Original Research Paper

# The origins of nomadic pastoralism in the eastern Jordanian steppe: a combined stable isotope and chipped stone assessment

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The circumstances in which domestic animals were first introduced to the arid regions of the Southern Levant and the origins of nomadic pastoralism, have been the subject of considerable debate. Nomadic pastoralism was a novel herd management practice with implications for the economic, social and cultural development of Neolithic communities inhabiting steppe and early village environs. Combining faunal stable isotope and chipped stone analysis from the Eastern Jordanian Neolithic steppic sites of Wadi Jilat 13 and 25, and 'Ain Ghazal in the Mediterranean agricultural zone of the Levantine Corridor, we provide a unique picture of the groups exploiting the arid areas.

**Key words** Neolithic; stable isotopes; nomadic pastoralism; lithic analysis; fauna.

## Introduction

Some of the earliest evidence for domestic sheep and goats herds in the Eastern Jordanian steppe has been recovered from the sites of Wadi Jilat 13 and 25 at the beginning of the seventh millennium cal. BC (Garrard 1998; Garrard *et al.* 1994b; Martin 1999; Martin and Edwards 2013), although the possibility of their introduction in the Late Pre-Pottery Neolithic B (henceforth LPPNB)

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has been raised (Baird *et al.* 1992; Emra 2011; Martin 1999; Quintero *et al.* 2004; Rollefson *et al.* 2002; 2013). Wadi Jilat 13 and 25 were occupied during the Early Late Neolithic (henceforth ELN, 6900 – 6300 cal BC) in the archaeology of the steppe regions of the Southern Levant; contemporary with the Pre-Pottery Neolithic C (henceforth PPNC, 6900 – 6500 cal BC) and the onset of pottery production in the Mediterranean agricultural zone of the Levantine Corridor (Baird 1993; Fujii 2009; Garrard *et al.* 1994a). Prior to the introduction of domestic herds, the area was inhabited by hunter-gatherer groups who possibly also practised small-scale sporadic cultivation, and the debate as to what motivated the change to the exploitation of herded animals in this region has resulted in two main schools of thought (Baird 1993; Bar-Yosef 1984; Betts 1992; 1987; 1989; Byrd 1992; Cropper 2006; Garrard 1998; Garrard *et al.* 1986; 1987; 1994a; 1996; Köhler-Rollefson 1988; 1989; 1992; Lancaster and Lancaster 1991; Maher *et al.* 2012; Makarewicz 2014; Martin 1999; Richter *et al.* 2009; 2011; 2013a; 2013b; Rollefson 2016; Rollefson *et al.* 2014; Rollefson and Köhler-Rollefson 1993; Rowan *et al.* 2017).

Köhler-Rollefson (1992) (also see Gilbert 1983; Hole 1978) has suggested that Neolithic communities from large ecotone sites, such as 'Ain Ghazal, negotiated the putatively (see Bogaard and Isaakidou 2010) competing demands of animal pasture and crop cultivation through the seasonal removal of caprine herds to the neighbouring steppe. Other scholars acknowledged that this type of colonisation may have played a part, but also propose the successful adoption of domestic animal herds by communities indigenous to the steppe (Byrd 1992; Baird 1993; Baird 1994; Cropper 2006; Garrard *et al.* 1994b; Lancaster and Lancaster 1991; Martin *et al.* 1999).

This paper presents the results of a unique study: combining the evidence from faunal stable isotopes and chipped stone analysis to explore the identity of the groups that played a role early in the development of pastoralist lifeways in this region. The results of stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) analysis from the bone collagen of caprines from ELN steppe structures Wadi Jilat 13 and 25, and Mid-Late PPNB and PPNC phases from the large ecotone village site of 'Ain Ghazal, are presented to show the dietary characteristics of herded animals at each site, and whether this indicates large-scale movement to areas represented by different vegetation. In combination, chipped stone materials are assessed to indicate the technical traditions of the humans associated with the animal remains. As anthropologists like Sigaut (2002) have long indicated, technology cannot be separated from the social practices in which learning and production are embedded. Chipped stone reduction strategies, and especially techniques, are craft practices likely learned young in prehistoric societies, requiring the sort of knowledge best communicated face-to-face. Skills result from constant renewal through practice, and learning is not complete until physical actions become virtually automatic (Sigault 2002). Specifics of complex reduction strategies, the overall plan for knapping, and particularly specifics of technique factors, such as where to strike the core and the amount of force to use in combination with the nature of tool to deliver the force, are all procedures difficult to convey by speech alone and best transmitted and learned by direct observation. These learned behaviours are maintained as much by 'muscle memory' as intellectualised thought patterns (Sigault 2002) and thus traditions of techniques, where there is clear patterning in the data, are powerful indications of the nature of communication within and between groups. These learned behaviours in lithic reduction methodologies, and technical differences associated with Wadi Jilat and 'Ain Ghazal throughout the Neolithic period (Baird *et al.* 1993; Cropper 2006), will serve to highlight regional production traditions, community affiliations and group identities.

Together, stable isotope and lithic analyses have implications for identifying early pastoralist groups at Wadi Jilat and thus also the mechanisms by which animals were introduced to steppic regions and the relationships between communities in the steppe and the sedentary villages of the Mediterranean zone. Identifying either the onset of transhumance or the commencement of nomadic pastoralism through this study would highlight significant social and economic developments for groups that saw the potential of the steppe areas of the Southern Levant for pastoral activities: key to human exploitation of the landscape over the following nine millennia.

### ***Identifying pastoral practices in the Neolithic steppe regions***

The suggestion that steppic-zone herders originated at large village sites, such as 'Ain Ghazal (Köhler-Rollefson 1992; Makarewicz 2014; Quintero *et al.* 2004; Rollefson and Köhler-Rollefson 1993), is formulated as part of an argument that such developments resulted, at this early stage, in a split community with some undertaking arable farming and others employed with pastoral activities. Inhabitants at the recently excavated sites at Wisad Pools and Wadi Qattafi (Fig. 1) in the eastern Jordanian panhandle are suggested to represent the pastoral side of such a split economy: dated to the latter half of the seventh to the sixth millennium cal. BC, substantial numbers of pastoralists were seemingly occupying large, virtual village sites in the steppe for considerable amounts of time on a seasonal basis (Rollefson 2016; Rollefson *et al.* 2014; Rowan *et al.* 2017). A shift from meat production to dairying is thought to have allowed for greater efficiency in using the steppe regions for animal raising (Rollefson *et al.* 2014; Vigne and Helmer 2007) while hunting continued to be important (Rollefson *et al.* 2016). Moving between a sedentary village base and seasonal pasture in the steppe would have required the development of transhumance, or tethered pastoralism, whereby movement was beyond the agricultural zone and/or several days walk from the village. Distinctions in domestic architecture at 'Ain Ghazal have been suggested to point to increasingly segregated economic strategies of this nature beginning in the PPNC (Rollefson *et al.* 2014).

Transhumance and/or tethered pastoralism are distinct from nomadic pastoralism, which is defined as a reliance on pastoral economic activities, with patterns of high mobility and changing of dwellings throughout the year (Abdi 2003; Khazanov 1984; Wasse 2000). This would likely be the result of incorporating herded animals into the practices of habitually mobile groups, like those indigenous to the steppe regions (Byrd 1992; Garrard *et al.* 1994b; 1996; Maher *et al.* 2012; Richter *et al.* 2009; 2011; 2013a; 2013b). The implication of this development is that steppe-based communities diversified their subsistence strategies; becoming hunter-gatherer-cultivator-herders (Baird 1993) as part of a long-lived suite of mobile, steppe-adaptations. In this scenario, it is likely pastoral activities would have become the primary economic activity as periodic changes of pasture and herding dominated day-to-day activities (Abdi 2003; Khazanov 1984).

***The study sites***

The sites of Wadi Jilat 13 and 25 were identified in a programme of survey and excavation in the 1970-80s (Baird 1993: 1994: 2001b: Baird *et al.* 1992: Garrard 1998: Garrard *et al.* 1985: 1986: 1987: 1994a: 1994b: Wright *et al.* 2008) (Fig. 1). The Wadi Jilat itself is in the Azraq basin, part of the *Badia,* a classical Arabic word for the semi-arid region. The centre of the basin was the site of a former prehistoric lake (Jones and Richter 2011; Maher *et al.* 2012), current annual rainfall in the Azraq Basin varies from c.200mm in the northwest of the area to less than c.50mm in the southeast (Garrard 1998). At present, in some years, water and vegetation are readily available, in others it is severely restricted (Lancaster and Lancaster 1991). Thus, the area is characterised by drought-tolerant Irano-Turanian vegetation consisting of few trees and dominated by dwarf shrubs and perennial plants found in areas where water is retained, such as wadi beds and slopes. The early Holocene of the southern Levant witnessed higher rainfall than today, as evidenced by speleothem data from Soreq cave (Bar-Matthews *et al.* 1997) and other stable isotope date (Roberts *et al.* 2018). Recent evidence from soil profiles at Wisad Pools suggests that rainfall was significantly higher in the Neolithic than the hyper-arid conditions of today, with charcoal of oak (*Quercus ithaburensis*) and *Tamarix sp.*, which is characteristic flora of forest-steppe vegetation, being found in hearths (Rowan *et al.* 2017). Therefore, between 9700 and 6200 cal BC, precipitation in the eastern steppe was as a consequence likely higher, with the 200mm isohyet further east than today. Nevertheless, eastern Jordan was certainly relatively arid compared to the area to the west given that precipitation would have been introduced predominantly from the west, even if there was more summer rainfall from the south than today. Mobile hunter-gatherer groups in the prehistoric Azraq basin utilised stands of wild nuts, fruits and legumes (Garrard *et al.* 1994b), as well as consuming cereals and hunted *Gazella subgutturosa*, small mammals, reptiles and birds (Martin 1999). Despite being beyond the current limits of reliable dry farming, Early and Middle Pre-Pottery Neolithic B (henceforth E and M PPNB, respectively) Wadi Jilat 7 and ELN Wadi Jilat 13 (Fig. 1) have evidence of domestic emmer, wild and domestic barley, and wild and domestic einkorn. Significantly, the flora taxa lists are comparable between the two sites, suggesting that the supply of cereals is unlikely to have changed over time (College 2001; Garrard *et al.* 1994b). Whether this meant sustained importation or local steppe cultivation is unclear.

The Wadi Jilat 13 and 25 structures are typical of Neolithic Azraq Basin architecture in that they are curvilinear, semi-subterranean buildings with upright stone surrounds, probably with light and limited superstructures, given the absence of evidence for associated supports (Baird *et al.* 1992; Garrard *et al.* 1994b). This shows a continuity of local traditions, likely defined by resource availability and environmental imperatives that result in a similar style of structure over disparate steppic ranges. There are strong parallels between Wadi Jilat structures, other Southern Levantine Neolithic steppe occupations, and those used by present day nomads (Banning and Köhler-Rollefson 1992; Bar-Yosef 1984; Cribb 1991; Digard 1987; Khazanov 1984). Wadi Jilat 13 and 25 ELN steppic structures are notably larger than those of the PPNB in the same region (Betts 1993; Baird 1993; Garrard *et al.* 1994b), potentially to encompass a larger co-resident group and/or livestock associated with the introduction of herding. The nature of the settlement at ELN Wadi Jilat is different to that at the later Wisad Pools and Wadi Qattafi sites, particularly in terms of numbers of structures and thus likely size of resident population (Rollefson 2016; Rollefson *et al.* 2014; Rowan *et al.* 2017).

