



HAL
open science

Al-Madam and the Archaeology of the Falaj in South East Arabia

Anne Benoist, Michele Degli Esposti, Julien Charbonnier, Timothy J. Power

► **To cite this version:**

Anne Benoist, Michele Degli Esposti, Julien Charbonnier, Timothy J. Power. Al-Madam and the Archaeology of the Falaj in South East Arabia. Adolfo Sominguez Monedero, Carmen del Cerro Linares, F. Javier Villaba Ruiz de Toledo, Francisco L. Borrege Gallardo. Nomina Aqua Scripta. Homenaje a Joaquin Maria Cordiba Zoilo., Universidad Autonoma de Madrid Ediciones, pp.165-182, 2021, 978-84-8344-762-8. hal-03339631

HAL Id: hal-03339631

<https://hal.science/hal-03339631>

Submitted on 24 Oct 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

al-Madam and the Archaeology of the *Falaj* in South East Arabia

Anne Benoist

(UMR 5133 ARCHÉORIENT – Environnements et sociétés de l'Orient ancien - Université de Lyon 2; anne.benoist@mom.fr)

Michele Degli Esposti

(UMR 6566 CReAAH “Centre de Recherche en Archéologie, Archéosciences, Histoire” - University of Rennes; michele.degliesposti@gmail.com)

Julien Charbonnier

(UMR 7264 CEPAM “Cultures et Environnements : Préhistoire, Antiquité, Moyen-Âge” - Université Côte d’Azur, Nice ; julcharbonnier@gmail.com)

Timothy Power

(Archaeological consultant to the Historic Environment Department, Abu Dhabi Department of Culture and Tourism (DCT Abu Dhabi); timcpower@gmail.com)

Summary

J. Cordoba is famous in the U.A.E. for his investigations in the oasis of al Madam (Emirate of Sharjah) where he could demonstrate the use of a *falaj* (pl. *aflaj*) during the Iron Age period and associate it to a cultivation area and to a settlement. This settlement could be dated between the 8th and the 4th century BCE, that is, between the local Iron Age II and Iron Age III periods. The *falaj* system has been interpreted in the late 90^{ies} as a technical innovation at the origin of a redevelopment and extension of the oases in SE Arabia during the Iron Age, itself favouring a demographic and economic growth during that period. Investigations carried out on the *falaj* AM-2 at al-Madam by J. Cordoba and his team brilliantly illustrated its characteristics and components as well as its progressive drying up at the beginning of Iron Age III, with a deepening of the *falaj*'s floor followed by a final abandonment of the system – an of the nearby settlement and cultivation.

Recent investigations carried out at Masafi (J. Charbonnier, A. Benoist), at Bin Ati (T. Power, P. Sheehan), and at Salut (M. Degli Esposti) have brought to light new data on the archaeology of the *aflaj*, which suggest a more nuanced picture of the irrigation techniques used in Iron Age oases in SE Arabia. The robust dataset built at al-Maam can thus be compared and contrasted with these new data an with the documentation from other SE Arabian sites, in orer to show that nothing as an archetypal *falaj* probably existed.

Keywords: falaj, South East Arabia, Iron Age, irrigation technology, aridity.

1. Introduction

The word *falaj* (pl. *aflaj*) is used in South East Arabia for designating several kinds of water tapping and water transportation systems between an underground source and a place where this water is used (settlement or cultivation area) using subterranean or at least covered galleries. One of the most important *aflaj* was discovered by Prof. Joachim Córdoba in the oasis of al-Madam in the Emirate of Sharjah (UAE). An Iron Age settlement site was unearthed at al-Madam 1 Thuqaibah supported by an associated *falaj* dubbed al-Madam 2 (AM-2). The excavated extent of the *falaj* included a subterranean gallery feeding an area of irrigated land characterised by agricultural plots and irrigation channels (Córdoba, 2016: 135-137). Falaj AM-2 is important because it is one of the most extensively excavated, best documented and closely dated *aflaj* in South East Arabia. The work of J. Córdoba and his team has therefore stimulated the construction of general theories. The present paper will attempt a critical evaluation of the archaeological evidence for the *falaj* in South East Arabia and consider the extent to which Falaj AM-2 supports general theories of the archetypal underground *falaj* often encountered in the textbooks (e.g. Cleuziou & Tosi, 2007: p. 152, Fig. 162; Magee, 2014: p. 216, Fig. 8.2).

2. The Archaeological Record

The discussion will focus on four *aflaj* for which an Iron Age II (meaning here the more conventional time span 1100-600 B.C.) dating is demonstrated or at least convincing and for which we have precise data regarding their organisation and building techniques. These include in addition to al-Madam two in al-Ain and one in Masafi, the first three located to the west of the open outwash plains of the Hajar Mountains, the last located at the confluence of steep-sided mountain *wadis* (fig. 1). Clearly these *aflaj* cannot be considered representative of the entirety of South East Arabia with its many ecological zones and local traditions.

Perhaps the most important of these is Falaj AM-2. A portion of the subterranean gallery including five access shafts has been excavated by J. Córdoba and his team in the al-Madam area, over a length of 120 m (Córdoba & Del Cerro Linares, 2005). Excavations were later extended to the downstream part of the irrigation system and to the gardens, a part of which has been brought to light, including a primary channel alimenting around twenty parallel secondary channels irrigating tree plantation pits (Córdoba, 2016: 135-137).

Two *aflaj* were discovered and partly excavated by W. Yasin al-Tikriti in the area of al-Ain. The first one is Hili-15, located to the south-west of a large settlement area including a collective fortified building (Hili-14) and a pottery workshop (Hili-17). The second one is the *falaj* discovered and partly excavated at Bida Bint Sa‘ud (hereafter, BBS), close to a collective building including a columned hall (Bint Sa‘ud House). Excavations allowed the unearthing of a cut-and-cover channel (see below) splitting into three channels after its outflow at Hili-15. This channel was followed over a total distance of 450 m with the excavation of several trenches named Hili-15 A to H. In Area H, located upstream, what appears to be the beginning of a subterranean gallery with a access shaft has also been partly explored. At BBS, a 100 m long portion of the *falaj* was explored digging two large and ten smaller trial trenches. It comprises a Y-shaped subterranean gallery with the two branches coming from the upstream part and joining each other in the vicinity of what appears to be a large subterranean cistern accessible by a staircase (al-Tikriti, 2002a; 2010; 2011).

