NEO-LITHICS 2/10

The Newsletter of Southwest Asian Neolithic Research

Special Topic on *The Domestication of Water*

Editorial

How rapid Neolithic research proceeds. Two trends can be observed in recent times: A struggle for new interpretative frameworks generating new topics (or old topics in new perspectives), and booming studies contributed by freshly applied technologies of science (all sorts of isotope analysis, for instance) or new interpretations from disciplines previously rarely involved in Neolithic research (*e.g.* evolutionary biology). In the good old times, all new questions and research generated by specialist studies and new frameworks were filtered, tested and coordinated with the project's archaeological, bio- and geoarchaeological results. Is this still the case these times? Only partially, and not to the same extent. There seems to be a tendency for some "isolated" if not "separatistic" Neolithic specialist research, also resulting from a lack of (alerted) competency by prehistoric research to understand, evaluate and integrate these results properly. In particular, information produced by the new „auxiliary" disciplines (as we tend to understand them) and new interpretative frameworks often remain neglected, or their use is delayed, because we traditional researchers of the Neolithic have little capacity and awareness to understand their new potentials, restrictions, terminologies, *etc*., and thus are not real research partners except on a very general level. However, we feel that much of our understanding has already or will become outdated and should be reconsidered by these new approaches. Often the new results or new directions of research render our beloved traditions and stereotypical understanding obsolete, or at least do question them, and a psychological barrier arises that hinders cooperation and adoption of their utility and explanatory power.

Where will this all lead? Certainly, the "cacophony index" of our research will rise, and there will be pressure to unite in circles to apply and promote certain interpretations, and the number of different research frameworks will increase. How good or bad is this diversity for our research?

This special topic issue of Neo-Lithics is much delayed. We apologize to the guest editor of this issue, Sumio Fujii, for tardy publishing. The domestication-of-water concept received an immense momentum by Sumio's outstanding results from his work near Ma'an, leading us to extend our invitation to him to coordinate a Neo-Lithics special issue on water domestication. The original concept to have keynotes on water domestication that we discussed with him failed for various reasons, thus this issue has to be understood as a sampler on the topic. We warmly thank Sumio Fujii for all his steady, patient and friendly efforts to have Neo-Lithics 2/10 materialize.

Hans Georg K. Gebel & Gary Rollefon

The Domestication of Water. A Short Introduction

Hans Georg Gebel and Sumio Fujii

This issue of Neo-Lithics, compiled by one of us as the guest editor (S.F.), assembles a number of papers on what we decided to call the domestication of water, understanding that there is a great behavioral difference between "foraged" water and water needed to maintain more than a basic need, the drinking: Remaining a basic requirement for physical survival, of course, water in Neolithic times took on a number of key functions in the establishment and flourishing of producing societies, their economies, and innovative and symbolic environments. But it also became subject of molding the early cultural landscapes, altering and most likely also attacking the integrity of land-, animal- and plantscapes and their biodiversity; domesticated water surely became also a medium of impact on nature, as water deficits became a medium of technological innovation and accelerating developments.

Water means all to life, but settled life means a lot to the water households of nature. The different kinds of water, starting from the seawaters bringing early PPNB-people to Cyprus, via the cooking water in the Neolithic pottery, or the freshwater territories with its fish habitats claimed by Neolithic property regimes, to the water in the landslides endangering Neolithic houses, all these should become the water subjects of Neolithic research if we if we want to understand Neolithization.

The recent outstanding findings of early water management, some of which are represented in this volume, provide a glance into the array of topics involved, and the need to explore the meaning of water for us sedentary people.

The Near Eastern Neolithic social, economic, innovative, and symbolic developments need to be linked with the conditions of their hydrological background, by which they expanded and retreated, altered, and changed in processes taking place over five millennia in regions highly diversified in their hydrology.

This issue of Neo-Lithics is far from an attempt to merge the isolated Near Eastern evidence of early domestic water installations and management from the various periods into a general potential trajectory of water domestication. Rather, it assembles highlights of evidence to explain the extensive character of this novel topic.

The Commodification of Water

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Water and the Neolithic Ethos[1]

Two basic behavioral dispositions in human water consumption should be distinguished: passive ones that could show a variety of adaptive behavior to forage or routinely access available surface water for immediate consumption, and more active and preventive dispositions that are in addition governed by the need to secure and manage water for drinking and its use in productive milieus. The latter represents the new sectors of complex human water management that increasingly spread with sedentary life and its socioeconomies, based on the need for stable conditions for their territories, climate and hydrology, agriculture, flocks, crafts, and social systems. More than ever before, water in the Neolithic became an agent of vulnerability. Both dispositions might already appear linked to some extent in hunter-gatherer groups (for example, in areas or cases of potential water pollution or in deficit locations), but basically the character of water behavior in these groups remained adaptive and exploitative. The two dispositions cannot be seen as opposed behavioral patterns; they remained linked in Neolithic times, with the productive water behavior involving increasingly complex risk-buffering strategies throughout the millennia of the Neolithic evolution. Sedentary conditions require such active water strategies, or water management, since even a secure natural consumption based on rich nearby springs would require a „hydrosocial" management to avoid deficits created by other impacts, such as territorial or ideological claims, hygiene, etc. The new Neolithic human territoriality must have created a new vital and potentially conflict-loaded level of dependence on water (Gebel n.d., 2010b), and human hydrological competence must have gained momentum in nature-observation, water technologies, and sociohydrological strategies.

Among other topics, much research needs to be invested into the ethological questions related water subsistence in early Near Eastern villages, since they would allow working out the assumed fundamental changes in water behavior coming up with the Neolithic. For example, to what extent was the choice of a spring location for an early village part of an active disposition or that shared much of the foraging attitude (*e.g.* the Ba'ja case, Gebel 2004b)? Or, what are the parameters by which simple water tapping from wadi gravels could be understood as Neolithic „water work"?

Water and Productive Milieus

Water, like mineral resources, forests, grazing land etc., was available in the sites' environments and was used by the productive milieus of the new Neolithic life modes. Often construction work had to be invested to harvest, manage and process water in these permanent acquisition, use and discharge frameworks: This notion of Neolithic water, still neglecting the changed cognitive disposition of man to water and the vital role it played to sustain sedentary territoriality, only started to change after 2000 when domestic water findings forced questions about the domestication of water (Peltenburg *et al.* 2000, 2001a-b; Gebel 2004b; Garfinkel *et al.* 2006; Gillmore *et al.* 2007a-b; Fujii 2006, 2007, 2010-this issue). Since the 1190's Neolithic research had become more open to the idea that "domestication" is not only a signal of biological mutation, but also of cultural mutation, of - partly fundamental - behavioral changes in symbolism, technological strategies, resource and space management, etc. Such sights had opened ways to new approaches and understanding of Neolithic abiotic resources, including water.

More than any other basic element or substance, water and the ability to manage its productivity were crucial for the establishment and preservation of permanent productive life modes. Beyond "foraging" water, settled life had to make water subject to permanent preventive care, as in cases of territorial, seasonal, hygienic, climatic impacts, among others. As the major agent securing the success of Neolithic production and storage modes in the emerging cultural landscapes of the Near East (*e.g.* Watkins 2009), domestic water studies deserve to become integral parts of Neolithic research projects without which evaluations of Neolithic socioeconomic strategies fail to be comprehensive and conclusive.

I propose to consider all human behavior and measures to secure water and water access and discharge beyond its immediate consumption as Neolithic water subsistence; this definition includes the features of permanent "water territoriality" as well as measures of water storage and safeguarding against water. In other words, Neolithic water subsistence is characterized by an active behavior to secure and optimize the biotic and abiotic conditions by which food and other water-dependent products become available. It means that productive milieus were maintained and ruled by artificial water conditions, and artificial water conditions determine productive milieus. Developing water techniques found their immediate reaction and expression in the communities' social, technical, environmental and symbolic evolution. Water storage of its various kinds and water-based land use are the key socio-economic sectors in which new water techniques influenced, triggered and protected new modes and structures of sedentary life. The specific regional or local blend of water conditions and related technological opportunities created the special regional and local modes of water management. It is especially the storage aspect - from the possible harvesting of water in the sediments caught by wadi barriers to the introduction of impermeable containers - that makes water a subject of domestication, or commodification (Gebel 2010a), if not to speak of the „Neolithization of water".

Water was a basic commodity of Neolithic life. It was part of the early village reciprocity that was generated and supported by the commodification processes (*cf.* below) of its productive milieus, and played its vital role in many interacting contexts (landscape types, settlement patterns, resources, goods and labor, internal settlement/house organization, social identities, technological and ideological innovation); the need for, and use of, corporate and pacifying behavior and strategies to use water must have characterized the emerging Neolithic water frameworks. The Neolithic productive milieus are also known for their tendency for prolific momenta and accelerated developments, including the implosion of such processes (*e.g.* the Mega-Site Phenomenon, Gebel 2004a, 2007). Progressive population dynamics and surplus production appear to be related to new strategies of water management (*e.g.*, the development of hydraulic and pastoral societies in the 7th millennium BC): Water and its management in Neolithic times appears to have been a motor of innovation, and water deficits appear to have set free the strongest innovative energy. We have to expect that not only did water consumption increase due to the increasing population sizes, but also that the individual water consumption increased by the various new and prolific production spheres, probably introducing "modern" problems like the depletion of water resources and their quality or the reduction of biodiversity.

Basic work has been carried out on protohistoric and historic productive water milieus (*e.g.*, Wilkinson 2003, Brunner n.d., and others), and studies such as that by Araus *et al*. (1999) remain scarce in Neolithic research. Rather, prehistorians "meet" findings of Neolithic water work and so far interprete them in their conventional frameworks. However, and as a start, several models developed for later periods could be transferred with some modification to the Neolithic (such as the "water cube" of Ueli Brunner, Fig. 1).

Among others, the key questions of T.J. Wilkinson (2010- this issue) are vital for research success in Neolithic water management. Especially obstacles and limits have to be taken into account, such as the preservation of Neolithic water installations in the landscape (their ephemeral or non-permanent character, the re-use of such structures in succeeding periods, *etc*.). The Ma'an evidence (Fujii 2010- this issue), for instance, has probably survived because it came to exist in a marginal location that was not later re-useable as an irrigable wadi system. Apart from standard methods (sedimentology/ granometry, ^{14}C/TL/OSL dating, ICP-MS, palaeoethnobotany/ palaeo-palynology, traditional survey and excavation) much pioneer research would be needed to evaluate chances for data from indirect evidence of water use.

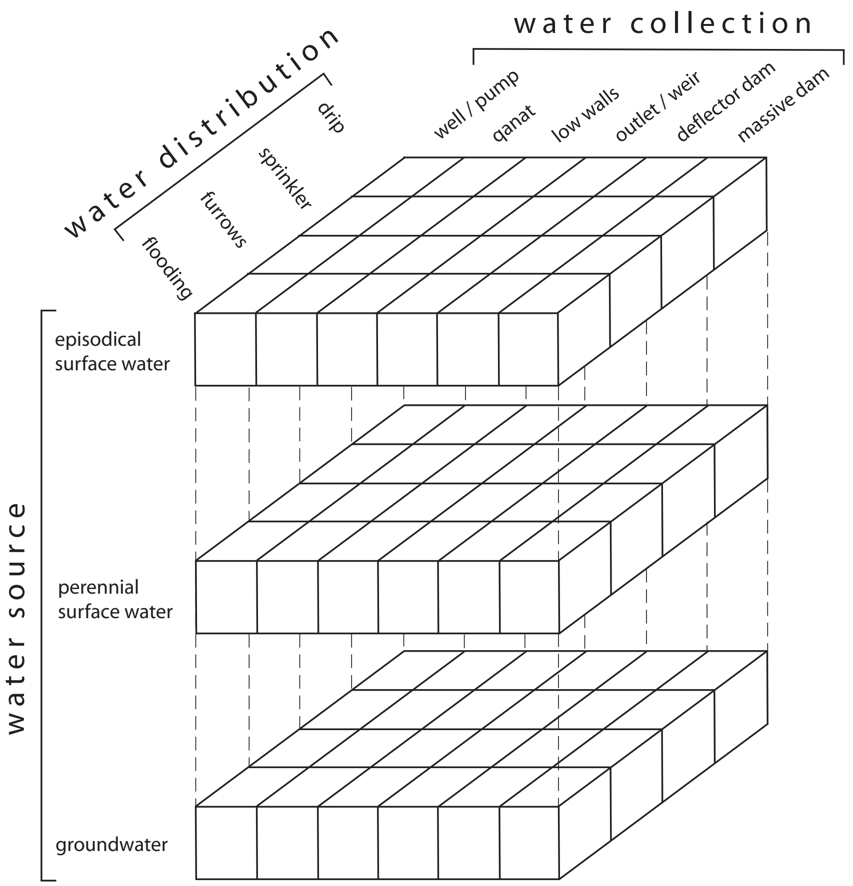

Fig. 1 The "water cube" of Ueli Brunner, developed for the antiquity (Brunner n.d., reproduced with the kind permission of the author).

Water and Commodification

This contribution to the special topic issue of Neo-Lithics on The Domestication of Water (Neo-Lithics 2/10) aims to adumbrate a new interpretative framework for Neolithic water, leading beyond the limits of its segregated understanding as an individual ingredient of Neolithization (or as an isolated "cultural domesticate"), offering rather its holistic contexts by understanding water as part of the Neolithic commodification processes (*cf*. Table 1).[2, 3]

The domestication of water might be understood as any sort of a constant human manipulation

Table 1 Preliminary attempt by author to structure potential features, parameters and questions of the early water commodification regimes in the Near East by subsystems and context/ use levels. (for this system's approach *cf*. Hermansen and Gebel 2004)

Environmental, Socio-Economic, and Cognitive Subsystems of Water Commodification	**Water Sources/ Aquatic Habitats**	**Acquisition Level (A) Procurement and Control Management**	**Consumption Level: (B) Production and Refinement**	**Consumption Level: (C) Processing / Use**
Local Environmental Subsystem: (1) Local Sources and Conditions	specific local environmental conditions of water availability (topography, precipitation/ melt water/ climate, sub-surface drainage, water storage capacity of soils/ woodlands/ etc., vegetation cover, etc.) permanent, intermittend, seasonal and/ or ephemeral water sources/ aquatic habitats: surface water: seepages, pools, springs, lakes, rivers, marshes/ swamps, brackish waters/ *sebkhas*, sea aquifers/ groundwater rain-fed drainage systems (potentially) arable rain-fed/ irrigable land, grazing land, drainage systems stability/ instability of water sources and related habitats water-salt balance parameters	removing water from open and "opened" (e.g. tapping aquifers, alluvial fans etc.) sources for consumption, craft work, gardening etc. ?manipulating groundwater (streams?) run-off/ flood water management relocating water from source for watering/ irrigation local exploitation of fresh- and seawater habitats: (seasonal) fishing, shell-fishing, amphibians, fowling, hunting, shell collection for ornament industry/ trade local share of (potentially) arable rain-fed/ irrigable land, grazing land, drainage systems etc. in relation to non-productive habitats	establishing hydraulic landscapes/ landscapes with water installations: building and maintaining irrigations systems gardening and farming, animal husbandry sedimentation/ salinization/ water logging impact management	direct consumption of water at natural source (humans, animals)
Regional Environmental Subsystem: (2) Regional Sources and Conditions	specific regional environmental conditions of water availability (topography, precipitation/ melt water/ climate, water storage capacity of soils/ woodlands/ etc., vegetation cover, etc.) permanent, intermittend, seasonal and/ or ephemeral water sources/ aquatic habitats: surface water: lakes, rivers, marshes/swamps, brackish waters/ *sebkhas*, sea aquifers/ groundwater (potentially) arable rain-fed/ irrigable land, grazing land, drainage systems stability/ instability of water sources and related habitats	removing water from source for consumption, for craft work etc. run-off/ flood water management relocating water from source for watering/ irrigation regional exploitation of fresh- and seawater habitats: (seasonal) fishing, shell-fishing, amphibians, fowling, hunting, shell collection for ornament industry	establishing hydraulic landscapes/ landscapes with water installations: building and maintaining irrigation systems	direct consumption of water at natural source (humans, animals)
Exchange/ Network Subsystem: (3) Long-Distance Sources	long-distance influence/ impacts on water availability (precipitation/ melt water/ climate, topographies, vegetation zones, etc.) permanent, intermittend, seasonal and/ or ephemeral water sources/ aquatic habitats: surface water: rivers, sea aquifers/ groundwater streams (potentially) arable rain-fed/ irrigable land, grazing land, drainage systems stability/ instability of water sources and related habitats	long-distance exploitation of fresh- and seawater habitats: (seasonal) fishing, shell-fishing, amphibians, fowling, hunting, shell collection for ornament industry		sea-based network transport/ migration/ trade, seafaring river-based network of transport/ migration/ trade
Technological Subsystem: (4) Household Production		clean/ potable water procurement and hygiene measures ? tapping aquifers/ groundwater by digging wells rainwater harvesting	intra-mural structural measures to protect houses from rain, moisture and surface water/ for habitational comfort water-based health/ sanitation management building and maintaining horticultural, field and irrigation systems, animal husbandry production of organic and mineral containers for water transport and storage water-using household activities (food processing, tanning, tool production, etc.) house supplies of water field and gardening techniques (e.g. soil moisture enhancement, land use intensification by watering etc.)	water-based health/ sanitation management/ potable water treatment wastewater management fire fighting water

Technological Subsystem: (5) Specialized Work		?impact management (water logging, salinization, sedimentation etc.) tapping aquifers/ groundwater by digging wells water collecting/ hauling techniques and equipment	?construction/ maintainance supervision in water works ?well builders and maintaining ?boat builders "industrial" water in crafts (e.g. pottery, tanning, ground stone industries) irrigation in rain-fed agriculture	?construction/ maintainance supervision in water works ?impact management (water logging, salinization etc.) ?well builders and maintaining ?water guarding sea-/ river-based trade
Technological Subsystem: (6) Corporate/ Community Enterprises		corporate/ communual water supplies, tapping of aquifers/ groundwater by digging wells intra-site and intra-mural structural measures to protect houses, corporate space, fields, springs etc. from rain and surface water ?impact management (water logging, salinization etc.) measures against cataclysmic water events (floods, land slides etc.): deflection walls, dikes and ditches (protecting landscape topography, fields, site fringes, houses) rainwater harvesting	built structures of corporate/ communual water (springs, wells, channels etc.) intra-site and intra-mural structural measures to protect domestic areas, corporate space, fields, springs etc. from rain, moisture and surface water storage of water by cistern-type of constructions or natural traps water-based health management relocating water to fields and gardens, maintenance: contour ditch irrigation/ contour check method, basin irrigation, submersion irrigation, ?free flooding, storage of moisture by soil retaining walls	?water-guarding water-based health/ sanitation management/ potable water treatment wastewater management fire fighting water sea-/river-based trade
Socio-Economic Subsystem: (7) Social Means	territorial control of water sources economic organization and rights of water access and procurement at regional and distant water sources for mobile herdsman engaged also in hunting/ gathering/ fishering, or for foraging groups still in the area regional and distant water sources as places of social contact and exchange	social organization and status questions of labour in water working, ?water management hierarchies, conveyance regimes local/ regional coordination of water working corporate standards/ behaviour and (socio-political) organization of: clean/ potable water procurement and hygiene measures, water distribution/ irrigation/ deficit management, intra-site measures to protect houses and corporate space etc. from moisture, rain and surface water, measures against cataclysmic water events (floods, land slides etc.) water and gender	social organization and status questions of labour in water working, ?water management hierarchies, conveyance regimes local/ regional coordination of water working corporate standards/ behaviour and (socio-political) organization of: clean/ potable water procurement and hygiene measures, water distribution/ irrigation/ deficit management, intra-site measures to protect houses and corporate space etc. from moisture, rain and surface water, measures against cataclysmic water events (floods, land slides etc.) water and gender	conveyance regulations sea-/ river-based exchange and migration
Socio-Economic Subsystem: (8) Economic Means	economic importance of water access and procurement at regional and long-distance water sources for mobile herdsman engaged also in hunting/ gathering/ fishering, or for foraging groups still in the area	economic organization of labour in water working local/ regional coordination of water working economic organization of water access and procurement including irrigation and deficit management rainwater harvesting	surplus production through water, and its reliability ?water supplies function as stored nutrition and productive means storage of water in organic and mineral containers, cistern-type constructions, natural traps storage of moisture by soil retaining walls (fields)	surplus production through water, and its reliability sea-/ river-based exchange and trade
Cognitive Subsystem: (9) Innovation	regional and distant water sources as places of exchange	social, economic and cognitive innovation related to water procurement and management ?sustainable integrated water resources management sustainability of water management (efficiency, conservation/ recycling etc.)	social, economic and cognitive innovation related to water-related production and refinement	social, economic and cognitive innovation related to water processing and use sea-/ river-based exchange of innovation
Cognitive Subsystem: (10) Tradition/ Conception/ Ritual	water territoriality, ?territorial water identities ?perception of water/ water-modified landscape regional and distant water sources as places of social contact and ideological exchange	the local water commodication (regime) and its ideology in general ?planning in water consumption, land use cropping arrangement water territoriality, ?territorial water identities water-related conflicts and conflict management corporate/ communual and individual rights in water access and procurement culturally induced measures, values and elements of water procurement and control for ritual, hygiene, of property etc. water and gender	the local water commodication (regime) and its ideology in general ?water supplies understood as stored nutrition/ liquid food and base of wealth culturally induced measures, values and elements of water procurement and control for ritual, hygiene, of property etc. "holy water" water and gender	the local water commodication (regime) and its ideology in general sea-/ river-based exchange of ideas, values, symbols, innovation etc. culturally induced measures, values and elements of water procurement and control for ritual, hygiene, of property etc. "holy water" water and gender

of water and water resources in productive systems; the commodification of water understands water in the same way, but in addition traces its value and value-producing importance and consequences in the cognitive, social, economic, and technological contexts of a Neolithic society: Neolithic people granted values to water (as an object of commodification), and water gave values to people and their social relations. Here it is advocated that the emerging and accelerating human control of biotic, abiotic, and non-material resources under sedentary conditions during the Near East's 11th to 6th millennia BC should be seen as parts of an overall Neolithic commodification process; Neolithic manipulation and control of resources has comprehensively affected all material and mental environments of emerging domestic life, including steering its technological progress, social developments, and ideological spheres. Potentially, most resources were subject to processes of commodification, and Neolithic water was no exception.

Whenever direct consumption of resources – including water – becomes dependent upon stocks (foraging to food producing), it becomes necessary to protect these supplies and to structure their allocation; water was the essential element to sustain these. At the beginning these supplies were probably predominantly nutritional, and included the developing idea that the food-producing land around the group's settlement including its water is supply in the shape of property. But the organization of supplies, and the activities necessitated by the need to accumulate supplies, forced people to commodify or give value to things – including water – and then further to secure these values by supporting them with ideologies. However, we do not wish to make the mistake of restricting incipient commodification to artificial or natural supplies. Commodification, or the attribution of value to things, may, but need not, originate from sustaining supply systems.

What were the Neolithic milieus in which water became a material and non-material commodity? Progressive population dynamics through philopatry, the wealth of time and goods beyond subsistence needs, and competition through diversification gave order to life and generated social identity. Commodification promoted security on all levels, as de- and ex-commodification could do: The internal and external security of the individual, his/her group, and his/her koinon (*sensu* Jacques Cauvin) is balanced by commodification regimes. The values commodification provides – including those of commodified water – are essential to maintain sedentary loyalties and structures: productive types of commodification are directly related to a sedentary ethos and territoriality, and would hardly work in non-sedentary societies (Gebel 2010a, n.d.). The commodification of water also meant dependence on and inflexibility through all sorts of water-based specialization in the early productive milieus, triggering interrelated exclusive behaviour and acceleration/agglomeration processes.

As far as the definitions of commodities and commodification are concerned I refer to (Gebel 2010a) wherein the original ideas and definitions of Appadurai (1986) and Kopytoff (1986) had been modified and „translated" to the Near Eastern Neolithic conditions. According to these definitions, Neolithic water could have - in addition to its basic importance as drinking water - the following major characteristics (preliminary):

1) It is subject to consumption and territorial claim.
2) Its availablity assists the survival of social, economic, political, and ideological systems. It can be used to produce prestige, commemoration, and values.
3) It is endowed with social power, including symbolic power (*e.g.* identity through joint water ownership).
4) It causes and initiates services and ideas helping to establish belief systems, innovations, social standards, *etc*.
5) It is defined by certain social and ideological settings or arenas which prompt the character, alteration, and even disappearance of its commodity state.
6) It helps to produce material values for daily life and material exchange /surplus.
7) It creates other commodities or initiates commodification chains. For example, domestic (and ritual?) water can simultaneously be a commodity and commoditize space and things.

Following the understanding of water as a commodity in sedentary Neolithic systems, Table 1 represents a preliminary exercise to structure parameters and features of Neolithic water in subsystems and use/context levels.

Domestic Water and Its Early Evidence

After the very early evidence for wells (Early PPNB; Peltenburg *et al.* 2000, 2001a-b) in the littoral sedimentary rocks of southwest Cyprus became known, followed by reports on earliest PPNB basin irrigation using dams near Ma'an (PPNB; Fujii 2006, 2007, 2010- this issue), the hydrological background of Neolithization became an imperative topic in Neolithic research. From the evidence we have it cannot really be stated when, how, and where water started to be a commodity (in the sense above); probably such questions are irrelevant. Control strategies in water acquisition and procurement by modifying landscapes through dams or locating settlements in certain favourite hydrological settings to allow well digging evidently appear with the beginning of sedentary life's productive milieus. The evidence assembled in this issue of Neo-Lithics suggests that after the long history of direct water consumption at sources, early Near Eastern water commodification went through the following steps[4], characterized by their most progressive feature. I am aware that this simplistic trajectory is misleading for the actual and innovative regional trajectories which led water technologies to migrate to regions with similar conditions, but for the sake of clearity I dare to simplify the potential overall development:

1) Removing water from natural sources for consumption, and early long-distance use of rivers or the sea to spread productive milieus.
2) Removing water from manipulated or constructed sources for consumption, while establishing permanent life near water sources.
3) Territorializing water by permanent networks and/or transport means.
4) Relocating water by networks.

With respect to sedentism and water, it is necessary to mention that a stable and permanent occupation of the Arabian Peninsula only became possible by the latest act in Near Eastern water commodification during the formation of the Early Bronze Age oasis agroeconomy in the 4th millennium BC. While the western Near Eastern sedentism trajectory was fully established only by the various irrigation techniques in its riverine and alluvial lands of the 6th millennium, the arid lands of Arabia apparently "needed" an adaptation from the pastoral well cultures of the 5th millennium (representing periods of more moisture) into the oasis channel/ shadow horticulture or agroecosystem of the 4th millennium, following the onset of drier and cooler climate (Gebel and Mahasneh n.d.). This in a way also emphasizes that the Near Eastern establishment of sedentism was a matter of environmental technology and adaptation rather than a restricted Neolithic feature. Wells from present-day arid Chalcolithic landscapes are reported from the 'Uvda Valley (Avner 2002), Rajajil near al-Jawf/Skaka (Zarins 1979), and Qulban Beni Murra (Gebel and Mahasneh n.d.).

While foragers' camp sites apparently were related to springs and water courses, their locations seem to have respected the wild games' access to water and other factors related to water (such as insects). This adaptive attitude to water locations had to be given up whenever sorts of permanent life was established near water sources. The hitherto oldest primary evidence of water commodification, surprisingly, does not come from the Near Eastern mainland, but from the EPPNB of Cyprus („Cypro-PPNB"). In Kissonerga-Mylouthkia (*ca*. 8500 and *ca*. 7000 cal. BC; Peltenburg *et al.* 2001, pers. comm.) in littoral southwest Cyprus, several water wells with foot holes were found dug into the local havara (a kind of stiff marl) bedrock to tap underground watercourses. Their depths vary between 6 and 12 meters. Each well has a chamber-like extension at the bottom of the cylindrical shaft, cut into the impermeable limestone below the watercourse. When abandoned, the wells were deliberately filled with cultural debris and organic matter, helping to date the (undisturbed) fills to the later 8th millennium BC. Contemporary wells have been found at other Cypriot sites, such as Parekklisha-Shillourokambos. I think, E. Peltenburg (Peltenburg *et al.* 2001a: 47) is perfectly right in assuming that „well digging expanded with the growth of sedentism" rather than being forced by a PPN increase of settlement sizes. However, it should be questioned if well-digging really is a „western hydrological development": the still missing early evidence in the non-littoral PPN core areas of the Levant could have much to do with the mountainous or terrace settings of sites. Here underground watercourses probably were tapped mostly outside the immediate domestic areas by water holes and wells. Not much technological cognition is needed to "arrive" at a shaft well from the simple water hole experience: only the labor investment and its organization, both in building and maintaining a well, might require a different level of social networks.

The introduction and establishment of farming during the 9th and 8th millennia BC not only countered climatic variability as a potential threat to a stable subsistence economy, it also created new dependencies and balance regimes on/with water. Site settings were chosen to meet with several environmental needs, not only water, including the distance to fields, mineral resources (building material), *etc*. Natural landscapes were transformed into cultural landscapes and became productive territories, resulting in demographic growth and the spread and aggregation of settled people. Pressure must have reached "fringes" such as the Ma'an area that certainly witnessed a moister climate in the PPNB. The setting and palaeohydrological situation of the Late Pre-Pottery Neolithic B site of Ba'ja north of Wadi Musa provided strong secondary evidence for water harvesting by dams, or (at least) of a village sustained exclusively on tapping aquifers (Gebel 2004b). It is argued that the gorge's special topography forced the torrential run-off water to seep into its aquifers, which must have been one of the reasons for the choice of this extreme intra-montane location in an environment otherwise devoid of perennially flowing surface water.

Apart from the Early Neolithic well evidence of Cyprus, Shar Hagolan (Garfinkel *et al.* 2006) and Atlit-Yam off the Carmel Coast (Galili and Nir 1993; Galili and Sharvit 1998) provided prominent and clear primary evidence for PPNC well shafts. Atlit is a submerged site of some 4 ha at 8-12 m b.s.l.; its wells must have been subject to the previous coastal plain groundwater table that was affected by sea-level changes. More Pottery Neolithic wells existed in the neighboring submerged sites of Kfar Samir, Kfar Gilam, Tel Hreiz, Megadim, and Neve-Yam. Two wells have also been reported from Hacilar VI (Mellaart 1970).

The Pottery Neolithic witnessed the widespread establishment of impermeable vessels, advantageous for any sort of hygienic storage including water

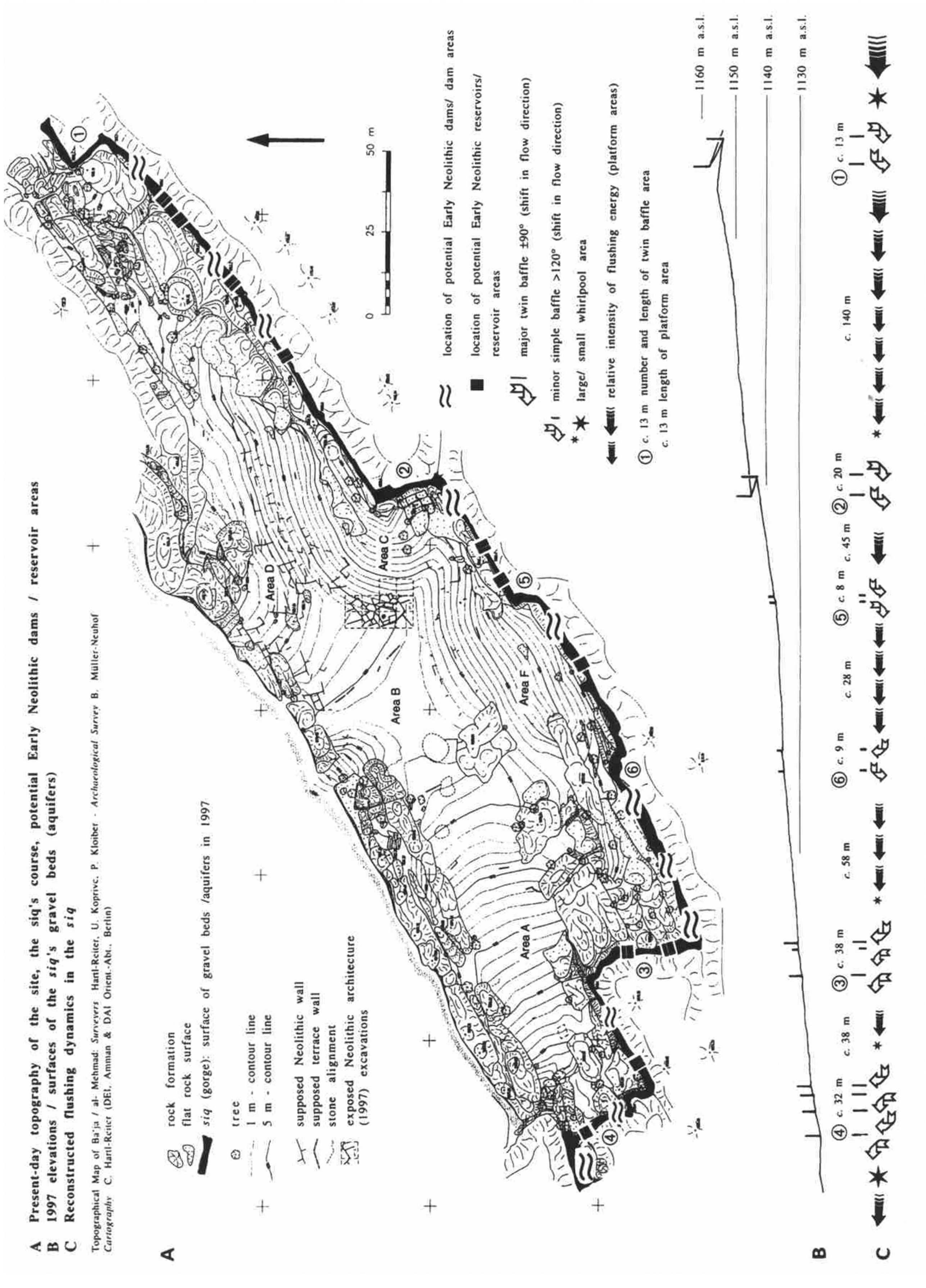

Fig. 2 Reconstruction of LPPNB Ba'ja's palaeohydrological setting and potential water harvesting. (from Gebel 2004b)

brought from some distance. Very little primary evidence, together with secondary evidence based on various palaeoecological arguments, can be cited for another epoch-making water technology in the Near Eastern Pottery Neolithic and the immediate post-Neolithic. The valleys of the Tigris and Euphrates drainage were the regions that introduced and established the first irrigation techniques. The advent of irrigation remains poorly known, and certainly it regionally prevented, delayed, or made impossible an efficient drainage that would avoid waterlogging and salinization. While irrigation generally is expected for the 6th millennium BC, Araus *et al*. (1999) would not exclude primitive irrigation at PPNA Tell Halula. I expect that contour ditch irrigation is likely to have been in practice from the Umm Dambaghiyah/ Ubaid 0 periods (6900 BC onwards), if not earlier in certain locations. It must have been a minor step in the human experience to understand that flooding slope areas helps to control flooding of fields on the valley floor. Submersion irrigation and arboreal shade in this topography would have allowed other types of crops to be raised. However, it could have developed in just the opposite way: that slope irrigation developed from irrigated basins in the valley floor. The alluvial (hydraulic) Hassuna, Samarra-Halaf and early Ubaid expansions (6400-5800 BC) most likely were based on developments in submersion irrigation using small basins as fields; at the Samarran site of Choga Mami a large irrigation canal was found. Permanent farm life entered the steppe fringes of the Mesopotamian rivers and faced local salinization problems due to absent or restricted drainage layers. In the lowland of the Deh Luran, western Iran, substantial evidence for agriculture and population growth is attested as the Pottery Neolithic approached, simultaneously witnessing the introduction of irrigation agriculture (Hole 1977, Neeley and Wright 1994). At Tell Pardis (in the Tehran Plain, *ca*. 5000 BC) a small channel-like feature was exposed in a section of a brick quarry, running at right angles to several other natural channels in the sequence, suggesting the management of water resources (Coningham *et al*. 2006; Fazeli et al. 2007; Gillmore *et a*l. 2007a-b). The Jeitun Sites at the edge of the Karakum Desert, Turkmenistan, possibly also witnessed early irrigation, benefiting from a high water table, swamps, and seasonally flooded surfaces (Harris *et al*. 1993; Harris, Charles and Gosden 1996; Kohl 1981).