Early phases at Wadi Jilat 13 are radiocarbon dated to 7030-6650 cal BC (OxA1800) and 7030-6600 cal BC (OxA1801). Related deposits contain Byblos, Amuq, Herziliya points and are dominated by Nizzanim points, with the relative importance of PPNB types and absence of Harparsah and Transverse arrowheads further indicating an ELN occupation (Baird 1993). Two dates, 7030-6640 cal BC (OxA2411) and 6830-6510 cal BC (UB3462) from a stratigraphically late phase come from *in situ* fills of stone-lined hearths set in a stone pavement. The point assemblage in this phase includes extensively pressure flaked Byblos, and Amuq, Nizzanim and Herziliya points, as well as infrequent recovery of Harparsah points and Transverse arrowheads (Baird 1993).

Twenty-one $m^2$ of the north-eastern third and the immediate external areas of the Jilat 25 structure were excavated. This contained 60cm of stratified deposits in two major episodes of deposition; continuous use and reoccupation phases of the structure followed by an episode of infilling. A radiocarbon date of 7070-6810 cal BC (OxA2408) is available for the earliest phase of Wadi Jilat 25 and the point assemblage throughout the three phases was the same; dominated by Nizzanim points (Baird 1993). The absence of Haparsah points and Transverse arrowheads is suggestive of an ELN occupation, but the PPNB/ELN transitional nature of the point assemblage of Wadi Jilat 13 is not seen at Wadi Jilat 25. The Wadi Jilat 25 points appear to post-date the early phase at Wadi Jilat 13 and pre-date the Transverse and Haparsah presence, however the smaller scale of excavations and resulting sample size at Wadi Jilat 25 makes this difficult to be certain about (Baird 1993). While it is not possible to say that the two sites are precisely contemporary, the dates and relative point chronology suggest that they are broadly contemporary.

‘Ain Ghazal was a large, multi-period PPN-PN (8100–5800 cal BC) village site in the Mediterranean region of the Southern Levant (Fig. 1). Excavated and published extensively through the 1980s-90s (Köhler-Rollefson 1989; Köhler-Rollefson and Rollefson 1990; Köhler-Rollefson *et al.* 1993; Neef 2004; Rollefson 1983; 1986; 1990; 1993; 1997; 1998; 2004; 2010; Rollefson and Simmons 1988; 1985; 1986; Rollefson *et al.* 1994; 1992; Von Den Driesch and Wodtke 1997; Wasse 1997). It is a key reference site for understanding Southern Levantine PPNB and PPNC archaeology. With current annual rainfall of c.300-350 mm, ‘Ain Ghazal is an ecotone site on the border between Mediterranean and Irano-Turanian vegetation regimes (Simmons *et al.* 1988) which means the vegetation may include evergreen, conifer and deciduous trees, but also dwarf-shrubs as it transitions between the forest and steppe environments (Colledge 2001). A so-called ‘mega-site’ in the Late PPNB, the settlement was densely packed with rectilinear compartmentalised buildings. The PPNC saw the remodelling and reuse of earlier architecture, and the development of semi-subterranean ‘Corridor Buildings’, which have been posited as storage structures for use by village-based herders (Köhler-Rollefson *et al.* 1993; Rollefson 1993; 1997; Rollefson *et al.* 2014), although there is little evidence for storage or function beyond the domestic (Byrd 1994; Galili *et al.* 1993; Kirkbride 1968; Makarewicz *et al.* 2006). Rows of stones thought to date to the PN have been identified as tent weights for ephemeral structures. These may have had many functions, but of particular importance here is the interpretation that these may have been occupation sites for herding groups, occasionally living close to the settled ‘Ain Ghazal community (Rollefson 1997).

During the Middle PPNB (henceforth MPPNB) the Mediterranean zone village communities were cultivating domestic plants and herded animals were present. At ‘Ain Ghazal, new domesticate species were subject to evolving exploitation strategies (Arbuckle and Atici 2013; Conolly *et al.* 2011; Horowitz *et al.* 1999; Köhler-Rollesfon 1989; Makarewicz 2013; Martin and Edwards 2013; Von Den Driesch and Wodtke 1997; Wasse 2000; 2002). Domestic resources were incorporated alongside a range of wild plant and animal species that continued to be hunted and gathered, although by the LPPNB the c.50 animal species utilised was reduced to c.20, and 71% of the animal remains are from domestic caprines. This trend marks the pivotal point at which animal husbandry, rather than hunting, supplied the primary source of meat at the site (Banning 1998; Kuijt and Goring-Morris 2002).

## Methods and materials

### *Stable isotope analysis*

The measurement of $\delta^{13}C$ and $\delta^{15}N$ isotopes in bone collagen represents an established method for reconstructing human and animal palaeodiets (examples of Near Eastern applications include Makarewicz 2014; Makarewicz and Tuross 2012; Pearson *et al*. 2007; 2010; 2013; 2015; Pearson and Meskell 2015; Richards *et al.* 2003; Wiedemann *et al.* 1999). These isotopes are sourced from proteins in the diet and assimilated into consumer tissues. In bone, this assimilation occurs over several years through tissue turnover (Ambrose 1993). The underlying principles of this approach have been explained in detail elsewhere (see Ambrose 1993; 2000; DeNiro 1985; Katzenberg 2000; Lee-Thorp 2008; Sealy 2001) and are therefore only briefly recounted as they are applicable to this study.

In herbivore bone collagen, $\delta^{13}C$ and $\delta^{15}N$ isotope ratios reflect a long-term average of the plant proteins consumed, derived from the breakdown of carbohydrates in the form of plant cellulose (Ambrose and Norr 1993). Plants incorporate atmospheric $CO_2$ through photosynthesis, discriminating against the heavier carbon isotope ($^{13}CO_2$) as it is less metabolically active than $^{12}CO_2$. The degree to which plants discriminate against $^{13}C$ in their $CO_2$ uptake is largely related to their photosynthetic pathway; $C_3$ plants (most temperate plants including wheat, barley, most fruits and nuts bearing trees, pulses, legumes and tubers) have a much higher affinity for $^{12}C$ than $^{13}C$. $C_4$ photosynthetic plants, mainly arid-adapted (often tropical) grasses and chenopodiaceae that are tolerant to high temperature and drought conditions, discriminate less against $^{13}C$, and therefore have an increased uptake and more positive tissue $\delta^{13}C$ values (Hartman and Danin 2010).

Water stress is another factor that may affect the $\delta^{13}C$ values of plants and animals across the sites under investigation. Where soil moisture is limited, plant stomata close to prevent loss of water, reducing the availability of $CO_2$ to the plant (Araus *et al.* 1997; Ehleringer *et al.* 1986; 1993; 1997; Farquhar *et al.* 1982; 1989; Styring *et al.* 2016). In these circumstances, plants photosynthesise more of the available $CO_2$, and are less discriminatory against $^{13}CO_2$ (Tieszen 1991; Riehl *et al.* 2008). Animals consuming $C_4$ plants and/or in water stressed conditions will have more positive $\delta^{13}C$ values than those on a well-watered, $C_3$ plant diet.

On the border of water-impoverished Mediterranean - Irano-Turanian vegetation, it is possible that $C_4$ plants were present in the 'Ain Ghazal locality in small numbers (Makarewicz 2007; 2014). However, Wiedemann (1999) suggests that $C_4$ plants are likely to have been restricted to the more steppic regions, such as the Azraq Basin and the Wadi Jilat. $C_4$ plants including chenopod species, *Zygophyllaceae* and *Polygonaceae* families are known to be abundant in the Wadi Jilat beds and slopes (Akhani *et al.* 1997; Shomer-Ilan *et al.* 1981; Vogel *et al.* 1986; Winter 1981). As such, animals drawing their diets exclusively from the areas around the Wadi Jilat are likely to have more positive $\delta^{13}C$ values when compared to those feeding at 'Ain Ghazal, or a mixed diet representing long-term movement between the two environments.

Nitrogenous compounds in plants are taken up from soil or fixed directly from atmospheric nitrogen depending on plant physiology (Cheng *et al.* 1964). This is then incorporated into the consumer tissues. An added enrichment factor of 3-5‰ in $\delta^{15}N$ can be seen at each step in the food chain because metabolic discrimination favours the lighter isotope, $^{14}N$. As a result, herbivore $\delta^{15}N$ is 3-5‰ higher than the plants they consume (Minagawa and Wada 1984; Schoeninger 1985; Schoeninger and DeNiro 1984).

A positive correlation between aridity (low rainfall and high evapotranspiration) and $\delta^{15}N$ values has been found in studies of soils and vegetation (e.g. Aranibar *et al.* 2004; Austin and Vitousek 1998; Craine *et al.* 2009; Handley *et al.* 1999; Hartman and Danin 2010; Heaton 1987; Styring *et al.* 2016; Swap *et al.* 2004). Plant growth and microbial activity diminish with decreasing soil moisture. This is thought to mean that metabolically active soil-$^{14}N$ is more readily lost as ammonia gas ($NH_3$) and therefore less available to plants (Barber 1995; Stark and Firestone 1995). The result is that plants are grown on $^{15}N$ enriched soils, largely accounting for the $\delta^{15}N$ variation in unmanaged (not manured or irrigated, etc. (Styring *et al.* 2016)) arid environments (e.g. Craine *et al.* 2009; Handley *et al.* 1999; Hartman and Danin 2010; Styring 2016; Swap *et al.* 2004). Hartman (2011) has shown that this negative relationship is likely to influence herbivore $\delta^{15}N$ values through the consumption of plants that vary in $^{15}N$ uptake according to local rainfall patterns, particularly when there is a contribution from $C_4$ vegetation. $C_4$ plants growing under similar conditions are on average c.2‰ enriched in $^{15}N$ compared with $C_3$ plants (Hartman and Danin 2010). As primary consumers source their nitrogen from the plants they eat, this relationship between aridity and plant $\delta^{15}N$ values is seen in a measurable trophic effect in herbivores (Hartman 2011; Murphy and Bowman 2006). The consumption of $C_4$ plants gives rise to more positive $\delta^{15}N$ and $\delta^{13}C$ values in diets and subsequently bone collagen, but all plants from arid regions will have higher $\delta^{15}N$ values than the same species in well-watered conditions.

As the $\delta^{15}N$ values of herbivore body tissue are directly derived from their diet it means that the strong relationship between plant $\delta^{15}N$ values and rainfall in relatively arid regions will be reflected in herbivore consumer tissues (Hartman 2011; Murphy and Bowman 2006). Where these data are preserved, they can be used to reconstruct palaeorainfall patterns, past environments and local foraging ecology (Hartman 2011). While animal mobility may be investigated through the analysis of oxygen and strontium isotopes (Balasse *et al.* 2002; Makarewicz 2014; Slovak and Paytan 2011), in these circumstances carbon and nitrogen stable isotope values can reveal early animal management in primarily arid environments through evidence of diets with increased $C_4$ and water-impoverished plant contributions.

***Isotope sample selection***

In total, 442 caprine samples were analysed from Southern Levantine sites. All samples were taken from skeletally mature animals and where possible elements were selected that would allow for consistency and species determinations between *Ovis* and *Capra*, those that could not be determined are classified as *Caprine* (Zeder and Lapham 2010). Consistency in element selection was hampered due to small collections of the faunal assemblages available; for example, most of the sheep/goat individuals from Wadi Jilat 13 and 25 were sampled, but numbers were low. ‘Ain Ghazal samples came from the partial collections at UCL, UK and in Irbid, Jordan but were limited by the requirement that all samples came from secure PPNB or PPNC contexts, to cover the timespan when animals are most likely to have been taken to the steppe. These issues of sample composition introduce limitations to the dataset, such as the possibility of sampling the same animal more than once, however this is unavoidable when working with small collections with poor preservation.

