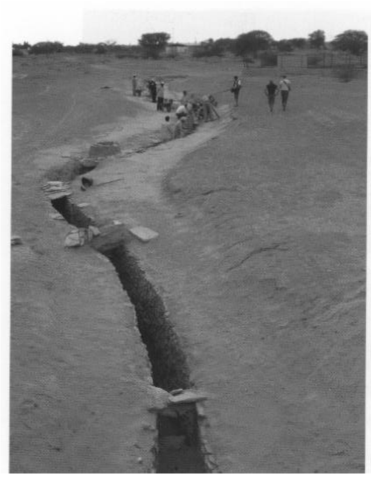
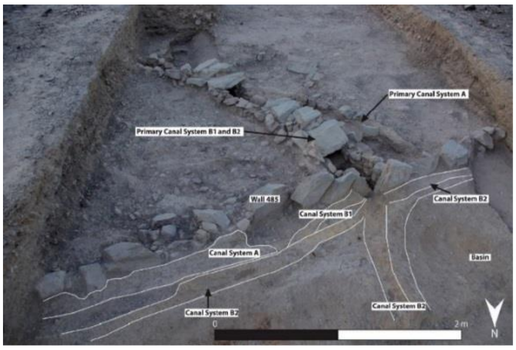
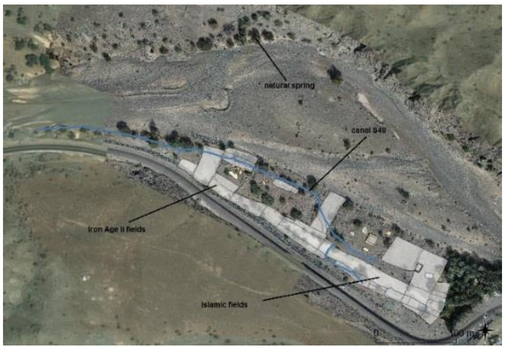
Innovating irrigation technologies –

Four communities in the Southeastern Arabian Iron Age II







Sources of pictures (clockwise):

Picture 1: Al-Tikriti 2010, 231

Picture 2: Cordoba and Del Cerro 2018, 95

Picture 3 : Charbonnier et al. 2017, 18

Picture 4: Map created by Anna Lipp, © WAJAP (www.wajap.nl)

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Four communities in the Southeastern Arabian Iron Age II.

Anna Lipp

MA Thesis

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Glossary:

Aini falaj = *Falaj* system, that is tapping a spring

Dawoodi= *Falaj* system, that is tapping water from a well; *qanat*-type *falaj* system

Falaj, pl. *aflaj* = irrigation system, by which a water source is tapped and water is transported either via an underground gallery with a small gradient up to the ground surface by means of gravity or via an open surface canal. Eventually leads to subcanals or gardens

Ghaili= *falaj* system, that is fed with water from a wadi

Gharrag=part of a *falaj* system that channels water underneath a wadibed

munzifah or *shaduf* wells= way to carry water up water from a well to the surface. A bucket is fixed on a rope and the rope is fixed on one side of a pole. A countwerweight is fixed at the other side of the pole and the pole itself is supported by a scaffolding. Water users pull the rope to lower the bucket and push the counterweight down to lift the bucket up again

Sha'ria = part of a *falaj* system which diverts water from the main canal into subcanals

Thugbah, pl. *thugab* = Shafthole and part of a *qanat*-type irrigation system. It provides access to the underground water gallery

Qanat = see *falaj*

zajarah wells= way to carry up water from a well to the surface, by which an animal (mainly cattle) is moving several metres away from the well and back. When the animal moves away a bucket of water is carried up from the well up to the surface and the water is pouring into a canal or basin

I. Introduction and research questions

Irrigation activities in the Iron Age II (1000-600 BC) on the Southeastern Arabian Peninsula at four different locations are compared in this thesis: at Hili, Al Madam, Masafi and Wadi Fizh (Figure 1). This is an interesting research topic for three reasons: A large population boom during the first millennium BC is indicated by a large number of settlement structures present in the archaeological record. More than sixty settlements that were dated to the Iron Age II, mostly based on the building structures and pottery evidence, have up until now been identified on the Southeastern Arabian Peninsula (Figure 2).

Figure 1: The southeastern Arabian Peninsula (U.A.E. and Sultanate of Oman) and the four irrigation systems discussed in this thesis

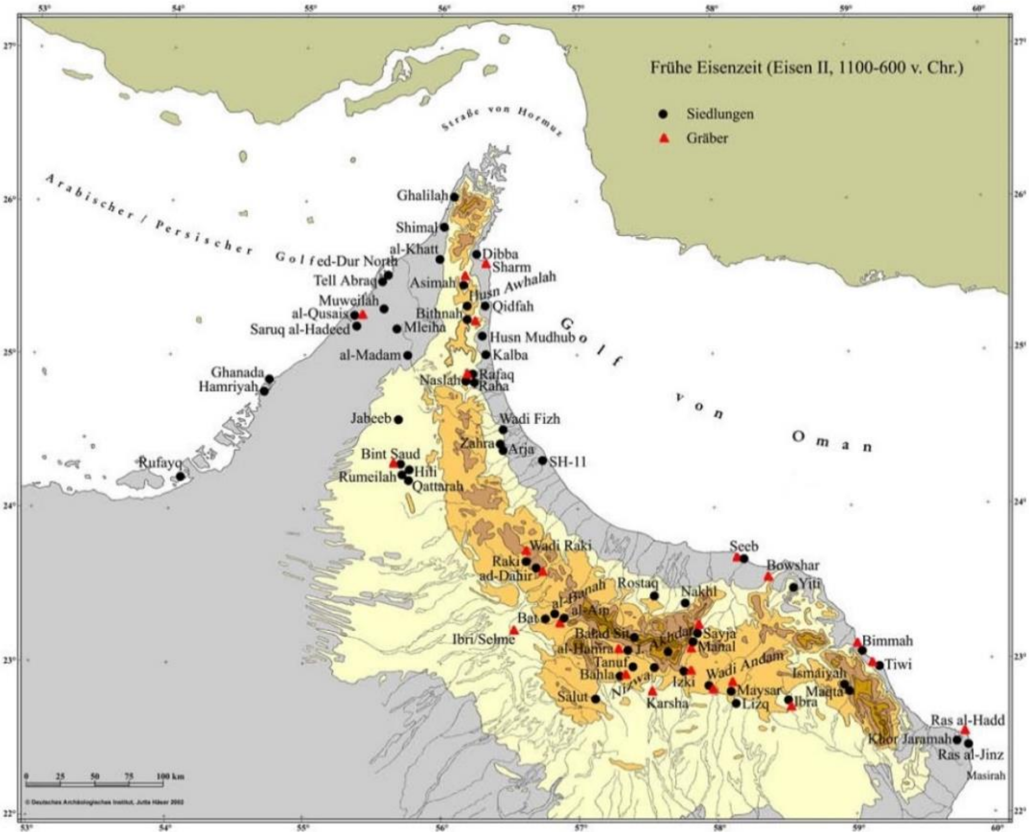

Figure 2: Settlements dated to the Iron Age II period – as in 2007 (Schreiber 2007, 52)

As paleoclimatic studies show (Fleitmann et al. 2007, Fuchs and Bürkert 2008, Van Rampelbergh et al. 2013), hot arid climate prevails on the southeastern Arabian Peninsula during the Iron Age II period. Water was therefore a rather scarce resource for the increasing number of communities. How did they deal with these conditions? Simultaneously to the settlement boom, there is evidence for the development of several irrigation systems in different regions of the Southeastern Arabian Peninsula. This thesis aims at investigating this subject further by addressing the following three research questions:

- In which areas are the four irrigation systems located (e.g. desert-like, coastal, mountainous region)?
- What are characteristics of the applied irrigation technology (e.g. fields and channels)?
- How were these irrigation structures dated by archaeologists?

The first question assesses, in what kind of environment the four irrigation systems are located. By answering the second research question, different types of irrigation technologies are assessed in detail to later compare them effectively. Thirdly, dating of the irrigation systems is discussed, because this is a controversaly-debated subject due to a lack of absolute dates.

The main aims of this research are:

- Assessing the variety of Iron Age II irrigation systems
- comparing case studies of different Iron age II irrigation systems along three parameters (location, type, archaeological dating method)
- finding out what can be expected from the archaeological record when researching irrigation systems

The following chapter introduces region and cultural history of Southeastern Arabia, starting with the geology and palaeoclimate of the Southeastern Arabian Peninsula, then moving to the cultural history of the region. In chapter three, theoretical approaches to irrigation activities are discussed and several regional irrigation technologies are introduced. Finally, the methodology of this thesis is discussed. In chapter four, the three research questions are discussed along case studies of four irrigation systems, located at the oasis of Hili (United Arab Emirates, hereafter: U.A.E.), at Al Madam (U.A.E.), Masafi (U.A.E.) and Wadi Fizh (Sultanate of Oman). Then, I will compare the results from the analysis with each other contextualize these results with the wider context of the debates in Arabian Archaeology. Chapter six offers the final conclusions, a reflection on this research and suggestions for further research.

II. Region and cultural history

This chapter introduces the geology and the paleoclimate of the Iron Age II on the Southeastern Arabian Peninsula. Secondly, a brief history of Arabian Archaeology and the prehistoric chronology of Southeastern Arabia is provided. Eventually, Iron Age II settlements, buildings and material culture will briefly be introduced in order to contextualize this assessment in the Iron Age II period and its culture.

II.1 Geology

Two mountain chains are located in Southeastern Arabia; the Al Hajar mountain chain in the North and the Dhofar mountain chain in the South, bordering the Republic of Yemen. The Dhofar mountain chain however is not within the research region of this thesis. Alluvial fans are flanking the Al Hajar Mountains to the Northwest and East. The Batinah coastal plain East from the Al Hajar mountains is composed of gravel and sand and covered by debris of oceanic rock. Furthermore, two sand dune bodies, the Wahiba and Sharquia sands are located on the Southeastern Arabian Peninsula (Hoffmann et al. 2016, 30-33; Figure 3). The latter developed during the Quarternary (ibid, 45).

Figure 3[1]: Topography of the Southeastern Arabian Peninsula showing the Al Hajar mountain chain in the centre, the eastern Batinah coast and the Sharquiya sands to the south, as mentioned

In the Late Cretaceous, the Arabian Promontory of the African plate collided with the oceanic crust of the Eurasian plate. Thereby, the eastern margin of the Arabian part of the African plate was subducted under the oceanic crust of the Eurasian plate. The ophiolite nappe occurred, becoming the Semail ophiolite (Hoffmann et al. 2016, 42; Searle and Cox, 2002; Figure 4). Because of this obduction process, tha major geological units on the Southeastern Arabian Peninsula are divided up into autochthonus rocks formed on the Arabian continent and allochthonous rocks, that previously formed on the crust of the Neothethys, aswell as post-nappe autochthonous rocks that formed after the obduction occurred during the Late Cretaceous (Hoffmann et al. 2016, 34-40, 45).

[1] Figure retrieved from www.mappery.com/map-of/Northern-Oman-Map

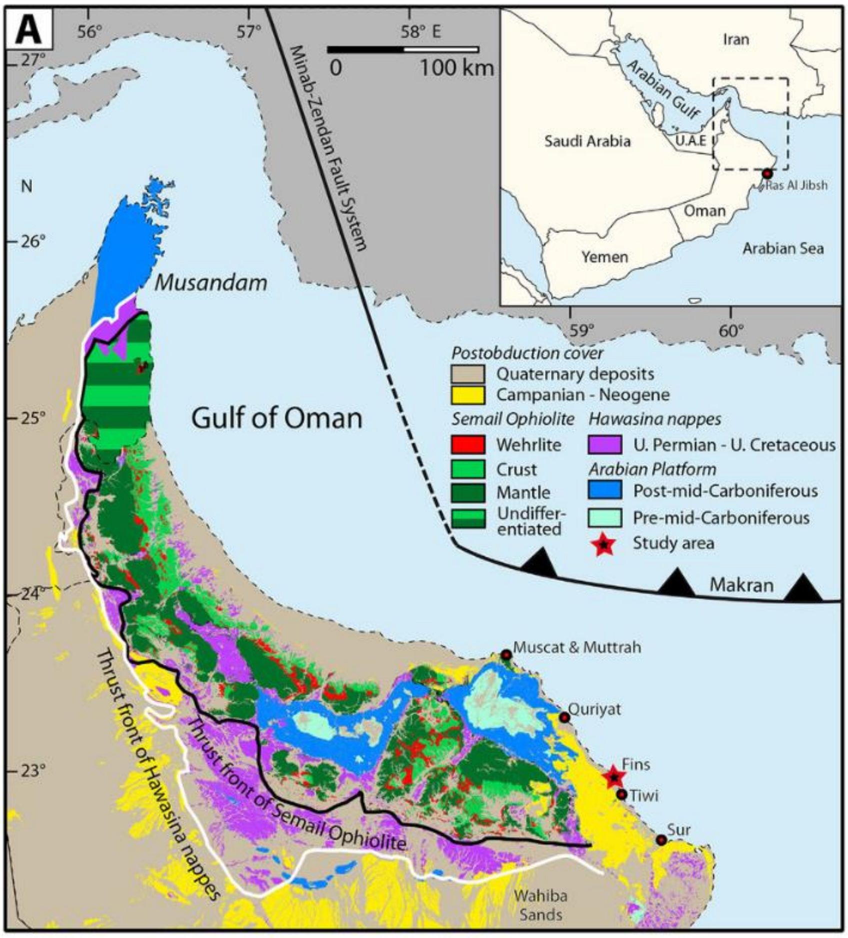

Figure 4: Map showing the different sedimentary units present in the Southeastern Arabian Peninsula, the thrust belt of the Semail ophiolite and the Wahiba sands in the South (Mattern et al. 2018, 193)

II.2 Paleoclimate on the Arabian Peninsula

Several studies claim that a wet period occurred on the Arabian Peninsula between 8 and 6 ka BC. According to Van Rampelbergh et al., an influential factor is the northward shift of the ICTZ [2] (Intertropical convergence zone) and the intensification of the IOM [3] (Indian Ocean Monsoon) (Van Rampelbergh et al. 2013, 132; furthermore, Fuchs and Bürkert 2008). The end of this wet period results from the southward movement of the ITCZ to today's position at the coast of southern Arabia (Van Rampelbergh et al. 2013, 132, Fleitmann et al. 2007, 176 ff.). Studies however suggest different timings for the exact change from a wetter to a

[2] The ICTZ (Intertropical convergence zone) is a term that refers to a band of precipitation and strong winds, which are located along the Equator. They do not have a fixed location and shift seasonally. Their change of location effects the rainfall in the areas.
[3] IOM stands for Indian Ocean Monsoon.

more arid period in the region. Results from an analysis of speleothem samples form Oman (Fleitmann et al. 2003a, 2007) and a study by Lezine et al. (2010), suggests that precipitation decreases gradually from 8ka onwards (see Fuchs and Bürkert 2008). By contrast, Burns et al. (2001) and Parker et al. (2006) suggest the end of the wet period at 6 ka.

The general trend of aridification, latest from the sixth millennium BC, seems to show in all palaeoclimatic studies. Since the position of the ICTZ has not changed since this aridification process and because the ICTZ's effect on the regional precipitation is considerable, one suggestion is that modern precipitation levels are similar to the regional levels after the onset of the arid period.

II.3 Early Arabian Archaeology

Archaeological research on the Arabian Peninsula began with Bibby's investigation initiated by the Aarhus University on the island of Bahrain (Bibby 1972). Danish teams started campaigns in 1959 on the island of Umm an Nar in the archipelago of Abu Dhabi (Frifelt 1975) and continued researching in the region for several years. In the 1980's, French teams supervised by Cleuziou started their research work at Hili in the U.A.E. for several years to come (Cleuziou 1980, Cleuziou 1982). Italian teams supervised by Tosi began their research in Oman and the U.A.E in the same decade (Tosi 1986). Long time team members joined the teams and their research is a long-term effort and contribution to the knowledge on the material culture and social structures of prehistoric communities on the Arabian Peninsula. Today, Dutch, French, Italian, Omani, German and Australian Teams are researching on prehistoric archaeological sites in the region and there are more publications to expect to expand knowlegde on and insights in Arabian prehistory in the upcoming years.

II.4 Chronologies

Before the 1990s, Bibby referred to the distinct material culture of the first century BC on the Southeastern Arabian Peninsula as the 'Dibba-complex' and Weisgerber as the 'Lizq-period' (Schreiber 2010). An initial, relative and absolute chronology of the southeastern Arabian Iron Age was put forward based on the archaeological records of the settlements at Shimal, Rumeilah and Tell Abraq in the 1990's (Table 1). Combining dates from this relative chronology based on pottery evidence with additional absolute dates, Peter Magee suggests the following chronology: Iron I (1300-1000 BC), Iron II (1000- 600 BC) and Iron III (600-300 BC) (Magee 1996, 249). Earlier, Potts suggested keeping local sequences and phases, instead of applying chronologies from other regions. Based on an example of an aceramic site in Oman where herding and fishing was conducted and copper tools were used, he argued that this site can terminologically and culture-historically not easily subsumed under the term 'Bronze Age' (Potts 1993, 168). He emphasized that more attention shall be put on different Southeastern Arabian communities that applied distinct technologies and economic activities in the same time period, acknowledging and stating however that a supraregional chronology was helpful. Thus Potts suggested a prehistoric chronology, in which the first millennium BC in southeastern Arabia is subdivided in Early historic E-G (Potts 1993, 167-169, see Table 2).

Rumeilah	Tell Abraq	Shimal
	Phase 1	Phases 4a-4b
Period I	Phase 2	Phases 4c-4d
Period II	Phase 3	

Table 1: Relative chronology of the Assemblages at Tell Abraq, Shimal and Rumeilah (Magee 1996, 244)

Philipps suggests the chronological division into an Early Iron Age (1100-600 BC) and a Late Iron Age (600-300 BC) based on the archaeological record at Salut. The settlement of Salut is located near Izki in Oman (cf. Figure 2). Pottery of the Rumeilah 1 type, painted spouted jars and small carinated cups, that are considered as typical Iron Age II assemblage[4], were found in two building levels at Salut. Results from C14 analysis (95% probability) of nine wood charcoal pieces from both layers, suggested dates of eight of the nine pieces for the time period between 1300 and 1000 cal. BC. One wood charcoal sample from the uppermost layer was dated to ca. the time period between 1000 and 900 cal. BC (Philipps 2010, 73).