As noted above, the Pottery Neolithic with its hydraulic innovations must be seen as the confirmation of the Neolithic trajectory for the alluvial lands of the Near East, while the development of pastoralism and transhumance ratified the success of the Neolithic trajectory in its mountainous zones and semi-arid fringes. In the Fertile Crescent's post-Neolithic periods, the development of the later literate civilizations, the early state societies, appears to be fueled in most respects by their sociohydrologcial coordination, progress, and regression.

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Endnotes

[1] For the term "Neolithic ethos", *cf.* Gebel 2010a.

[2] The author's long research on the Near Eastern Neolithic has resulted in the realization that the formation of Neolithic life and social identities was governed by interfering commodification regimes that were conditioned by the specific blend of productive milieus and their specific complexities that the specific conditions in the diversified Near Eastern regions allowed (Gebel 2010a).

[3] For German speaking colleagues I should explain that the term *Kommodifizierung* is used here in its special Neolithic sense, meaning *Wertschaffungsprozesse*, *Wertschöpfungsprozesse* or *Inwertsetzungsprozesse* at the advent of producing economies; *Werte- und Wertbildungsprozesse* would come closer to the meaning discussed in this contribution.

[4] These are preliminary, as the evidence presented in this chapter is selective.

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Domestication of Runoff Surface Water: Current Evidence and New Perspectives from the Jafr Pastoral Neolithic

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Introduction

Aside from that included in the atmosphere and natural life forms, available water occurs, in general, in the following three modes: static surface water of springs and lakes, runoff surface water of rivers and ‘*awdiya* (plural of *wadi*), and underground water contained in aquifers. These modes not only determine the accessibility to and the manageability of water, but they also define a direction for its domestication. Furthermore, they also have an obvious effect on the archaeological visibility/traceability of the domestication process itself[1].

Static surface water, for example, is easy to approach and control, thereby requiring little effort for daily use. This, in turn, makes its domestication process less visible/traceable from an archaeological point of view. As a matter of fact, no specific evidence for the process has been attested to, notwithstanding that numerous Neolithic sites are prefixed or suffixed by ‘*Ain* (Arabic), *En* (Hebrew), *Pınar* (Turkish), or *Çeshme* (Persian). Underground water, on the other hand, is usually difficult to access and handle, thus necessitating much effort for full-scale exploitation. It is for this reason that the domestication process of this mode of water is relatively easy to distinguish, as represented by deep wells found at two PPNB sites in Cyprus (Peltenburg *et al.* 2000, 2001), the PPNC site of Atlit Yam (Galili and Nir 1993; Galili *et al.* 1993; Galili and Sharvit 1998), and the early PN site of Sha’ar Hagolan (Garfinkel *et al.* 2006). Runoff surface water is intermediate in nature, being relatively easy to access yet often hard to manipulate. Hence, it involves a considerable amount of labor investment for constant use. This explains the reason why its domestication process has a certain level of archaeological visibility/traceability, as illustrated by the retaining walls at PN Dhra’ (Kuijt *et al.* 2007) and the various features around PPNB Ba’ja (Gebel 2004), for example.

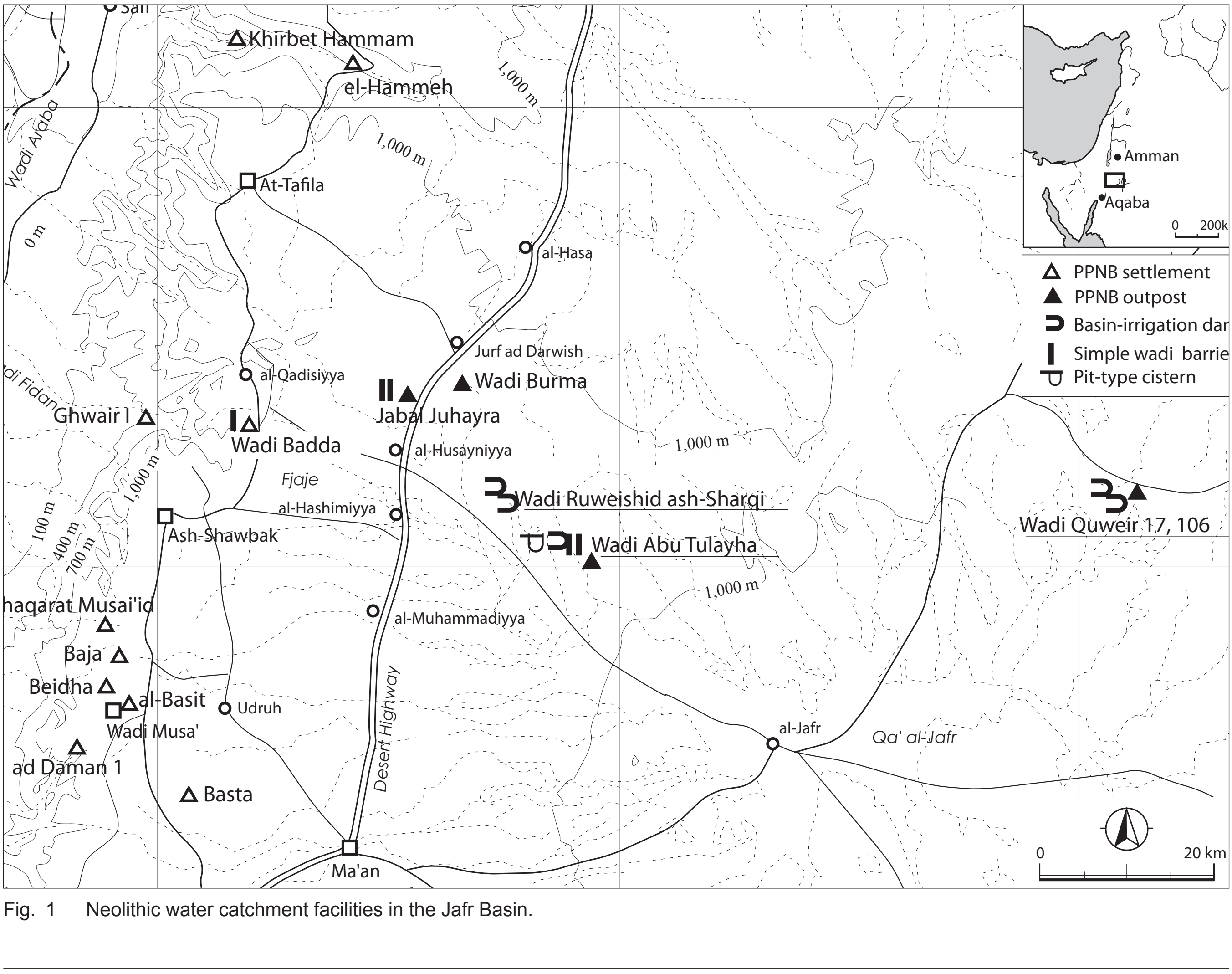

Fig. 1 Neolithic water catchment facilities in the Jafr Basin.

This paper focuses on the domestication of runoff surface water, making no direct reference to that of the other two modes of water. This is because our evidence comes from the Jafr Basin where seasonal runoff surface water has long been the sole source of survival. Come to think of it, it is strange that the evidence for the Neolithic water management has been reported exclusively from the core area under the Mediterranean climatic regime and rarely found in its arid peripheries more sensitive to water procurement. The evidence from the Jafr Basin will add balance to the basic information between the two[2]. This brief paper aims to shed new light on the issue of water domestication from the viewpoint of the Jafr Pastoral Neolithic.

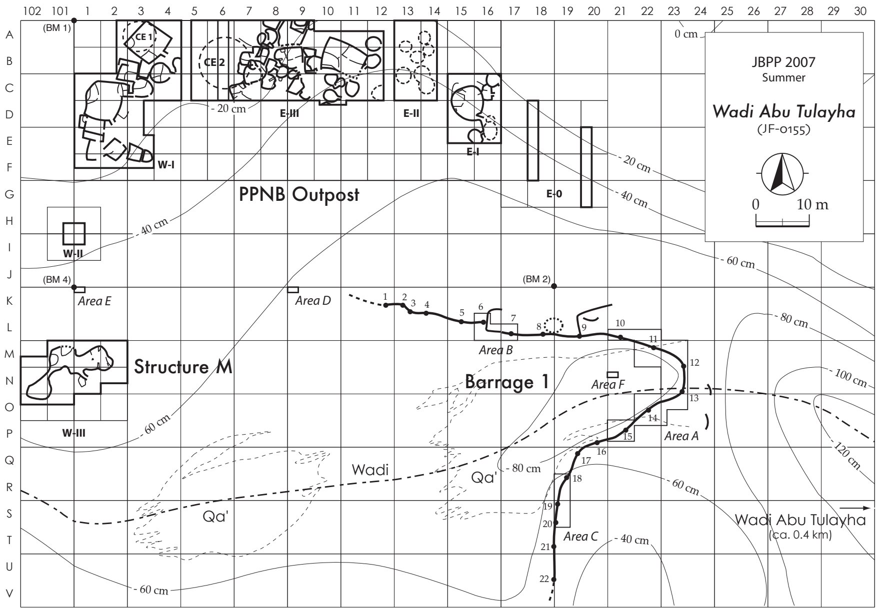

Fig. 2 Wadi Abu Tulayha: site plan.

The Jafr Basin and the Investigations

The Jafr Basin is a large inland depression occupying the southeastern corner of the Transjordanian Plateau (Fig. 1). It is characterized by an extensive flint-strewn desert (or *hamada* in Arabic) and dotted playas (or *qa*', plural *qa'at*) in terms of topography, and by an arid climate and consequent poor vegetation with respect to bioclimatology. Thus, with the exception of a few traditional settlements such as Ma'an and al-Jafr, it has long been occupied by pastoral nomads. It is no wonder, therefore, that the basin has attracted little attention of archaeologists who are liable to focus on permanent settlement sites.

Our continuous investigations since 1997 have shed new light on the archaeological potential of the basin. To date, several dozen prehistoric sites have been located and a dozen of these were excavated either partly or extensively (Fujii and Abe 2008). Neolithic runoff surface water catchment facilities, our main concern, were confirmed at two of these[3]. They were stone-built structures of various sizes and profiles, falling into barrage-like wadi barriers and a cistern-like water hole in terms of functional morphology. The former may be further subdivided into large-scale basin-irrigation barrages and reservoir-type simple barriers. Our discussion deals with these two or three forms of water catchment facilities known to date in the Neolithic Jafr Basin. A brief review of the published evidence for two barrage systems comes first, followed by the description of a cistern-like feature newly found in the 2007 summer field season.

Evidence for the Jafr Barrage System

At present, a total of ten barrage-like features have been found in the Jafr Basin: two along Wadi Qusayr (Fujii 2005a), three along Wadi Burma (Fujii 2004, but see also 2005a), three along Wadi Abu Tulayha (see below), and two along Wadi Ruweishid ash-Sharqi (also see below). The first five are yet to be dated for certain due to the deficiency of relevant evidence and are therefore omitted from the present discussion. The latter five, on the other hand, are dated to the PPNB on the basis of a line of evidence referred to below. They are combined to form the following two barrage systems.

Wadi Abu Tulayha Barrage System

The site of Wadi Abu Tulayha is a M/LPPNB agro-pastoral outpost lying in the northwestern part of the basin. It was first found during our survey in the winter season of 2001 (Fujii 2002). Excavation started in the spring field season of 2005 and is still in progress. Our continuous investigations have shown that it consisted of the following three distinct structural components: a M/LPPNB elongated outpost occupying the northwestern corner of the site, a pair of EBA (Early Bronze Age) burial cairns overlying it, and a barrage system constructed along a side wadi flowing eastward across the southern edge of the site (Fig. 2). Available evidence suggests that the outpost served as a seasonal station for multi-faceted transhumants who were engaged in hunting and agriculture as well as herding of sheep and goats (Fujii 2006a, 2007d).

Barrage 1 is the largest of the three features that constitute the barrage system, occupying the lower edge of an upstream plain of the side wadi (Fig. 3). It was tested in the first season (Fujii 2006a, 2006b) and then extensively excavated, together with Barrages 2

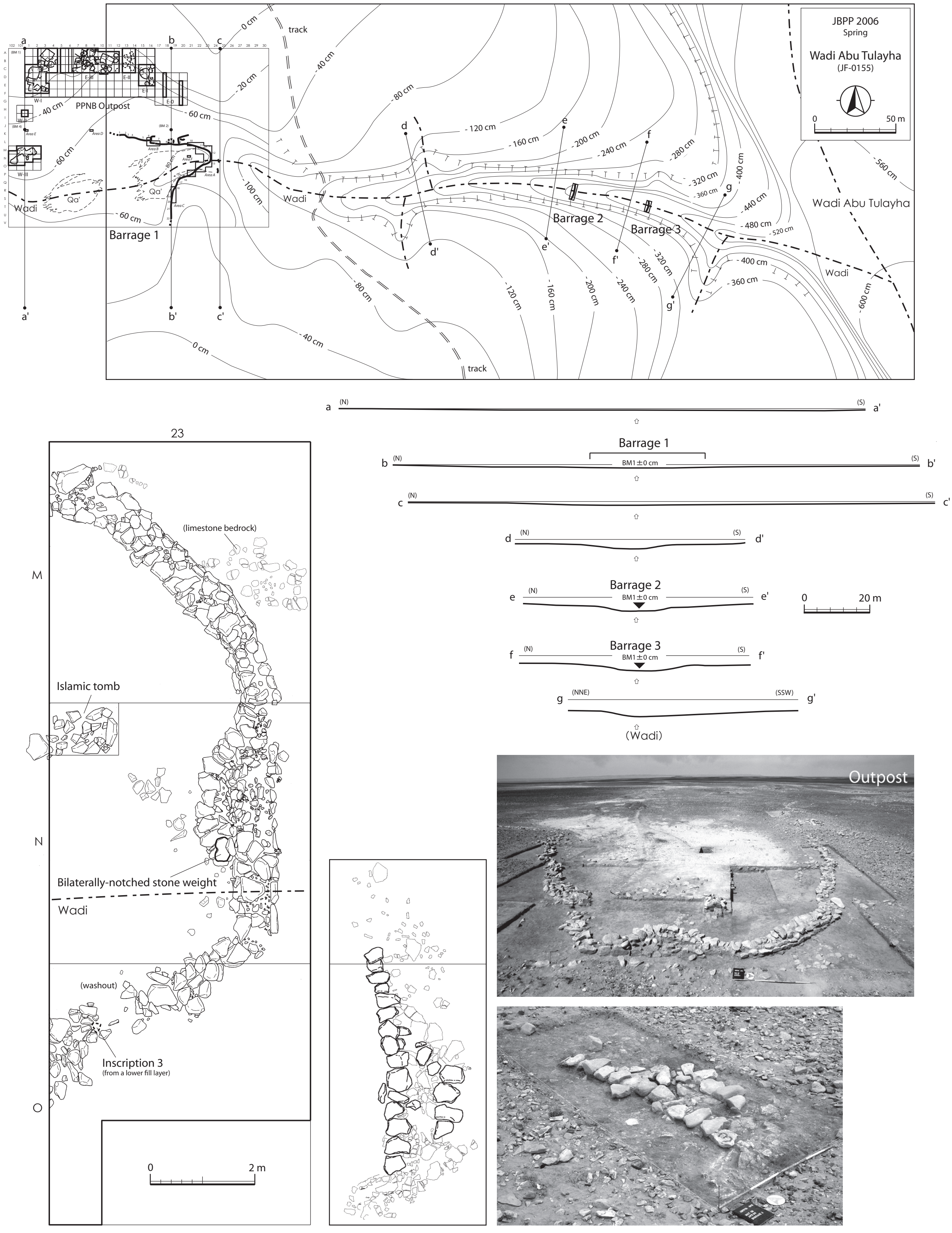

Fig. 3 Wadi Abu Tulayha: Barrage system.

Fig. 4 Wadi Abu Tulayha: Unit 38 of Complex 00 (from SW).

and 3 described below, in the 2006 spring field season (Fujii 2007b, 2007c). The excavation showed that it was a roughly V-shaped masonry structure one or two stone-rows (or *ca*. 0.2-1.0 m) wide, preserved up to a height of three to four courses (or *ca*. 0.3-0.5 m), and *ca*. 120 m in total length. It was equipped with a semi-circular, protruded reinforcement wall *ca*. 3 m wide at the converging point.

This barrage can be dated to the PPNB on the basis of a line of evidence including the stratigraphic correlation with its neighboring outpost and the occurrence of a bilaterally notched and grooved stone weight, a distinctive find shared with the outpost (Fujii 2007b: 14, figs. 7, 9). The 2007 summer field season added another line of evidence. That is to say, a protruded reinforcement wall unique to Barrage 1, albeit in an opposite direction, was incorporated into Unit 38 in Area E-III also (Fig. 4). This finding has made the synchronism between the two even clearer (Fujii 2008a). There is little doubt that Barrage 1 dates back to the PPNB.

The function of this barrage is easy to understand, since a line of collateral evidence - the unique location across the wadi, the distinctive V-shaped profile opening toward the upper course, the wall layout following contour lines, and the attachment of the protruded reinforcement wall to the converging point - clearly indicates its use as a water catchment facility (Fujii 2007b: 15). It is questionable, however, whether it was used as a simple reservoir, since the imperfect waterproof property of the barrage wall casts doubt on this use. We should also note that: first, the barrage occupied, of all locations, the flat and permeable (thus unfavorable for long-term water storage) terrain; second, it was designed so as to produce a shallow extensive flooded area, again incompatible with prolonged water storage; and, third, as referred to below, other facilities specializing in water storage coexisted along the same wadi. Considered in this light, it is more reasonable to suppose that the barrage was used for basin-irrigation agriculture, a form of cultivation accomplished by means of interrupting the runoff surface water and facilitating water infiltration into the ground. As a matter of fact, carbonized cereal and pulse seeds as well as agricultural implements such as querns and sickle elements occurred in substantial quantities from the neighboring coeval outpost (Nasu *et al.* 2008, n.d.). Given that the rainfall in the Neolithic Jafr Basin was not enough to make dry farming possible, it follows that the crops were cultivated within the flooded area of the barrage. Incidentally, the barrage is estimated to have produced a few hectares of elongated crop fields along the winding course of the side wadi, a sufficient area under cultivation for a short stay of a small group of transhumants (Fujii 2007c: fig. 32). It should be added, however, that the fields might have changed into a mere pasture for livestock in a dry year (Fujii 2007b: 16).

Barrage 2 and 3, on the other hand, are located *ca*. 200-250 m downstream of Barrage 1 (Fig. 3). In contrast to Barrage 1, both of these occupy a slightly dissected stony terrain where impermeable limestone bedrock layers are exposed everywhere. They are constructed on such a slightly raised limestone bedrock layer, which provided them with not only solid foundations but also a natural depression favorable for water storage. This is especially the case for Barrage 2, the cross-section of which clearly indicates that it was constructed to make efficient use of a natural pond in front of it (Fujii 2007c). In this sense, these two barrages may be defined as additional walls to increase the capacity of the natural ponds. They are much smaller in scale and simpler in structure than Barrage 1, but the volume of fallen stones suggests that they were originally somewhat larger than the preserved state (Fujii 2007b, 2007c).

The dating of these two barrages is difficult due to the scarcity of pertinent evidence. Nevertheless, a semi-circular reinforcement wall attached, albeit in an opposite direction, to their central part and a header-bond technique applied to their forefront are suggestive of a technological similarity and possible synchronism with Barrage 1. The total absence of settlement sites around them (with the only exception of the outpost) is also in favor of this assumption. On the other hand, their function is easily understandable. In light of their location on a slightly dissected, stony, impermeable terrain, there is little doubt that they served as simple wadi barriers specializing in reserving drinking water. Their simpler yet sturdier structure also supports this view. These two reservoir-type wadi barriers probably supplied drinking water for the transhumants at the outpost and their livestock, although their small dimensions and the co-existence of a cistern-like feature referred to below are suggestive of their supplementary nature. They are estimated to have reserved up to several tons of water respectively.

Wadi Ruweishid Barrage System

The site of Wadi Ruweishid ash-Sharqi (hereafter referred to simply as Wadi Ruweishid) is situated *ca*. 7-8 km WNW of Wadi Abu Tulayha. Two barrages were found at this site (Fujii 2007b: fig. 11). They are constructed along a small side wadi, at a moderate (*ca*. 0.4 km) distance from the main stream to the east. Thus it appears that the two barrage systems known to date in the Jafr Basin were constructed following the same topographical standard. Nevertheless, unlike that of Wadi Abu Tulayha, the barrage system of Wadi Ruweishid consists only of two basin-irrigation barrages, unaccompanied by reservoir type wadi barriers, to say nothing of a neighboring outpost.

The two barrages each yielded a bilaterally notched and grooved stone weight, which is suggestive of a synchronism with Barrage 1 at Wadi Abu Tulayha. This is particularly the case of Barrage 2, which produced the distinctive find in the same context as Wadi Abu Tulayha Barrage 1, namely, at the right-hand corner of the protruded reinforcement wall (Fujii 2007b: fig. 12). The function of the two barrages is also explicit. In view of their location on a flat permeable terrain and imperfect waterproof property, there is little doubt that they were used for basin-irrigated agriculture (Fig. 5). Given the synchronism and the reciprocal accessibility, this isolated barrage system might possibly have served as an enclave field or pasture for a small group of PPNB agro-transhumants who made a round trip between a parent settlement to the west and the outpost at Wadi Abu Tulayha.

Fig. 5 Wadi Ruweishid ash-Sharqi: Barrage 2.

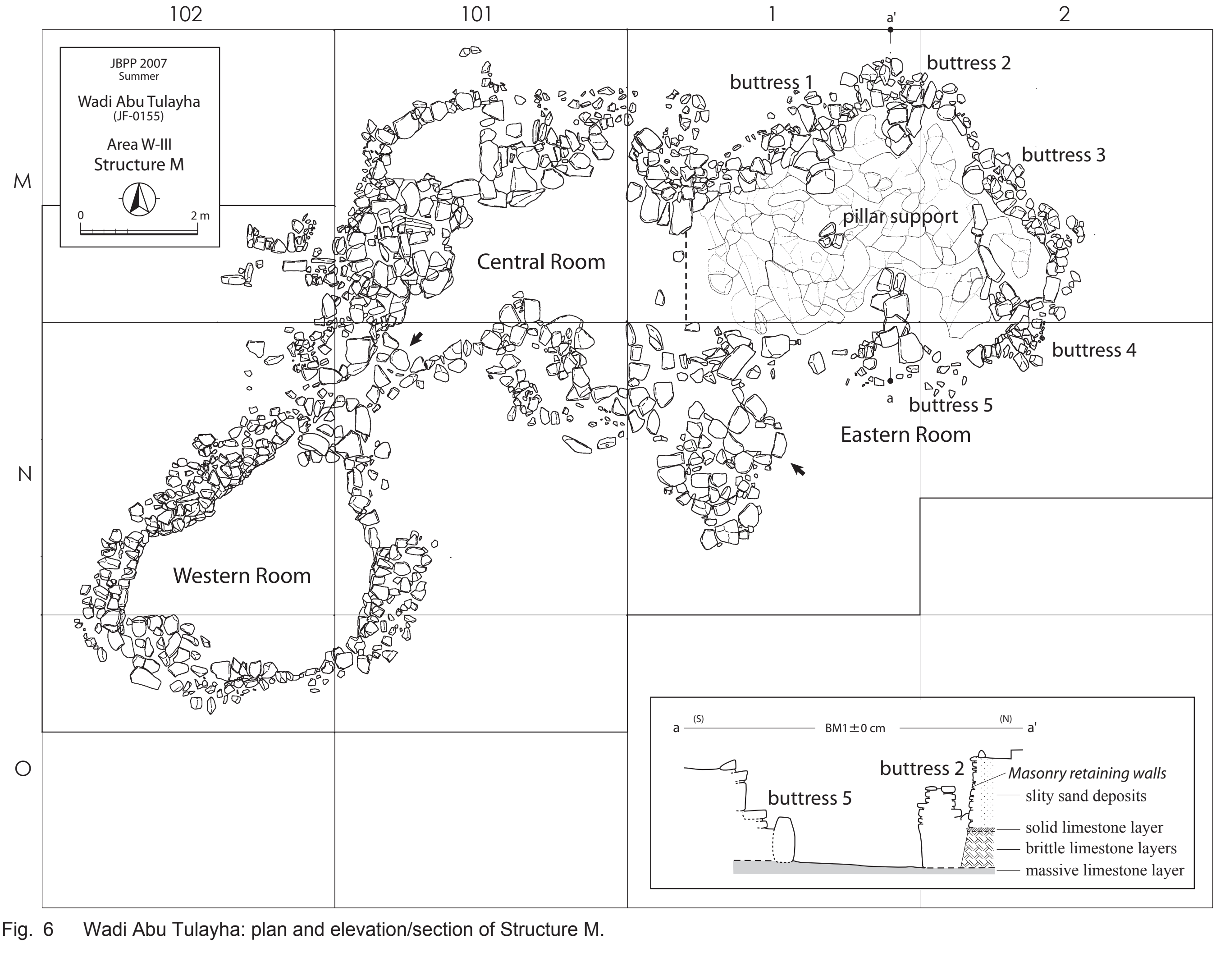

Fig. 6 Wadi Abu Tulayha: plan and elevation/section of Structure M.

Fig. 7 Wadi Abu Tulayha: general view of Structure M (from S).

Fig. 8 Wadi Abu Tulayha: the eastern room of Structure M (from SW).

Fig. 9 Wadi Abu Tulayha: the eastern room of Structure M (from W).

New Evidence for a Cistern-like Feature

The 2007 summer field season newly confirmed a large cistern-like feature on the north bank of the side wadi (Fujii 2008a). This finding shed new light on another aspect of the runoff surface water exploitation strategy at Wadi Abu Tulayha.

Structure M

The cistern-like feature or Structure M was found in Area W-III, an operation sector newly opened in an effort to define the southwestern edge of the elongated outpost (Fig. 2). It was separated *ca.* 20 m from a simple stone alignment found in Area W-II or more than 30 m from the main body of the outpost, thereby abutting on the flooded area of the side wadi.

This large composite structure, *ca.* 18 m in total width, consisted of three irregularly shaped rooms that were connected in an east-west or northeast-southwest direction (Figs. 6 and 7). Only the central room was equipped with a stone-lined stepped entrance. Unexpected was its floor depth up to *ca.* 2 m, which was more than twice as deep as any other features in the outpost. In addition, it was buried with highly consolidated silty sand deposits. For these two reasons, the excavation could not make rapid progress and the structure is yet to be fully excavated except for the eastern room.

The limited excavation has shown that this large semi-subterranean structure was constructed by means of digging through, in a top-to-bottom order, the following three layers: 1) silty sand deposits *ca.* 1 m thick, 2) a hard limestone layer *ca.* 0.10-0.15 m thick, and 3) a granular, relatively brittle limestone layer *ca.* 0.6-0.7 m thick (Figs. 8 and 9). No traces of floor pavement were confirmed but, instead, the upper surface of a massive limestone layer underlying the third layer was used as a natural floor. A total of five robust buttress walls were attached to the peripheral masonry retaining walls, probably in order to cope with wall inclination and collapse due to strong lateral soil pressure.

What interested us most was the unique construction method of the masonry retaining walls encompassing the eastern room. Strangely, they were not founded on the floor; instead, they were based on protruded fringes of the hard limestone layer dug through during the construction (Fig. 10). For this reason, they covered only the silty sand deposits in the upper half, leaving the underlying granular limestone layers exposed. As referred to below, this unique construction method holds a key to understanding the function of this remarkable structure.

Fig. 10 Wadi Abu Tulayha: the southern wall of Structure M (from N).

Incidentally, traces of domestic life were quite scarce. No small features were found on the floor with the only exceptions of a few freestanding boulders in the middle of the floor and a questionable bin at the southeastern corner. Even charcoal remains and ashy deposits, to say nothing of hearths, were rarely included. In addition, the finds were limited in both number and variety, consisting largely of flint and limestone implements that seem to have been swept in from the surrounding terrain in view of their archaeological contexts.

Date and Function

Although no radiometric dates are available yet, both the stratigraphic correlation and the incorporation of a pillar base into the southern wall (Fig. 10; see also Fujii 2007c, 2008a) are suggestive of a synchronism between Structure M and the main body of the outpost. In addition, the finds from Structure M were dominated by naviform core and blade components, chronological indicators of the PPNB flint assemblage. The frequency of Jericho type points in the tool kit allows us to tentatively date the structure to the MPPNB (Fig. 11).

The question is the specific function of this unique feature. Suggestive in this regard is its isolation from the main body of the outpost. It is also important to note that it differed in both size and technology from the other structures. Both facts suggest that the structure was used for a non-residential purpose. Furthermore, a communal or ritual use seems also questionable, first because unlike Structure M, the outpost always incorporates a large elaborate communal building (*e.g.* Unit 03 in the Complex I and Structure B in the Complex IV) within every complex (Fig. 2, 12), and second because distinctive artifacts common to such key features (*e.g.* bilaterally notched and grooved stone weights, diagonally truncated stone bars, red pigment, limestone palettes, and small clay objects; Fujii 2006a, 2007d, 2008a) rarely occurred from Structure M. Considered in this light, it is highly doubtful that Structure M was used for a communal or ritual occasion, to say nothing of a residential purpose.

The second key to understanding the function of Structure M is its floor depth of up to *ca*. 2 m. It is noticeable that it dug through the hard limestone layer *ca*. 1 m below the contemporaneous ground surface, seeing that this layer usually served as a natural floor for the structures belonging to the main body of the outpost[4]. Of further significance is the fact that despite its great floor depth, it is located immediately beside or almost within the flooded area of the side wadi. This is all the stranger because the other structures, albeit less than 1 m in floor depth, remained at a greater distance from the wadi bed probably for humidity control. This inexplicable phenomenon cannot reasonably be understood until we suppose that the structure was used as a water catchment facility. The absence of hearths and ashy deposits on the floor and lower fill layers also accords with this interpretation.

A more telling key is the unique masonry technique that built up walls from the middle of the side surface of the room. This construction technique is unsuitable for normal dwellings in terms of safety, among other matters. This is even clearer, considering that the walls of the eastern room still retain several large holes left by fallen stones[5]. The addition of five robust buttresses also illustrates that the room was often exposed to wall inclination and collapse. It is quite impossible that such an extra-hazardous structure was put to a residential or communal use. Instead, it seems more reasonable to assume that the masonry wall covered only the upper layers because of their delicate and permeable texture, leaving the lower layers intact because of their solid and impermeable nature. The great floor depth may also be understood as an earnest effort to reach an impermeable floor rather than ensure a large pondage. Presumably, those who were involved in the construction of Structure M stopped the digging for a moment when they reached the hard limestone layer *ca*. 1 m below the ground surface, and soon constructed the masonry retaining walls to protect the silty sand layers. Subsequently, they resumed the digging in search of an impermeable floor, leaving the newly exposed side surface intact because of its favorable nature for water storage. This assumption, if accepted, would first explain the reason why such a hazardous construction method was applied to Structure M only.

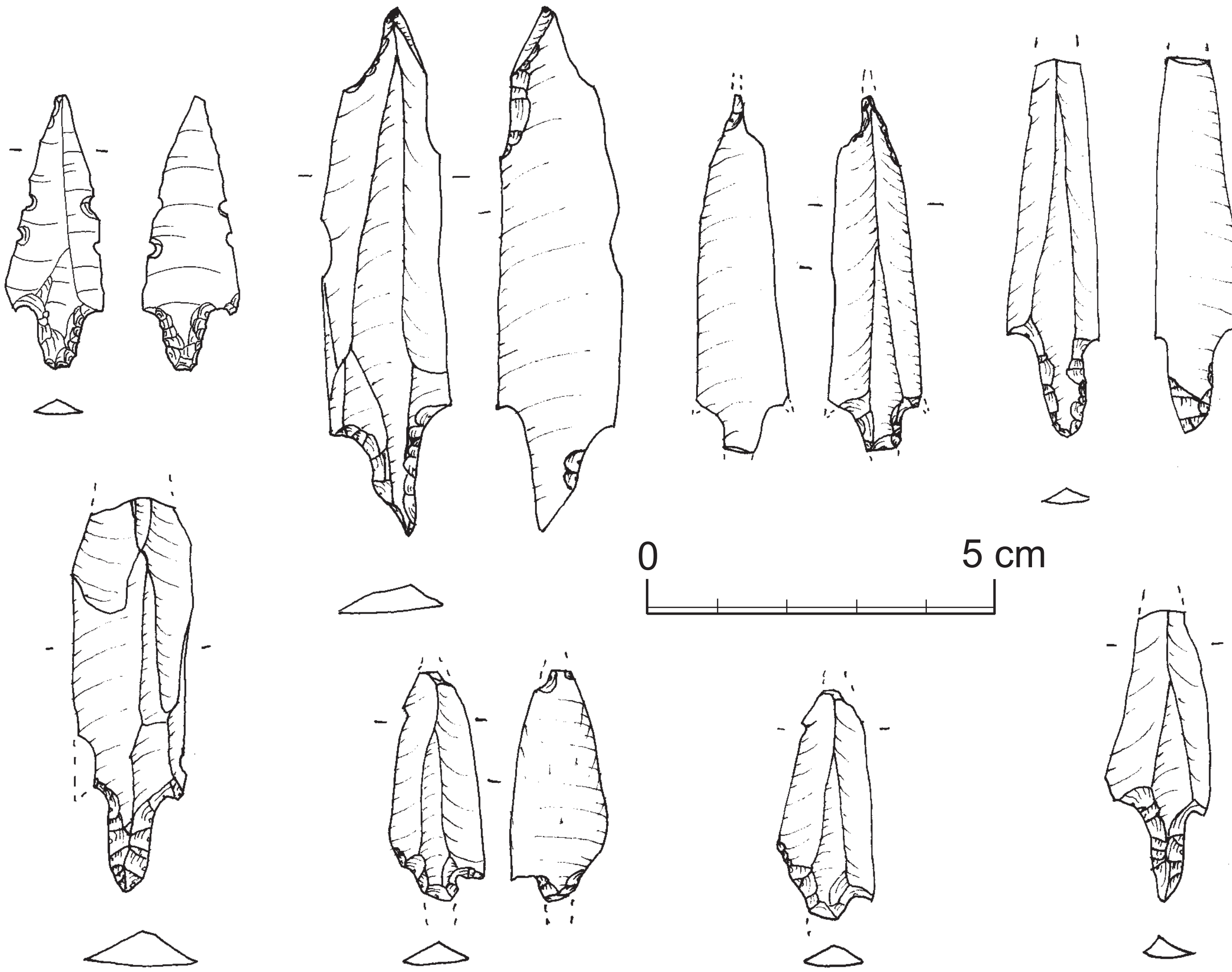

Fig. 11 Wadi Abu Tulayha: Helwan- and Jericho-type points from Complex 00 (above) and Jericho-type points from Structure M (below).

