Large-scale cereal processing before domestication during the tenth millennium cal BC in northern Syria

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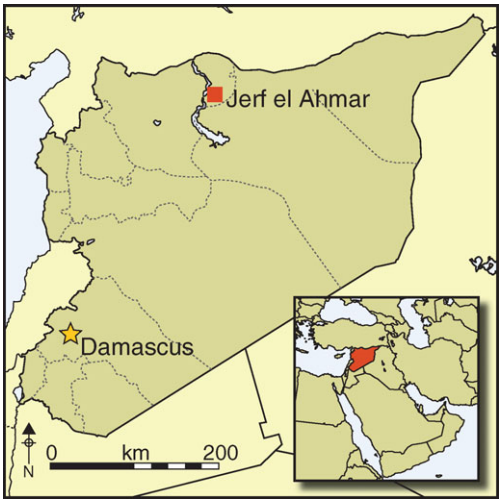

At Jerf el Ahmar in northern Syria the authors have excavated a settlement where the occupants were harvesting and processing barley 1000 years in advance of its domestication. Rows of querns installed in square stone and daub buildings leave no doubt that this was a community dedicated to the systematic production of food from wild cereals. Given the plausible suggestion that barley was being cultivated, the site opens a window onto a long period of pre-domestic agriculture. Rye was also harvested, its chaff used to temper mud walls.

Keywords: Levant, Syria, agriculture, barley, querns

Introduction

The adoption of cultivation in the Near East involved a shift from gathering a broad spectrum of plants during the Natufian to cultivation of a reduced range of cereals and pulses during the PPNA and PPNB (Weiss *et al.* 2004). Charred cereal grains are abundant on PPNA Euphrates sites, but what was the scale of cereal exploitation? How important were cereals for the subsistence economy? In this paper we will attempt to answer these questions by examining archaeobotanical and archaeological discoveries at the PPNA site of Jerf el Ahmar in northern Syria, occupied between 9500 and 9000 cal BC. We conclude with a brief discussion of the regional and social implications that lends support to recent theories on the origins of agriculture presented by Trevor Watkins (2010).

Pre-domestic cultivation, that is, cultivation of morphologically wild plants, has been suggested for PPNA levels at Mureybet, Jerf el Ahmar and Tell 'Abr 3, and for early PPNB levels at Dja'de and Cayönü (van Zeist & Bakker-Heeres 1984; van Zeist & Roller 1994; Colledge 1998; Willcox *et al.* 2008). In the southern Levant, cultivation of wild cereals has been proposed for the PPNA sites of Netiv Hagdud, Gilgal, Dhra, el-Hemmeh and Zahrat

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adh-Dhra (Edwards *et al.* 2004; Weiss *et al.* 2006; Kuijt & Finlayson 2009; C. White *pers. comm*.). Arguments for pre-domestic cultivation at PPNA sites have been based on weed assemblages, reduction of gathered plants, the introduction of cultivars, changes in grain size, and the presence of staples outside their natural habitats (Colledge 1998; Willcox 2004; Fuller 2007; Willcox *et al.* 2008). The economic scale of cereal exploitation is also considered an important factor by some scholars (Weiss *et al.* 2006; Kuijt & Finlayson 2009).

Excavation at Jerf el Ahmar exposed a surface area of over 1000m^2 with 11 distinct levels, providing a wide range of architectural features (Stordeur *et al.* 2000; Stordeur & Abbès 2002; Stordeur 2003, 2004, 2006, 2010). With a dataset of over 30 000 identifications of charred plants (excluding charcoal) and the discovery of storage structures, cereal processing installations, rodent activity, grinding tools such as querns, and widespread use of chaff, we were able to assess the scale and significance of cereal exploitation.

Jerf el Ahmar is one of five contemporary PPNA sites which include Mureybet (Cauvin 1977; Ibanez 2008), Cheikh Hassan (Cauvin 1980), Tell 'Abr 3 (Yartah 2005) and the recently discovered early levels at Dja'de (Coqueugniot *pers. comm*. and 2000). These sites, situated along the left bank of the Euphrates (Figure 1), were occupied at the beginning of the Holocene during a period of climatic amelioration (Willcox *et al*. 2009). They have similar architectural, symbolic and chipped-stone traits, suggesting a cultural unity (Stordeur & Abbès 2002; Helmer *et al.* 2004; Stordeur 2010). Farther north in south-east Turkey, the sites of Göbekli (Schmidt 2007), Demirköy and Hallan Çemi (Rosenberg 1999; Savard *et al.* 2006) present similar parallels, but in these cases charred cereals are less frequent.

The region where the Euphrates sites are situated receives 250–300mm of rain per annum in the north, where dry farming is practiced under the present-day climate. To the south, the area receives only 150–250mm making dry farming unreliable. During the Early Holocene more moisture may have been available, with lower temperatures and perhaps higher rainfall.

The charred plant remains

The charred plant assemblages from Jerf el Ahmar, Tell 'Abr 3, Mureybet and Dj'ade include over 120 taxa and over 70 000 identifications, excluding charcoal. The data were obtained from flotation samples collected from diverse contexts such as buildings destroyed by fire and hearths where charred plant remains occurred *in situ*. Other samples came from floor and ash layers where gradual accumulation represented multiple burning events.

Wild cereals (Figure 2) with ears that shattered at maturity were the most frequent food plants. Barley and rye were the most common. Einkorn increases in later levels at Jerf el Ahmar while emmer appears later at Dja'de where it was probably introduced (Table 1). For counts of non-cereal taxa we refer the reader to Willcox *et al.* (2008). At Jerf el Ahmar 227 samples were analysed from which 34 067 charred seeds and fruits were identified. Cereals and pulses increase in the upper levels at the expense of gathered taxa suggesting more reliance on cereal cultivation and less gathering for the upper levels. This is demonstrated by an increase in frequencies of wild barley and single-grained einkorn, whereas non-founder gathered food plants such as seeds of Knotgrass/Dock and the small-seeded grasses are common in the lower, earlier levels and diminish in the later levels (Figure 3; Table 2).

