

A PRELIMINARY REPORT ON THE NEOLITHIC BARRAGE SURVEYS IN THE EASTERN JAFR BASIN, 2013 - 2014

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1. Introduction

The Jafr Basin Prehistoric Project (JBPP) was established in 1995 with a view to tracing the process of pastoral nomadization in southern Jordan on the basis of archaeological evidence. The first two phases of the project, which took place in 1997 - 2002 and 2003 - 2008 respectively, focused on the establishment of a local chronology for the basin during the early Holocene. To achieve this objective, we successively excavated more than a dozen sites varying in date and nature from Pre-Pottery Neolithic B (hereafter PPNB) outposts to Early Bronze Age (hereafter EBA) cairn fields. This series of excavations have enabled us to draw a rough flow chart of the process of pastoral nomadization in southern Jordan (Fujii 2013).

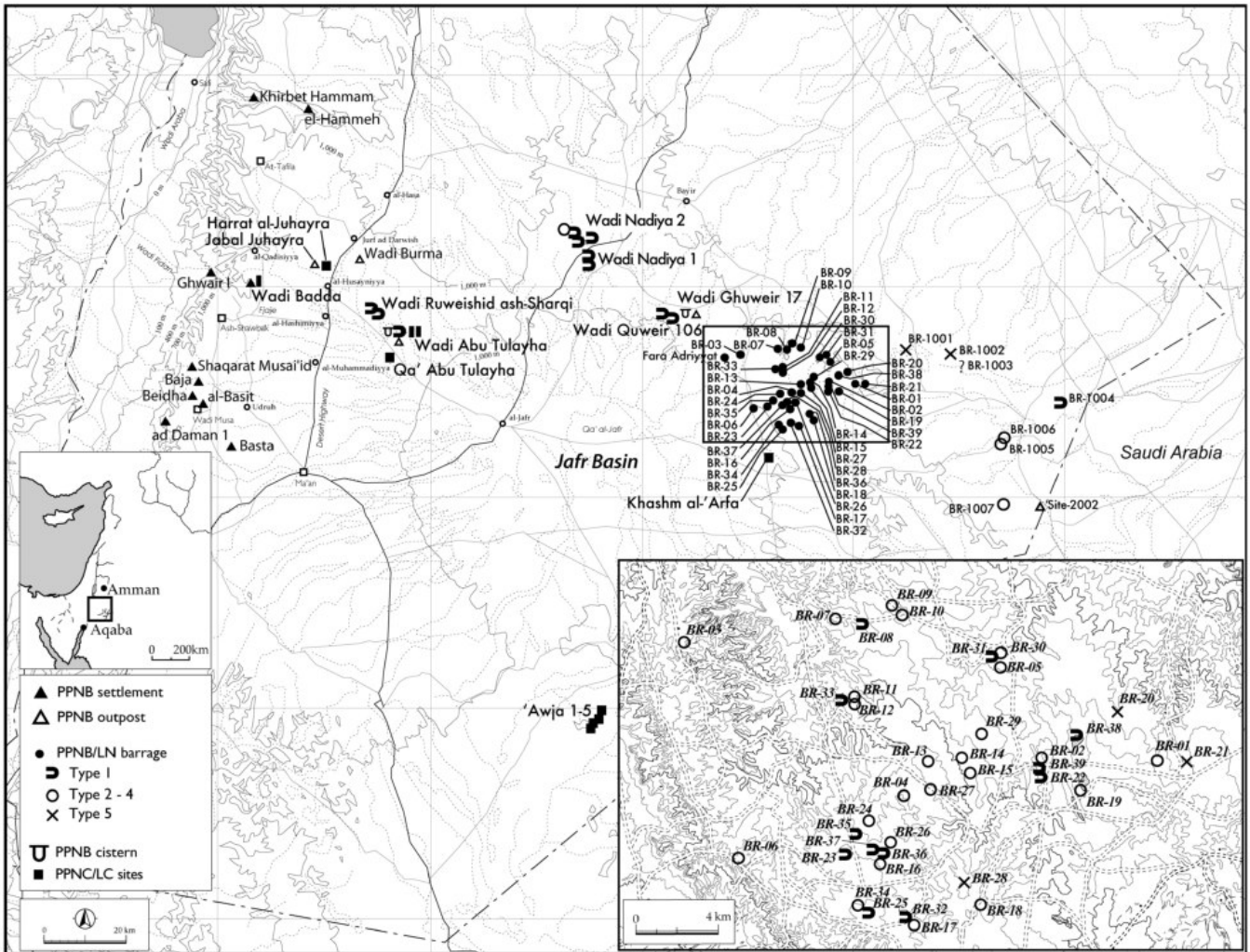
The subsequent Phase 3 started in 2009 and continues until now (**Fig. 1**). This phase has dealt with the history of water use in the Neolithic Jordanian *bardia*, which was inspired by the discovery of basin-irrigation barrages and a cistern at the Middle to Late PPNB (hereafter M-LPPNB) outpost of Wadi Abu Tulayha in 2006 (Fujii 2007a, 2007b, 2007c, 2010b, 2010c). To date, we have conducted a total of eight seasons. The first, which took place in summer 2009, was devoted to a retrospective survey of supposedly prehistoric water catchment facilities known in the basin at that time (Fujii 2010a, 2010b). It enabled us to define a general direction for subsequent research.

