 7.3-8.2.

The buried soils at the base of both Sheikh-e Abad and Jani are also yellowish brown in colour, and have been sampled for a range of analyses.

## 6. Conclusions

Recent archaeological and lake core evidence question previous suggestions that the Zagros was colder and drier than other regions of the Near East and more inhospitable to settlement (Stevens *et al.* 2001). This review suggests that there was settlement during this period and that the Zagros comprised a mosaic landscape which included wetlands, grasslands and a significant number of trees, including pistachio and almond, which are under-represented in pollen records at Zeribar and more widely. It is argued here that these resources provided a rich and varied environment in the Zagros in the Early Holocene for hunting, gathering and early sedentism and plant and animal management, and are an important example of the range of local and regional variations in early Neolithic ecological and settlement strategies observed across the Near East more widely (Savard *et al.* 2006).

Initial assessments for future local and regional palaeoclimate and palaeoenvironmental research were undertaken during fieldwork at Sheikh-e Abad and Jani in summer 2008. Future research with the Soil Science Department, Bu Ali Sina University Hamedan, and researchers in the CZAP will include study of sediments,

isotopes, pollen, phytoliths, charred plant remains, molluscs and macro- and micro-fossils from cores and exposures through alluvial channels and fans, buried soils, and colluvial sequences, as well as study of tectonics and speleothems.

Speleothems in cave-sites in the region are a key source of information, with the potential to provide a high-resolution record of climate change, through analysis of isotope values (Fleitmann 2007). Speleothems and flowstones are widespread and stratified in cave sites, sealing in some cases Middle Paleolithic layers, as observed by Heydari and Biglari (Biglari and Heydari 2001; Heydari 2007).

We hope this paper has highlighted aspects of three key issues for continued investigation in the study early Holocene climate and environments and the importance of understanding local and regional variation in (1) the nature and rate of climatic change, (2) responses by plant and animal populations, and (3) human settlement and ecological strategies and practices.

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