To conclude, the pottery assemblage, which at other sites is an indicator for a date between 1000 and 600 BC, appeared in Salut in layers, which were dated to 1300-1000 BC. What do these finds imply for the Southeastern Arabian chronology debate? As no other Radiocarbon dates from other sites yielded the same early date yet, it was not possible to Argue that the Iron Age started 300 years earlier. Philipps therefore suggests instead to distinguish between an Early Iron Age (1300-600 BC) and a Late Iron Age (600-300 BC) (Philipps 2010, 72).

Schreiber similarly suggests the differentiation between an Early and a Late Iron Age period. As the Iron I period is present in the archaeological record at coastal sites and absent in the interior of region of the Sultanate of Oman and the U.A.E., Iron I could be a coastal phenomenon and the Iron II culture (after Magee), a developing material culture in the following centuries until the distinct Iron III assemblage appears at different sites in the seventh century. Schreiber therefore suggests, following an earlier article by Philipps, the differentiation between an Early Iron Age period (1300-600 BC) and a Late Iron Age period (600-300 BC) (Schreiber 2010). Magee’s chronology is used by several authors and it is the one being referred to in this thesis.

[4] See later in this chapter at page eight a summary of what is considered to be ‘classical Iron Age II pottery’.

Potts 1993	Magee 1996	Schreiber 2007	Philipps 2010
Early historic E (1200-1000 BC)	Iron I 1300-1000 BC	Early Iron Age 1300-600	Early Iron Age 1100-600
Early historic F (1000-600 BC)	Iron II 1000-600 BC		
Early historic G (600-300 BC)	Iron III 600-300 BC	Late Iron Age 600-300	Late Iron Age 600-300 BC

Table 2: Chronologies suggested by Potts, Magee, Schreiber and Philipps

In the following, the material culture of the Iron age II period will be briefly introduced. Settlement patterns, pottery evidence and subsistence activities of the members of the Iron Age II communities are presented and discussed. The aim is to contextualize this assessment in the broader cultural history of the region.

II.5 Settlement boom

Iron Age I sites are rather located at the coast (Figure 5, Magee 1998, 53; Schreiber 2007, 47-50) to the extend that Phillipps suggested the Iron I sites might be a ‘local phenomenon’ (Philipps 1998).

In the Iron Age II (1000-600 BC), several communities start settling on the coast as well as further Inland, on plains and along the flanks of the Al Hajar mountain range (cf. Figure 6, Magee 1998, 51-54; Schreiber 2007, Schreiber 2010, 83). Up until today, more than sixty Iron Age II settlements have been surveyed and excavations took place at circa 10-15 sites. Unfortunately, there is no recent complete dataset. Schreiber’s (2007) dataset contains sixty-two sites. Archaeological teams conducted excavations at Tell Abraq (Potts 2000), Hili 15 (Al Tikriti 2010), Bida Bint Sa’ud (Al Tikriti 2010), Al Madam (Córdoba 2013), Masafi (Charbonnier et al. 2017), Muweilah (Magee et al. 2002), Mleiha (Overlaet 2016), Rumeilah (Boucharlat and Lombard 2001), Maysar (Yule 1998), Shimal

(De Cardi 1988, 46-72), Salut (Avanzini 2018) and Saruq al Hadid (Weeks et al. 2017). Different teams surveyed most other settlements.

In the Iron Age III between 600 and 300 BC, only approximately a dozen settlements remain inhabited (see Figure 7). Del Cerro suggests that the Iron Age II settlement at Al Madam was suddenly abandonded and that a drop of the local water table could have worsened the living conditions at Al Madam (Del Cerro 2012, Del Cerro 2015, 250). There is however yet not a well-founded explanation, why several Iron Age II settlements are abandonded and some remain. In central south Oman the distinct Samad period develops during the Iron Age III (600-300 BC) at Samad and Lizq (Yule 2016).

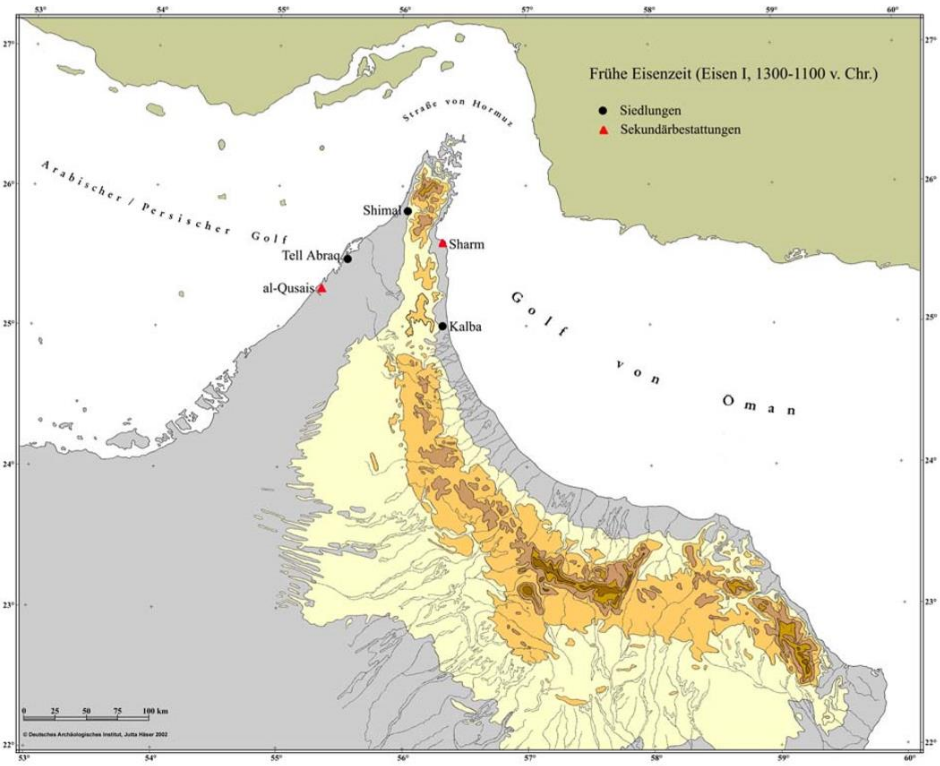

Figure 5: Map of Iron I sites in Southeastern Arabia (Schreiber 2007, 48)

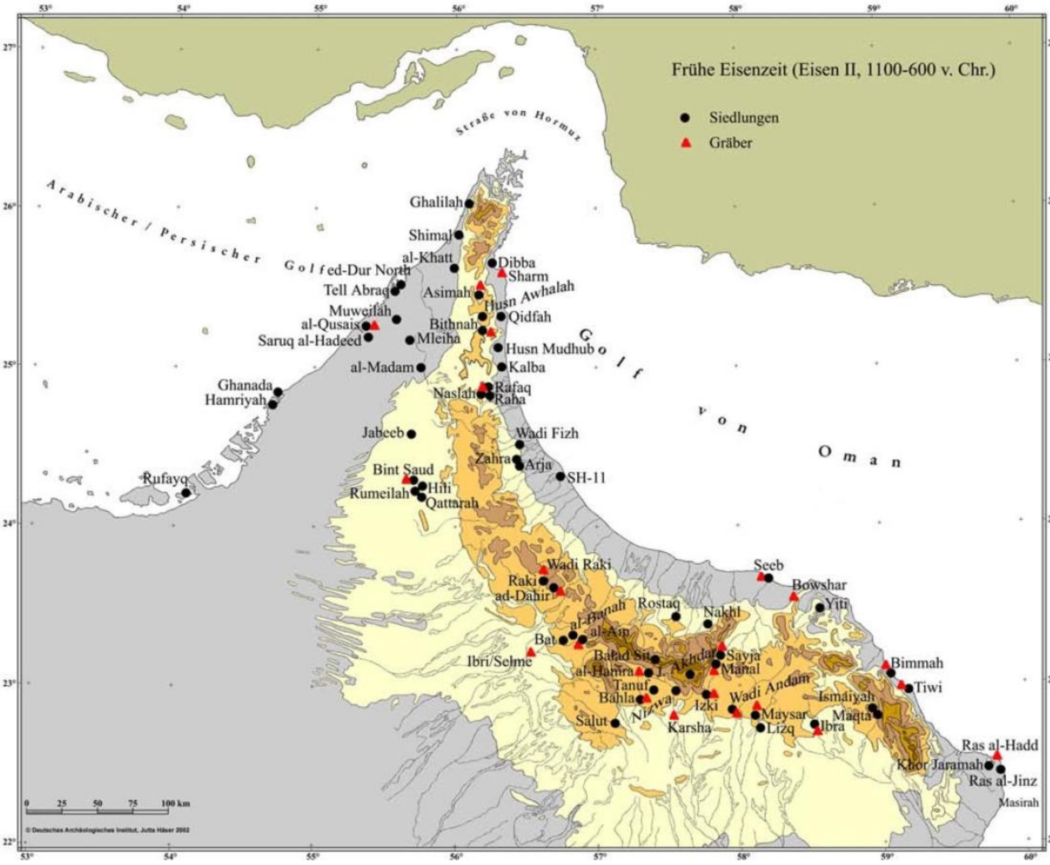

Figure 6: Map of Iron Age II sites (Schreiber 2007, 52)

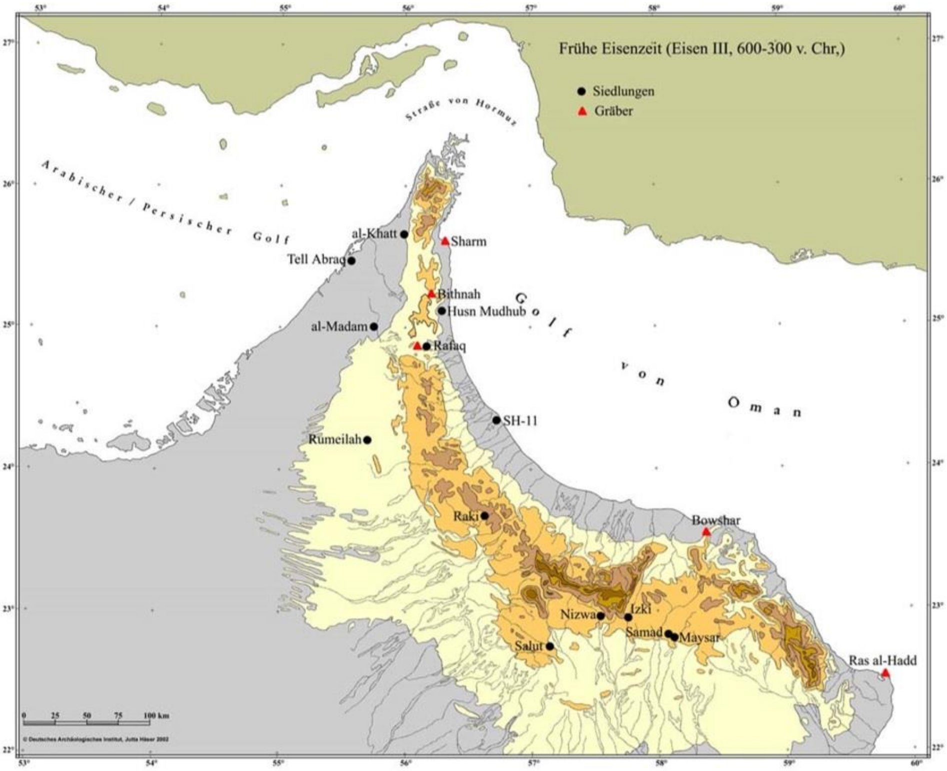

Figure 7: Map of Iron Age III sites (Schreiber 2007, 63)

II.6 Settlement outlines

In the following section, some characteristics that Iron Age II settlements share, are discussed. These are: fortification structures, houses, building material and columned houses.

There is not one general settlement outline, which all Iron II settlements have in common. Several Iron Age II settlements such as Muweilah, Al Thuqeiba, Husn Awhala (Potts et al. 1996, 215, Figure 9) or Salut (Avanzini 2018, 35, Figure 9), Tell Abraq (Magee et al. 2017), Husn Madhab, Bithnah-24, Masafi-2, Asimah-97, Lizq, Fizh-2 (Bénoist 2010, 135) are fortified. There are several settlements with fortification walls but it is not a general characteristic, as some settlements were not fortified, for example Rumeilah (Boucharlat and Lombard 2001, 232-233).

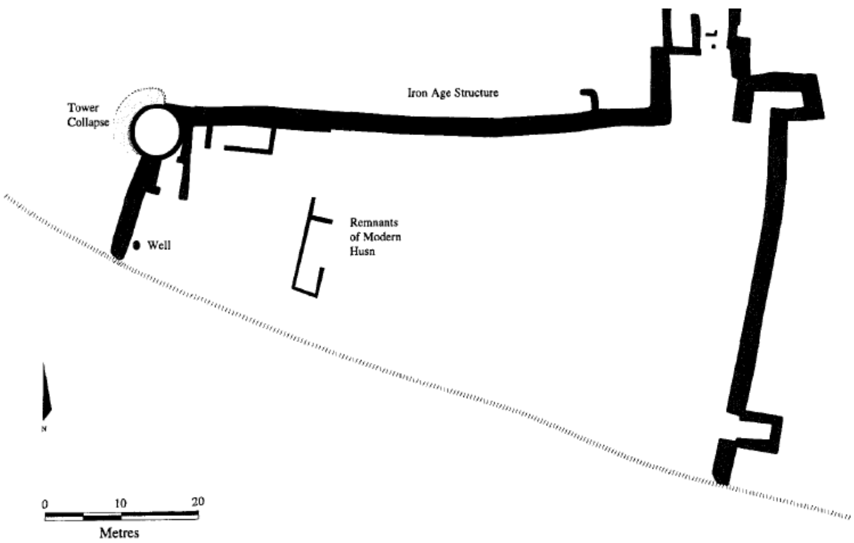

Figure 8: The Iron II fortification of Husn Awhala (Petrie 1998, 247)

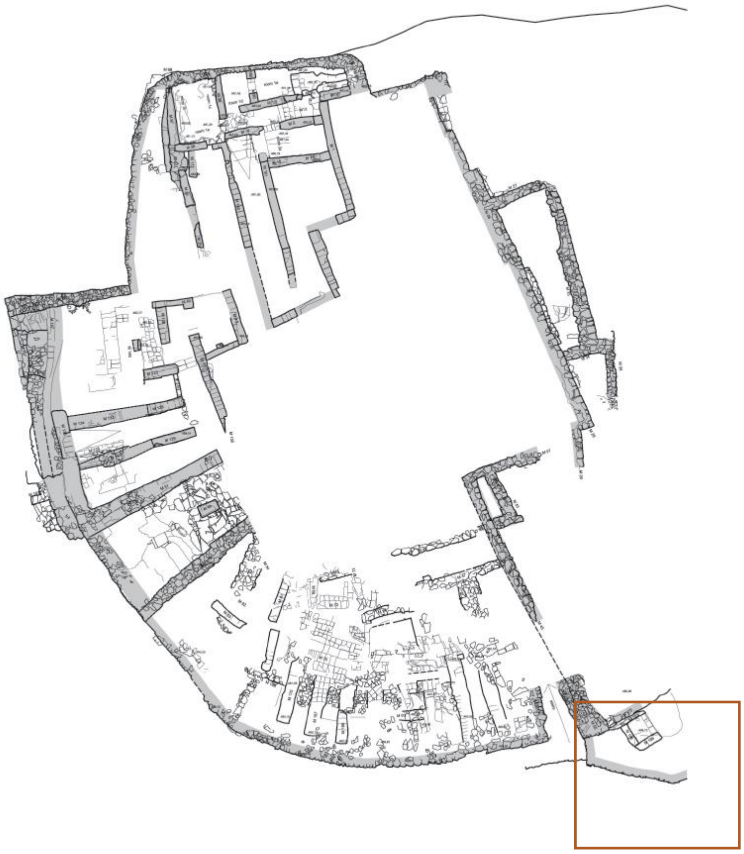

Figure 9: Early Iron Age (1300-600 BC) building phase at Salut. The fortification wall is located on the Eastern outskirts of the settlement (after Avanzini and Phillips 2010, 98)

II.7 Houses

The settlement of Muweilah was excavated by French and Australian teams. It can be considered as one example of an Iron Age II settlement, that is well-documented and systematically excavated for several years. The houses at Muweilah are made from mudbrick. Nine buildings of roughly 20-25 m² size in the East of Muweilah are rectangular and host rectangular rooms (Figure 10). The buildings are all structured similarly and host three room types: an ancillary structure, a corridor and a main room. It was suggested that the ancillary structure is an open structure established for air circulation purposes (Karacic et al. 2018). The larger, columned room is separated from the smaller rectangular buildings by a wall, as it is the case in Bithnah and Masafi, too, according to Karacic et al. (2018, 52).

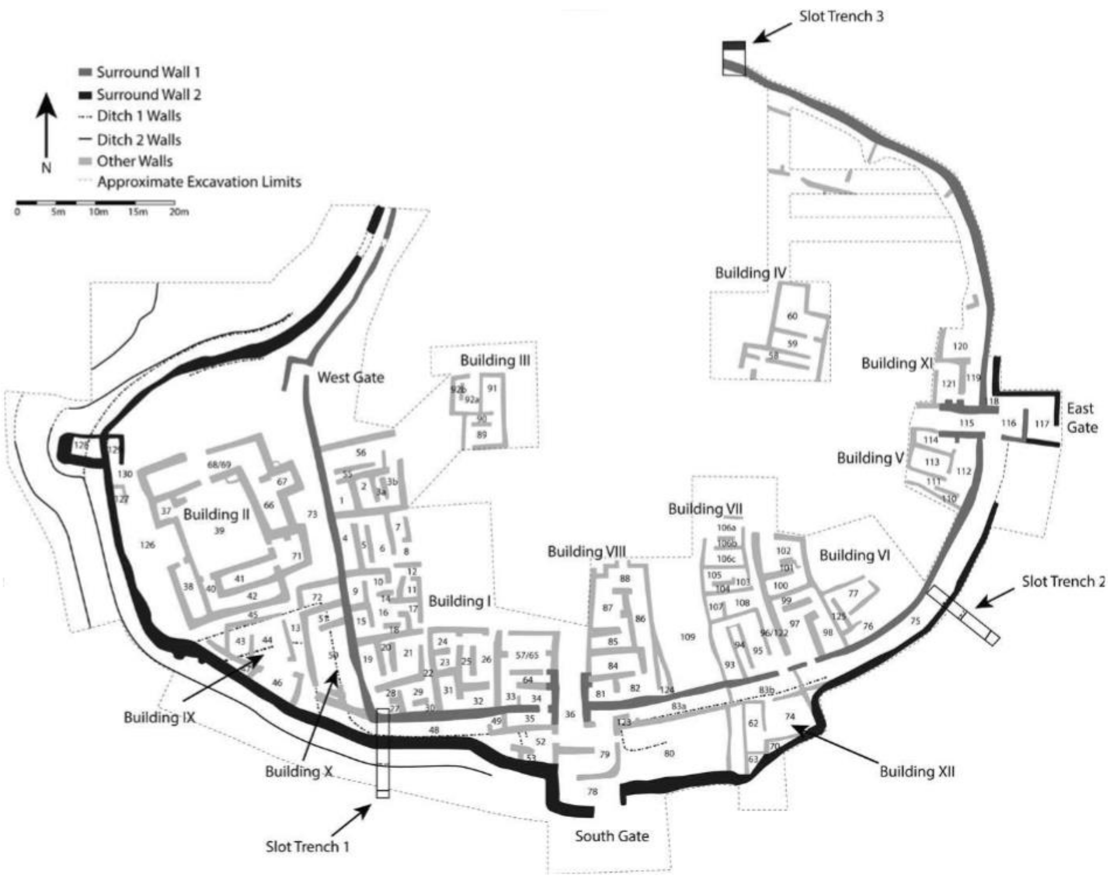

Figure 10: Map of Muweilah (Karacic et al. 2018, 29)

II.8 Columned rooms or *beyt al falaj*

Building II (on the left on Figure 10, Figure 11) holds more spacious rooms compared to the other smaller buildings and further a central room, carried by columns. Since excavating teams found traces of burning and charred beams in the construction debris, Karacic et al. suggest that the beams were made from wood (Karacic et al. 2018, 38). Three large storage jars (1m diameter) were set in the floor of the large room and further, several pits were found. Another characteristic is that another single column is often found in a smaller side room as it is the case in Muweilah (Room 71) and Rumeilah (see Figure 12). As Karacic et al. explain, similar larger columned rooms have been uncovered at Rumeilah (Building G, Figure 10), Masafi-1, Bida Bint Sa'ud, Hili (Hili 14), Thuqeibah (House H4) and Bithnah (Bithnah-44) (Karacic et al. 2018, 41).