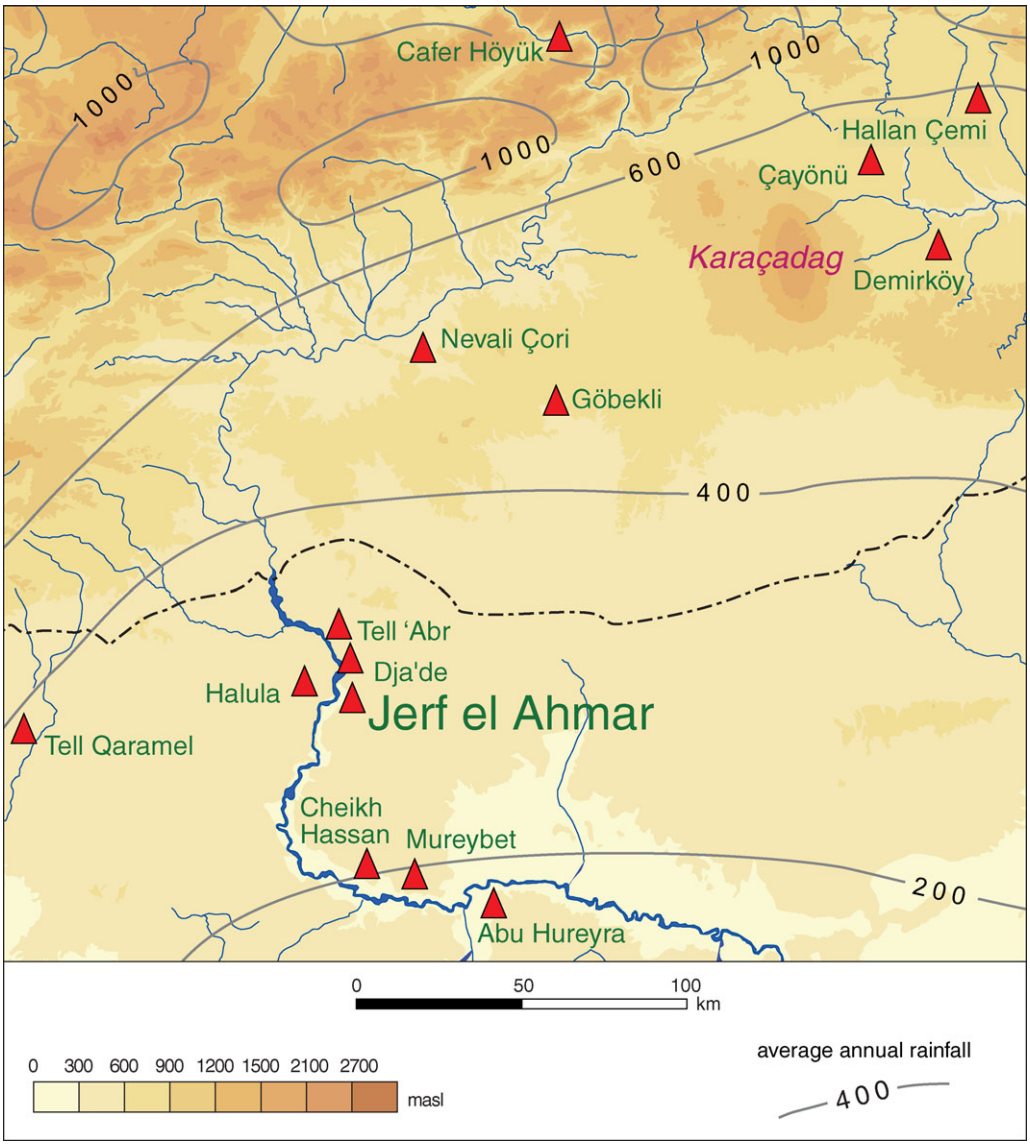

Figure 1. The location of the principal sites mentioned in the text, average annual rainfall and relief.

Querns, food processing installations and remains of prepared food

Querns were very common at Jerf el Ahmar: about 400 were unearthed in all. Over 30 were preserved *in situ*, in their original working position. Some were set into specially constructed bases. Eleven houses contained *in situ* querns, of which nine had querns in groups of two, three or four. However, the majority of querns recovered were reused for building foundations. The querns are oval and ideal for grinding grain (Figure 4). Many show signs of prolonged use, being worn thin at the base, and in some cases the bases were pierced. Querns from Late Pleistocene and Early Holocene Near Eastern sites have been