The outflow of a *falaj* was recently excavated by the French Archaeological mission at Masafi-1. The related channel was unearthed over a distance of roughly 15 m to the north of a collective building which included a columned hall. The upstream part of the *falaj* could not be physically explored, but the geo-archaeological study of the sediment found in the channel provided data regarding the most probable place of water catchment of this irrigation system, which has been interpreted as runoff harvesting system tapping water from a valley located to the east of the settlement area (Charbonnier et al., 2017: 25).

Other *aflaj* have been dated to the Iron Age with varying degrees of reliability, but the available data do not allow a precise reconstruction of their shape and building techniques. This means that they cannot be directly compared and contrasted with Falaj AM-2 as documented by Córdoba. However, they are presented here to give an indication of the archaeological record and opportunities for further research.

This is the case for example of one of the *aflaj* recorded around Salut in Oman. In the area of this ancient oasis, the remains of an *aflaj* system extending along the beds of the Wadis Sayfam and Bahla, over no less than 49 km in total, were surveyed and studied, showing the substantial complexity of the history of irrigation in this region. These ancient *aflaj* were in fact re-cut, deepened, re-used several times, which has partly or totally transformed their shape. During the latest surveys in 2016, for example, the access shafts pointing a long stretch of Falaj Salut were being recut with the use of a bulldozer and lined with cement. Given this situation, and the impossibility to access the shafts and tunnels (now more than 20 m deep), a detailed reconstruction of the Iron Age water supply system feeding the oasis is not possible. In particular, there are no grounds to establish the contemporaneity of all or part of the *aflaj* network of Salut. Nevertheless, geoarchaeological study has provided a much-needed radiometric date for Falaj Shaww, which was in all likelihood serving the prominent Iron Age site which overlooks the ancient oasis (Cremaschi *et al.* 2018: p. 136 & Table 1). The *falaj* tunnel had a squared section, definitely inconsistent with a natural cavity, and was surely active during the fifth-century BC, which corresponds to the Iron Age III period, i.e. the moment where evidence for *aflaj* abandonment are reported from the region of al-Madam.

Absolute dates are further available for a *falaj* near Nizwa, not far from Salut, at the outlet of which calcareous deposits were sampled and, among others, two dates at 2610 ± 130 and 2730 ± 140 were obtained (Clark & Fontes, 1990: Table 1), thus fitting into the Iron Age II period but potentially also extending into the Iron Age III (600-300 B.C.). These dates, however, can only be associated to the well-known fact that the area was certainly densely occupied during the first millennium BC, as evidenced by abundant survey data (e.g. Schreiber, 2007b), but no direct connection with an Iron Age settlement or field system is reported, nor details on the channel structure, apart from the fact that it would tap water from the *wadi* gravels (Boucharlat, 2003: 168).

Falaj Maysar-46 in the area of al-Moyassar – the earlier toponym was recently replaced with al-Moyassar by Sultan's decree – was published by the German team (Weisgerber, 1981; Yule, 1999). In 1981, this *falaj* was still visible on the surface over a distance of 3.5 km, its trajectory being marked by alignments of shafts coming from the north and the north-east of the area of Maysar. It runs near the Iron Age settlement of Maysar-42, dated to the first half of the first millennium BC (i.e. the Iron Age II period), but also next to the later settlement of Maysar-43,

located 1 km downstream and dated to the Samad period (after the third century BC). Moreover, it still supplied the nearby village of Maysar in the 1970s. The schematic section of a collapsed portion of the *falaj* shows a high gallery, which although represented as only accessible down to a depth of around 1.5 m in the drawing of Yule (1999: p. 101, Fig. 3), was shown by Weisgerber (1981: 246) to reach a height of 8 m. The German team supposed the gallery to have been deepened several times over a long period of use – or in occasion of several moments of re-use – extending from the Iron Age up to the Late Islamic period (see also Yule 2017: fig. 10). This suggests a possible first construction during the Iron Age II.

Also excluded from our description of Iron Age *falaj* morphology and techniques should be the *aflaj* of al-Ayaay, Dhahret al-Hasa and al-Jabeeb, only surveyed and mentioned by al-Tikriti (2010) in Abu Dhabi Emirate; the *falaj* at Muweilah in the Sharjah Emirate published by M. Mouton (2001); Falaj D at Sohar on the Batina Coast of Oman which is supposed to be of Partho-Sasanian date (Costa & Wilkinson, 1987: 54); and Falaj Izki IZ0747 surveyed by J. Schreiber in Central Oman (2007a: 134-135). For these, in fact, an Iron Age dating is supposed only because of their proximity to Iron Age sites. In the case of Muweilah the similarities between some of its features (the location of the mother well near a depression; the reduced distance between the access shafts along the tunnel; the splitting into two gallery in its downstream section) and those of other *aflaj* better dated to the Iron Age are also mentioned as possible chronological indicators (Mouton, 2001: 230), although other authors consider them to be not distinctive (Boucharlat 2003: 165).

3. The Morphology of the Archetypal *Falaj*

It is widely believed that the archetypal *falaj* is comprised of several parts. Upstream, a well is dug to reach the source of water tapped by the *falaj* (fig. 2). This is the so-called mother well (*umm al-falaj* or *umm ma'*). The shape of the well itself seems to have no importance in terms of typology. There can be one or several mother wells feeding a single *falaj*, the higher number of the mother wells insuring a more reliable tapping of the water. When several mother wells are excavated, they can show a fan-like disposition, each well being linked to the main gallery. Three types of *aflaj* are distinguished depending on the source they tap (e.g. al Ghafri 2004: 17-20; al-Sulaimani *et al.* 2007; Charbonnier 2017: 55), namely the *dawudi falaj*, tapping water from deep underground aquifers usually located in piedmont areas; the *ghayl falaj*, diverting

wadi base flows or exploiting shallow water tables from alluvial fans; and the *'ayni falaj*, directly deriving waters from springs.

