

The Udhruh Archaeological Project – the 2011-2012 Field Survey^{*}

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INTRODUCTION

The Udhruh Archaeological Project was launched in 2011. The project is a joint venture between the Petra College for Tourism and Archaeology of the Al-Hussein Bin Talal University from Wadi Musa – Ma'an (Jordan) and the Faculty of Archaeology of the Leiden University (The Netherlands). The project is an international and interdisciplinary research program that combines archaeology, geoarchaeology, archaeological related disciplines, sustainable tourism and environmental sciences as irrigation and land degradation. With this interdisciplinary approach in mind it is feasible that other research partners will be added to the project in the future.

UDHRUH

The site of Udhruh has enormous archaeological potential. Situated 15 km east of Petra the site covers 4,4 ha, in places with more than 3 m of intact stratigraphic layers. Where else can one find a Roman legionary fortress that is not overbuilt by a bustling modern town (Fig. 1) or has not been completely demolished by the need for easily available building materials throughout later periods? Considering the numerous Roman settlements in the wider region with Nabatean origins the expectation of finding some remains of an earlier Nabatean site beneath or near the Roman fortress of Udhruh is by no means implausible¹. Besides the surviving remnants of the Roman *castra*, it is the long term occupation of this site and surroundings that make it a challenging place for archaeological research. The site was occupied continuously throughout the Byzantine and Islamic periods, with all intriguing

cultural, technical, socio-economical and religious transformation processes concerned. These transformation processes can be followed not only on the site itself but also in a surrounding landscape with limited disturbance caused by later human activities. A landscape where antique field systems, sophisticated water management and irrigation techniques, watch towers, roads and stone quarries can still easily be distinguished. An environment that can nowadays be characterized as harsh and dry but with a very friendly and cooperative population that has a great interest in the history of the people who altered this landscape in ancient times. For an archaeologist it is clear that Udhruh has great potential not only in studying the site and the environment from a local and regional perspective with all diachronic developments but also in broader comparative analyses. Supraregional exchange and trade, religious transformation processes and the purpose and role of the Roman limes are possible subjects of such broad comparative studies. Udhruh offers interesting possibilities for applied archaeology and interdisciplinary research related to modern sustainable agricultural use and community-based tourism. Because of the impact of these interactions and possibilities it is necessary to understand the regional embedding before beginning to formulate research objectives and start excavations. This can be accomplished by starting the archaeological research in and around Udhruh with systematically set-up field surveys.

THE FIELD SURVEYS – METHODOLOGY

Archaeological field surveys can be based on the premises: “*that human actions may occur, and leave*

^{*} This paper is submitted on 9 February 2013, with some small editorial changes on 17 July 2014.

¹ For Nabatean origins of many Roman military sites see e.g. Kennedy 2004.

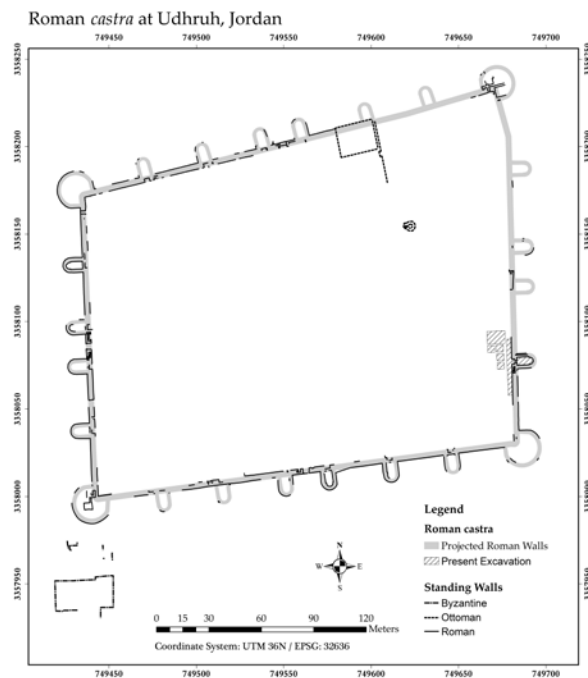


Fig. 1. The Roman castra at Udhruh (illustration by R. Emaus)

an essentially continuous 'blanket' of traces, anywhere in the landscape, that the resulting surface is a palimpsest of such traces through time, and that patterns in this record may be explained in part by the in turn limiting and enabling qualities of the landscape" (Van Leusen 2002, 1-3). The objectives of the Udhruh field surveys are threefold. Datable and diagnostic (cultural) material is collected to get information about the chronology of the habitation in and around Udhruh. The identification of structures and systems will provide information about the social, economic, infrastructural and military embedding of the site in the surrounding area. The surveys will give insights into the local, regional and supraregional functions of the site of Udhruh in a diachronic comparative framework.