***Collagen extraction***

The collagen extraction protocol followed a modified version of the Longin method (Brown *et al.* 1988). A fragment of bone weighing c.0.5g was sampled from each specimen using a Dremel hand drill with a diamond cutting wheel attachment. The outer cortex of the bone was abraded to remove any adhering contaminants. Each sample was then placed in a test tube and demineralised in 10ml of 0.5M HCl at 4°C. The HCl was changed approximately every two days until demineralisation was complete. Demineralised specimens were thoroughly rinsed in 18.2 MΩ ultrapure water and then gelatinized in a pH3 solution of HCl at 70°C for c.48 hours until complete. The supernate containing the soluble collagen was collected using an ezee-filter before freezing and freeze-drying. 0.6mg of collagen from each sample was weighed into tin capsules and measured in duplicate. In addition to the archaeological samples, a modern cattle sample of known isotope composition (SADCOW) was subject to the same extraction process and subsequent analysis to identify any procedural problems.

Isotope ratios of carbon and nitrogen were measured by continuous flow-elemental analyser isotope ratio mass spectrometry (CF-EA-IRMS) at the NERC Isotope Geosciences Facility at Keyworth, Nottinghamshire, UK. The instrumentation comprises an elemental analyser (Flash/EA) coupled to a ThermoFinnigan Delta Plus XL isotope ratio mass spectrometer via a ConFlo III interface. Replicate analysis of randomised samples indicated a precision of better than ±0.2‰ for both isotopes and samples with a C/N ratio of 3.2 (±0.3) were sufficiently well preserved to yield reliable $\delta^{13}C$ and $\delta^{15}N$ ratios (DeNiro 1985).

Collagen carbon and nitrogen isotope values ($\delta^{13}C$, $\delta^{15}N$) are reported per mil (‰) relative to VPDB and calibrated using an in-house reference material M1360p (Powdered gelatine from British Drug Houses) with expected delta values of -20.32‰ (calibrated against CH7, IAEA) and +8.12‰ (calibrated against N-1 and N-2, IAEA) for C and N respectively. The 1σ reproducibility for mass spectrometry controls in this study were $\delta^{15}N$ = ± 0.12‰ and $\delta^{13}C$ = ±0.15‰.

Statistical differences between isotope values from the study sites were tested using the parametric Student's t-test, following confirmation that the data were normally distributed using the Shapiro-Wilk test. P-values lower than 0.05 were considered statistically significant. As sample sizes were relatively small, estimates of the sampling distributions of mean values for the three sites were produced via bootstrapping (i.e. random sampling with replacement). Mean values were calculated for 1,000 bootstrap replicates for each site, providing distributions of probable mean values from which 95% confidence intervals for the means could be calculated (Grove and Pearson 2014).

***Chipped stone analysis***

The study of chipped stone offers the clearest potential for investigating questions of the social relationships and interactions between the groups inhabiting Wadi Jilat 13, Wadi Jilat 25 and 'Ain Ghazal, as they are often present in high quantities on aceramic prehistoric sites. Lithic technologies can also be assessed for distinct techniques of production that may follow localised traditions, signifying local continuity and/or change. Whether this change reflects the influence of other populations and their techniques of production can be assessed through comparison with contemporary assemblages from neighbouring regions. How quickly and exactly any purported related changes came about can suggest the intensity of interactions between groups.

***Chipped stone sample selection***

The chipped stone study focuses on two highly contextualised assemblages from discrete floor contexts at Wadi Jilat 13 and 25 and draws comparison with published data from 'Ain Ghazal (Rollefson 1988; 1990). The contexts assessed from Wadi Jilat 13 (Locus B69 and C56) and 25 (Locus 10 and 15) relate to specific phases of use of the structures and recovery of these materials was undertaken using a grid system to ensure tight spatial control (Baird 1993; Garrard *et al.* 1994b). In total, 26,485 pieces of chipped stone were analysed as part of this study, 18,943 from the floor surface at Wadi Jilat 13 and 7,542 from the floor surface of Wadi Jilat 25. Occupation of the excavated structure at Wadi Jilat 13 is thought to have been more frequent and repeated over a longer period than at the excavated Wadi Jilat 25 structure (Garrard *et al.* 1994b). Due to this more frequent occupation and larger area of recovery at Wadi Jilat 13, this analysis focuses on similarities and differences in tool types and technologies across the two sites, rather than a detailed quantitative analysis of all aspects of the assemblages.

***Chipped stone recording***

The two samples were sorted and analysed separately, being primarily divided into basic typological categories commonly used in Near Eastern chipped stone analysis (flake, blade, tool, core,

core preparation elements, etc.). The recording system followed Baird (1993) for comparability. While typological assessment is likely to have masked some variability, this was undertaken to assess a large body of material, comply with regional analysis and because certain broad categories of attributes have been shown to have analytical value (Inizan *et al.* 1992). Raw material, cortex retention and type of cortex of each piece was recorded, along with distinguishable modifications or use damage; heat modification, uncontrolled burning, notable taphonomic differences such as rolling and patination and use-wear signatures such as spalling, polish, small removals or striations. Analysis was undertaken macroscopically with the naked eye and a Benomo Triplet hand lens at 10x magnification.

Reduction strategies were analysed by examining core morphology and type, noting flaking direction, blank type removals and platform attributes such as number, position and preparation evidence. In order to examine variation in knapping technique across the two sites, platform and bulb characteristics were further recorded for a sample of 1685 unmodified blade debitage and retouched items. Analysis of 717 and 528 items from Wadi Jilat 13 and 25 respectively have been added to a sample (380 items from Wadi Jilat 13 and 60 items from Wadi Jilat 25) from other contexts analysed by Baird (1994). Technological indicators such as platform preparation, flaking direction and evidence for technique of removal; relatively harder hammer or softer hammer, indirect percussion or pressure were assessed. Specific 'hammer' type (actually more broadly the method for delivery of force including punch/pressure) is not identified using this approach but rather the technique indicators can point to the hardness or softness of the 'hammers' relative to raw material types, in this case the bulk of the raw material, local cherts, is of relatively uniform hardness across the study sites (Baird 1994; Bonnichsen and Sanger 1977; Ohnuma and Bergman 1982). It is important to stress technique discrimination is here made not on the basis simply of traditional 'hammer' indicators but a constellation of indicators of necessarily related technique aspects including preparation and point of impact as well. Modification was recorded on retouched items according to type, position, location and extent as defined by Inizan *et al.* (1992). Alongside technological analysis tools were, where appropriate, further categorised by broad typologies to aid regional comparisons.

## Results

### *Stable isotopes*

Of the 442 caprine isotope samples taken from ‘Ain Ghazal (n=159) and sites across the Eastern Steppe (Wadi Jilat 13 n=100; Wadi Jilat 25 n=37; Azraq 31 n=59; Dhuweila n=25; Burqu 27 n=20; Wadi Abu Tulayha n=42), samples from ‘Ain Ghazal, Wadi Jilat 13 and Wadi Jilat 25 proved the most reliable in terms of collagen preservation, producing viable samples in 21, 16 and 8 samples respectively (Table 1). The ‘Ain Ghazal data from this study has been enhanced by the inclusion of a further 25 values from a study by Makarewicz (2007; Fig. 2). The other Eastern steppe sites failed to produce reliable collagen with a C/N ratio of 3.2 (±0.3). Preservation of bones from prehistoric sites in the Near East is generally poor, likely due to a combination of factors including sandy soils, long surface exposures, high temperatures and flash flooding (Child 1995; Collins *et al.* 1995; Grupe 1995; Makarewicz 2007; Weiner and Bar-Yosef 1990). The resulting small sample size potentially limits the robusticity of interpretation, however, several interesting trends can be seen within the available data and have been subjected to statistical analysis.

The results in Table 1 and Fig. 2 show notable contrast between the ‘Ain Ghazal values from both studies, and those from Wadi Jilat 13 samples. On average, the Wadi Jilat 13 sample is more positive by 2.10‰ in $\delta^{13}C$ and 2.85‰ in $\delta^{15}N$ values when compared to ‘Ain Ghazal values in this study (t-test $\delta^{13}C$: $p<0.0001$; $\delta^{15}N$: $p<0.0001$); this is indicative of a significant difference in caprine diet between the two sites. In contrast, much of the Wadi Jilat 25 sample overlaps with the distribution of the ‘Ain Ghazal values, and only two values exhibit the high nitrogen values that are more characteristic of the Wadi Jilat 13 sample. There is no significant difference between the $\delta^{13}C$ (t-test $p=0.2498$) or $\delta^{15}N$ (t-test $p=0.1307$) of the caprine bone collagen values from ‘Ain Ghazal in this study and Wadi Jilat 25.

The $\delta^{13}C$ value of carbonised plant remains from ‘Ain Ghazal (Wallace *et al.* 2015) and Wadi Jilat (Hedges *et al.* 1992) have been compared to give a $\delta^{13}C$ value baseline of $C_3$ and $C_4$ plants that may have been available to caprines at the sites (Table 2). The mean $\delta^{13}C$ value of these $C_3$ plants is -23‰. When consumed, the $\delta^{13}C$ of the plant diet is enriched by a fractionation of 5‰ (Bocherens and Drucker 2003), therefore, the average $\delta^{13}C$ value of an animal feeding on these $C_3$ plants would be -18‰. This value acts as a baseline indicator of the cut-off for dietary contribution of $C_4$ plants; a $\delta^{13}C$ value of <-18‰ would indicate a pure $C_3$ diet, while >-18‰ suggests the inclusion of $C_4$ plants in the diet (Fig. 3). Based on the carbonised $C_4$ plant values from the Wadi Jilat, a pure $C_4$ feeder would have a $\delta^{13}C$ value of c.-7‰, values that are not seen in this study. To determine the approximate contribution of $C_3$ and $C_4$ plants across these animal populations, the stable isotope data were bootstrapped (1000 replicates) to provide estimates of the sampling distribution of mean $\delta^{13}C$ values at each site. The resulting 95% confidence intervals for mean $\delta^{13}C$ are: ‘Ain Ghazal (this study) [-18.41,

-17.76], 'Ain Ghazal (Makarewicz 2007) [-19.30, -18.60], Wadi Jilat 13 [-16.38, -15.56], and Wadi Jilat 25 [-18.25, -17.16]. Distributions of bootstrap means are plotted against a histogram of global $C_3$ and $C_4$ plant values published by O'Leary (1988) in Fig. 3. Figure 3 suggests that animals at all sites had a $C_4$ contribution, which was to be expected given their relative locations. Despite being characterised by Mediterranean vegetation and $C_3$ dominated, the 'Ain Ghazal locality borders the steppe where $C_4$ plants are present, as seen in the Wadi Jilat 13 caprine diet. Of course, the steppe boundary is likely to have been some distance further east in the early Holocene. What is particularly interesting is the relative $C_4$ contribution across these populations. Wadi Jilat 13 samples have the highest with an average $\delta^{13}C$ value of -17‰, whereas the Wadi Jilat 25 and 'Ain Ghazal samples have an average of -18‰, indicating a lesser contribution of $C_4$ plants to the diet and a great reliance on $C_3$ plants.

The positive correlation between aridity and $\delta^{15}N$ values, as affecting the underlying soils and vegetation in the food-chain (e.g. Aranibar *et al.* 2004; Austin and Vitousek 1998; Craine *et al.* 2009; Handley *et al.* 1999; Hartman and Danin 2010; Heaton 1987; Styring *et al.* 2016; Swap *et al.* 2004), is clearly more apparent in the Wadi Jilat 13 animals. In part, this will also be due to the increased contribution of $C_4$ vegetation in the diet (Hartman and Danin 2010). It is again notable that the majority of Wadi Jilat 25 samples do not have $\delta^{15}N$ values that show aridity effects and are more in-line with results from both 'Ain Ghazal samples, where animals are likely to have had access to better watered conditions. The outlying values from the Wadi Jilat 25 sample suggest that some animals may have been incorporated to the site from another, more arid, source. Both indicate consumption in areas of greater aridity, but only one sample overlaps with Wadi Jilat 13 by showing signs of an increased $C_4$ dietary contribution. In terms of the nitrogen stable isotope values, the effects of aridity on the metabolisms of plants and animals varies across dietary ranges, and that these too can be identified through this analysis of herbivore bone collagen.