An additional key is the fact that Structure M is buried consistently with cemented silty sand deposits from the top fill down to the floor layer. This picture has much in common with the situation of Area F, a small operation sector inside the flooded area of Barrage 1 (Fujii 2007b, 2007c). In contrast to them are the structures constituting the main body of the outpost, which usually include relatively loose ashy deposits especially on their floors. Such a marked contrast also underscores the non-residential use of Structure M.

The series of collateral evidence – the isolated location completely separated from the main body of the outpost, the scarcity of traces of residential use, the considerable floor depth despite its location immediately beside the flooded area, the hazardous construction method, and the unique nature of the fill deposits – strongly suggests that the structure served as a water catchment facility rather than a residential or communal building. In view of its distinctive form, there is little doubt that Structure M served as a cistern to collect seasonal runoff surface water of the side wadi. It probably supplied drinking water for the inhabitants of the neighboring outpost and perhaps their livestock.

Incidentally, the maximum capacity of the eastern room is estimated *ca*. 20 cubic meters if it stored water up to the top level of the impermeable limestone layers. Given that the other two rooms also had the same floor depth, it follows that Structure M, as a whole, stored up to *ca*. 50-60 cubic meters of water. Moreover, if the mortared masonry retaining walls in the upper half had a sufficient waterproof property, the estimate would increase further. Such a value may sound excessive for a small group of transhumants, but we should note that although they used the outpost on a seasonal basis, it was possibly for a relatively long term, as represented, for example, by the occurrence of half-finished game boards as well as their finished products (*e.g.* Fujii 2007c: fig. 31). We should also note that they brought along a certain number of sheep and goats (Hongo 2008). Thus, if a few dozen transhumants stayed at the outpost for about one month together with their livestock, the maximum capacity of the cistern (*i.e.*, *ca*. 50-60 cubic meters) seems very reasonable and not excessive. This is even more acceptable if they stayed even longer, or when the seasonal flooding was not enough to reach the top level of the impermeable limestone layers.

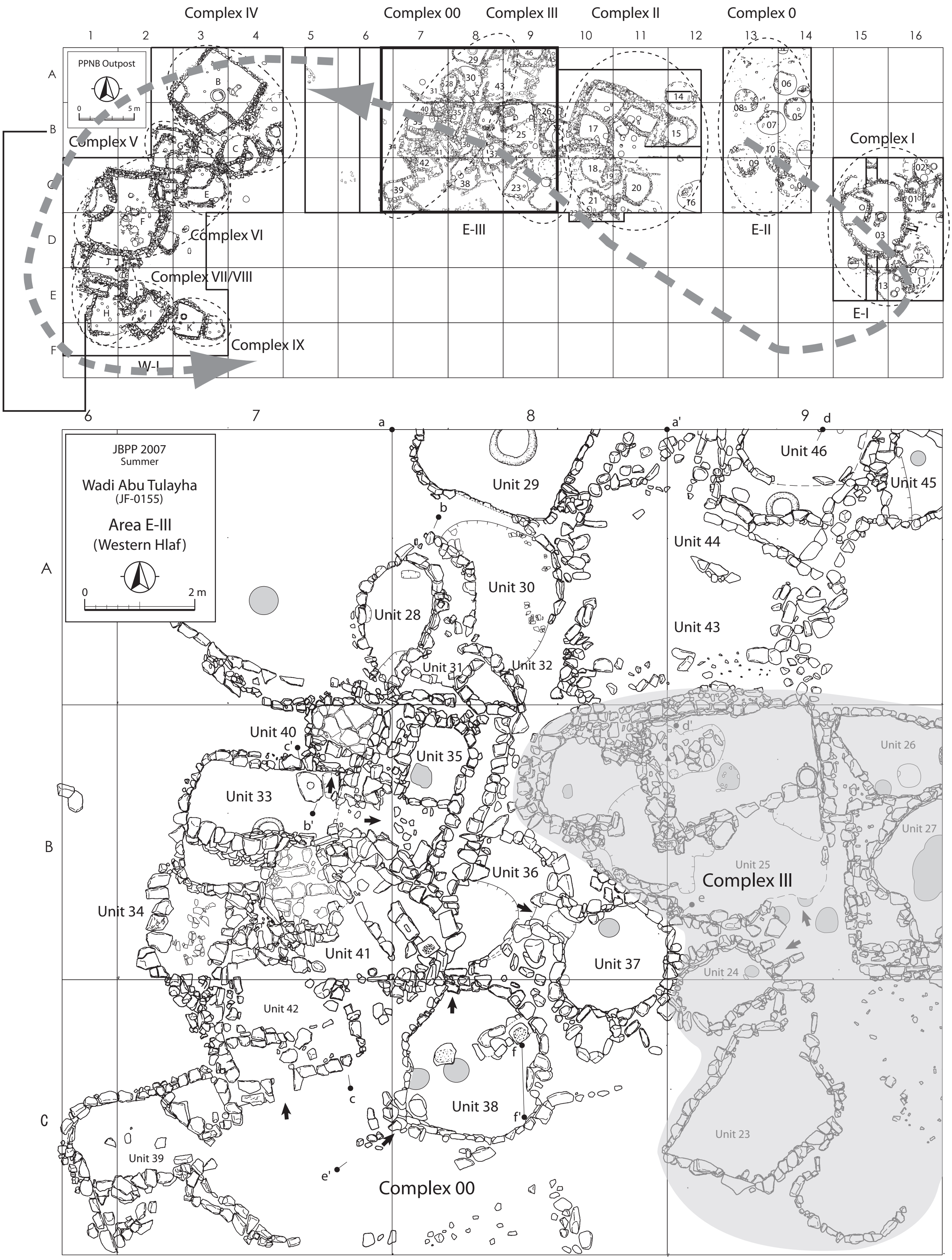

Fig. 12 Wadi Abu Tulayha: the outpost and Complex 00.

Correlation between the Water Catchment Facilities and the Outpost

Before entering into discussion, our previous perspective on this issue will be briefly reviewed (Fig. 12). To begin with, with respect to the formation process of the outpost, we suggested that: first, the elongated outpost contains a total of a dozen structural complexes; second, with the only exception of Complex 0, every complex consists of a large oblong or rectangular key structure and several smaller round features; third, the lateral renewal of such a bimodal complex, involving gradual techno-typological changes, resulted in the formation of the seemingly chaotic appearance of the outpost *ca*. 100 m in total length; and, fourth, in view of the wall-sharing and concavo-convex wall relations, the renewal most likely took place from the east toward the west or southwest. These observations or suggestions led us to the perspective that the outpost began with a cluster of temporary sheds (Complex 0) at Area E-II, then shifted to Complex I at Area E-I, and was continuously renewed westward skipping the existing Complex 0 (Fujii 2006a: 27-30; 2006b: 12; 2007d). On the basis of this perspective, we also suggested that in view of the reciprocal proximity, the barrage was probably constructed at the stage of Complex I, and that the outpost and its neighboring barrage system can be dated, on the basis of three ^{14}C dates and the predominance of Amuq-type points, to the LPPNB.

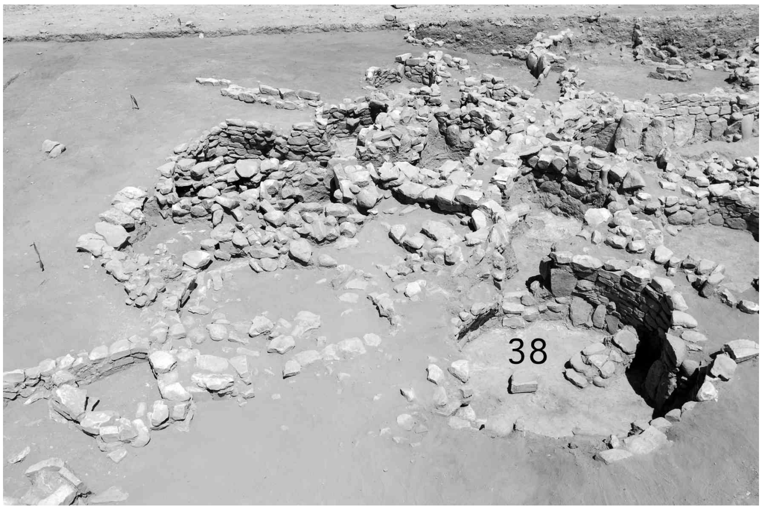

Fig. 13 Wadi Abu Tulayha: general view of Complex 00 (from S).

A few minor revisions are needed for these perspectives. First, we should note that the three radiometric dates (uncalBP 8409±41; 8464±51; 8443±51) came exclusively from Structure K in Area W-I, probably the last component of the elongated outpost. Also, these dates fall equally within the time range of the beginning of the LPPNB. Both of these imply that several complexes in the eastern half of the outpost date back to the very beginning of the LPPNB or the latter half of the MPPNB. As a matter of fact, a series of ^{14}C dates from Complex 00, the earliest component newly found in the western part of Area E-III, falls within the time range of the MPPNB (Fujii 2007d: table 1). Understandably, the same applies to the neighboring barrage system. It is suggestive in this regard that parallel examples of the stone weight and the protruded reinforcement wall, both a key to the dating of the barrage system, focused on the eastern half of the outpost. There is little doubt that both the outpost and the neighboring barrage system were constructed in the MPPNB and continuously used until the early half of the LPPNB.

As discussed above, Structure M has also a strong probability of dating back to the same horizon. Given this, it follows that the outpost was founded in the MPPNB together with the cistern and the barrage system. This makes sense considering their essential role for the survival in the arid margin. However, there seems to be a minor temporal gap between the two, since the cistern resembles Complex 00 rather than Complex I probably related to the construction of the barrage system (Fujii 2009a). Noticeable is the fact that unlike the others, the complex is devoid of an outstanding key feature and, instead, consists only of relatively homogeneous minor components (Figs. 12 and 13). In addition, some of them were connected with each other through narrow passages, thereby forming a tripartite or beehive-like cluster. Both traits are common to Structure M as well as MPPNB settlements in southern Jordan such as Shkarat Msaied (Hermansen and Jensen 2002; Hermansen *et al.* 2006; Jensen 2004; Jensen *et al.* 2005), ‘Ain Abu Nukhayla (Henry *et al.* 2003), and the early phases of Beidha (Kirkbride 1966; Byrd 2005). It should also be added that unlike the other complexes, but like Structure M, Complex 00 produced a certain percentage of Jericho-type points (Fig. 11). Taking these into consideration, we can argue that the cistern was constructed from the very beginning of the outpost and continuously used together with the barrage system added a little later.

From the above, the correlation between the water catchment facilities and the neighboring outpost can be tentatively reconstructed as follows (Fig. 14):

1. A small group of MPPNB transhumants came to this area and noticed its ideal topographical conditions. They embarked on the construction of a seasonal outpost, which started with the combination of the cistern (Structure M) and the tripartite or beehive-like structural complex (Complex 00).

2. With some temporal gap in between, for the construction of the barrage system, they relocated themselves to Complex I with Complex 0 as a transfer point. In this sense, Complex I may represent an episode of re-infiltration into the arid margin involving the new water management technology. Nevertheless, it is not improbable that small-scale cultivation had already taken place at the natural swamp, since Complex 00

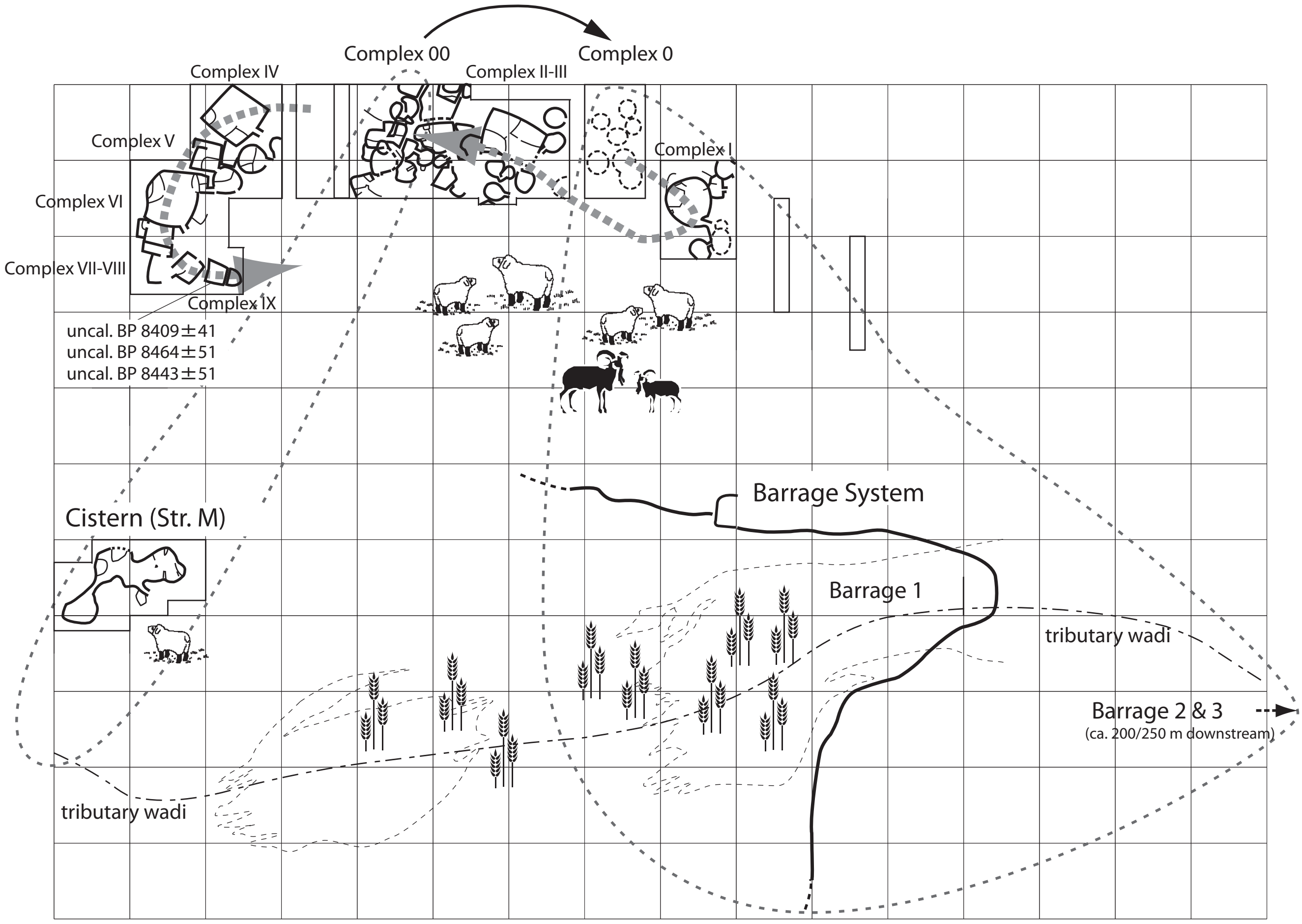

Fig. 14 Wadi Abu Tulayha: correlation between the outpost and the water catchment facilities.

also yielded carbonized cereal and pulse seeds as well as a large number of agricultural implements. Given this, it would be more appropriate to suppose that Barrage 1 was added to increase the productivity of the existing naturally-irrigated crop fields.

3. From this stage onward, the combination of the cistern and the barrage system long supported the outpost until the early half of the LPPNB. Meanwhile, a bimodal structural complex (consisting of a large key feature and several minor components) became the norm of the outpost.

4. It is probably at the same stage that another barrage system was constructed at Wadi Ruweishid. It was possibly used as enclave fields or pastures for the initial transhumants who made a round trip between the outpost of Wadi Abu Tulayha and its parent settlement probably to the west.

Hypothetical Perspectives

Current evidence suggested that the Jafr pastoral Neolithic was equipped with a variety of water catchment facilities. Nevertheless, opinions will be divided as to whether this picture is unique to arid peripheries more sensitive to water procurement or shared with sedentary farming communities favored by sufficient rainfall. Seemingly, the former view sounds likely, since no parallel examples have been reported from the core area. However, seeing that the site of Wadi Abu Tulayha can be defined as a seasonal outpost probably derived from a parent settlement to the west, it seems more likely that such systematic water exploitation was common in both areas. In this sense, we shall be allowed to amplify our evidence, though cautiously, to the whole range of the PPNB cultural sphere. The following are hypothetical perspectives from the viewpoint of the Jafr pastoral Neolithic.

To begin with, as for the domestication of runoff surface water, our main concern:

We confirmed that the initial transhumants infiltrated into the Neolithic Jafr Basin, bringing along the technology of cisterns as well as sheep and goats. Given this, the suggested correlation between the Wadi Sirhan PPNB and natural pools seems likely (*e.g.* Wasse and Rollefson 2005, 2006). Or rather, such a combination may have been the norm of the Neolithic arid frontier, as previously suggested for a Wadi Jilat site (Waechter and Seton-Williams 1938; Miller 1980). In the core area too, the same may be true of the correlation between Ba'ja and its surrounding cistern-like features (Gebel 2004). Cisterns, either natural or anthropogenic, deserve greater attention in the sense that they are effective devices to transform (easy to access yet often hard to manipulate) runoff surface water to (easy to approach and control) static surface water. The tripartite composition and unique masonry technique confirmed at Structure M may provide a key to identifying PPNB anthropogenic cisterns.

Similarly, the careful land choice attested to in the Jafr Basin (Fujii 2007b, 2007c) may serve as a guideline for locating PPNB barrage systems especially in the Transjordanian Plateau. In this sense, a tributary wadi beside Beidha, for example, may be worthy of intensive research. In addition, the two specific key elements - a protruded reinforcement wall attached to a converging point and a bilaterally notched and grooved stone weight incorporated as a ritual object into a reinforcement wall – may also be useful for identifying PPNB basin-irrigation barrages, although their specific function must be defined individually, on the basis of their scale, structure, waterproof property, and surrounding topography. It should also be added that such facilities were not always essential to Neolithic basin-irrigated agriculture. Available evidence from 'Ayn Abu Nukhaylah (Henry *et al.* 2003; Albert and Henry 2004) and the initial phase of Wadi Abu Tulayha suggests that a natural swamp or seasonally flooded *qa*' sufficed present needs. In this case, macroscopic archaeological evidence cannot be expected.

PPNB reservoir-type barrages or wadi barriers can also be identified following the same criteria, as illustrated by Wadi Abu Tulayha Barrages 2 and 3. In light of their universal use and easy-to-construct nature, there is a good possibility that they were much more common than basin-irrigation barrages. A masonry wall found at Wadi Badda, for example, may fall into this type of water catchment facility (Fujii 2007a). Several masonry retaining walls found at Dhra' (Kuijt *et al.* 2007) can be understood as an eclectic form between the basin-irrigation barrage and the reservoir type wadi barrier in the sense that it resembles the former in terms of function but has something in common with the latter as to technology. The existence of such a wide variety of water catchment facilities highlights the fact that the Levantine Neolithic population possessed the ability to adjust their water-use technology to local topographies, whether on sloping fields around a sedentary farming community to the west or on flat terrain encompassing a remote outpost to the east.

On the other hand, the domestication of underground water is yet to be evidenced in the Jafr Pastoral Neolithic. This is probably because its exploitation depends on local geology, particularly the depth of aquifers. Hence it makes sense that the evidence for early Neolithic wells has been limited to the lowlands along the Levantine coasts (both continental and insular) and the Jordan Valley, although further investigation may shed new light on the issue.

The domestication of static surface water is also yet to be traced in the Jafr Basin, but the same applies to the sedentary farming society to the west. This is precisely because, as noted at the beginning, its easy-to-access, easy-to-handle nature lessens not only the need for the full-scale domestication but also the archaeological visibility of the process itself. Nevertheless, the possibility is worth investigating at many '*Ain* sites, especially those in the Jordan Valley. Water "semi-domestication" at PPNA sites should also be put in perspective, as has been suggested for Jericho (Sherratt 1980; Miller 1980; Wikander 2000).

Finally, a tentative perspective should be offered with reference to the correlation between runoff surface water domestication and the pastoral nomadization in the Neolithic Jafr Basin. Our investigations have shown that the short-distance transhumance evidenced at the M/LPPNB outpost of Wadi Abu Tulayha was followed by the initial pastoral nomadism suggested by a few unique funerary sites such as Harrat al-Juhayra (Fujii 2005b) and Qa' Abu Tulayha (Fujii 2001). It is possible that the post-PPNB climatic deterioration caused a gradual decline in basin-irrigated agriculture at the outpost, which in turn, taking the opportunity of the 8200 calBP aridity event (Alley *et al.* 1993; Weninger *et al.* 2006), finally triggered pastoral nomadization[6]. If this is the case, the initial pastoral nomadism in the Jafr Basin may be defined as a later type of transhumance that was no longer able to maintain basin-irrigated agriculture as an essential key of the fixed outpost. It can readily be imagined that the reduction in group size and the increase in group mobility, both involved in the pastoral nomadization, led to the dependence on less substantial water catchment facilities either natural or anthropogenic. This explains the reason why in contrast to the core area, the archaeological visibility of water domestication in arid peripheries suddenly decreased after the PPNB and long remained low until technological innovations such as deep-well sinking were introduced in later times.

Concluding Remarks

The investigation of the Jafr Pastoral Neolithic is a succession of surprises. Aside from domestic goats (Henry *et al.* 2003), the existence of domestic sheep in the MPPNB southern Levant may be controversial in view of the current consensus among zooarchaeologists (Köhler-Rollefson 1992; Ducos 1993; Garrard *et al.* 1996; Horwitz *et al.* 1999; Martin 1999; Peters *et al.* 1999; Helmer 2000). It is even more so if they really accompanied transhumance (Rollefson 2001; Rollefson and Köhler-Rollefson 1993). What we have dealt with in this paper were unfamiliar features found in such a previously unknown scenario. Understandably, opinion will be divided over their interpretation. We ourselves still puzzle over the situation. However, it is now indisputable that the Neolithic Jafr Basin was equipped with a variety of runoff surface water catchment facilities. Our new perspectives from the Jafr Pastoral Neolithic would hopefully trigger an in-depth discussion on the issue of water domestication in the prehistoric Near East.

Acknowledgements: I would like to appreciate Dr. Hans Georg K. Gebel, Dr. Gary O. Rollefson, Dr. Henning Fahlbusch, and Dr. Bo Dahl Hermansen for their useful comments on my first draft. My special thanks go to the former two colleagues, whose sincere advice extended from the framework of the initial draft to the wording of the final draft. It is needless to say, however, that the author is responsible for all deficiencies and misunderstandings.

Appendix I: Subsequent Investigation at Wadi Abu Tulayha

The above discussion on Structure M or the cistern-like feature at Wadi Abu Tulayha was based on the investigation result of the fifth field season when it was half excavated. It is for this reason that there remained some ambiguity. The sixth and final field season, conducted in the summer of 2008, gave the full particulars of the unique feature (Figs. 15, 16). As a result, our initial perspectives were validated anew.

As for the dating, three more ^{14}C dates are now available (Fujii 2009a: fig. 46). All of them - 8365±35 uncalBP [a middle fill layer of the eastern room], 8355±39 uncalBP [a middle fill layer of the same room], and 9144±41 uncalBP [the basal layer of the same room] - fall within the time range of the Middle to Late PPNB period, thus corroborating our tentative dating based on a stratigraphic correlation and a comparative study of diagnostic artifacts. In addition, small finds found in the final season made the synchronism between Structure M and the neighboring outpost even clearer (Fujii 2009a: figs. 44, 45). Of particular interest is the occurrence of a petroglyph depicting several herbivorous animals, which shows clear resemblance to the examples found at the outpost (Fujii 2008b). It should also be added that an earlier phase of the tripartite structural complex was newly found underneath Complex 00 (Fujii 2008b). This finding not only pushed back the date of the outpost further but also bridged a minor chronological gap left between the outpost and the basal layer of the cistern radiometrically dated.

The functional identification of Structure M as a cistern has also obtained further evidence. To begin with, a *ca.* 10 cm thick coating of clay was attested to at the lower half of the northern wall of the central room (Fujii 2009a: fig. 34). A tough coating combining clay and limestone slabs was also confirmed in the western room (Fujii 2008b: fig. 39). There is no doubt that both of these construction works were executed to improve the imperfect waterproof property

Fig. 15 Wadi Abu Tulayha: general view of fully excavated Structure M (from S).

Fig. 16 Wadi Abu Tulayha: general view of fully excavated Structure M (from E).

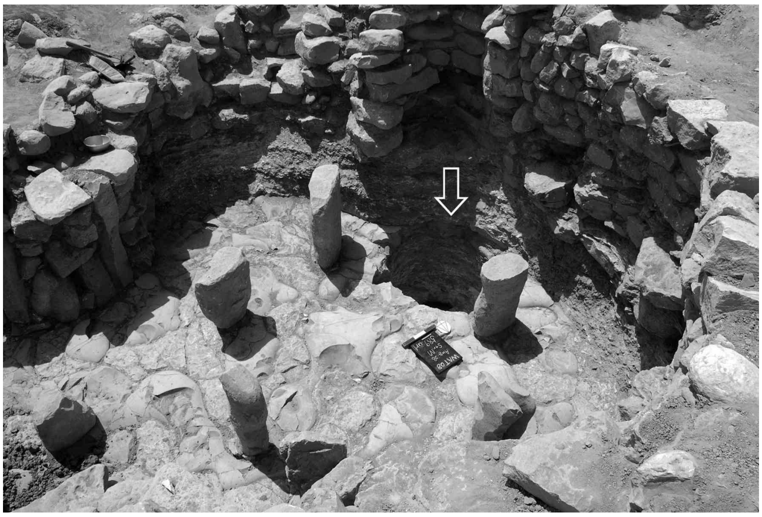

Fig. 17 Wadi Abu Tulayha: sludge tank (white arrow) and upright limestone boulders of Structure M (from NE).

of the brittle limestone layer exposed at the lower half of the structure. Second, a cylindrical sludge tank, *ca*. 1 m in both diameter and depth, was found at the western edge of the floor of the central room (Fig. 17). In addition, a dividing channel *ca*. 2 m long was unearthed between the central and the western rooms (Fujii 2008b: fig. 40). Both devices highlight the use of the structure as a cistern. Also of interest is the fact that the structure was first reused for a temporary encampment when it was buried up to the top level of the semi-permeable limestone bedrock layer. This fact implies that the structure continued to impound some water until then and, therefore, impede the functional diversion (Fujii n.d.). Taking the series of new evidence into consideration, it is now indisputable that Structure M was used as a cistern for supplying drinking water to the neighboring outpost. Incidentally, a series of upright limestone boulders encompassing the sludge tank resembles a stone-circle-like feature found at Atlit Yam (Galili in this volume: figs. 2, 2a). The unique water ritual that took place at the submerged PPNC site along the Mediterranean coast might have its remote origin in the cistern ritual in the M-LPPNB Jafr Basin. Anyhow, we can argue that our chrono-functional identification of Structure M as a PPNB cistern has been fully substantiated.

The subsequent investigation at Wadi Abu Tulayha has firmly established that the M/LPPNB agro-pastoral outpost was equipped with the large cistern specializing in storing drinking water as well as the barrage system. In addition, the outpost has a good possibility of having possessed another barrage system as enclave crop fields. Presumably, such a careful water exploitation strategy first enabled the full-fledged penetration into the arid margin. There is little doubt that the PPNB Jafr Basin witnessed the first zenith of the domestication of runoff surface water (Mithen 2010).

Appendix II: The Third Barrage System at Wadi Quweir 106

The 2010 summer field season of our research project addressed a rescue excavation at Wadi Quweir 17 and 106 both located in the northeastern part of the Jafr Basin (Fujii *et al.* n.d. a, n.d. b). As a result, the former site turned out to be the second example of the PPNB agro-pastoral outpost after Wadi Abu Tulayha, and the latter site proved to be the third example of the contemporary barrage system after Wadi Abu Tulayha and Wadi Ruweishid ash-Sharqi. The investigation has provided further insights into the close correlation between the two essential

Fig. 18 Wadi Quweir 106: Barrage 1 (from W).

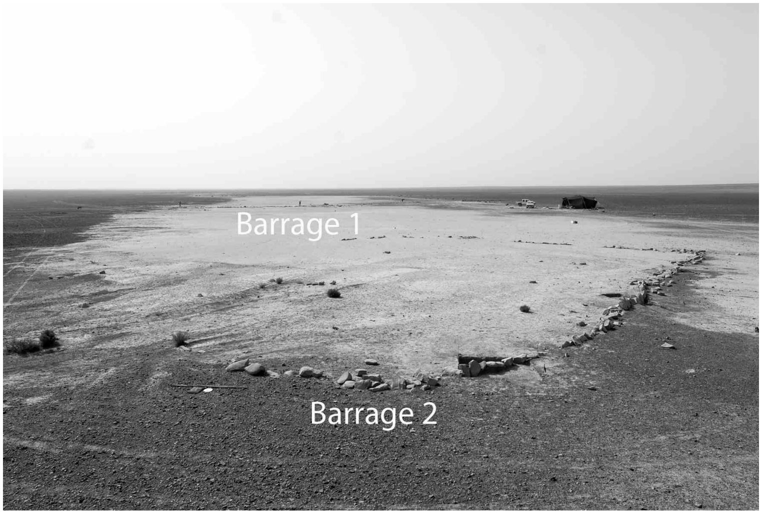

Fig. 19 Wadi Quweir 106: Barrage 2 (from N).

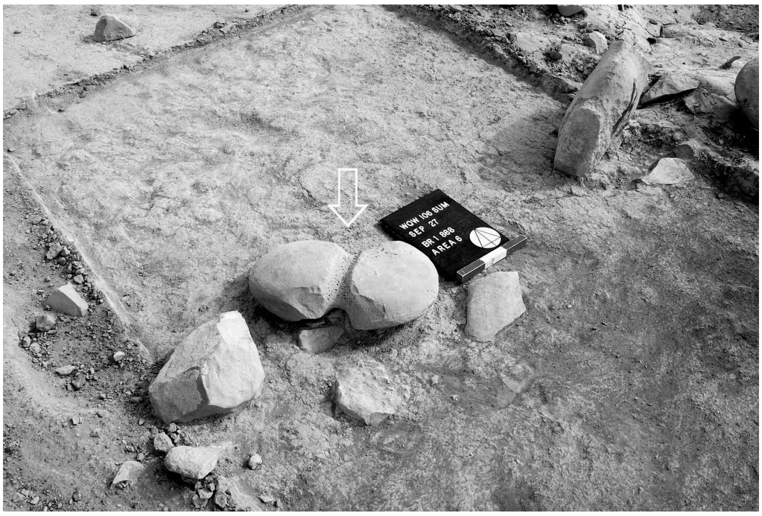

Fig. 20 Wadi Quweir 106: Barrage 2 (from N).

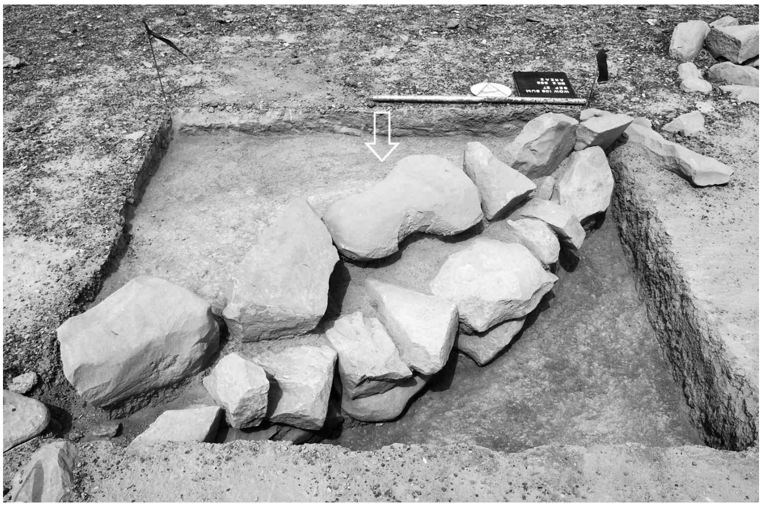

Fig. 21 Wadi Quweir 106: stone weight incorporated into Barrage 1 (from S).

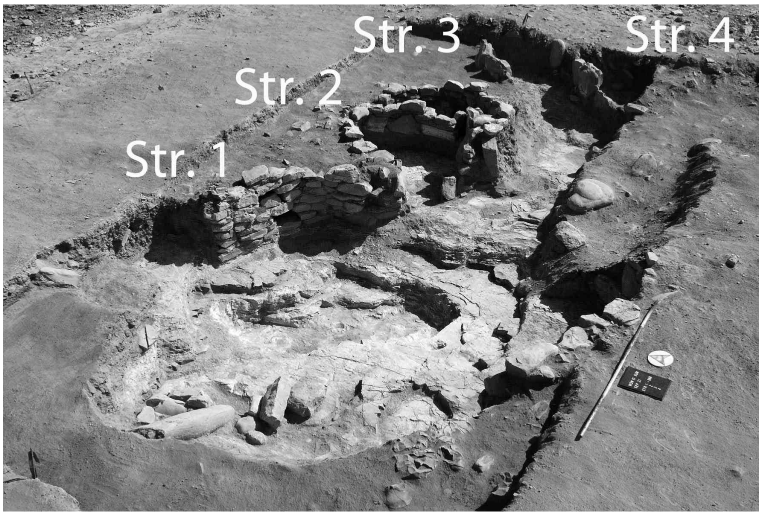

Fig. 22 Wadi Quweir 17: general view of the outpost (from SW).

Fig. 23 Wadi Quweir 17: stone weight found in situ on the floor of Structure 1 (from SW)

components of the Jafr pastoral Neolithic.