On the basis of archaeological and epigraphic evidence concerning settlements around Roman castra and their surrounding *canabae legionis* along the European Roman frontiers an area of 25 km² around Udhruh was selected for the field surveys. Inscriptions from the Pfaffenberg at *Carnuntum* indicate that the outer boundary of the *canabae legionis* is to be found at 1 *leuga* (1.5 Roman mile; approx. 2.2 km) from the legionary fortress. At most European castra a third – civil, not military – settle-

ment is located at a distance of around 2.5 km from the fortress (Piso 1991, 138 ff.). This *extra leugam-vicus* would have been situated outside the military territory and had a different juridical status which probably allowed the inhabitants to own the ground they lived upon (Driessen 2007, 149; Mason 1988, 148). It is not clear if this *intra leugam*-principle was also implemented for the castra of the Roman province Arabia. Although the legionary fortress of El Lejjun was surrounded by *canabae legionis*², no research has been conducted outside Europe to trace the boundaries of these *canabae* and *extra leugam-vici*. Because the Roman legionary fortress provides the earliest evidence for large scale habitation in and around Udhruh it was decided to make use of this Roman *intra leugam*-principle by selecting a radius of 2.5 km from the fortress of Udhruh – extended to four square blocks of 6.25 km² each – as the initial basis for the area of the surveys.

The archaeological survey area of 25 km² is divided in three zones which are divided by the three main contemporary roads: the road from Udhruh to Ma'an, the road from Udhruh to Wadi Musa (Petra) and the road from Udhruh to ash-Shawbak (fig. 2). A fourth research area focusses on the ancient water management systems southeast of Udhruh in the direction of Ma'an. This separate transect lies for the most part outside the key survey area of 25 km².

Aerial photographs, satellite images and preliminary investigations of the area surrounding Udhruh, show not only a differentiation in geological zones, but also make clear that the antique landscape was affected by different natural and anthropogenic processes, which will necessarily affect the quality of retrieved data and artefacts. The methodology of the survey has been adapted to these differentiations in the landscape by describing and mapping the geomorphology in detail. The landscape is subdivided by units, called tracts, the edges of which are distinguished in the field by topographic and geomorphic features. The tract boundaries are mapped during the field surveys by both digital and analogue methods. The spatial and chronological distribution patterns of archaeological remains are naturally important research criteria. All (possible) archaeological structures are categorised and described in full detail³. These archaeological structures, their relation to the geomorphology and archaeological patterns within and between the dif-

² See for the *canabae* of El Lejjun: Clark 2006; Crawford / Parker 2006; De Vries 2006.

³ For this classification of the archaeological remains we relied upon the categorisation used by the Wadi Fanyan Landscape Survey (Creighton / Barker / Mattingly 2007, Table 4.1) which was extended and adjusted with own criteria and observations.

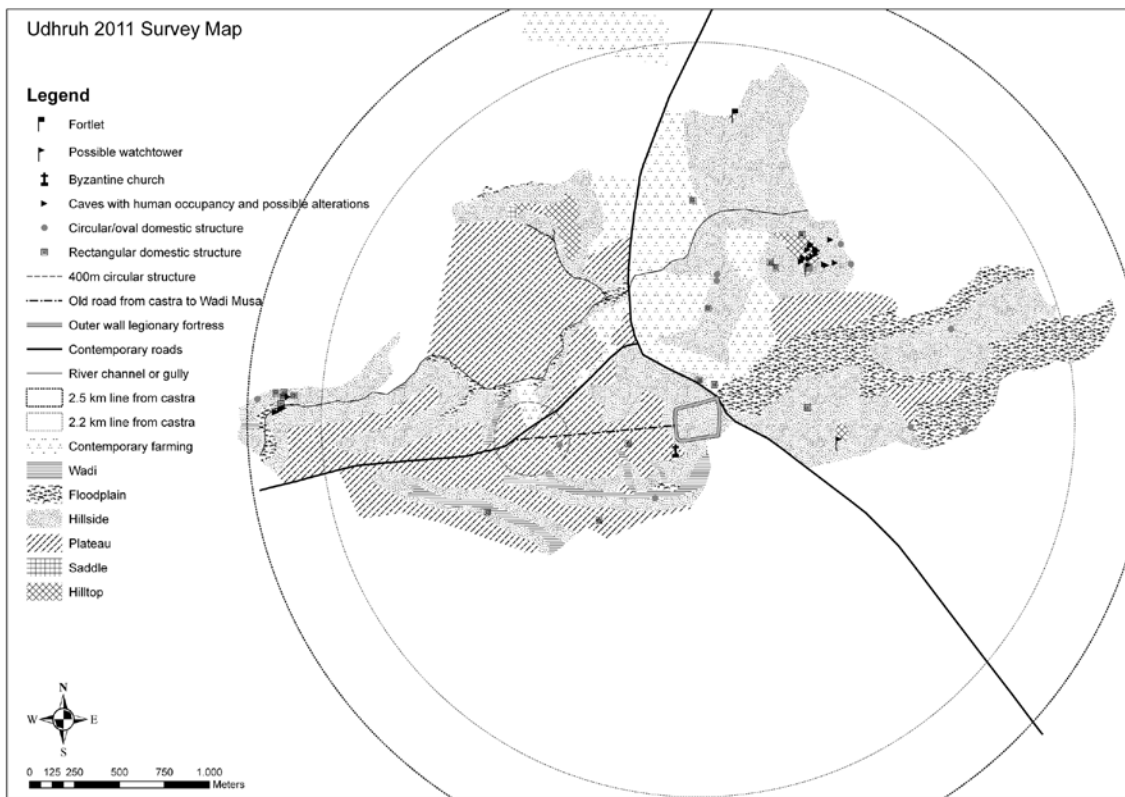


Fig. 2. Map of the archaeological structures retrieved during Udhruh 2011 campaign (illustration by R. Emaus)

ferent tracts of the survey area will be analysed by means of the GIS-databases. During the pilot field survey it was decided not to collect individual artefacts with the exception of diagnostic material that might help with the dating of (larger) archaeological structures.