They differ in size, structure and by assemblages found within, from the assemblages of other houses in the settlements. Bénoist discusses the purpose of the columned rooms. In her PhD dissertation, she suggested that the columned rooms could have had cultic purposes or that they represented places where community resources could have been managed. Bénoist, among others, later put forward collective and administrative functions because no religious altars, for example, where identified in the columned halls (Bénoist 2010, 109, referring to Boucharlat and Lombard 2001, Magee 2003). Al Tikriti suggests, that the columned room of Bida Bint Sa'ud, was a so called *beyt al falaj*. Members of the settlement could meet here and discuss the management and discussion of *falaj* shares (Al Tikriti 2010, 240). However, columned houses were found at Muweilah and Rumeilah – but no prehistoric *falaj* structures have been identified at the two sites. At Hili and Bida Bint Sa'ud, *falaj* structures and columned houses were identified. The purpose of the columned rooms is still debated.

Figure 11: Room 39, the columned room of building II at Muweilah (Karacic et al, 2008, 37)

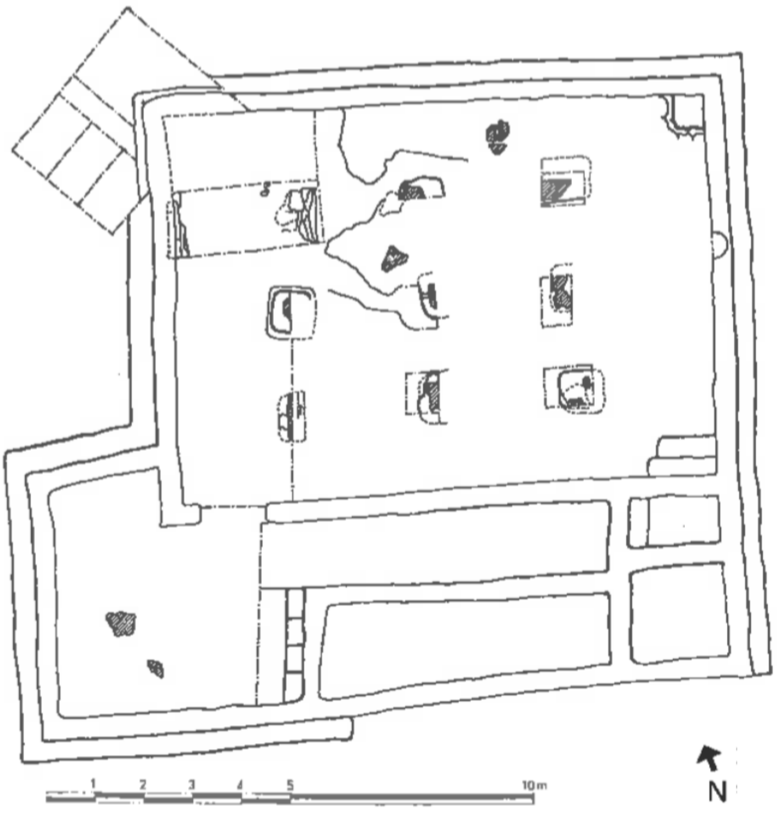

Figure 12: Building G at Rumeilah (Boucharlat and Lombard 2001, 237)

II.9 Subsistence activities and trade

Bellini et al. published a study on the palaeoenvironment and agricultural activities at the Iron Age settlement Salut. They conducted pollen analysis (Absolute pollen frequency based on grains per grams of sediment) and investigated plant-macroremains (Bellini et al. 2011, 2780). According to their pollen analysis, shrubs from the Capparacae (*Maerua*) and trees from the Leguminosae family (*Acacia, Proposis*) were growing in the surrounding. From the charcoal samples, *Ziziphus spina-christi* (jujube), *Acacia sp.* (acacia) And *Tamarix sp*. (tamarisk) are most commonly found. The three trees are common in the region and have been found in archaeological contexts of prehistoric sites, for example at Tell Abraq (Potts 2000, 69). Jujube trees are producing sweet fruits that could possibly be exploited and wood from all the tree trees was likely to be used as building material (Bellini et al. 2011, 2785). Furhermore, pollen of cultivated *Sesamum (sesame), Ocimum (basil), Triticum (wheat), Hordeum gr.* and *Phoenix dactilifera* (date palm) were part of the samples at Salut. Date palm micro- and macroremains were found all over the site at Salut. Burnt date stones have been found in two assemblages at Salut (Bellini et al. 2011, 2786), as well as in all layers at Tell Abraq (Potts 2000, 68).

Furthermore, according to Potts, domesticated wheat and barley was present at mudbrick imprints at Tell Abraq since the earliest occupation level from the early third millennium BC (Potts 2000, 66). Similarly, imprints of cereals in mudbricks from Bronze Age buildings have been found at Hili 8 (Cleuziou and Constantini 1989). These specifically and generally are controversially discussed. Firstly, because from the published pictures, it is not clear what kind of cereal is depicted and secondly if it was domesticated or not. Furthermore, it is not a sufficient indicator for practised agriculture in situ.

How can the Iron Age evidence from Salut and Tell Abraq however be interpreted and how can a better understanding of Iron Age II agriculture be developed? Firstly, it is difficult to determine from pictures whether the cereals were domesticated or not. Possibly some sort of datepalm garden agriculture was practised at Salut (Bellini et al. 2011, 2787) and Tell Abraq or in the vicinity.

A study on the dental pathologies of two Bronze and Iron Age communities in the region of Samad, an area that is located ca. 400 kilometres further southeast from the region of the four sites studied in this thesis, concluded: A high degree of caries and ante mortem teeth loss prevailed at the Late Iron Age community members. Nelson et al. suggested that a carbohydrate-rich diet, for example based to a large extent on dates, could have led to the pathologies observed (Nelson et al. 1999, 335-342). To conclude, analysis of micro- and macroplant remains (Bellini et al. 2011, Potts 2000, 68), dental pathologies (Nelson et al. 1999, Littleton and Frohlich 1993) and further, groundstones (Davis 1998), is available, but it is yet not clear how to draw the evidence and these analyses together to come to a good understanding of Iron Age II agriculture and subsistence.

Subsistence activities differed regionally. Uerpmann states that cattle, fish and dromedary bones were found at Tell Abraq. Less sheep bones than in the Iron Age I and Bronze Age layers were found in the Iron Age II layers. Dromedary bones were smaller than comparative Bronze Age material from Tell Abraq and clearly showed morphological signs of domestication (Uerpmann 2001, 229-232). Magee argues, *falaj* irrigation and the domestication of the camel decisively drove the settlement intensification during the Iron Age II millennium BC (Magee 2014, 214). The camel as a means of transportation facilitated trade and exchange between the communities in the coastal, mountaineous and desert areas. As sherds from several regions in Southeastern Arabia, from sites at Bahrain and Mesopotamia were found at Muweilah, Magee argues that Muweilah was an influential economic 'hub' in the Iron Age II trade network (Magee 2004, 36-41).

II.10 Pottery

Generally, local potteries produced two different types of pottery in the Iron Age II: the *fine red painted* and the *sandy buff* ware. Other types found within Iron Age II contexts are the *white-gritty* ware and *mineral-gritted* ware, green buff ware and *light orange buff* ware. Vessel forms and decoration styles are often similar, whereas the composition of the fabric varies to different degrees. Common forms are bowls, large open vessels, small jugs, brigde-spouted vessels and large storage jars (Bénoist 2008).

Fine red painted ware has a clear red paste and sometimes has a grey core as a result of oxidation while burning. Sherds are hard and compact. From pottery samples of fifteen Iron Age sites generated by Sophie Méry, most red painted ware fragments derived from bridge-spouted jugs and small bowls, decorated with geometric motifs in black or red black (Figure 13). The fragments were found in collective reunion halls, dwellings and burial contexts in Muweilah, Building G in Rumeilah and Masafi-1. Bénoist and Méry suggest their use for consumption due to their find contexts and shapes (Bénoist and Méry 2012, 76). The production centres of the fine painted ware vessels are still debated. *Fine red painted* pottery yet appears earlier in central Oman, at Salut and at Lizq at 1300 and 1200

BC, before it appears further North at Muweilah and Rumeilah. Therefore, Bénoist and Méry suggest a production centre and origin of the vessels in central Oman (Bénoist and Méry 2012, 88).

Figure 13: Fragment of a bridge spouted, decorated vessel and depiction of entire vessel (A.1451, Rafaq -1) (from Bénoist and Méry 2012, 77)

A second vessel commonly found in Iron Age II assemblages is the *sandy buff* ware type (Figure 14). It has a light-coloured paste. There are two variants: One with a light temper, used for small vessels, such as small jugs, bowls and spouted jars and a second variant with red inclusions and a coarser temper, used for jars and open bowls. Petrogaphic analysis of the samples lead to the result that a group of *sandy buff* ware produced in the region of Al Ain, was identified at Al-Madam, Kalba and Muweilah, however, *sandy buff* ware type fragments with a different composition have been identified at Hamriya, Rafaq and Muweilah (cf. Figure 2), therefore, Bénoist and Méry conclude that vessels of the *sandy buff* ware type circulated from the Al Ain region to other settlements.

Figure 14: Fragment of a large open vessel (A.1431, Al-Madam, Thuqeibah) (Bénoist and Méry 2012, 79)

The *common orange ware* appeared in the Iron Age III (Figure 15). The clay contains some ultr-basic and basic minerals, which suggests its origin from mountaineous regions. Fragments were found at the fortress of Husn Madhab and in burial contexts at Fashga- 1, Rafaq-2 and the Wadi Al Qawr. They are dated either to the End of the Iron Age II or to the Iron age III period. Bénoist and Méry suggest the shift of trade networks and the preference of orange colour, as explanations for the emergence of the common orange ware (Bénoist and Méry 2012, 80).

Figures 15: Fragment of a bowl. Sherd A. 1438 from the sample, Rumeilah II (Bénoist and Méry 2012, 83)

Coarse Iron Age II pottery from the samples taken by Anne Bénoist and Sophie Méry (Figures 16 and 17) are heterogeneous in terms of the texture and colour of the paste, the nature of the added minrals and the presence or absence of vegetable temper. Vessel can be decorated and incised and usually have thick walls. Vessels are for example storage jars or basins. Bénoist and Méry recognize similarities between the coarse and sandy buff ware and considering the fact, that most sherds have been collected in the Al Ain region (Rumeilah I, Hili 17, Bida bint Sa'ud), they suggest that local inhabitants produced coarse vessels in the same workshops as the sandy buff ware by adding coarse sand (Bénoist and Méry 2012, 82).

Figures 16 and 17: Fragment of a jar from Husn Madhab (A.1458) and fragment of a holemouth jar from Rumeilah (A. 1414) (Bénoist and Méry 2012, 83-84)

To sum up, the majority of the retrieved Iron Age II pottery is likely to be produced locally in Southeastern Arabia. It is wheel-made. The *red painted* ware was produced in central Oman (Bénoist and Méry 2012) as confirmed by petrographical analysis. By petrographical analysis, the distribution of vessels from the Al Ain area towards other areas could be confirmed.

III. Theory and examples of irrigation systems, debates in Arabian Archaeology and methodology

This chapter contextualizes this research in the wider field of research on irrigation activities in archaeology. Secondly, it introduces different types of irrigation technologies that are present in the archaeological record of the Southeastern Arabian Peninsula. Thirdly, different positions within Arabian Archaeology on Iron Age II irrigation systems are assessed. Finally, the methodolody of this thesis is discussed.

III.1 Theoretical approaches to irrigation

As Uphoff showed by comparing several ethnological studies, several tasks come into play when groups of humans irrigate (Table 3). Research questions can approach the different characteristics of irrigation systems or techniques. Specifically, *qanat*-type *falaj* irrigation in Southeastern Arabia was researched extensively by Wilkinson in the 1970s (Wilkinson 1977). He investigated how communities were running *qanat*-type *falaj* irrigation systems and which roles, that were tied to specific tasks, were held by community members while irrigating (Wilkinson 1977).

Hunt and Hunt 1976	Coward 1979	Kelly 1983	Freeman and Lowdermilk 1985	Uphoff 1986
Acquisition	Acquisition	Aquisition	–	Acquisition
Allocation	Allocation	Allocation	Allocation	Allocation
–	–	Delivery	–	Distribution
–	–	Drainage	Drainage	Drainage
–	–	–	–	Design
Construction	–	Construction	Construction	Construction
–	–	Operation	–	Operation
Maintenance	Maintenance	Maintenance	Maintenance	Maintenance
Decision-making	–	–	–	Decision-making
Resource mobilization	Resource mobilization	–	–	Resource mobilization
–	–	–	–	Communication
Conflict resolution	Conflict resolution	Conflict resolution	Conflict resolution	Conflict management

Table 3: Tasks related to water management and irrigation from comparative ethnological studies (Uphoff 1986)

Perhaps one of the best-known cultural historical theories on irrigation was put forward by Wittfogel based on Marxian and Weberian approaches (Wittfogel 1957, 5-7). Thereby Wittfogel mainly focused on organizational, institutional, economic, power- and class-related aspects of irrigating groups or communities to eventually characterize a type of “hydraulic society” or “hydraulic civilization” (ibid, 3). His theory is not centrally relevant in this thesis, because I am focusing on aspects of location, technology and dating methods and I am excluding aspects of task organization while irrigating because this is a limited study. Secondly, overarching state-like structures did however not exist in the Arabian Iron Age II. There was not a centrally organised ‚state‘, which coordinated for example trade movements. Some settlements can better be regarded as ‚hubs‘: The Peninsula was well connected between the inland and the Iranian coast (Magee 2004) and similar ways of producing pottery and presumed ritual activities, the snake cult (Bénoist 2007), were shared. It seems that then irrigation systems developed as a regional technology built by skilled workers which exploited the local environmental conditions. As discussed earlier, a certain form of organizational hierarchy might have existed if one considers evidence from the columned houses at several Iron Age II settlements (Bénoist 2010, Al Tikriti 2010). Yet, Iron Age II irrigation systems thusfar seem to be rather small-scale technologies that were perhaps locally managed.

It was looked at how different irrigation technologies can be grasped theoretically. Now, different technologies of irrigation, which are applied at sites on the Southeastern Arabian Peninsula will be addressed. Nine different technologies are discussed according actual evidence from the Iron Age II and regarding their presence in the archaeological record of the region of research, stretching from the Batinah hinterland to the Hajar mountains. After each discussed technology I will close with mentioning how evidence for the respective technology can appear in the archaeological context.

III.2 Goundwater irrigation: wells for irrigation purposes

a) Hand dug wells

How a well functions, is described easily: A hole is dug in the ground and an aquifer is tapped. Water then needs to be carried up to the surface against the force of gravity. This is possible by means of man- or animal power and since the 19th century, by means of electric pumps. The second step then is to carry the water to the fields. This is possible by means of carrying utensils. As Costa and Wilkinson state, hand dug wells are usually used for domestic purposes or to irrigate small kitchen gardens today in the Batinah region of Oman (Costa and Wilkinson 1987, 39).

In the archaeological record, wells can show as upcast (Costa and Wilkinson 1987, 43-78, Wilkinson 2003, 67). Costa and Wilkinson identified simple mounds as former hand-dug wells and complex mounds, as former animal powered wells. Trial excavations of four mounds confirmed their hypothesis. Following this hypothesis, Costa and Wilkinson identified 124 wells in a confined area in the Batinah hinterland, which appeared as simple mounds on the surface. They dated the wells to the period between the ninth, up until the eleventh centuries AD, due to scattered pottery evidence (Costa and Wilkinson 1987, 46-53). Because neither domestic layers were found in the trial excavations, nor domestic traces on the surface, the authors claim that the wells were used for agricultural purposes.

b) *zajarah* wells

A more common way to irrigate fields in the 1900s on the Batinah coast is irrigation by means of animal power. In Southeastern Arabia these types of wells are called *zajarah* wells. They function as follows: A regular well is dug. Secondly, a wooden scaffold or masonry building is built next to the well. Then, one end of a rope is tied to a carrying utensil, for example a leather bag or bucket (Figure 18). The other end of the rope is tied to the harness of an animal, for example of an ox or a donkey. The rope runs via a weel, that is attached to the scaffolding. By having the animal walking away from the construction (Figure 19), the carrying utensil is carried up to the surface. Once the carrying utensil reaches the surface, the water pours into a channel or catchment basin. The water the flows via the channel towards the fields and the irrigation process begins. The animal turns and the carrying utensil is again pulled towards the ground of the well. In the archaeological record, *zajarah* wells can occur as complex mounds on the surface.

