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Archaeology of a *falaj* in al Madam Plain (Sharjah, UAE); a study from the site

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Abstract Since the 1990s, several archaeological teams have been investigating the link between Iron Age settlements in the Oman Peninsula and *qanat* systems. It is assumed that the development of water-draining galleries, such as *qanat*, or *falaj* as they are called in Oman, allowed for the settlement of populations on the desert fringes and the growth of villages at this time. Fieldwork undertaken by a Spanish archaeological team working at al Madam has provided evidence for the existence of wells and water-draining galleries (*falaj*/*aflāj*) in contemporaneous use at the beginning of First Millennium BC. The excavation of an underground gallery, the course of which forms a zig-zag pattern, has revealed a system that would have permitted the collection of a significant amount of groundwater. This proves the existence in Antiquity of a large shallow water table in the area of al Madam. The water that was brought to the surface by this system was diverted into secondary channels, tree-pits, ponds and pools, corresponding to the ancient cultivated fields. This unprecedented network of irrigation channels was dug into the natural rock. The archaeological record of al Madam shows that this cultivated area was situated to the east of the village in the Iron Age, and included a palm grove of significant size (at least 15 ha).

Keywords Oman Peninsula · Iron Age · *falaj* · Irrigation Channel Network Area · Agriculture in Antiquity

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Following J. C. Wilkinson, *qanat*[1] technology involves the exploitation of groundwater by galleries that lead to the surface. The water is taken from the water table and, thanks to a gentle slope and the help of gravity, is carried to a corresponding settlement, which can be several kilometers away. Therefore, *qanat* technology does not depend on the rhythm of natural rainfalls. The flow of water is continuous in the underground galleries, although it can vary seasonally in some areas. The gradient of the galleries is generally between 1 and 3‰ (Boucharlat 2017a, p. 282) and their length can reach several kilometers, with access shafts regularly spaced along their course.

This hydraulic system is found in many places across the Near and Middle East, like Saudi Arabia,[2] Yemen,[3] Central Asia, and Iran, but also in Spain (in Madrid this system is called *viajes de agua*). One of the most famous examples from Madrid, located in the city center, was excavated several years ago. Visitors to, and residents of Madrid, can visit this *qanat*, dating to the 16th century AD, using the subway at Opera train station close to the Royal Palace. The Royal Village of Aranjuez, located only 50 km south of Madrid, also incorporated a net of *viajes de agua* that have been studied since 1775.[4] However, this paper focuses on the Oman Peninsula, where *qanats* are called *falaj* (pl. *aflāj*).

In the United Arab Emirates, there are about 30 known *aflāj*, some of them still in use, while in Oman more than 70% of the water consumed in the early eighties came from *aflāj*, and 55% of irrigated crops took water from this system. These data are not extraordinary if we consider that the government has cataloged 44.066 *aflāj* in Oman, 3.023 of which are still in use.[5]

In the Oman Peninsula, many *aflāj* are located in areas with a very high water table (like in the al Madam Plain which is situated in the interior of the Oman Peninsula and belongs in its totality to the emirate of Sharjah, UAE), or in regions with large concentrations of *wadiān* that allow water to seep into the ground (like the Batinah coast, Oman).

Qanat/falaj or catchment gallery

Since the 1990s, archaeological teams working on Iron Age settlements (i.e. Hili, Qarnt Bint Sa'ud, Maysar, Muweilah) have been contemplating the relationship between these sites and *qanats*; according to researchers, the development of these structures, which accessed underground water resources, would explain the establishment of populations on the fringe of the desert, and the growth of villages during this period (Fig. 1). Indeed, overall settlement numbers increased during the Iron Age, and these settlements were spread more widely across the region than ever before. This seems to be related to the diversification of resources and environments exploited during this period (Magee 2000).

The oldest *aflāj* in the Oman Peninsula can be dated to the Iron Age (al Tikriti 2011). Unfortunately, we know little about the nature of the groundwater source tapped by these early structures. It has been suggested that the water came from alluvial fans or *wadi* underflows. These water sources would be sensitive to climate change (Boucharlat 2003, p. 162). Therefore, it is assumed that the abandonment of several *aflāj* at the end of the Iron Age was related to aridification and the subsequent depletion of shallow groundwater resources.

[1] Wilkinson (1997), pp. 73–121, Goblot (1979), Beaumont et al. (1989), Lombard (1991) pp. 68–86.