The barrage site of Wadi Quweir 106 lies in the middle of a flint pavement desert that extends behind an escarpment fringing the northern edge of the basin. It is far removed from PPNB sedentary farming communities, being located *ca*. 70 km east even of Wadi Abu Tulayha (Fig. 1). Understandably, the surrounding natural environment is very harsh and no perennial water source is available around the site. This extramural barrage site was found for the first time in 1999 by an American team, who noticed the resemblance to the PPNB barrage systems thus far known in the Jafr Basin and recommended us to undertake further investigation (Dr. Philip Wilke personal communications). It is for this reason that we embarked on the short-term rescue excavation in the remote wilderness.

Topographically, the site occupied the lower edge of a semi-open playa system that was connected by a braided or flat channel. It contained two elongated, slightly incurved, stone-built features, both of which were constructed across the lower edge of the lowest playa and spread both wings toward the upstream. Barrage 1 was situated upstream and larger in scale, being *ca*. 72 m in total length and up to *ca*. 0.2-0.5 m in preserved height (Fig. 18). Barrage 2, on the other hand, was located *ca*. 130 m downstream of Barrage 1, having a total length of *ca*. 74 m and a preserved height of *ca*. 0.2-0.5 m (Fig. 19). Barrage 1 was equipped with a semi-circular, protruded reinforcement wall at the central part, whereas Barrage 2 was structurally less strengthened, being devoid of such an essential device. This is probably because it was located downstream of Barrage 1 and, for this reason, was relieved to a large extent of strong sideways water pressure. Thus, Barrage 2 may be defined as a later addition to or renewal of Barrage 1, although as discussed below, it still falls within the time range of the PPNB period. As with the other PPNB barrages known to date in the Jafr Basin, both barrages were poorly waterproofed and designed to form a shallow, extensive, temporary flooded area on permeable fluvial deposits. There is little doubt that they were used for basin-irrigated agriculture.

The dating of the two barrages is based on the following two keys: first, existence of the protruded reinforcement wall at Barrage 1 and, second, the occurrence of bi-laterally notched and/or grooved stone weights from both barrages (Figs. 20, 21). It should also be added that most of the stone weights from Barrage 1 were incorporated into the reinforcement wall. All of these traits are shared with Wadi Abu Tulayha Barrage 1 and Wadi Ruweishid Barrage 2, attesting to the synchronism with them.

Of interest is the fact that a similar stone weight was found *in situ* at the nearby outpost of Wadi Quweir 17 (Figs. 22, 23). This small settlement, found again by the American team (Quintero and Wilke 1998a, 1998b; Wilke and Quintero 1998), produced diagnostic finds such as Amuq and Byblos type points, flint bowlets (Fujii 2009b), and game boards, thus being dated to the PPNB period with certainty[7]. The concurrence of the unique artifact highlights a synchronism between the two sites.

The investigation at Wadi Quweir 106 has provided further insights into the conditions for location of the Jafr barrage system. What attracted our attention were the following three observations. First, any two adjacent features of the playa system were connected by a braided or flat channel, thus forming a semi-open drainage system. Second, while upper playas were not accompanied with barrages, only the lowest playa was equipped with them. Third, the two barrages occupied the lower edge of the lowest playa. The reason for the last condition is easy to understand, since the location at the lower edge of a playa first makes it possible to create an extensive flooded area. The reason for the first and second conditions requires further scrutiny, but we can argue that the lowest feature of a semi-open playa system is well drained and, therefore, less subject to salt damage, an unavoidable problem besetting dry land irrigated agriculture. As a matter of fact, the other two barrage systems known to date in the Jafr Basin are located again at the lowest feature(s) of a semi-open drainage system. In contrast, no barrages have been found at upstream features of the same drainage systems, to say nothing of closed playas common in the basin. This contrast indicates that the PPNB basin-irrigation barrage gave high priority to the convenience of drainage no less than the availability of influent water.

Taking these new perspectives into consideration, the conditions for location of the PPNB basin-irrigation barrage system can be summarized as follows. Aside from the availability of influent water, arable deposits, and construction material, the first essential condition is that the supposed flooded terrain should be not only flat and extensive but also permeable and water-retentive. This is because basin-irrigation agriculture requires both the infiltration of impounded water into the ground and the retention of infiltrated water. It is for this reason that a silty playa rather than a rocky or sandy depression was preferred as a candidate site for construction. Another prerequisite is that influent water should dampen the terrain and, at the same time, wash it to some extent so as to cope with salinization of surface soil due to capillarity. This explains the reason why semi-open drainage systems were preferred to closed ones, and why the lowest component of a semi-open drainage system was preferred to upstream features. This is not to say, however, that the PPNB barrage constructors reached such a complicated conclusion after a great deal of effort. Seeing that present vegetation also focuses on the lowest component(s) of a semi-open drainage system, the truth may be that they merely followed the distribution of contemporary vegetation.

Whatever the case, it is a great surprise that the PPNB transhumants successfully coped with the two contradictory propositions endemic to dry land agriculture, namely, irrigation and soil salinization, several millennia ahead of Sumerians and Akkadians. Both the incomplete waterproof property of a barrage body (evidenced at every site) and the downstream renewal of the barrage system[8] (suggested at Wadi Quweir 106) can also reasonably be understood in this context. Nevertheless, the downstream renewal is incompatible with the preference for the location at the lower edge of the lowest playa. This discrepancy may explain the reason why every barrage system was short-lived, and why the PPNB transhumants must have moved their remote outpost at regular intervals. In this sense, we can argue that the Jafr PPNB transhumance involved a momentum for nomadization from the very beginning.

The finding of the third example of the PPNB barrage system has substantiated anew that basin-irrigation agriculture was among major aspects of the Jafr Pastoral Neolithic. Personal communications from several colleagues and local inhabitants suggest that similar barrage systems spread further inland or even beyond the Saudi Arabian border. If this is really the case, it follows that the Jafr barrage system hold a key to tracing the process of the Neolithization in the northern half of the Arabian Peninsula as well as the pastoral nomadization in southern Jordan (Fujii 2010a, 2010b). This makes sense, however, considering that runoff surface water domestication is an essential prerequisite for the full-fledged penetration into arid peripheries.

Endnotes

1 The "domestication" of plants and animals is defined, in general, as the process of commensal or mutual symbiosis through constant interference in their life cycle and their reproduction processes in particular. The same is roughly true of water domestication, which can be defined as the process of a sort of commensal symbiosis through continuous involvement in the autonomous behavior of flowing, stagnant, evaporating, or infiltrating water. Such a general definition, albeit far from satisfactory, will do for this paper, since our main concern consists in archaeological evidence of facilities involved in water domestication, not in the taxonomic distinction between wild and domesticated water.

2 This is not to say that the Neolithic Jafr Basin was under hyper-arid climatic conditions as it is today. In view of the general climatic amelioration during the PPNB, it can readily be imagined that the basin witnessed a less arid episode. If this was the case, it would be unwise to emphasize the "marginality" of the Jafr Basin too much. Nevertheless, we use the term "margin" or "periphery" in the strict sense of the word, that is, as a term referring to the edge of the core or an area just beyond - not as an emotive word implying a remote wilderness far beyond. Thus our eyes are upon a difference between the core and the edge, not a contrast between "the desert and the sown." Incidentally, the reason why we defi-

ne the Neolithic Jafr Basin as an arid margin or periphery is that instead of permanent settlements, it included seasonal stations for short-distance transhumance probably derived from the core. This allows us to regard it as a proper margin closely tied with, yet different in nature from, the core.

[3] Our comprehensive survey conducted in the summer of 2009 added a few possible examples at Wadi Badda and Jabal Juhayra (Fujii 2010a). Their location is shown in Figure 1.

[4] It is most unlikely that normal digging tools will do for such a tough operation. Suggestive in this regard is the fact that Structure M as well as the neighboring outpost produced several diagonally truncated stone bars *ca.* 10-20 kg in weight (*e.g.* Fujii 20089a: fig. 45). Structure M also yielded a few rectangular chipped limestone tools *ca.* 40-50 cm long, *ca.* 25 cm wide, and *ca.* 6-10 cm thick (Fujii 2008a: fig. 28). These heavy-duty tools bear remarkable edge damage, suggesting that they were used for digging through the thick limestone layers.

[5] It is evident that these episodes took place when Structure M was still in use, because a large number of fallen stones were found *in situ* (in the derivative sense of the word) on the floor.

[6] Suggestive in this respect is the fact that a few hearths and heavy-duty limestone querns were found *in situ* in the upper fill layers of Structure M (Fujii 2009a: figs. 42, 43). This implies that the structure was first converted into a temporary encampment when it was buried up to the top level of the impermeable limestone layers and, therefore, became fully dysfunctional as a cistern. As referred to in Appendix I, the series of ^{14}C data suggests that the episode took place immediately after the abandonment of Structure K, the last component of the elongated outpost. Those who left their footprints on the upper fill layers of Structure M can be defined as initial pastoral nomads in the sense that they abandoned the management of the fixed outpost and tentatively encamped at the discarded cistern (Fujii n.d.).

[7] Wadi Quweir 17 consists only of a single structural complex, which appears to resemble Complex I at Wadi Abu Tulayha in terms of architectural composition (Fujii *et al.* n.d. a). The possible combination of this outpost and the third barrage system would corroborate our perspective that the stage of Wadi Abu Tulayha Complex I witnessed the re-penetration into the arid margin bringing along the new technology of the barrage system.

[8] The downstream renewal hypothesis is based on the perspective that aside from the Wadi Abu Tulayha system (including two reservoir-type barriers), the other two systems (consisting only of basin-irrigation barrages) represent not a group of coeval barrages but an accumulated picture of a barrage reconstructed in sequence at an abutting lot. If this was really the case, it follows that both the elongated settlement of Wadi Abu Tulayha and the contemporary barrage system shared an underlying formation principle. This perspective is important to avoid the possible overestimation of the Jafr Pastoral Neolithic and deserves further testing.

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The Domestication of Water: Early Hydraulic Systems

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Introduction

Water is fundamental for human life, and during the early Holocene when sedentary settlements were attaining sizes of up to 12 ha, naturally occurring water sources for domestic use must have become increasingly important and were perhaps even contested features in the landscape. Here a distinction is made between water for everyday domestic purposes, or for animals, and water for irrigation, because even where there is early evidence for water supply it does not necessarily indicate that irrigation was practiced. The objective of this commentary is to provide a context for the recent important discoveries of what appear to be pre-pottery Neolithic water supply systems sites in the Jafr basin, southern Jordan. This discussion must necessarily cover a wide range of issues such as:

- To what degree was irrigation necessary during the relatively benign climate of the early Holocene?
- How will feature survival affect the recovery of early water supply installations.
- Problems of dating.
- How do the Jordanian features fit into the emerging picture of early water supply systems recovered from elsewhere in the Middle East?

The Nature of Water Supply

It is now well attested that Jordan was significantly moister during the early Holocene, and the presence of early Holocene flow stones in the Wadi Feynan near the Neolithic site of Beidha demonstrate that rainfall was significantly higher during the early Holocene (Rambeau 2006), so that irrigation may not have been necessary for the growth of crops. Moreover, recent investigations in the Wadi Feynan support the evidence for a verdant early Holocene environment by demonstrating that the vegetation cover consisted of a relatively rich woodland of oak, juniper, tamarisk and other trees in contrast with the steppic vegetation of today (Barker *et al.* 2007: 405). However, although less erratic than that of the Pleistocene, the climate was hardly constant and the early moist phase was terminated by the approximately 400 year interval of cooler, more arid conditions known as the "8200 BP event". This event might have required agricultural communities in climatically marginal areas to adapt to the increasing aridity by developing systems of water management, or in even drier locations, such as the Jafr basin, increasing aridity could have discouraged settlement entirely.

It is frequently assumed that irrigation, as a means of soil moisture enhancement, was only applied when it was absolutely necessary for plant survival. In other words irrigation was applied in areas that were so dry that without irrigation there would be no crops. This is not the case, and today it is common to see irrigation being applied in areas where it is not absolutely necessary, because it is used to supply supplementary water to enhance crop growth. That this was also the case in the past is apparent when we examine ancient irrigation systems in relation to the average rainfall of the area being irrigated. In this case only prehistoric irrigation systems occur exclusively in the drier areas where rainfall is today less than 200 mm per annum. Before about 1000 BC, irrigation was used in those places where it was essential for crop survival. Such irrigation may be termed water deficit irrigation systems. However, from about the first millennium BC onwards, when the technological manipulation of water had become much more sophisticated, we see irrigation systems being used in both climatically marginal areas, as well as to provide supplementary water in areas within the rain-fed farming zone. In other words irrigation was deployed to increase crop yields per hectare, that is for land use intensification. The sites in the Jafr Basin fall well into the category of water deficit irrigation because the rainfall (< 50 mm per annum) is well below that required for the cultivation of cereals, even if allowance is made for the somewhat moister conditions at the time. Elsewhere, for example in northern Syria and Iraq where Neolithic settlements are common, there is no evidence (to my knowledge) for Neolithic gravity flow irrigation.

Another important consideration is whether evidence for the earliest water channels will actually survive. Processes of landscape transformation are fundamental to the interpretation of features in the landscape, and are often rather taken for granted by archaeologists. Nevertheless, it is clear that the features in the Jafr basin occur well out in the desert where there will have been little subsequent activity to remove or disturb any archaeological features. On the other hand if such a site had occurred in the area of rain-fed cultivation, post-Neolithic activity, specifically agriculture or selective stone robbing for wall construction, would have probably removed such fragile features. For example, the well known features known as desert kites, which arguably can be traced back to the pre-pottery Neolithic, survive well in the desert or dry steppe, but near the agricultural margins they become incorporated into later field systems, often of Roman-Nabataean date, if they survive at all (Kennedy 1982). More generally it can be argued that the survival of so many pre-pottery Neolithic sites in Jordan, may be because much of the country consists of a "landscape of survival" where conditions were ideal for the development of early prehistoric sites, but where the expansive settlement systems of the Bronze Age and later periods were less well developed thereby ensuring the survival of many of the earliest sites.

The loss of archaeological features is particularly acute in the case of water systems of all periods. This is because the prime water conduction channels are frequently located in highly erosive environments, or where riverine deposition can obscure built or dug features. Therefore, according to the experience of the present writer, only limited lengths of channel are discovered because many structures, including the most protected parts, have been destroyed or masked by alluvial processes. This is relevant to the interpretation of the site of Ba 'ja in Jordan, where Gebel (2004) has postulated the former existence of a Neolithic water system. The case of the *siq* gorge is precisely the type of location where the evidence of water supply systems will have been lost, although without some form of evidence of a water system the argument for the existence of water systems will always be hypothetical.

Indirect Evidence for Irrigation

Some of the earliest evidence of irrigation derives from carbonized plant remains which takes the form of enlarged cereal grains or assemblages of plants and weeds associated with wet habitats. For example, a convincing case can be made for irrigation at Chagha Sefid, in Iran, between 5200 and 5000 calBC and it is possible that this might be extended to as early as 6000 BC (Hole 1977; Helbaek in Hole *et al.* 1969: 424). In addition to carbonized plant remains, the evidence from enlarged plant phytoliths should also provide evidence for water enhancement to be recognized in pre-pottery Neolithic contexts.

Questions of Dating

One of the perennial problems associated with landscape archaeology is the dating of the features themselves. Hence, it is hardly surprising that the features in the Jafr basin are difficult to pin down chronologically. It is very easy to assume a date for even a well-developed channel system, especially when it is in the proximity of other more well dated features. Obviously surface artefacts can be a very misleading guide to the date of a canal or water conduit, and dating by spatial association is hardly robust. Even if a channel has been systematically excavated, many of the artefacts will be residual because they will have been washed in from earlier deposits. By way of example, a major canal in the Balikh valley of Syria, which on the basis of indirect evidence from cuneiform texts was thought to be Old Babylonian in date (early 2nd millennium BC), contained pottery as early as Halaf in date. However, the excavated artefacts, when taken as an assemblage, together with a single radiocarbon date on carbonized wood from the channel deposits in the base, demonstrated that the channel was in fact Roman – Byzantine in date. Even this carefully obtained date cannot give a history of the earlier phases of use of the channel, because many canal systems have been cleaned out over millennia. Consequently the upcast and clean-out deposits which usually occur alongside a water channel can provide invaluable supporting dates.

In addition, the excavation of diagnostic features that are demonstrably an integral and functional part of the channel (*e.g.* water mills or lime baking kilns) provide reliable dates. Spatial proximity or dates by association are much less reliable and must remain tentative. Of course, in the case of apparently early remains in the Jafr basin, such opportunities for dating are absent, thereby making the dating of such features extremely difficult.

The Evidence for Early Water Supply Systems beyond Jordan

The earliest known water supply systems in the region are the wells at Mylouthkia, Cyprus, which have yielded radiocarbon dates on organic materials in the fills around the 9th and 8th millennium BC (Peltenburg *et al.* 2000; Table 1). These were probably for domestic water supply, as well as perhaps some supplementary water for gardens, but they do not constitute evidence for early gravity-flow irrigation systems. Such early wells are important however, because like the ceramic Neolithic wells in northern Iraq dated to the Samarran and Hassuna periods (*ca.* 6000 BC) these greatly increased the location flexibility of early settlements so that sedentary communities were not tied to specific springs or rivers. As a result, the inhabitants could harness shallow ground water and this allowed the possibility for small settlements to be dispersed across the landscape.

In a seminal article published in 1980, Andrew Sherratt stated:

"*The earliest demonstrated examples of channel irrigation in the Near East are related to the braided streams which flow down alluvial fans on the margins of the semi arid basins.*" (Sherratt 1980: 24)

Alluvial fans, provide the evidence for some of the earliest irrigation systems. The attraction of alluvial fan locations for human occupation is enhanced by the frequent presence of springs that issue from the toe of the fan, usually within the transition zone where the fan meets the plain. However, by harnessing such perennial supplies as well as ephemeral flows, the inhabitants of such alluvial fans were not only positioning themselves in locations that were vulnerable to flooding, because such floodwaters carried a substantial sediment load, the associated sites and field systems developed in what might be described as "self consuming" landscapes. In other words, the act of choosing a location on an alluvial fan resulted in the settlements themselves being vulnerable to sediment masking because of their locations in areas of active sedimentation. Because such locations were frequently the focus of early irrigation systems, it is likely that many of the best examples of early irrigation systems are buried beneath considerable depths of alluvium. Good examples of early irrigation systems recovered from such "self consuming landscapes" include the following.

Qazvin and Tehran Plains

On a broad area of coalescing alluvial fans on the Iranian plateau in the region of Qazvin and Tehran, Neolithic, Chalcolithic and later prehistoric mounded settlements (tells or tepes), are evident both as surface features or are partially buried by alluvium.

Specifically, on the Tehran plains to the east of Qazvin, excavation coupled with geoarchaeological surveys on the Jajerud alluvial fan system have revealed that the site of Tepe Pardis experienced some 3.5 m of deposition since the 6th millennium BC and *ca.* 2 m during the last millennium (Coningham *et al.* 2006: 52). The acute loss of sites by burial required the survey to focus on the examination of upcast from *qanat* mounds to recognize the artefacts from deeply buried sites. As a result, six buried prehistoric sites of Chalcolithic date were recorded along some 30 km of *qanats* walked, compared with 8 sites from 105 km of surface transects (Coningham *et al.* 2006: 51).

At Tepe Pardis, earth-lined channels were buried below the occupation deposits of the site as well as within the stratigraphy thereby providing a sealed stratigraphic context for early irrigation. The radiometric dates, which fall in the region of 6000-5000 BC, provide a relatively secure date for the early introduction of irrigation. Again, alluvial fans supplied both a water supply and a location for settlement with the result that the selection of sites for inhabitation resulted in their eventual loss as a result of sediment masking.

Daulatabad, Iran

The earliest evidence for irrigation in eastern Iran comes from near Daulatabad, near Tepe Yahaya. This takes the form of a remarkably preserved landscape of relict fields and occasional low prehistoric mounds occupied during the late 6th and 5th millennium BC (Prickett 1986). Occasional traces of possible canals were apparent within the field area, but more convincing were the profiles of what appeared to be canals up to *ca.* 1.4 m wide and 0.7 m deep stratified within one or two of the sites and buried below some 4.5 m of cultural strata. Irrigation water was apparently derived from the annual floods of a nearby river, although it appears that the flow was eventually cut off so that the landscape was not buried.

Choga Mami, Iraq

The sixth millennium BC site of Choga Mami, is located within a zone of alluvial fans that debouch from a western ridge at the edge of the Zagros Mountains near Iraq – Iran border. Like the examples from the Tehran plain and Daulatabad, examples of early canals have been recorded stratified within the site itself (Oates 1969: 122-27). However, the spring floods from the Zagros would have arrived too late to nourish the crops, for which we have compelling archaeobotanical evidence (Helbaek 1972). In this case the requirement of getting water to the crops during the winter growing season appears to have been dealt with by constructing irrigation channels along a gentle gradient roughly parallel to the mountain front (Oates and Oates 1976: fig. 4b). By decreasing the gradient to below that of the normal distributaries, flow energy along the canals would have been lessened, thereby encouraging sedimentation and associated aggradation. These channels derived their water from the nearby Gangir River (Helbaek 1972: 35), although it is unlikely that this was from the "natural inundation" of the alluvial fans by the annual spring floods because these come too late for the germination and growth of cereals during the winter and early spring. Rather the annual rainfall of between 200-300 mm per annum, which falls mainly between November and February, would have supplied some of the necessary soil moisture (Hunting 1968: 3), with supplementary flow perhaps deriving from the lower flows of the Gangir River as required. Such an expedient would, however, have increased the instability of any canals, because the rising spring flood would threaten to flow along the canals thereby causing damage to irrigation structures, canals and fields.

Upper Khuzestan Plain (Iran)

Within the Upper Khuzestan Plains of southwest Iran the abrupt shift of one of the main river channels has resulted in an entire alluvial plain being dissected by a complex of gullied badlands. This has revealed occasional Chalcolithic sites of the 6th-4th millennium BC, some of which are buried and interleaved within alluvial sediments emanating from the fans of Dar Khazineh, Abgenji and Naft Sefid (Lees and Falcon 1952: 31-34; Moghadam and Miri 2007, fig. 3). At Dar Khazeneh, one of the sites exposed by this phase of dissection, the presence of thin archaeological horizons interstratified with fine silt and loam overbank deposits implies that intermittent occupation occurred within a low-energy aggrading environment (Alizadeh *et al.* 2004: 73). That occupation may have been seasonal and temporary is supported by the presence of bones of very young or recently born sheep/goats together with a dominant assemblage of charred seeds of wild grasses and legumes. Together the geoarchaeology and bioarchaeology suggests that such sites were occupied intermittently alongside a wadi system draining from the nearby ridges of the Zagros mountains. The occasional presence of buried sites in the area suggests that this area had been deliberately selected by prehistoric agro-pastoral communities because the aggrading alluvial environment provided an ideal environment for flocks and perhaps opportunistic flood recession agriculture. Ironically, however, it appears that the deliberate selection of aggrading wadi edge locations has almost inevitably resulted in the burial of prehistoric sites and the loss of the archaeological record.

Whereas in the Qazvin and Tehran plains the bulk of many prehistoric sites lie buried beneath the alluvium with the summits remaining visible, in the Mianab plains of Khuzestan some sites have been entirely buried. They have only been revealed because the diversion of a major channel (the Gar Gar) initiated a major phase of incision that exposed the sites together with their full stratigraphic sequences (Alizadeh *et al.* 2004: 80-82).

Altogether, the above evidence of water supply systems demonstrates that wells, presumably for domestic water, were already in use by 8000 BC, and by 5000-6000 BC communities in the Near East were manipulating seasonal floods for irrigating fields and for perhaps for the enhancement of pasture lands. How such precocious developments relate to the earliest riverine irrigation systems of Mesopotamia is difficult to say, although evidence from Oueli in southern Iraq suggests that early irrigation was already in place by 6000-5500 BC (Huot 1989; 1996).

The remarkable group of features recorded in the Wadis Abu Tulayha and Ruweishid ash-Sharqi can therefore be seen to fit between the precocious development of early wells in Cyprus and the Israel/Palestine and the slightly later evidence for alluvial fan irrigation systems of Iran. Although on first impression the systems of the Jafr Basin may appear to form an unusual outlier, they do in fact fit within a rather longer period of adaptations to specific types of water course.

The Features of the Jafr Basin and Processes of Water Management

The association of agro-pastoral settlements with a series of valley floor barrages provides compelling evidence for pre-pottery Neolithic water management systems. Both barrage 1 at Wadi Abu Tulayha and barrages 1 and 2 at Wadi Ruweishid ash-Sharqi are located in medium-size tributary wadis leading into the main wadis (Wadi Abu Tulayha and Wadi Ruweishid ash-Sharqi; Fujii 2007: 16 and figs 3 and 11). Such locations are similar to those of the water diversion systems for *birkeh* (*i.e.* water tanks) on the Darb Zubeidah in Saudi Arabia. In the case of these early Islamic water systems, low walls were used to deflect water from minor wadis or enclosed depressions to the water tanks which supplied water for the pilgrims and their pack animals passing along the Hajj routes en route to Mecca. Significantly, many of the tanks and their deflector walls were located so as to avoid the main wadi channels, because the powerful flows would not only damage any built structures, but would also rapidly infill and overwhelm any storage facilities as well (Wilkinson 1980). Not only are flows from the side wadis easier to manage, the relatively low discharges are less damaging to the containment walls. In the case of the Jafr basin, if the aim of the barrages was to accumulate both soil and water for encourage grazing or forage, a location within a side wadi would pose no threat to the vegetation that developed behind them.

The water systems of the Jafr basin systems provide a good example of the incremental enhancement of well-favoured niches. In other words over long periods of time the presumably mobile inhabitants of the area observed how water was shed from the raised areas of ground to gather in shallow wadis or basins (*qa*) thereby enhancing the growth of vegetation to create an ideal pasture resource. It took only a limited amount of imagination and work to construct walls to enhance the existing natural flow patterns and to use them to secure a bonus grazing resource, or even to cultivate cereals. For example, today the mobile inhabitants of the Badia have an intimate knowledge of the landscape as well as both soil moisture and water availability, so that each type of water gathering location has its own name (Lancaster and Lancaster 1997).

Both the walls and their location are consistent with early Islamic water-gathering features recorded by the writer in Saudi Arabia (where rainfall is in the range 50-100 mm per annum), as well as Roman-Byzantine or perhaps PPN water gathering features recorded in Jordan by Betts and Helms (1989). This suggests that the systems of the Jafr basin represent an extremely long tradition of water management that is well adapted both to the needs of the inhabitants as well as to the nature of the local environment. Of course, the sceptical observer may argue for an alternative conclusion, namely that the barrages were built by later mobile pastoralists in an area that had previously been intensively used by Neolithic communities, and that the Neolithic artefacts then became incorporated into the later structure. Overall however, I find the context, association and dating evidence persuasive, although it is necessary to further enhance the dating framework.

The approach of incrementally managing resources is in line with other examples of early water management found in the Near East. These include the use of crevasse splays along rivers in Mesopotamia for primitive irrigation, or of runoff and receiver areas in the Negev and Arabia deserts as a prelude to runoff agriculture. In the case of runoff agriculture in the Negev, drier parts of the desert shed more water as runoff than wetter areas. This is because the areas to the north that receive higher rainfall have a greater cover of soil and loess, which absorbs more rainfall. On the other hand, in drier areas further south, where the terrain has more impermeable rocky outcrops, the run-on or field areas downslope receive a greater bonus of water because of the enhanced run-off. Similarly, smaller wadi catchments shed a higher percentage of run-off than the large basins, because the latter absorb water flow within wadi sediments and colluvium (Yair

Location	Rainfall	Date Cal.BC	Comments	Reference
Mylouthkia well		8740-8280	Direct dating of fill	Kinnaird *et al.* 2007
Mylouthkia well		7450-6690	Direct dating of fill	Kinnaird *et al.* 2007
North Jazira, (Iraq). Well/ water hole	350 mm	ca. 6000	Artifacts from fill (Samarran & Hassuna)	Wilkinson & Tucker 1995
Wadi Abu Tulayha (Jordan)	< 50mm	7000-6000	Associational dates & artifacts	Fujii 2007
Tepe Pardis (Iran) (channel)		6000-5000	Dates on fills above & below	Conningham *et al.*
Chogha Mami (Iraq)		6000-5000	Associated cultural layers within tell	Oates & Oates, 1976
Daulatabad (Iran)		5500 - 4500	Channels stratified within sites	Prickett 1986
Dar Khazineh (Iran)		4800-4000	Site buried in valley fill associated with possible flood recession agriculture.	Alizadeh *et al.* 2004
Sedd edh-Dhra 'ah (Yemen)		3960-3630	Radiocarbon date on soil behind check dam	Wilkinson 1999
Wadi Sana (Yemen)		4000-3000	Radiocarbon dates	Harrower 2008

Table 1 Early water supply

2001; Wilkinson 2003: 169-170). Such variations in run-off and water yield would have been observed and noted by the local, presumably transitory, residents of the region and would be adapted by them to produce the earliest water systems. Presumably initial attempts to "domesticate water" would be minimal, whereas later attempts would entail greater investments of time and effort to produce larger and more well managed systems. Clearly the examples from the Jafr basin fall into the earlier simpler category of water system.

Conclusions

The ancient water supply systems of the Jafr basin have the potential to make a significant contribution to the history of water supply. Chronologically, they appear to fall towards the beginning of a 10,000 year sequence of water management, and their form and location falls logically within those used for millennia in Arabia. This makes it even more important that they, or similar systems, should be dated as unambiguously as possible. As pointed out above, dates for water supply systems are notoriously difficult to obtain and can be ambiguous, therefore it is crucial that dates are sampled from as many different contexts as possible. For example, dating by association can vary in its credibility. In interior Syria at the site of Andarin, a functional relationship between kilns and a water tank supplied secure dating evidence for the water tanks because the kilns were required to fire the limestone to make the plaster (Mango 2002). Obviously, in the case of prehistoric systems, such relationships are unlikely to obtain because the systems were without plaster, but this example emphasises that associational dating can vary from strong (if it is a clear functional relationship) to less secure, when the associational relationship is less clear. Demonstrating a clear, functional relationship between the neighbouring sites and the water systems would therefore enhance the associational date.

OSL dating of the accumulated sediments themselves has the potential to provide an independent and absolute date for the associated sediments.

Further survey is necessary to determine if examples of similar water systems can be found, or if such examples occur within a secure stratigraphic context. For example, in Yemen a low valley floor check dam was securely dated, not only because of the radiocarbon date obtained from charcoal within the soil built up against it, but also because it was stratified within a well-dated 10 m deep sedimentary sequence, some 6 m below the ground surface (Wilkinson 2003: 190). Because water management systems are well placed to be either swept away by floods or buried by sediments, the ideal water management system would include systems that possessed a clear spatial layout, such as those in the Jafr basin, together with other components that are buried within a well dated and unambiguous sedimentary sequence. The discovery of such contexts is of course a tall order, but the systems from the Jafr basin represent an excellent first step in our understanding of the initial phases of water management in the Middle East.

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Social Aspects of Water Technology in the Protohistoric Near East

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In this contribution I would like to discuss the social aspects involved with the domestication of water in the Protohistoric Near East. Since the early 1990's it became apparent that the Protohistoric communities of the Near East had the knowledge of digging wells for water. In accordance to the geological setting these were either dug or cut in stone, from the site surface into the water aquifer, 4-9 m deep. The wells were found in the open areas of the prehistoric villages, and not inside closed courtyards. The digging of such an installation required much labor. Thus, the location on site and the technical difficulties suggest that the digging of wells was a public, communal enterprise of the settlement, and not the activity of individual households.

Protohistoric Wells in the Near East

The earliest Neolithic wells, dated to *ca.* 8000 BC (Pre-Pottery Neolithic B), were uncovered in two Cypriote sites: Kissonerga-Mylouthkia and Shillourocambous. In Kissonerga-Mylouthkia, near the Mediterranean coast of western Cyprus, two cylindrical shafts dug into the local sandstone were exposed (Peltenburg *et al*. 2000; 2001). Each well is about 2 m in diameter and 7 to 8 m deep. However, since erosion and modern quarrying have destroyed the upper part of the wells, the exact original depth is unknown. In Shillourocambous, located inland in southern Cyprus, three wells were reported (Guilaine *et al*. 1999, Fig. 1; Guilaine and Briois 2001: 41, Structures 2, 66, 114). So far little information has been published on these wells, which were cut in the local rock like the two wells reported from Kissonerga-Mylouthkia.

Three wells were reported from the underwater Pre-Pottery Neolithic C (*ca.* 7000 BC) site of ‘Atlit Yam, near the Mediterranean coast of Israel (Galili and Sharvit 1998; Galili *et al*. 2002), but only one of them has been described in detail (Galili and Nir 1993). The settlement of ‘Atlit Yam is characterized by elongated walls running through the village. The wells, however, are not bordered within enclosures, but seem to be open to all.

One well was discovered during my excavations at Sha‘ar Hagolan (Figs. 1-2), a Pottery Neolithic site in the central Jordan valley, radiometrically dated to *ca.* 6400-6200 BC (Garfinkel *et al*. 2006). The site of Sha‘ar Hagolan is characterized by large courtyard houses built abutting each other, on both sides of streets conveying the impression of a well-organized village (Figs. 3-4). These courtyard houses were composed of one large courtyard surrounded by 8-24 rooms, and reach 220-700 m² in size. These were used by extended families. The well was not found inside such a structure, but in open area of the village.

Another well was found during my excavations at Tel Tsaf, a Middle Chalcolithic village in the central Jordan valley (Fig. 6). It is radiometrically dating to 4700 calBC (Garfinkel *et al*. 2007). The settlement is characterized by large buildings; each is composed of an enclosed courtyard. In the courtyard various rectangular or rounded rooms were found. The well, however, was not found inside of one of these buildings, but in Area B, an open area at the southern outs cart of the settlement.

A Late Chalcolithic well was reported from Abu Haf (Alon 1988, Fig. 2), but no detailed information was supplied.