The second season, conducted in summer 2010, dealt with a rescue excavation at Wadi Ghuwayr 106, a barrage system located above the escarpment fringing the north-eastern edge

of the basin (Fujii 2012; Fujii, Adachi *et al.* 2011). The excavation provided insights into the procurement of construction material and the system by which Jafr Neolithic barrages were renewed. We also excavated the nearby PPNB outpost of Wadi Ghuwayr 17, which proved to be a promising candidate for an operating component of the barrage system (Fujii, Quintero *et al.* 2011). Not only that, a supplementary excavation undertaken in the summer 2012 showed that the outpost was equipped with a small-scale, semi-subterranean cistern as well. This series of findings confirmed once again that the 'triple set' evidenced at Wadi Abu Tulayha (i.e. the combination of an outpost for seasonal habitation, a basin-irrigation barrage system supporting a standalone cereal field, and a cistern as the major source of drinking water) was the norm for the Jafr Pastoral PPNB.

The third to fifth seasons, conducted from spring 2011 to spring 2012, excavated a total of six barrages constituting the newly discovered Wadi Nadiya 1 and 2 barrage systems in the northern part of the basin. The excavations suggested that the system started with a large-scale, open-type, basin-irrigation barrage which gradually morphed into a small-scale, semi-closed, cistern-type barrage over the course of downstream renewal (Fujii 2012b; Fujii, Adachi *et al.* 2012, 2013). It is our present interpretation that the former was part of the fully-fledged social infrastructure of PPNB pastoral transhumants, whereas the latter represents an ad hoc water-use facility associated with early pastoral nomads.

Following these results, the sixth to eighth field seasons, undertaken from spring 2013 to



1. Neolithic barrages located in the Jafr Basin (as of March 2014).

spring 2014, moved to the eastern part of the Jafr Basin where several dozen barrages were newly discovered. The surveys have made it possible to trace the process of pastoral nomadization from the perspective of water use in the arid periphery. This report summarizes the results of the recent surveys in the eastern Jafr Basin and briefly discusses their archaeological implications.

2. Site Setting

As noted above, our recent surveys have focused on the hilly terrain fringing the eastern edge of the Jafr Basin. The natural environment of the area is characterized by a hyper arid climate with an average annual rainfall of less than 50 mm (Jordan National Geographic Center 1984: 114). Thus the local vegetation is very poor, with local land use being limited to seasonal

pasturing taking advantage of thorny perennial shrubs dotted in *wadi* beds and the appearance of annual grasses in early spring. Understandably, no traditional settlements are present. All that can be seen, if anything, are isolated black goat hair tents and pick-ups driving off in clouds of dust.

This is not to say, however, that the hilly terrain is a sterile desert. In fact, it serves as a major migration route for modern local nomads. This is, first, because the terrain is actually relatively flat in topography and easy to pass through with livestock and, second, because it occasionally experiences unpredictable torrential rain and for this reason witnesses the appearance of seasonal watering places and pasture (Fig. 2). What gives further advantage to the area is the presence of high-quality Eocene flint deposits (Fig. 3), which were exploited - though intermittently



2. Small pasture around BR-10 (looking north).



3. Tabular scraper flint mines in the Adriyyat area, eastern Jafr (looking south-east).

- from the Palaeolithic to at least the EBA (Quintero and Wilke 1998a, 1998b; Quintero *et al.* 2002). The hilly terrain must have attracted prehistoric occupants for this reason as well. The concentration of Neolithic barrages in the area can be understood in these contexts.

3. The Survey

We conducted a preliminary survey over the last few days of the summer 2012 field season and confirmed that supposedly Neolithic barrages were concentrated in the western part of the hilly terrain (Fujii, Adachi *et al.* 2013). To cover this promising terrain, we established a survey area demarcated by the following four straight lines: latitude 30°28.000 N for the northern limit, latitude 30°17.000 N for the southern limit, longitude 037°08.000 E for the eastern limit and longitude 036°49.000 E for the western limit. The 2012 - 2013 surveys took

place in this survey area, which covers *ca* 620 km² and lies at an elevation of *ca* 850 - 1,000 m.

The surveys focused on water-catchment facilities only. When we encountered other archaeological features, such as cairns and enclosures, we briefly recorded their general traits, leaving their details to future investigation. Since the survey area was extensive, we examined satellite images from *Google Maps and Bing Maps* in advance to identify promising areas. We then visited these areas with a portable GPS receiver and registered, or occasionally rejected, individual examples on the basis of this ground-truthing. The barrages registered in this way account for nearly the half of the total. The other half consists of barrages that were newly discovered without prior reference to satellite imagery.

Forty-six barrages were registered. Thirty-nine (BR-01 to -39) were located in the original survey area, and the remaining seven (i.e. BR-1001 to -1007) were found by chance outside it during our day-off excursions. We recorded their attributes (including coordinates, surrounding topography, dimensions, construction, technology and surface finds) and then produced a ground plan. When not windy, we tried aerial photography using a remote-control helicopter as well. In addition, we produced a site contour map of several typical examples and examined, in a few cases, their internal structure by means of excavating a test trench across the barrage wall.

The following description will deal only with the barrages located in the original survey area, leaving the others for future publication. We would like to point out in advance that our surveys were less intensive and, therefore, require further scrutiny for grasping all the details of the Neolithic barrages in the area.