[2] Nasif (1980), pp. 75–80, Nasif (1987), pp. 127–135.

[3] Serjeant (1988), p. 152.

[4] Aguirre (1775).

[5] Various authors (2000), p. 102.

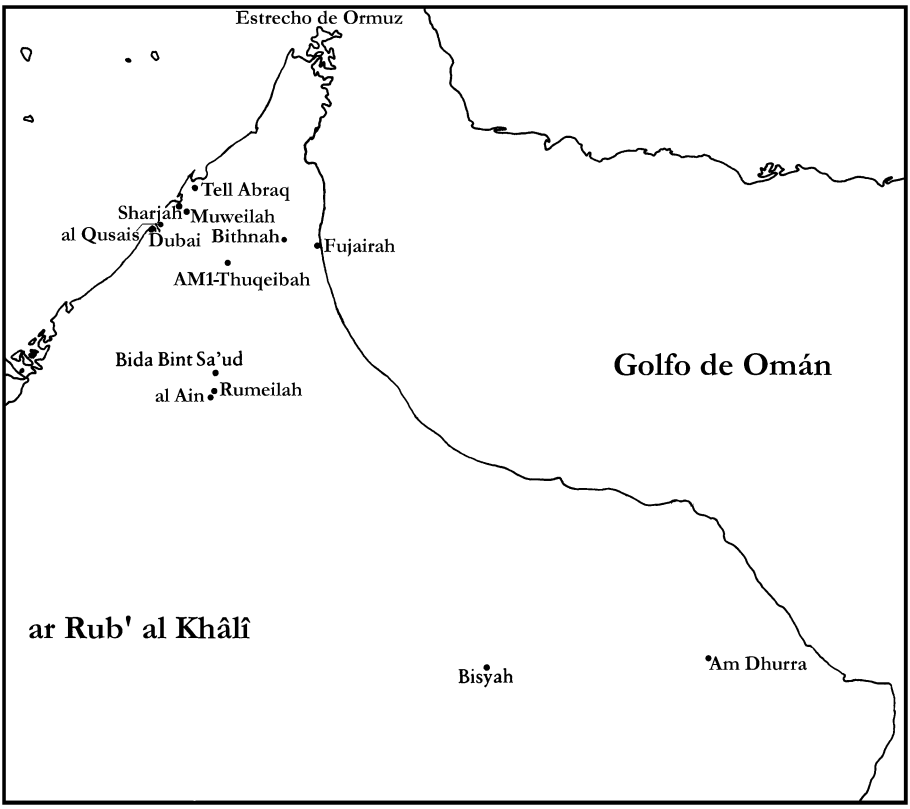

Fig. 1 Oman Peninsula showing the most important sites from Iron Age. Mañé (2005, p. 263)

If the water table drops, it is necessary to re-excavate a *falaj* along its whole length until water once again flows into the gallery. If this occurs, then the old tunnel slope is no longer sufficient; for this reason, it must be corrected and the outflow of the *falaj* has to be moved downstream. As a consequence, water can no longer reach the original fields and settlements. There are various solutions to this problem:

- Fields and settlements are moved downstream, near the new outflow of the *falaj*, as observed in Maysar 46[6] (Oman)
- Fields are lowered and sunk into the ground in order to reach the level of the outflow.[7] The excavated soil is stacked at the edge of the oases, giving rise to large mounds called *nadds,* as can be seen at Nad Ziba (Ras al Khaimah)[8]
- A large reservoir is constructed into which the water flows. This case is archeologically documented in Qarn bint Sa'ūd[9] (Abu Dhabi) and nowadays at Hatta[10] (Dubai)

[6] Schreiber (2001).

[7] Costa (1984), p. 249, Mershen (1998), p. 202.

[8] de Cardi (1984), p. 203, de Cardi et al. (1994), p. 50.

[9] al Tikriti (2011), pp. 86–101.

[10] Forman (1996), pp. 140–142.