THE 2011-2012 FIELD SURVEYS – RESULTS

During the 2011 pilot field campaign a total area of 5.6 km² (fig. 2) and in 2012 more than 15 km² was surveyed. Although the data of this second, five week field campaigns had not yet been processed, a résumé of this campaign is included here. The field surveys demonstrated that the area around the castra of Udhruh was actively exploited. As it concerns still work in process it was decided to mention here only some aspects which are interesting for this volume.

Traces of a straight road coming from the western gate of the castra in the direction of Wadi Musa – Petra were discovered during the survey (fig. 2). This old road becomes unclear at about 900

m west of the fortress where it converges with the modern tarmac road to Wadi Musa⁴. The connectivity of the fortress of Udhruh in a wider setting becomes also clear from the survey of several hilltop sites in the region. Seven of them were probably part of a signalling system due to retrieved remains of watchtower-like structures on top and/or the sight lines that connect them to each other, the fortress of Udhruh and Petra (fig. 3; table 1)⁵. On top of Jabal al-Tahkim – 1600 metres north of Udhruh – one can find the remains of a small L-shaped fortress⁶. Next to 1st century AD Nabatean pottery, sherds from Roman, Byzantine and Early Islamic pottery were also collected here. The so called Relais Tower, halfway between Udhruh and Petra, with a square watchtower on top⁷ was probably an important structure within the (military) signalling and communication system as there are excellent views over the whole area from this site, making it a very strategic point for the region. Tell Abara (2000 m southwest of Udhruh) is a strategic territorial marker for this region and has an overall view in all directions

⁴ See for instance the aerial picture of Udhruh with traces of the old road converging with the modern road to Wadi Musa in the upper right corner of this picture: <http://www.flickr.com/photos/apaame/4928247123/in/photostream/>.

⁵ See Woolliscroft 2001 for the basic ideas behind this system.

⁶ See for this fortress also Glueck 1935, 77; Killick 1983, 127.

⁷ This watchtower is probably the one Killick (1986, 440) mentions and is depicted in his Plate 24.14.

Network of visibility: Towers in the Udhruh Area

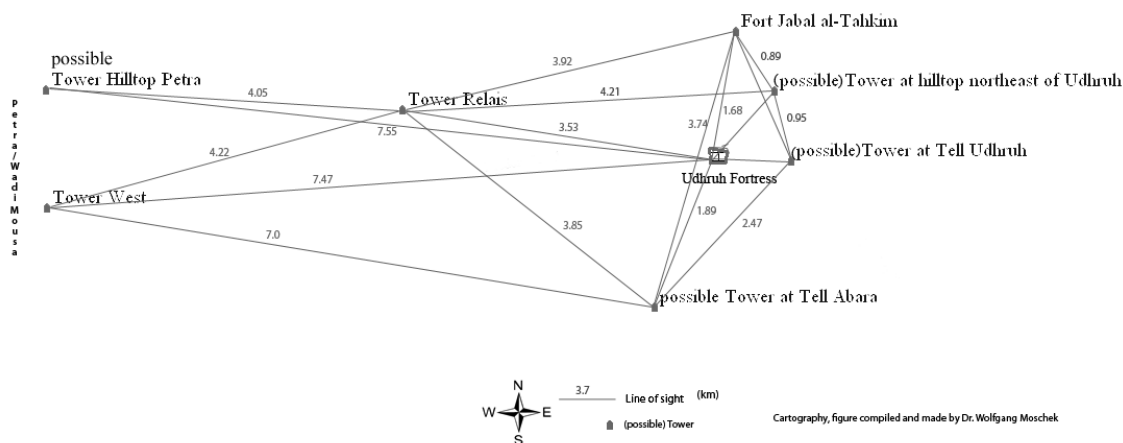


Fig. 3. Network of visibility: Towers in the Udhruh area (illustration by W. Moschek)

Visibility	Fortress Udhruh	Tell Udhruh	Hilltop NE Udhruh	Jabal al-Tahkim	Tell Abara	Relais Tower	Hilltop Petra	Hilltop West
Fortress Udhruh	NA	Y	Y	Y	Y	Y	N	Y
Tell Udhruh	Y	NA	Y	Y	Y	Y	Y	Y
Hilltop NE Udhruh	Y	Y	NA	Y	Y	Y	Y	N
Jabal al-Tahkim	Y	Y	Y	NA	Y	Y	Y	N
Tell Abara	Y	Y	Y	Y	NA	Y	Y	Y
Relais Tower	Y	Y	Y	Y	Y	NA	Y	N
Hilltop Petra	N	Y	Y	Y	Y	Y	NA	N
Hilltop West	Y	Y	N	N	Y	N	N	NA

Table 1. Visibility between (possible) watchtowers in the Udhruh area and the legionary fortress of Udhruh

and has sight lines that connect it with all the visited hilltops (fig. 3; table 1). A rectangular enclosure on this hill was described as a possible temporary Roman camp (Killick 1986, 436-8; Kennedy 2004, 180). This enclosure lies on the very steep slopes of the southern side of the hill, which makes it not very suitable as a location for a Roman camp⁸. Although no remnants of a watchtower were retrieved from this site, the location has distinct strategic value for the region. The further examination of the hilltops in the region, their sightlines and the collection and determination of cultural artefacts are planned for the coming seasons.