Overall, the isotope values of animals from Wadi Jilat 25 show similarities to those from 'Ain Ghazal. This contrasts the values that are seen from the Wadi Jilat 13 animals, despite the proximity of Wadi Jilat 25. The values from Wadi Jilat 13 samples are more likely to reflect the consumption of plants in the local, more water limited environment. This supports the view that eastern Jordan was part of a relatively arid steppe zone despite higher precipitation in the early Holocene.

***Chipped stone***

All stages of the reduction sequences are present in the floor surface assemblages at both Wadi Jilat 13 and 25. This provides good evidence that knapping took place within these structures, as does the presence of refitting pieces, blanks, debris and primary (cortical) removals.

Reduction strategies were analysed to evaluate the relationship between knapping practices at Wadi Jilat 13 and 25. Cores characterised as to platform relationship demonstrate the importance of single, multiple and change of orientation strategies at both sites (Fig. 4), with the single platform cores dominating at Wadi Jilat 13 and change of orientation at Wadi Jilat 25. Opposed and bidirectional platform cores, that had been more regularly utilised in the PPNB blade-dominated arid zone industries, had a continued presence, more so at Wadi Jilat 13. Evidence for Naviform technology, an important component of PPNB assemblages across the Levant (Quintero and Wilke 1995), comes from a single core and refitting removals from this sample at Wadi Jilat 25 (Fig. 4) and appears absent from the Wadi Jilat 13 floor sample.

In terms of the products of knapping, flakes dominate both assemblages although blades of both single and opposed platform strategies were recovered. Flake-blank tools also dominate the tool assemblages. However, blade-blanks are seen in higher proportions in the tools than they are in the debitage, particularly at Wadi Jilat 25, suggesting that they were preferentially selected for retouch. The use of raw material types is broadly similar across the two sites, although it is notable that the Wadi Jilat 13 sample had a small exotic red and translucent flint component that is absent at Wadi Jilat 25.

Possible contrasts in packages of platform attributes are here reviewed as technique indicators (Table 3). There are fewer instances of platform faceting and removal surface preparation at Wadi Jilat 25. These are generally indicative of careful preparation of core surfaces and platforms prior to knapping. There are higher instances of cortical platforms at Wadi Jilat 25 in comparison to Wadi Jilat 13. There are much higher proportions of punctiform and filiform platforms at Jilat 13 than at Jilat 25 (Baird 1993, 268; Baird 1994 and this study), these derive from striking the core very close to the edge of the striking platform and are often associated with softer hammer use or indirect percussion. There is also a, likely related, lower frequency of platform indicators that might relate to the use of a softer hammer in the Wadi Jilat 25 materials, such as diffused bulbs of percussion, and higher frequency of indications of harder hammer use, notably large bulbs of percussion. There is more evidence for the use of softer hammer techniques at Wadi Jilat 13 and certainly a different approach to core preparation and method of impacting the platform at Jilat 13 compared to Jilat 25.

Non-formal tools (retouched flakes and blades), burins, notches and denticulates, scrapers, bifaces and tile knives, drills, borers and projectile points respectively make up most of the retouched elements. The prevalence of truncation burins and frequent instances of drills made from the resulting spalls is notable at both sites (Fig. 5), as is the novel presence of tile knives, which were unknown in the area before the Early Late Neolithic (Baird 1993; see Baird in Garrad et al 1994b). The tool kits at both sites are very similar (Fig. 6).

## Discussion

### *Stable isotope analysis*

The results of the stable isotope investigation at ‘Ain Ghazal show caprine bone collagen values consistent with animals maintained in a well-watered area on a largely $C_3$ diet, with a small contribution of $C_4$ plants which are likely to have been present within the immediate range of the site. By contrast, the caprines from Wadi Jilat 13 show evidence of a water-impoverished plant diet in $\delta^{15}N$ values and a more significant contribution of $C_4$ plants, leading to less negative $\delta^{13}C$ values and increased incorporation of $^{15}N$ in bone collagen. The $\delta^{13}C$ and $\delta^{15}N$ values from the bone collagen of caprines from Wadi Jilat 25 overlap in most instances with those from ‘Ain Ghazal in the values reported in this study and by Makarewicz (2007; 2014). In general, they do not conform to the pattern of diet that reflects the local environment, as observed in the animals from neighbouring Wadi Jilat 13, 300m away. Most Wadi Jilat 25 animals have values consistent with foraging in Mediterranean vegetation, some 50km away today, although perhaps closer in the Neolithic, and in only two cases do the Wadi Jilat 25 values appear to indicate water-stressed or $C_4$ plant intake in individuals. Differences in these dietary isotope values are unlikely to be due to the ages of the animals as samples were taken from skeletally mature animals and Martin (1999) argues that there was no discernible focus on sub-adults at either Wadi Jilat 13 or 25, therefore adult caprines were included in the kill-off at both sites.

There are numerous scenarios which may have led to animals raised in a Mediterranean setting being deposited at the arid zone site, as appears to be the case at Wadi Jilat 25:

1. A mobile population indigenous to the steppe regularly acquired animals from a Mediterranean community through exchange. Surplus animals, such as males and older females may have been regularly killed at this point in the landscape.
2. Mobile groups indigenous to the Mediterranean region moving into the steppe, possibly for social reasons, or having lost or extended their previous range.
3. A mobile population regularly traversed the Mediterranean zone and penetrated the steppe more sporadically.
4. A Mediterranean zone village group adopted a strategy of transhumance as a new economic strategy as suggested by Kohler-Rollefson (1992)
5. A Mediterranean zone group brought a small number of animals into the steppe while undertaking specific tasks, as a 'mobile lunch' or 'travelling larder'.
6. Skins were imported to Wadi Jilat 25 from the Mediterranean agricultural zone; however, the sample bone elements are not all foot bones that would be consistent with what might be left within a skin (Klenck *et al.* 1995). This option is therefore considered unlikely.
7. Feral or raided populations of Mediterranean zone animals were incorporated into steppic herds.

Caprines, and therefore the accompanying people from Wadi Jilat 13, appear to have spent most of their time in the steppe regions. This supports the theory that animal herds were adopted by groups indigenous to the Wadi Jilat region, thus clearly involved in early nomadic pastoralism. Complicating this picture is the Wadi Jilat 25 evidence which indicates that, in addition, animals who spent a significant proportion of their time in the better watered areas of the Mediterranean zone were introduced to the steppe of the Southern Levant at a similar time as the emergence of steppe pastoralism. This is not unlikely as the first herded caprines must have been, at least in the first instance, introduced from the Mediterranean zone, given the extreme rarity of caprines in the steppe zone before 7500 cal BC (Martin *et al.* 1999). From the isotope evidence alone, the question remains as to whether an associated group of people accompanied the animals into the steppe. Either way, the model of Köhler-Rollefson (1992), which states that animals in the steppe must have been present as part of herds from sedentary villages, cannot be supported as an exclusive phenomenon on the grounds of the Wadi Jilat 13 isotope evidence.

***Lithic production traditions***

From the chipped stone analysis, it is possible to assess the remains of the human groups alongside their associated animals. The material from Wadi Jilat 13 and 25 highlight similarities and differences across the two sites, between these occupations and earlier Neolithic Eastern steppe sites, and those of the Mediterranean agricultural zone. The results of analysis representing single occupational floor-level finds are perhaps the most accurate sources of chipped stone information because they are highly unlikely to be the result of dumping-in, as evidenced by several features of the material; refitting pieces, association of tools and debris resulting from tasks in which the tools were probably used like bead making (Wright et al), and close associations with other features on the floors.

The arid region PPNB pattern of high levels of blade production and the dominant use of tabular materials changed in the 8$^{th}$-7$^{th}$ millennium cal BC transitionary period in the Wadi Jilat (Baird 1993; Baird 2001b). Increased flake production and the use of wadi cobble raw materials is seen in both Wadi Jilat 13 and Wadi Jilat 25 assemblages, although the change is more apparent at Wadi Jilat 25. These broad changes reflect similar developments at the Mediterranean sites (Baird 2001b; Bar-Yosef 2001; Rollefson 1988; 1990; Watkins 2003) but there are also indications that some local production traditions continued, including the use of some tabular material, opposed platform techniques and occasional Naviform strategies. This suggests that trends seen in the Mediterranean region, and reflected in arid zone production, were influential, but that their incorporation into local technological behaviour was not a linear, uniform or synchronous development across the Southern Levant.

Another major element of technological practice concerns the production of truncation burins and drills on the resulting spalls for use in bead manufacture. This is a tradition that originates in the Jilat area in the MPPNB, a steppe practice not witnessed in contemporary PPNB sites in the Mediterranean zone where we have reports of piercer/drill blanks (see Baird in Garrard *et al.* 1994; Baird 1993: 645; Baird 2001a: 645; Garfinkel 1987; Rollefson 2002; Waheeb and Fino 1997). Wadi Jilat 13 and 25 both continue the Jilat tradition of spall drills, with the ‘Ain Ghazal evidence suggesting that there may have been some influence on Mediterranean zone tool production from the knappers of the steppe with a modest increase in truncation burins there in the PPNC (Baird 2001a; Rollefson 1988).

The clearest difference in the knapped materials across the Wadi Jilat 13 and 25 assemblages is in knapping techniques. The decreased use of core and platform preparation, and more frequent harder hammer indicators, as well as a clearer preference for flakes and wadi materials at Wadi Jilat 25 contrasts with Wadi Jilat 13, and more closely reflects contemporary developments in the lithic materials of the Mediterranean zone sites (Baird 2001a). The more careful preparation of cores for knapping and the selection of higher quality materials, more regularly knapped with softer hammer techniques at Wadi Jilat 13 seems to reflect continuity in the pre-existing arid zone knapping practices (Baird 1993; 2001b). These trends were also noted by Baird (1993; 1994; 2001a; 2001b) in his analysis of the larger samples of material from different contexts at the two sites.

Distinct techniques of lithic production are likely to follow localised traditions as they are socially learned behaviours, from necessity acquired on a face-to-face basis; they illustrate dynamic and complex choices which are generally executed according to learned practices detectable through aspects of the manufacturing process (Baird 2001a; Bar-Yosef 2001; Watkins 2003). While broad patterns in lithic production are similar at Wadi Jilat 13 and 25, that is the increased production of flakes and use of wadi materials, and a reduction in opposed platform techniques, it is the nuances of reduction that suggest there may be fundamental differences in the choices of technique applied to knapping practices. The more frequent indications of careful preparation and softer hammer reduction at Wadi Jilat 13 suggest that there is continuation of arid zone techniques at this site (Baird 1993; 1994; 2001a; 2001b); these are not seen at Wadi Jilat 25 where materials more closely relate to changes in contemporary PPNC Mediterranean zone chipped stone materials. The Wadi Jilat 25 knappers had more in common with contemporary Mediterranean zone technological practices. When this is considered together with the results of the isotope analysis, it suggests that the inhabitants, human and non-human animal, of Wadi Jilat 25 were more likely to have been closely linked to communities in Mediterranean zone, as transhumant from there or because they were nomadic pastoralists who spent significant time in the Mediterranean zone, while those at Wadi Jilat 13 were tied into longstanding arid zone traditions.