Al Madam

The area of al Madam-Mleiha, which lies northwest of the Oman Peninsula, is a steppe sprinkled with trees and dotted with cultivated fields and palm groves that have been irrigated by wells and *aflāj* from Pre-Islamic times up to the present day (Fig. 2). The present inhabitants of this region are exploiting a water table that nowadays lies considerably deeper than in Antiquity. Water shortage, and its impact on the evolution of settlement patterns, has for a long time captured the attention of scholars working on the Iron Age of the Oman Peninsula. Evidence from al Madam provides new insight on this process. The Spanish team concentrated its work on sectors 1 (the Iron Age II-III settlement)[11] and 2 (*falaj*).[12] We established that al Madam was supplied with water coming from wells (Fig. 3) and water-draining galleries, as early as Iron Age I. A *falaj* system seems to have been the best choice for providing water in this context because of low rates of evaporation and the fact that the water table was shallower in antiquity. Precipitation would not have been sufficient for dry farming since the average annual rainfall did not exceed 100 mm and would have been highly variable from year to year. Water capture in the area (by wells or *falaj*) must have been sizeable if we note that Thuqeibah (the name of area where our main excavation is located) means small well, small pool, pit, or can even mean "small mouth of a *falaj*".

When archaeological surveys began in the al Madam area, Iraqi scholars reported the remains of a mudbrick village in the modern hamlet of Thuqeibah. This site, referred as al Madam 1-Thuqeibah,[13] revealed itself as the first stable settlement in the region at the beginning of 1st. millennium B.C. The French archaeological mission in the UAE that worked in the al Madam Plain from 1993 until 1995 undertook an extensive survey that identified c. 54 locations where archaeological remains were present. During the survey[14] the French team located seven linear alignments of whitish mounds in sectors 2, 21, and 31. These linear alignments were identified as the remains of *falaj* access shafts that had been eroded over time. Interestingly, several of these alignments seemed to lead to the Iron Age settlement of al Madam 1-Thuqeibah.

Whilst we dug at the Iron Age village in sector 1 and studied its environment, objects, faunal and botanical remains, we never forget those alignments of whitish mounds, (located 2 km further east). The detection of the site's main cultivation area near the outflow of the *falaj*, and archaeobotanical evidence for the cultivation of date palm at al-Madam during the Iron Age made it clear that an investigation of the *falaj* system was crucial to understanding water exploitation in this period (Fig. 4).

Al Madam 2 *falaj*: underground gallery

In the year 2002 we wanted to confirm, not only the existence of at least one *falaj* in the area, but also its relationship with the Iron Age village. The initial opening of a sounding around one of the whitish mounds located in sector 2, led to the finding of the first access

[11] Oman Iron Age chronology was agreed and accepted in 1997 after meeting at the office of the CNRS at Lyon: Iron Age I, 1300–1100 B.C.; Iron Age II, 1100–600 B.C.; Iron Age III, 600–300 B.C.

[12] Córdoba and del Cerro (2005), pp. 515–532.

[13] Córdoba and Mañé (2000), pp. 251–265, Córdoba (2003), pp. 173–180.

[14] Mouton (1990–1992), pp. 3–10, Benoist (1997), pp. 59–74.

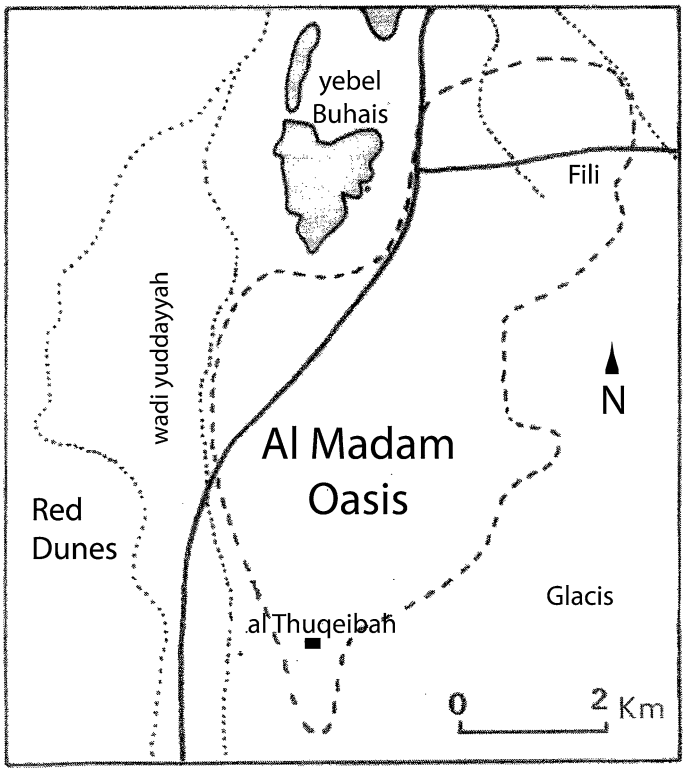

Fig. 2 Map showing the inland basin (Meliha-al Madam region) with major archaeological sites. Jasim et al. (2016, p. 11)