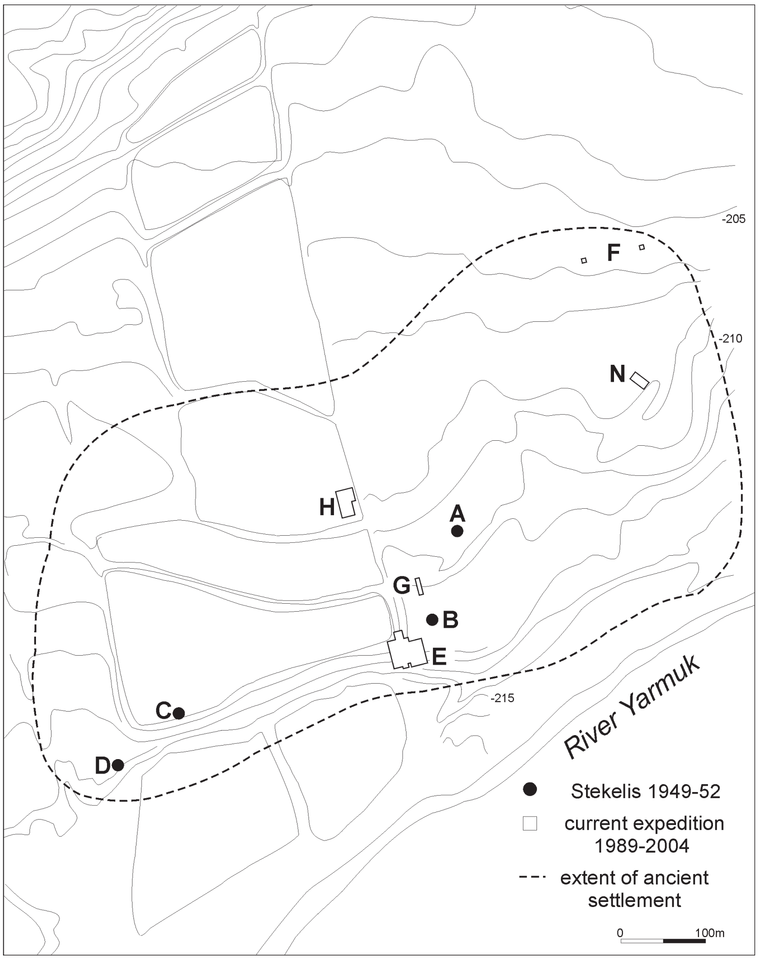

Fig. 1 Sha‘ar Hagolan site with the location of the excavated areas. The well was discovered in Area G.

Fig. 2 The Neolithic well of Sha'ar Hagolan.

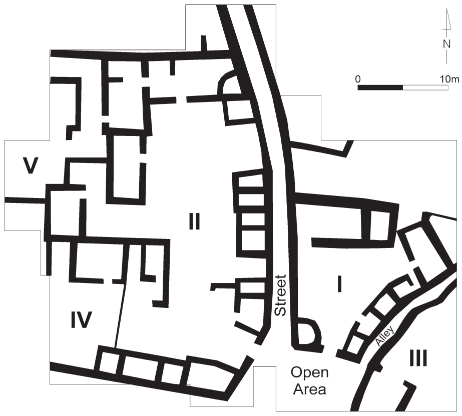

Fig. 3 Sha'ar Hagolan: Courtyard structures at Area E.

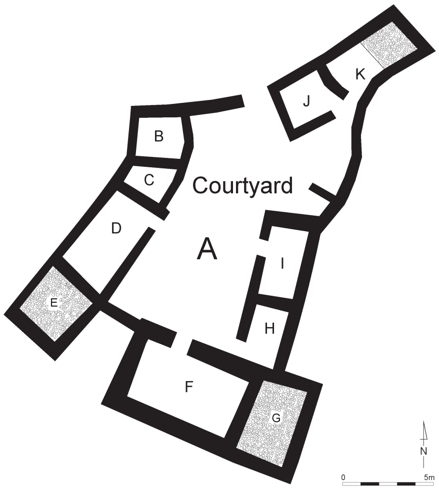

Fig. 4 Sha'ar Hagolan: A courtyard structure at Area H.

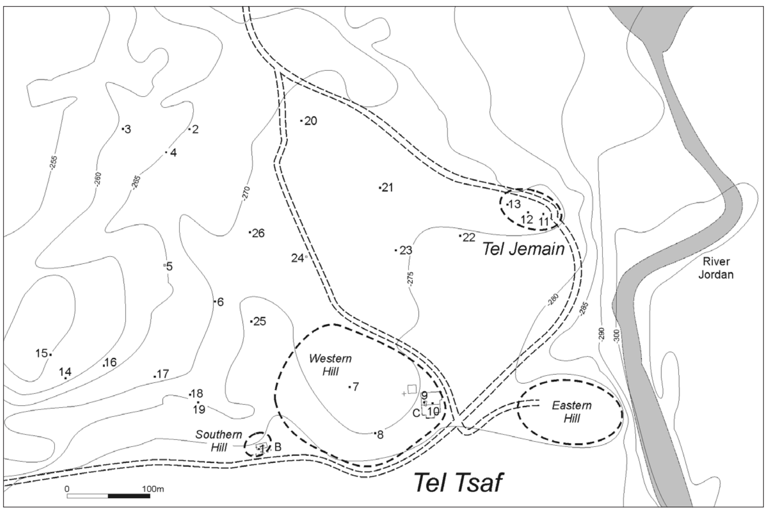

Fig. 5 Tel Tsaf site with the location of the excavated areas. The well was discovered in Area B.

Fig. 6 The Middle Chalcolithic well of Sha'ar Hagolan.

Discussion

Nature of Work: The construction of a well required various stages of work:

1. Digging, or cut in stone, into depth of 4-9 m.
2. Removing cubic meters of sediment. A few tons of matrix need to be lifted up the well shaft and damped away.
3. Collecting and transporting hundreds of stones for the lining of the well.
4. Regular maintenance is needed to keep the well working during the period of usage.

All these stages are labor intensive operation, far beyond the individual person, or even one extended family. It required the involvement of a large group of people.

***Location on Site*:** At Sha'ar Hagolan and in Tel Tsaf the location of the wells is clearly in the open areas of the settlements. They were not found in the large courtyard buildings, which existed in both sites (Figs. 3-4, 7). Technically, people could have dug private wells in their large confirmed privet courtyards. In such a situation the wells would not be accessible to everyone in the community, but only to the specific family.

However, wells were never found inside closed courtyards, and this seems to be the case not only in the two sites in the Jordan valley, but to all the other sites mentioned: Kissonerga-Mylouthkia, Shillourocambous and Atlit Yam.

The combination of these two aspects clearly indicates that the digging and usage of wells was done on the community level, and not by the individual families. The wells were part of the public activity in the early village communities. Technologies like flint knapping, pottery making, beads manufacturing or building houses, were done on the individual level. The transmitting of this knowledge was probably done from one individual to the other. In contrast, the knowledge of digging wells is a technology practiced on the community level. This situation raises various questions. If digging wells was a "common knowledge", who was coordinating the community during the construction? Alternatively, if specific people, "well engineers", were responsible for the activity, this was another aspect of specialization in the Protohistoric period.

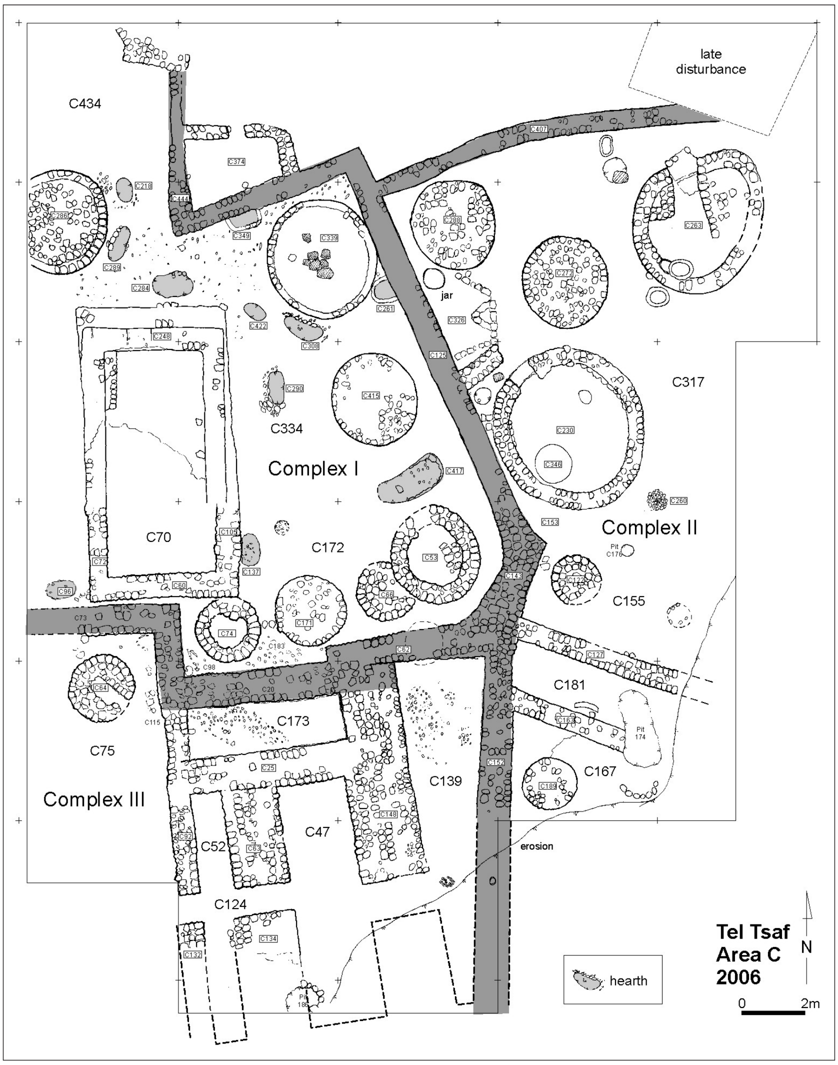

Fig. 7 Tel Tsaf: Courtyard structures at Area C.

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Early Agriculture and Ditch Irrigation

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By the sixth millennium BC, substantial water management systems had developed across diverse regions of the Middle East. The discoveries of substantial Pre-Pottery Neolithic B (PPNB) installations for the storage and distribution of water in the Jafr Basin of southern Jordan (Fujii, this volume) augment roughly contemporaneous facilities discovered in northern Iraq (Oates 1969) and eastern Iran (Prickett 1986). In turn, these discoveries prompt us to turn our attention to the earlier Pre-Pottery Neolithic A (PPNA) of the Levant as a likely origin point for simple irrigation techniques. In the Jordan Valley, PPNA agrarian hamlets were tethered to permanent water sources, positioned on alluvial fans and/or below springs. Well-known examples are Tell as-Sultan at Jericho (Kenyon and Holland 1981) and the sites of the Salibiya Basin, including Netiv Hagdud (Bar-Yosef and Gopher 1997) and Salibiya IX (Enoch-Shiloh and Bar-Yosef 1997). In north Syria they emerged also in riverside contexts, such as at Mureybet (Ibáñez 2008), Jerf al-Ahmar (Stordeur and Abbès 2002) and Sheikh Hassan (Cauvin 1980).

Archaeology now stands well-prepared to investigate simple irrigation works which left little or no direct traces in the archaeological record. The theoretical consequences have been deliberated over several decades; perhaps best articulated by Sherratt (1980). Sherratt observed that the expansive canal systems of early urban Mesopotamia tended to promote a vision of irrigation technology as complex and evolved with respect to early farming. On the other hand (as he countered), irrigation is likely to have been a precondition for small-scale horticulture, rather than an outcome of it. Sherratt observed that rain-fed agriculture, with its requirements for tillage, laborious land clearance and raising water to elevated land, is in fact the more difficult proposition. Instead, lowland wetland environments - where communities practiced flood-recession farming or trained spring-waters onto small cultivated fields by the expedient of digging channels (which we might better term as ‘ditches’ to keep an appropriate scale in mind) - more likely witnessed the birth of agriculture. The idea was already an old one by the time of Sherratt’s paper, given Spinden’s (1928: 52-53) proposition that irrigation is a “conception which accounts for the very origins of agriculture.”

We should not doubt that PPNA communities lacked the social capital or technical wherewithal to build irrigation systems. Communities such as the one at Jericho which could erect a large town wall, build an elaborate tower with a vaulted staircase, large tanks - and not least - carve out a massive ditch that stands comparison (at least in girth), with any irrigation canal from old Sumer, could have met with no difficulties in diverting spring waters onto small garden plots (Dorrell 1978: 11-12; Miller 1980). The accomplishments of hunter-gatherer groups, past and present, provide us with a baseline for their capabilities. In order to promote the growth of wild plants, bands of Paiute in the Owens Valley of southern California were recorded as having irrigated two substantial fields (of 5 km^2 and 10 km^2 respectively), by damming a creek and then diverting water from it through two separate ditches (Steward 1929). It took only a day for a couple of dozen men to complete the work. In the alternate hemisphere, prehistoric networks of channels lined with basalt were constructed near the south-west coast of Victoria (Australia) for the purpose of trapping eels and fish, by the diversion of flood waters (Coutts *et al.* 1978). Such devices have a long antiquity. The Kuk swamp in the highlands of Papua New Guinea was already drained by a substantial channel at 9,000 BP (Golson 1980).

As several authors have noted (*e.g.* Wilkinson, this volume, Rosen 1999), it is unlikely that small ditches will have survived in the archaeological record even if they did exist in the Levantine Neolithic. Fortunately, several circumstantial lines of evidence can signal the presence of irrigation. The most convincing of them is the presence of high levels of multicellular cereal phytoliths, including ‘silica skeletons’, in archaeological sediments (Rosen 1999; Rosen and Weiner 1994). It has also been suggested that the present of hydrophilic plants such as *Scirpus* and *Cyperus* in archaeobotanical assemblages indicate irrigation practices in wetland environments (Flannery 1969; Leroi-Gourhan 1974). This may be true in some cases, but it does not automatically follow that proximity to wetlands necessitates the practice of irrigation. At Çatalhöyük in the seventh millennium BC, Roberts and Rosen (2009) have established that wheat was not cultivated as an irrigated crop, despite the abundance of seasonal wetlands adjacent to the mound. Instead, it was grown a considerable distance away, under rain-fed conditions.

Of course, we should not expect the early irrigation scenario to be a *fait accompli* for PPNA sites. Wadi Faynan 16 in southern Jordan has been investigated by the phytolith method, with negative results. Situated at the confluence of Wadi Ghuwayr, Wadi Shuqayr and Wadi Faynan (Finlayson and Mithen 2007: 11), the site overlooks a stream fed by perennial waters. Yet cereals and pulses make only a desultory presence among the charred macrobotanical remains (Kennedy 2007) and there is no evidence for elevated phytolith levels among cereal remains (Jenkins and Rosen 2007). The local phytogeography and topography may explain

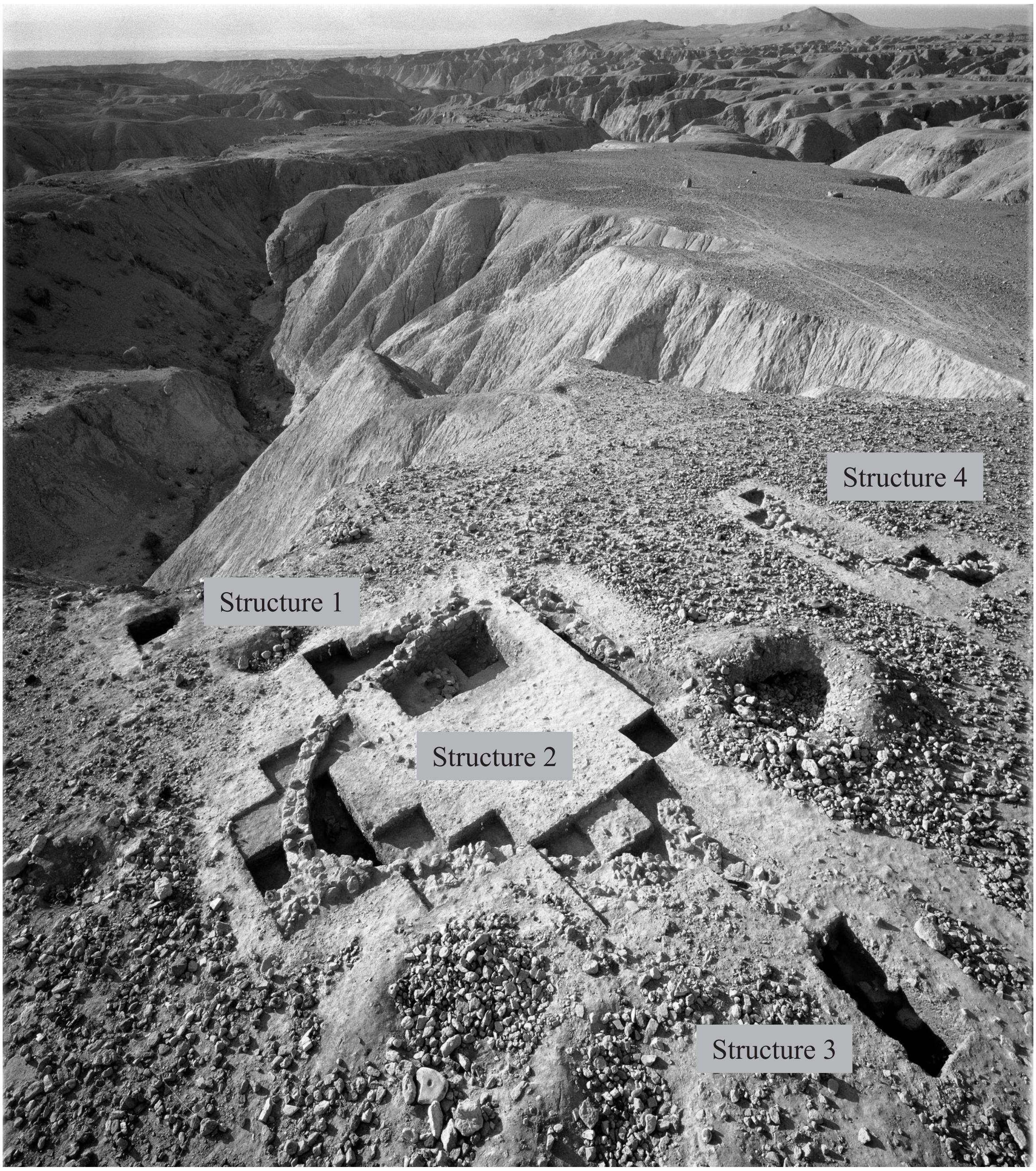

Fig. 1 Zahrat adh-Dhra‘ 2: general view looking west.

the scarcity of cereals which are more commonly encountered in PPNA settlements further to the north. Wadi Faynan 16 sits atop a knoll, elevated at least eight metes above the adjacent wadi bed, just downstream from the point where Wadi Ghuwayr broadens after emerging from a steep gorge (Mithen and Finlayson 2007: 476). There is sloping land above the wadi that might have been suitable for irrigated crops. However, the level of entrenchment of the stream might have precluded the easy diversion of water to higher ground. It is also unclear whether winter and spring floods would not have repeatedly scoured the wadi beds and its banks during the growing season (Mithen and Finlayson 2007: 476). Wadi Faynan 16 lies at a considerably higher altitude (~ 400 metres above sea level; Tipping 2007: 170) than the Jordan Valley PPNA sites. The settlement enjoyed close proximity to habitats that supported mixed woodland (Austin 2007) resources and an understory of Mediterranean grasses (Kennedy 2007: 427). There may not have been the same impetus to cultivate as in those settlements lying outside the Mediterranean zone.

Nevertheless, ongoing phytolith analysis of samples from Netiv Hagdud and Dhra‘ (another Jordan Valley PPNA site), have not yet reported evidence of cereal irrigation (Jenkins and Rosen 2007: 435). Dhra ‘lies at the base of the Kerak Plateau on a perennial spring, near the south-eastern shore of the Dead Sea (Finlayson *et al.* 2003). The situation of its downstream PPNA neighbour, Zahrat adh-Dhra‘ 2 (ZAD 2) seems even more propitious as a likely locale for ditch irrigation (Fig. 1). Indeed, it seems difficult to explain the settlement without invoking cultivation by irrigation as a rationale. At 220 metres below sea level, ZAD 2 is s located in a region of low rainfall which was always beyond the support of Mediterranean grasses (Edwards *et al*. 2004; Edwards and Higham 2001; Edwards and House 2007). The underlying sediments are composed of sterile evaporites which are also unsuitable for Mediterranean vegetation. The deeply entrenched Wadi adh-Dhra now runs past the site and has destroyed part of it by erosion. Hydrophilic *Melanopsis* shells occur in the archaeological sediments, however; and during the period when the site was occupied the stream flowed at the current altitude of the plain (House 2003).

Located in a hot and treeless plain, the site's only apparent advantages were the expanses of flat land that lay to the south, which could have been gravity-fed by water directly from the wadi. A rocky alluvium in the vicinity of Dhra‘ village might have been induced to support crops (as it does now with the aid of irrigated water). Furthermore, a large-seeded form of wild barley was common at the site, suggesting that it had been cultivated (Meadows 2004, 2005). A planned program of phytolith sampling at the site should form a decisive test of the theory that 'ditch irrigation' played a crucial part in the development of early PPNA agriculture. In the meantime, we can look forward to the development of further indicators of ancient irrigation, such as Emma Jenkins' current research on carbon isotopes and irrigated cereals at the University of Reading.

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Submerged Neolithic Settlements of the Mediterranean Carmel Coast and Water Mining in the Southern Levant

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Introduction

Fresh water is essential to human societies. Some drinking water can be transported over distances but can not fully support settled communities. The shortage of permanent fresh water sources left certain areas unsettled. The PPN novel invention of mining underground aquifers using wells created a man-made source of fresh water which enabled the settling of previously unusable territories, *i.e.*, coastal areas. Recently early Neolithic wells were discovered in Cyprus (Peltenburg *et al*. 2001), submerged Atlit-Yam, and Sha'ar Hagolan (Garfinkel *et al.* 2005; Garfinkel 2006). The Holocene sea level rise inundated the Pre-Pottery Neolithic (PPNC), Pottery Neolithic, and Wadi Rabah (Fig. 1) settlements on the Carmel coast. These were later uncovered by coastal erosion.

The PPNC Site of Atlit-Yam

Atlit-Yam (AY) PPNC submerged village thrived some 9200-8500 years ago (calibrated). It is located in the north bay of Atlit at a depth of 8-12 m, and is 4 hectares in area. Excavations there revealed rectangular and round installations, megaliths (Figs. 2, 2a), anthropomorphic stelae, and hearths. Artifacts of stone, bone and flint were recovered as well as human skeletons. Organic remains include terrestrial animal bones, fish bones, and plant remains suggesting a complex economy based on hunting, incipient herding, fishing and farming (Galili *et al*. 1993).

The Water Wells of Atlit- Yam

Thirty round stone structures were found in the site, and two, identified as wells, were excavated (Galili *et al*. 2004a; Galili and Nir 1993). Well 66 (Fig. 3) is at 10.5 m, depth. A single stone course, part of upper structure, survived above site surface (ASS). The well, lined by undressed stones, was dug in clay. Excavation revealed seven construction courses and the structure continued to an unknown depth. Its inner diameter was 110 cm and the upper course was formed of 19 stones in a circle. The fill contained soft clay with small and medium *kurkar* and lime stones, basalt stones (which is not found locally), bones of fish, reptiles, rodents, herbivores, carnivores and humans as well as flint, stone and bone artifacts, mostly broken. Well 11 lies some 10.5 m below present sea level (Figs. 3, 4). It is cylindrical, 5.5 m deep and 1.5 m in diameter (Fig. 4.). The upper section, a tower-like structure, 0.7 m ASS, is built of several stone courses, three uppermost survived marine erosion *in situ* forming a protective wall circumscribing the shaft. The middle section was cut into the clay sediments, built of 22-25 courses of undressed stones, (14-24 stones in a course) down to 3.60 below site surface (BSS). The lower section 3.60-5.15 m below the site surface, was excavated into the *kurkar* bedrock. The lower 50 cm is asymmetric, 128 x 150 cm. The bottom is circumscribed by a small notch (Fig. 4).

The fill of well 11 consist of layers representing several events. It presents a complex multilayered structure (at least 14 layers varying in thickness, content and composition) divided into three main sedimentation phases, the upper (layer 1) is composed of small/ medium (3-15 cm) undressed *kurkar* stones and broken limestone pebbles, most were exposed to heat, hence "small and medium stones", it contained crushed and whole mollusks (*Glycimeris sp.*), a late intrusions? The middle phase (layers 2-5), 2 m thick, extends from the surface to 2.10 m BSS. It contains artifacts and animal bones, few in partial articulation, embedded in brown clay. The sediments are soft clay, small and medium

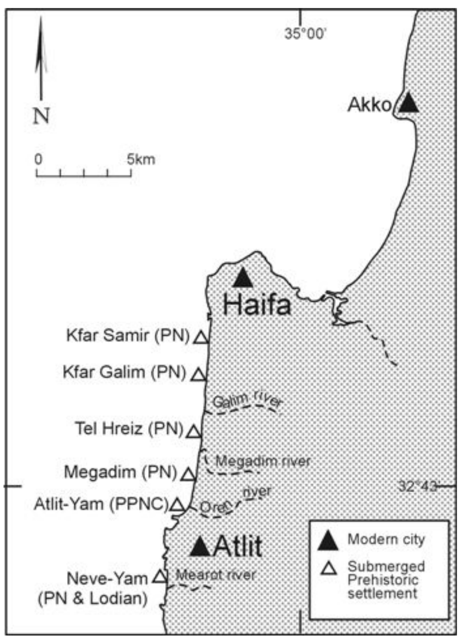


Fig. 1 Location map of the Carmel coast and submerged prehistoric sites referred to in the text.

Fig. 2 The megalithic structure of Atlit-Yam; 2(a) Artist's reconstruction of the megalithic structure; note the spring, stones with cup marks and fresh water vegetation.

stones, quartz and carbonatic sand. Lenses of fine, soft clay were attached to the walls, at depths of 60-120 cm and 170-200 cm BSS. Large stones were embedded at 90-110 cm (layer 4) and 180-200 cm (layer 6) respectively BSS. Gypsum at the bottom of layer 2, at *ca.* 80 cm BSS, indicates high salinity. At the layer bottom number 5 *ca.* 180-210 cm BSS, were numerous land snails. The middle phase contained animal bones, plant remains, and flint industry tools and waste. The lower phase sediment, three meter thick (layers 6-14) (500-200 cm BSS) is typical to wells, containing mostly *kurkar* stones embedded in sandy clay, artifacts and animal bones. Three C-14 dates (Table 1) from this section, ranging 8210-8370 calBC. Due to continuous cleaning there is no sequential order of the dates within the fill (Galili 2004a; Galili *et al.* 2002).

The Floral Assemblages of Well 11

The seed assemblage includes about 100 mediterranean species, 23 of them, typical of Mount Carmel, are absent today on the coast. Five are absent there today but exist in colder habitats. Remains of a weevil (*Stiophilus granarius*), infesting cereal grains in colder regions, were identified indicating colder climate (Kislev *et al.* 1996; Galili *et al.* 1997a). Pollen from the well are rich in ruderal plants exhibiting low arboreal levels. The common west winds could not bring arboreal pollen from the Carmel and runoff water did not enter the wells (Galili *et al*. 1993; Weinstein-Evron 1994). Macrobotanical assemblage is biased by human import. The high hydrophilous pollen counts indicate marshes near by in poorly drained lowlands.

The well was used as a refuse pit after becoming useless. Numerous animal bones in the central section represent consumption debris discarded into the well after it stopped functioning. Re-using water wells as garbage pits is common in prehistoric Levantine sites. Stone tools from the upper section are mostly broken. In the lower section, ornaments and decorated artifacts were found with few broken tools.

Fig. 3 Atlit-Yam Well No. 11 during excavation.

The Pottery Neolithic Wadi Rabah Sites

Five Pottery Neolithic (PN) sites (Kfar Samir, Kfar Galim, Tel Hreiz, Megadim and Neve-Yam) are at a present water depths of 1-5 m (Fig. 1). Stone and wood structures, artifacts, ceramics installations and pits, plant remains, and animal bones were found in them as well as stone-built graves containing human skeletons.

The PN Water Wells

At Kfar Samir and Kfar Galim (Fig.1) (presently 0.5 -5 m below sea level) water wells constructed of tree branches and limestone pebbles were found (Galili *et al.* 1997b; Galili and Weinstein-Evron 1985). Additionally, paved floors and installations for extracting olive-oil pits containing broken olive stones and pulp were found together with wooden bowls, mat fragments and stone basins. One well, built of alternating courses of wooden branches and limestone pebbles, having a 1 x 0.8 m rectangular opening was excavated to a depth of 2 m, not reaching the bottom of the well (Figs. 5, 6, 7). Its fill included soft clay with small stones, a few bird bones and potsherds, olive stones, flint flakes and mat remains.

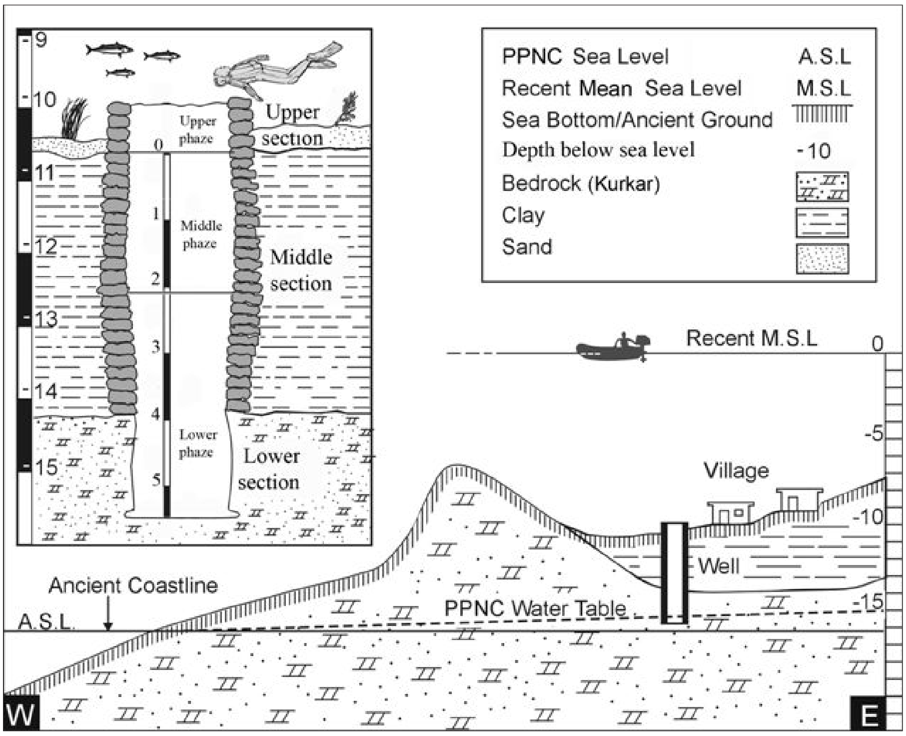


Fig. 4 Cross-section of Atlit-Yam Well No. 11 and schematic reconstruction of the topography and sea level at the site region during the PPNC.

Chronology of the Submerged Settlements

The C-14 dates from the Atlit Yam wells (Table 1) are around mid to late 9th millennium BP, but they had probably been constructed earlier, at the end of the 10th millennium BP: continued cleaning exposed traces of earlier stages. In the PN Kfar Galim and Kfar Samir wells, C-14 dates were obtained from the construction materials of the wells, giving true direct construction dates.

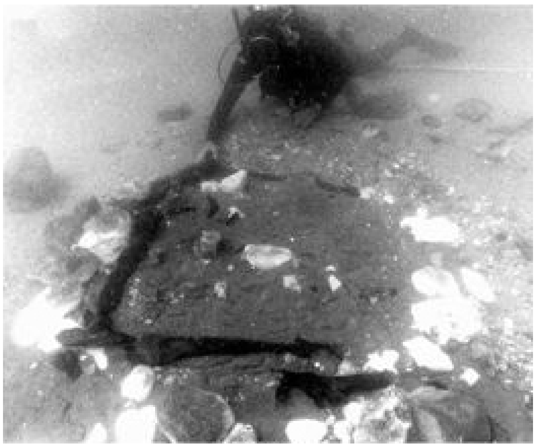
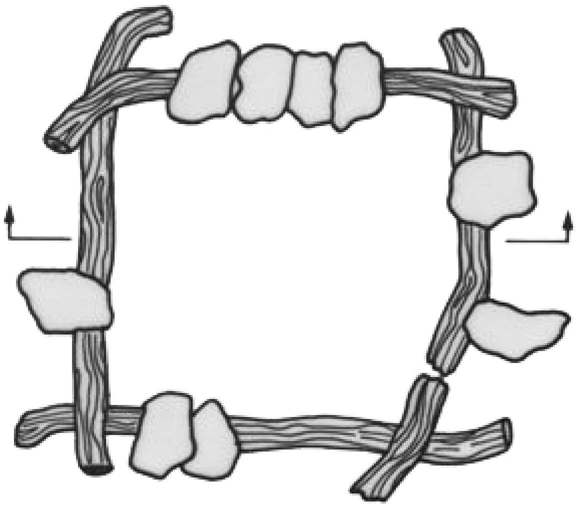


Fig. 5 The Kfar Samir well constructed of tree branches and stone pebbles before excavation. PPNC.

Fig. 6 The Kfar Samir well after excavation.



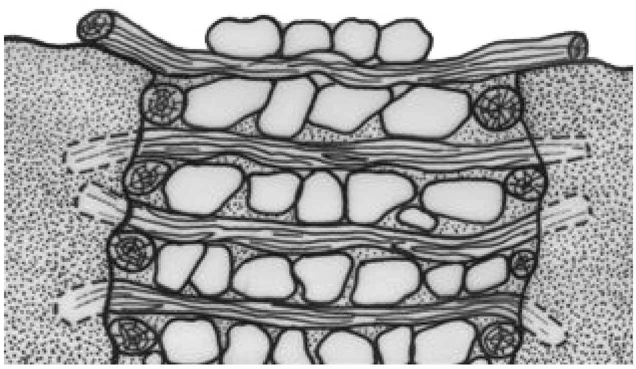


Fig. 7 Cross section of the Kfar Samir well.

Discussion

Sustainable Self-contained Fresh Water Supply: a Pre-condition for a Permanent Coastal Settlement

The Neolithic period was a turning point in human subsistence modes. Food production in the form of animal and plant domestication appeared. Permanent settlements intensified exploitation of resources in the surrounding habitats. The large permanent settlements („mega-sites“) of the PPN were established near perpetual water sources. Supplying drinking water is a limiting factor along the Mediterranean shores, except in river deltas and river valleys. In the northern and central Levantine coasts water is abundant, and wells are not needed. In the southern Levant, the coastal streams are mostly dry in the summer. In an area rich in economic resources but lacking in fresh drinking water, excavating wells is rewarding. This would facilitate the occupation of new territories and would significantly increase the carrying capacity. The appearance of coastal water wells is associated with a PPN attempt at occupying new areas to cope with increased population, shrinking resources, and a growing demand for unexploited agricultural land. It occurred where wells brought notable benefits. The Israel coastal plain overlies a high aquifer exploitable all-year-round using the proper technology. Creating a sustainable, coastal self-contained fresh water source enabled the occupation of this uninhabited area.

The development of water mining may be associated with the emergence of the first Mediterranean fishing village. The Atlit Yam wells indicate that water mining existed as early as 9th millennium BP. It is yet to be investigated whether this practice was only on the Carmel coast, due to the available high water table (under-ground water), or if it occurred in other places north and south of Atlit Yam.