The mother well feeds a subterranean gallery conveying the tapped water from its source to the irrigated area simply by gravity. The length and shape of the gallery vary from a place to the other and also changed over time (al-Tikriti, 2011; Boucharlat, 2003; 2015). Several types of galleries can be distinguished, being sometimes associated together in a single *falaj*. The gallery can be a tunnel dug in the ground without any masonry reinforcing it, when the natural ground is sufficiently strong or hard for no masonry to be necessary. It can also be partly built in stones or, in the early Islamic period at least, baked bricks (al-Tikriti, 2011: 118-130). The gallery can also take the shape of a channel or a trench dug in the floor, covered with some stone slabs (the so-called “cut-and-cover” technique). Between these types, there can be several variants, depending on the nature and the strength of the substratum in which the gallery is dug. A gallery can comprise a tunnelled part upstream and change into a cut-and-cover channel downstream, where it approaches the surface. The gallery is punctuated by shafts (*thuqba*, pl. *thuqab*) that are primarily used by the constructors to dig the tunnel and later serve as accesses to the *falaj* for its maintenance and cleaning. These access shafts usually form long, characteristic alignments in the landscape and are the best indicators of the presence of the underground tunnel.

Downstream, the outflow of the *falaj* can also have several shapes. The point where the water reaches the surface is locally called *shari'a*. It represents the first point where water can be directly drawn by inhabitants for domestic purpose or for specific collective uses. The *shari'a* can comprise a simple open air channel or it can be marked by a built feature including a cistern or a basin. When reaching the surface, the gallery of a *falaj* can also be split into several branches bringing water to different places (garden lots but also dwellings or handcraft areas). The *shari'a* can also be associated to some kind of device (e.g. sluice gates) used for regulating water sharing between the people benefitting from the *falaj*, the latter representing all or part of the population of a village.

3.1 The underground gallery: water capture

Several catchment galleries seem to have converged to form the *aflaj* of Hili-15 (fig. 3) and BBS (fig. 4). Such a configuration, which increases the length of the tunnel directly in contact

with the water table and thus increases the flow rate, also characterizes many still-functioning *aflaj* presumably dug in the Late Islamic period (Charbonnier, 2013: Figure 2; Wolski, 1965: 190). These *aflaj* do not appear to have had a single mother well nor did they tap into a deep aquifer, but were instead *ghayl falaj*, exploiting shallow water tables. This is quite a different system to the schematic diagrams that appear in textbooks (see however the scheme reported by Boucharlat [2003: fig. 2] which illustrates the case of a shallow water table).

So far, only two underground galleries have been excavated, AM-2 and BBS, and even these only partially. Our knowledge on the Iron Age digging techniques is therefore limited. Excavated to a distance of 35 m, the AM-2 underground tunnel is the only one to have been cleared over a substantial length. Nevertheless, it is possible to make a number of observations. These well-documented Iron Age underground galleries were merely dug in the ground, without any masonry reinforcements. In al-Madam, traces observed on the side of the gallery suggest the use of a “very thin sharp pickaxe” to dig the bedrock (Del Cerro & Córdoba, 2018: 91). Iron Age underground galleries can be quite narrow as suggested by AM-2, which does not exceed 50 cm in width (Córdoba & Del Cerro 2005: 522-523), whilst the gallery of BBS is a little wider and is about 70-80 cm. Both AM-2 and BBS have more or less vertical walls and flat bottoms. The ceiling of the gallery of AM-2 is corbelled and widens slightly in the upper part. The latter is also very deep, 4.80 m at the excavated section. This seems to suggest that the structure has been deepened in order to address the lowering of the water table (see below).

While the access shafts of AM-2 are roughly aligned, its underground gallery does not follow a straight course, but instead meanders between the access shafts. The underground gallery of *falaj* Hili-15 is not preserved, yet it must be noted that the open-air, primary channel into which it conveyed water downstream is also meandering. This phenomenon, which allegedly distinguished ancient (Iron Age) *aflaj* from later, straight tunnelled ones (Mouton, Benoist, and Córdoba, 2011: 17), is not properly explained. Al-Tikriti puts forward an interesting hypothesis: to dig the underground gallery, two groups of diggers started from two neighbouring shafts and converged toward each other. As it was undoubtedly difficult to estimate the direction underground, the groups voluntarily deviated their trajectory in the same direction so as to be sure to intersect each other (al-Tikriti 2010: 228). This, however, does not explain why the primary channel of Hili-15, which was open air, also meanders. On another hand, Del Cerro assumes that AM-2 was meandering in order to extend the length of the underground gallery and, therefore, the surface in contact with the water table, thus increasing the volume of water

drained by the *falaj*, as explained above (Del Cerro, 2015: 251). The possible echo of the well-documented Iron Age snake cult has also been mentioned as an additional reason for such a morphology (Mouton, Benoist, and Córdoba, 2011: 17).

Downstream, when a *falaj* underground gallery approaches the surface, it is customary to dig it as an open trench and then cover it with stone or cement slabs in order to limit evaporation (Charbonnier, 2016). Such a construction technique, which has been termed ‘cut-and-cover’ by al-Tikriti, is characteristic of Hili-15 (fig. 3). Uncut stone slabs cover its gallery for about 150 m. They rest on the masonry sidewalls of the structure which are made of flat stone slabs, cut from the local calcareous substratum. Unlike Hili-15, the gallery of AM-2 leads directly to an open air trench (Del Cerro, 2015: 251; see below). The downstream end of the BBS *falaj* was not identified.

3.2 Access shafts and sharia: cleaning and repairing

Access shafts were excavated along the underground galleries of AM-2 and BBS, whilst a shaft was also identified along the ‘cut-and-cover’ section of Hili-15 (fig. 3).

The distance between the shafts varies from one *falaj* to another and indeed within each *falaj*. For instance, it is c. 10 m downstream and c. 20 m upstream of AM-2. On the surface, AM-2 and Hili-15 shafts are circular or oval in plan while BBS shafts are oval-shaped on the outside and rectangular on the inside. Dimensions of the shafts also vary, they range between 0.4 and 0.5 m in diameter in BBS and AM-2 and are about 0.4 m wide and 0.7 m long in Hili-15. Both BBS and Hili-15 are characterized by masonry walls in the upper part. This is due to the fact they are dug in soft ground: the masonry prevents topsoil erosion and sand infiltration. The same applies to the channels and hydraulic structures located along these *afraj*. On the contrary, AM-2 was dug through the hard bedrock and compact sand and is thus devoid of masonry. A kind of mortar, obtained from the calcareous bedrock, was however used to strengthen the upper part of AM-2 shafts as they were dug through looser sand (Del Cerro, 2015: 251).