### ***Mobility and Sedentism in the Neolithic Southern Levant***

The typology of the stone tools can be used to suggest the activities and occupations of the sites' inhabitants. For example, while the projectile points from Wadi Jilat 13 and 25 are of the types known from the Levantine Corridor sites (Baird 1993; Gopher 1994), they are more commonly seen at ephemeral steppe structures, likely due to the continued importance of hunting (Martin 1999). In contrast, sickle elements are extremely rare, representing a fundamental difference between the steppic regions and the agricultural zone, although occupations at Azraq 31 and Ain Abu Nekhayla have some of these tools, which may have been used for harvesting plants and wetland vegetation in these areas (Fujii 2009; Garrard *et al.* 1994; Henry *et al.* 2003).

Finely worked tabular ovate-lanceolate biface tools and tile knives appear in the steppe in PPNB contexts, increasing in ELN contexts in the eastern steppe before becoming common at Mediterranean sites (Baird 1993). Similar tools are known from blanks, roughouts and mistakes across workshop sites in the Negev and Sinai (Goring-Morris 1993). It has been suggested that these cortical and bifacial knives were functionally related to herding communities (Goring-Morris 1993). However, the PPNB development of these tools, prior to the introduction of domestic animals to the steppe, suggests that they may have had more general butchering and skinning applications, initially associated with hunting in the PPNB, and increasingly useful for pastoralists in the ELN when these activities were scaled up in the presence of domestic herds (Baird in Garrard *et al.* 1994b).

Burins tend to be a significant component of tool kits across both regions in the PPNB-PPNC/ELN, yet in eastern Jordan, northwest Arabia and western Iraq many sites and lithic scatters are dominated by angle truncation burins (Baird 1993; Betts 1992). It has been posited that the explosion of burin sites in the ELN was related to the introduction of animal herding in the arid margins (Betts 1992; Quintero *et al.* 2004; Rollefson 1998); however, it has been demonstrated that burin dominance developed at Azraq basin sites during the MPPNB period, prior to the introduction of caprines (Baird 1993; Baird in Garrard *et al.* 1994b; Cropper 2006). Instead, burins, their resulting spalls and spall drills are often associated with evidence of stone bead manufacture, something that is prolific at the Wadi Jilat sites, particularly those of the ELN (Baird *et al.* 1992; Wright and Garrard 2003; Wright *et al.* 2008). Baird has pointed out that the spall drill technology, originating in the PPNB, seems to be a distinctive traditional practice of steppe dwellers (Baird 2001a). It is suggested here that the proliferation of bead manufacture in the LN may be related to the development of nomadic pastoralism in the Eastern steppe by arid zone occupants like those at Wadi Jilat 13, and the movement of herders to and from the Mediterranean zone, such as those indicated at Wadi Jilat 25. Activities are likely to have brought these groups together more regularly for standing water and good pasture. With increased interaction, whether social, economic or political, if these can be so categorised, a necessary consequence of regular contact at watering places, opportunity and prudence may have encouraged groups to keep highly mobile items of trade and exchange on hand. Indeed, the shared technological practice of truncation burin production becoming significant in the Mediterranean zone only in the PPNC, might suggest that the Wadi Jilat 25 group may also have originated in the steppe, and was perhaps a mobile group that included the Mediterranean zone and steppe in its rounds.

Mobility in this range of the Eastern steppe would also have drawn people close to Dabba marble, a popular source of material for beads that are found across the Wadi Jilat and Mediterranean zone sites (Baird *et al.* 1992; Wright and Garrard 2003; Wright *et al.* 2008). Baird (1993) also noted the presence of obsidian, probably from Lake Van in Anatolia at Wadi Jilat 13, as well as the exotic red and clear chipped stone materials noted above. In the analysis of bead technology at the two sites, Wright *et al.* (2008) found nuances of material and typological choices that differed between them, although they noted that this may be explained by independent, non-centralized, dispersed workshops. They suggest that Wadi Jilat 13 may have been inhabited by hunter-herder corporate groups from a network engaged in special activities, in remote areas, involving art, personal ornaments and ritual (Wright *et al.* 2008). This study suggests that Wadi Jilat 13 inhabitants may have had wider regional links than Wadi Jilat 25, indicating continuity of steppic networks and traditions that were unavailable at this time to those that were newcomers or who spent significant time in the Mediterranean zone. However, Wadi Jilat 25 also appears to have been less intensively occupied, which may also be a factor in different patterns of accumulation.

To judge the significance of the evidence from Wadi Jilat 13 and 25 we should see these sites in the wider context of current early herding debates in Southwest Asia. In a recent review of the evidence for pastoralism in Anatolia, Hammer and Arbuckle (2017) highlight that the development of pastoral economies in the Early Neolithic (c. 9000–7500 BC), at sites such as Nevalı Çori, Çayönü, Cafer and Aşıklı, is diverse and localised, with animals kept close to settlements (Arbuckle and Atici 2013; Helmer 2008; Hongo *et al.* 2004; Losch *et al.* 2006; Pearson *et al.* 2013; Peters *et al.* 2013; Stiner *et al.* 2014).

In the Later Neolithic (c. 7500–6000 BC), isotope evidence suggests that animals may have been foddered and moved seasonally for grazing, often in a pattern of local, horizontal transhumance (Meiggs 2010), but that overall pastoralism was relatively spatially confined and continued to be tethered to permanent settlements such as Gritille, and exemplified by the relationship between Pınarbaşı B and Çatalhöyük (Pearson *et al.* 2007; Baird *et al.* 2011; Bogaard *et al.* 2013; Makarewicz and Tuross 2012; Meiggs 2010; Henton 2012). While the early seventh millennium BC saw the regional spread of pastoral practices (Arbuckle *et al.* 2014), these are thought to have only set the scene for longer-distance herding and potentially the origins of nomadic pastoralism in the Chalcolithic (Hammer and Arbuckle 2017).

Similarly, Makarewicz and Tuross (2012) have shown that humans provisioned goats with fodder and moved herds to pastures as early as 8000 cal BC in the Southern Levant, and that these movements tended to be varied and relatively localised around large village site environs, as shown by the isotope values of Basta and Abu Ghosh goats. Makarewicz (2014) has further investigated the sheep and goats from 'Ain Ghazal and, while suggesting the complex development of caprine management strategies over time at the multi-period site, suggests that goats were likely pastured near 'Ain Ghazal, with no evidence for regular exploitation of the *badia* during the Pre-Pottery Neolithic. Yet, by the earliest Pottery Neolithic/Late Neolithic levels there is evidence of a substantial population of pastoralists living at Wisad Pools and Wadi Qattafi (Rollefson 2016; Rollefson *et al.* 2014; Rowan *et al.* 2017).

Considering the current evidence from Southwest Asia, and the results of the study presented here, we suggest that Wadi Jilat 25 is one of the earliest cases currently known of either transhumance or longer-distance herding between Mediterranean zone and steppe in the Neolithic. As the evidence from the sites further east, at Wisad Pools and Wadi Qattafi is somewhat later, it is suggested that early pastoral groups, like those at Wadi Jilat 25, may have seen the potential of the *badia* for caprine movements early on, and that the successful adoption of mobile lifeways in this region by groups previously found in the Mediterranean region, may have opened the way for larger groups that went on to exploit the Wisad Pools and Wadi Qattafi ranges. While the isotope values of caprines from 'Ain Ghazal have been used in this study to illustrate the potential for an exploitation of both the Levantine Corridor and the Jordanian steppe by certain groups, it does not follow that the animals at Wadi Jilat 25 were drawn from that site, rather from areas with similar environmental conditions, particularly in light of Makarewicz's (2014) suggestion that there is no direct evidence that the 'Ain Ghazal community was involved in the development of nomadic pastoralism.

The lithic and isotope evidence from Wadi Jilat 25 presented here, suggesting either transhumant groups from a Levantine Corridor location or highly mobile nomadic pastoralists exploiting steppe and Mediterranean zone, might be used to provide a temporally proximate analogy to explain ephemeral Levantine corridor sites such as 'Iraq ed-Dubb and Sefunim Cave (Banning 1998; Bar-Yosef 1998; Kuijt *et al.* 1991). These sites have been posited as temporary hunting campsites for task groups of village populations (Banning 1998; Bar-Yosef 1998; Kenyon 1957; Kuijt and Finlayson 2009). It is unlikely that the early Holocene saw a uniform simultaneous adoption of sedentary practices; these small, ephemeral sites, and increased occupation of the steppe regions, may indicate that reduced residential mobility was just one of a range of lifestyles available to the Neolithic inhabitants of the Southern Levant, one that may have been highly fluid and non-linear in terms of the development of widespread sedentism. As such, the settlement of the Levantine Corridor would have been significantly more complex and varied than is currently known from the relatively visible archaeology of large village sites. Some groups may have become more mobile after initial sedentarization, others may have never adopted more sedentary practices but remained mobile around emerging village communities.

The end of the LPPNB at Mediterranean zone sites supposedly saw site contraction, abandonment, depopulation and dispersal: a collapse (Rollefson and Köhler-Rollefson 1989). The end of the 'mega-sites' has been linked with reduced social complexity (Galili *et al.* 1993; Rollefson *et al.* 1992). However, the PPNC appears to have developed, largely uninterrupted, from the LPPNB on a number of sites including 'Ain Ghazal and el-Hemmeh (Garfinkel 1994; Makarewicz *et al.* 2006; Makarewicz and Goodale 2004; Simmons *et al.* 2001; Waheed and Fino 1997) and in terms of settlement patterns, dispersal in the PPNC was no broader than in other Neolithic phases (Campbell 2009; contra Kuijt and Goring-Morris 2002 and Rollefson 2001). Similarly, the Pottery Neolithic developed directly from the preceding PPNC on a number of sites such as 'Ain Ghazal and Wadi Shu'eib (Rollefson 1993; 2001; Simmons *et al.* 2001). Settlement size was highly variable but reduction in site densities and cultural deposit depth suggests a decreased number of occupants living in close association (Köhler-Rollefson 1988; 1992; Rollefson 2001) and the development of single family and small group occupations such as ash-Shalaf (Kenyon 1981; Muheisen *et al.* 1988; Rollefson 2001), Abu Thwwab (Kafafi 1986; 2001; Rollefson 2001) and 'satellite settlements' in the surrounding wadis of 'Ain Ghazal (Kuijt and Goring-Morris 2002; Rollefson 2001). The different patterns of mobility indicated by the lithic and isotope evidence from the Wadi Jilat sites are perhaps best indicative of a highly fluid mix of strategies in and around the Levantine Corridor. Both indigenous and previously settled people may have been using the arid margins for similar activities, although not necessarily in the same way.

**Conclusion**

Animals were moved into the eastern steppe regions of the Neolithic Southern Levant by different mechanisms. The $\delta^{13}C$ and $\delta^{15}N$ isotope values presented here provide evidence that animals at Wadi Jilat 13 and 25 sourced diets that can be effectively attributed to different regions due to environmental factors. The herders accompanying animals in the steppe also exploited different areas and had distinct social networks: while similar tool types and day-to-day activities are evidenced across the two sites by the chipped stone remains, knapping strategies, associated with culturally learned social behaviours, differ.