During the Early Holocene settlers from the mainland colonized Cyprus. The PPN site of Mylouthkiya, on the south-west coast, contains several water wells (Peltenburg *et al*. 2001), the earliest known now. They were dug into the porous Pleistocene Havara overlaying the impermeable Pliocene marls, exploiting the local coastal aquifer, which is also the origin of springs along the coastal cliffs (Galili *et al*. 2004a; 2009). Probably the ephemeral water streams on the island and the geology of the coastal cliffs encouraged early water mining. Coastal erosion, due to post glacial sea level rise, created visible fresh water sources in the coastal cliffs between the impermeable Pliocene marls and the porous sediments above the marls, including aeolian sandstone, Havara and beach deposits. The water attracted the immigrants, settling near it and later excavating unlined shafts as wells. The early Neolithic coastal sites (Mylouthkiya and Akanthu/Tatlisu) adjacent to such water sources along coastal cliffs support this hypothesis.

Alternative water sources in Atlit Yam

The post-glacial rising sea elevated the groundwater level, moving the interfacial water plain eastward. Wells suffered salination and the Atlit Yam inhabitants had to dig new wells further to the east. Some of the round structures found in the site may represent such wells. The rising water table created springs in village area, and traces of one were discovered near a megalithic ritual structure (Fig. 2) which perhaps could represent a symbolic response to the water crisis ending by water spouting in the village (Galili and Sharvit 1998).

Abandonment of Atlit Yam

It has been proposed that a tsunami generated by the collapse of Mount Etna *ca.* 8,300 BP[1], destroyed Atlit Yam (Pareschi *et al.* 2006; 2007). The proposal is not supported by field evidence: the C-14 dates contradict that proposal. The skeletal pathologies are not associated with a natural disaster (Hershkovitz and Galili 1990; Galili *et al.* 2005a). The animal bones bear meat-consumption cuts, but not breaks, indicating disaster (Horwitz and Tchernov 1987; Galili *et al.* 1993; Lyman, 1994). Well infrastructure *in situ* above the present sea floor could not have survived a tsunami.

Atlit Yam was abandoned due to sea level rise and well salination: the wells ceased functioning due to saltwater contamination. The layers of large stones may indicate an attempt to obtain water from higher le-

Sample No.	Lab ref.	Material	Location	Uncalibrated date (yrs. BP)	Calibrated date (yrs. BC)
Atlit-Yam PPNC					
1	RT - 2477/8	Tree branch	water well (structure 11)	7605 ± 55	6458-6385
2	RT - 2479	Tree branch	water well (structure 11)	7460 ± 55	6361-6216
3	RT - 2489	Tree branch	water well (structure 66)	7880 ± 55	6993-6596
Kfar Samir					
4	RT - 682 A	Tree branch	Pit (structure 3)	6670 ± 160	5716-5675
5	PTA - 3820	Tree branch	Pit (structure 5)	6830 ± 80	5748-5632
6	PTA - 3821	Tree branch	Water well	6830 ± 160	5780-5580
7	BETA -82850	Tree branch	Pit (structure 10)	6940 ± 60	5940-5665

Table 1 Radiocarbon dates from the submerged Atlit-Yam and Kfar Samir wells (BETA = Beta Analytic Inc., Miami, Florida, U.S.A.; PTA = Pretoria Lab., South Africa; RT = Weizmann Institute of Science, Rehovot, Israel). Calibration was carried out according to Stuvier and Reimer (1993).

vels of the aquifer. Gypsum in Layer 5 testifies to high salinity and supports such a scenario. Post-salination, it became a refuse pit (Galili *et al.* 1993; Galili and Nir 1993). The few articulated bones in the well indicate a deposition with soft tissue. Humans would not pollute a fresh-water source with discarded waste. Re-using water wells as garbage pits was common in prehistoric Levant, for example at Mylouthkia in Cyprus (Peltenburg *et al*. 2001) and Sha´ar Hagolan in Israel (Garfinkel *et al*. 2005).

The Carmel Coast Wells and Sea Level Changes

Coastal wells provide valuable information on sea level changes. Sea level rise results in ground-water table rise and well salination. The bottom of Well 11 is 15.5 m below sea level, hence the sea level was 16 m lower, the coastline was a kilometer to the west, and the well was about 600 to 800 m inland during its construction. Pottery Neolithic sea level was *ca.* 10 m below present sea level and the coastline was 600 m westward, with some islands 1-15 km offshore (Galili *et al*. 2005b; 1988). The earlier a submerged Prehistoric site in the Carmel coast is, the farther offshore it is located. Atlit Yam is located 200 to 400 m off shore at 8 to 12 m depth. The PN sites are located 10 to 180 m offshore at a depth of 0.5 to 5 m. There is a direct correlation between the constant rise in sea level, settlement abandonment, and translocation eastward. Sea level rose from 9000 to 4000 BP in two main stages. Between 9000 to 7000 BP sea level rose some 12 m (from -16 m to -4 m), at a mean annual rate of *ca.* 5-6 mm/yr. From 7000 to 4000 BP sea level rose an additional 14 m (from -4m to the present level) and the mean annual rate was *ca.* 4-1 mm/yr. From *ca.* 4000 BP sea level remained relatively constant, with possible minor changes of less the local tidal range (± 0.25 m).

The Emergence of the Mediterranean Fishing Village on the Southern Levant Coast

The Levantine and Cilician coasts are the closest marine environments to areas where plants and animals were first domesticated. By the 9th millennium BP, a new subsistence system appeared on the Levantine coasts, as discovered at Atlit Yam, Ashkelon and Ras Shamra. This innovation - the Mediterranean fishing village - evolved by combining agriculture and animal husbandry, arriving to the Levantine shores from inland, with indigenous coastal inhabitants' ability of to utilize marine resources. This agro-pastoral-marine subsistence included cultivation of domesticated cereals, legumes, fruit trees, animal husbandry, and intensified use of marine resources together with some hunting and foraging. Later (during the PN) olive oil was added as indicated by finds at Kfar Samir and Kfar Galim. Later on, in the 6th millennium BP, additional fruit trees appeared. The appearance of grapevines (Zohary and Hopf 2000) and the continuing agro-pastoral food procurement strategies with exploitation of marine resources, completed the so-called Mediterranean subsistence system as it is known today (Galili *et al*. 2002, 2004b).

Endnote

[1] All dates are calibrated years BP, groups of dates from the same structure were averaged with ±1 sigma (Elizabetta Boaretto, Radiocarbon Dating Laboratory, Environmental and Energy Research Department,Weizmann Institute of Science, Rehovot, Israel).

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Water in the Village

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Following the editors, we use the phrase "domestic water" to refer to water consumption without manipulating its source, or water not consumed directly from the source but elsewhere. Other contributions to this session concentrate on the control over surface run-off water away from the village as a means to facilitate agriculture. Taken literally, of course, "domestic" refers to water consumed *within* the village ('domus', house). For prehistoric villages in the Near East, we may reconstruct various activities in which water will have played a role: drinking, food processing, and industrial activities. In addition, there are important activity spheres in which water most probably played a role, such as personal hygiene, and ritual. As a contribution to the water management discussion, we shall briefly review some of the evidence for water management in the Late Neolithic (7000-5300 calBC), using the prehistoric site of Tell Sabi Abyad as a case study. More specifically, we shall focus on possible water-related uses of containers made in pottery and gypsum plaster.

Situated in the valley of the River Balikh, a perennial tributary of the Euphrates in the semi-arid northern Syrian steppes, Tell Sabi Abyad was a busy, nucleated village in an otherwise rather sparsely populated landscape. The site was inhabited from the later PPNB into the Halaf period. Here we focus on its Early Pottery Neolithic phase, *ca*. 6700-6200 calBC (levels A-10 to A-2 in Operation III), roughly coinciding with final PPNB-PPNC in the southern Levant. The surrounding landscape was, of course, far from empty. There were a number of other villages nearby. People crossed the landscape regularly for essentials such as economic exchange and investing in a bristling social life, and as part of their semi-pastoral lifestyle (Verhoeven 1999). But the focal point of life will have been the village itself (Akkermans *et al*. 2006). It remains unclear exactly how many people relied on the village. Estimates vary widely from as few as 50 to as many as 670 people, depending on the interpretations of the spatial layout and the social organization (Akkermans 1993; Akkermans and Duistermaat 1997; Verhoeven 1999).

These people must have used a fair quantity of water on a daily basis. Exact figures of course are impossible to establish; in addition to the uncertainties in reconstructing population size and the precise range of water-related activities conducted, notions of hygiene are culturally determined and far from universal (Hodder 1982). If modern standards were applied, in which one person needs at least some 15 litres on average (WHO 2005), villages such as Sabi Abyad would have consumed between 750-9000 litres a day. The higher range of this estimate is certainly unrealistic. The number of people present in the village will have varied highly with the seasons (Verhoeven 1999). Even at peak times of feasts and festivals, with everybody engaged in exchanging goods, spouses and gossip, the maximum number of people aggregating at Tell Sabi Abyad are unlikely to have surpassed several hundred (Akkermans 1993: 166). Furthermore, it is not unreasonable to expect that minimum water requirements in the Neolithic were below those of today.

Nonetheless, it is safe to assume that no small amount of water was consumed in the village. Most of this, if not practically all of it, will have been "domesticated water". There was no substantial standing body of water available anywhere in the village. The excavations have not attested any evidence of artificial pools or large pits suitable for holding rain. The steep slopes of the village, characteristic of many tell sites, meant that rainfall quickly drained into the surrounding fields. So far, the excavations have not uncovered any wells (Garfinkel *et al*. 2006; Wilkinson and Tucker 1995). Certainly, the Balikh may have flowed closer to the mound in prehistoric times (Akkermans 1993) – today it runs some 5 km away from the mound – and in spring and early summer local wadis would have offered water. It is certainly possible that people constructed facilities for controlling run-off water adjacent to the mound, but a thick alluvial cover makes it virtually impossible to study the prehistoric landscape (Wilkinson 1996). How did people keep, consume and process water or, for that matter, other fluids of a non-watery kind?

If we look at the use of storage vessels for water in developing countries today, we notice some universal factors that influence the choice of container. First of all, the vessels need to be portable and easy to handle. This influences their shape, size, and weight, as well as the presence of handles. Secondly, they should be resistant to mechanical shock and sufficiently durable to hold the liquid. Thirdly, it should be possible to cover or close the vessel to avoid contamination. Finally, the presence of a tap, spout or other narrow orifice is preferable, though not a necessity, for pouring. Cross-culturally, the optimum vessel would have a capacity between 10 and 25 litres, a rectangular or cylindrical shape, one or more handles and preferably a flat bottom for easy storage (Arnold 1985; Mintz *et al.* 1995; CDC 2001).

How do these requirements correlate with the containers found at Tell Sabi Abyad? Unfortunately, several categories of containers have been lost. We know for certain that people kept various containers made of

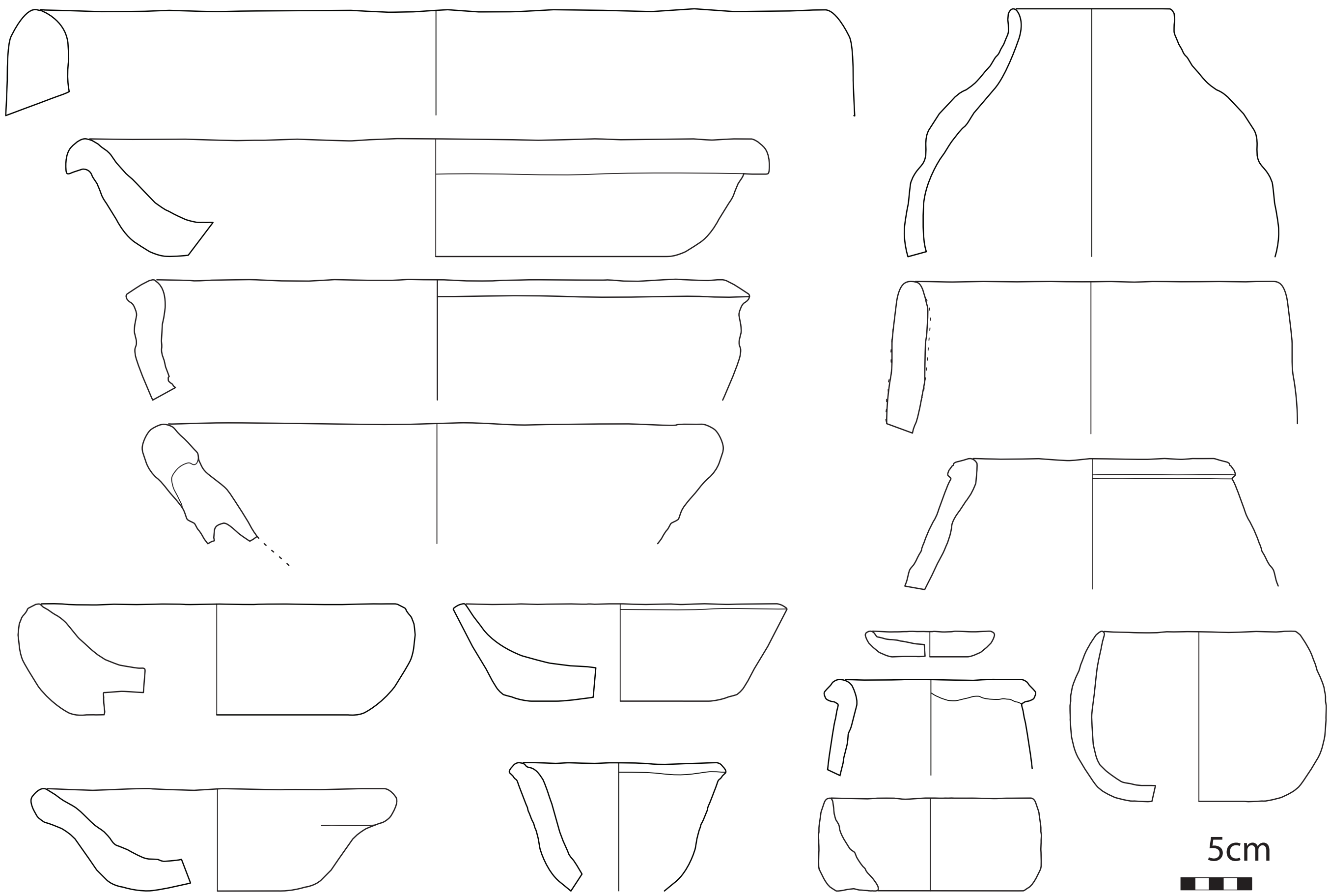

Fig. 1 Tell Sabi Abyad. Characteristic Early Pottery Neolithic white ware shapes.

perishable materials. In the somewhat later Pre-Halaf levels, there is empirical evidence for the presence of leather and textiles at the site, imprinted on the reverse sides of clay sealings (Duistermaat 1996). In the Early Pottery Neolithic people used bitumen-coated baskets (Akkermans *et al*. 2006). Containers made of wood and leather, ethnographically attested well into the early 20th century (Kalter *et al*. 1992), probably existed but have not been preserved. Such non-durable containers may well have been the major means for holding water and other liquids. In addition, however, Late Neolithic people kept themselves surrounded by containers of a very durable kind, made of pottery and plaster.[1] The adoption of both pottery and white ware around 7000 calBC opened up a vast new range of possibilities for manipulating fluids and goods of all kinds (Nieuwenhuyse *et al.* 2010; Nilhamn *et al*. 2008; Nilhamn and Koek forthcoming). As has recently become clear, at Tell Sabi Abyad both pottery and white ware became exceptionally abundant between 6700-6200 calBC, during the Early Pottery Neolithic (EPN) (Fig. 4: upper). Were containers in these categories involved in domestic water management?

The material for making white ware could be either lime (calcinated calcium carbonate, $CaCO_3$) or gypsum (hydrated calcium sulphate, $CaSO_4 \cdot 2H_2O$), usually tempered with organic or small mineral inclusions. Larger pieces of reused pottery or stones are sometimes found as "temper" as well, to give the vessel more sturdiness. Most white ware vessels were made by adding layer onto layer; the individual layers are often clearly visible in the material. Flaking of layers and colour differences between layers are common. Often the outermost layer is just a few millimetres thick, resembling the thin plaster coating also found on ceramics. Of course, white ware containers always needed a support during shaping; in some cases it is clear that the plaster was folded around or inside another container, for instance a ceramic vessel or a basket. The vessels could be built up in horizontal segments as well, which is shown by the characteristic breakage patterns in the sections that superficially resemble pottery 'coils'.

It will be clear that the material puts limits on the range of containers possible. It is rather heavy, and it hardly allows building up freestanding objects more than a few decimetres tall. Most portable white ware objects are open bowls with a maximum height of 20 cm (Fig. 1). These could have large diameters, some of them reaching truly enormous sizes (60-70 cm), and some bins even reaching a diameter of two metres! These very large "containers" sometimes have rough exteriors suggesting that they were shaped against the interior face of a pit – these were certainly "fixtures" (Cribb 1991: 68). On average, however, their estimated volume was between 1 and 14 litres. From a water-management perspective these low, open containers

Fig. 2 Tell Sabi Abyad. Characteristic Early Pottery Neolithic pottery vessel shapes.

would seem to be far from ideal. However, there were some closed vessels as well, and although appendages are virtually absent (n = 1), some vessels had shallow knobs applied to the body that made them easier to handle. An interesting feature in this regard is the frequent beaded rim. Some beaded-rim vessels show clear traces of wear and tear underneath the rim. This may reflect the practice of closing off the containers with some cloth or hide, fixed with a rope.

It is important to realize that lime and gypsum plaster production represent two entirely different technologies, and even if superficially the end results often look quite similar, containers made in either category have quite different performance properties when it comes to managing fluid substances. The solubility of lime plaster ($CaCO_3$) is much less than that of gypsum ($CaSO_4$), for instance (resp. 0.015 g/L against 2-2.5 g/L at 25 °C, depending on acidity) (Kingery *et al*. 1988: 22). Lime plaster is more water-resistant, harder, and survives mechanical wear and tear much longer. Lime is less vulnerable to fungal and bacterial growth, as it allows moisture to evaporate more quickly. In contrast, when exposed to fluctuating moisture levels, gypsum plaster more readily attracts fungal and bacterial growth due to its pores and interstitial spaces where moisture accumulates[2]. Its relative hygroscopicity means that water is more easily sealed between individual plaster layers especially if these have different compositions, causing them to flake off. At Tell Sabi Abyad, ongoing XRF-analyses of the white ware containers show that 86 % was made of gypsum.[3] When water absorption was tested this confirmed that gypsum plaster was more susceptible to water damage than lime plaster. Thus, water management would not appear to have been the primary function of most white ware containers.

As to the pottery, comparatively simple shapes are characteristic for the Early Pottery Neolithic. These include vertical straight-walled pots, often with loop handles on either side, hole-mouth pots, and S-shaped vessels, characterized by a low, non-distinct collar (Fig. 2). The latter would eventually evolve into real jars with tall, distinct necks at the very end of the period. In terms of shape and size many pottery vessels fit the requirements for water containers. Yet, the ceramic assemblage at this stage did not yet include any “industrial” shapes such as funnels, tubular appendages, perforated pedestal-based bowls, or sieves. These vessel types, all of which may have involved the management of fluids, came into use only after around 6200 calBC. (Nieuwenhuyse 2007). Morphologically, a concern with using ceramics for closure is evidenced in the gradual development of the neck, which went hand in hand with a progressive increase in vessel volume. It is also shown in the presence of so-called cordons, appliqué bands running horizontally below the vessel rim, which may have been used as a means to fix a piece of cloth with a rope. But although vessel typology clearly indicates that bulk storage in pottery was becoming

Fig. 3 Tell Sabi Abyad. Left: Renske Dooijes, conservator at the National Museum of Antiquities Leiden, cleaning and opening a completely-preserved large hole-mouth pot with its gypsum lid *in situ* (level A-1). Right: reconstruction of the vessel.

increasingly important, it remains unclear *what* was stored. The larger vessels were most likely intended for dry goods. Water and other fluids may have been kept in the smaller types of pottery.

For protecting daily water consumption the main concern regarding water containers would be evaporation and pollution from dust or other wind-blown impurities. As a preventive measure, a distinct neck or other technologically advanced contraption would not even be necessary; a simple lid of unfired clay, wood, reed or leather would do. Of course, such non-durables stand little chance of surviving in the archaeological record unless as imprints or when accidentally fired; none has been attested so far in this period. Not a single unequivocal "pottery lid" was found.[4] It is possible that a little bit of what we today would call dirt or pollution was simply not an issue.

A major exception was the extraordinary find of a large, intact hole-mouth ceramic pot, heavily plastered on the interior, which had a gypsum lid *in situ* (Fig. 3; admittedly, not from the Early Pottery Neolithic but from the earliest Pre-Halaf level A-1). It was found dug into the floor in a corner of one of the larger rooms of a building, close to the entrance (Akkermans, pers. comm. December 2010). Upon opening, somewhat to everyone's dismay, the vessel contained a very soft, loose fill of dust-size particles, which no doubt had accumulated over the millennia. This vessel may have been discarded empty, or it may have been left standing filled with something fluid.

Most interestingly, although this particular vessel appears to have been unique, the practice it represents may have been more common. The excavations in Operation III have yielded several examples of large pottery vessels dug into floors (Kaneda in prep.), while one of the buildings in the level 8 village (Operation I, Pre-Halaf period) contained a square platform that held an intact hole mouth pot decorated with an appliqué. These were fixtures (Cribb 1991); immovable containers integrated into the architecture. Intriguingly, these vessels were always placed close to the entrance leading into one of the larger rooms of the building. Here they may have served as water containers serving guests or the occupants of the building.

With regard to water management, the strong porosity of the pottery containers must have been an issue as well. Characteristic for this era were pottery vessels made of very porous, plant-tempered material ("Coarse Ware") fired at low temperatures. This made many vessels very poor water containers. However, there were good ways to reduce porosity, for instance by burnishing the vessel wall. Fig. 4 (centre) shows the popularity of various types of exterior surface finishing for Coarse Ware during the Early Pottery Neolithic. At first sight, it might seem that through time potters gradually moved away from applying porosity-reducing finishing techniques, as burnishing is proportionally reduced in the later EPN levels. However, this was more than sufficiently compensated for by the rapidly increasing amounts of pottery vessels in daily circulation, as shown by the raw-sherd counts (Fig. 4: upper). In absolute terms, there was always a certain amount of carefully burnished, less porous pottery available.

A second strategy for reducing ceramic porosity, or so it would seem, is to *combine* the two technologies of pottery and plaster, more specifically by covering

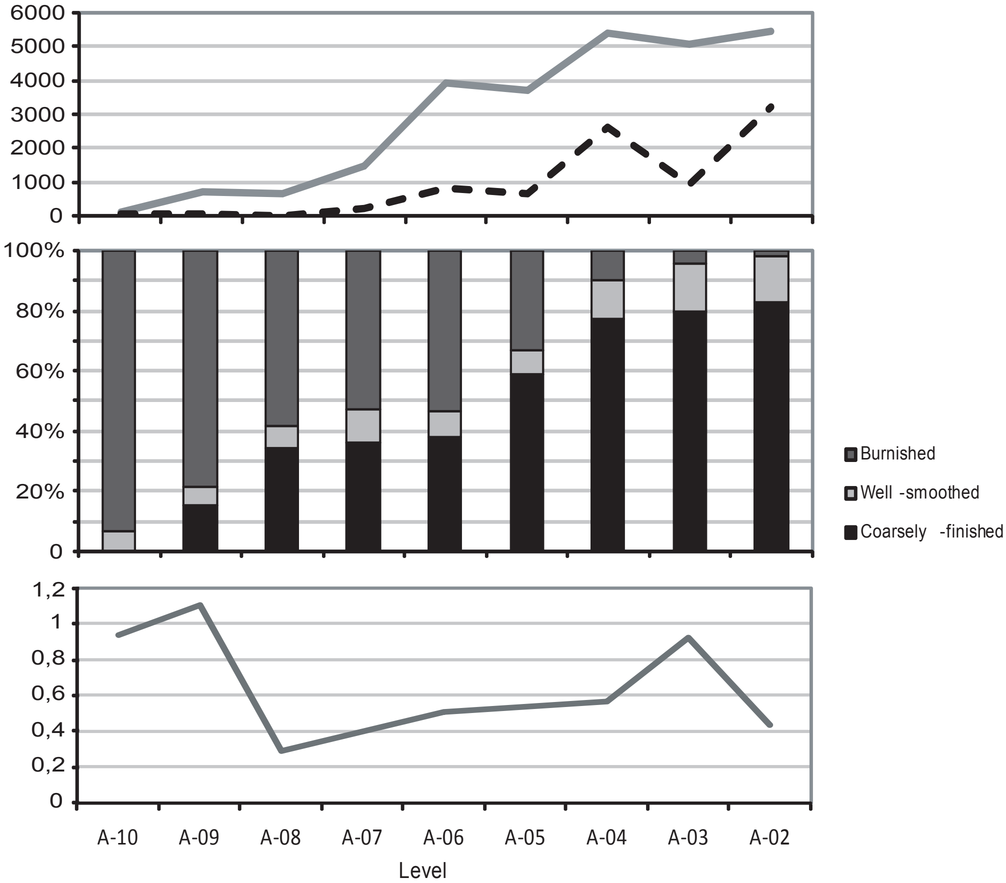

Fig. 4 Tell Sabi Abyad Early Pottery Neolithic levels (Operation III). Upper: raw counts of pottery (solid line) and white ware (dotted line) sherds by level. Centre: proportions of surface finishing strategies for Coarse Ware pottery (exterior surface). Lower: proportion of plastered Coarse Ware sherds.

the pottery vessel with plaster. We have already discussed one voluminous plastered Coarse Ware pot (Fig. 3). Plastered Coarse Ware sherds are present in all EPN levels at the site, their proportion fluctuating between about 0.5 and 1% of the bulk (Fig. 4: lower). If we combine the small numbers of plastered Coarse Ware sherds with those of the increasing amounts of pottery, it becomes clear that especially in the later phase of the EPN plastered Coarse Ware vessels must have been common in the village. Coarse vessels were about equally often plastered on their exterior and interior surfaces, often on both. The thickness of the plaster ranged from just a millimeter or even less to, frequently, several centimetres. All types of vessels were plastered, but there was definitely a preference to apply this procedure to jars, followed by vertical straight-walled pots. Most interestingly, plaster was also used to repair pottery containers when they had broken (Nieuwenhuyse and Dooijes 2008).

Did this plaster facilitate the containment of fluids, water or otherwise? Here insight in the raw material becomes crucial. An earlier analysis of a single, plastered Coarse Ware sherd from contemporaneous Tell Damishliyah had shown this to be gypsum (Rehhoff *et al*. 1990). As part of an MA thesis at the Institute Collection Netherlands (ICN), fifteen additional plastered sherds from Tell Sabi Abyad were analysed (Koek 2009). This analysis confirmed all samples to be gypsum. On the basis of this sample Koek (2009: 73) has concluded that the materials used for plastering Coarse Ware pots at Tell Sabi Abyad were the same as those generally used for making white ware containers.

Analyses show that the greater majority of the white ware was made of gypsum, and that pottery vessels were plastered with the same material. At first sight this contradicts their use as water containers, as gypsum is functionally less suitable than lime for managing fluid contents. Instead, as has been suggested by earlier studies, plastered pots may have facilitated the long-term storage of dry bulk goods. Both lime and gypsum plasters offered two major advantages over plain pottery vessels and baskets. Their alkaline composition reduced bacteria growth, while their hygroscopicity protected the contents against moist. These properties made plastered pots especially useful for the long-term bulk storage of dry organic goods (Rehhoff *et al*. 1990; Nilhamn *et al*. 2008).

Nonetheless, in spite of its relative disadvantages gypsum, may still be a valuable water-resistant coating, as long the softened contact surface is not exposed to significant friction, and as long as there is sufficient ventilation to let the material dry. Furthermore, in theory its water-resistance might be improved by burnishing or impregnating the plaster with oily substances. The burnishing of white ware containers is attested at Sabi Abyad by a few sherds that show the characteristic traces. The additional application of sealing agents cannot be excluded either. Natural sealing materials ethnographically attested include beeswax, soap and linseed oil. The sealing material would have been applied with a brush or cloth when the plaster was perfectly dry. Remaining visible traces of such treatment would be fine scratches and brush marks. Intriguingly, many white ware sherds at Tell Sabi Abyad show precisely these traces. Future residue analyses are planned to explore the possibility that Neolithic people sealed their white ware containers.

We may conclude this briefest review of ongoing work on pots and plaster at Tell Sabi Abyad by saying that it is clear that during the Early Pottery Neolithic a broad variety of containers made from different materials was available. The two most durable categories, white ware and pottery, were almost certainly implicated in domestic water management. However, we believe that this was not their only or even their primary role. In terms of vessel shape and size, white ware containers were usually too heavy and too open to have been regularly used as domestic water containers. Pottery vessels, too, may mostly have had alternative functions. Coarse pottery vessels during the EPN constituted a broad-purpose technology less functionally specialized than in later stages of Syrian prehistory. Some of the smaller vessels, however, especially those with burnished surfaces, were almost certainly used for containing water or other liquids. These comprised a minority in the ceramic assemblage, but this will have been sufficient to meet the daily needs of the village in terms of water management. Large, non-portable plastered pots built into buildings probably served water management as well. In addition, non-durable categories probably existed, which will have been more convenient to water management.

Around 6200 calBC the use of white ware declined, while pottery flourished. Part of the explanation may have been that white ware production was comparatively costly in terms of fuel (Rehhoff *et al*. 1990: 86). White ware containers, moreover, were relatively clumsy, heavy, and less portable. Significantly, they always remained inherently limited in terms of the range of shapes and sizes possible (Nilhamn 2003; Nilhamn *et al.* 2008). The manufacture of portable, intricately-shaped containers became much more important after 6200 BC (Nieuwenhuyse 2007), while on the other hand potters had finally reached the level of expertise needed to construct large, voluminous pottery vessels. These factors may have stimulated advances in pottery production at the cost of white ware. The limitations of white ware for managing liquid substances may have constituted yet another reason for its demise. After 6200 BC, new types of pottery vessels point to the increasing social importance of eating and drinking together, in a much more conspicuous manner than before (Nieuwenhuyse 2007). Fashionably decorated serving vessels, often with slipped or thoroughly-burnished surfaces, may have been used not only for drinking just water but for liquids of a different kind as well.

Acknowledgements: The pottery and white ware drawings were digitalized by E. Dooijes (www.dpph.nl).

Endnotes

[1] In addition to pottery and white ware, small vessels made of stone are characteristic for the EPN. Although these were exceptionally well-suited to contain water (and other liquids) they will not be considered here, as their limited volume and rarity mean that they will not have affected domestic water management on a large scale.

[2] Technically, mould does not grow on plaster as plaster is inorganic. However, the porosity may trap organic materials (grease, dirt) that in combination with moisture allow microbial activity.

[3] Interestingly, lime plaster was somewhat more common in the earliest levels, and virtually absent in the later stages of the Early Pottery Neolithic.

[4] EPN people may have used small bowls, placed upside down, as a pottery lid. The first unequivocal evidence for this practice stems from the Halaf period (Akkermans 1993).

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Living by the Water – Boon and Bane for the People of Körtik Tepe

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Introduction

Despite a long and on-going discussion on the development of early sedentism and the broad spectrum revolution as a precondition for sedentary farming communities, many studies have been biased by focusing on the study of wild cereal remains. However, recent botanical and archaeozoological studies have shown clearly a wide spectrum of plants and small game that were used by hunter-gatherers opportunistically (*e.g.* Hillman *et al.* 1989; Stiner *et al.* 2000; Savard *et al.* 2006; for theoretical considerations see Benz 2000:75-90; Olszewski 2004). Many ethnographic examples and pioneering studies on prehistoric coastal fishing and even trade of marine fishes into the hinterland during the early Holocene (*e.g.* Lernau and Lernau 1994; Zohar *et al.* 2001:1051, for further literature see Sampson 2008:205) demonstrate the importance of fish for sedentary communities. Nevertheless, fish remains have rarely been studied systematically. In a recent overview on data of Near Eastern Early Neolithic sites, van Neer *et al.* (2005) could list only a hand-full of Epipalaeolithic and Early Neolithic sites for which a systematic collection of fish bones had been practised. The missing systematic collection of microfauna and fish remains from flotation or fine sieving has hampered quantitative as well as qualitative analyses of fish remains and microfauna on many sites.

Although a systematic collection of fish remains from flotation samples will become possible at Körtik Tepe only in future seasons, we argue that the archaeological materials and archaeozoological remains in the sediments and graves clearly illustrate that fresh water resources such as fish and waterfowl, besides other small game such as tortoise, played an important role for the flourishing of the Körtik Tepe community during the PPNA[1] and contributed much to its richness and identity.[2]

The Site and Environmental Conditions

The extraordinary findings and the lavishly endowed burials of the early Holocene site of Körtik Tepe (37°48'51.90" N, 40°59'02.02"E) have been presented recently in this journal and in many other publications (*e.g.* Özkaya 2009; Özkaya and Coşkun 2009; for ^{14}C-data see Coşkun *et al.* 2010). The site is located near the confluence of the Batman Creek and Tigris River. An old channel of the Batman Creek visible on the aerial photo passes directly by the site. Preliminary analyses of charcoal remains suggest that Körtik Tepe lay in the oak park-woodland at the beginnings of the Holocene, with the dominance of oak and some *Amygdalus* sp., Maloideae, *Pistacia* sp., *Celtis* sp. and *Rhamnus* sp. Furthermore, *Tamarix* sp., *Populus* sp. /*Salix* sp., *Vitis* sp., *Alnus* sp. and *Fraxinus* sp. hint at the proximity of gallery forests indicative of water. The seed remains underline the proximity to water reservoirs.[3] They comprise a wide spectrum of wild plants including hygrophilous species such as sea club rush (*Scirpus maritimus*) (12 %). The abundance of taxa such as tragant (*Astragalus* sp.) and medusahead (*Taeniatherum caput-medusea/crinitium*), however, indicate the presence of open vegetation. Large-seeded grasses (Poaceae) contribute the main portion (37 %) and occur in every sample, whereas progenitors of modern cereals account for less than 6 %. A specialization on one or the other plant does not show up in the botanical remains, and domestication of plants could not been proven so far (Riehl *et al*. n.d.). The people of Körtik Tepe thus had access to at least three different environmental milieus, of which they used the plant and animal resources opportunistically.

Matting

Remains of fibers on the floors, on stone vessels and in graves suggest that mats and lines (nets) were common on the site. Impressions of textiles on the gypsum, which surrounds some of the burials, indicate that the skeletons were additionally wrapped in mats. Additional evidence for matting is the geometric decoration of many stone vessels that resembles basketry. An especially thoroughly decorated stone object looks like a plaited container with a lid (Fig. 1). Although the fibers have not been determined so far, it may be suggested that sea club-rush was one possible resource that was used for matting.

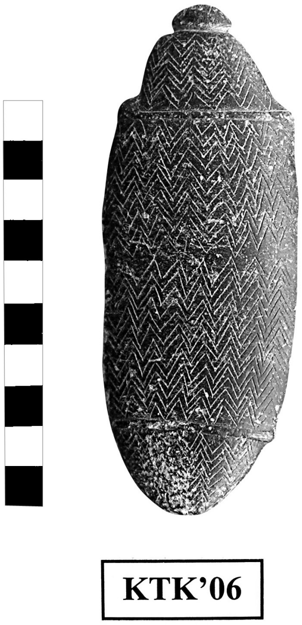

Fig. 1 Chlorite stone object decorated with a pattern similar to woven textiles or matting.