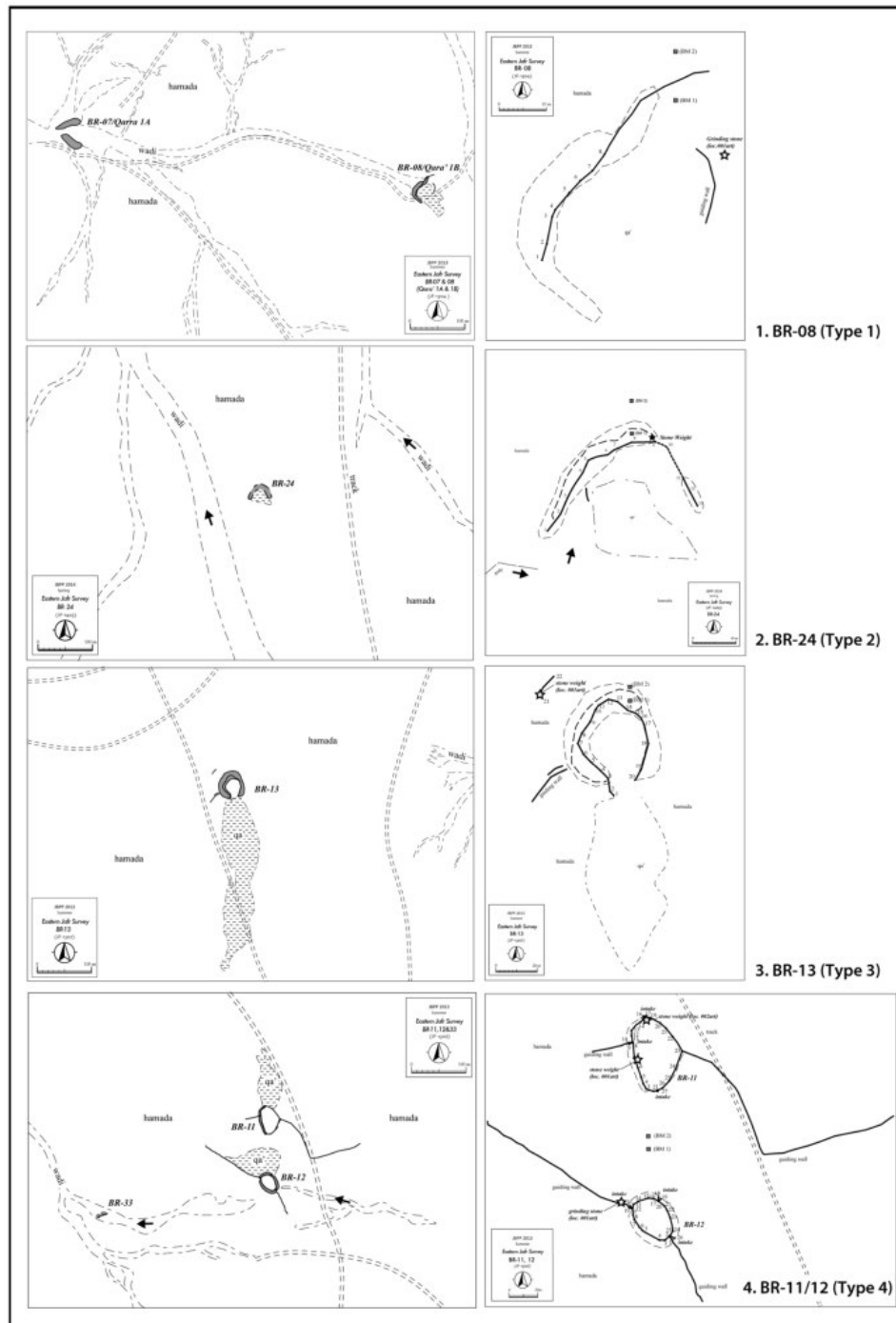
4. The Barrages

The registered barrages fall into the following five major types, including one variant. Since we cannot afford to go into the details of individual examples, the following description will only summarize the general traits of each barrage type.

Type 1a

This type of barrage is characterized by its large scale, open plan like a spread bird, and its location at the lower edge of a small- to medium-scale, semi-open drainage system or across a small-scale open drainage system (Fig. 4:1; Fig. 5). It is simple in terms of structure, consisting only of a low masonry wall and undeveloped rear bank. Most of the PPNB

barrages currently known in the western half of the Jafr Basin are of this type (Fujii 2010c, 2013). In contrast, the eastern Jafr Basin has only a few examples. Among them is Barrage No 08 (hereafter BR-08), which measures *ca* 55 m long and *ca* 0.3 m in preserved height. The Type 1a barrage has a shallow and extensive flooded area and would, therefore, have been unsuitable for long-term water storage. Thus, it



4. Barrage Types 1 - 4: surrounding topography and plans.

was probably used for short-term basin-irrigation of a standalone cereal field (Fujii 2010c). It may be meaningful in this regard that this type of barrage is predominant in the western Jafr Basin, closer to Neolithic farming communities, but is rare in the more distant eastern basin.

Type 1b

The Type 1b barrage is a smaller or miniature version of the Type 1a barrage, having a total length of *ca* 10 - 20 m in most cases and a straight or slightly curvilinear plan. The rear bank of this type of barrage is even more undeveloped than in Type 1a. The use of the Type 1b barrage has yet to be firmly confirmed, but a use similar yet supplementary to Type 1a is conceivable. In the western Jafr Basin, BR-2 and -3 of Wadi Abu Tulayha and BR-1 and -11 of Wadi Nadiya 2 belong to this type. In the east, a dozen examples, including BR-36, are



5. BR-08 (Type 1a): general view (looking north-west).



6. BR-36 (Type 1b): general view (looking north).

similar (Fig. 6). However, these might include *ad hoc wadi* barriers of a later period and thus require further scrutiny for final categorisation.