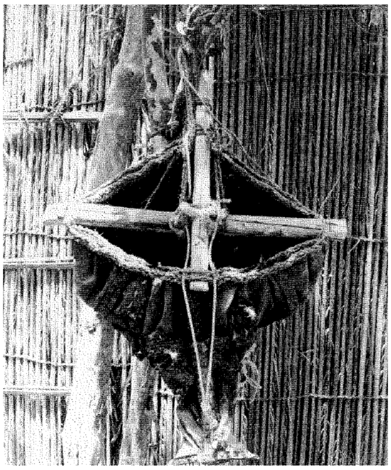

Figure 18: Leather bag from a *zajarah* well (Costa and Wilkinson 1987, 38)

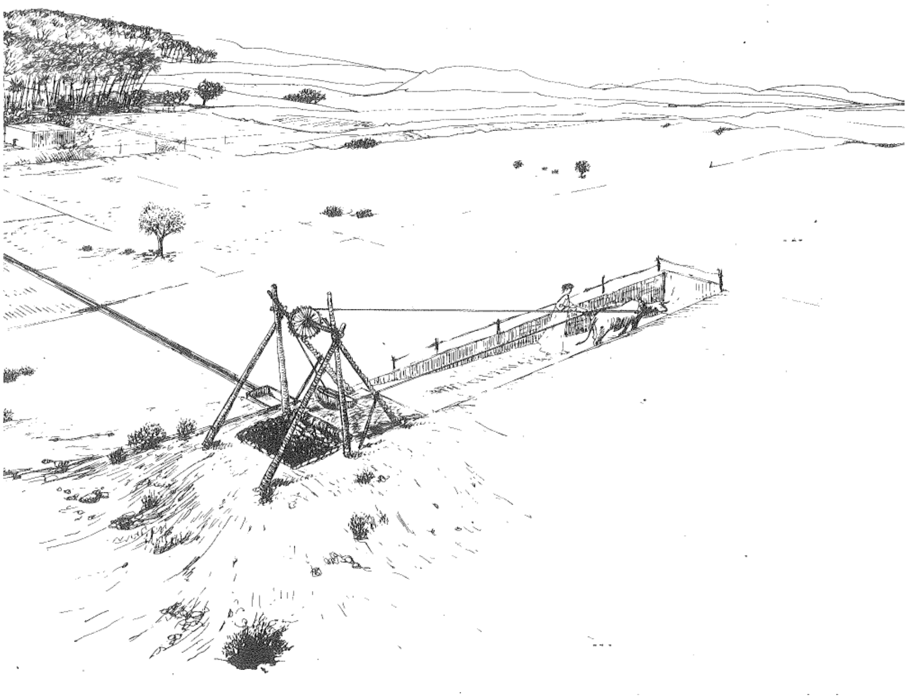

Figure 19: Drawing of a *zajarah* well (Costa and Wilkinson 1987, 40)

The trampled paths of animals can appear as upcast mounds on the ground surface (Figure 20). Costa and Wilkinson dated several *zajarah* wells to the 17-20th centuries by surface pottery. There is yet no evidence of animal powered wells from earlier periods (Costa and Wilkinson 1987, 58). Costa and Wilkinson put forward the hypothesis that distance between wells could indicate the size of the irrigated fields: The larger the distance between wells, the larger the fields. Secondly, the larger the fields, the more likely were they irrigated by means of animal powered wells instead of hand dug wells, because a larger amount of water could be carried to the surface by means of animal power in an easier way. However, they could not confirm their hypothesis with evidence from modern *zarajah* irrigation in the Batinah region, because irrigation was conducted irregularly and only parts of field areas were irrigated, not entire fields, according to Costa and Wilkinson (1987, 52).

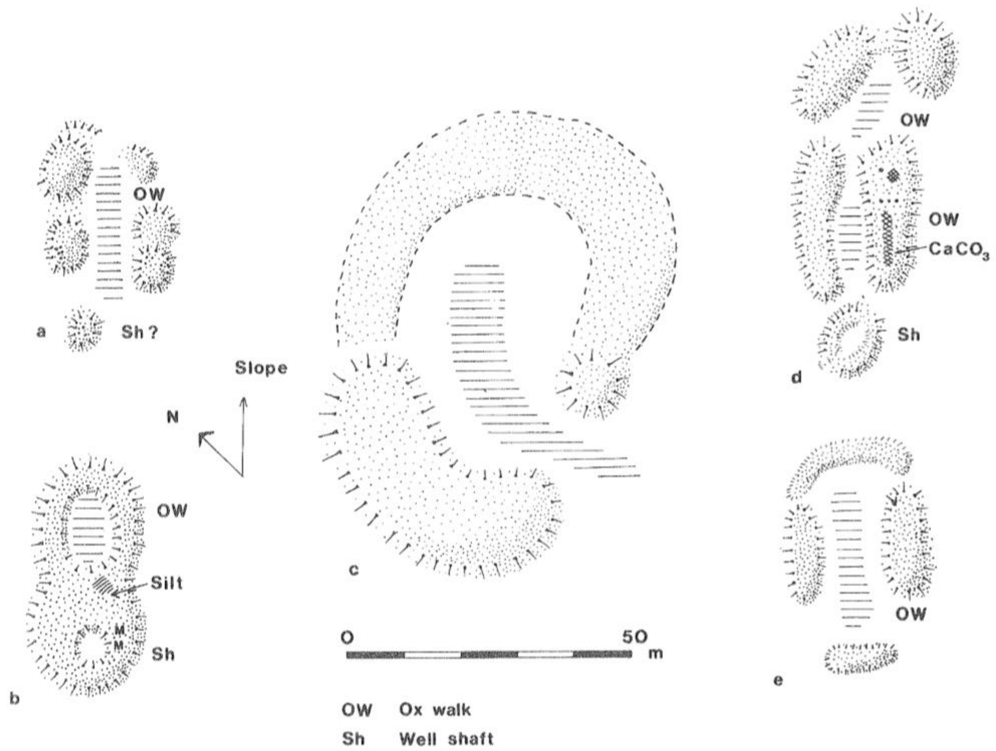

Figure 20: Drawing of complex mounds and potential *zajarah* wells (Costa and Wilkinson 1987, 44)

c) Munzifah or *shaduf* wells

When operating a *munzifah* or *shaduf* well, a rope with a bucket is fixed at one end of a pole and a counterweight is fixed at the other end of the pole. The pole is attached to a supporting scaffolding or pole. Water users lower the bucket by pulling on the rope and push the counterweight down to lift the bucket up to the surface (Figure 21).

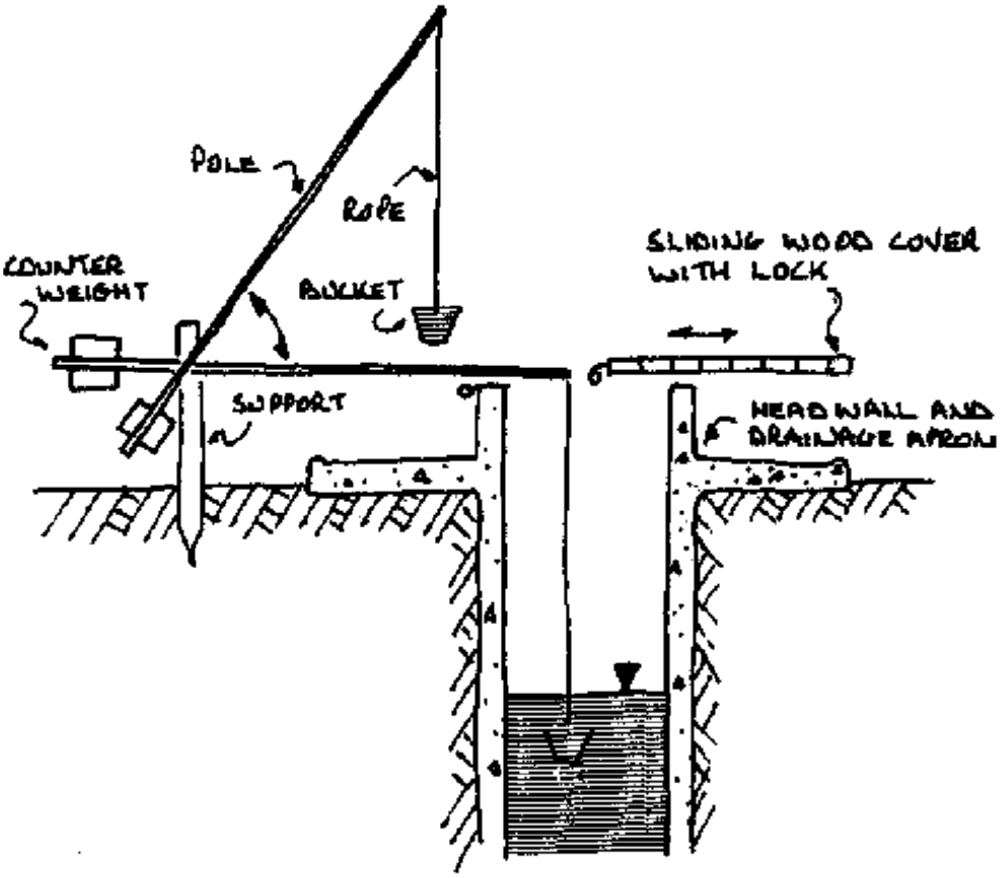

Figure 21: A *shaduf* well (Watt and Wood 1979, 30)[5]

One example of an actively used *munzifah* well was identified by Costa and Wilkinson in 1975 in the Batinah region (Costa and Wilkinson 1987, 41). In the archaeological record they could show as simple mounds with some sort of soil upcast next a mound (Costa and Wilkinson 1987, 39). If *munzifah* wells were used at an earlier point in the region prior to 1975, is not known.

[5] The drawing shows a *shaduf* well in Thailand. Wells that function based on this technique or by the same principle, were built in different countries and regions and carry different names.

III.3 Qanat-type *falaj* systems

Furthermore, the technology of the *qanat*-type *falaj* system was applied. There are different ways of building a *qanat*-type *falaj* system. Members of the ‘Awamr tribe, who live in the region around Izki in the Sharquiah region of the Sultanate of Oman [6], begin the building process by constructing shaftholes. From the access shafts, the channels are dug and carved into the local stone. From there, the channel is dug upstream. The gradient of the channels is levelled by eyesight with an ideal gradient of 1 in 100. The properties of the local rock layers are prioritized to the ideal course of the channel. The diggers work with hammer and chisel. The harder the stone, the smaller the dimensions of the access shafts and channels or differently put, the dimensions of the *falaj* systems vary according to the hardness of the stone (Birks and Lett 1976, 96).

The underground gallery is carved into the ground or built underground. It is necessary that the underground gallery lightly slopes, so the water can run by gravity with a small gradient towards the fields (Figure 20). Several shaftholes are running from the underground channels towards the ground surface. On the Arabian Peninsula these shaftholes are called *thugba* (pl. *thugab*). The underground water gallery then usually ends in a dispatching basin which in southeastern Arabia is called *sha’ria*. From there, several subchannels run towards the irrigated fields. This *qanat*-type *falaj* system, is in Southeastern Arabia also called *Dawoodi Falaj* (Figure 22). Other types of *falaj* systems are *Aini Falaj* and *Ghaili Falaj* systems. *Aini Falaj* systems (Figure 23) tap springs and Ghaili *Falaj* systems (Figure 24) tap water from wadis. Both transport the tapped water via open surface canals to fields or gardens.

[6] Most of the skilled *falaj* and well diggers are living in the vicinity of the settlements Adam, Al Ayun and Mudhaybi in the Sultanate Oman. Some dispersed communities are living in the Batinah region. The building of wells requires less diggers (2-3) and time (3-4 days) in the Batinah region, than in other regions of the Sultanate further inland, where the soil is not as loose and the water table as not as shallow (Birks and Letts 1976, 93). Due to dangers of snake bites, masonry and roof falls and potential bad consequences for the ones entering, as local community members believe, the digging of *falaj* systems can be and is regarded as a dangerous task. Therefore the ‚Awamr tribe had a monopoly in their field, according to Birks and Letts (Birks and Letts 1976, 96).

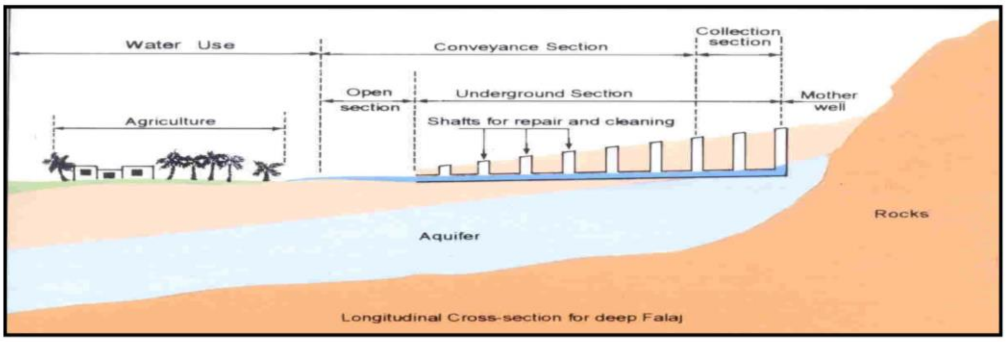

Figure 22: A *Dawoodi Falaj* system (MRMEWR 2001)

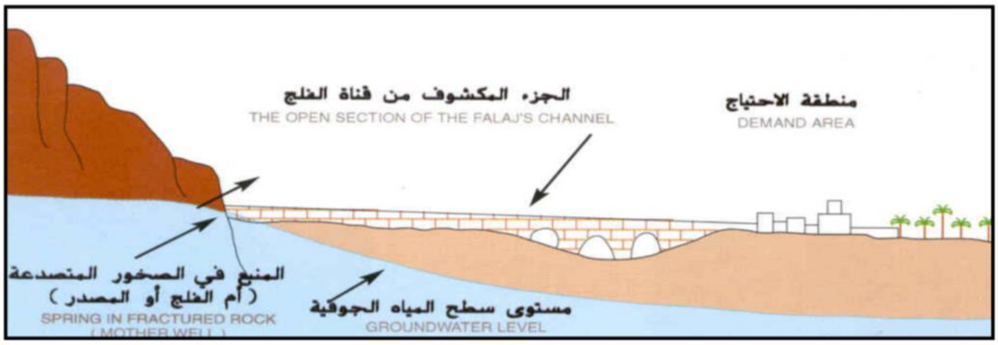

Figure 23: An *Aini Falaj* system (MRMEWR 2001)

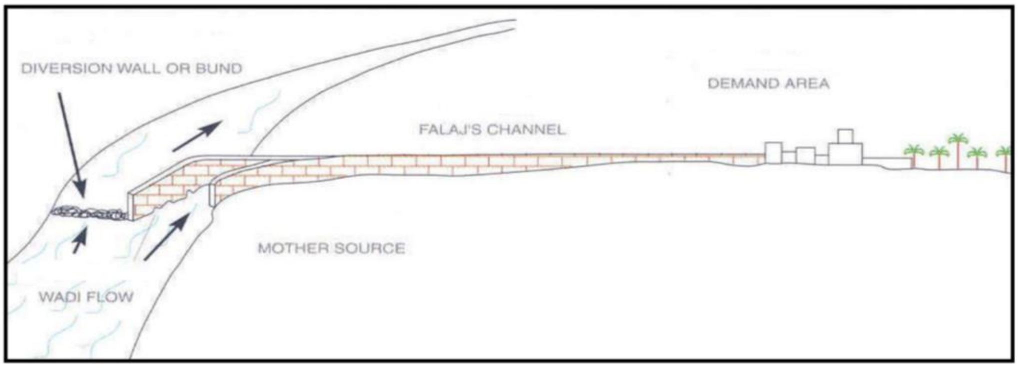

Figure 24: A *Ghaili Falaj* system (MRMEWR 2001)

III.4 *Gharrag Falaj*

Gharrag Falaj is the description for a part of a *qanat*-type *falaj* system. Its function is to guide water below the ground across a wadi (see Figure 25). *Gharrag Falaj* have been dated only to historic periods and are mentioned here, because they are present in the Batinah region, and therefore in the research area addressed in this thesis.

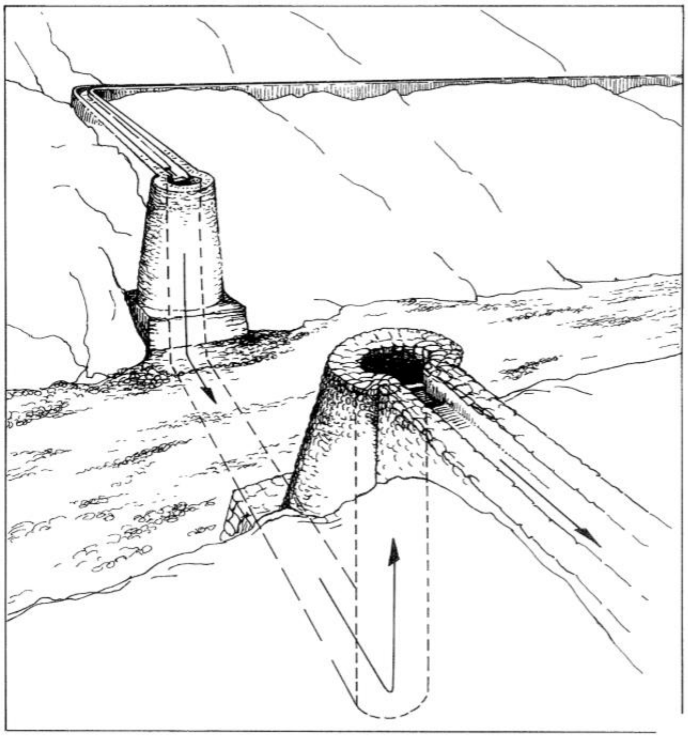

Figure 25: Drawing of a *gharrag falaj* in the Batinah hinterland (Costa 1983)

III.5 Ground- or surface water irrigation: Runoff irrigation

Barrow suggests to define runoff irrigation as the following: “Runoff agriculture effectively uses moisture which would otherwise run to waste” (Barrow 1999, 7). Several techniques can be subsumed under the term runoff irrigation: Water floods from precipitation, water from flowing water bodies (streams or wadis) or from springs that are either used for irrigation *in situ* or transported to a different location, where a field or garden is irrigated. Dams are used to keep the water; they can be made from earth or dry stone. Dug canals or earthen bunds can transport the water to fields (Costa and Wilkinson 1987, 35-36).

One example of runoff irrigation during the Iron Age II is found at the oasis of Masafi (U.A. E.). Runoff floodwater from a hill north of the site was channeled towards palm gardens (Charbonnier et al. 2017; case study three of this thesis). Further archaeological examples of runoff irrigation are found on the Musandam Peninsula and on some locations in the Jebel Akhdar mountains (Costa 1983, 88-89, Costa and Wilkinson 1987, 35-36). Modern examples of water collection by means of runoff irrigation are found today in the Eastern Hajar mountains (Rizkh and Alsharhan 2003, 246-247).