Animal Remains

The wide spectrum of plant remains is corroborated by the many faunal remains that were exclusively from wild species, including wild cattle, red deer, sheep, and goats, which make up the majority of the sample. Other wild animals include pigs, fox, wolf, hare and gazelle. Waterfowl such as mallard (*Anas platyrhynchos*), goose (*Anser* sp.) and two other members of Anatidae were identified. Because of the high frequency of wing parts Arbuckle and Özkaya (2006: 17) suggested that the feathers of the birds could have been used for decoration. But once hunted, their meat was probably consumed too. Most of the identified waterfowl were a good additional food in winter as they are typically winter visitors to eastern Turkey except for mallard, which is a summer visitor (Arbuckle and Özkaya 2006: 126).

So far, fish remains have been recovered by hand and by sieving the sediment from graves. One specimen has been identified as a Cyprinidae (Arbuckle and Özkaya 2006). Yet, if remains are collected by hand, ubiquitous and large fish such as Cyprinidae are systematically overrepresented (Van Neer *et al.* 2005). The sample is therefore probably biased for large species, but in the following seasons it will be possible to collect fish remains and microfauna systematically during flotation.

Grave findings document that fish vertebrae were occasionally used as beads, but the emphasis was clearly on other jewelry like small stone ring beads, serpentine beads, and shell/gastropod beads. Additionally, 21 fish jaws were found, of which two were found in graves. Three of them show some polish. The graves in which fish remains were found do not show any other specificity but reflect the wide spectrum of grave types from Körtik Tepe. It is however interesting to note that

Fig. 2 32 stone vessels with this standardized specific decoration of concentric circles (a) (sometimes combined with the representation of long horned animals [b]) have been found so far on the site, but in none of the burials discussed in this paper such a vessel has been found.

in the graves with fish remains decoration of stone vessels with concentric circles and goats (*cf.* below, Fig. 2) never occur, and the vessels' decorations are generally rather crude.

Fishing Equipment

Fish Hooks

Nine fish hooks made of bone (Fig. 3) have been found so far (Özkaya 2009: Fig. 11); eight of them come from levels between -310 cm and -235 cm below the zero point of the excavation, suggesting that they belonged to the second main occupation period associated with stone buildings.[4] There is only one hook that stems from a higher level (-175 cm) (Fig. 3 b). The distribution on the site does not hint at a specialization because fish hooks have been found in all parts of the settlement (Fig. 4). Three items of a rather crude shape were found in the grave of a male adult (M10, A80; *cf.* Tab.1 and Fig. 3 c, h, i and Fig. 5) combined with a pestle, a bone pin and a tortoise shell lying on the head of the individual. The hooks and the pin lay close together suggesting that they had been placed in a perishable container.

The most recent hook (Fig. 3 b) was found in a grave (M5, A80) that belongs to the lavishly endowed graves of the upper layers. Beside 275 stone beads and 242 shell beads, the grave goods comprised two rectangular serpentine beads, two large perforated stone objects (possibly net weights), two longish perforated stone objects (7.8 cm and 6.6 cm respectively) and two stone bowls, one of which is decorated with a rather crudely incised, unrecognizable pattern or representation. All of these items might be interpreted as that of a fisherman with fish hooks, net and fishing line weights.

Many perforated but otherwise unworked stones have been found in some graves and in other contexts. According to their use traces they may have hung on a line as sinkers for the hooks.

Shape of the Hooks

Most of the Körtik Tepe fish hooks have a U-shape with a high and thick bow part, more resembling Mesolithic fish hooks than Neolithic ones (*cf.* Hernek and Jonsson 2003; Hüster-Plogmann 2004: Fig. 326; Herling 2007; Sampson 2008: 203-207, plate 12.1A-B). The gapes, the space between the shank and the point, is quite large except for one exemplar. None of the Körtik Tepe fish hooks has a barbed point. Two items, the one from the upper level and one from a deeper level (-303 cm) have a different shape with a rectangular lower part of the bow. Additionally the recent exemplar has a very wide gape and two holes. These two holes might have been used to fix a second hook or hook sinker. Perhaps the holes connected by a string were made for protecting the hook that it would not break while catching big fishes (Fig. 3 b). As Olson *et al.* (2008) could demonstrate, bow fractures are the most common fresh fractures within their sample of 384 fish hooks of the Stone Age site of Ajvide, Sweden, and of replicas, which have been used for material strength tests. The top of the shank is preserved only in three items, which have a thickened round end to fix the line. None of the items has grooves or a perforation on the shank, but three of them show a thickened top. The strength tests of Olson *et al.* demonstrate that the fixing of the line has no consequences on the load which can be caught.

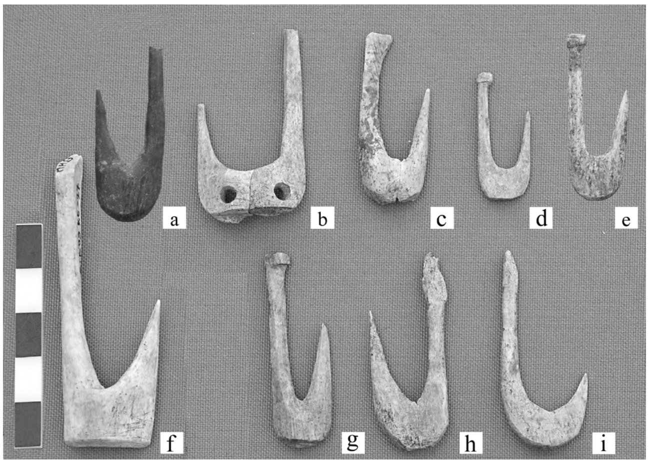

Fig. 3 Fish hooks found on the site, in grave A80, M5 (b), and in grave A80, M10 (c, h, i).

Concluding from the shape and the few numbers and the distribution of fish hooks from Körtik Tepe, fishing with a pole was technologically not very elaborated, nor was it obviously a very specialized occupation. However, fishing with such equipment implies good skills and knowledge as the line must be kept tight once a fish has been caught. Otherwise the risk that the fish unhooks itself is very high. Additionally, the thickened part of the bow of nearly all items indicates that the producer of the hooks knew the weak point of the hooks very well. It is astonishing that none of the hooks had a barbed point.

The stratigraphic position of the hooks shows that there was no typological change from the upper to the lower layers. The rectangular shape of the most recent hook is similar to an older item. The shape of the few examples was quite standardized and did not change too much over time. But as there is only one piece from the upper levels and none from the deep cut this observation has to be verified by further excavation.

Net Fishing

Net fishing is one of the neglected occupations in prehistory. Several hundreds of net sinkers have been recovered in the circum-alpine pile dwellings (*e.g.* Hüster-Plogmann 2004). Probably some of the Körtik Tepe perforated ground stone tools may have been used as net sinkers too. Use traces on the left and right side of the hole on some of the perforated stone objects also suggest that they have not been fixed on a stick as mace heads or other tools, but that a string had been pulled through

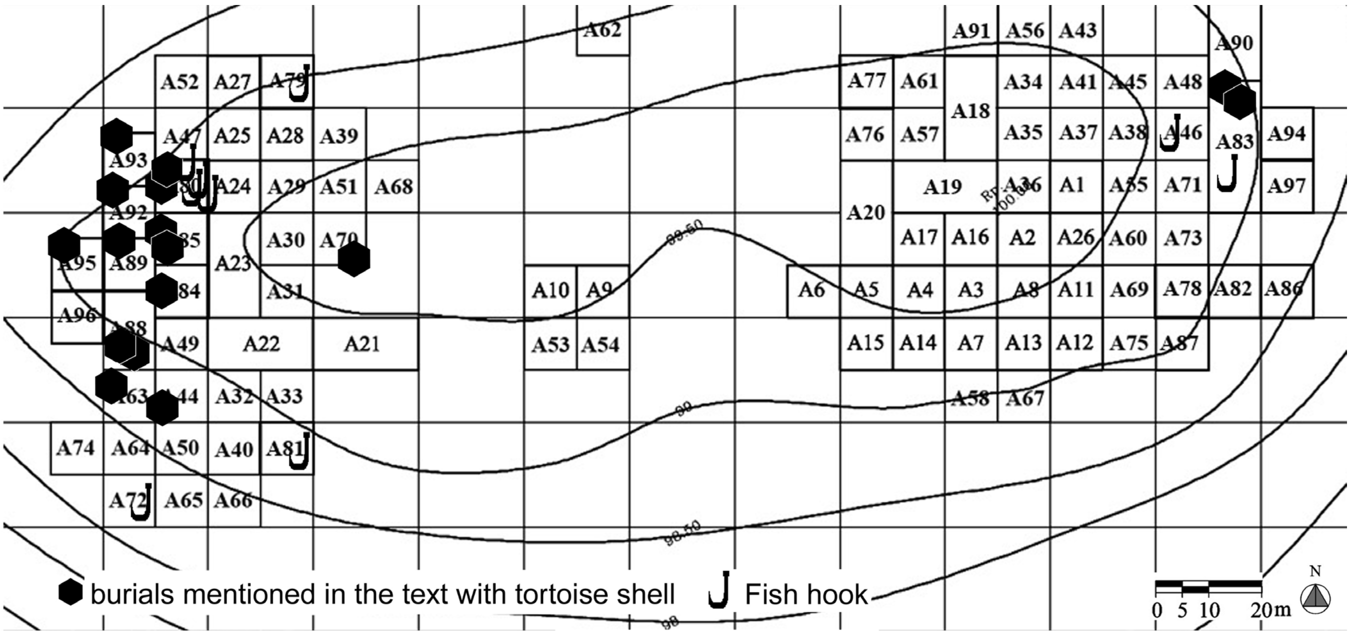

Fig. 4 Distribution of fish hooks and graves with tortoise shell on or nearby the head.

the hole and moved back and forth (Fig. 6). Many other perforated stones have been found and document the ubiquity of this occupation. Several bone awls and fine needles illustrate that at least technologically net knitting would have been possible (*cf.* anthropological evidence).

One technology that leaves no traces is fishing with traps. However, the above mentioned preliminary analyses of the botanical remains indicate that sea club-rush (*Scirpus maritimus*) is very frequent on the site. In combination with willow twigs, for example, it could have been possibly used for the construction of traps, too.

Although quantitative and qualitative estimations of fish consumption are not possible so far (*cf. e.g.* Gross *et al.* 1990; Schibler *et al.* 1997: 329-335), we can deduce from the faunal and archaeological remains that

Fig. 5 Burial of an adult man (A80, M10) with three fish hooks, a bone pin, a pestle, and a tortoise shell.

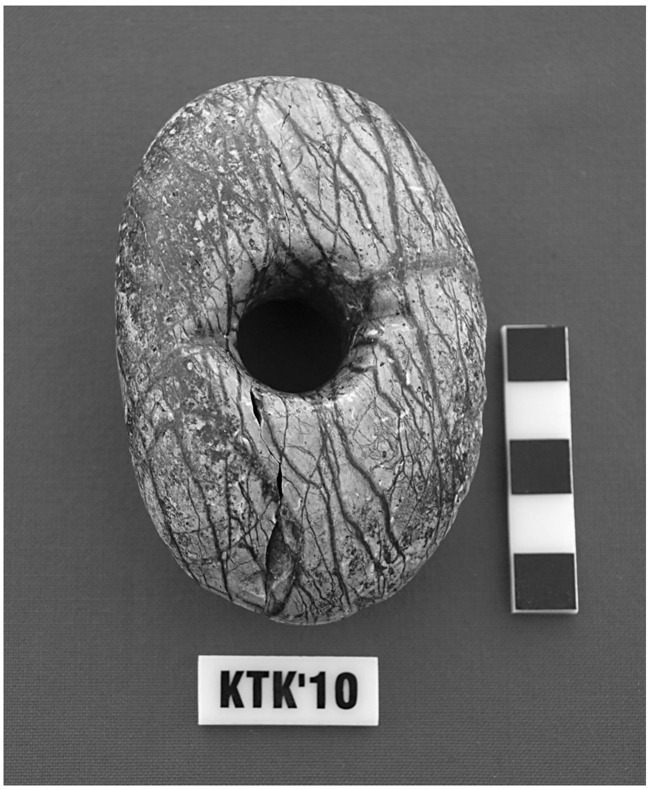

Fig. 6 Perforated stone item with use traces on the left and right side of the hole.

fish and waterfowl were consumed (*cf.* anthropological evidence).

Excursus: of Tortoises and Men

Because of their slow motion tortoises are highly valued small animals (Stiner *et al.* 2000). The findings from Körtik Tepe additionally illustrate the high social value these animals might have had. In 16 burials tortoise shells were found lying nearby or covering the head of the individuals (Table 1, Fig. 5). Most of them (n=14) are located in the western part of the site (Fig. 4), but whether this implies a certain spatial affiliation (household) has to be verified by deeper excavations in the eastern part.

Most of the identified individuals buried with tortoises are adults of different ages, but also children and one perinatal individual were buried with tortoise shells. There is no differentiation by gender either. Concerning the burial ritual, these individuals do not differ much from the other burials. Their orientation is typical for most of the Körtik Tepe burials. Also for the use of plaster it is not unusual that in the most upper burials little or no plaster was used.

Concerning additional grave goods, it is interesting to note that in none of the burials with tortoises, as it was observed for the burials with fish remains, stone vases with concentric circles have been found. Additionally, some of the other equipment can also be related to fishing activities, such as the fish hooks of M10 of Trench A80. Individuals with tortoise shells cover the whole spectrum of the quantity of grave goods: from lavishly endowed ones to burials without any additional grave goods.

It can thus be summed up, that there was a selection for some individuals, but that the criterion was neither chronology nor gender or age. The fact that children also were buried with a tortoise shell on or near the head makes a certain professional occupation improbable, but it cannot be excluded that a certain social affiliation or ritual position was attributed to these children, too. The exclusion from skillfully decorated stone vessels is striking and might imply a different corporate identity of the "fisher-tortoise-men".

Anthropological Evidence

Possible further hints to the activity of fishing can be gained by the anthropological analyses of the skeletons from Körtik Tepe. Besides a low caries frequency indicating a low intake of carbohydrates and ground resources (Özbek 2005: 42-43), the most important evidence hinting at fishing activities comes from auditory exostosis (AE), which is a bony anomaly located on the tympanic portion of the temporal bone (Frayer 1988). Of 48 skeletons having at least one temporal bone, 21 individuals (43.8 %) have variously sized AE. Of these, 63.6 % are male (n=11) and 57.1 % (n=14) female individuals. AE has not been observed among infants younger than 2.5 years, but it was observed first at about the age of 6.5-7 years. While the frequency of AE is 38.5 % in children, it increases to 50 %, 60 % and 80 % in young adults, adults and old adults, respectively; in contrast, there is no statistically significant difference between males and females. Körtik Tepe adults have a higher frequency of AE than other living populations, which show a pretty low frequency of AE (Hanihara and Ishida 2001; Okumura *et al.* 2007; Velasco-Vazquez *et al.* 2000).

Experimental research carried out with guinea pigs and humans indicates that there is a strong relation between the prolonged exposure to cold water and the presence, frequency, and degree of AE (Standen *et al.* 1997; Chaplin and Steward 1998). Similarly, clinical investigations demonstrate that the AE frequency is between 73-80 % among surfers, surf life-savers and white-water kayakers (Wong *et al.* 1999; Chaplin and Steward 1998; Moore *et al.* 2010). Moreover, it has been widely accepted that there is a significant relationship between the years spent in cold water and AE (Wong *et al.* 1999; Chaplin and Steward 1998; Moore *et al.* 2010).

The presence of AE in Körtik Tepe and its relation to prolonged exposure to cold water have been proposed by Özbek (2005: 44-45). Such pathologies have also been observed in other skeletal populations living by water sources such as the Neolithic sites of Çayönü and Aşıklı (Özbek 1992: 151; Özbek 2004: 33). Similar anthropologic interpretations have also been made for different sites in the world. Namely, it has been suggested that the Mesolithic population of Vlasac living by the Danube were associated with aquatic activities taking in account the faunal remains and 34 % of AE (Frayer 1988). In addition, Standen *et al.* (1997), who have worked on three different Chilean populations dated to 7000 BC and 1450 AD, have emphasized the strong relationships between the activities such as diving and fishing (by which the ear is exposed to cold water) and the development of AE. Similarly, archaeological findings indicating fish and shell-fish consumption suggest that life at Gran Canaria mostly depended on marine resources (Velasco-Vazquez 2000).

Generally, these investigations have shown that the lifestyle depending on fishing and the exposure of the ear to cold water can cause the development of AE, and in these kinds of populations the frequency is higher than in other populations having different lifestyles. Although the exposure to cold water might be due to activities such as bathing, cleaning, swimming and playing in water as an entertainment, the above mentioned archaeological data suggest that fishing played an important role in daily life in Körtik Tepe, which is located by rich water sources like the Batman Creek and Tigris. While fishing with poles and nets does not require the ear to be

Trench	Grave	Sex1,2	Age1,2	Inside house²	Level cm	Face	Orien-tation	Posi-tion²	Plaster²	Grave goods
A 80	M10	male	30-40 yrs	X	-309	S	NE-SW	Hl	X	3 fish hooks, pestle, bone point
A 85	M3	male	45+ yrs	?	-269	S	E-W	Hl	X	Ovoid chlorite pendant (2 x 1,1 x 0,5cm)
A44	M1	?	adolescent	X	-268	E	N-S	Hl	X+ ochre	None
A92	M3	?	adult³	?	-253	N	E-W	Hr	X	Horn of a wild goat, animal bones, fragments of a bone pin.
A63	M1	?	adult³	?	-241	W	NE-SW	Hl	X+ ochre	1 bone point (borer)
A83	M15	?	10 yrs	X	-233	S	N-S	Hb	X+ ochre	two tortoises
A89	M3	female	young adult	X	-227	E	NE-SW	Hl	X+ ochre	241 stone ring beads,532 gastropod/shell beads, 1 undecorated lime stone vessel
A93	M5	?	adult³	Outside	-227	S	E-W	Hl	-	None
A85	M2	male	25-28 yrs	?	-219	N	NE-SW	Hr (?)	X	7 undecorated stone vessels, 3039 gastropod/ shell beads, 5091 small stone beads.
A84	M7	female	23-27 yrs	X	-218	W	NE-SW	Hr	X+ ochre	1 fish bone [?]
A83	M27	?	child³	X	-217	NW	NE-SW	Hr	X	395 stone ring beads, 492 gastropod beads, 1 undecorated shaft-straightener, 2 perforated stone tools,1 perforated limestone tool, 2 undecorated stone vessels, 1 bone awl, 1 piece of obsidian, 1 net weight/mace head⁴.
A70	M5	?	adult³	?	-200	E	N-S	Semi Hl	X+ ochre	1 bone point
A88	M8	?	Perinatal	?	-193	?	?	destroit	-	2 gastropod/shell beads, fragments of undecorated stone vessels, piece of bone decorated with parallel lines.
A95	M5	?	child³	?	-172	N	E-W	Hr	-	None
A 80	M1	female	35-40 yrs	X	-163	SE	N-S	Hb	-	1 piece of obsidian, flint stone, 2 decorated, 1 undecorated stone vessel, 1 perforated stone tool, 1 mace head/net weight⁴, 1 mortar, 585 small ring stone beads, 1 serpentine bead, 799 gastropod/shell beads, 19 fish vertebrae as beads.
A88	M1	male	45-50 yrs	?	-118	W	N-S	Hr	-	1 fragment of undecorated stone vessel

[1] Determination of age and sex (pers. comm. Y.S. Erdal)
[2] ? unknown; Hr=Hocker lying on the right side; HL=Hocker lying on the left side; Hb=Hocker lying on the back.
Plaster: X=present; - =without
[3] approximate estimation of age according to bone measurements (humerus/femur/tibia) and cranial sutures taken from photos.
[4] a final distinction between mace heads and net weights will become possible only when systematic use traces will be analysed.

Table 1 Burials with tortoise shells near or on the head of the skeletons.

exposed to cold water, it is highly possible that Körtik Tepe individuals might have been subjected to cold water while setting traps and diving in order to catch fish or other aquatic resources. In brief, the ears of Körtik Tepe people might have been exposed to cold water over the long term, and this kind of daily life must have been continued for a lifetime.

Secondary data related to fishing have been extracted from dental grooves on 11 individuals out of 53 adults. Dental abrasion observed on the anterior dentition has mainly resulted from the production of cord, rugs, blankets, duck decoys, funerary bags, baskets, and fowling bags. Moreover, it could also result from the manufacture of nets, traps for fish, and also fishing activity (Cybulski 1974; Larsen 1985). It is concluded that some of the dental grooves on the anterior dentition might have resulted from the activity related to fishing (Cybulski 1974; Schulz 1977; Larsen 1985). These data suggest that the richness of the fauna and flora near the water was thus not only a boon, but also a bane for some individuals. They paid with their dental or/and ear health, and probably their general health.

Isotopic Evidence

Despite fairly bad preservation of collagen, we have managed to gain the δ^{13}C- and δ^{15}N-values from 18 out of a total sample of 42 individuals so far. Some preliminary results show that although the group of individuals is quite small, there is some variation of the dietary input that consisted of protein of plant and animal origin (Siebert *et al.* in prep.). However, concerning the management of water resources, the δ^{13}C- and δ^{15}N-values do not indicate a significant proportion of fish in the diet. A lowering effect of δ^{15}N-values due to a high intake of pulses as has been suggested for Nevalı Çori (Lösch *et al.* 2006) seems to be rather improbable because the δ^{13}C-values also hint at a mixed diet rather than a specialization on aquatic resources.

Water and Aquatic Resources in Figurative Representations

Figurative representations at Körtik Tepe show a wide spectrum of animals comprising long-horned animals (sheep or goat), birds, scorpions, deer, snakes and some

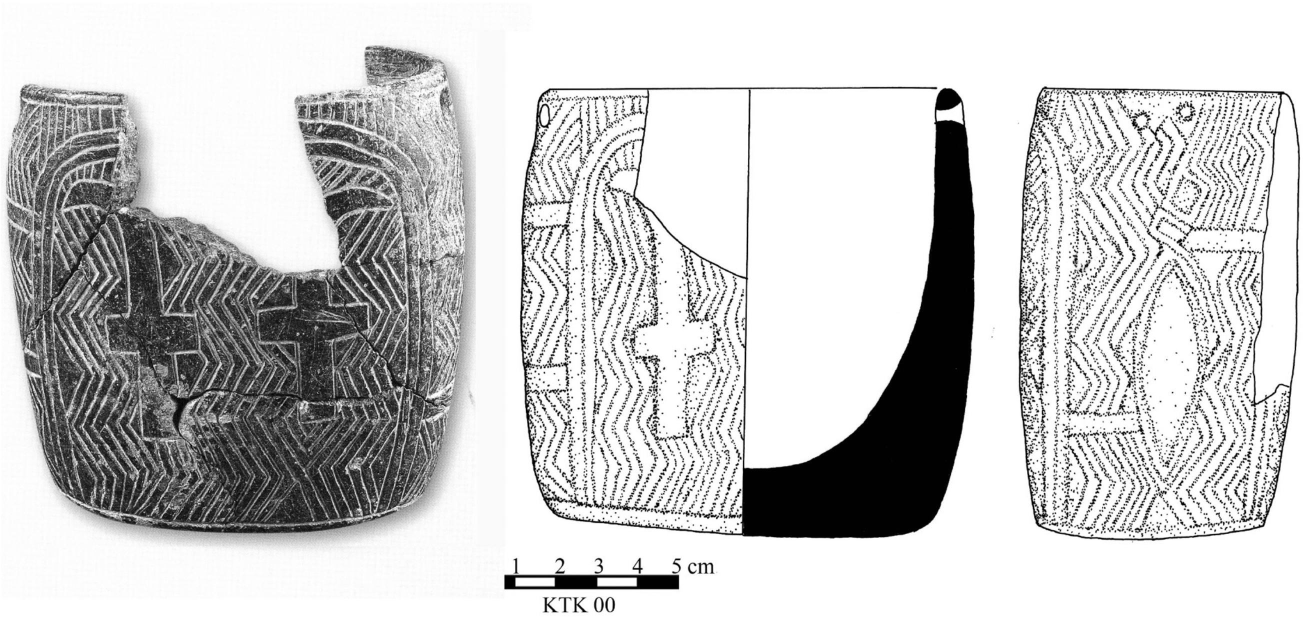

Fig. 7 Stone vessel with the representations of water and birds, possibly waterfowl. (Özkaya and Coşkun 2007: 146; Arbuckle and Özkaya 2006: fig. 3).

unidentified animals, possibly insects, which are very similar to figures interpreted as "insects" or "spiders" on the pillars of Göbekli Tepe (*e.g.* Schmidt 2007: 90). However, representations of aquatic resources are quite scarce. The many wavy and zigzag lines in metopes, all-over decoration, or ribbons surrounding the stone vases might be interpreted as stylization of water, but as the decoration of a bone item and of a stone vessel with concentric circles clearly show, these lines could be stylizations of snakes too (Fig. 2). However, abstract representations could be polyvalent and so one interpretation does not exclude the other.

There is one stone vessel which could give a clue to the identification as waterfowl and fishes (Özkaya and Coşkun 2007: 146; Fig. 7). On this vessel the typical stylization of birds is surrounded by many parallel zigzag lines and a half bow surrounding the birds. Whether the double line surrounding the birds should represent a trap or fishing pole remains speculative. On the opposite side, an elliptical form with pointed ends is surrounded by the same zigzag pattern. Although this form could be interpreted as a boat which is attached to some kind of footbridge, it might represent a fish or a shell too. The same almond-like sign is represented on two bone amulets, in combination with a scorpion and a snake respectively. This could speak in favor of an animal.

Similar bundles of zigzag lines combined with identically stylized birds were incised on several stone vessels (*e.g.* Özkaya and Coşkun 2007: 145-146; Özkaya and San 2007: Fig. 17). In the above mentioned grave with a tortoise (M1, A80; *cf.* Table 1), one stone vessel was decorated all over on its upper part with similar parallel zigzag lines.

Besides the naturalistic and abstract representations of birds/waterfowl, the upper ends of some stone pestles have the shape of bird heads. Although a clear identification as waterfowl has to be proven, given the high frequency of waterfowl in the archaeozoological remains and the frequent combination of zigzag lines and birds on the vessel decoration, it can be suggested that the stylized birds could represent waterfowl and need not be related coercively to vultures and death as it has been convincingly demonstrated for other sites (Stordeur n.d.; Schmidt 2007). A small chlorite animal head resembling more a duck or goose than a bird with a pointed beak could corroborate this interpretation (Fig. 8).

If we accept this interpretation, waterfowl are represented quite frequently. The high frequency of wing parts led Arbuckle and Özkaya (2006: 17) to suggest that the feathers might have been used for decoration. Both observations hint at the social importance - at least of the secondary products of waterfowl - for the identity of the people.

In contrast, fish and tortoises are almost absent in decorative art. Besides the above mentioned geometric symbol, two ovoid forms on a bone item, which might be interpreted as catfish (Yayın balığı, Silurus triostegus), were combined with some kind of insects and again scorpions (Fig. 9). The decoration of a small chlorite item could represent a turtle/tortoise head (Fig. 10).[5] It should be kept in mind that - except in one case (Özkaya 2004: 598, Fig. a) - none of the representations of birds or fishes were combined with the concentric circles so often used as decorations on stone vessels and other stone items (Fig. 2). Additionally, the latter representations have been found in none of the above mentioned graves with fish hooks or tortoises, but instead those of water.

This exclusion of one or the other decoration in the graves is significant and might hint at a special identity of the people with the tortoise and fishing equipment. However, there seems to be no exclusive use by one

Fig. 8 Chlorite item in the shape of a goose or duck head.

Fig. 9 Decorated bone item with representations of scorpions, some kind of insect and possible representations of (cat-) fish found in Grave M13, A87.

segment of the society. Vases with concentric circles as well as graves with tortoises and bird representations have been found in the same trenches.

Discussion

Taking the evidence from the different studies altogether, we suggest that the people of Körtik Tepe used a wide spectrum of freshwater animals and hygrophilous plants for their subsistence, personal adornments, and equipment. A mix of hunted large and small animals and wild plants seems to have provided the main calorific input. Our results thus corroborate the findings of other contemporaneous sites where an opportunistic use of plants and animals could be demonstrated (Savard *et al.* 2006; Starkovich and Stiner 2009). We suggest that the intensive, probably year-round permanent use of the site is not due to the intensive use or even cultivation of cereals as has been suggested for the Natufian of the Levant. Rather, it seems that highly valued and/or calorie-rich resources such as acorns, pistachios, hackberry, and probably almonds, as well as easy to catch small animals like tortoises or fish, contributed to the diet. The rich and diversified environment made the site attractive for a permanent settlement. A specialization on cereals could not be observed so far. The interpretation of plant remains has long been biased by our modern perspective, where the focus on cereals as one of the basic nutritional elements has been projected onto the past (Olszewski 2004).

Microwear analyses on the grinding and pounding tools from Körtik Tepe could further elucidate which plants were ground. Concerning small game, fish have especially been a neglected resource because sampling methods for a systematic analysis have

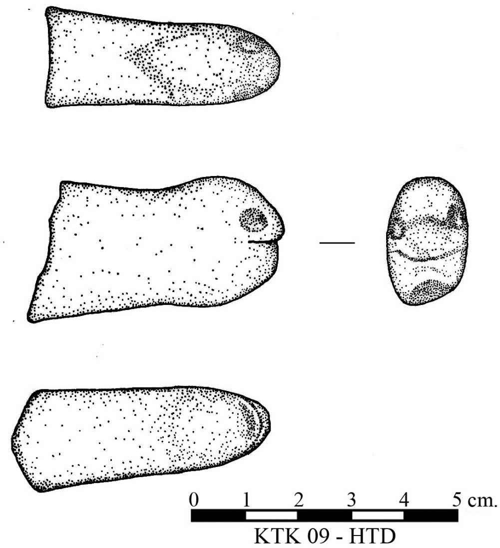

Fig. 10 Chlorite item, which might represent a tortoise head.

been insufficient (*e.g.* Starkovich and Stiner 2009: 50). Even if their quantitative contribution to the diet and their social role for the inhabitants of Körtik Tepe were of minor importance, they were probably a valuable addition to the diet. Pathological findings, such as auditory exostosis, hint at prolonged exposure to water, possibly by fishing or collecting other aquatic resources (Frayer 1988; Standen *et al.* 1997; Özbek

2005: 42-45; Erdal and Koruyucu n.d.). Furthermore, dental grooves could result from preparing fibers for nets or other fishing equipment.

As far as it is possible to conclude from the distribution of artifacts, a specialization on fishing by some inhabitants did not exist. Fishing with a pole was not a very developed technology, either. However, fish remains have to be sampled systematically to consider the importance of fish and other possible technologies for fishing. Although tortoises might have been eaten as it has been recorded for the nearby contemporaneous site of Hallan Çemi (Starkovich and Stiner 2009: 58), the use of the tortoise shell to indicate a special social identity has been restricted obviously to a few individuals. The comparison with other sites where tortoise shells have been found in a burial (Grosman *et al.* 2008) suggests that the role of these individuals might have been in the ritual shamanistic sphere. However, at Körtik Tepe children were also endowed with tortoise shells, therefore, a shamanistic identity seems rather improbable.

Conclusion

Although there was no "domestication of water", no installations such as dikes, footbridges or fishing ponds, the evidence discussed above suggests that permanent water and its related resources made the site attractive for a permanent living near the Batman Creek and Tigris River and contributed to its success. Burial remains hint at a highly differentiated social community with many richly endowed burials. Obviously, the different social identities had to be demonstrated by personal items and body decoration (in its widest sense). Despite similarities with other contemporaneous sites, the people of Körtik Tepe developed their own iconographic repertoire. They seem to distinguish themselves from the other people in the region, although they took part in wide exchange networks of obsidian and of other exotic materials such as serpentine (Özkaya 2009).

However, within their own village access to aquatic resources does not seem to have been restricted to a certain group. If there was a commodification of resources (*sensu* Gebel 2010), it did not show up in the economic realm of aquatic resources or access and use of water but rather in the personal and ritual/ideological sphere with the tortoise burials and body decoration. Fish obviously did not play an important role for the demonstration of social identities. They do not show up – or if so only rarely – in the symbolic repertoire of the site, and the fish vertebrae, which might have been used as beads, are of a negligible quantity compared to other ornaments. In contrast, tortoise shells and probably the feathers of birds/waterfowl were used to demonstrate a personal – and more probably – a certain group identity. The burials with tortoise shells are distinct from other symbolic repertoires, such as the concentric circles and goats. However, the distinction was neither gender- nor age-specific. Future studies are necessary to clarify this matter, whether a distinction is, for example, also reflected in a different kind of subsistence or provenance.[6]

These trends will be verified by systematic and detailed studies of the fish bones and microfauna to gain more information on subsistence practices at Körtik Tepe. Morphometric studies of small game could contribute as much to questions of subsistence as will do systematic isotopic studies. The shift of focus on the opportunistic behavior of early Holocene hunter-gatherers avoids projecting the importance of cereals onto the past and contributes to a better understanding of the process of sedentarisation and commodification of resources and material culture during the Early Holocene.

Endnotes

[1] We use the term *Pre-Pottery Neolithic A* (PPNA) as a chronological term, being aware of the cultural differences between the PPNA of the Levant and southeastern Anatolia, and despite the fact that neither domestication of plants nor of animals could be demonstrated at Körtik Tepe and despite the Epipalaeolithic character of the flint and obsidian remains. The more appropriate term of *Protoneolithic* as it has been suggested by several authors (Schyle 1996; Benz 2000; Aurenche *et al.* 2001) could not be established in the scientific community. The term *Round House Phase* (*cf.* Savard *et al.* 2006) is not used either because it uses a constructional specificity which also occurs in other prehistoric periods.

[2] This study was made possible through samples and materials provided by one of the authors, Prof. Dr. Vecihi Özkaya, director of the Körtik Tepe Excavation. We are grateful to him for the permission to study these materials.

[3] The archaeobotanical and isotopic analysis could be done thanks to the financial support of the German Research Foundation (BE-4218/B1-2; AL287/9-1). We are grateful to Prof. Dr. Vecihi Özkaya for the permission to study these materials.

[4] An older settlement period with round buildings dug into the sediments with post holes has been identified in a test deep cut during the 2010 season. However, the excavated surface is too small to conclude anything about fishing so far during this earliest settlement period.

[5] The only possible, but much debated representation of a turtle/tortoise stems from the later MPPNB site of Nevalı Çorı, on the Euphrates (Hauptmann 1999).

[6] Familial relationships might have played an important role, but unfortunately DNA is preserved too poorly for systematic analyses of this kind.