Dozens of quarries, large and small, were discovered northwest, southeast and southwest of Udhruh. The dimensions of these limestone-, sandstone- and flint-quarries vary from 20 to almost 1000 m². More, even larger quarries were no-

ticed in the large plateau area northwest of Udhruh. Different techniques of quarrying stone blocks could be distinguished when exploring these sites. At a few quarries some unfinished blocks were left behind (fig. 4a-b). The provenance and the dimensions of these blocks correspond with those used in the fortress. Samples of all the different provenances of natural stone used in and around the fortress of Udhruh were collected and examined⁹. Some of these samples could already be compared with quarry sites.

A settlement was discovered at 2.2 km distance in western direction from the legionary fortress of Udhruh (fig. 2). It consists of many caves with cut-out rooms and outside enclosures. One rectangular cut-out cave was used as a cistern (7x4x3 m). At the eastern entrance of this cistern a broken well covering stone (1x1 m) was still *in situ*¹⁰. The OSL-

⁸ See also <http://www.flickr.com/photos/apaame/4928846474/in/photostream>.

⁹ This was executed by Guus Gazenbeek: our stone and building ceramics specialist.

¹⁰ The missing corner was found at the bottom of the cistern.

dating of the mortar used for the cistern walls will hopefully give an indication of the date of construction. Two now abandoned houses of (reused) stone blocks were probably rebuilt over older buildings. The foundations of these houses are quite different in size, material and set-up than the contemporary walls. The first analysis of the pottery around these houses and caves seems to indicate that this site was already in use in the Roman and Byzantine periods, though contemporary refuse shows that these cave sites are still being (temporarily) used, most probably by local shepherds¹¹. Foundation walls of other buildings and structures indicate that this site was most probably L-shaped along the *wādī* and measured around 20,000 m² (5 acres). Broad foundation walls made of large cut stones of flint were probably used to block the water coming from two *wādī*'s at the western side of the settlement, directing it through the main gully to prevent flooding the lower parts of the settlement. At the place where this dam abuts the gully the natural bedrock terrace of hardstone (local flint) is tooled. At the edge of this natural terrace two parallel trenches of about half a metre wide and a meter long were cut in the bedrock. The use of these trenches is till unclear, but a function as a mill is possible¹². Quite remarkable is the fact that the eastern side of this settlement is situated at 2.2 km westwards from the legionary fortress. Between the fortress and this settlement – except for the large circular structure and some stone heaps – no clear archaeological structures could be traced. Nor did we notice any clear artefact 'sites' of spatially concentrated ceramic clustering between the two sites. When approaching this settlement from eastern direction through the *wādī* – that flows in west-east direction – we encountered higher concentrations of pottery than at any point since leaving the perimeters around the fortress. Further analysis of the layout and use of this settlement, the pottery and the OSL-dating of the mortar will provide more information concerning the dating of this site and whether the location might be related with the intra leugam-hypothesis. On the northern slope above the caves and houses of the village three flat bedrock floors with side walls of cut stones were found (180-550 m²). These could possibly have been used as threshing floors, as other ancient threshing floors have also been found in this region. North and west of this settle-

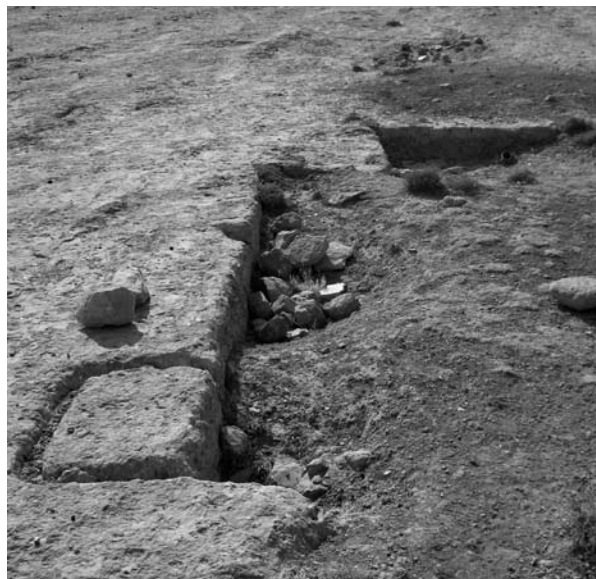


Fig. 4a. Unfinished block in quarry to the west of Udhruh



Fig. 4b. Unfinished blocks in quarry northwest of Udhruh

ment extensive (terraced) field and wall systems have been retrieved.