Type 2

Type 2 barrages have a semi-circular plan with a diameter of *ca* 20 - 40 m (Fig. 4:2; Fig. 7). Unlike the Type 1 barrages, this type of barrage is usually located across a small gully or shallow depression surrounded by gentle slopes and equipped with a relatively high rear bank. These differences are suggestive of a functional shift from short-term basin-irrigation to long-term water storage. The Type 2 barrage can be defined a transitional form between these two functions. While the western Jafr Basin has only one example (BR-3 of Wadi Nadiya 2, being the final component of the Nadiya barrage system), the eastern Jafr Basin has several examples including BR-24. The focus of Jafr Neolithic barrage activity was to shift eastward from this type of barrage onwards.

Type 3

The Type 3 barrage has a more closed form, being characterised by a round to oblong plan, the incorporation of a relatively narrow entrance *ca* 5 - 10 m wide and the attachment of a few short water-guiding walls (Fig. 4:3; Fig. 8). It is relatively large in scale, measuring up to *ca* 50 m in diameter (or across the longer axis) and up to *ca* 1 m in preserved height. In comparison with the Type 2 barrage, it has a tendency to be located in even smaller and more enclosed drainage systems. There is no doubt that the Type 3 barrage developed out of the Type 2 barrage with a greater focus on long-term water storage. A trench excavated across the north-western wall of BR-02 demonstrated that the barrage was associated with a shallow pond *ca* 1 m deep that was protected with a retaining wall (Fig. 9). It is however possible that the pond was originally dug as an open-air limestone / flint quarry for barrage construction. No typical examples of this type have been found in the western Jafr Basin, whereas the eastern basin has a dozen



7. BR-24 (Type 2): general view (looking south-east).



8. BR-13 (Type 3): general view (looking north-east).



9. BR-02 (Type 3): trench excavation at the north-western wall (looking north-west).

examples including BR-13. As suggested above, this contrast probably means that the centre of gravity of seasonal pasturing shifted eastwards during the course of pastoral nomadization.

Type 4

This type of barrage represents the final form in this sequence of typological change and is characterized by a closed plan, the incorporation of a few very narrow inlets less than 1 m wide and the attachment of a few long water-guiding walls (**Fig. 4:4; Fig. 10**). The location of Type 4 barrages is similar to that of Type 3 barrages, with a shallow depression or flat terrain surrounded by gentle slopes being preferred. There is no doubt that this type of barrage was used for water storage. Again, no examples have been located in the western Jafr Basin, but the eastern basin has several examples including BR-11 and -12. The Type 4 barrage is usually large in scale, having a long axis measuring *ca* 50 m in, for example, the case of BR-11. The trench excavations at BR-12 demonstrated that it incorporated a man-made pond *ca* 1.5 m deep within the barrage wall, and that the soil and rubble thus derived were used in the construction of the barrage wall and rear bank (**Fig. 11**).

Type 5

The Type 5 barrage is a catch-all category that includes all miscellaneous barrages other than the abovementioned types. They include a few large-scale, amorphous barrages such as BR-20 and -28 (**Figs. 12 and 13**). This type of barrage differs from the others in terms of location and often occupies the flat bank of a medium-sized *wadi*. In addition, unlike the Type 1 - 4 barrages, it yields no diagnostic artifacts of the Jafr Pastoral Neolithic such as bilaterally notched stone weights or diagonally truncated stone bars. It is therefore likely that the Type 5 barrage belongs to a post-Neolithic period. Again, no parallel examples have been found in the western Jafr Basin.

5. Small Finds

Small finds from the barrages are scarce in both variety and quantity, being limited to a dozen bilaterally notched stone weights, a few diagonally truncated stone bars and other miscellaneous artifacts. This scarcity



10. BR-12 (Type 4): general view (north-west).



11. BR-12 (Type 3): trench excavation at the western wall (looking west).

of small finds is normal for Jafr Neolithic barrages, but makes sense when we consider they are extramural, non-residential structures. Some stone weights were found *in situ* in barrage walls, but all of the other artifacts (including the remaining stone weights) occurred as stray finds around the barrages.

Bilaterally Notched Stone Weights

The limestone bilaterally notched stone weight is a hallmark of the Jafr Pastoral Neolithic, being characterised by a figure-of-eight-shaped profile formed or emphasized by a pair of bilateral notches and / or bifacial grooves (**Fig. 14:1-2**). It is conceivable that they were originally produced as stone weights for tightening the ropes of a thatched or tent-like structure and were then incorporated into a nearby barrage

wall, either as repurposed building material or as a ritual object aimed at guaranteeing the safety and longevity of the barrage concerned (Fujii, Adachi *et al.* 2011: 203-204).