During the Iron Age, access to the underground galleries for cleaning and repair was granted by the presence of small steps dug into the shaft sidewalls, and leading to the bottom of the gallery. A large double-flight staircase was instead realised along BBS for the same purpose of reaching the bottom of the gallery, c. 4 m below the ground surface (al-Tikriti, 2002b: 124).

Just as today, this access could also have been used to draw water or do the washing. Immediately to the west of this staircase, a large 15 by 7 m open-air cistern might have been constructed in order to store *falaj* water when it could not be used, for example at night (al-Tikriti 2002b: 129).

3.3 Channels ('cut-and-cover'): carrying water above ground

Underground galleries lead to an open air primary channel, sometimes preceded by a 'cut-and-cover gallery' (see above), whose role is to carry water to the oasis. Secondary and tertiary channels branch off from the primary channel and deliver water to each plot. Network of channels have been partially excavated at Hili and al-Madam (fig. 5). The primary channel of AM-2 is simply dug into the compact calcareous substratum, while the one of Hili-15, dug in soft ground, was furnished with masonry sidewalls. The latter is preserved on c. 500 m and measures c. 0.5 m in width (al-Tikriti, 2002b: 78). From the outlet of the underground gallery to the first plot, the primary channel of AM-2 extends over 200 m. This structure is about 1 m wide and 0.5 m deep and has a roughly rectilinear layout (Córdoba, 2013: 148). Although at present the AM-2 irrigation system has not been completely unearthed, the primary channel appears to continue along the entire system and feed secondary channels that branch-off at right angles.

At the Bin Ati site in Qattara Oasis in al-Ain, a negative linear feature c. 25 m long was exposed in the Energy Centre (ENR) area of excavations (Power *et al.* 2019). It runs diagonally across the site and neither its source nor destination is clear. ENR {108} has a steep 'V'-shaped profile, c. 1.5 m deep with a maximum upper width of c. 80 cm and lower width of c. 10 cm. A crack tapering from c. 6 to 3 cm wide continues down to an uncertain depth, probably created by the water as it eroded away the soft natural conglomerate during its period of use. This feature may therefore be interpreted as the primary surface channel of a *falaj*. Its 'V'-shaped profile is however unparalleled and highlights the diversity of *falaj* morphology. This putative *falaj* cuts through the underlying phases of agricultural activity associated with a well feeding channels watering tree pits, constituting the latest agricultural feature in the stratigraphic sequence of the Iron Age II phases, which might further be interpreted as an intensification of agricultural practices from well to *falaj* irrigation.

The gardens fed by *falaj* Hili-15 are at least partly preserved but have not been fully investigated. Along the primary channel, a few secondary and tertiary earthen channels have been excavated, which branch off at right angles from each other. At Masafi-1 the remains of three successive irrigation systems could be partly explored to the north of the collective building on both sides of a stone-built fence wall that separated the settlement area, where the building was standing from a garden area located more to the north (fig. 6). The oldest system (System A in Level 4A) included a primary channel which took the shape of a small earthen-made channel 10 cm deep with a crescent-shaped profile, reinforced on the western side by a row of stones. The bottom of the channel, c. 7 cm in thickness, was made of compact fine silt, light-beige in colour with nodules of carbonates, small oxide, micro-charcoals and a few small gravels. Silty-clay sediments, orange in colour deposited at the bottom of the channel (Charbonnier et al., 2017: 17-18).

System A crossed the fence wall enclosing the garden area via a small opening that was later closed by a stone and fed a subsidiary channel. Built above the ground, this channel had a 'U'-shaped section and was delimited by earthen borders. The junction between the primary and the secondary channel was destroyed. The hypothesis of their connexion is based on the similarity of the deposits at the bottom of their filling. To the east the primary channel System A, a portion of a further channel coming from the east was partly excavated, which might have belonged to this first phase. This channel measured 15 to 23 cm in width and 5 cm in depth, with a 'U'-shaped profile. This structure was running in the direction of the primary channel, at a slightly higher altitude, but their respective fillings indicate that they were not connected.

A second irrigation system was later rebuilt in the same area (System B1 in Level 4B). It included a primary channel oriented SE-NW, which was bringing water from the NE. This new channel was 20-25 cm wide and 30 cm deep and was delimited by walls vertical or slightly inclined, made of stone blocks and pebbles of irregular size and shape arranged in irregular courses assembled without mortar. To the north, at its downstream end, the channel was running below the level of the ground. It was partly covered by 2 groups of 3 to 4 stone slabs around 50-70 x 20 cm to 40 x 20 cm, laid transversally across the channel. They were probably meant to protect the water from evaporation. An opening was separating the two groups of slabs, probably used to clean the channel (Charbonnier et al., 2017: 18).

The channel was distributing water into a earthen-made subsidiary channel, heading toward the east and located north of the fence wall, via a small ‘V’-shaped opening between two stones. Later (System B2 in Level 4B), this initial channel was replaced by three channels that were probably delivering water to different agricultural plots: two going to the east, a second one to the north-east, a third one to the west. All these channels were built of simple earth over the floor (Charbonnier et al., 2017: 18-19). A 14C dating was obtained from a charcoal sampled in a layer directly associated to the latest secondary channels. It yielded a dating of 2680±30BP (897-801 BC after calibration) thus showing that System B2 was in used in the middle of the Iron Age II (Charbonnier et al., 2017: 19).

A small basin or water tank dug into the ground was built at the corner of two subsidiary channels. It was only partly preserved as it has been damaged to the north by the digging of a modern channel. The basin is bordered by a low and slightly curved earthen levee. Initially, the basin may have been oval or circular in shape and c. 3 m in diameter. It is only preserved on a length of 1.7 m. A thin layer of clayey orange sediments, forming a sub-circular patch of c. 60 cm in diameter, was noticed at the bottom of the basin. It was most probably filled through a small opening on the western subsidiary channel. This basin could have surrounded a palm or a fruit tree but neither remains of roots nor any organic material were recovered during the excavation. Alternatively, the basin could have been used to store water or as a drinking place for animals.