An impressive network of ancient water conservation measures and irrigated field systems was investigated to the south and southeast of Udhruh. During the 2012 surveys emphasis was placed upon water distribution and field systems in the Wadi el-Fiqay region, 5.7 km southeast from the legionary fortress (fig. 5). The geomorphology of the approx. 7 km² area where these were retrieved was again mapped¹³. To get an idea of the interrelationship of the different parts, levels of all the water and field related systems were measured. Some of the built up channels had been exposed during recent

¹¹ During the field surveys we met a few shepherds around this site and a lot of sheep dung in and around these caves.

¹² See for Roman water mills: De Vries 2006; Spain / Spary-Green / Wilson 2010; Wikander 2000; Wilson 2008.

¹³ These surveyed systems lay outside the initially planned research area of 25 km².

¹⁴ See also Abudanh / Twaissi 2010.

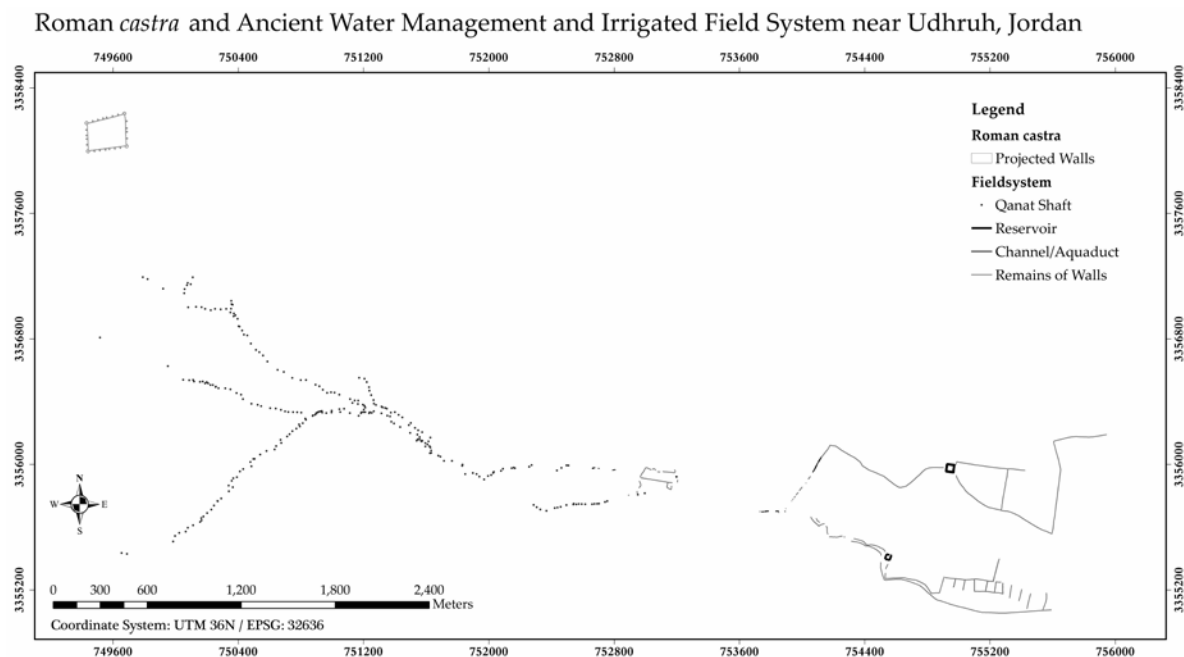


Fig. 5. Ancient water conservation measures and irrigated field systems southeast of Udhruh (illustration by R. Emaus)

wet seasons and are now visible in erosion gullies which are sometimes several meters wide and deep (fig. 6). Four *qanat* branches with more than 200 shafts are still recognisable in the landscape 1000-1400 m south to southeast of the Udhruh-fortress¹⁴. These filled up shafts, which are recognisable by the 4-6 meter wide spoil rings, were used for the construction and maintenance of subterranean galleries that tap water from aquifers. The *qanat* galleries lead this water over a distance of approx. 4-5 km by means of gravity flow to lower-lying ground where it flows through built-up channels and aqueducts to large reservoirs (fig. 7). One of these reservoirs was unfortunately demolished by treasure hunters who used a bulldozer in their search for gold and other valuables. Two other reservoirs are – till now – more or less intact. The most northern reservoir is made up of large cut stones, in size and provenance resembling the ones which are used in the walls of the Roman fortress at Udhruh. This 50x50 m open reservoir – with standing walls still up to 1.5 metres – was used to irrigate a walled field system of approx. 20 hectares (50 acres). This field system consisted in two large level or levelled fields which were divided by a wall. After determining the high measurements of the channels, aqueducts and the reservoirs, we could work out which water works related to this reservoir. These calculations brought us to a rough estimate of a height of 2 metres for this reservoir,

giving it a capacity of approx. 5000 m³ (= 5.10 litres water). The capacity of the second, southern reservoir (34x36m) could in the same way be estimated at approx. 2500 m³. This reservoir was used to irrigate a long rectangular field system of approx. 15 hectares (37.5 acres). This field system was subdivided into separate plots which were probably used for different purposes employing different irrigation techniques. At the eastern extremity a wall connected the eastern division walls of the two main field systems. At both the northern side of the northern field system as on the southern side of the southern field system walls were retrieved that continued for at least an extra 900 metres for the northern system. We followed and measured the southern wall for approx. 400 m, but it could be seen to continue for several hundred metres.