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Early Water Exploitation and its Post-Neolithic Aftermath

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Introduction

Even though water is essential for the existence of human beings, its use in early times has long been neglected. The usages of water differ and change during prehistory, but in contrast to the archaeology of early metallurgy (*cf.* Hauptmann and Strahm 2009; Strahm 1994), up to now there has been little effort on a systematic dealing with water. (I do not have enough space here to elaborate on all innovations connected with water; a larger volume is currently under preparation; *cf.* Eichmann *et al*. in press)

Apart from drinking water, water is a source of subsistence (Fig. 1): Already in Palaeolithic times, human groups used the vicinity of predators to water to feed upon the carcasses left behind by these, for instance at El Known, Syria (Le Tensorer and Muhesen 1997; Le Tensorer *et al.* 2007; *cf.* also Baales in press). Being a natural barrier, water could also be used to trap fleeing animals, as the context of the famous spears from Schöninghen, Lower Saxony, Germany suggests (Thieme 1997; 1999). Last but not least, there was of course, also the possibility to prey upon marine animals, which seems to have become common from the Younger Palaeolithic onwards and resulted in the impressive highly specialised køkkenmoddinger (shell middens) that appear worldwide since the Epipalaeolithic (Noll 2002). Even the use of rafts or boats has been suggested for the older and middle Palaeolithic and is currently discussed (*cf.* Bednarik and Kuckenburg 1999; Bednarik 1997, 1999, 2008): The finds of flint tools from Mata Menge and Boa Leza on the island of Flores in the Soa Bassin were deposited during a period in which the island was divided from the mainland by 50-150 m of water and thus the makers and users of these tools are thought to have had access to primitive watercraft to reach the island (Gibbons 1998). There are significant improvements in the already known uses during the Epipalaeolithic and Neolithic. Sea voyages in the Mediterranean are becoming a daily routine and able to bridge much greater distances. This is visible, for instance, in the finds of obsidian from the island of Melos in the Franchti cave on the Argolis (Jacobsen 1972: 83ff; Cherry 1985: 14-16; Torrence 1986; Williams-Thorpe 1995) or the settlement of Cyprus during the PPN which not only brings colonists to the island but also domestic and wild animals (*cf.* Guilaine and Le Brun 2003; Peltenburg and Wasse 2004; Simmons 2007; *cf.* also: Ammerman *et al*. 2008); from northern middle Europe there is also artefactual and pictorial evidence from early seagoing vessels from the Late Upper Palaeolithic, though both finds are not undisputed (Elmers 1980; Tromnau 1984). Since V. Gordon Childe masterfully described the spreading of archaeological cultures along the Danube, it is clear that water is an important medium over which long-distance contacts, exchange networks and social relations evolve (Childe 1929). B. Cunliffe elaborated on these ideas and has lately written an archaeological "history" of Western Europe in which he tries to explain the specific cultural evolution: because all Western European societies were "Facing the Ocean" (Cunliffe 2001).

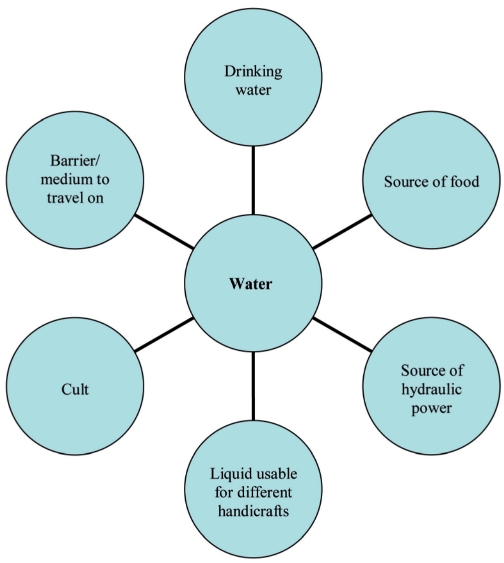

Fig. 1 Schematic overview about the possible uses of water in pre- and protohistoric times (Klimscha).

These modes of using water change drastically after the advent of Neolithic economies. Ceramic vessels made cooking with water now easier and allowed much more complex dishes to be prepared (Sherrat 2002); even though cooking with boiling stones was known from Palaeolithic times onward, the use of ceramic pots allowed a new quality in its use. And finally the cultic use of water seems to go along with the Neolithisation, although one has to stress that this seems to be rather a phenomenon typical for the later Neolithic of Europe (*cf.* Rech 1979; Klimscha 2011).

A Hydrological Revolution? Neolithic Water Use

The most striking change in using water is, however, the building of wells and earthen structures. The new technologies available in the Neolithic allowed for new ways of allocation, conduct and storage of water. Water has to be collected in vessels to move it from the source. The easiest possibility for this is the employment of organic vessels. Even though there are no such finds in the early prehistory of the Near East, a small number of birchbark vessels are known from the Baltic (Ošibkina 2007) and central Germany (Gramsch 1993, 2000). As long as this is the only possibility to move and store water, the activity of human groups is closely bound to natural water sources and the possibility to manufacture and transport storage vessels. The construction of wells on the other hand enabled human groups to build settlements independently of natural water sources, like springs and rivers, which goes along well with current models for the Neolithisation which stress organisation among others as a typical Neolithic trait (*e.g.* Cauvin 2000; Bellwood 2005).The well was therefore accurately characterised as *eau portable* (Bakels 1983, 17). It enabled human groups to "create" water reservoirs of considerable size and thus to augment both their size and their Lebensraum.

Wells not only enable a better quality of drinking water but also to raise the quantity of available high-quality water; in comparison to Mesolithic water holes from the type as they were excavated by B. Gramsch in Friesack, Brandenburg, Germany (Gramsch 1998). Therefore the well enables a society to develop an understanding of hygiene. It was even suggested that the higher water quality allowed for a social stratification of Neolithic societies into groups with primary rights on the water from wells and those without those rights (Campen and Stäuble 1998/1999; Stäuble 2002), although one has to be careful here, not to overemphasize the still sparse number of Neolithic wells, which could also be a product of archaeological research strategies (Weiner in press).

During the PPNA the earliest wells, yet discovered, are known from Cyprus (Peltenburg *et al.* 2001) and shortly thereafter from the southern Levant (Garfinkel *et al.* 2006). If this technology is transported to Europe with the arrival of Neolithic people, or if the wells of the European Neolithic are an independent invention is still under discussion. Since modern excavations regularly detect wells in Early Neolithic settlements in Europe (*e.g.* Kottera 2007; Lorscheider and Schade-Lindig 2007; Elburg 2008; Stäuble and Fröhlich 2006), it seems reasonable that at least the knowledge how to attain subterranean water sources was part of the Neolithic package and was translated into locally adapted technologies.

The dating of the invention of wells is still under discussion, because there is the possibility that it may be older than the Neolithic: In Northern America there has been excavated a vertically sunk shaft, that can

Fig. 2 Tall Hujayrat al-Ghuzlan. Overview of the Late Chalcolithic/Early Bronze Age tell site, facing NW in spring 2010 (Becker/DAI; to be published in Khalil and Schmidt forthcoming).

plausibly be interpreted as a primitive well. Downright sensational is the age of this structure which can be attributed to the Clovis culture and thus dated into the Paleolithic (Green 1962). Comparable structures are up to now unknown in the Near East, but their existence is possible, as I will show: Pit extraction of chert is known since the Acheulean, but with the Upper Palaeolithic underground mining was practiced. In Nazlet Khater 4, situated in the Upper Egyptian Nile valley, an Upper Palaeolithic blade industry was produced from chert that was mined on the site. The excavations discovered vertical shafts which were dug at least 1.5m deep into the gravel; these were sometimes enlarged at their base. Several carbon 14-datings securely fix the digging activities between *ca.* 35,000 and 30,000 BP (Vermeersch *et al.* 1984, 1995; Vermeersch 2003). The sinking techniques displayed at Nazlet Khater 4 are comparable to those needed for the construction of wells. The discovery of mining in Paleolithic times therefore could be very closely connected with the necessary technical evolution that finally enabled well sinking. In contrast to flint and chert, water was easier available in many regions, and therefore the knowledge of sinking does not necessarily have pushed the construction of wells; however it should be kept in mind, that the necessary pre-requisites were available in the Near East from at least the Upper Palaeolithic. Once a group understood, that within the hydrological circuit water was constantly exchanged between subterranean reservoirs, above-ground sources and the atmosphere, the knowledge developed via chert mining could be made use of to "mine" for water.

Positive (walls, dikes) and negative (ditches) earthen structures allowed the transport of water. Water could now be diverted from a human habitation or brought into it, to be more specific onto the fields. The innovative use of earthworks for the control of water movement was discussed by Gebel (2004) as well as the use of stone dikes which could have been used to stop wadi floodings (Kujit and Goring-Morris 2002). Storage of water in larger dimensions can only be meaningful to groups which constantly stay on the same place (or at least who stay as long at the same place as necessary to use up the stored water).

The Combination of Neolithic Technologies: Early Irrigation Systems of the Chalcolithic in Jordan

The transport of water is a major shift in man's relationship to nature. While the Palaeolithic and Epipalaeolithic usages summed up further above used water as a transport medium or as a food source in its unmodified natural environment, the construction of wells and earthworks, changes the environment to ease the access to water. Human communities begin to loosen larger amounts of water from the hydrological circuit for domestic and agricultural use.

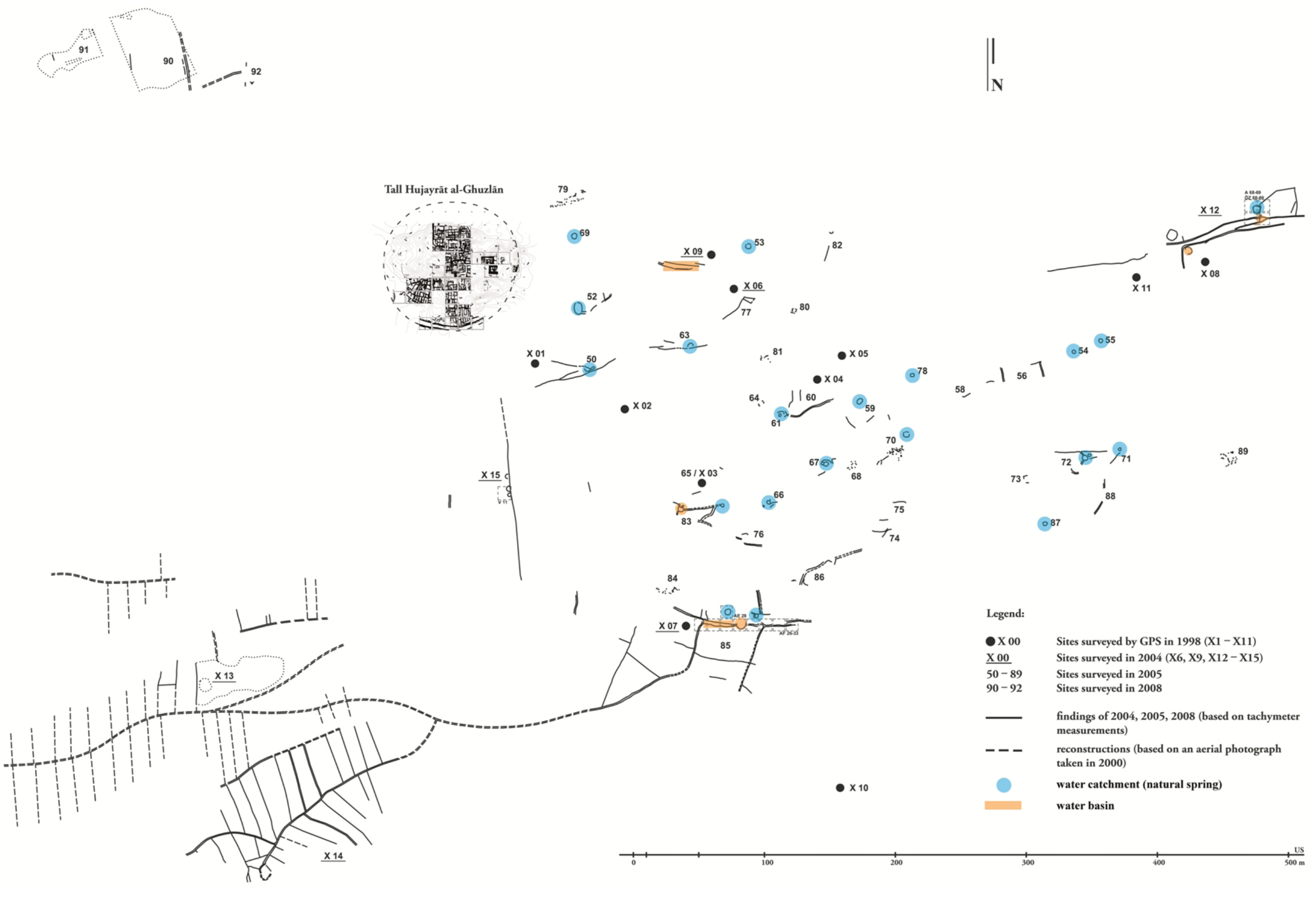

Fig. 3 Overview of the hydrological structures in the vicinity of Tall Hujayrat al-Ghuzlan (Siegel/DAI).

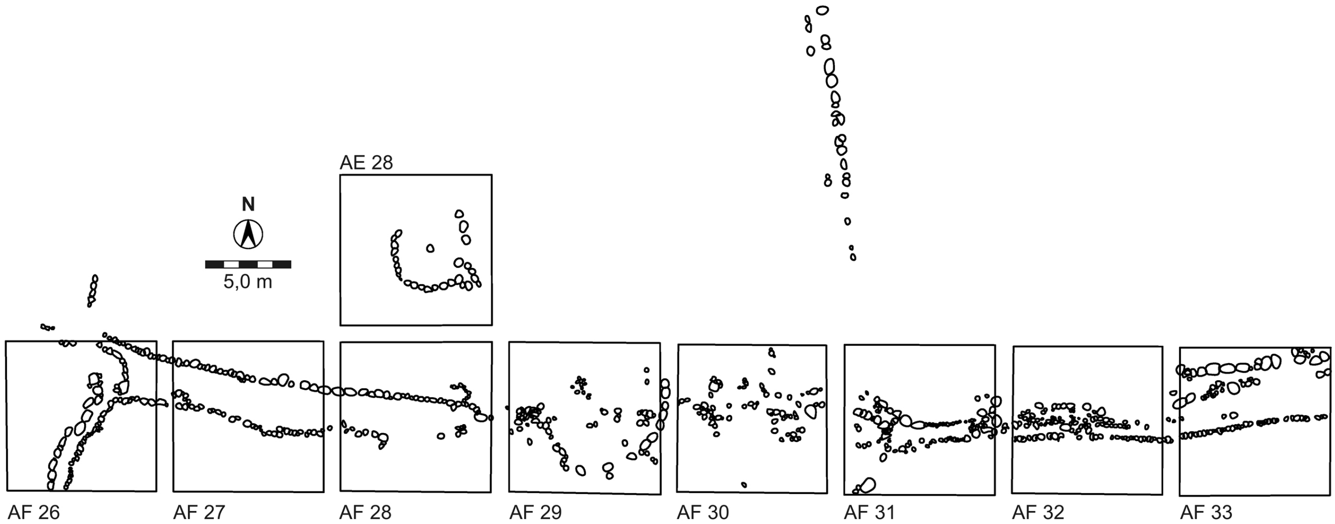

Fig. 4 Surroundings of Tall Hujayrat al-Ghuzlan. Area of site 85; wadi boulder structures in the south of Tall Hujayrat al-Ghuzlan showing a system of water catchment and water distribution (Heemeier *et al.* 2009: 262, Fig. 12).

However, if water was to be used in a distance from where it was "extracted", some means of conduction had to be used. To be successful, such a transport needed the combination of several technical achievements already mentioned: First of all a regular source of water, that is either a natural one or one or more wells to provide enough water to make an artificial transport expedient. In contrast to most other substances, water moves by itself, and therefore is easy to move. All that is needed is a slight slope to create hydrostatic pressure plus structures that confine its way, i.e. either a ditch or walls or a combination of both.

Such a system was examined between 2004 and 2006 in Tall Hujayrat al-Ghuzlan (Fig. 2), a late Chalcolithic/Early Bronze Age settlement, near Aqaba, southern Jordan (Khalil and Schmidt 2009; Heemeier *et al.* 2009; Klimscha and Siegel 2007; Siegel 2009; Klimscha *et al.* in press). The Aqaba area is researched since 1998 by a Jordanian-German cooperation between the University of Jordan and the Orient Department of the German Archaeological Institute. The ASEYM Project (Archaeological Survey and Excavation in the Yutum and Magaşş Area) is directed by R. Eichmann, K. Schmidt and L. Khalil (The research was assisted by the A. Hauptmann, Bochum and M. Grottker, Lübeck. For the history of research *cf.* to Khalil 2009; Klimscha and Siegel 2007; Müller-Neuhof *et al.* 2003; for the final results of the research 1998-2006 *cf.* Brückner *et. al.* 2002 and Khalil and Schmidt 2009; another volume dealing with the period of 2006-2010 is currently under preparation). Since 2002 the excavations and surveys were focused on Tall Hujayrat al-Ghuzlan and its surroundings and work was financially assisted by the German Research Foundation (DFG).

Here a combination of basins and canals was used to accumulate water and transport it to agricultural areas 300 meters south-west of the settlement (Fig. 3). Several areas with water saturated soil layers consisting of a sand/gravel mixture could be identified via geoelectrics (Heemeier *et al.* 2009: 257-261). During a survey structures build from large boulders and wadi pebbles could still be seen above-ground. The structures can be sorted into roundish and sub-rectangular "basins" on the one hand and longish rows of parallel stone rows on the other hand (Fig. 4).

Excavations were undertaken 2005 and 2006 and could provide evidence for the use as an irrigation system: There were no artifacts inside any of the structures excavated and sinter accumulations in the longish, parallel rows suggest that water had run here on a regular basis. Dating the structures is not easy, because the carbon 14-analyses of the sinter accumulations were probably contaminated and allowed a dating between the Neolithic and the Islamic period (*cf.* Klimscha in press). However since there are no other archaeological features in the vicinity of the structures than the Chalcolithic tell and since optical-stimulated Luminescence dating (OSL) generated the same age range for the tell and the irrigation system, one can relatively securely attribute the latter to the Chalcolithic period. The water was collected in open, round basins near the areas where it came to the surface (Fig. 5) and from there it was transported via the canals (Fig. 6; 7) onto terraced fields in the south and south-western area of the settlement (Fig. 8). Especially the south-eastern fields were very well preserved and show that there existed several zones of similar shape and size onto which the water was brought (Fig. 9).

Such a system is atypical for the Chalcolithic of the southern Levant and not known from neighboring areas in northern Jordan and Israel and also not in predynastic Egypt. Comparable structures are, however, documented on the Golan (Epstein 1978): Within the circumference of Majami' several rectangular structures were recognised and near those structures staggered "stone heaps" were found and identified as the

Fig. 5 Surroundings of Tall Hujayrāt al-Ghuzlān. Humid area with increased soil humidity enclosed by wadi boulders; site 85, loc 8 (Siegel 2009: 291, Fig. 87).

Fig. 6 Surroundings of Tall Hujayrat al-Ghuzlan. Canal during excavation; site 85 loc. 1 and 4 seen from the west (Siegel 2009: 291, Fig. 84).

boundaries of fields. Stone settings which were either parallel to or divergent from areas with an increased humidity on the other hand were interpreted as an early irrigation system that tried to control the spreading of this moisture (Epstein 1978: 32). Irrigation systems are also considered for some of the Chalcolithic sites in the Negev (Epstein 1978; Gilead 1988; Levy 1995: 230; Bourke 2002).

Since the tell was situated in an arid, desert like zone, it was the prerequisite of the settlement, which allowed 150-200 people to live there (*cf.* Klimscha *et al.* in press), which engaged in copper smelting and the production of adornments made from mollusk shells and copper ingots. Currently geological examinations in the Aqaba region suggest that during the Chalcolithic, the coastal zone was marshland; therefore the number of inhabitants may be corrected slightly upwards in the future (*cf.* Allison and Niemi 2010; Niemi and Smith 1999).

The single elements of the irrigation system are neither new nor innovative; however, their combination and resulting from this efficiency is remarkable. The building and especially cleaning of such a system required a form of central control over labor and, therefore, social innovations which had resulted in tenser organization and probably social inequality have to be assumed before such system could be built. There must have been rules regulating who was to do the additional work added to the work-load of a society and there must also have been a way of accessing a society's accumulated experience with Neolithic water technology. Without some experience about how to raise and move subterranean water, such a system as encountered in Tall Hujayrat al-Ghuzlan would not only be unthinkable to its prehistoric builders but also unefficient. There must have been experience with all different elements and especially with moving larger masses of water over shorter distances. This experience must have been accumulated over several generations and probably outside of the Aqaba region, because there are no predecessors of the irrigation system. Consequently, the system proves the existence of social mechanisms enabling a Late Chalcolithic, alliterate society to refer to experience collected in preceding times, and use it to construct innovative hydrological strategies that allowed the permanent life in desert regions.

An Evolution of the Use of Water. Some Thoughts on the Use of Innovative Techniques in Hydrology

The evolution of water-use, *i.e.* hydro-technology, can be understood best when comparing it with that of fire-use, *i.e.* pyro-technology. The first one is essential for living and innovations enable larger quantities of water to be made available from the Neolithic onwards. Fire is also essential for human life, but its use for the manufacture of ceramics and metals is aimed at producing secondary products. These technologies were perfected and allowed the production of more goods that are easier available. The population explosion of High Medieval Europe, for example, can partially be explained by the extensive use of iron scythes made available by advances in smithing technology which resulted in a shortening of the harvesting period (Ohler 1997). The use of water had the same tendencies already in prehistoric and protohistoric times. Contrasting the Mesolithic water holes with Neolithic wells and Chalcolithic irrigation systems makes clear that the quantity of available water is the main criterion by which these three can be explained in an evolutionary historical scheme.

The first phase of such an approach would be the simple use of natural water resources as it can be seen from (at least) Early Lower Palaeolithic times onwards (Tab. 1). This includes not only the acquisition of foods and drinking water from surface water but also the use of primitive watercraft. This strategy is bound to a foraging way of life and can be seen in perfection within the late Mesolithic hunter-gatherer-fisher societies in the Baltic who still cling to their subsistence nearly a thousand years after neighboring regions have changed

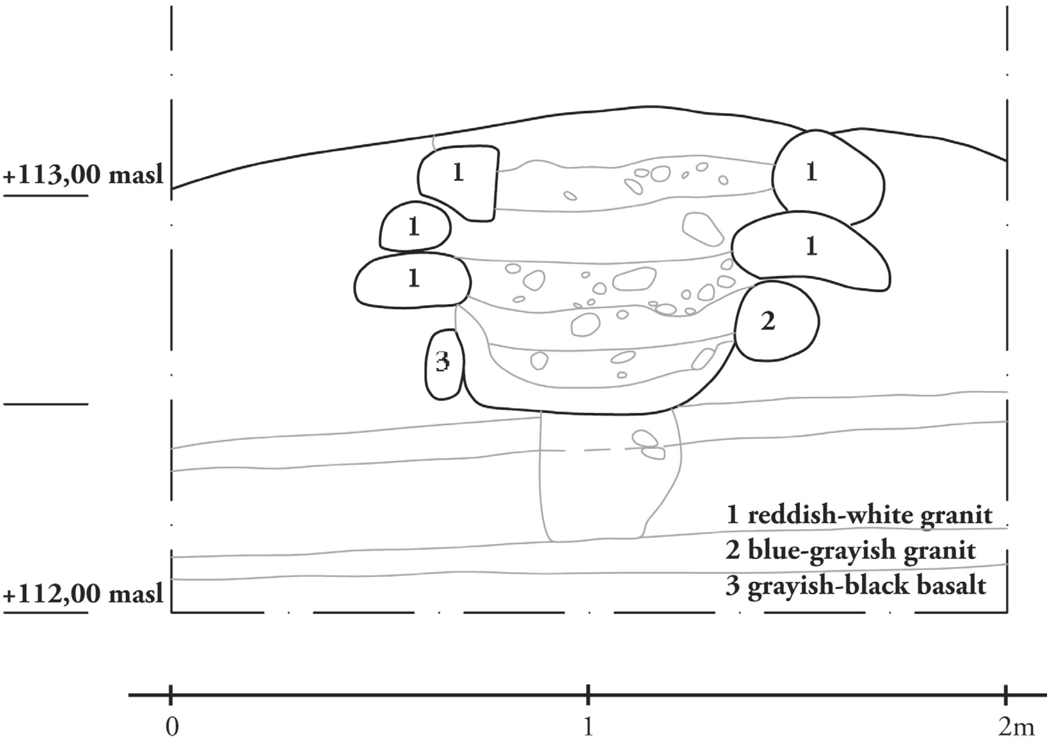

Fig. 7 Surroundings of Tall Hujayrat al-Ghuzlan. Profile of the canal construction excavated at site 85, loc 2 (Siegel 2009: 292, Fig. 90)

to the Neolithic mode of production. Human societies are bound to a vicinity of water. Therefore waterways are also the ideal means of travelling longer distances and push innovative technologies like dug out canoes which again allow advanced fishing techniques and a higher mobility. Even the late Copper Age societies in the Eastern Balkans still partially use this subsistence strategy to feed a society which is ground-breaking in the working of copper and precious metals, as can be seen in the extremely rich graves in the Varna cemetery on the Black Sea coast (Fol and Lichardus 1988). Human societies are bound to water in the Palaeolithic; while they use it intensively and advantageous from the Epipalaeolithic/Mesolithic onwards.

Fig. 8 Surroundings of Tall Hujayrat al-Ghuzlan. Terrace wall at site X13 (Siegel 2009: 280, Fig. 16).

With the construction of wells in the Neolithic it becomes possible to be independent from surface water and this also raises the quality and quantity of drinking water. Even if the invention of wells may be subject of further discussion, it has to be stressed that the innovative use of wells seems to be clearly bound to the Neolithic. The Neolithic, if then, is that turning point in which the hydrological circuit is changed for the first time. The building and use of wells implies knowledge about that hydrological circuit, namely the

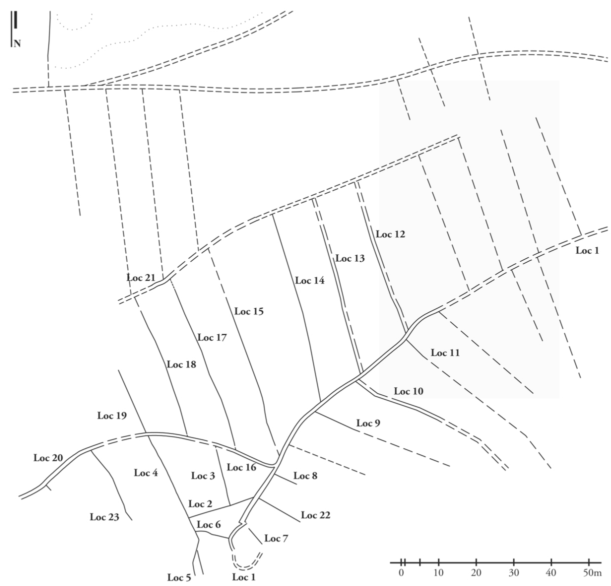

Fig. 9 Reconstruction of the canal and terrace system at the sites X13 and X14 (Siegel 2009: 280, Fig. 17).

Characteristics	Innovations	Technical and social consequences
Human groups are forced to connect their habitats to natural sources of water	Settlement along rivers Use of the food resources bound to waters Use of water surfaces as for travel (early watercraft)	Regular contact with water "favours" the improvement of innovations.
Human groups make intensive use of surface water reservoirs in many ways	Specialised weapons and tools for fishing Dug out boats Water holes	Improvement of known innovations; Conservative economies in coastal areas with large quantities of food make extensive use of old and new techniques and often ignore the Neolithisation Improvement of personal mobility Improvement of hygiene with drinking water
Change of the hydrological circuit. Human groups start to change their natural environment to use water; water can now now be bound to human groups	Wells Dikes, ditches (unclear if used for water protection/distribution)	Better mobility for Neolithic groups Permanent settlement in areas without natural water Improvement of personal mobility Improvement of hygiene with drinking water Increase of settlement size
Human groups make use of more extensive changes to the environment; Known elements are combined into the first irrigation systems	Cisterns Canals Artificial irrigation systems	Settlement sizes may be further increased Arid zones can be permanently settled

Table 1 Evolutionary scheme about the use of water in early prehistory (Klimscha).

existence of underground water; however certain constructional innovations are also necessary to build a well (see above). The combination of these two features allow human groups to interact with their surroundings in a new way; they start shaping the environment to suit human needs.

A further evolutionary "step" can be seen in the invention of hydrological systems as they are known in Mesopotamia from the Ubaid time onwards and in Tall Hujayrat al-Ghuzlan, Jordan. These systems are characterised by the controlled combination of known hydrological elements (wells, ditches and dikes).The permanent settlement of arid, hostile zones is probably the greatest advantage of these systems which seem to be necessarily evolving into complex societies in which labour is controlled regulated by a small social group (*cf.* Wittfogel 1963). The technology allowed human life in zones which were hostile and *terra incognita* for the preceding Neolithic communities. Settlements therefore could not start on a try and error basis but must have had a inventory of knowledge about natural phenomena, especially the sources of water, and a technological repertoire to bring this water onto the desired spot.

These phases are not simply following one after the other, but as I tried to show are bound to certain social and technological prerequisites. Since cultural evolution never goes uniformly straight ahead and also does not need to be similar everywhere, the use of water does neither perfectly go along with the archaeological periods nor is it limited to the time of its first appearance. While the Balkans in the Copper Age seem to have enjoyed a mixture of specialised use and re-shaping of water, we can grasp a controlled combination of known elements in the southern Levant as an afterlife of Neolithic water technology.

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A Radiocarbon Date from the Wall Plaster of Enclosure D of Göbekli Tepe

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The PPN settlement of Göbekli Tepe in southeastern Turkey has delivered the oldest examples of religious monumental architecture known so far. The archaeological dating of the sites´ two main layers is quite clear. The oldest Layer III, which contains the well-known circular enclosures formed by T-shaped pillars gathered around a pair of bigger central pillars can be dated to the PPNA through lithic finds comprising projectile points mainly of the Nemrik and Helwan types. The superimposing Layer II with its smaller, rectangular rooms often containing only two, considerably smaller central pillars, or none at all, is characterised especially by Byblos and a few Nevalı Çori type projectile points dating to the early and middle PPNB. Late PPNB finds are absent from Göbekli Tepe. Concerning the momentary state of the radiocarbon chronology for the Pre-Pottery Neolithic, one would expect a duration of 9600–8800 calBC for the PPNA complexes of Layer III and 8800–8200 calBC for the EPPNB / MPPNB activities in Layer II, respectively.

But, as a recent review of the data available shows, a bigger part of them is biased by methodological problems, although quite different sampling strategies were applied (Dietrich, in press). A bigger series of data was obtained from pedogenic carbonates on architectural structures (Pustovoytov, Schmidt and Parzinger 2007). Unfortunately they are of no use in dating the sampled structures themselves, as the carbonate layers started forming only after the moment of their burial. At least these samples offer a good terminus ante quem for the refilling of the enclosures. For layer III this terminus ante quem lies in the second half of the 9th millennium calBC, while for layer II it is located in the middle of the 8th millennium calBC.

A recently obtained series of data from bones discovered in the filling and layers is at least partially biased by methodological problems (Dietrich, in press). At least within the group of samples chosen, collagen conservation is poor and isotopic exchange processes with carbon rich surface and ground waters may have cause alterations in the carbonate contents of bones that lead to problems with the dating of apatite fractions.

The best dates available so far for Göbekli Tepe stem from charcoal samples of short-lived plants. Two dates for Enclosure A settle in the late 10th and early 9th millennium calBC (Kromer and Schmidt 1998), but they could also indicate the use of older fill material. The last intrusions in the big enclosures can be dated by a charcoal sample found under a fallen pillar fragment in Enclosure A to the middle of the 9th millennium (Dietrich, in press).

As charcoal seems to be the sample material of choice at Göbekli, an attempt to date the big Enclosures of layer III directly was made by sampling the wall plaster of Enclosure D (Area L9-68, Loc. 782.3, 29.10.2010). This plaster is formed of loam, which fortunately contains also small amounts of charcoal. At the 14C laboratory Kiel a sample big enough for an

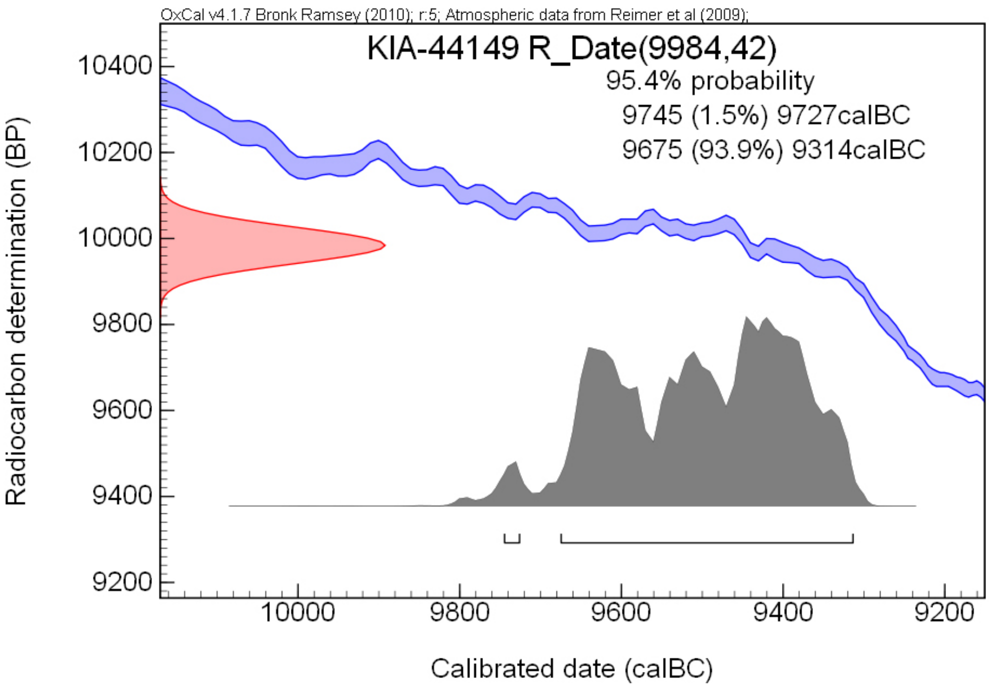

Fig. 1 Calibrated Radiocarbon Age using OxCal 4.1 (Datensatz IntCal09); two Sigma Range: 9675 (93,9%) 9314 calBC

AMS dating could be obtained from the plaster. The result reads as follows (Fig. 1):

Radiocarbon Age (KIA-44149): 9984 +/- 42 BP, δ13C -26,31+/-0,57.
Calibrated Radiocarbon Age using OxCal 4.1 (Datensatz IntCal09); two Sigma Range: 9675 (93,9%) 9314 calBC

With this date there is for the first time undisputable evidence for the absolute construction time of the big enclosures in the early PPNA. Also the date seems to be proof to the observation that Enclosure D is older than Enclosure A. In addition, a succesful sampling strategy for Göbekli Tepe has been lined out, which will be pursued further in the future.

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