Gabarbands or barrages

Gabarbands are dams made from earth or stones, which enable runoff irrigation (Baloch et al. 2016, 8-10). *Gabarbands* and dams have the same function: blocking water *in situ* or channeling it to another location They can be located next to wadis or on hillsides.

Three linear stone walls, identified as *gabarbands* and potentially channelling runoff water, have been identified by Hastings et al. at the Bronze Age sites of Wadi Samad 4 and Wadi Samad 5 in the Southeast of the Sultanate of Oman (Hastings et al. 1975, 18-19). As the *gabarband* at Wadi Samad 4, they can be combined with irrigation systems in order to irrigate the same field.

III.6 Transporting water: mills

Like *gharrag falaj*, water mills have only been dated to historic periods thusfar, but are mentioned because they are found in the research area of this thesis. Costa and Wilkinson identified five mills as part of the Falaj al Mutaridh (Costa and Wilkinson 1987, 56-57). The *arubah penstock* mill (Figure 26) was very common in the 11th and 12th century AD in Southeastern Arabia and was not regularly built later (Costa and Wilkinson 1987, 63). Here, water from a canal flows on a horizontally operating wheel. The wheel turns by water pressure (see Figure 27). It is an efficient technique when irregular, limited waterflow is available, because water flow can be further regulated by adjusting the nozzles (No. 24 and No. 25 on Figure 27) (Avitsur 1960, 45). Furthermore, construction and repair of the mill were simple (ibid, 45).

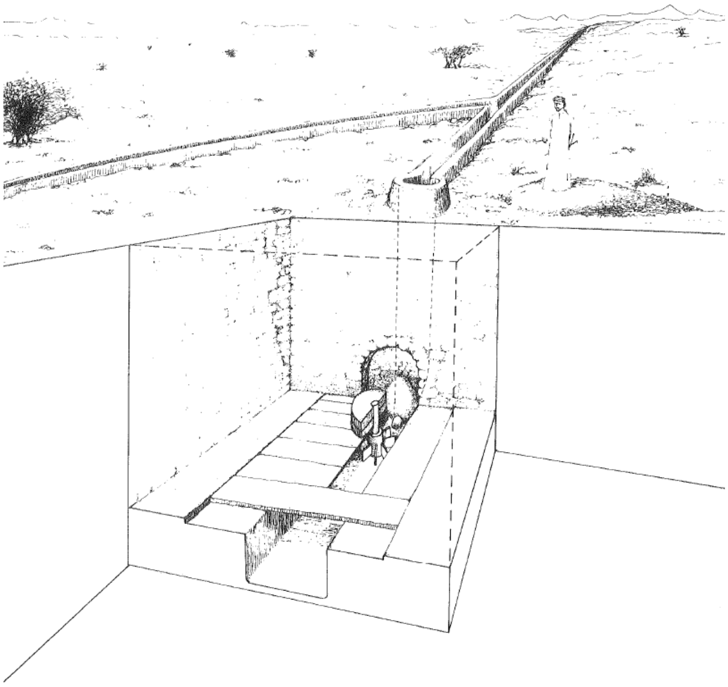

Figure 26: Drawing of an *arubah penstock* mill in the hinterland of the Batinah coast. (Costa and Wilkinson 1987, 72, Drawing by L. Couvert)

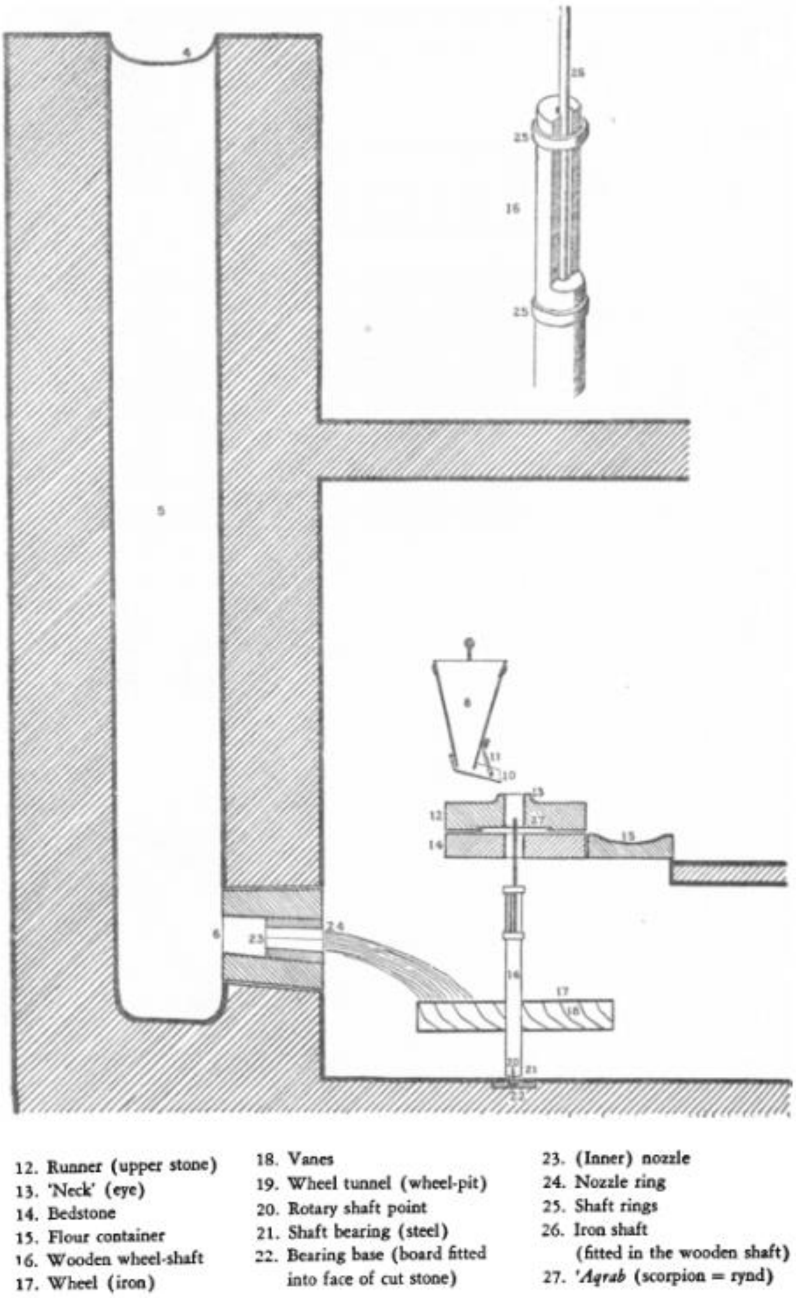

Figure 27: Sidecut of an *arubah penstock* mill (Avitsur 1960, 43)

III.7 Collecting water: Cisterns

Cisterns enable storing and conserving rainwater or groundwater. Canals can lead from the cisterns to agricultural fields (Figure 28). Cisterns can secondly occur as storage units as part of a *qanat*-type *falaj* system, as it is the case at the *falaj* system at Bida Bint Sa'ud, which is dated to the Iron Age II period based on surface pottery. Al Tikriti suggests, that as the groundwater table decreased during the Iron Age II, a cistern was built by the community members to collect the water (Al Tikriti 2010).

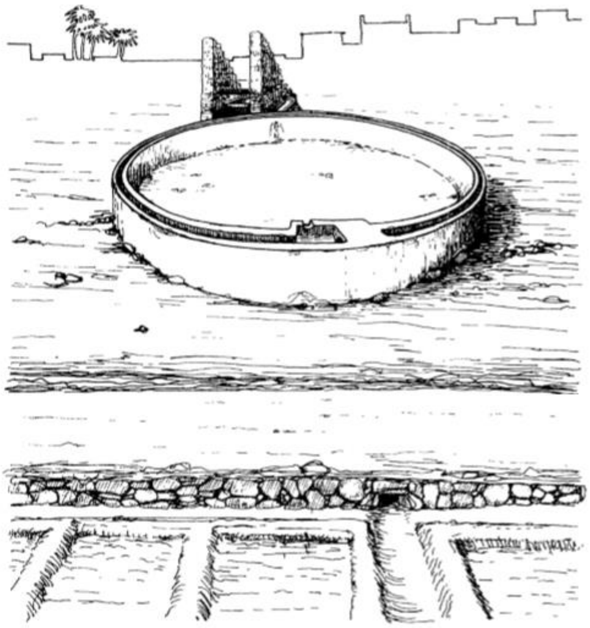

Figure 28: Drawing of a cistern and subchannels leading to fields near Nizwa (Costa 1983, 287)

Nine technologies of storing and transporting rain- and groundwater for irrigation purposes have been discussed. In the following part, different positions on the subject of irrigation technologies during the Iron Age on the Southeastern Arabian Peninsula will be introduced and discussed.

III.8 Debates in Arabian Archaeology

To contextualize this research with ongoing related debates in the field of Arabian Archaeology, I will discuss in this section three debates: The origin of the qanat-type irrigation system, dating and impacts of the technology.

Origin of the *qanat*-type irrigation system

Several authors put forward the hypothesis that the *qanat*-type irrigation technology was introduced to the Southeastern Arabian Peninsula by the Achaemenids (559-330 BC), arriving from the modern Iranian coast (English 1968, Lightfoot 2000, Wilkinson 1977). That knowledge on *qanat* construction existed is historically attested by an inscription of the Assyrian King Sargon II (722-705 BC) on a clay tablet, in which he states to have learned about the technology of tapping groundwater and using it for irrigation purposes from the Persians. Later, his son built a water supply by means of a *qanat*-type irrigation system for the palace at Niniveh (English 1968, 218).

Lightfoot suggests, that the flourishing of the Southeastern Arabian Iron Age settlements coinicides with the conquest of Cyrus the Great (536 BC) and that its likely that the *qanat*-type irrigation technology spread at this time on the Southeastern Arabian Peninsula (Lightfoot 2000, 221). He states furthermore that some *qanat*-type irrigation systems might have been built prior at around 1200 BC as a result of trade relations, probably with Persia (ibid). He locates the origin of the *qanat*-type irrigation system in modern Iran. Al Tikriti on the contrary suggests, that the system originates in southeastern Arabia. He dates the first *qanat*-type *falaj* systems on the Southeastern Arabian Peninsula at Bida Bint Sa'ud, Hili and Jabeeb to the Iron Age and states that the first evidence in southern Persia dates to the Sasanian period (Al Tikriti 2002, 353).

Orchard and Stanger developed a hypothesis on irrigation activities by tapping groundwater aquifers in the Al Hajar region during the final centuries of the third millenium BC at the Bronze Age structures at Hili 8 and Bat. Their argument: As rainfall was unreliable, flashfloods occurred and no permanent surface flow was available. Therefore, water provision had to rely on groundwater aquifers. Secondly, Orchard and Stanger argue that perennial and annual crops were harvested in the Al Hajar region. They suggested that first, agriculture was practised, secondly that irrigation was conducted at Bat and Hili and that thirdly, a canal system tapping an aquifer, was installed in order to irrigate the cultivated fields (Orchard and Stanger 1994, 87). Orchard and Stanger compare their hypothesis with archaeobotanical evidence from closeby Hili.

At Hili, mudbrick imprints and a small amount of charred seeds of wild (*Hordeum vulgare*) and domesticated barley (*Hordeum distichum*), domesticated wheat (*Triticum aestivum*), Emmer (*Triticum dicoccon*), domesticated sorghum (*sorghum bicolor*), of melon (*cucumis sp*.) and dates (*Phoenix dactylifera*), as well as wild oat grains (*avena sp.)* have been identified at Hili 8 in layers dating to 2500 BC (Cleuziou and

Constantini 1989, 79-80). From this evidence, Cleuziou (1989, 80) suggested, that a kind of irrigation and agriculture was conducted at Hili 8 in the mid third millenium BC. However, Cleuziou and Constantini (1980) state, no irrigation structures were identified. The mudbrick imprints from Hili 8 are controversial subject to debate because the imprints few charred seeds and mudbrick imprints alone, are not sufficient evidence for practiced agriculture at the site.

Later, Orchard and Orchard (2007) published an article on a *falaj* system, identified at Bahla (Sultanate of Oman), which they dated to 3000 BC, which is the earliest date suggested for a *falaj* system in southeastern Arabia until now. I do not have access to this publication; however, it was strongly critized by Charbonnier (2015). According to Charbonnier who refers to Orchard and Orchard (2007), the evidence consisted of a tunnel and an open surface channel, that was crossed by several small ‘brigdes’. The tunnel cuts a ditch, that surrounds a circular mound. The mound was covered with Bronze sherds and thereby dated to the Bronze Age. Similar Bronze Age towers surrounded by ditches were found at Hili (Cleuziou 1989, 63-66) and Bat (Desruelles 2016, 42). Two Radiocarbon samples were furthermore taken: One from a hearth, partly dug in one of the ‘brigdes’ and part of the fill and a second sample from a hearth in the fill. The hearths dated to 2910-2850 cal. BC and 2620-2470 BC. Secondly, Bronze Age sherds were found in the filling (cf. Charbonnier 2015, 47). Charbonnier critises that first, the stratigraphic relationship between the ditch, the tunnel and the hearth on the ‘brigde’ is unclear, as the description is not clear and no pictures were provided by Orchard and Orchard. It remained unclear which feature cut which – the ditch the gallery or the gallery the ditch. Charbonnier secondly questions the dating of the filling, as Bronze Age material could have been falling inside the tunnel, which could date to a later period instead. It is difficult to take a stance on the evidence at Bahla without having assessed the original article and the evidence, but as there is yet no evidence at Bahla for a systematic stratigraphy of the structures and since furthermore, no evidence of a *falaj* system dating to the Bronze Age which could render the dating of the Bahla *falaj* possible, the evidence for *falaj* irrigation at

Bahla seems not likely so far. The first *falaj* irrigation systems, that are dateable to prehistoric periods, are the systems at Hili, Bida Bint Sa'ud and Al Madam.

Dating

Al-Tikriti suggests that the *qanat*-type *falaj* system was firstly built on the Southeastern Arabian Peninsula during the Iron Age II (Al-Tikriti 2002). He bases his argument on evidence from four *qanat*-type irrigation systems, which he and his team excavated: The *qanat*-type *falaj* systems at Hili, Bida Bint Sa'ud, Jabeeb and Umm Safah. At Hili 15 and Bida Bin Sa'ud, Iron Age II pottery sherds were found within the *falaj* structure and associated with it. The *falaj* system at Jabeeb was dated by Al Tikriti to the Iron Age, based on surface pottery (Al Tikriti 2002).

Charbonnier stated that securely dated *qanat*-type *falaj* systems do not appear before the Islamic period (Charbonnier 2015). He critiques the insufficient absolute dating of *falaj* systems that are mostly only associated with Iron Age II structures and material (Charbonnier 2015 and Charbonnier 2019). However, considering the evidence of suggested Iron Age II *falaj* systems at Al Madam (Del Cerro and Cordóba 2018; see case study IV.2 in this thesis) and at Hili (Al Tikriti 2010; see case study IV.1 in this thesis) and considering evidence of groundwater exploitation by means of wells and workshop areas, as at Al Madam, it is possible that the falaj technology was introduced during the Iron Age II (Charbonnier 2019, 232-236).

Magee accepts the Iron Age dating of *falaj* systems at Hili 15, Bida Bint Saud, Jabeeb, Al-Ayaay, Dharhet-Al-Hasa, Al Madam and near Salut at Wadi Bahla (Magee 2014, 216-217). Al Tikriti supports the same evidence (Al Tikriti 2010). Dating of irrigation systems remains a difficult subject because some systems are reused in later periods and secondly, few absolute dates from e.g. charcoal or shells found in situ, are available. Thirdly, dateable material can have fallen into the canals at a later point or during repair works, which makes it difficult to find reliable dateable evidence.

Impacts

Magee argues that the innovation of the *qanat*-type *falaj* system, along with the use of the dromedary as means of transportation, drove the settlement increase in the second millenium BC considerably (Magee 2014, 215). Al Tikriti similarly argues, that the invention of the *qanat*-type *falaj* system effected the location of the Iron Age II settlements. He states that Iron Age II settelements were built further West in the U.A.E. than earlier Bronze Age sites and secondly, that the distance between coastal and Inland Iron Age sites is quite small – therefore seasonal movement between coastal and Inland sites is likely (Al Tikriti 2010, 238-239).

III.9 Methodology

This final part addresses the methodology. First, the archaeological evidence which will be assessed and secondly how it was recorded, is presented. Secondly, why literature review is a suitable approach to answer the research questions, will be discussed. The research aims are presented and how to reach them is discussed. To conclude, the strengths, weaknesses and limitations of this methodology will be discussed.

Archaeological evidence

The evidence will be discussed along four case studies: The *qanat*-type *falaj* system H15 at Hili, north of the modern oasis of Al Ain/Buraimi (U.A.E.), the *qanat*-type *falaj* system AM-2 on the Al Madam plain (U.A.E.), the canal system B1 and B2 at Masafi (U.A.E.) located in the Northern Hajar Mountains and agricultural fields (S48) in Wadi Fizh in the hinterland of the Batinah coast (Sultanate of Oman) (Figure 29). To sum up, the archaeological evidence includes *qanat*-type *falaj* systems, furthermore two canals at Masafi and fields at Wadi Fizh.

Figure 29: The four sites and case studies: Hili 15, AM 2, Canals A and B and S48

Recording

This thesis is a literature review. Archaeological evidence from reports and publications, recorded by several teams according to their methodologies is discussed. An introduction to the four sites, a brief research history and the research methodologies of the teams will introduce each case study.

Methodology of this thesis

The case studies will be discussed along three research questions addressing location, size, archaeological dating. The results will be compared among the four case studies and with positions from Arabian Archaeology in order to see, how irrigation activities in the Iron Age II can be characterized and how the different datasets can be compared. Therefore, this thesis is a systematic assessment of the four case studies and different positions held in Arabian Archaeology, in order to understand if and which irrigation technologies were applied by Iron Age II communities.

Strengths of the approach

A large amount of literature on prehistoric irrigation in Southeastern Arabia has been published during the past 40 years (Lightfoot 2000, Al Tikriti 2010, Magee 2014, Charbonnier 2015, Charbonnier et al. 2017). The debate is ongoing. Here, known and new evidence (S48, Al Madam) is reviewed and (re-)assessed. A recent synthesis of these different positions and evaluation of known and new evidence can add to the debate, so hypotheses can be refined and developed.