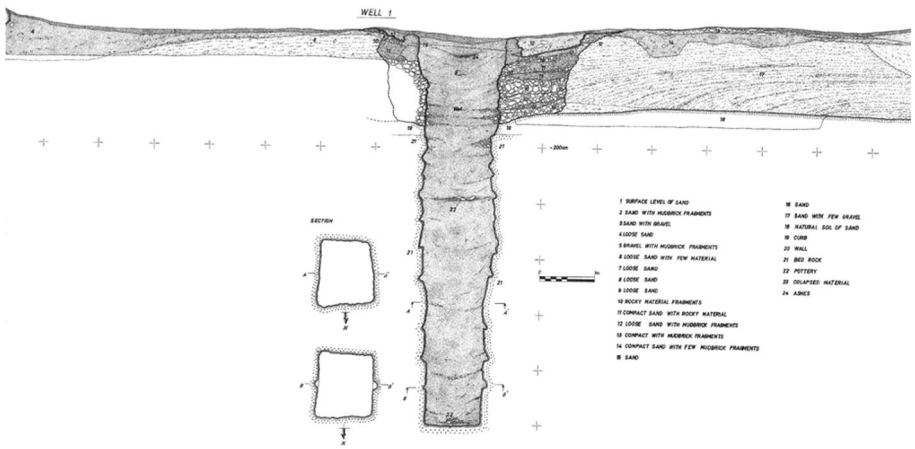

Fig. 3 Inner stratigraphy of al Madam 1-Thuqeibah well. (M. Nuñez Villanueva, Spanish Archeological Team)

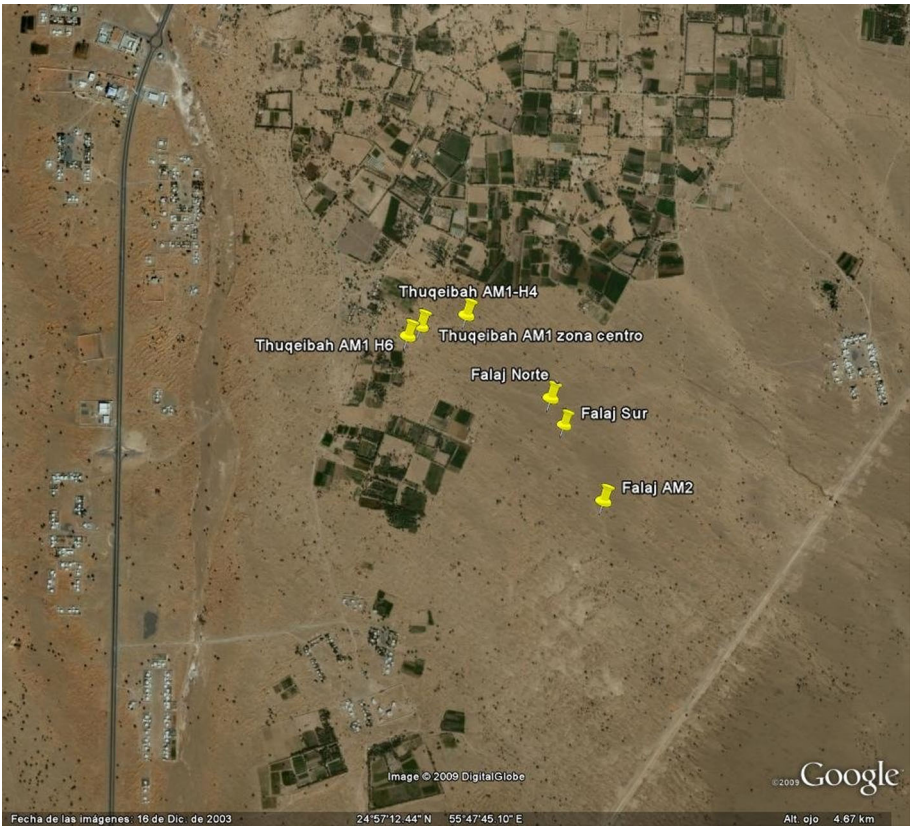

Fig. 4 Aerial view of al Madam showing the archaeological sectors (Spanish archeological team, 2014)