3.4 Distributing water

We have evidence for sluices regulating and orienting the flow of water in both AM-2 and Hili-15 (al-Tikriti, 2002b: Figs. 31 & 32). Sluices gates were made of stone slabs or, in the case of AM-2, large potsherds. Two stone slabs, one still *in situ*, were found along AM-2 channels (Del Cerro, 2015: 251-252). One has to keep in mind that perishable material might have been used as well. In Hili, some of these sluices were implemented along a water distributor as indicated by vertical jambs located on each sides of its outlets. This structure is named *shari‘a* by al-Tikriti although it mainly distributed water into sub-channels. The distributor corresponds to a broader section of the main channel, reaching a width of c. 1 m and paved with large stone slabs, which feeds three secondary channels: one aligned with the main channel and two branching-off at right angles, toward the northwest and the southeast (al-Tikriti, 2002b: 120). Many Iron Age sherds were found inside this structure. Combined with the stone pavement,

this would suggest its use for domestic activities. The stone slabs could however also have been placed to prevent scouring when water was diverted to either channel.

3.5 Irrigated spaces

The excavation of AM-2 by the Spanish team led by J. Córdoba and M. Del Cerro has provided unprecedented and invaluable information regarding Iron Age field systems. Preserved under the sand dunes and entirely cut into the upper, and decayed, substratum, the irrigation system of AM-2 is estimated to extend over about 15 hectares (fig. 5) (Del Cerro & Córdoba, 2018: 85). Large elongated basins or small circular ones, cut into the substratum, are aligned along the secondary channels, and are interpreted as planting holes. These basins and the channels were infilled with sand and no trace of organic matter is reported. Only a few date stones were discovered (Del Cerro & Córdoba, 2018: 96), suggesting the cultivation of date palms in at least some of these basins. Other basins, perhaps the elongated ones, could also have been dedicated to annual crops such as wheat and barley. The absence of organic matter could be explained by its poor conservation in sandy soil.

The study of the channel systems provide indication on water distribution during the Iron Age. The presence of sluices, along channels and distributors, indicate that water flow was regulated and thus that plots were irrigated sequentially. Some sort of rotation must have been established. In the absence of any text, we do not know if water shares were owned by individuals, lineage groups or tribes. The absence of plot boundaries in al-Madam could argue for community-based land management. Be that as it may, the spatial setting of AM-2, a primary channel running along the entire oasis with secondary channels at right-angle, has no modern parallel. Contemporary water systems tend to adopt an arborescent spatial pattern: this reinforces the impression that one is dealing with a very old landscape. At Masafi-1 the distribution of the water inside the garden area (or at least the small excavated portion of it) also suggests the irrigation of several plots but does not seem to follow a mapping as regular as in al-Madam.

4. Conclusion

Falaj AM-2 constitutes one of the most important in South East Arabia largely owing to the careful documentation of J. Córdoba and his team. This allows us to compare and contrast Falaj AM-2 with the other reasonably well-documented *aflaj* discussed above. Two of these (Hili 15,

BBS) appear to be *ghayl aflaj* tapping shallow ground water; one was fed by runoffs (Masafi-1); the forth is the only one which might have tapped a deep aquifer, as it was cut through calcareous bedrock (AM-2). The schematic diagram of a *Dawudi falaj* tapping mountain aquifers that usually accompanies most books and articles dealing with Iron Age *aflaj* (e.g. Cleuziou & Tosi, 2007: p. 152, Fig. 162; Magee, 2014: p. 216, Fig. 8.2) is as such inappropriate and possibly anachronous. The known Iron Age II *aflaj* therefore appear to broadly correspond to the ‘water draining galleries’ previously discussed by Rémy Boucharlat (2003). Similarly, the ‘cut-and-cover’ section of the *falaj* is absent from AM-2 and all other well-documented Iron Age *aflaj* with the exception of Hili-15. The primary surface channels of AM-2, Masafi-1 and Bin Ati were all open. It thus seems that the ‘cut-and-cover’ section of the Hili-15 *falaj* cannot be considered archetypal. These disparities raise questions that still await an answer, regarding the geographical extension, the magnitude, the relation with technical aspects of *falaj* construction, the possible different cultural response to, and the ultimate geo-hydrological reasons for their development. Nevertheless, significant progresses have been made in the study of these phenomena, and a relevant part of these are owed to the great effort put by J. Cordoba and his team in the large-scale investigation of its development in the al-Madam plain.

Bibliography

Al-Ghafri, A. (2004), *Study on Water Distribution Management of Aflaj Irrigation Systems of Oman*. (Doctoral Thesis, Hokkaido University, Sapporo, Japan).

Al-Sulaimani, Z. bin K., Helmi, T. and Nash, H. (2007), *The Social Importance and Continuity of Falaj Use in Northern Oman, International History Seminar on Irrigation and Drainage, Tehran-Iran May 2-5, 2007*. The Iranian National Committee on Irrigation and Drainage (IRNCID). Available at: <https://ore.exeter.ac.uk/repository/handle/10036/15174> (Accessed: 16 October 2018).

Al-Tikriti, W. Y. (2002a), “The south-east Arabian origin of the falaj system”, *Proceedings of the Seminar for Arabian Studies*, 32, 117–138. ISSN: 0308-8421. Available at: <http://www.jstor.org/stable/41223728>.

Al-Tikriti, W.Y. (2002b), *al-aflâj fî daoûla al-emirât al-‘arabîa al-moutahîda. Dirâsa athâria fî anzîma al-raî al-qadîma*, Abu Dhabi: Department of Historic Environment/Abu Dhabi Authority for Culture and Heritage.

Al-Tikriti, W. Y. (2010), “Heading North: an ancient caravan route and the impact of the falaj system on the Iron Age culture”, in Avanzini A. (ed.), *Eastern Arabia in the first millennium BC. International Conference - Pisa, 1211 - 13th May 2008*, (227–247), Roma: l’«Erma» di Bretschneider.

Al-Tikriti, W. Y. (2011), *Archaeology of the Falaj: A Field Study of the Ancient Irrigation Systems of the United Arab Emirates*. Abu Dhabi: Department of Historic Environment/Abu Dhabi Authority for Culture and Heritage.

Boucharlat, R. (2003), “Iron Age water drainig galleries and the Iranian ‘Qanât’”, in Potts, D.T., Al-Naboodah, H. and Hellyer, P. (eds.), *Archaeology of the United Arab Emirates. Proceedings of the First International Conference on the Archaeology of the U.A.E.*, (162-172), London: Trident Press.