Qanat systems are difficult to date, but it seems that they were in use from at least the Late Roman period in the Levant region (Kamash 2010, 34-37). In appearance and construction of the *qanat* channels around Udhruh it is clear that these were made by highly qualified water engineers (fig. 6). Kamesh suggests that the Roman army played an important role in the construction of the *qanats* and irrigation works in the Roman Near East (Kamesh 2012, 70-72). The Petra Papyrus 25 mentions a well-irrigated, cultivable plot of land around Udhruh – described as *patrimonium* – which was sold under control of

¹⁵ We hope the optically stimulated luminescence dating will work out as this technique has proven to be effective for the area (see Beckers et al. 2013).



Fig. 6. Built up channels in recent erosion gully in Wadi el-Fiqay, 5 km southeast of Udhruh (picture by S. Al Karaimeh)

Ancient Water Management and Irrigated Field System near Udhruh, Jordan

Version: 1.1

Udhruh Archaeological Project

Cartography by R. Emaus

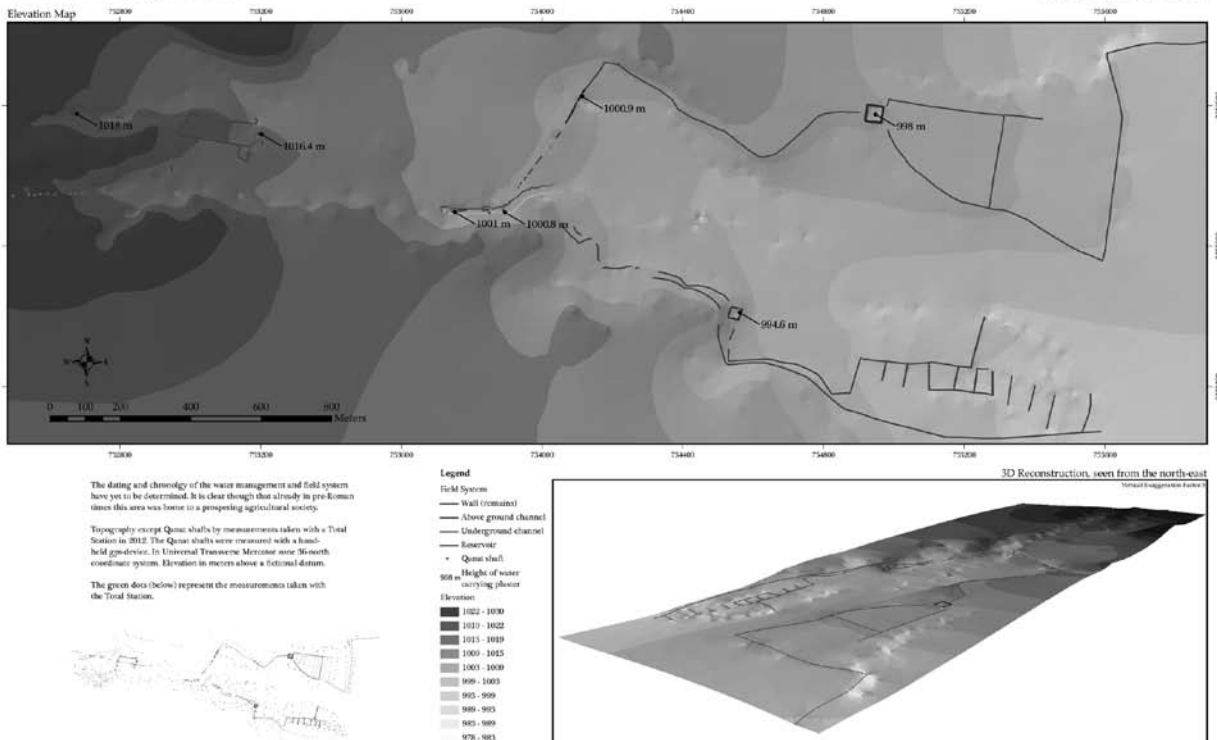


Fig. 7. Map of the ancient built up channels, aqueducts and irrigated fields in Wadi el-Fiqay, southeast of Udhruh (illustration by R. Emaus)

the imperial treasury in 559 CE (Arjava et al. 2007, 79-83). This description makes clear that the irrigation system around Udhruh was (still) in use in the Byzantine period. Mortar samples were taken of foundations, side walls, bottom and wall linings of the exposed channels, aqueducts and reser-

voirs. These will be used for OSL-dating and XRS-analysis¹⁵. The two fields of the northern field system were intensively surveyed to collect all possible diagnostic cultural finds. With the kind permission of the DOA all the diagnostic pottery sherds from this intensive field survey are taken to the Faculty

of Archaeology of Leiden University to be analysed the coming year. Diagnostic artefacts such as fragments of Mamluk and Ottoman glass bracelets were left at the Al Hussein Bin Talal University.