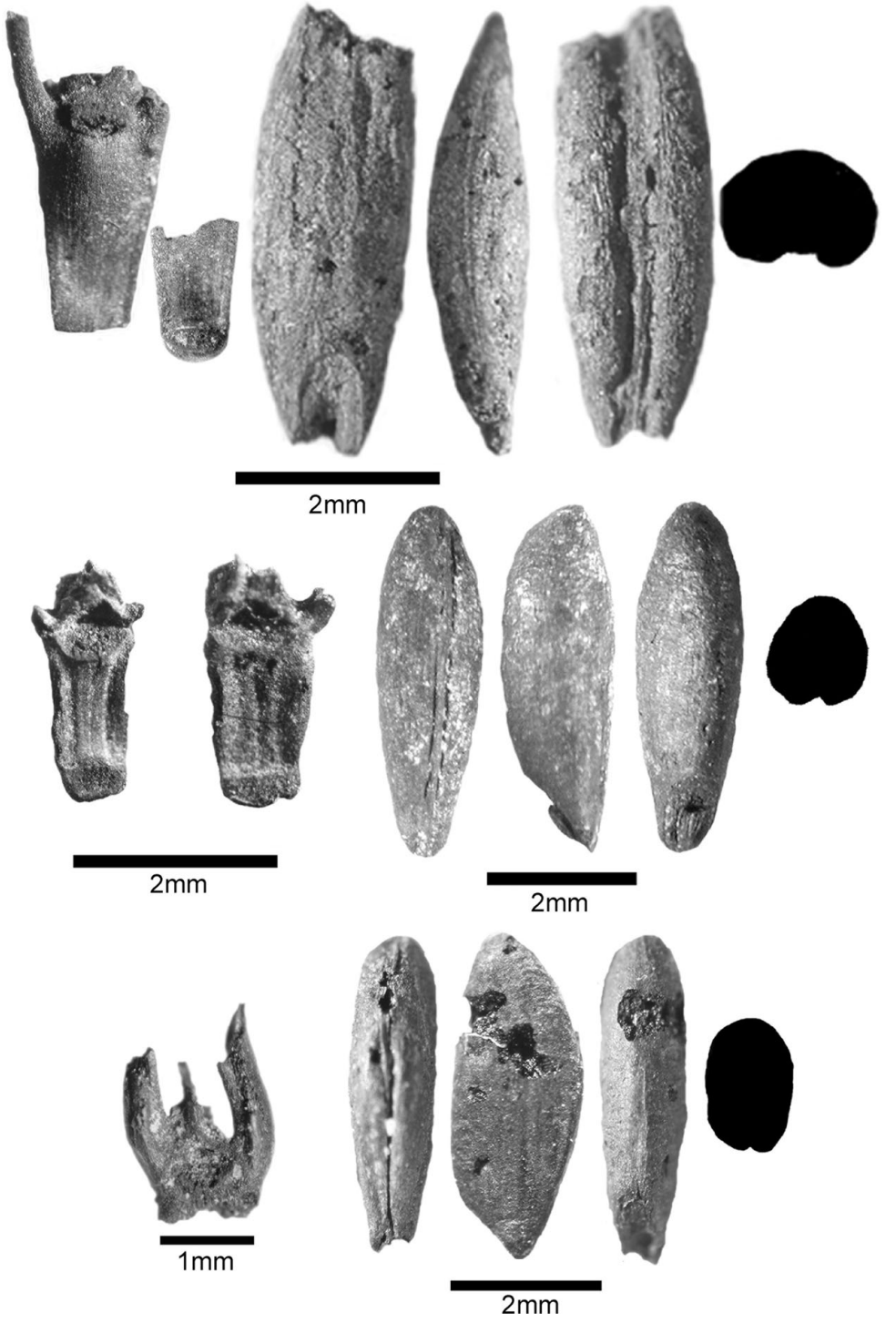

Figure 2. Charred wild cereals remains: spikelet bases (left) and grains (right): top row) barley; middle row) rye (Jerf el Ahmar); bottom row) single-grained einkorn (Tell Qaramel).

Table 1. Absolute counts (Σ) and ubiquity percentage values (ub %) for cereal items from four Euphrates sites. The number of samples, total number of identifications excluding charcoal, volume of sediment sampled and number of rodent droppings are also given for each site.

Approx. date range cal BC	Tell'Abr 9500–9200		Mureybet 3 9500–9200		Jerf el Ahmar 9500–9000		Dja'de 9000–8300	
	Σ	ub %	Σ	ub %	Σ	ub %	Σ	ub %
Wild barley grain	190	57	164	86	9639	91	3763	79
Wild barley spikelet base	0	0	6	4	3325	58	153	11
Rye + a few einkorn grains	2999	86	2000	90	2539	81	1120	64
Rye spikelet base	0	0	p	0	144	11	16	3
Einkorn/emmer spikelet base	0	0	0	0	5	2	16	5
Singled grain einkorn	90	40	1	4	67	11	302	32
Wild emmer	0	0	0	0	0	0	192	21
Rodent droppings	0	0	0	0	51	11	221	25
Total plant items identified	4528		2934		34 067		32 964	
Vol. sediment litres	452		?		1211		6122	
No. of samples	30		27		227		229	

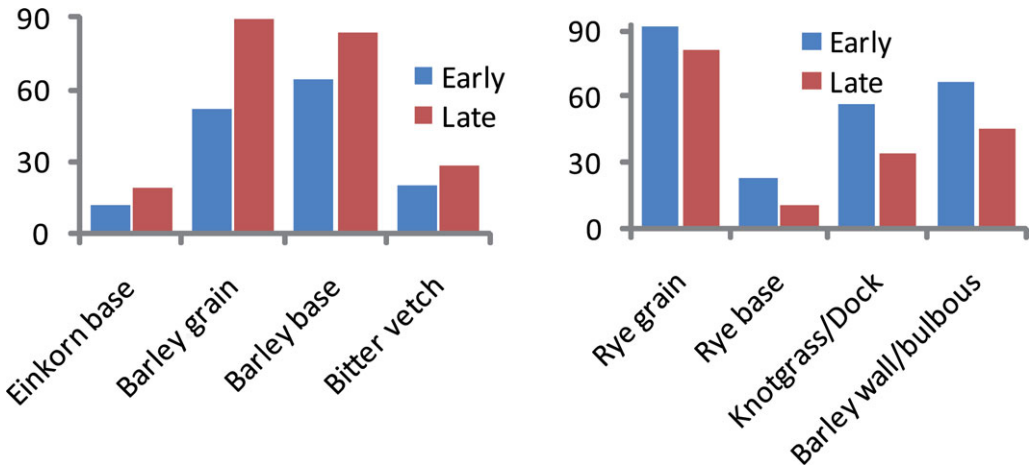

Figure 3. Bar charts giving percentage values of ubiquity of selected taxa comparing the early and late levels at Jerf el Ahmar. Ubiquity depends on presence/absence of a taxon in a given number of samples and is considered more reliable than absolute counts. On the left are taxa that increase in the later levels and were domesticated at more recent sites. On the right, gathered small-seeded grasses (including rye) that decrease in later levels and were gradually abandoned. We suggest this represents a trend towards cultivation. Data is presented in Table 2 and in Willcox et al. (2008).

interpreted as being used for processing cereals (Dubreuil 2004; Kuijt & Finlayson 2009). This was confirmed at Jerf el Ahmar where residues of milling in the form of grain that had fragmented prior to charring were found in the vicinity of *in situ* querns (Willcox 2002).