In both forms of evidence Wadi Jilat 13 adheres to patterns associated with indigenous steppic communities, undertaking animal herding as a continuation of their mobile strategies. Isotope values from caprine bone collagen show the increased contribution of water-stressed and $C_4$ plants to the herbivore diet, associated with the more arid conditions of the steppe. Lithic materials retain local patterns of careful preparation in knapping strategy. At Wadi Jilat 25 isotope values have more in common with those from 'Ain Ghazal and lithic technological traditions show a mix of Mediterranean zone and steppe practices. The lithic evidence from Wadi Jilat 25 shares new practices with those in the Mediterranean agricultural zone, which saw the widespread abandonment of careful preparation techniques, and with groups in the steppe, where the use of the spall drill technology was widespread (Baird 2001a). The herded animals have isotope values consistent with a diet sourced from better watered conditions where $C_3$ plants were prevalent. It also appears that Wadi Jilat 13 was part of long-standing trading networks across steppe regions. The more recent inhabitants at Wadi Jilat 25 do not appear to have been included in these interactions.

Given the evidence from Wadi Jilat 13, the Köhler-Rollefson (1992) model that posited that all animals in the steppic regions were related to Levantine Corridor village sites cannot be supported here. Instead, these results would support the model suggested by Byrd (1992) and Baird (1993); indigenous adoption of animal herds by mobile peoples in the steppe, with some incorporation of movement from the better watered areas. A mixed model of indigenous herders and either transhumants or hitherto poorly documented groups of nomadic pastoralists that traversed steppe and Mediterranean zone is appropriate for understanding early nomadic pastoralism in the eastern steppe of the Southern Levant; the inhabitants of Wadi Jilat 13, therefore, represent the earliest unequivocal evidence for nomadic pastoralists in this region.

The people of Wadi Jilat 25 were also undertaking a new way of life; whether originating in the sedentary villages of the Mediterranean zone or as nomadic pastoralists exploiting both zones, they spent substantial time as a mobile group. This would have led to the reconfiguration of family groups, task groups, gender-specific roles, economic dependencies, social interaction and trading links. The reorganisation of sedentary communities to facilitate these roles and/or communities would have had implications for the organisation of settlement, scheduling and undertaking collective community activities, possibly transforming the nature of the aggregate communities that existed in preceding periods. These factors may be central to the interpretation of 'collapse' in the archaeological record of the Levantine Corridor (Rollefson and Köhler-Rollefson 1989), which may be little more than on-going developments in the highly variable Southern Levantine Neolithic.

Neolithic peoples from the Mediterranean and relatively arid regions of the Southern Levant are likely to have crossed the environmental divide between woodland and steppe zones for various reasons and durations, in movements which may have been fluid, even if mechanisms for doing so were in some way controlled; namely through intermarriage, social and kinship gatherings, direct procurement, trade and exchange. The potential for arid zone exploitation is likely to have been known to both groups, although initially utilised differently, as shown here. The onset of this pastoralist existence, early in the development of caprine herding, also highlights the potential for a more mobile pattern of exploitation within the Mediterranean agricultural region itself, hidden from archaeological detection by the nature of the resulting archaeology: temporary organic structures, opportunistic and natural shelters and more dispersed material culture remains are less visible than large village sites.

Nomadic pastoralism and possible village-based transhumant herding in the Southern Levant would have led to increased social and economic interaction across and beyond the steppic areas. This ultimately means that patterns of animal management and community developments throughout the Neolithic should not be considered without reference to the steppe regions.

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**ORCHID**

Miller *et al.* The origins of nomadic pastoralism in the eastern Jordanian steppe: a combined stable isotope and chipped stone assessment

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**Table 1:** Samples and stable isotope values from successful analysis from the sites of Wadi Jilat 13, Wadi Jilat 25 and ‘Ain Ghazal

| **Site** | **Species** | **Element** | **$\delta^{13}C$ (‰)** | **$\delta^{15}N$ (‰)** |
|---|---|---|---|---|
| Wadi Jilat 13 | *Ovis* | Humerus | -14.5 | 11.2 |
| | *Ovis* | Metacarpal | -17.2 | 11.1 |
| | *Capra* | Phal. 2 | -16.2 | 11.8 |
| | *Ovis* | Metacarpal | -17.3 | 11.1 |
| | *Ovis* | Metatarsal | -16.2 | 11.2 |
| | *Capra* | Humerus | -15.2 | 13.3 |
| | *Ovis* | Radius | -15.7 | 11.5 |
| | *Capra* | Metatarsal | -14.8 | 11.3 |
| | *Capra* | Metatarsal | -15.3 | 11.3 |
| | *Ovis* | Metacarpal | -17.0 | 11.2 |
| | *Capra* | Phal. 2 | -16.8 | 11.8 |
| | *Ovis* | Metacarpal | -16.3 | 11.5 |
| | *Capra* | Phal. 2 | -16.2 | 13.3 |
| | *Capra* | Humerus | -15.3 | 11.0 |
| | *Ovis* | Phal. 2 | -16.2 | 11.3 |
| | *Ovis* | Phal. 2 | -15.2 | 11.5 |
| Wadi Jilat 25 | *Caprine* | Phal. 1 | -18.2 | 9.0 |
| | *Capra* | Humerus | -18.2 | 12.9 |
| | *Caprine* | Phal. 2 | -16.3 | 12.1 |
| | *Ovis* | Calcaneus | -17.2 | 9.0 |
| | *Ovis* | Metatarsal | -18.4 | 8.3 |
| | *Ovis* | Phal. 2 | -18.5 | 8.2 |
| | *Capra* | Metacarpal | -18.6 | 9.0 |
| | *Ovis* | Phal. 2 | -17.3 | 8.7 |
| ‘Ain Ghazal | *Ovis* | Metacarpal | -17.1 | 10.1 |
| | *Ovis* | Metacarpal | -18.4 | 10.4 |
| | *Ovis* | Metacarpal | -18.8 | 9.2 |
| | *Capra* | Metatarsal | -19.8 | 6.8 |
| | *Capra* | Tibia | -18.6 | 8.2 |
| | *Capra* | Metatarsal | -18.5 | 8.2 |
| | *Ovis* | Humerus | -17.4 | 9.5 |
| | *Capra* | Tibia | -18.3 | 8.1 |
| | *Caprine* | Metatarsal | -18.5 | 8.4 |
| | *Caprine* | Tibia | -17.6 | 9.8 |
| | *Ovis* | Humerus | -19.1 | 8.1 |
| | *Capra* | Radius | -17.4 | 8.1 |
| | *Capra* | Phal. 2 | -17.1 | 8.8 |
| | *Capra* | Metatarsal | -17.0 | 8.7 |
| | *Capra* | Astragalus | -18.6 | 8.4 |
| | *Ovis* | Calcanium | -18.2 | 8.2 |
| | *Ovis* | Phal. 2 | -17.5 | 9.3 |
| | *Ovis* | Phal. 2 | -17.6 | 9.7 |
| | *Cparine* | Metatarsal | -19.3 | 8.1 |
| | *Capra* | Metacarpal | -17.4 | 9.3 |
| | *Ovis* | Metacarpal | -17.2 | 10.6 |

**Table 2:** $\delta^{13}C$ ratios of plant materials at 'Ain Ghazal and Wadi Jilat sites (after Hedges *et al.* 1992; Wallace *et al.* 2015; Styring *et al.* 2016)

| Site/ Sample | Number | Average $\delta^{13}C$ (‰) | Average $\delta^{15}N$ (‰) |
|---|---|---|---|
| **'Ain Ghazal $C_3$ vegetation** | | | |
| *Triticum monococcum* | 2 | -22.94 | 5.00 |
| *Hordeum vulgare* | 9 | -23.23 | 4.13 |
| *Lens culinaris* | 2 | -22.03 | 1.30 |
| *Pisum sativum* | 5 | -22.32 | 2.34 |
| **Azraq Basin $C_3$ vegetation** | | | |
| Wadi Jilat 7 U/s C (Unspecified Charcoal) | 1 | -23.4 | N/A |
| Wadi Jilat 13 U/s C | 1 | -24.2 | N/A |
| **Azraq Basin $C_4$ vegetation** | | | |
| Wadi Jilat 22 U/s C | 2 | -14.15 | N/A |
| Wadi Jilat 26 U/s C | 2 | -12.00 | N/A |
| Wadi Jilat 25 U/s C | 1 | -11.1 | N/A |
| Azraq 31 U/s C | 1 | -10.5 | N/A |

**Table 3:** quantities and percentages of platform and bulb attributes from a sample of blades from Wadi Jilat 13 and Wadi Jilat 25. This combines the data from Baird (1994) with that from Miller's study of contexts (Wadi Jilat 13 Locus B69 and C56; Wadi Jilat 25 Locus 10 and 15.

| | **Wadi Jilat 13** | | **Wadi Jilat 25** | |
|---|---|---|---|---|
| | **number** | **percentage** | **number** | **percentage** |
| **Platform type** | | | | |
| Plain | 590 | 53.8 | 220 | 37.4 |
| Winged | 19 | 1.7 | 16 | 2.7 |
| Dihedral | 65 | 5.9 | 45 | 7.6 |
| Punctiform | 35 | 3.2 | 3 | 0.5 |
| Filiform | 67 | 6.1 | 2 | 0.3 |
| Platform facet | 88 | 8.0 | 16 | 2.7 |
| Removal surface facet | 172 | 15.7 | 19 | 3.2 |
| Cortical | 79 | 7.2 | 138 | 23.5 |
| Crushed | 222 | 20.2 | 147 | 25.0 |
| Lip | 277 | 25.2 | 125 | 21.2 |
| Ring crack | 45 | 4.1 | 22 | 3.7 |
| **Bulb features** | | | | |
| Diffuse | 375 | 34.2 | 137 | 23.3 |
| Prominent | 124 | 11.3 | 189 | 32.1 |
| Clear cone | 72 | 6.6 | 77 | 13.1 |
| Conical | 19 | 1.7 | 1 | 0.2 |
| Siret | 7 | 0.6 | 0 | 0 |
| Large eraillure | 88 | 8.0 | 13 | 2.2 |
| **Totals** | **1097** | | **588** | |

**Figure 1:** Map of Jordan showing locations of 'Ain Ghazal, Wadi Jilat sites and Wisad Pools. Detail box shows map of Wadi el Jilat showing the location of sites including Wadi Jilat 13 and 25.

**Figure 2:** $\delta^{13}C$ and $\delta^{15}N$ (‰) isotope values from caprine bone collagen from Wadi Jilat 13, Wadi Jilat 25 and Ain Ghazal (this study and Makarewicz (2007)) with 95% confidence ellipses (as per Grove and Pearson 2014). The confidence ellipse for Wadi Jilat 25 is large because of the small sample size and the two outlying samples. Also marked is the -18‰ fractionation line indicating a $C_3$ contribution to the diet (see Figure 3).

**Figure 3:** Histograms a-d showing: (1) the $\delta^{13}C$ distribution values of global $C_3$ and $C_4$ plants after O'Leary (1988: 329), original vertical axis not preserved as raw data is not available, but areas marked $C_3$ and $C_4$ show the relative frequency of plants at these $\delta^{13}C$ values. (2) the bootstrapped distribution of mean $\delta^{13}C$ values of caprine bone collagen from a) Ain Ghazal (this study), b) Ain Ghazal (Makarewicz 2007), c) Wadi Jilat 13, and d) Wadi Jilat 25. (3) The mean local $C_3$ (=-23‰) and $C_4$ (=-12‰) plant values from the 'Ain Ghazal and Wadi Jilat environs (see Table 2). (4) The approximate fractionation value, or cut-off, for caprines consuming a diet that includes $C_4$ plants; -18‰. < -18‰ would suggest a pure $C_3$ feeding animal, >-18‰ would indicate a mixed $C_3$-$C_4$ diet.

**Figure 4:** Cores: a. opposed platform, subpyramidal core; b. multi platform, globular core; c. opposed platform, irregular core; d. single platform, subpyramidal core; e. refitting Navirform core. a. – c. Wadi Jilat 13 cores; d. and e. Wadi Jilat 25 cores.