One of the *qanat* shafts was partially excavated: at a depth of 3 metres the original shaft was located, cutting right straight down through the bedrock. The rectangular shaft – which could be excavated for a further 3 metres – is 0.9 by 0.6 metres. On the short sides, round 10 cm holes were drilled at regular distances possibly to hold wooden pegs for some kind of ladder. For the 2013–2014 seasons it is planned to excavate several of these vertical shafts to reach the horizontal *qanat* shafts and the original aquifers. This might shed light upon the way the *qanat* was constructed and maintained, while the OSL-datings of the deepest sediments will hopefully clarify the point of abandonment.

COMMUNITY BASED AND INTERDISCIPLINARY APPROACH

The Udhruh Archaeological Project was not only initiated to satisfy the professional and scientific wishes of the archaeologists involved. We also hope to meet the interests and needs of other stakeholders, as for instance the local community. During a meeting with the local authorities and the people of Udhruh several wishes and ideas came to light. First of all it became clear that the local community showed great interest in the archaeological heritage they live among. So we decided to start with an oral history project for the coming season. Local perceptions, ideas and oral traditions about the archaeology of the region are being collected to create a multi-vocal perspective on the site, to learn what value is ascribed to the place, and to promote awareness of the archaeological heritage among the local community. This information is gathered through semi-structured interviews and conversations with the local population. The plan is that the collected narratives will be published by a local printing company in both Arabic and in English. This booklet will first of all be distributed among the people with a connection to the heritage site: inhabitants as well as professionals and visitors. This will give the local community a voice in the archaeological project and it will give the professionals the opportunity to take the local views into account by the interpretation and management of the remains. Secondly, the booklet will be distributed among a wider public,

through touristic places in the country (e.g., Wadi Musa, Jerash, Wadi Rum), to inform potential visitors and to attract them to the site. Although the Udhruh-region has great archaeological potential and is situated close to the touristic town of Petra, its inhabitants do not benefit from the nearby tourist industry. Collecting, publishing and distributing local stories can help to acquire more publicity for this archaeological site. This might be a start for the development of local community based tourism which will be of long-term economic value for the local population. To this end, contacts with the Cultural Geography Group of Wageningen University (The Netherlands) are being developed. With this we come to the second wish of the local community, that of economic development. There is a high level of unemployment in the region and the level of agriculture is mostly very basic. A quick scan showed that fertile and cultivable soils are still available. For proper analyses of the soil and sediments in the region a joint venture with the Institute of Geography of the Friedrich-Alexander-University Erlangen-Nürnberg (Germany) is being set up. There seems to be good agricultural potential here, as in the region several farms using efficient water application are already very profitable cash crop producers. A sustainable and very efficient method of irrigation seems to be the key to long term success in this. An annual precipitation of 100 mm does of course not allow large valley-based agricultural schemes, but history and archaeology show that the region used to be agriculturally rich in the past¹⁶. Antique sources point out that Udhruh was one of the richest towns in the province *Palaestina Tertia* in the Byzantine period¹⁷. Profitable agriculture was possible because of the antique *qanat* and field systems. Preliminary research of these systems point to a long period of use, which can be supported by the still ongoing use of these systems in other parts of the Middle East. These seem to be sustainable water supplying systems, provided that they are well maintained and that limited amounts of water are drained from the aquifers, in order to prevent them from drying up and also to avoid the salinization of the soils. In the future – in cooperation with local/regional communities and irrigation and dry-agricultural experts of Wageningen University – the ancient know-how and perhaps even (some of) the surviving antique system can be used to promote small scale, sustainable community based agricultural schemes. In try-

¹⁶ There is some evidence that the region seem to have been dry but a bit wetter in the Roman and Byzantine period than today (see e.g., Bar-Matthews et al. 1998; Bruins 2006, 32; Gilbertson et al. 2007, 417–418).

¹⁷ See for instance Beersheba edict; Stephanus of Byzantium 18,18.

ing to accomplish this many years of research will have to be carried out by a wide range of experts, but these somewhat weighty ambitions are a great goal to aim at.

The 2011-2012 field surveys have produced some interesting results. Hopefully these surveys will be continued in the coming seasons to get a more complete and diachronic view of the human activities in and around antique Udhruh. The joint venture between the two international institutes has proved to be full of success and synergy. We are confident that this international cooperation can

benefit us all – the people of Udhruh as well as the archaeological partners.

ACKNOWLEDGEMENTS

The results of the Udhruh archaeological project and this paper were not possible without the work and assistance of our team. The Udhruh archaeological project core team consists of Roeland Emaus, Guus Gazenbeek, Sufyan al Karaimah, Maarten Sepers, Frans Theuws, Sarah Wenner, Fawzi Abudanah and Mark Driessen.