Boucharlat, R. (2015), “Le falaj ou qanât, une invention polycentrique et multipériode”, *ArchéOrient - Le Blog*, 25 septembre 2015, (on-line). Available at: <https://archeorient.hypotheses.org/4692>

Charbonnier, J. (2013), “La maîtrise du temps d’irrigation au sein des oasis alimentées par des aflâj. Étude de cas à Adam (Sultanat d’Oman)”, *Revue d’Ethnoécologie*, 4/2013. DOI : 10.4000/ethnoecologie.1471.

Charbonnier, J. (2015), « Groundwater management in Southeast Arabia from the Bronze Age to the Iron Age: a critical reassessment”, *Water History*, 7, 39-71. ISSN: 1877-7244. Available at: <https://doi.org/10.1007/s12685-014-0110-x>

Charbonnier, J. (2017), “The ethnoarchaeology of qanât systems: a comparative study of water-sharing practices in the old world”, *Water History*, 10, 53-71. ISSN: 1877-7244. Available at: <https://doi.org/10.1007/s12685-017-0196-z>

Charbonnier, J., Purdue, L., and Benoist, A. (2017), “Taming Surface Water in Pre-Islamic Southeast Arabia: Archaeological, Geoarchaeological, and Chronological Evidence of Runoff Water Channeling in Masāfī (UAE)”, *Journal of Field Archaeology*, 42(1), 13–28. <http://doi.org/10.1080/00934690.2016.1256172>

Clark, I. D. and Fontes, J.-C. (1990), “Paleoclimatic reconstruction in northern Oman based on carbonates from hyperalkaline groundwaters”, *Quaternary Research*, 33, 320–336. ISSN: 1096-0287. DOI: [https://doi.org/10.1016/0033-5894\(90\)90059-T](https://doi.org/10.1016/0033-5894(90)90059-T)

Córdoba, J. M. (2013), “New perspectives about Iron Age and the oasis culture in the Oman peninsula. Two conclusive seasons at al Madam (Sharjah, UAE)”, *Isimu*, 16, 139-152. ISSN: 2659-9090. Available at: <https://revistas.uam.es/isimu/article/view/3181/3376>

Córdoba, J. M. (2016), *En los confines de Oriente Próximo. El hallazgo moderno del país de Magán*, Madrid: UAM Ediciones.

Cordoba, J. and Del Cerro Linares, C. (2005), “Archéologie de l’eau dans al Madam (Sharjah, Emirats Arabes Unis). Puis aflaj et sécheresse pendant l’Age du Fer”, *Iranica Antiqua*, 40, 515-532. ISSN : 1783-1482. DOI: 10.2143/IA.40.0.583224

Costa, P. M. and Wilkinson, T. J. (1987), “Chapters 3. Traditional methods of water supply”, *Journal of Oman Studies*, 9, 35–42. ISSN: 0378-8180.

Crevaschi, M, Degli Esposti, M, Fleitmann, D and others (2018), “Late Holocene onset of intensive cultivation and introduction of the falaj irrigation system in the Salut oasis (Sultanate of Oman)”, *Quaternary Science Reviews*, 200, 123-140. ISSN: 0277-3791. Available at: <https://doi.org/10.1016/j.quascirev.2018.09.029>

Del Cerro, C. (2015), “Iron Age water supply systems regarding agriculture at al Madam, Sharjah (U.A.E.)”, in Affanni, G, Baccarini, C, Cordera, L. and others (eds), *Broadening Horizons 4*, (BAR International Series 2698), (249-255), Oxford: Archaeopress.

Del Cerro, C. and Córdoba, J. (2018), “Archaeology of a *falaj* in al Madam Plain (Sharjah, UAE); a study from the site”, *Water History*, 10, 85-98. ISSN: 1877-7244. DOI:

Mouton, M. (2001), “Des structures légères de l’Age du Fer et un falaj ancien à Muweilah”, in Mouton M. and al-Tikriti W.Y : (eds.), *The architectural remains of the Iron Age sites in the United Arab Emirates and Oman*, (Documents d’Archéologie de l’Arabie 2), Lyon : Maison de l’Orient Méditerranéen [CD-Rom].

Mouton, M., Benoist, A. and Cordoba, J. (2011), “The snake figuration in Iron Age society”, *Liwa*, 3, 3-25. ISSN: 1729-9039.

Power, T., Benoist A. and Sheehan, P. (2019), “An Iron Age Ceramic Sequence from the Bayt Bin Ati, al-Ain, UAE”, *Arabian Archaeology and Epigraphy*, 30, 75–102.

Schreiber, J. (2007a), “Transformation processes in oasis settlement in Oman 2005 archaeological survey at the oasis of Nizwā: a preliminary report”, *Proceedings of the Seminar for Arabian Studies*, 37, 264-275. ISSN: 0308-8421. Available at: <https://www.jstor.org/stable/41224071>

Schreiber, J. (2007b). *Transformationsprozesse in Oasensiedlungen Omans. Die vorislamische Zeit am Beispiel von Izki, Nizwa und dem Jebel Akhdar*. (Doctoral Thesis, LMU, München, Germany).

Weisgerber, G. (1981), “Mehr als Kupfer in Oman – Ergebnisse der Expedition 1981“, *Der Anschnitt*, 33, 174-263. ISSN 0003-5238.

Wolski, K. (1965), “Les kārēz. Installations d’irrigation de terrains semi-désertiques. Afghānistān-Baloutchistān”, *Folia Orientalia*, 6, 179-204. ISSN: 0015-5675.

Yule, P. A. (1999), “Valorising the Samad Late Iron Age”, *Arabian Archaeology and Epigraphy*, 27, 31–71. ISSN:1600-0471. Available at: <https://doi.org/10.1111/aae.12060>

Yule, P. A. (2017), “Al-Moyassar is the Gift of the Falaj”, in Al Tikriti, W. Y. and Yule, P. A. (eds.), *Water and life in Arabia. Abu Dhabi, 14th-16th December, 2014*, (87-102), Abu Dhabi: Abu Dhabi Tourism and Cultur Authority.