Nine rooms contained installations of querns grouped in cramped conditions that left little room for other activities, suggesting that these rooms were devoted to cereal processing and food preparation. House EA23 is the largest (7.4 × 5m) of a group of 12 houses in level I/E (Figure 5). The larger of the two rooms contained an installation of three querns arranged

Table 2. Ubiquity (% ub) and absolute counts (Σ) of selected taxa from Jerf el Ahmar in different combinations of phases. 'Total items' refers to all taxa identified. Ubiquity values were used from lines in bold type for Figure 3. Taxa which were cultivated are more frequent in later levels regardless of the combination of phases, ubiquity or absolute totals.

Taxa with frequencies that increase in the later levels

Combined phases	Total samples	Total items	Einkorn base	Einkorn grain		Barley grain		Barley rachis		***Ornithogalum***		***Bellevalia***		Bitter vetch	
	Σ	Σ	Σ	Σ	% ub	Σ	% ub	Σ	% ub	Σ	% ub	Σ	% ub	Σ	% ub
1, 2, 3	154	15 972	4	49	14	6474	65	1746	59	13	6	145	34	45	21
4, 5	**81**	**12 097**		**18**	**11**	**2353**	**52**	**1546**	**64**	**1**	**1**	**34**	**25**	**10**	**20**
1, 2	**76**	**10 638**	**3**	**41**	**18**	**5234**	**90**	**1622**	**84**	**13**	**6**	**106**	**47**	**31**	**28**
3, 4, 5	159	17 431	1	26	11	3593	93	1670	50	1	1	73	23	24	12

Taxa with frequencies that decrease in the later levels

Combined phases	Total samples	Total items	***Rye (few einkorn) grain***		Rye base		Knotgrass/Dock		Panicoid	***Wall/bulbous Barley***		***Ziziphora***
	Σ	Σ	Σ	% ub	Σ	% ub	Σ	% ub	Σ	Σ	% ub	Σ
1, 2, 3	154	15 972	1055	77	22	6	126	32	1	226	38	1
4, 5	**81**	**12 097**	**1382**	**93**	**121**	**23**	**359**	**57**	**19**	**614**	**66**	**26**
1, 2	**76**	**10 638**	**396**	**82**	**18**	**10**	**73**	**34**		**116**	**45**	
3, 4, 5	159	17 431	2041	83	125	13	412	44	20	724	49	27

Figure 4. Two of the three querns found in the kitchen of house 10: left) in limestone (length 420mm, width 280mm, thickness 66mm), oval with a deep active surface (65mm); right) in basalt (length 350mm, width 220mm, thickness 107mm), active surface 34mm.

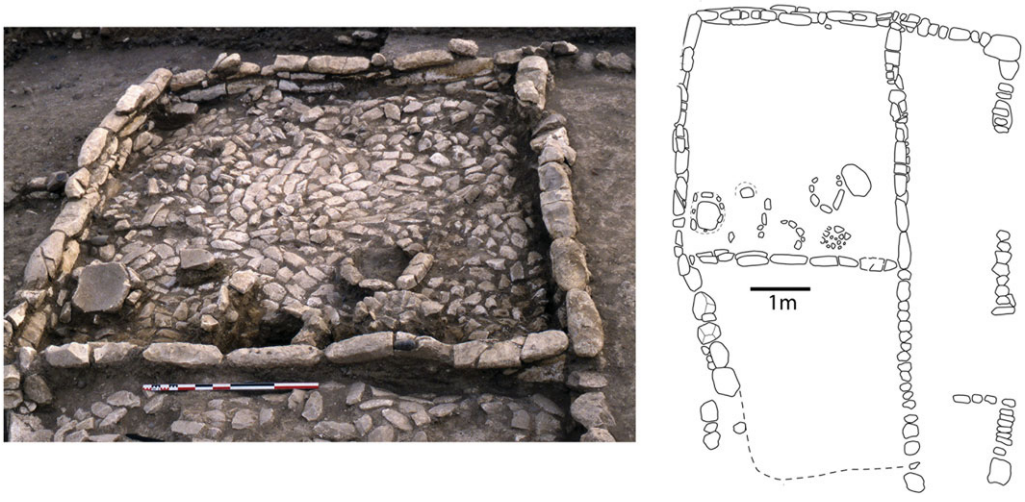

Figure 5. House 23 consisted of two rooms, one contained an installation of three querns.