BIBLIOGRAPHY

- Abudanh, F. / Twaissi, S.* 2010. Innovation or Technology Immigration? The Qanat Systems in the Regions of Udhruh and Ma'an in Southern Jordan. – *Bulletin of the American Schools of Oriental Research* 360, 67-87.
- Arjava, A. / Buchholz, M. / Gagos, T.* (eds.) 2007. *The Petra Papyri III*. Amman.
- Bar-Matthews, M. / Ayalon, A. / Kaufman, A.* 1998. Middle to Late Holocene Paleoclimate in the Eastern Mediterranean Region from Stable Isotopic Composition of Speleothems from Soreq Cave, Israel. In: Issar, A.S. / Brown, N. (eds.). *Water, Environment and Society in Times of Climatic Change*, Amsterdam. 203-214.
- Beckers, B. / Schütt, B. / Tsukamoto, S. / Frechen, M.* 2013. Age determination of Petra's engineered landscape – optically stimulated luminescence (OSL) and radiocarbon ages of runoff terrace systems in the Eastern Highlands of Jordan. – *Journal of Archaeological Science* 40, 333-348.
- Bruins, H. J.* 2006. Desert environment and geoarchaeology of the Wadi Arabah. In: Bienkowski, P. / Galor, K. (eds.). *Crossing the Rift: Resources, routes, settlement patterns and interaction in the Wadi Arabah*, Oxford (Levant Supplementary Series 3). 29-43.
- Clark, V. A.* 2006. The Vicus Temple (Area Q). In: Parker, S.T. (ed.). *The Roman Frontier in Central Jordan: Final Report on the Limes Arabicus Project, 1980-1989*. Washington (Dumbarton Oaks Studies 40). 259-270.
- Crawford, P. / Parker, T.S.* 2006. The East Vicus Building (Area P). In: Parker, S.T. (ed.). *The Roman Frontier in Central Jordan: Final Report on the Limes Arabicus Project, 1980-1989*. Washington (Dumbarton Oaks Studies 40). 247-258.
- Creighton, O. / Barker, G. / Mattingly, D.* 2007. Recording and classifying the archaeological record. In: Barker, G. / Gilbertson, D. / Mattingly, D. (eds.). *Archaeology and Desertification. The Wadi Faynan Landscape Survey, Southern Jordan*. Oxford (Wadi Faynan Series 2 – Levant Supplementary Series 6). 97-140.
- De Vries, B.* 2006. The Water-mills in Wādi Lejjūn. In: Parker, S.T. (ed.). *The Roman Frontier in Central Jordan: Final Report on the Limes Arabicus Project, 1980-1989*. Washington (Dumbarton Oaks Studies 40). 271-280.
- Driessen, M. J.* 2007. Bouwen om te blijven: de topografie, bewoningscontinuïteit en monumentaliteit van Romeins Nijmegen. Amersfoort (PhD thesis: The Topography, Settlement Continuity and Monumentality of Roman Nijmegen: University of Amsterdam – Rapportage Archaeologische Monumentenzorg 151, with summaries and conclusions in English and German).
- Gilbertson, D. / Barker, G. / Mattingly, D. / Palmer, C. / Grattan, J. / Pyatt, B.* 2007. Archaeology and desertification: the landscapes of Wadi Faynan. In: Barker, G. / Gilbertson, D. / Mattingly, D. (eds.). *Archaeology and Desertification. The Wadi Faynan Landscape Survey, Southern Jordan*. Oxford (Wadi Faynan Series 2 – Levant Supplementary Series 6). 397-421.
- Glueck, N.* 1935. *Explorations in Eastern Palestine II*. New Haven (The Annual of the American Schools of Oriental Research 15).
- Kamash, Z.* 2010. *Archaeologies of Water in the Roman Near East*. New York (Gorgias Near Eastern Studies 54).
- Kamash, Z.* 2012. Irrigation technology, society and environment in the Roman Near East. – *Journal of Arid Environments* 86, 65-74.
- Kennedy, D. L.* 2004. *The Roman army in Jordan*. London.
- Killick, A. C.* 1983. Udruh. The frontier of an empire: 1980 and 1981 seasons, a preliminary report. – *Levant* 15, 110-131.
- Killick, A. C.* 1986. Udruh and the southern frontier. In: Freeman, P.W.M. / Kennedy, D.L. (eds.). *The Defence of the Roman and the Byzantine East*. Oxford (BAR Int. Series 297). 431-446.
- Mason, D. J. P.* 1988. *The Roman Site at Heronbridge, near Chester, Cheshire: Aspects of Civilian Settlement in the Vicinity of Legionary Fortresses in Britain and Beyond*. – *Archaeological Journal* 145, 123-157.
- Piso, I.* 1991. Die Inschriften vom Pfaffenberg und der Bereich der *Canabae legionis*. – *Tyche* 6, 131-177.
- Spain, R. J. / Sparey-Green, C. / Wilson, A.I.* 2010. The Roman watermills. In: Bennett, P. / Riddler, I. / Sparey-Green, C. (eds.) *The Roman Watermills and Settlement at Ickham, Kent*. Canterbury (The Archaeology of Canterbury New Series 5). 42-67.
- Van Leusen, M.* 2002. Pattern to Process, methodological investigations into the formation and interpretation of large-scale patterns in archaeological landscapes. Groningen (PhD thesis, University of Groningen).
- Wikander, Ö.* 2000. The Water-Mill. In: Wikander, Ö. (ed.).

Handbook of Ancient Water Technology. Leiden (Technology and Change in History 2). 371-400.

Wilson, A. I. 2008. Hydraulic Engineering. In: Oleson, J.

P. (ed.). Handbook of Engineering and Technology in the Classical World. Oxford. 285-318.

Wooliscroft, D. J. 2001. Roman Military Signalling. London.

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