Figures

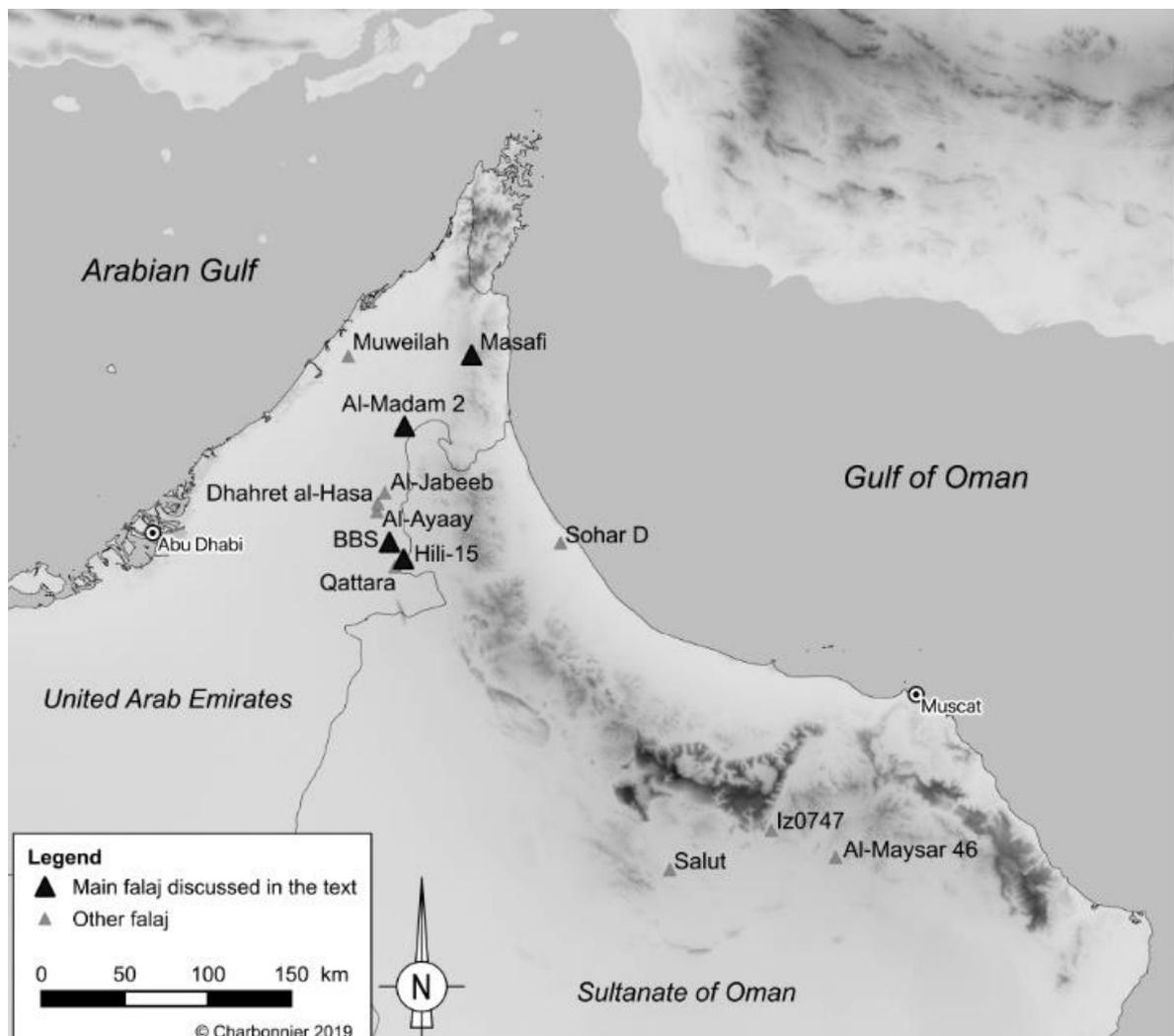


Figure 1. Map of Southeast Arabia indicating the location of *aflaj* discussed in the text (© J. Charbonnier).

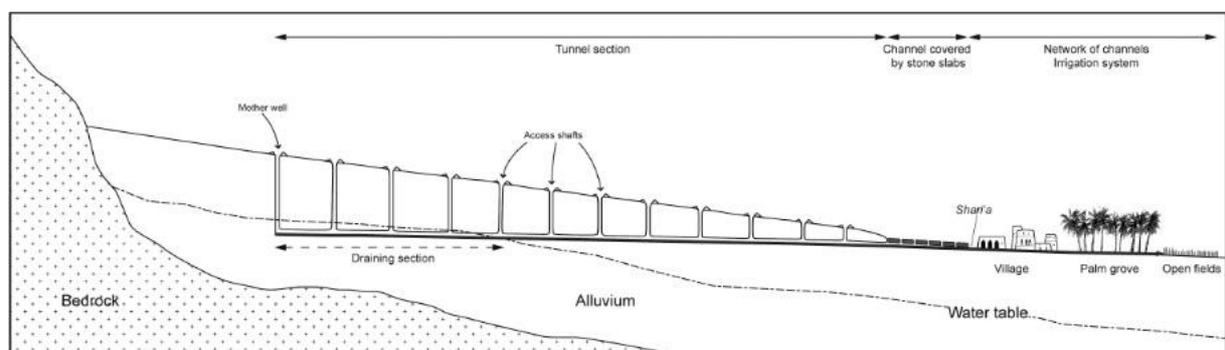


Figure 2. Archetypal section of a *falaj* (© J. Charbonnier).



Figure 3. Map of *falaj* Hili-15 and associated archaeological sites (© J. Charbonnier). Top left: photo of Area H (©T. Power)



Figure 4. Map of Bida Bint Sa'ud *aflaj* and associated archaeological site (© J. Charbonnier).