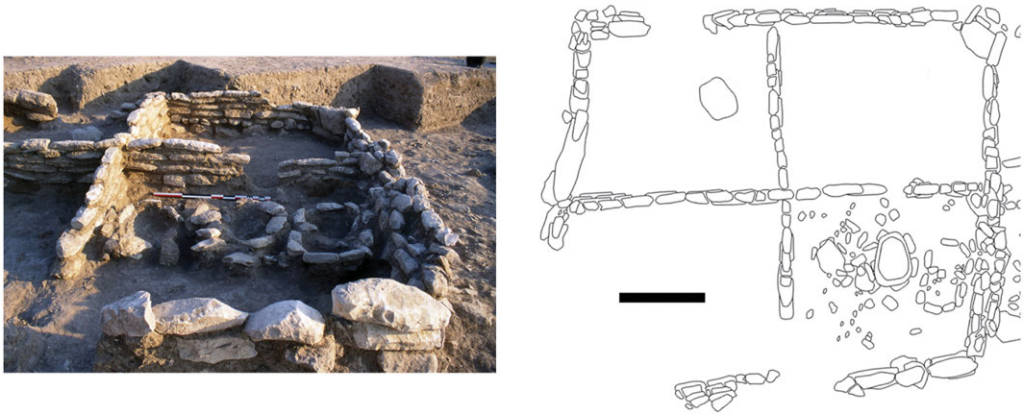

Figure 6. House 54 consisted of four rooms, one of which contained a processing installation of three aligned querns in a confined space.

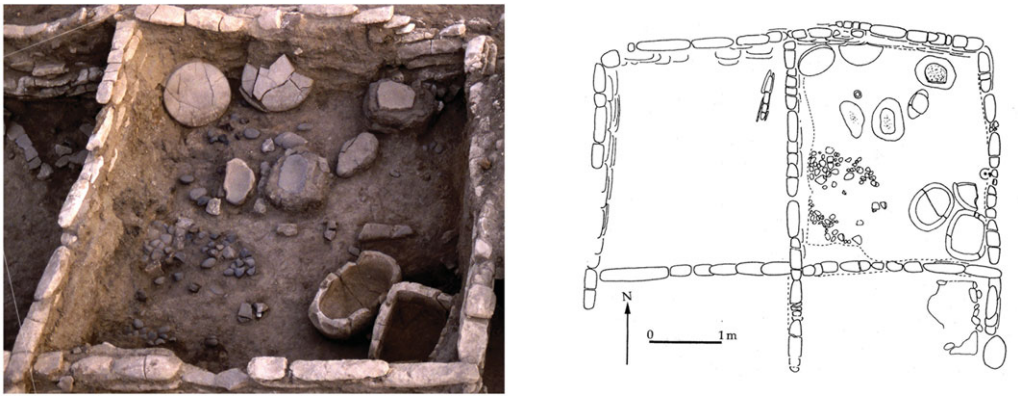

Figure 7. House 10, which was destroyed by fire and contained a rich array of food processing objects and charred plant remains in situ. Four querns are aligned diagonally (for further explanation see text).

parallel to the dividing wall. The querns were set into bases constructed of stone and earth, and several handstones were found nearby. The middle quern was broken and the one to the right had been removed and placed beside its base. House EA54 (level I/W) measured 4 × 5m and was divided into four rooms (Figure 6). Two were empty; one contained an installation of three aligned quern bases, two of which still held the querns in place. In an adjacent room connected by an opening there were a concentration of handstones and five sickle-like curved stone handles (Stordeur 2004).

House EA10 (level II/W; Figure 7), one of a group of houses situated around communal building EA30, contained the best preserved charred remains, having been damaged by fire (Stordeur *et al.* 2000). Of the two rooms, one contained a large array of objects associated with food processing and was apparently devoted to food preparation and cereal processing (Willcox 2002). Of the four querns unearthed, two were set into bases, a third located

between them was upturned and may have served as a stool. A fourth (situated to the lower left) had no constructed base but was wedged by stones. Next to this quern there was a small stone bowl and three handstones. Two large stone platters with diameters of 65 and 55cm, weighing about 55kg each, were set against the wall (Figure 7, top left). One is complete while the other has lost its upper half. The active surfaces were highly polished, suggesting work surfaces that had undergone intensive use, perhaps for mixing or pounding food products. This area was rich in charred plant remains; on one quern two charred seed cakes were found, consisting of finely crushed seeds. These were identified as belonging to the genus that includes mustard or rape and were perhaps residues from oil extraction or simply a kind of mustard (Willcox 2002). In the south-west corner of the room a shallow depression contained ash and pebbles that had been fractured by heat. The pebbles may have been used for cooking. Charred lentils and fragments of seed cake were found in this area. In the south-east corner (Figure 7, lower left) were three limestone basins which measured 75 × 55 × 30cm and could hold at least ten litres of liquid. These containers could have been used to soak plant materials or for storage. Concentrations of barley were found in this area of the room as well as a small receptacle in unfired clay. R. Haaland (2007) suggests that the kitchen and in particular this area may have been used to prepare barley for brewing. We cannot refute this hypothesis but there is no solid evidence to support it except the juxtaposition of barley and the 'vats'.

Remains of charred prepared food were common at Jerf el Ahmar, Tell 'Abr 3, Dja'de and Tell Qaramel (Willcox *et al.* 2008). Some of these consist of crushed seeds bound together in a matrix, others are amorphous in nature and could be finely ground food which had become charred. Small fragments were common; the whole seed cakes from the kitchen at Jerf el Ahmar are an exception. None of the other samples has been analysed in detail, but these finds could in the future provide some specific results concerning food preparation during the PPNA. Finds other than cereals imply that food preparation used a complex array of ingredients. Monk's pepper (*Vitex agnus-castus*), an oriental mint (*Ziziphora*) and caper seeds (*Capparis*) may have been used for seasoning. Other examples of gathered taxa that were used on a regular basis include oleaginous crucifer seeds, nuts of the oriental turpentine tree that resemble small pistachios and almonds.