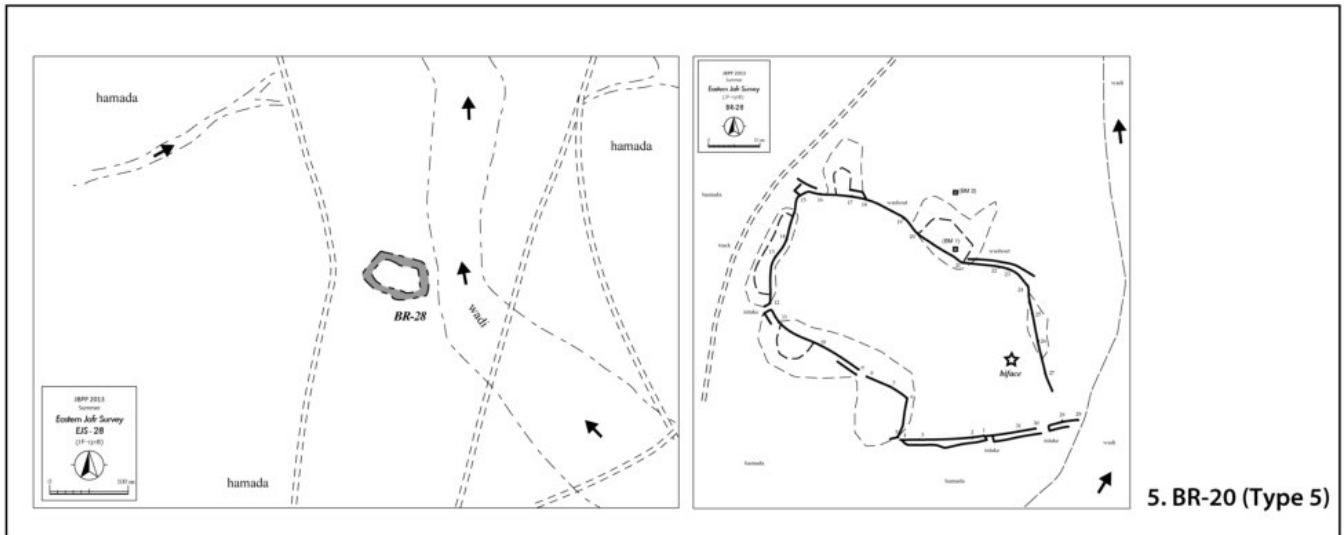
More than a dozen barrages (excluding Type 5 examples) yielded this unique artifact. The number of stone weights per barrage was usually one, less frequently two. (Only BR-10 yielded a total of four stone weights, which included three stray finds found by chance at points more than 100 m away from the barrage.) Similar limestone products occurred at most of the PPNB barrages known to date in the western Jafr Basin, indicating that the incorporation of these unique stone weights was normal for Jafr Neolithic barrages (Fujii 2013: fig. 13). It should however be noted that while the PPNB examples are usually large (> *ca* 50 cm long) and heavy (> *ca* 50 kg), all of the new finds from the eastern Jafr Basin are much smaller (< 30 cm long) and lighter (< *ca* 10 kg). This contrast seems to reflect a chronological difference between the two, noting that the nearby LPPNB / PPNC encampment of Khashm al-'Arfa yielded the latter type only (Fujii *et al.* this volume). Thus, these stone weights may serve as a chronological indicator for the eastern Jafr barrages.

Diagonally Truncated Stone Bars

The diagonally truncated stone bar made of limestone or flint is another hallmark of the Jafr Pastoral Neolithic and occurred, albeit as stray finds, at a few barrages (again excluding Type 5 examples) (**Fig. 14:3-5**). They are less standardized than the PPNB examples from the western Jafr Basin and can be regarded as debased successors. The remarkable edge damage on these heavy-duty tools suggests that they were used for digging a pond (which doubled as a limestone / flint quarry) in front of barrage walls.

Miscellaneous

Miscellaneous finds consist mostly of flint tools, which are dominated by various types of hard-to-date digging tools (**Fig. 14:7-10**). As



12. Types 5 of Barrage: surrounding topography and plan.

with the stone bars, these heavy-duty tools were probably used for digging a shallow pond in front of barrage walls. The consistent colocation of a barrage and digging tools is suggestive of chronological synchronism between the two, even more so when we consider how isolated the barrages are in the desert.

In addition, a sickle blade was found beside Type 1b barrage BR-22. It has invasive retouch along the lateral edge, suggesting a post-PPNB date. Remaining finds include a large limestone vessel or quern *ca* 60 cm in diameter (**Fig. 14:6**), a few grinding slabs made of porous basalt and several dozen reddish ware sherds, but their dates and contextual association with adjacent barrages are still unknown.

4. Discussion

These surveys have provided basic information for tracing the history of water-use in the Neolithic Jafr Basin. The question is whether the barrages that were discovered really belong to the Neolithic and, if so, what their specific use was. The following discussion will deal with these essential issues.

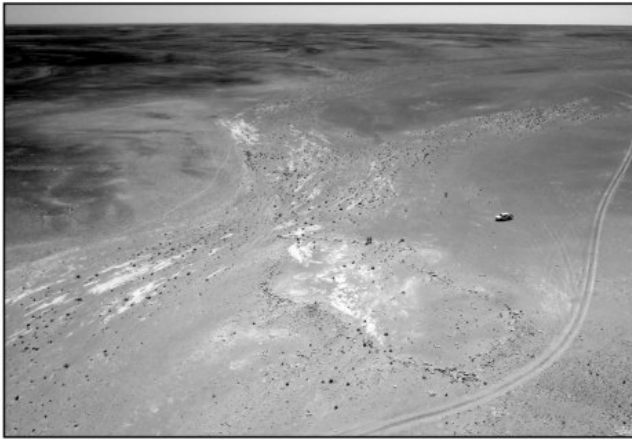
Dating

As with other extramural non-residential features, the stone-built barrages in the eastern Jafr Basin are deficient in contextual information, including C-14

data, and are therefore difficult to date. However, a few lines of collateral evidence suggest that most of them date back to the Neolithic.