Limitation of the research design

It will be insightful to include research questions on social and organizational aspects of how Iron age II irrigation was conducted by community members. Were different roles for maintenance and and management tasks held by community members to keep the *falaj* systems at Hili and Al Madam running? Was there a form of hierarchy involved? These questions can hardly be answered due to the scarcity of evidence and including these aspects in the discussion will exceed the limitations of this research. Turning to the four irrigation systems at Hili, Al Madam, Masafi and Wadi Fizh, the research questions will be discussed in the following chapter four.

IV. Irrigation in four regions

In this chapter, I will discuss four sites where communities conducted irrigation activities. The first case study is the *qanat*-type irrigation system H15 at the oasis of Hili. A second *qanat*-type system, AM 2, at the Al Madam plain is addressed as second case study. Thirdly, I address evidence for runoff irrigation at Masafi. I will assess the case of manual irrigation of the fields at Wadi Fizh as a fourth case study. I will pose the three research questions in each case study. Eventually, I will draw conclusions from there and I will link the results back with different positions in Arabian Archaeology on the subject of prehistoric irrigation.

IV.1 Hili

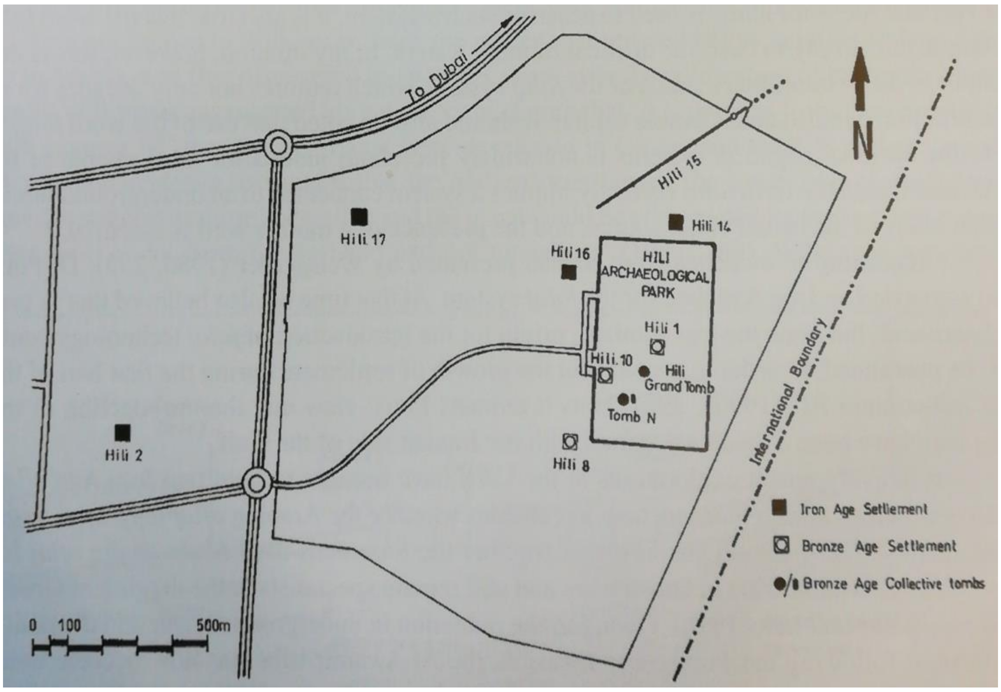

Figure 30: Map of the sites at Hili (Al Tikriti 2002, 344)

The oasis of Hili is located west from the Hajar mountain range in the U.A.E.. The archaeological sites are located north of the modern city of Al Ain (Figure 29). The Danish team of Karen Frifelt firstly surveyed and excavated at Hili (Frifelt 1975). Surveys and excavations by French teams, supervised by Cleuziou followed later (Boucharlat and Lombard 1985, Cleuziou 1989). The French teams identified several archaeological sites, dating to the Umm-an-Nar period (2600-2000 BC), Wadi Suq (2000-1300 BC), Late Bronze Age (1300-1000 BC) and the Iron Age period (1000-600 BC) and labelled the site structures as Hili 1 until 11 (Figure 30). In 1983, construction work North of Hili Park revealed canals, which belonged to a *qanat*-type *falaj* system. These canals were excavated in 1983 and in five seasons (Al Tikriti 2002, 120). The team labeled parts of the irrigation system as A-H (cf. Figure 31). The Hili sites are now briefly introduced in chronological site order and then the research questions are addressed.

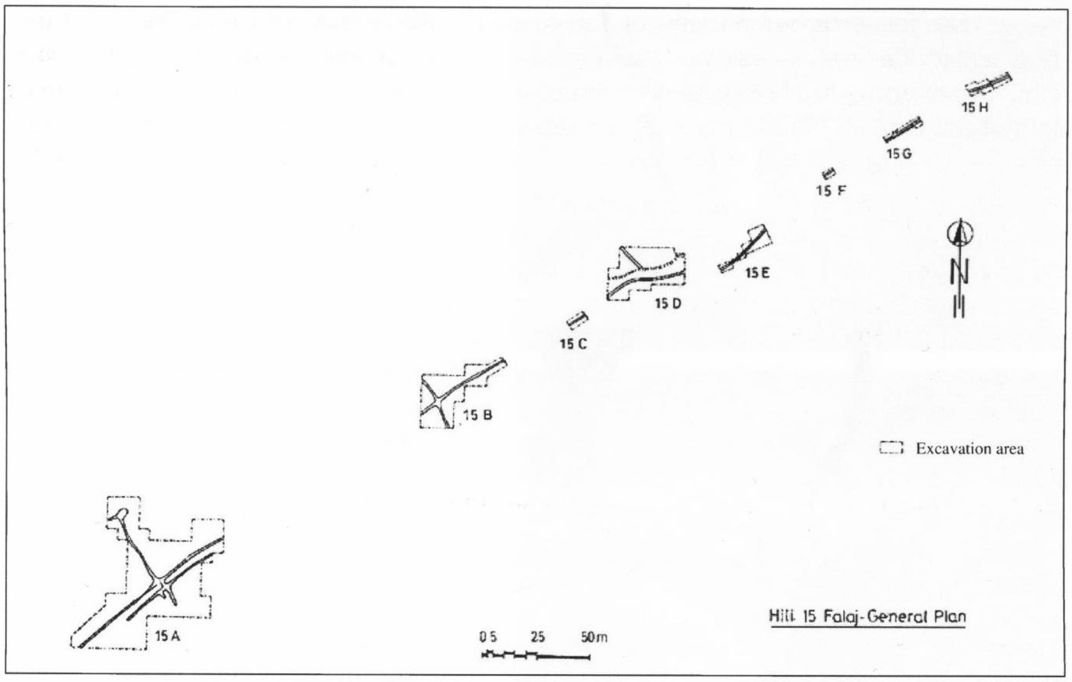

Figure 31: The excavated areas of the *qanat*-type *falaj* system Hili 15 (Al Tikriti 2002, 345)

Hili 1 consists of a tower surrounded by a ditch, which Frifelt and her team dated by a Radiocarbon sample and pottery assemblages, to the Umm-an-Nar period (2600-2000 BC) (Frifelt 1975). At Hili 2, Cleuziou and his teams identified two walls among several vessels. They dated Hili 2 and Hili 3 to the Umm-an-Nar period through their pottery assemblages (Cleuziou 1989, 82). The teams furthermore identified surface pottery, dating to the Wadi Suq period (2000-1300 BC) at Hili 7. The teams did not find any architectural remains at Hili 7 (Cleuziou 1989, 83). They however found several multi-chambered tombs (Hili M, Hili North), which they dated to the Umm-an-Nar period (2600-2000 BC) (Cleuziou and Vogt 1983, 37).

The teams of and around Frifelt identified a tower at Hili, that was later further excavated by the teams of Cleuziou. At the site, named Hili 8, three main phases of occupation were identified, attesting occupation at the site from the Umm-an-Nar-period (2600-2000 BC) until the Iron Age (1000-600 BC). A squared tower with rounded corners and built from flat mudbricks is located on top of the virgin soil. The tower's sides measure ca. 16 metres and several rectangular compartments filled with gravel and sand are found in the center in the earlierst phase dating to the third millennium BC (Figure 30). The tower was extended and modified through walls that have been built as annexes in the following centuries. Furthermore, the teams found several hearths and pottery in all three phases. Radiocarbon dates from the Phases resulted in a date of 3100/2900 BC for Phase one and 2470 =/- 150BC and 2400 +/-150 BC for Phase 2, 2235 +/- 150 BC and 2200 +/-150 BC for Phase III. The excavations at Hili 8 have resulted in a full pottery sequence from the early third millennium BC up until the Iron Age (ibid, 74-79). Grinding stones, hammers and hammer stones have been found in all three phases as well as copper pins and copper slag. Among other bones, cattle bones were found in a rubbish pit from the earliest occupation phase indicated traces of repetitive work, for example agriculture or water lifting at a well (Cleuziou 1989, 81). Lastly, archaeobotanical material was found, mostly in the earliest phase. Charred seeds of *Hordeum distichum*, *Hordeum vulgare*, *Hordeum vulgare*, *Hordeum sp*., *Triticum cf. aestivam*, *Sorghum bicolor*, *Cucumis sp*., *Zizyphus sp*. and *Phoenix dactylifera* were found as well as mudbrick imprints from all mentioned plants in the early occupation phase Ib as well as mudbrick imprints of some plants in later periods. Considering the canals (T1, T2, T4), assumingly used for water transport, Cleuziou argues that agriculture was fully developed in the third millennium BC, as the evidence from the rubbish pit of layer Ib suggests.

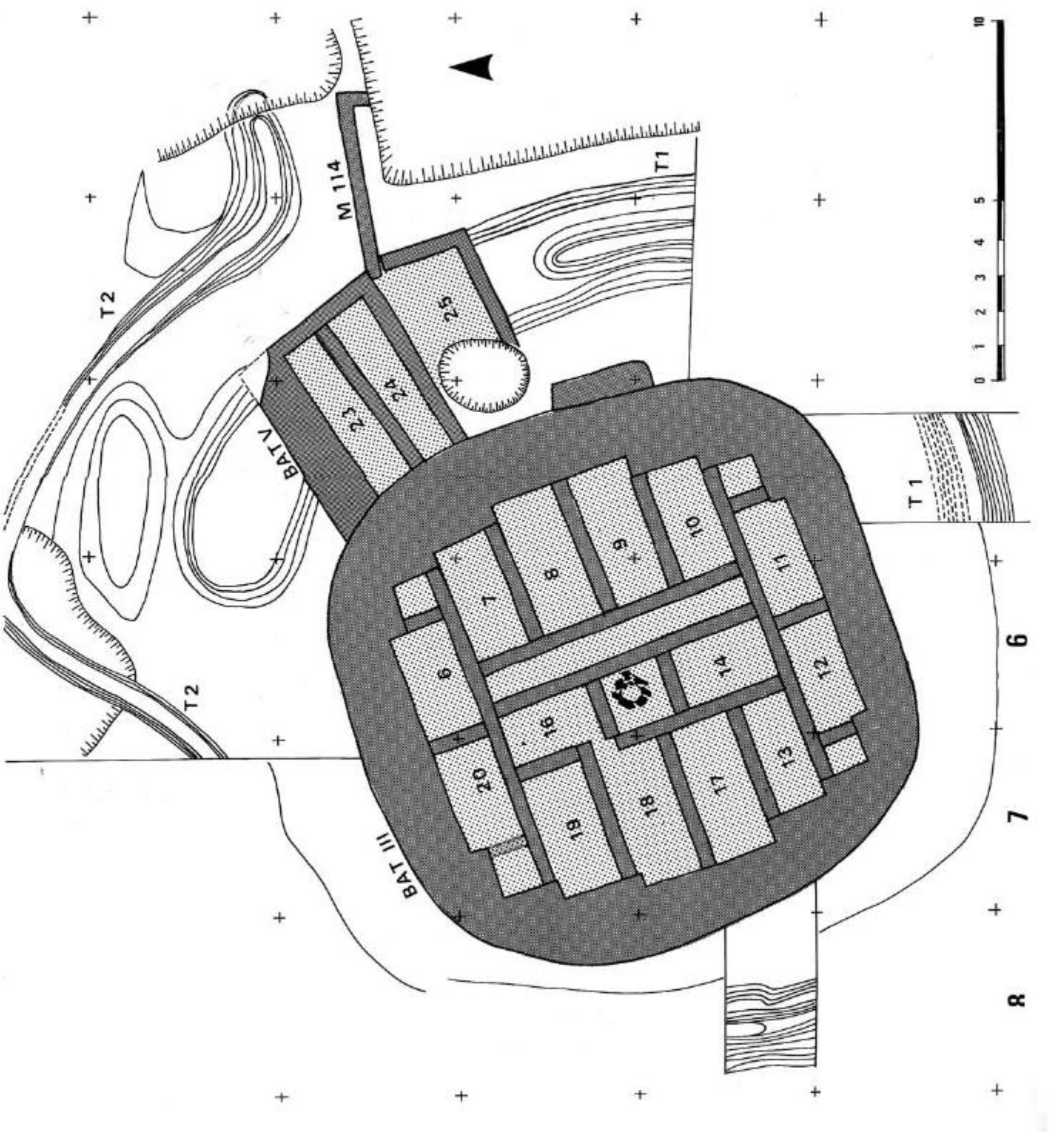

Figure 32: Earliest building phase 1a at Hili 8, dating to the third millennium BC (Cleuziou 1989, Pl. 11)

Eventually, Cleuziou’s teams found surface pottery and not clearly identifiable structures at Hili 10 and Hili 11 (cf. Figure 30). They dated both sites based on pottery evidence to the third millennium BC (Cleuziou 1989, 82-83).

From the research conducted by the teams of Frifelt and of Cleuziou, we can now state that communities continuously inhabited the Hili region from the Umm-an-Nar period (2600-2000 BC) until the Wadi Suq period (2000-1300 BC) and there is some evidence for occupation during the Iron Age

(1000-600 BC). The site is today lightly damaged due to bulldozing activities in the vicinity (Al Tikriti 2010). Having introduced the general topography of the sites at Hili, the research questions will now be addressed.

The first research question addresses the region in which the irrigation system H15 is located. According to publicly available climate data[7], the climate at al Ain can be considered as hot desert climate, following the Köppen-Geiger classification[8]. Annual mean precipitation was 5,26 mm/year between 2013 and 2017 according to publicly available precipitation data from Al Ain[9]. Seven *falaj* systems are supplying the Al Ain oasis today with water. Two contain natural flow water and all seven are supported by pumped water from wells or desalination water. The *falaj* systems are supplying an area of 250 ha in Al Ain city. The mother sources of all seven falaj systems are located on the Al Jaww plain to the East of Al Ain oasis (Brook and Al Houqani 2006).

Al Tikriti claims that the oasis of Al Ain began to exist in the Iron Age II and that the aquifer, which provided the Al Ain oasis with water was located East from the site (Al Tikriti 2002). Furthermore, Jorgensen and Al Tikriti suggested that the water table decreased between the mid third century BC, the Early second century BC and the Late Islamic period by comparing depths of three wells and additional data from premodern times. According to their measurements, the water table at Hili already dropped between 2500 BC and 1800 BC by 3,8 metres (Jorgensen and Al Tikriti 2002, 39-44). No dates for the Iron Age II are available. Having introduced the climatic and regional setting of the Hili sites, the

[7] Data accessible via www.en.climate-data.org.
[8] The Köppen-Geiger classification is the most widely used climate classification scheme. It was developed by Köppen in 1900 and most recently adapted in 1966 by Geiger. The map classfies every region on the earth based on temperature and precipitation data by assigning a classification to it, that can be abbreviated with four letters, such as for BWh for ‘hot desert climate’. The first letter refers to the main climatic area (dry, temperate, tropical, continental or polar) in which a region is located. The following two letters specify the region’s climate based on precipitation and temperature data. See for example Kottek et al. 2016, for further information.
[9] Data retrieved from www.worldweatheronline.com.

characteristics of *falaj* system H15 will be addressed in the following section.

During five seasons from 1983 to 1988, sections the *qanat* type-*falaj* system were excavated. Several characteristic parts of *qanat* type-*falaj* system were among the excavated parts. Shaftholes, parts of the cut and cover-section, a *sha'ria*[10] and parts of the surface channel leading to the presumed fields (15A, Figure 30), were identified. As it was presented in the second chapter, the shaftholes enable access to the underground channel. At Hili, the 'cut and cover'-section was found at parts 15C-15E, as depicted on Figure 30.[11]

Fireplaces and isolated wall fragments were found in the surface canal's vicinity and were interpreted by Al-Tikriti as boundaries of cultivated areas. Al-Tikriti states furthermore that parts of H15's tunnel section were found in the courtyard of two private houses ca. 1.5 km northeast of the *qanat* type-*falaj* system remains. (Al-Tikriti 2010, 228) He suggests that these two tunnel sections might have been located between the source or aquifer, and the other identified parts of the *qanat*-type *falaj* system. It is unclear, how to determine if the tunnel sections were part of H15. They might have been built in the same building style. However, that is not visible in the pictures published by Al Tikriti (see Al Tikriti 2010). The sections might as well be part of another *qanat* type-*falaj* system, since the course of H15 is not clear and several *falaj* systems dating to different periods, are supplying the Al Ain oasis.

North of the excavated parts A-E (Figure 31) two shaftholes were identified. The tunnel section between the shaftholes was uncovered in 2002. It runs in a zig-zag shaped line (see Figure 33). The canals of the *qanat*-type *falaj* system AM 2 at Al Madam (see p. 56), are built in the same zig zag shaped way. Al Tikriti gives two reasons. First, the zig zag

[10] The *sha'ria*, is the element of the *qanat* type-*falaj* system, which distributes water from the main channel and dispatches it into several subchannels. The *sha'ria* is indicated as 15B on Figure 27.
[11] "Cut and cover" describes the technique of covering surface canals of *qanat*-type *falaj* systems with flat stone slabs.

shape of the canals slows down the water flow. The second reason relates to the building process of the tunnel. As Al-Tikriti states, these *qanat* type-*falaj* system channels are dug starting from two shaftholes towards each other. Diggers are according to Al-Tikriti more likely to miss each other if they are excavating in a straight line. When digging in zig zag lines instead, the two diggers are more likely to cross each others way. This reason is less convincing. From recent ethnographic evidence it is known that the ‘Awamr tribe from the south of Oman indeed digs channels from two shaftholes towards each other.[12] It is not clear if the canals dug by the Áwamr tribe are dug in a zig zag shaped or a straight line. The hypothesis that a similar way of building existed in prehistory is possible. According to Birks and Letts, the ‘Awamr are constructing the channels according to the morphology of the subsurface geology. This hypothesis can be tested in the field. Secondly, it is useful to compare the evidence for the digging techniques of both channels of H15 and of AM 2 as they are not built a long distance from each other. As *falaj* digging is a distinct profession in Oman today (cf. Birks and Letts 1976), it could have been one in earlier periods as well. It is far-fetched to assume that today’s conditions are the same as earlier ones, but it is a hypothesis worth testing in the field. Perhaps the same group of diggers constructed the canals the Hili oasis, the nearby *falaj* systems at Bida Bint Sa’ud and Jabeeb.