shaft (in Arabic *thuqba*, pl. *thuqāb*). Since then, a 70 × 3 m trench allowed for the excavation of seven access shafts that led to the underground gallery. The mouths of these *thuqāb* had been directly dug into the sand and, after extending through a level formed by gravel, the wells entered the natural rock (Fig. 5). These mouths are protected by a sort of mortar made with material taken from the rock itself[15] and have small steps carved into the walls, which would have allowed a person to climb down into the tunnel. We fully excavated *thuqāb* Tqb-1, 2 and 3, but Tqb 4 was dug in a section. The results indicate that the access shafts were blocked-up on purpose, probably after the drying up of the structure (Fig. 6). A progressive infilling of the tunnel, can be clearly seen in its stratigraphy, and is also suggested by the inner empty sections that are visible in the centre of the underground gallery. Indeed, the latter was partly infilled by two meters of loose wind-blown sand. At a certain point, which is difficult to date, the wells were, however, completely blocked, leaving the empty spaces preserved in the tunnel. This can be deduced from the features of the inner slopes.

The vault of the *falaj* gallery is 0.70 m below the mouth of the access shaft. The vault is carved into the natural rock in the same way as the wells found in the village of AM 1, that

[15] Córdoba (2016), p. 135.

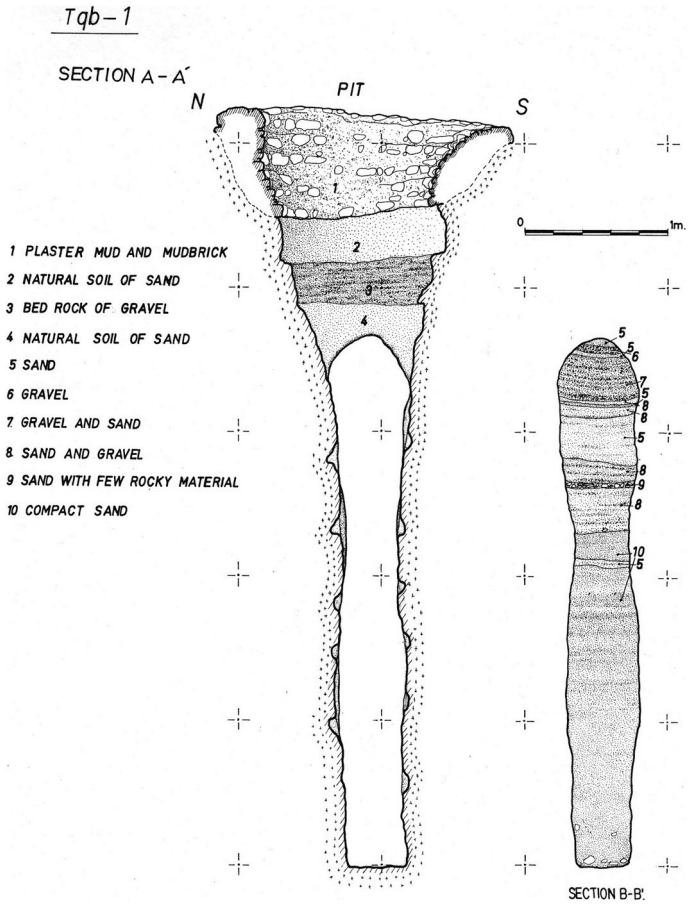

Fig. 5 Section of Thuqba 1 and *falaj* 1, found at al Madam 2. (M.A. Núñez Villanueva and I. Martín Gútiez, Spanish Archeological Team.)

is, with a very thin sharp pickaxe whose traces are visible in the rock. After first removing the sand between *thuqāb* Tqb 1 and Tqb 2 we found an angled tunnel with a width of 0.5–0.55 m and a total height of 4.80 m (Fig. 7). Eventually we cleared 35 m of gallery, the course of which follows a zigzag pattern. As such, its design differs from later *falaj* and from the traditional Iranian *qanat* that follow a straight-line course for several kilometres from the head of the *qanat*—the point where it meets the water table—to the outflow (Fig. 8). Several hypotheses can be put forward to explain the specific layout of al Madam *falaj*. Without an accurate measuring device, Iron Age diggers may have faced difficulties in estimating directions underground (Boucharlat 2017b). Alternatively, we suggest that the meandering trail of the gallery at al Madam would have permitted the collection of a greater amount of water than a straight tunnel. This would suggest that water was collected all along the whole water table not just at its headwaters, although it is unclear at the moment if the portion of gallery excavated corresponds to the infiltration or transportation section. The mother well of the *falaj* was not identified, as it is hidden by sand dunes near the border with the Sultanate of Oman; however, the survey suggests that it was located in