To begin with, the horizontal stratigraphy at the Wadi Nadiya 1 and 2 barrage systems suggests that Jafr Neolithic barrages started with a large-scale, open type (Type 1a) which gradually gave way to a small-scale, closed type (Type 2) over the course of pastoral nomadization (Fujii, Adachi *et al.* 2012, 2013). The former type can be dated to the same horizon as the neighboring M - LPPNB outposts in view of the consistent colocation of the two. The latter type, on the other hand, probably dates to the immediately subsequent phase, *viz.* the end of the LPPNB or beginning of the PPNC. Assuming that the Type 3 - 5 barrages followed immediately on from Type 2, they could be attributed to the PPNC and / or Late Neolithic. It is our present perspective that the eastern Jafr Basin barrage complex covers, as a whole, a period from the M - LPPNB (Type 1a) to the PPNC / Late Neolithic (Types 2 - 4). Meanwhile, nothing can be said about the Type 5 barrage except that they probably postdate Type 4.

Further support for this provisional dating comes from the presence of bilaterally notched stone weights incorporated into barrage walls. As mentioned above, similar objects were found at the nearby encampment of Khashm



13. BR-28 (Type 5): general view (looking south).

al-‘Arfa, which is tightly dated, on the basis of several C-14 dates and diagnostic artifacts, to the LPPNB - PPNC transition (Fujii *et al.* this volume). In addition, diagonally truncated stone bars, another hallmark of the Jafr Pastoral Neolithic, are also shared between the encampment and the barrages. (Thus, it is possible that the encampment was an operating component of the barrages dotted across the surrounding area.) These facts, together with the horizontal stratigraphy referred to above, strongly suggest that the eastern Jafr Basin barrages (excluding Type 5) date to the Neolithic. OSL dating is now in progress and is expected to yield specific evidence relating to the provisional dating outlined above.

Location and Use

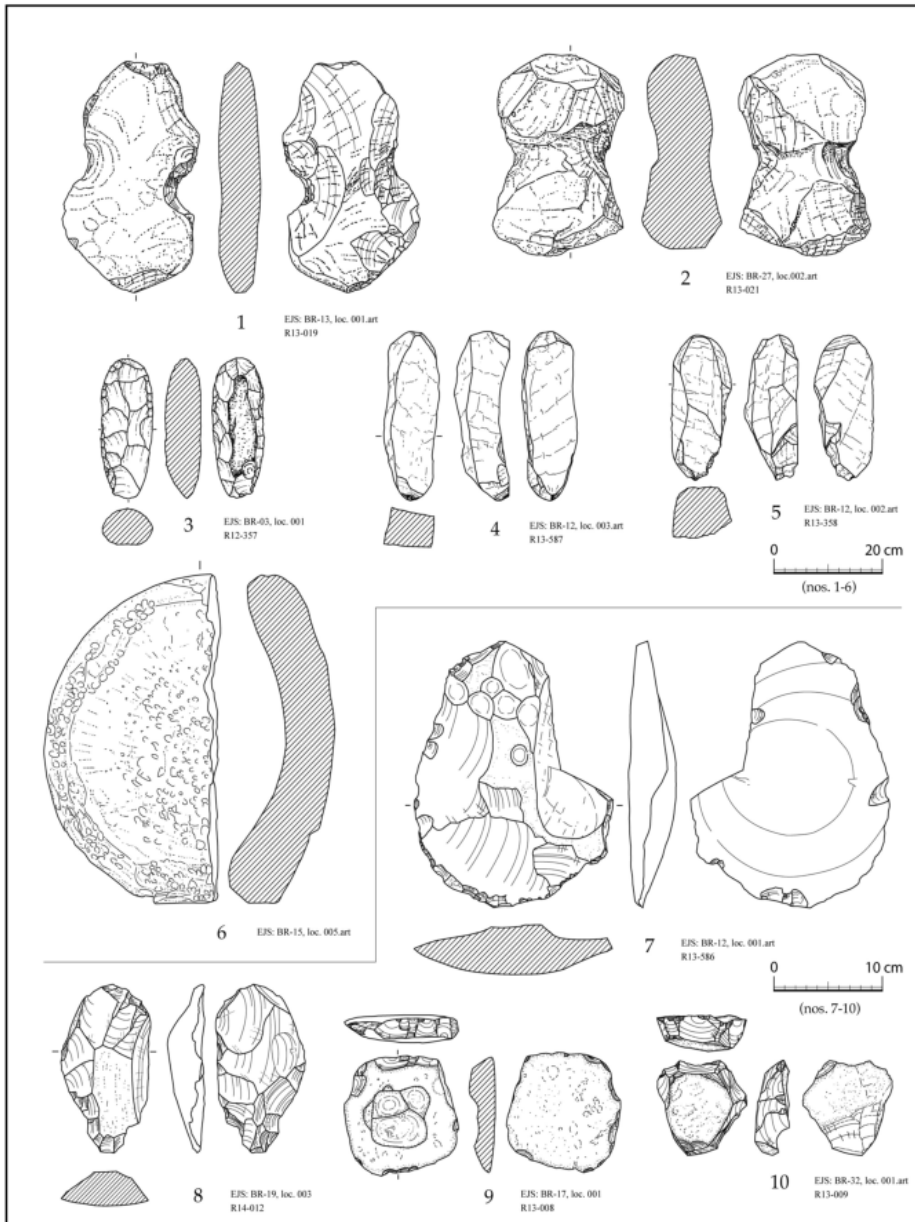
Our previous excavations in the western Jafr Basin showed that: (1) the M - LPPNB barrages are large in scale and open in plan, (2) they are located at the lower edge of a small-scale, semi-open playa system and (3) they are often combined with an agro-pastoral outpost such as Wadi Abu Tulayha or Wadi Ghuwayr 17 (Fujii 2010c, 2013). The first two observations suggest that the barrages were designed to produce an extensive, shallow, flooded area on permeable terrain adjacent to the barrage wall. Taking the third observation into consideration, it is likely that M - LPPNB barrages in the eastern Jafr Basin were used for basin-irrigation of a standalone cereal field or pasture. They were