[12] Lambton refers to another historical example of a building technique applied by diggers in the Yazd province in Iran in the 11th century AD. Here, the diggers start constructing the *qanat* type-*falaj* system in a rather straight line, starting from the fields towards the water source or occasionally, from both ends towards each others. These two techniques are described in a book, dated to the 11 century AD and written by Abu Bakr Muhammad b. al-Hasan al-Hasib al Karaji. A persian copy appeared 1966 in Tehran (Lambton 1989, 6).

Figure 33: Zig zag shaped section between the two shaftholes. The section was uncovered in the 2002 cmapaign (Al-Tikriti 2010, 231)

The canals excavated in area 15A are 80 cm wide and 60cm deep. In Area A, four canals running southeast and southwestward and sluices were identified (Figure 34). Sluices enabled controlling the water flow. Perhaps, different shares were managed by the community. Having discussed the characteristics of the *falaj* system H15, the dating of the structures will be discussed in the following paragraph.

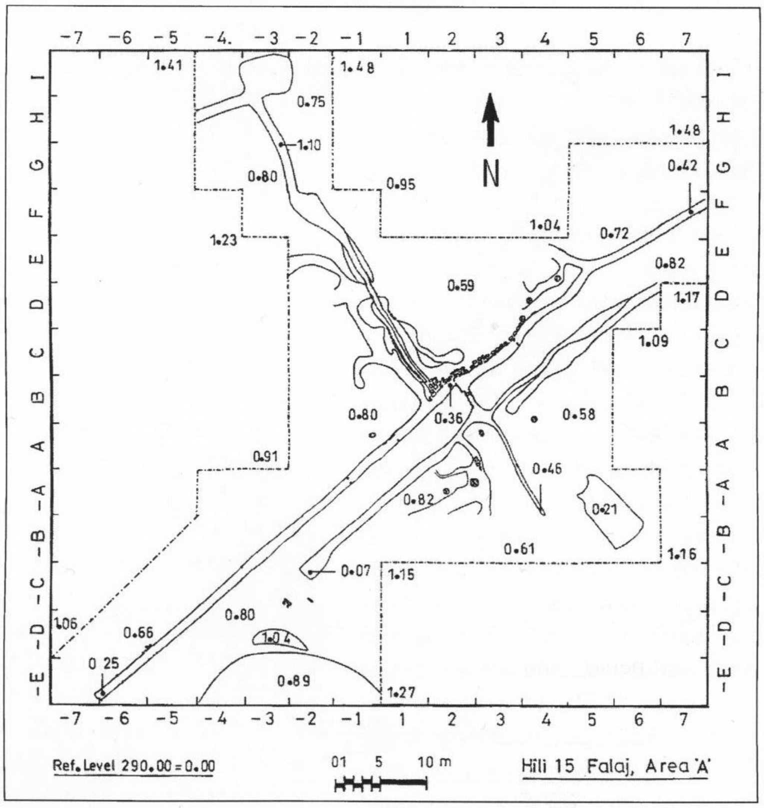

Figure 34: Channels running southeast and southwestward and sluices, identifiable in the centre area (Al Tikriti 2002, 345)

H15 was dated by Iron age II sherds that were found in larger amounts inside and next to the canals of section 15A. More sherds were found next to section 15A between fireplaces and wall remains within the potential agricultural fields. These wall remains and fireplaces are indicating the field boundaries of the Iron Age II fields, according to Al Tikriti. There is however no picture of the Iron Age II sherds found in situ published in the reports, therefore examining the sherds is not possible. Secondly, no Radiocarbon sample was retrieved to further support the dating to the Iron Age II with an absolute date. The contexts of H15 seem to have been undisturbed, as parts of the canals were firstly discovered during unrelated construction work in the site’s vicinity in 1983.

The Iron Age II evidence on irrigation activities is not very strong as it is based on pottery evidence that is not published. There is no published evidence of use of the irrigation structures at H15 at a different time and no sherds from other periods were found at H15. Since only Iron Age II sherds were found at H15 and since the contexts are undisturbed, it is possible that the *qanat*-type *falaj* system was used only in this period. However, radiocarbon dates of ashes from the fireplaces would have been helpful to add an absolute date to the evidence.

IV.2 Al Madam

The archaeological sites in the region of Al Madam are located on the Al Madam plain in the East of the U.A.E.. Bronze and Iron Age structures and remains from the Islamic period were identified in the region. The French archaeological mission in the U.A.E. surveyed the region between 1993 and 1995 and identified 54 archaeological sites. A large amount of Iron Age II pottery had been identified during the survey, as well as several domestic houses (Bénoist, Cordoba and Mouton 1997, 61-68). The Iron Age structures at Al Madam were later excavated by the Spanish team led by Del Cerro. A mudbrick production site, whose features were carved in bedrock, as well as an extensive irrigation system was excavated by the team, of which the latter is discussed in this case study (Del Cerro 2015).

The area around *falaj* AM 21, was suveyed by Iraqi scholars and later by french teams in the 1990's. AM 21 was then excavated by the spanish team of Del Cerro and Cordoba in 2002 (Del Cerro and Cordoba 2018, 88-94).

To begin with, the environmental conditions of the area where Al Madam is located, will be assessed. According to the Köppen-Geiger scheme, the region is classified as hot arid climate.[13] Mean annual precipitation at Ash Shu Ayb (U.A.E.), which is located in the vicinity of Al Madam, was 5,52 mm between 2013 and 2017.[14] Dryfarming is not possible under these conditions. According to Del Cerro, the region is sprinkled with trees today and some cultivated fields and palm trees exist. Compared to other regions of the U.A.E., the Al Madam region is a relatively fertile region, as Bénoist et al. state (Bénoist et al. 1997, 59). Flash flooding and surface

[13] Data retrieved from en.climate-data.org.
[14] Precipitation data available at worldweatheronline.com.

runoff from strong, short rain intervals occurs in the Eastern U.A.E. in the Hajar mountain region. Several dams have been built recently which contribute to groundwater recharge (Rizk and Al Sharhan 2007, 246-247). Irrigation at Al Madam relies however on water by tapped aquifers or springs, as runoff irrigation can be excluded on the plain and as the sites are located too far from the Hajar mountains as to be reached by desert flooding after strong rainfalls. Three water management features are found at the site: One well, a mudbrick procession site and a *qanat*-type *falaj* system were identified at Al Madam. As well We-1 is located in an enclosure between two houses and distant to the agricultural fields, Del Cerro suggests domestic use. At a depth of 4,50 m We 1 was lowered with the same tool to a depth of ca. 6m. Since a vessel dated to the Iron Age III was found at the bottom of the well, Del Cerro suggests, that the water table dropped in the late Iron Age and the well was lowered to tap the lower available water. Secondly, a unique feature, the mudbrick working area was identified at Al Madam, where the inhabitants mixed gravel with clay to fabricate mudbricks. Thirdly, the *falaj* system AM 2 was found. Three conclusions follow: One, the water table during the earlier Iron Age period was 4m. During the late Iron Age, it was at 6m depth. Secondly, evidence from the three structures suggests that they were all in full use and then abandonded. According to Del Cerro, this can be seen from hand and foodprints at the mudbrick fabrication site and secondly at the vessel lying at the bottom of We 1, indicating that the well was used into the Iron Age III and then abandonded. Thirdly, the inhabitants of Al Madam had good rock carving, water tapping and management skills. As the location of the archaeological sites at Al Madam was assessed, the second research question and thereby the characteristics of the *qanat*-type irrigation system identified at Al Madam will be discussed in the following paragraph.

Secondly, a *qanat* type-*falaj* system (AM 2) was identified. Seven shaftholes of the structure were excavated. After digging out the fillings, the team reached the underground gallery which was 0,5 to 0,55 metres wide and 4,8 metres deep. The underground channels were filled with sand and were dug out by the team for a distance of 35 metres. The channel was slightly carved out until a depth of 1,5 metres and later deepened with a small pick-axe-like item to the depth of 4,8 metres (see Figure 36), as Córdoba and Del Cerro suggest. The tunnel was built in a zig zag-shape as the channels of H15 at Hili (Figure 35). As the mudbrick production site is well adjusted to the bedrock formation, it is possible that the channels too, are zig zag-shaped because the channels adjust to the underlying geological formation. This hypothesis has yet to be verified.

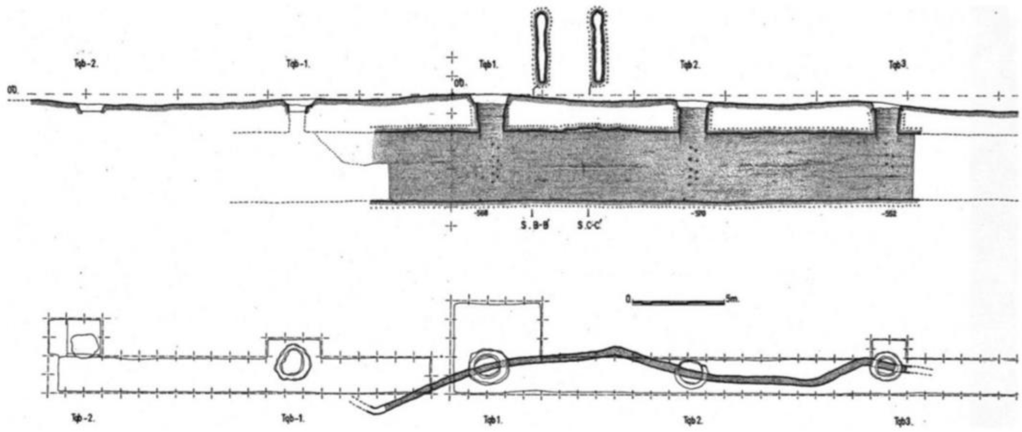

Figure 35: Zig zag shaped course of the underground water gallery with five shaftholes (Del Cerro and Córdoba 2018, 93)

Figure 36: Underground water gallery next to the second shafthole, *Thugba* 2 (Del Cerro and Córdoba 2018, 94)

Thirdly, an irrigation channel network was uncovered west and east from the main canal (Figure 37 and 38). This canal network is a unique evidence of irrigation systems in the wider region. Visible is a main canal, which is connected to the underground gallery of the *qanat*-type *falaj* system (Figure 35). Several subcanals lead from the main canal to the left and right. Along the subcanals, small, round pits have been identified. Cordoba suggests, that these pits could have been tree pits, which can be irrigated by the limited, constant water flow, running through the channel (Córdoba 2013, 147-150). A similar technique is applied today at plots, located close to AM 2, as Córdoba states. There are however no pollen preserved within the structure which could provide further information on agricultural activities because of the sandy soils that do not preserve pollen, according to Cordoba. Two date stones have been found within the channels (Córdoba and Del Cerro 2018, 97).

Figure 37: The channel network at Al Madam (Córdoba and Del Cerro 2018, 95)

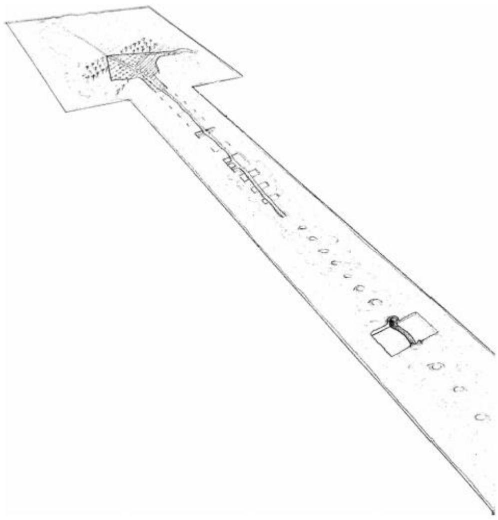

Figure 38: Sketch of the *qanat*-type *falaj* structure and the canal network (Córdoba and Del Cerro 2018, 96)

Córdoba and Del Cerro explain that the water table was shallower in antiquity than it is today (Córdoba and Del Cerro 2018). This hypothesis is probably based on the depth of the wells found at the settlement of Thuqeibah and the depths of the *falaj* canals. Deducing from the canal depth, the water table has been 1,5 metres and at a later point to 4,8 metres deep. The deepening of the canal could indicate a depletion of groundwater at a certain point and consequently, tapping of the deeper running groundwater (Córdoba and Del Cerro 2018, 93).

Having discussed the characteristics of the the *qanat*-type irrigation system AM 2 and the canal network, the focus of the following paragraph will now address how AM 2 was dated. AM 2 was dated to the Iron Age II by pot sherds, found in several canals of the irrigation network (Figure 39). Furthermore, a high amount of *Thiaridae* and *Therebralia* type shells were found in the canals of the network (Figure 37), as well as date stones. Radiocarbon analysis of the shells, resulted in a date for the shells between 1060 and 850 BC with 95% probability (Córdoba 2013, 148). It is difficult to evaluate the dating of the pottery evidence by the picture published in the publication. The sherds at the left can well belong to the coarse Iron II pottery, whereas the three sherds in the upper row might be of the *common orange ware type* (Figure 39, cf. Bénoist and Méry 2012, 83-84). The Radiocarbon date, further supports the dating of AM 2 to the Iron Age II. Thusfar, no evidence of later periods was identified in the immediate vicinity and the contexts are undisturbed. Analysis of soil samples of the cultivated fields will be helpful, to further develop the argument.

Figure 39: Iron Age sherds found within the channels of the canal network at AM-2 (Córdoba 2013, 148. source: Spanish mission)

IV.3 Masafi

The prehistoric and Islamic period sites at Masafi are located west from the Hajar mountain range in the East of the United Arab Emirates. More precisely, they are located in a watershed between two wadis, Wadi Abidalah running northeast from the sites and Wadi Ham running southeast. Research of the Masafi sites was initiated by initiative of the French Archaeological mission, the United Arab Emirates and the Fujarah Tourism and Antiquities Authority for the study of Iron Age communities in the Emirate of Fujarah in 2006. After a trial trench revealed remains of a large Iron Age II stone building and of an underlying mudbrick building while surveying, an outline for further research at the sites was set by the team and excavations followed in 2007, 2009 (Bénoist et al. 2012) and 2012 and 2013.[15] The identified prehistoric sites were numbered by the excavating team from 1 until 5. A pillared room and a rectangular podium further East, which contained five circular pits are located at Masafi 1. (Charbonnier et al. 2017, 49) Both structures were dated to the Iron Age II by pottery evidence. North from the pillared room and podium, irrigation canals have been identified, which will be discussed in this case study in detail. At the sloping hillside of Masafi- 2, a fortification wall and several

[15] see www.archeorient.hypotheses.org.

stone made terraces were identified. Furthermore houses, built in an orthogonal pattern on top of the terraces. Masafi-3 is a cemetery at which several snake figurines in bronze, vessels and incense burners with snake decoration have been found. Masafi-4 and Masafi-5 are not well preserved. Both sites are located on hills and were dated to the Bronze Age by evidence of pottery.[16] Eventually, south from the palm garden area and next to the modern road, settlement remains from the Islamic period were identified, according to the Bénoist et al. (Bénoist el al. 2012, 150). Islamic period remains were furthermore found on layers above Iron Age II structures (ibid, 155).

The canal system at Masafi (U.A.E.) was excavated by French teams in three field seasons in 2010, 2011 and 2015. The canal system was studied by applying an archaeological, planimetric and stratigraphical approach. In the third campaign, two micromophology samples were taken from the canal fills. Here, the aim was to understand the origin of the water flow and the nature of the surrounding soil. Furthermore, a radiocarbon sample was taken from a cultivated layer and the team looked at satellite imagery of the 1965 Corona mission in order to understand the watersheds in the surrounding. The overall aim was to reconstruct the hydraulic system at Masafi (Charbonnier 2017, 16-17).

Having introduced the topography of the Masafi sites, the first research question will now be assessed.

[16] see www.archeorient.hypotheses.org.

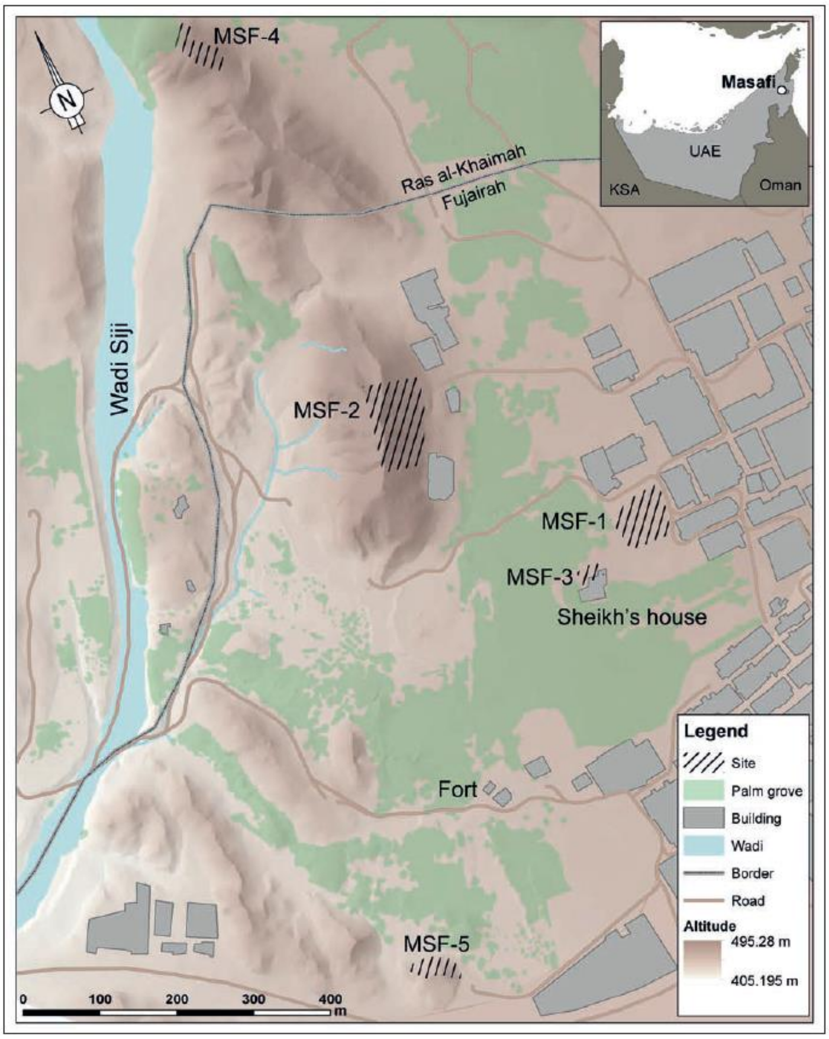

Figure 40: Map of the sites at Masafi (Charbonnier et al. 2017, 48)

The Bronze and Iron Age sites at Masafi are located west from the Hajar mountain chain in a mountainoeus region. According to the Köppen-Geiger classification scheme, the climatic conditions at Masafi can be defined as hot desert climate.[17] Annual mean precipitation between 2013 and 2017 was 22,06 mm/year.[18] Due to short, strong rainfall events between September and February, surface water runoff and seasonal floods occur in the region close by the Hajar mountain range. Today, several drainage basins exist in this area. Runoff water is not a reliable source in all locations in the region west from the Hajar mountains. At some basins, runoff occurs several times during the season, at others once a year and some receive runoff water every couple of years.