Communal storage of cereals

Direct evidence for storage from *in situ* charred crops was not found at Jerf el Ahmar. We attempted to recognise possible storage from areas that had a high density of charred grains. The average density was 1.3 cereal remains per litre of sediment. The density has rarely been calculated for Near Eastern sites but is low compared to reports from a study of European Neolithic sites (Kreuz *et al.* 2005). Table 3 presents samples with more than three cereal remains per litre, which potentially might represent storage and/or processing areas. Indeed the storage-like structures consisting of small cells in communal building EA30 (level II/W) (Stordeur *et al.* 2000) contained higher than average frequencies of cereals. Access into the cells by steps would have allowed inhabitants to climb over the partitions (Figure 8). Cells 4, 5 and 6 were empty of archaeological objects and had higher walls; these were possibly storage structures. Cell 2 contained between 3 and 7.4 grains per litre. Cell 5 contained high

Table 3. Samples from Jerf el Ahmar with three or more grains/chaff per litre of sediment suggest the possibility of storage or crop processing areas. Several samples came from probable storage structures.

Sample	House/SU	Volume/L	Barley grain	Barley chaff	Rye chaff	Einkorn grain	Rye/Einkorn grain	No. per litre
Chaff								
624	30 (5)	40	58	**116**	1		2	4.4
625	30 (5)	50	76	**172**	9		8	5.3
457	SU23	30	29	**118**	11	3	31	6.4
444	SU28	60	58	**175**	5		64	5
433	SU28	60	50	**228**	15		48	5.7
480	SU28	20	25	**247**	20	1	43	18
Grain								
700	10	913	**2240**	181			23	2.7
547	30 (2)	80	**194**	20		2	23	3
552	30 (2)	40	**110**	7			3	3
544b	30 (2)	60	**324**	89			34	7.4
259	SUC4	150	**328**	67	1		50	3
639	SUo19	50	**136**	29			3	3.4
622	47	20	7	3	3		**85**	4.9
466	47	60	15	28	1		**205**	4.1
579	SUe21	60	75	10	1	7	**347**	7.3

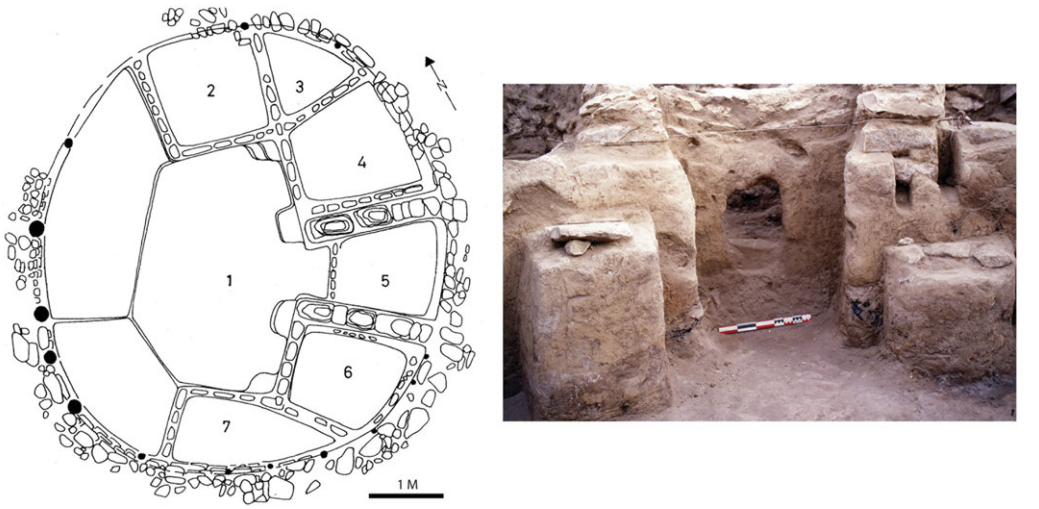

Figure 8. Communal building 30 was semi-subterranean and divided into cells. It was surrounded by habitation structures such as houses 10 and 54. The cells are interpreted as being communal storage structures. The photograph shows the opening into one of the storage structures, used to remove grain.

concentrations of barley chaff, which suggests that chaff was stored. An argument in favour of cell 5 being a storage structure was a small low opening, typical of traditional Syrian silos still used today which are filled from above and emptied by a small closable opening near the floor level. Cells 4, 5 and 6 could have held approximately 3m^3 of grain that would

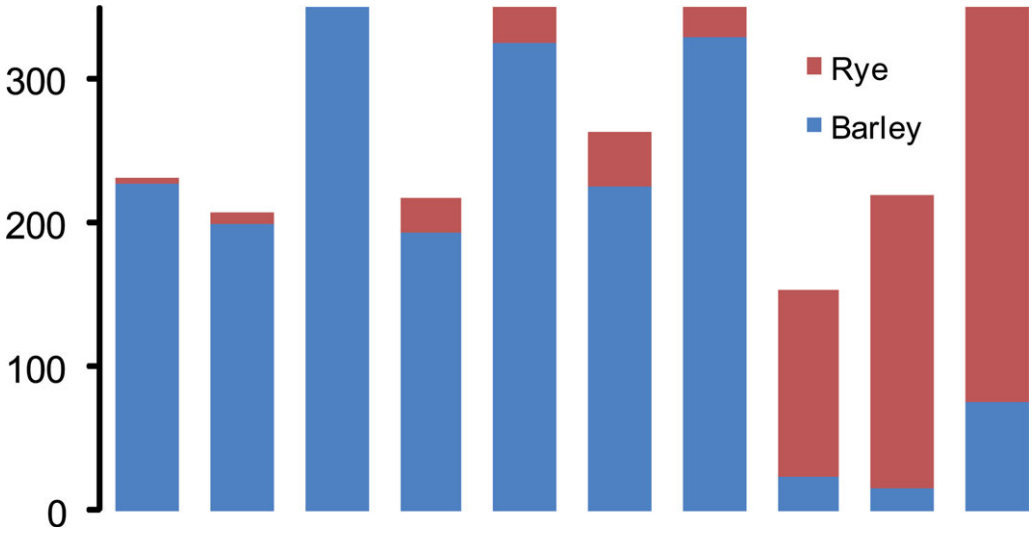

Figure 9. The y-axis gives absolute numbers of grains identified, bars indicate the proportions of barley (blue) and rye (red) found in 10 samples from Jerf el Ahmar. The proportions indicate that either barley or rye is dominant, suggesting that these two crops were processed separately.

represent a minimum of 2000kg. With a moderate consummation of 200g of cereals per person per day, a single cell could feed roughly 30 people for a year. Even if these estimates are incorrect by 50 per cent this still represents a considerable quantity of food.