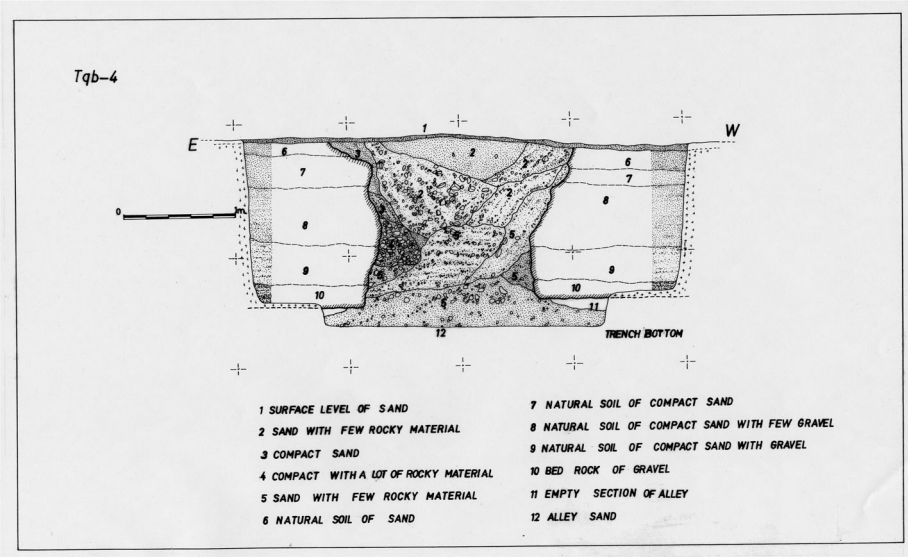

Fig. 6 Section of Thuqbah 4 from surface until the beginning of the gallery. Al Madan 2, *falaj* 1. (M.A. Núñez Villanueva and I. Martín Gútiez, Spanish Archeological Team.)

Fig. 7 Underground gallery of al Madam *falaj*. (Spanish Archeological Team)

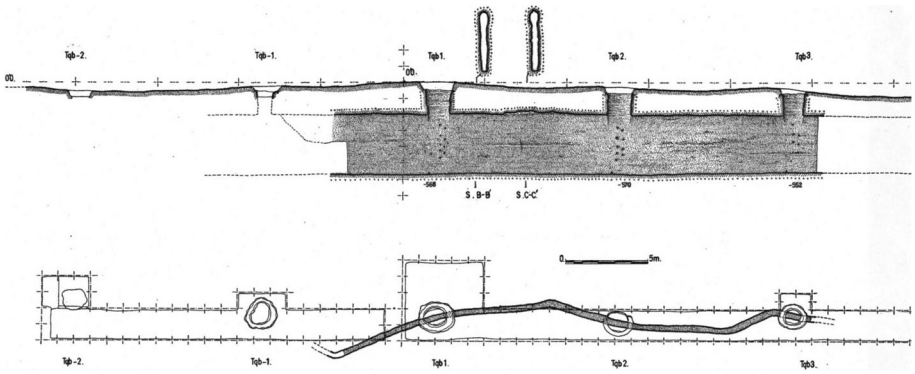

Fig. 8 Section and plan of the gallery of captage located in al Madam 2 after 2004 season. (M. Nuñez Villanueva, Spanish Archeological Team)

a small depression situated to the southeast of the site, at the confluence of several *wadis*. Therefore, the water table exploited during the Iron Age came from *wadi* underflows or shallow aquifers (Boucharlat 2017b, p. 147).

The incredible height of the gallery suggests that water depletion due to increased aridity, overexploitation or a combination of both, was a concern, and that actions were undertaken to overcome it; this is also evidenced by the structures in the village.[16] Excavation also revealed that the gallery of the Iron Age *falaj* had been undoubtedly deepened. Initially, the bottom of the gallery was located 1.50 m below ground; it was later deepened to reach 4.80 m, in an attempt to find water (Fig. 9).

As in the case of traditional *aflāj*, the amount of water that it extracts from the water table is never very abundant; Because the *falaj* would have specifically fed the gardens located outside of the village, another source would have been needed to supply water for people and cattle. Therefore, two wells were constructed within the village. We are certain however that the Iron Age village and *falaj* were contemporary.