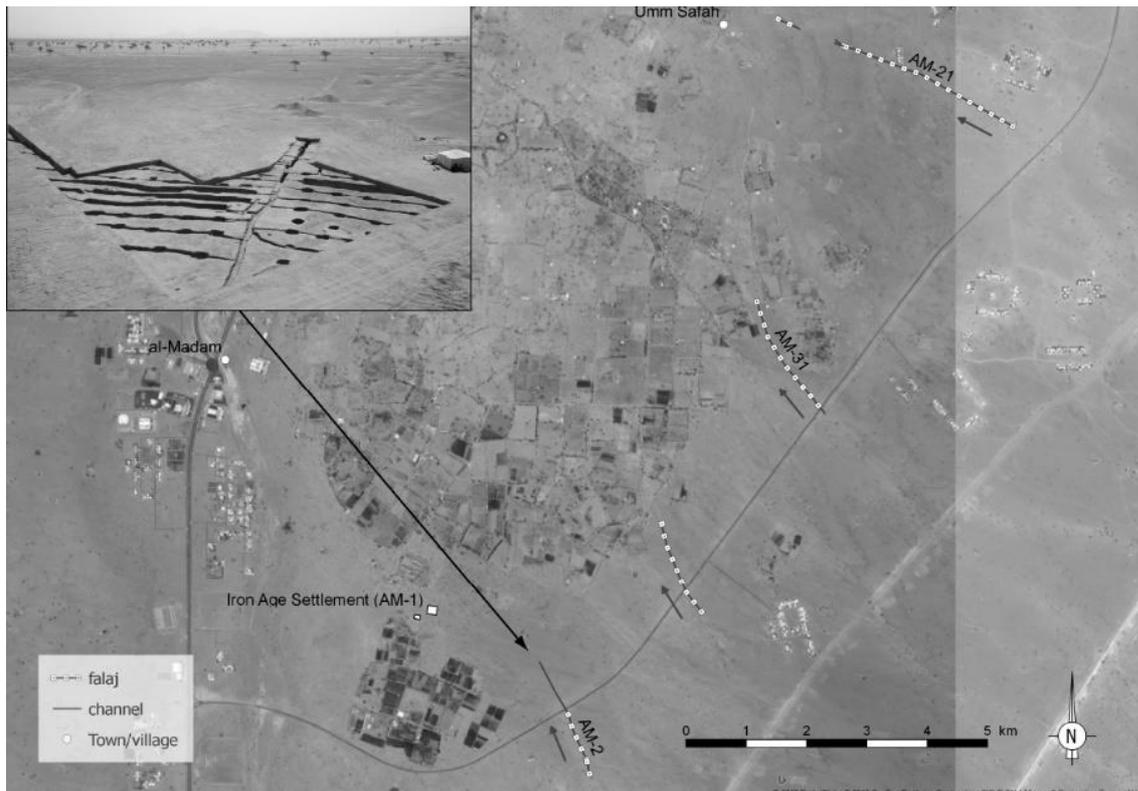


Figure 5. Map of Al-Madam *aflaj* associated archaeological site (© J. Charbonnier). Top left: aerial view of the irrigation area associated with *falaj* AM-2 (courtesy C. Del Cerro and J. Córdoba, © Spanish archaeological mission in the UAE).

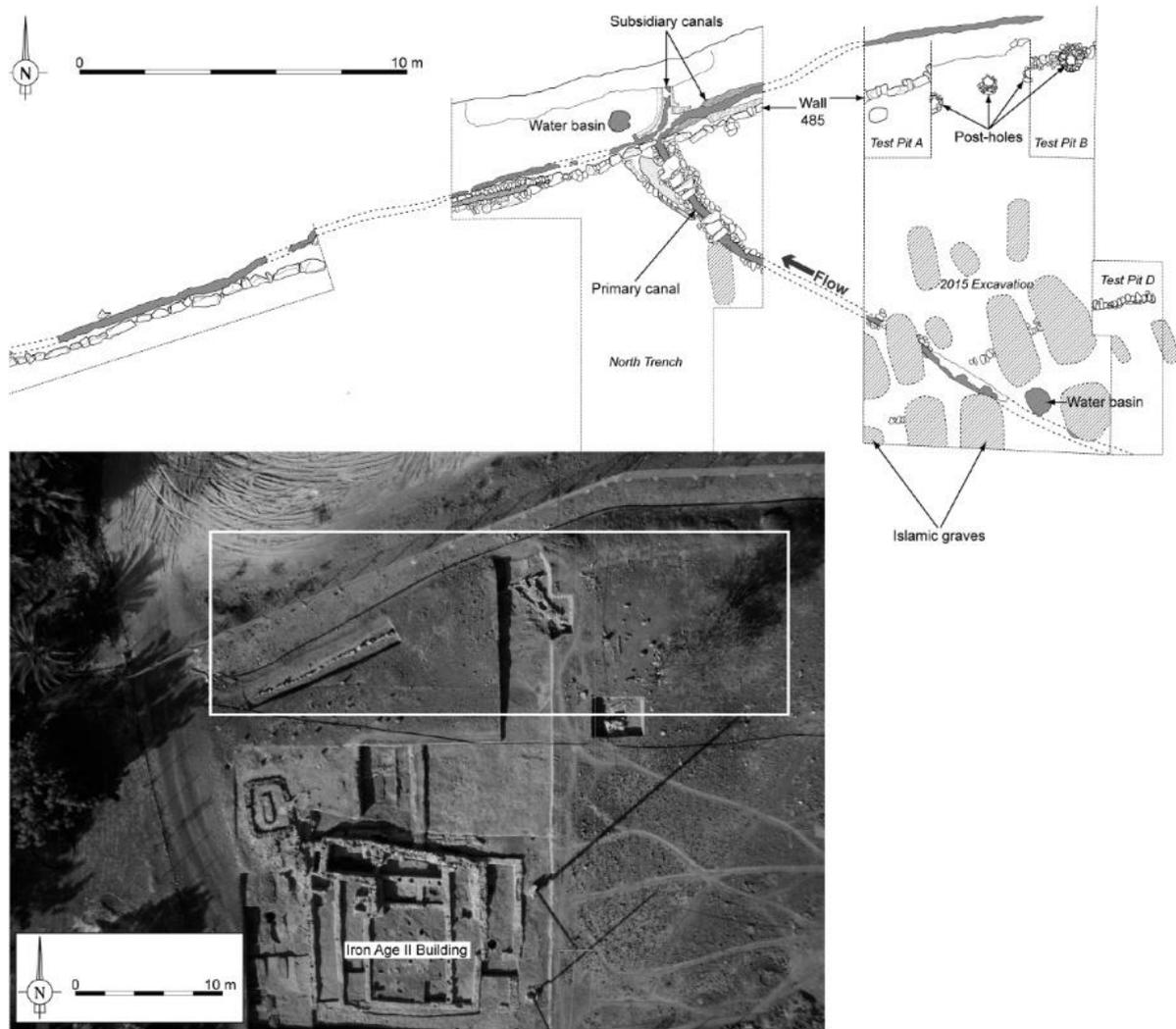


Figure 6. Map of Masafi-1 archaeological site (© J. Charbonnier, French archaeological mission in the UAE).