For the earlier phases no storage structures were found. House EA47 (level III/E) had a high density of charred rye grain, which could imply storage. The absence of constructed storage structures suggests grain was probably stored in sacks or simply as piles on the floor. This round house destroyed by fire stood out compared to others of this period because it contained four aurochs bucrania which may have been suspended on the wall (Stordeur 2010), a number of handstones and a polished stone axe. A similar house was found at the neighbouring contemporary site of Tell 'Abr 3, situated 50km upstream. A communal round sunken building 8m in diameter contained aurochs bucrania, five limestone basins and a number of querns. The sediment had a density of 7.2 grains per litre of rye, suggesting storage (Yartah 2005; Willcox *et al.* 2008).

At Jerf el Ahmar the density of wild hulled barley chaff compared to grain was high in six samples (Table 3). This is significant because chaff is less likely to be preserved than grain because it is more flammable and more fragile. When complete spikelets are burnt they leave a small proportion of chaff compared to grain (Boardman & Jones 1990). This taphonomic selection against chaff suggests that these high chaff densities may indeed represent storage for later use as temper for building earth.

Samples with over 150 grains contain a majority of either barley or rye, indicating that these crops were stored, harvested and processed separately (Figure 9). The majority of samples contain mixtures of these crops because they originated from midden deposits where charred material is in a secondary position, representing a slow accumulation of accidental residue from multiple activities.

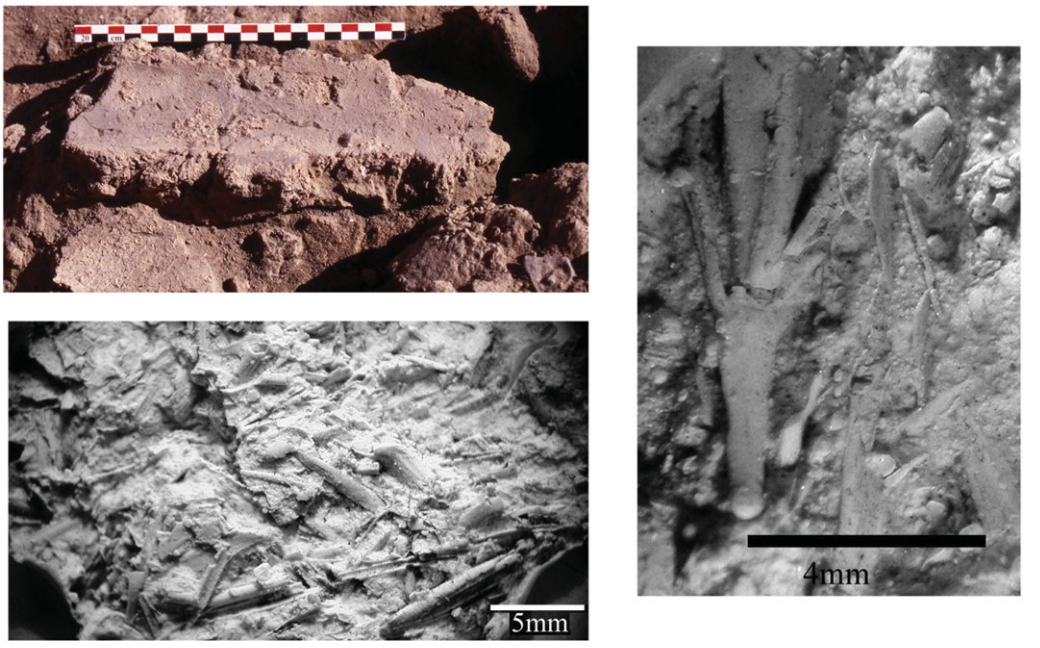

Figure 10. The remains of building earth from Jerf el Ahmar with the impression of a wooden beam (top left). All building earth examined contained dense cereal chaff temper, seen in the photographs of latex casts (below left, and right); detail of a complete barley spikelet (right).

Large-scale use of cereal chaff as a tempering material in building earth at Jerf el Ahmar

Buildings at Jerf el Ahmar were constructed of local knapped chalk bound together with an earth mortar and covered with 5–10cm of earth render. The roofs were constructed with wooden beams between which were laid twigs, straw or reeds that were then covered with building earth. A wide range of building earth was examined microscopically; all contained impressions of fragmented glumes, lemma, palea, awns and spikelet bases from wild barley, wild einkorn and wild rye (Figure 10). These elements represent chaff resulting from de-husking (Willcox & Fornite 1999). The chaff was finely fragmented, suggesting that de-husking was carried out by pounding, perhaps with mortar and pestle. Straw fragments were rare, suggesting that the chaff came from de-husking rather than threshing.

Large quantities of grain must have been processed in order to provide enough tempering material for the extensive structures at Jerf el Ahmar because building earth requires a third by volume of chaff (that found in present-day construction) and the ratio of barley chaff to grain is low compared to wheat. In addition, de-husking probably met short-term needs, so that the large quantity of chaff needed for construction would accumulate slowly over a long period, and would have to be stored in appropriate structures. Concentrations of chaff suggesting storage were found in an open space between houses EA31 and EA32 (level V/E, one of the earliest levels) and in cell 5 of communal building EA30.