**Figure 5:** Truncation burins and spall drills: a. – c. burins and d. – g. burin spall drills from Wadi Jilat 25

**Figure 6:** Tool kit: a. and b. Amuq points. c. Byblos point. d. – f. bifaces and tile knives. g. borer. a. d. - f. Wadi JIlat 13. b. c. and g. Wadi Jilat 25.

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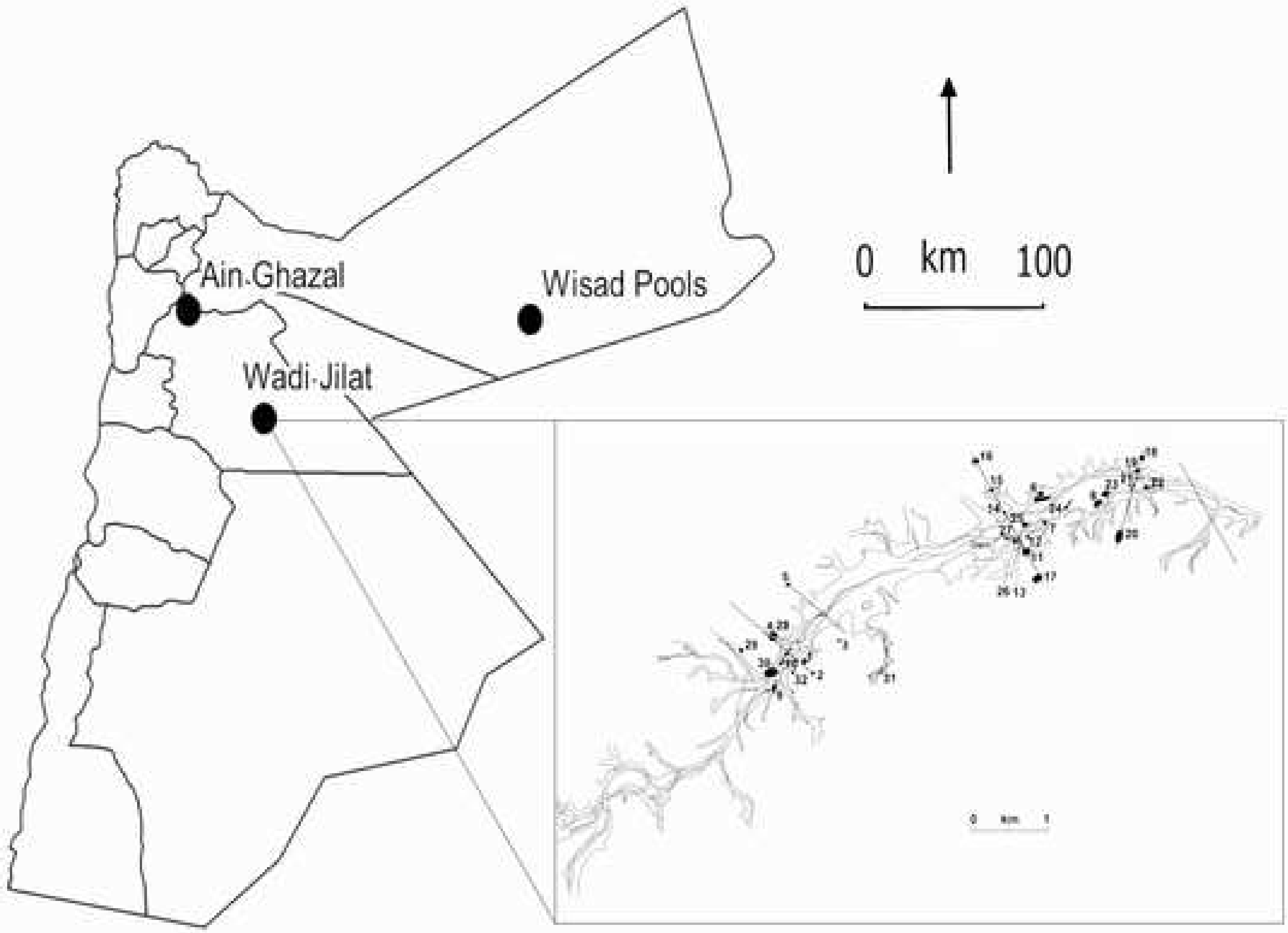

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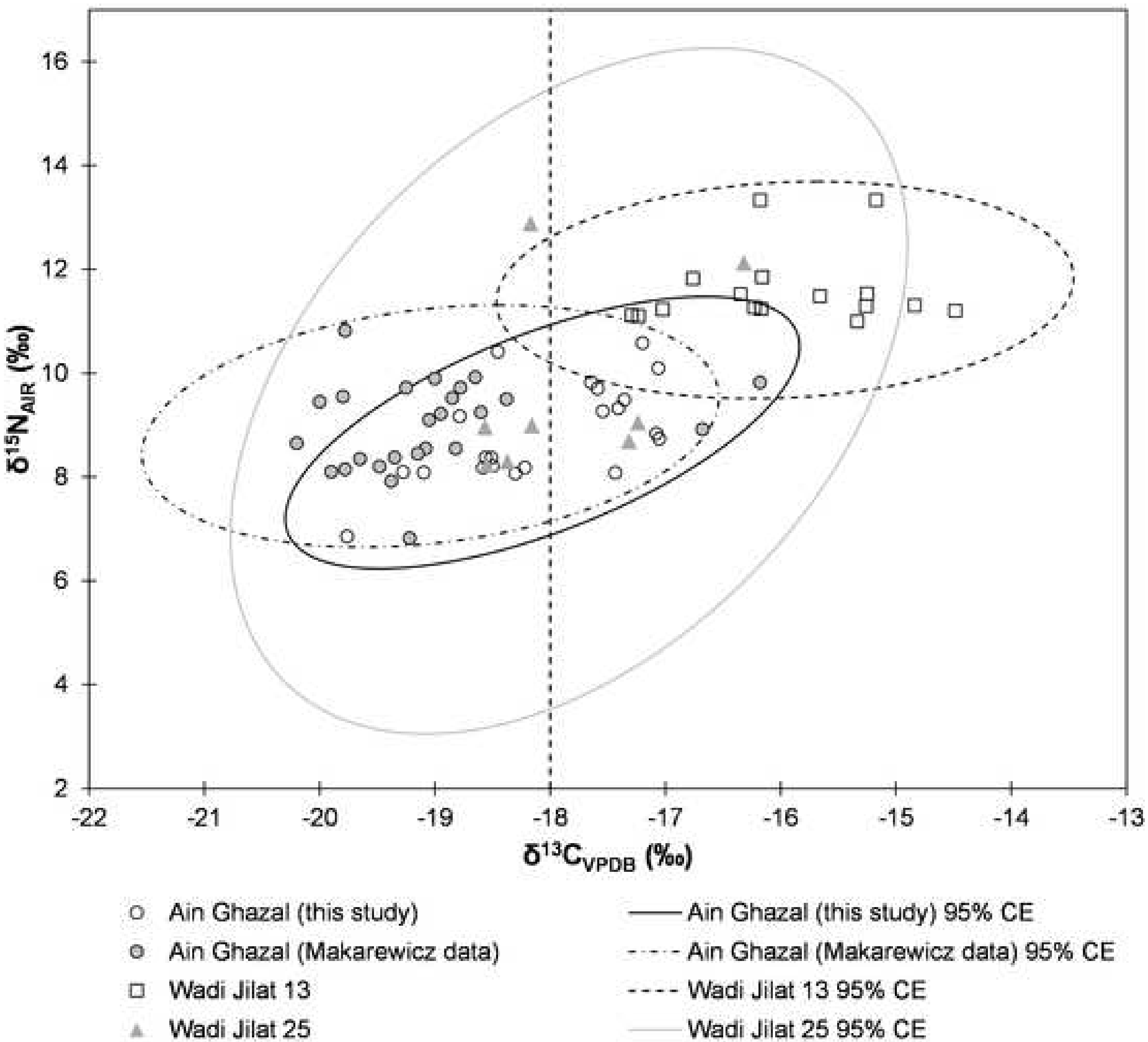

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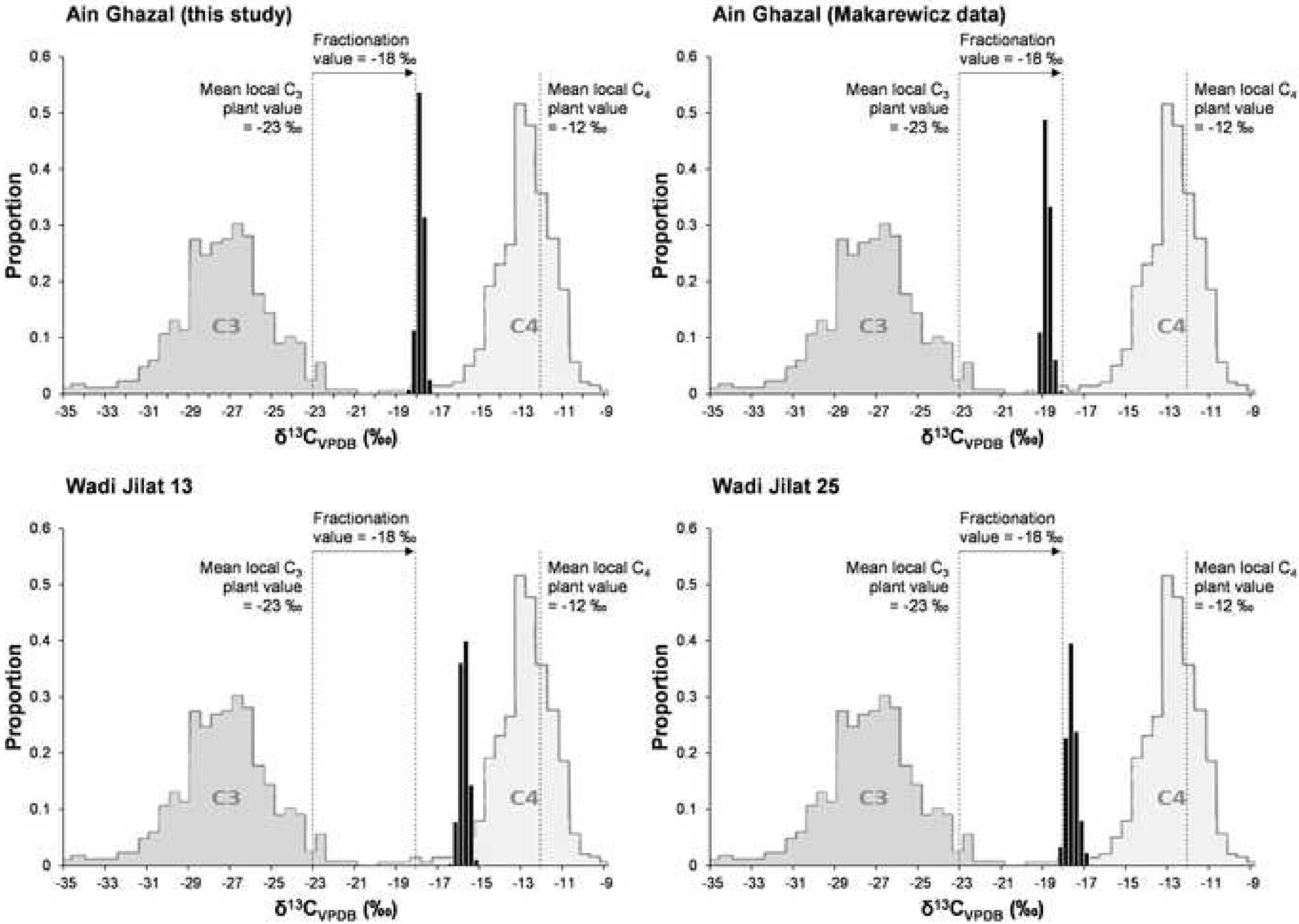