often renewed downstream along the same watercourse, which suggests that basin-irrigated agriculture in the arid periphery had to deal with salt damage (Fujii and Adachi 2011: 209-210).

The eastern Jafr Basin barrages stand in contrast to the M - LPPNB examples. Aside from the Type 1a and 1b examples common to both areas, they are not only smaller in scale and more enclosed in plan, but are also more typically located in even smaller-scale, semi-closed drainage basins. In addition, downstream renewal is rarely recognized with the exception of a combination that includes a Type 1a barrage as the upstream component. It is thus evident that most of the eastern Jafr Basin barrages were intended for long-term water storage rather than short-term basin irrigation. Most typical are the Type 3 and 4 examples, which were probably used as open-air cisterns for early pastoral nomads and their livestock. We may argue on the one hand that their location in the center of a small-scale, flat, semi-closed drainage basin made it possible to collect surface runoff water in safety, and on the other hand that they required the assistance of a few long water-guiding walls. The abandonment of downstream renewal is probably linked to the fact that cistern-type barrages no longer needed to worry about salinization of surface soil.

Barrage Chronology

The above discussion leads us to the view that Jafr Neolithic barrages began with large-scale, open, basin-irrigation barrages (Type 1a) located at the lower edge of a semi-open playa system, and then gradually gave way to smaller-scale cistern-type barrages (Types 2 - 4) located across a small gully or in a shallow depression at the center of a semi-closed drainage basin (**Fig. 15**). We should note that: (1) while the former are clustered in the western Jafr Basin nearer to PPNB farming communities, the latter penetrate deep into the desert far from settled areas; (2) while the former is often combined with a M - LPPNB agro-pastoral outpost, the latter is usually isolated in the desert and

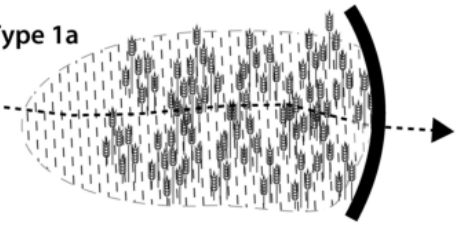

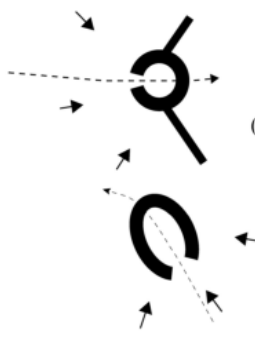
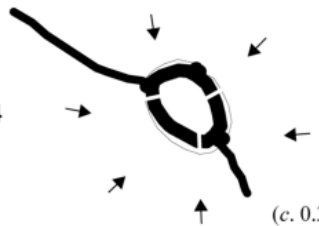
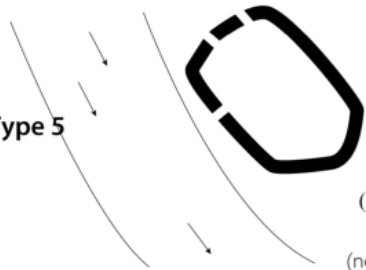


14. Small finds from Type 1 - 4 barrages.

not associated with such a fully-developed operating component; (3) while the former is low in density (despite intensive survey), the latter is much more common (despite the limited number of surveys). All this seems to indicate that while the western Jafr Basin barrages were part of the fully fledged social infrastructure of M - LPPNB pastoral transhumants, most - if not all - of the eastern basin barrages were instead *ad hoc* watering places of subsequent early pastoral nomads. However, this is not to say that the eastern Jafr Basin was first exploited in the post-PPNB period. The presence of a few

Type 1a barrages suggests that the area had been partially incorporated into the seasonal migration routes of M - LPPNB pastoral transhumants. Such a pre-adaptation probably paved the way for the florescence of early pastoral nomadism.

Though still tentative, the barrage chronology makes it possible to trace the process of pastoral nomadization from the perspective of water-use in the arid periphery. Incidentally, the M - LPPNB outposts were equipped with a semi-subterranean cistern as well as with basin-irrigation barrages (Fujii 2008, 2009, 2013, n.d.). Taking this into consideration, we can