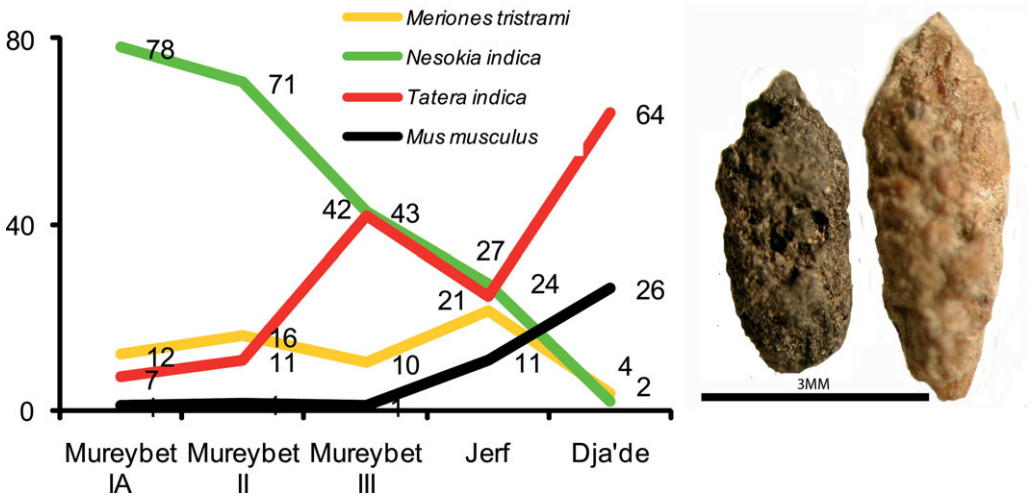

Figure 11. Rodent identifications from Euphrates sites. The house mouse increases during the PPNA (Haïdar 2004). The photographs show an ancient charred house mouse dropping (left) and a modern equivalent (right).

Harvesting tools

Efficient tools would have improved the harvesting of barley, rye and einkorn. F. Abbès (Stordeur & Abbès 2002) identified technological improvements in the tools used at Jerf el Ahmar to harvest cereals. Long, robust retouched blades identical to the sickle blades found at Mureybet (Cauvin & Stordeur 1978) were found in the early levels. During the later phases sickle blades become more refined, larger in size, more rectilinear and pointed with the development of a new technique in which the blade is predetermined on the core. A lustre on the cutting edge and traces of bitumen on the opposing edge of the blades show that the hafting was longitudinal (Abbès 2007). This lustre was studied on blades from Mureybet and is interpreted as resulting from the cutting of grass/cereal stems. In general during the PPNA there is an increase in the intensity of the lustre and the number of these blades, compared to earlier periods (Ibanez *et al.* 2007: 157).

Rodent activity and cereals

The domestic house mouse has been found on Natufian sites in the southern Levant (Cucchi *et al.* 2005). Rodent activity at Jerf el Ahmar was identified by charred droppings, bones, teeth and gnaw marks on archaeological objects and appears to have been intensive. Four rodent species were identified in the faunal analyses (Figure 11); two feed on stored grain crops, the common house mouse (*Mus musculus domesticus*) and the Indian gerbil (*Tatera indica*) (Haïdar 2004). The former nests in buildings but not the latter, which is rat-sized and edible. Remains of the house mouse in the form of teeth or bones are rare, but given the small size of these compared to the Indian gerbil, there may have been a recovery bias in favour of the latter. A total of 51 charred rodent droppings were recovered from flotation samples. Most were attributed to the common house mouse on the basis of size although a few large specimens are closer in size to the Indian gerbil. Some 30–40 were found in

buildings destroyed by fire. Droppings were most frequent in house EA47 and collective building EA30, where grain may have been stored. Further indications of rodent infestation are gnaw marks on handles, containers and even building stone made of chalk, which may have absorbed fats. These finds add weight to arguments for large-scale use of cereals.

Conclusion

Cereals were central to the subsistence economy at Jerf el Ahmar. This is revealed by large-scale use of chaff, large storage structures in communal buildings and processing installations in specialised rooms consisting of groups of querns. Cereals were clearly important in the diet, the other important element for subsistence being the hunting of aurochs, gazelle and equids (Helmer *et al.* 2004).

During the 500-year occupation trends can be traced, for example from circular houses in the early levels to rectangular ones in later levels. Communal buildings in the upper levels are more specialised. Cereals and pulses increase compared to gathered plants such as non-cereal grasses. Constructed storage structures occur only in the upper levels. Sickle blades from the upper levels are more intensively used and more efficiently produced. Grouped querns are more common in the upper levels, when there was also a significant increase in the surface area of the site. These trends represent a shift towards greater reliance on larger-scale cereal exploitation. Neighbouring sites such as Tell 'Abr, Mureybet and Cheikh Hassan have remarkably similar, if less well-preserved, remains and given the available evidence it is probable that comparable developments took place at these sites.

These trends point to an increase in social organisation. Large-scale cereal exploitation required labour for preparing land, sowing, weeding, crop protection, storage, harvesting and processing. These tasks would have been organised collectively, implying a social hierarchy. The cereal economy would have been intertwined with the social fabric of village life. Our evidence underpins Trevor Watkins' hypothesis that during this period there is an increasing "reliance on larger and more cohesive social groups", and that trends towards cultivation like those we have seen at Jerf el Ahmar "involved greater investment of labour and technology for . . . harvesting and food processing" (Watkins 2010: 622, 624).

Jerf el Ahmar thus provides a window of 500 years that illuminates the transition from foraging to farming which started during the Natufian and culminated in the Middle PPNB. In northern Syria this transition is exemplified by the contrast between the small pit dwellings at Natufian Abu Hureyra and the rows of quasi-identical dwellings at Halula, where mixed domestic farming was established by about 8000 cal BC. The discoveries at Jerf el Ahmar demonstrate that large-scale cereal exploitation and cultivation were practised at least a millennium before this date.

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