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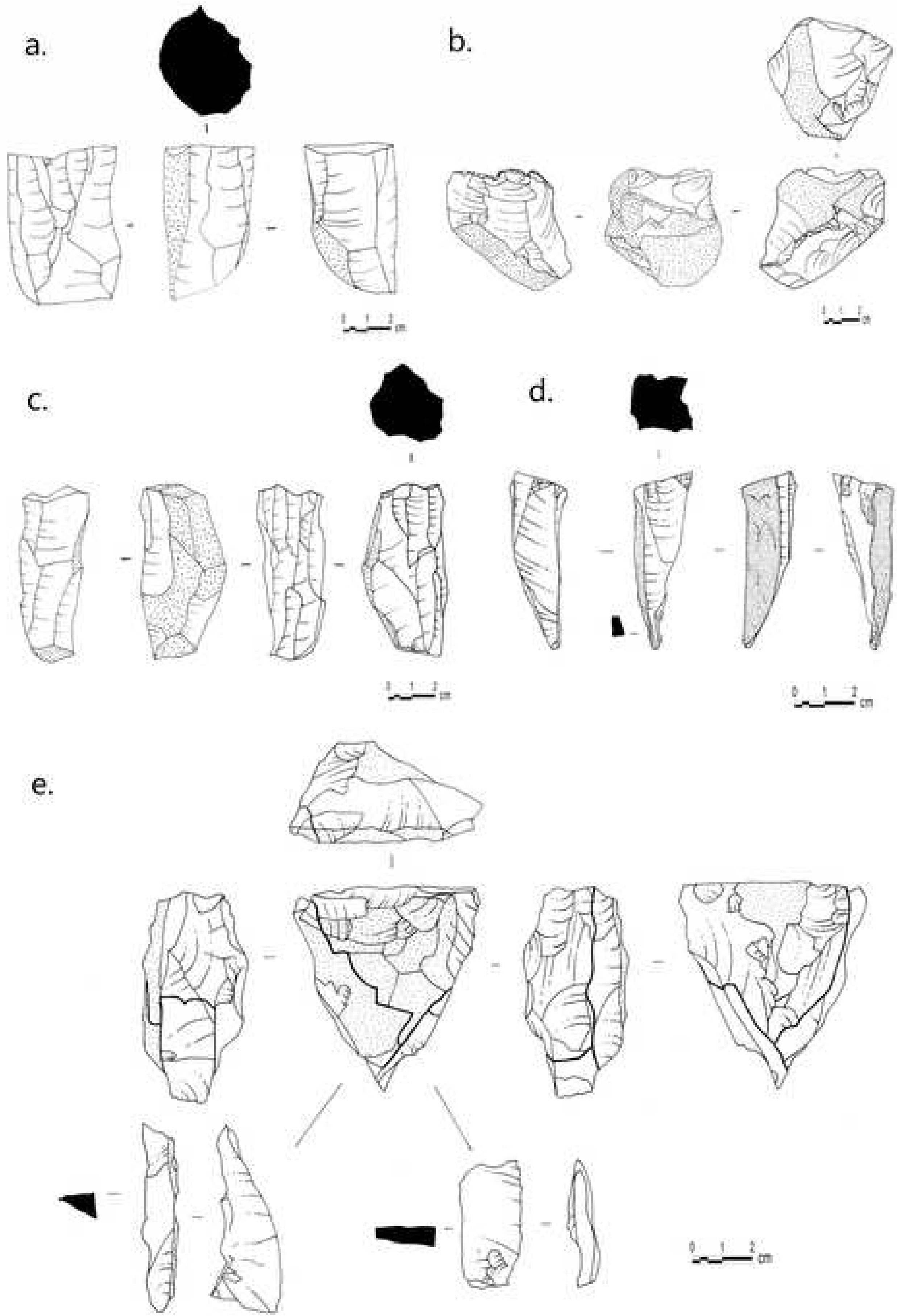

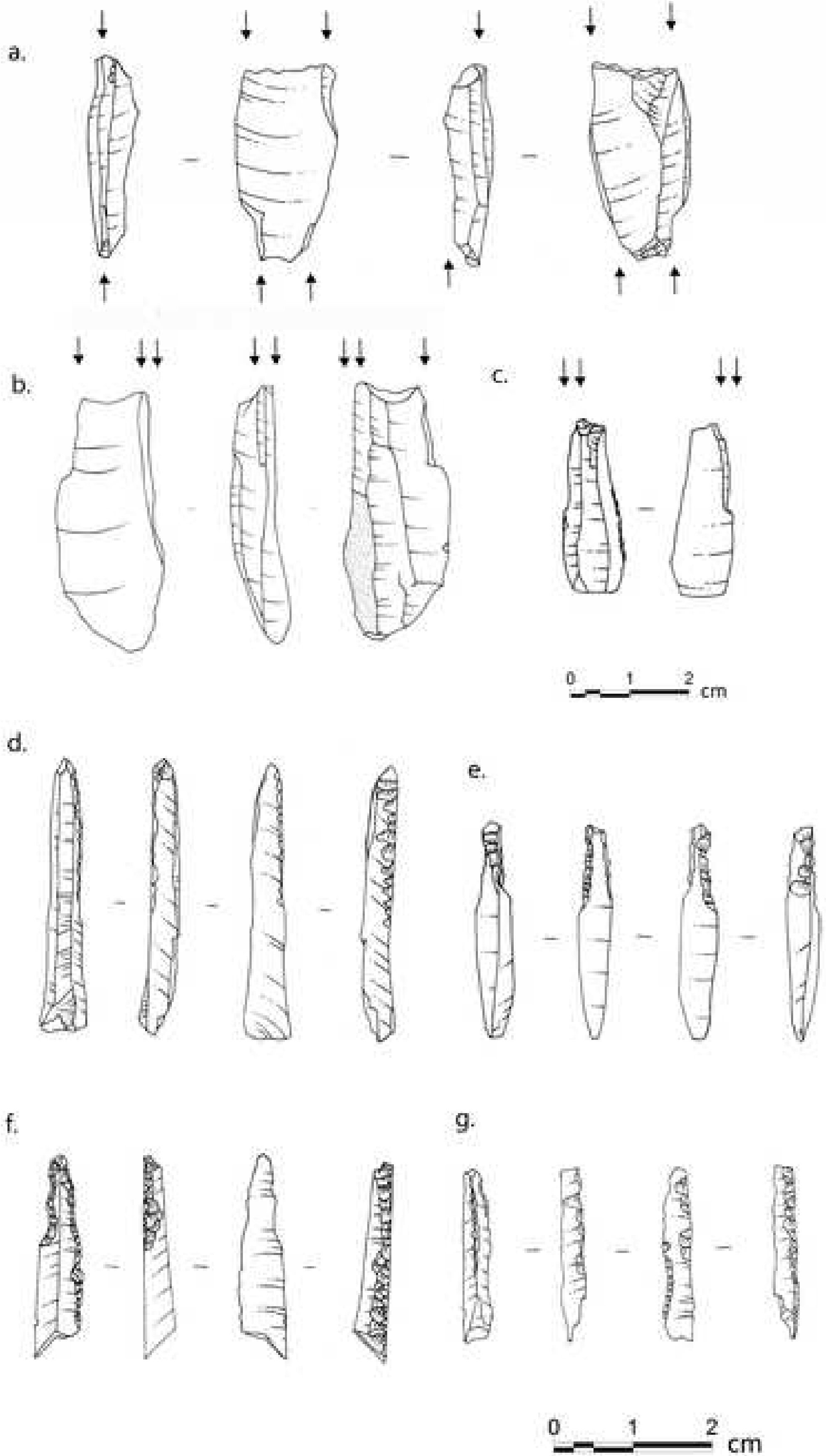

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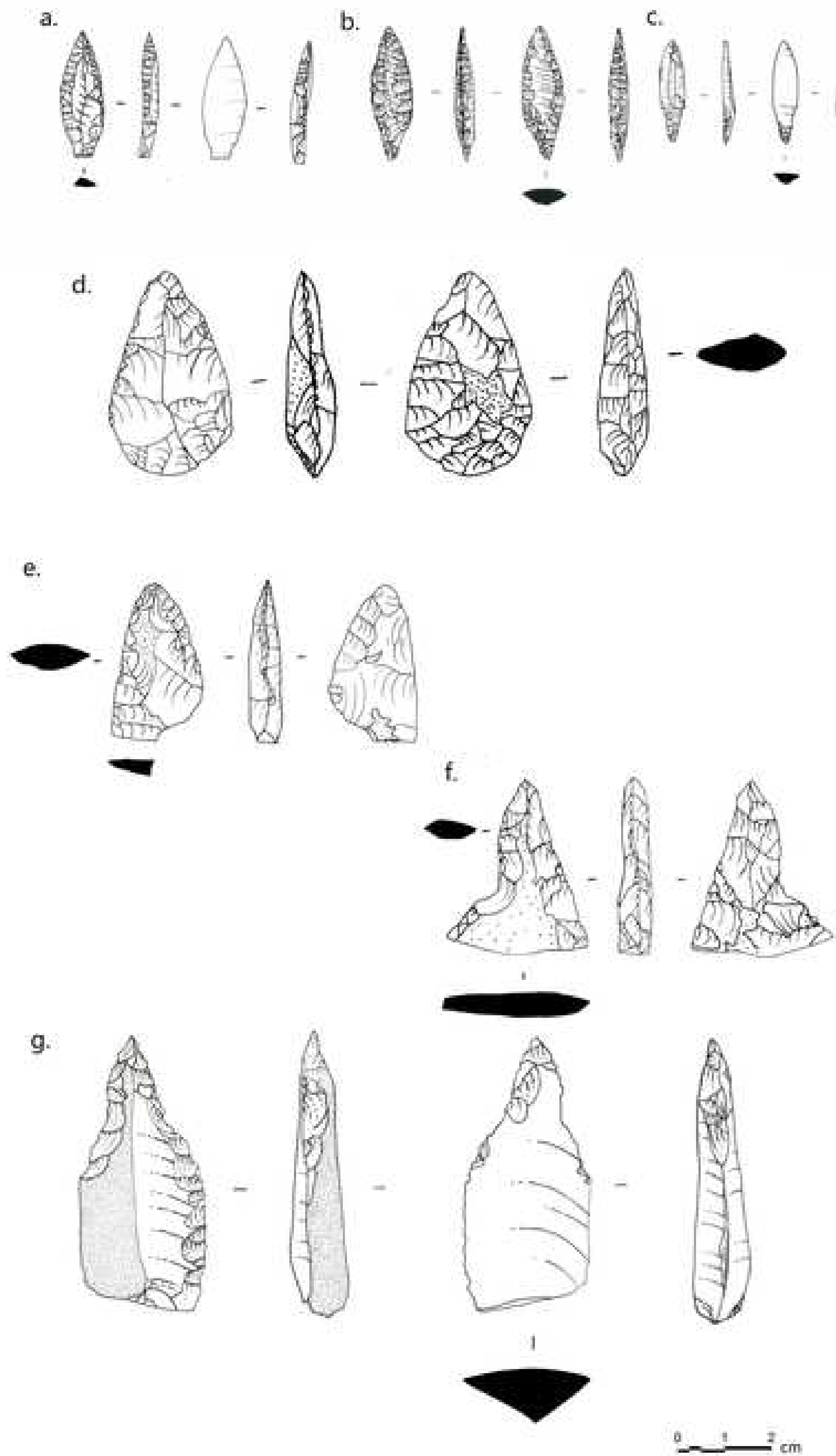
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