Barrage Types	Location	Western Jafr	Eastern Jafr
<p>LPPNB: Basin-irrigation barrage combined with an agro-pastoral outpost</p> <p>Type 1a</p>  <p>(flooded area: c. 2-3 ha)</p>	<p>lower edge of a semi-open playa system</p>	<p>WAT: Barrage 1 WRS: Barrage 1, 2 WGW: Barrage 1, 2</p> <p>WND 1: Barrage 1, 2</p> <p><i>downward renewal</i></p>	<p>BR-08, 32</p>
<p>Type 2</p>  <p>(c. 0.1-0.2 ha)</p>	<p>small wadi/gully bed</p>	<p>WND 2: Barrage 2</p> <p><i>downward renewal</i></p> <p>WND 2: Barrage 3</p>	<p>BR-07, 10, 24, 26, 27, 30</p>
<p>PPNC/LN: Cistern-type barrage isolated in steppe and desert</p> <p>Type 3</p>  <p>(c. 0.1-0.2 ha)</p> <p>(c. 0.3-0.5 ha)</p>	<p>small, semi-closed</p>	<p>?</p>	<p>BR-03, 06, 15, 29</p> <p>BR-13</p>
<p>Type 4</p>  <p>(c. 0.3-0.5 ha)</p>	<p>small, semi-closed</p>	<p>?</p>	<p>BR-11, 12, 18</p>
<p>Later Period ?</p> <p>Type 5</p>  <p>(c. 1-2 ha)</p> <p>(not to scale)</p>	<p>beside a turning point of a medium-scale wadi</p>	<p>?</p>	<p>BR-20, 21, 28</p>

15. Tentative chronology of the Jafr Neolithic barrage.

argue that early pastoral nomads combined the function of the cistern and the technology of the barrage to fulfill the demands of what was a new way of life in the arid periphery.

Archaeological Implications

In contrast to the relatively high archaeological visibility of the M - LPPNB pastoral transhumants, the presence of early pastoral nomads in the Jafr Basin has hitherto been barely understood through open-air sanctuaries such as Qa' Abu Tulayha (Fujii 2003), Harrat al-Juhayra (Fujii 2003) and the 'Awja sites (Fujii, Yamafuji *et al.* 2012; Fujii, Adachi *et al.* 2013). The newly discovered post-PPNB barrages, together with the small encampment of Khashm al-'Arfa, have offered us a first glimpse into their daily life. In this sense, they have the potential to lead to a breakthrough in coming to a comprehensive understanding of the formation processes of *badia* society.

To begin with, the survey data provide a means of exploring the distribution and migration patterns of early pastoral nomads. It is now evident that the hilly terrain of the eastern Jafr Basin was incorporated within their major itineraries. The question now concerns the seasonality of migration, which is typically constrained by rainfall patterns in Jordan and surrounding countries. Taking this into consideration, it is almost self-evident that use of the barrage would have been focused on a few months from late winter to early spring. Further support for this assumption comes from the faunal assemblage from Wadi Abu Tulayha, which indicates that M - LPPNB pastoral transhumants left settled areas to reside in the arid margins during late winter and spring (Hongo *et al.* 2013). Assuming that subsequent early pastoral nomads followed the same pattern, it would follow that the barrages in the eastern Jafr Basin represent pasturing in early spring. However, limited information is available at this stage and further investigation is required to understand year-round migration patterns.

The barrage data provide some insight into

early pastoral nomad group size as well. It is needless to say that, aside from Type 1b, barrage construction would have necessarily have involved more than a nuclear family. The residential complex at the contemporary encampment of Khashm al-'Arfa is a good reference for examining this issue (Fujii *et al.* this volume). It consists basically of three small houses, suggesting that early pastoral nomads migrated as an extended family or aggregation of a few nuclear families, at least in their late winter to early spring locations. Given this, such a group or an aggregation of such groups would likely have been involved in barrage construction.

The barrages also offer an intriguing hint regarding herd size in early pastoral nomadic communities. In view of their scale, it is conceivable that the barrages were designed for a relatively large herd. At the very least, it is highly unlikely that they were constructed for a dozen or so animals. Turning the argument around, it was likely the expansion of herd size (and probably the establishment of herd management techniques) that first made a nomadic way of life possible which, in turn, probably required the establishment of anthropogenic watering places along migration routes.

To conclude, a brief comment should be made about the archaeological implications of the eastern Jafr Basin barrages in a broader context. The presence of Neolithic barrages in the eastern basin, together with the existence of a contemporary water harvesting and storage system in the Azraq Basin (Betts and Helms 1989), again demonstrates that water-use technology was key to the full-fledged penetration of the arid margin in the early Holocene. Suggestive in this respect is Mushash 1, a small PPNB settlement recently located near the Saudi border, which is also associated with a barrage (Fujii *et al.* 2014). The hilly terrain in which the cistern-type barrages cluster corresponds to an intermediate area between the easternmost PPNB represented by Mushash 1 and the Jafr Pastoral PPNB represented by Wadi Abu Tulayha. Considered in this light it

is no wonder that the area contains many post-PPNB Neolithic barrages, even more so when we consider that the existence of the Saudi PPNB is now becoming clearer (e.g. Conolly 2013; Crassard *et al.* 2013; Drechsler 2009; Fares and Rokitta-Kurmnov 2013; Fujii and Adachi n.d.; Rothert 1938). The location of the post-PPNB barrages in the eastern Jafr Basin can be understood in this broader context.

5. Concluding Remarks

Our recent surveys have suggested that a large number of Neolithic cistern-type barrages are located in the eastern Jafr Basin. This in turn suggests that, as with the case of pastoral transhumance, innovation in water-use technology lay behind the emergence of pastoral nomadism. In this sense, the techno-typological sequence of the Jafr Neolithic barrages provides a valuable key in tracing the process of pastoral nomadization in southern Jordan. If the sample size increases as a result of future investigations, and if a barrage chronology is fully developed, it might also become possible to discuss the issue phase by phase. We would like to continue the Neolithic barrage survey with a view to gaining a more comprehensive understanding of the formation process of *badia* society.

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