Al Madam 2: Outflow of the *falaj*. Irrigation Chanel Network Area (ICNA)

In 2009, a geomagnetic survey identified the course of the *falaj* from the excavated *thuqāb*, to its downstream end. Sadly, the archaeological landscape of al Madam has been affected by a recently constructed road that fortunately has been elevated at the point where it crosses the *falaj*. Thanks to the intervention of the Department of Antiquities and Heritage of Sharjah Emirate, the road has not harmed the structure. North of this road a georadar survey, has also been undertaken that allowed us to identify the possible outflow of the *falaj*. Following the results of these geomagnetic and georadar surveys, seventeen soundings were dug along the course of the *falaj* in 2011–2014—which is 3 m deep at the level of the new road—up to the garden area.[17] Thanks to this work, it was possible to determine that when it emerges at the surface, the *falaj* became a deep open trench that ran for about 200 m before reaching the gardens. At this point, the *falaj* was about 20 cm deep.

[16] del Cerro (2012), pp. 133–139.

[17] del Cerro and Córdoba (2012), pp. 165–155.

Fig. 9 Underground gallery of the falaj showing the two stages of construction close Thuqba 2. (Spanish Archeological Team)

From the primary channel, which had the same orientation as the gallery, a series of secondary channels branched off at right angles. These conducted the water to a number of ponds, pools and cultivated fields located on both sides of the main channel. This proved to be a genuine network of irrigation channels dug into the natural rock[18] (Fig. 10).

During the season carried out in March of 2014, we located at least 32 secondary channels that connect hole-lines, which were interpreted as tree-pits; at the present time, we have uncovered 56 tree-pits. We also unearthed five large ponds, 2 m wide and approximately 30 m long, connected to the main channel through secondary channels. These ponds could be water reservoirs. The water was controlled by sluice gates made of local stone. We were also able to determine that the entire area had been modified and deepened at least twice just as the underground gallery of the *falaj* had. Due to a lack of water some adjacent tree-pits were also converted into ponds and the main channel was deepened. The reorganization of the network of channels was however never completed, as the water table became too deep and the area was abandoned.

As this area is still under excavation its overall dimensions are unknown to us, as is the storage capacity of the variously shaped ponds or the volume of water coming from channels with different widths and depths. However, we have observed that the cultivation area is framed by some raised mounds, still visible today, which might have resulted from the process of flattening the area for irrigation and dumping the removed soils at its edges. Taking into account this premise, we opened a transverse sounding between soundings 7 and 8 in February 2015, at the point where the eastern raised mound is located. Here, we

[18] Córdoba (2013), pp. 139–151.

Fig. 10 Aerial view of Ancient Irrigation Network area at al Madam 2 from northwest. (Spanish Archeological Team)

were able to establish the eastern limit of the cultivated area as we unearthed the most upstream water distributor and secondary channels.

During the last season, topographic field studies allowed us to estimate that the Irrigation Channel Network Area (ICNA, that is, the field system located on both sides of the main channel) covered approximately 15 ha (600 × 300 m). However, up to now we have excavated only 20% of the ICNA (Fig. 11).

This kind of irrigated garden area related to an Iron Age *falaj* is unique in the region and in the wider Oman Peninsula where groundwater draining systems are very well studied in the Late Islamic period, but for which many questions remain to be solved for earlier phases. Our example is a well-defined and articulated network, which is very similar to those from other arid regions such as southern Iraq, and from traditional oases of the United Arab Emirates. It is composed of lines of trees—usually date palm trees—protecting low crops with their shadow. In the present-day oases, date palms survive with little water and grow side by side with cereals, vegetables and fruits.

The modern inhabitants of al Madam have informed us that their ancestors grew crops directly upon the sand, suggesting that such a harvest was possible. While it was evident that the archaeological record would not be able to offer us evidence of crops grown on sand, amazingly, the system of water canalization and storage that irrigated these fields has remained preserved, excavated in the rock, since the beginning of the 1st millennium B.C.

Interestingly, the area also provided us with an abundance of Iron Age II potsherds that are clearly related to the material found at the nearby village of al Madam 1. Besides the pottery, considerable amounts of molluscs were also collected in all the channels.[19] They

[19] Morales and Llorente-Rodríguez (2016), pp. 141–142.

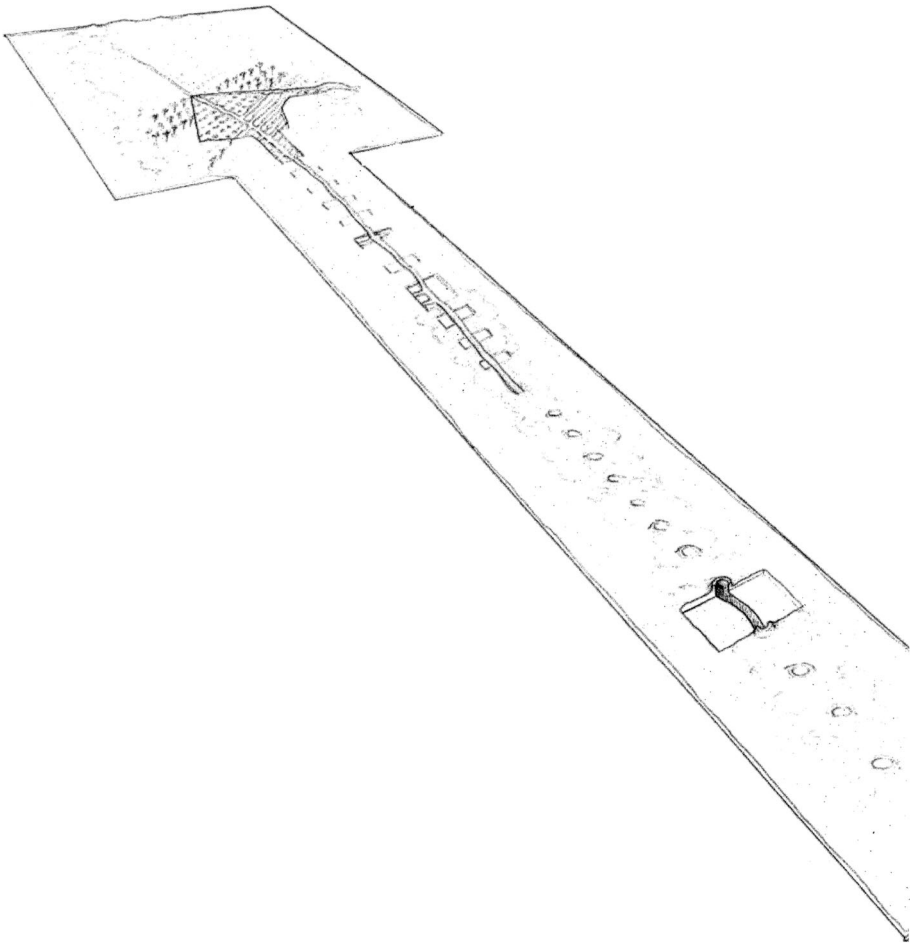

Fig. 11 Sketch of *falaj* systems founded at al Madam 1 following the archaeological record. (M. Nuñez Villanueva, Spanish Archeological Team)

belonged to the family of the *Thiaridae (Melanoides tuberculata and Truncatella marginata)*, suggesting a constant presence of clean and fresh flowing water in the whole network. At the outflow of the *falaj*, besides the *Thiaridae,* we also found two date stones and the remains of *Terebralia palustris*, which, after calibration with the marine calibration curve "marin09.14c" permitted us to date the structure to some point between 1065 BC and 808 BC.[20]

[20] We wish to thank the University of Tübingen and specially H.P. Ürpmann and B. Kromer for providing us the results of this dating.

Conclusion

The population of al Madam chose to remain in a very hostile environment that nevertheless could be generous if water was well managed. The evidence indicates that the Iron Age people of al Madam conducted groundwater to their fields through tunnels, channels, ponds and pits. It is evident that this community had an advanced knowledge of the subsoil: community members knew which natural rock could be dug into with minimal difficulty and where the water table was most easily reached. In fact, water probably oozed out of some of the depressions we find at the head of the *falaj*. This would have provided a clue to the water's depth below the surface. Al Madam's inhabitants knew how to maximise the potential of their environment, combining agriculture, cattle breeding, trade and hunting to remain in a place that, once abandoned, would never be inhabited again due to a decrease in the water table that clearly occurred sometime in the Iron Age. The hydraulic knowledge of the Iron Age inhabitants of this settlement continues to amaze us, and further reveals itself with every excavation campaign we undertake at al Madam.

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