[17] Data publicly accessible via www.en.climate-data.org.
[18] Precipitation data accessible via www.worldweatheronline.com.

Furthermore, several dams have been built recently in the area to conserve water resources, to prevent flooding and to contribute to the groundwater recharge (Rizk And Alsharhan 2003, 246). Thridly, the largest mineral water company in the U.A.E. is located at Masafi. It carries the same name as the town, ‘Masafi’. According to the company’s management, groundwater is tapped at approximately 150 m below the surface, which is then pumped up to the surface. [19] It follows that the groundwater level in the area is relatively deep today. Aquifer depletion, intrusion of saltwater into aquifers and nitrate contamination, which decrease the water quality, are challenges that the region faces and effective groundwater management is one solution to encounter these developments (Rizk and Alsharhan 2003, 259-263). Having discussed the environmental conditions of the Masafi region and the hydrological characteristics in particular, archaological evidence for water management in the region will now be discussed.

At Masafi, a runoff irrigation system was identified at the site Masafi-1 (Figure 40). The most recent field excavation identified three irrigation systems (A, B1 and B2) at Masafi, of which B1 and B2 are dated to the Iron age II. The evidence, named Irrigation system A, consists of channel remains of which a wall of vertical stone slabs, that runs ca. 32 metres in a Northeast-Southwest direction is identifiable. System A was probably buried by gravels due to runoff, as Charbonnier et al. state. System B was built at the same location. Two phases of construction were identified, therefore Charbonnier et al. distinguish between System B1 and System B2. The primary channel of B1 (Figure 41) runs North East-southwest and 8 metres of it were excavated. It is 20-25 cm wide and 30 cm deep. The canal was damaged by Islamic graves in the southeast. The water flows through the primary channel of B1 towards the North into earthen made surface channels. The primary channel was connected to three subisdiary ones: One running northeast, one running north and a third one running southwest (Figure 41). Charbonnier et al. mention similarities to today’s channels at the Masafi palmgrove.

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[19] See www.thenational.ae.

At irrigation system B2, traces of repair and modification were identified and Charbonnier et al. suggest that B2 was part of system B1 before it was repaired, modified and used at a later point in time. The channel of B2 filled up gradually as the filling contains several layers. Furthermore, a small basin, respectively water tank had been dug north of the system next to one of the subsidiary channels of B2 (see Figure 42; Charbonnier et al. 2017, 59).

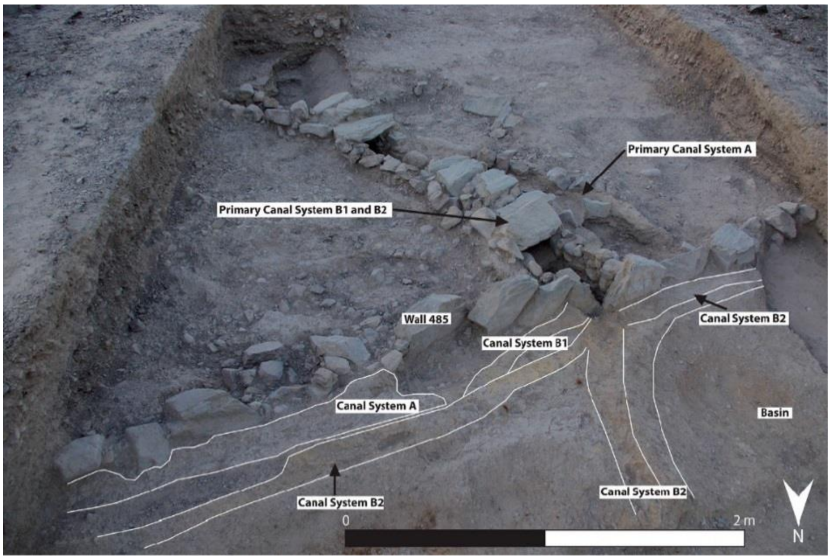

Figure 41: Canal systems I (Charbonnier et al. 2017, 18)

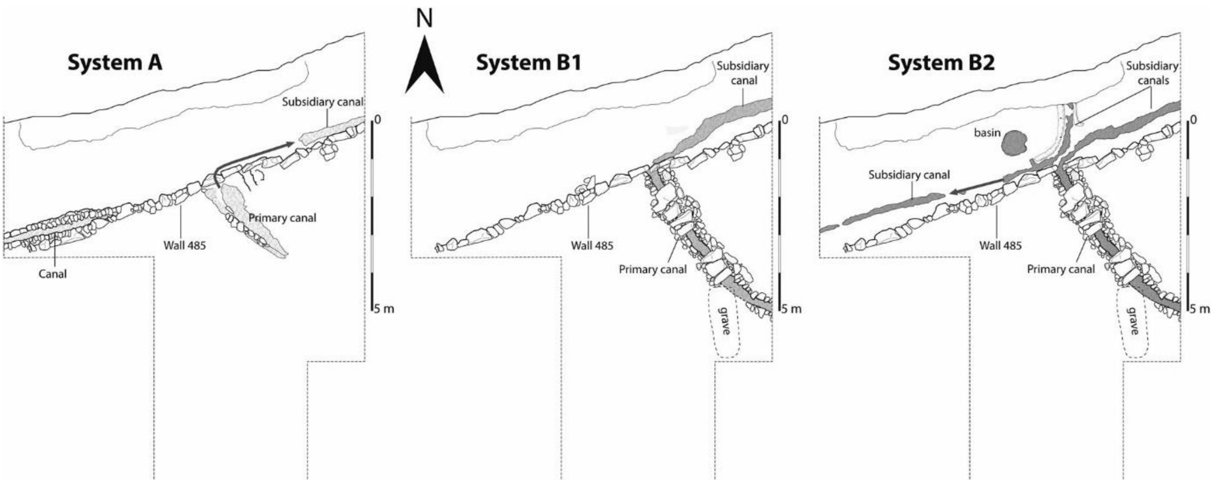

Figure 42: Canal systems II (Charbonnier et al. 2017, 17)

Charbonnier et al. put the hypothesis forward, that runoff water was channeled and used for irrigation purposes at Masafi-1. They base their argument on evidence from a 15 cm micromorphological sample from the filling of the primary channel. Eight layers were identified within. The sediment of the lower layers (1, 3, 4) is coarser, whereas layers five until eight are composed of finer sediment of a different kind. This indicates, according to Charbonnier et al., an earlier intense arrival of water and a rather seasonal water supply at a later stage. The sediment change, according to the authors, can as well be interpreted as indicator for changing water catchment technologies towards the end of the Iron age II period (Charbonnier et al. 2017, 59). The hypothesis of Charbonnier et al. is good. Since prehistoric precipitation does not diverge largely from today's, it is possible that run off water was channeled at Masafi -1 and used for irrigation purposes, probably in the rainy months between September and February. The authors do not specify how the finer ediment indicates a seasonal irrigation pattern and a change in water catchment technologies. Probably, the finer sediment is more washed out by water than the coarser layers, because seasonal water flows flew through the channel. There is yet no further evidence of water catchment devices found, for example indications for sluices or small dams within the channels. They could have been put in place temporarily, for example a stone or a wood construction. If and how a change of water catchment devices occurred, still needs to be backed up and explained by further archaeological evidence. The chances of irrigating regularly and on a longterm basis by means of run off irrigation in this area are however low, because the amount of rainfall varies considerably each year.

Having discussed the evidence for irrigation at Masafi, the following question will be addressed: How were the irrigation canals at Masafi dated? The team applied several dating methods. Microcharcoal remains from a supposingly cultivated layer (stratum 45), which contained fragments of bones and charcoal and that partially covers a subsidiary channel of system B1 and which appears to be contemporary with system B2 according to Charbonnier et al., were dated. Results from the analysis suggested a date between 897 and 801 cal. BC. As stratum 45 seems to be contemporary with systems B1 and B2, it follows that irrigation systems B1 and B2 had been in use during the Iron Age II. There is however the possibility that the channels are predating stratum 45. A third dated feature is wall 485 (see Figure 41). Several floors represent the context of wall fragment 485. One floor predates the wall, several floor layers abut it and several floors were covering the wall fragment. Iron age II sherds have been found in all layers from the predating one up until one of the layers (floor 1035), which covers wall 485. Most of the sherds are altered; therefore, the excavators suggest that the sherds were transported by runoff to their location. To sum up, Wall 485 is dated to the Iron Age II for three main arguments: All Iron age II sherds from predating, contemporary and covering layers are dated to the Iron age II. Secondly, the contexts are undisturbed. Thirdly, the two uppermost floors which cover wall 485 abut the primary channel of irrigation system B1 and are therefore likely contemporary with irrigation system B1 (Charbonnier et al. 2017, 20).

The team applied microcharcoal analysis and dated wall 485 and channels B1 and B2 by pottery evidence. Both dating methods resulted in a date in the Iron Age II period. A dating to the Iron Age II period seems therefore to be the best hypothesis. A later use of the structures can be excluded for now, as the contexts were undisturbed and because no evidence of later periods in the immediate vicinity of the irrigation systems was recorded.

IV.IV Wadi Fizh

Wadi Fizh is located between the Batinah coast and the Eastern Hajar mountains in the Sohar hinterland (Figure 43). Several archaeological sites from different prehistoric and historic periods have been identified in the area. Most have been surveyed by Costa and Wilkinson in the 1980’s (Costa and Wilkinson 1987) and later by teams of the Wadi Al Jizi project (hereafter, abbreviated: WAJAP) in field seasons between 2015 and 2018. The sites discussed in this case study are next to Wadi Fizh and west from the modern village Fazah. One sizeable settlement (S45, according to WAJAP terminology), extends across approximately 210 x 80 metres on a plateau (Figure 44). A large amount of Iron Age II sherds was found on the surface, based on which the settlement was dated by Costa and Wilkinson (Costa and Wilkinson 1987, 107) and later by the WAJAP team to the Iron Age II. A second settlement (S47) is located on a plateau further East overlooking the Wadi. It was dated to the Iron Age II based on house structures and Iron Age II coarse ware sherds found within the settlement. Late Islamic buildings built on top of some Iron Age II houses indicated that S47 was reinhabited in the Late Islamic period. Furthermore, a Bronze Age site (S84) was identified in the WAJAP campaign of 2018 between S45 and S47. The fields, discussed in this case study are located south from wadi Fizh at 24°30’20.3”N 56°25’40.5”E.

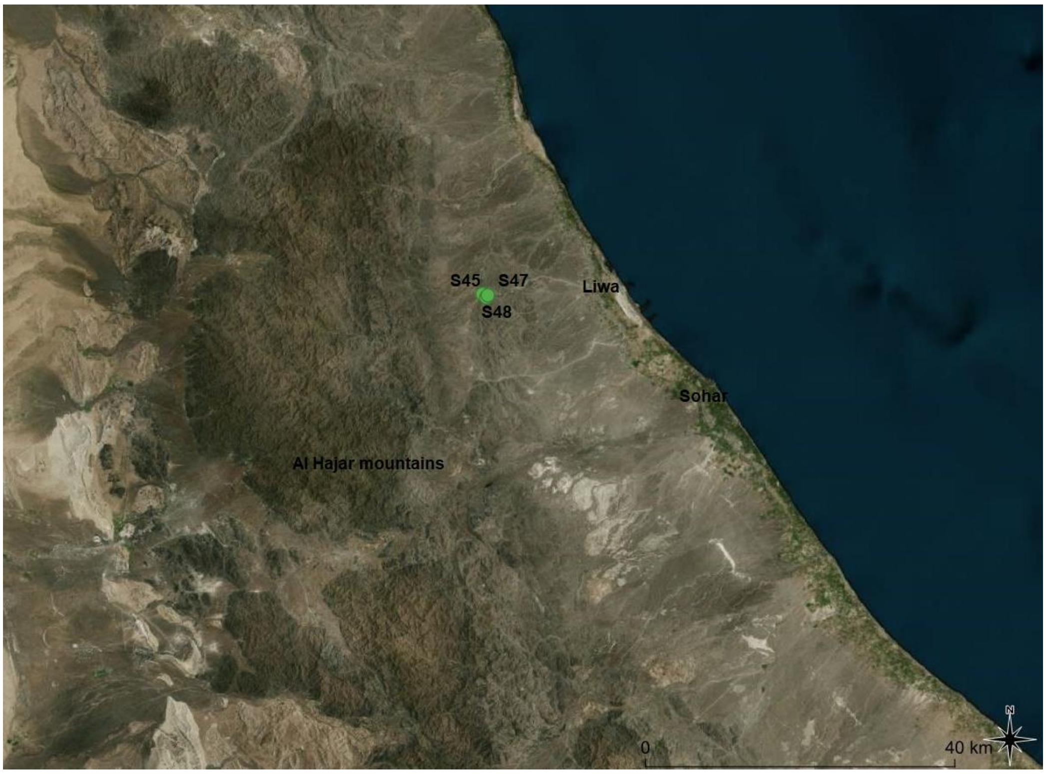

Figure 43: Sites at Wadi Fizh

These fields were surveyed by the WAJAP team (www.wajap.nl) from Leiden University. In the 2018 campaign, three OSL samples from the area below the divison walls of the fields, were taken. Analyses yielded unfortunately no results so far.

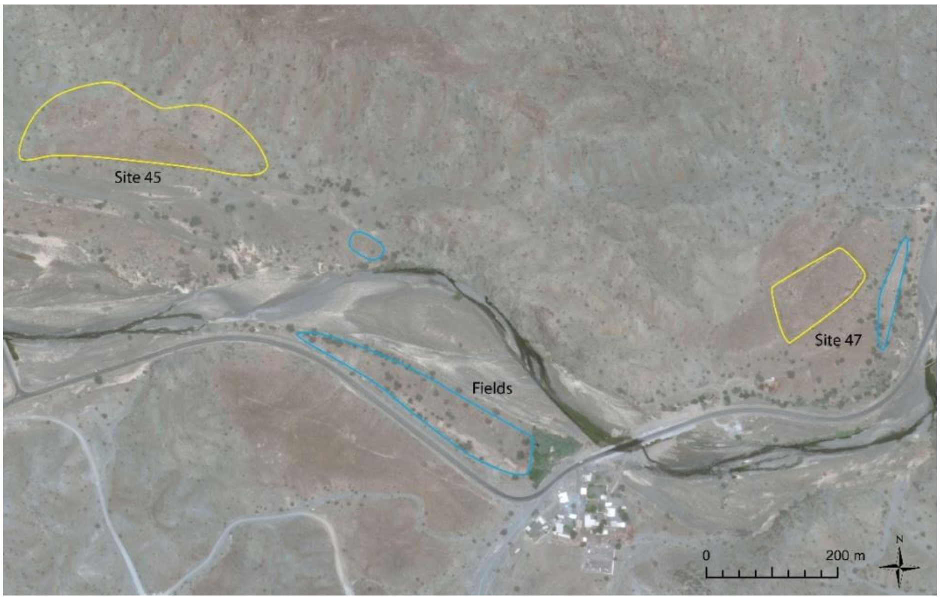

Figure 44: Location of the Iron age II settlement S45, the fields and the Iron age II settlement S47 (Figure provided by WAJAP)

Turning to the first research question, the regional setting of the potential Iron Age II fields will be assessed in this paragraph. The climatic conditions in the Batinah hinterland can be classified as hot desert climate following the Koeppen-Geiger classification.[20] Annual mean rainfall at Sohar was 5.78 mm between 2013 and 2017.[21] Additional precipitation data from the Batinah hinterland from the 1970s was provided by Costa and Wilkinson. Costa and Wilkinson state that mean precipitation never increased more than 200 mm/year between 1974 and 1981. Precipitation levels were measured at five stations, located at different altitudes throughout the Batinah region. The station located upmost in the mountains, had the highest rainfall rate. The authors conclude firstly, that rainfed agriculture is not possible under these conditions. Secondly, due to the high variability of rainfall at the different stations, for example at the coast or in the mountains, precipitation is not sufficiently reliable for rainfed agriculture. The potential Iron Age II fields are located in a distance of 40 metres south from Wadi Fizh. Although the climate is generally arid and dryfarming is not possible, the area is quite water-rich: Water from Wadi

[20] Data accessible at www.en.climate-data.org. It is referred to rain and temperature data from Shidah, because it is located in the hinterland of the coast but further southeast at a comparable location as Wadi Fizh. It was the closest weather station to Wadi Fizh.
[21] Data retrieved from www.worldweatheronline.com.

Fizh is today only a small runlet. I could not retrieve any information on how much water the Wadi carried in prehistory, so I cannot draw conclusions, if wadi water was tapped or not. However, a small spring is emanates next to Wadi Fizh at approximately 24°30'26.9" N 56°25'29.0"E. A couple of date palms are wildly growing next to the spring today. It is possible that this spring was tapped in prehistory, too.

The regional environment has been assessed. The second research question and the characteristics of the irrigation system will be addressed in this paragraph. The evidence is: Agricultural fields, a canal and a spring which could have provided water for the fields. The fields extend across an area of approximately 300 x 50 metres (Figure 45). They are separated into several differently sized plots by walls (up to 1.75 metres high and 80 cm wide) made from large stones (20-65 cm). The soil has a silty matrix. A canal (S49) runs west from the fields (S48) crossing some of the field walls. Canal S49 is between 30 and 80 centimetres wide. It is lined with stones (10-20 cm). At some parts, an 80 cm high wall supports the canal and at other parts, the canal was cut into the bedrock. It continues further to the East to some more recent fields. As most Islamic sherds have been found inside the canal S49 and in its vicinity, Bleda Düring suggests that this canal dates to the Islamic period. Iron Age pottery is absent. The southeastern fields are having a higher count of Islamic pottery. Secondly, they are lying lower, than the western fields (Figures 45 and 46). Furthermore, Canal 49 is cutting the boundary walls of the Nothern fields. Therefore, Bleda Düring suggests that S49 is cutting fields, which were cultivated in earlier periods.

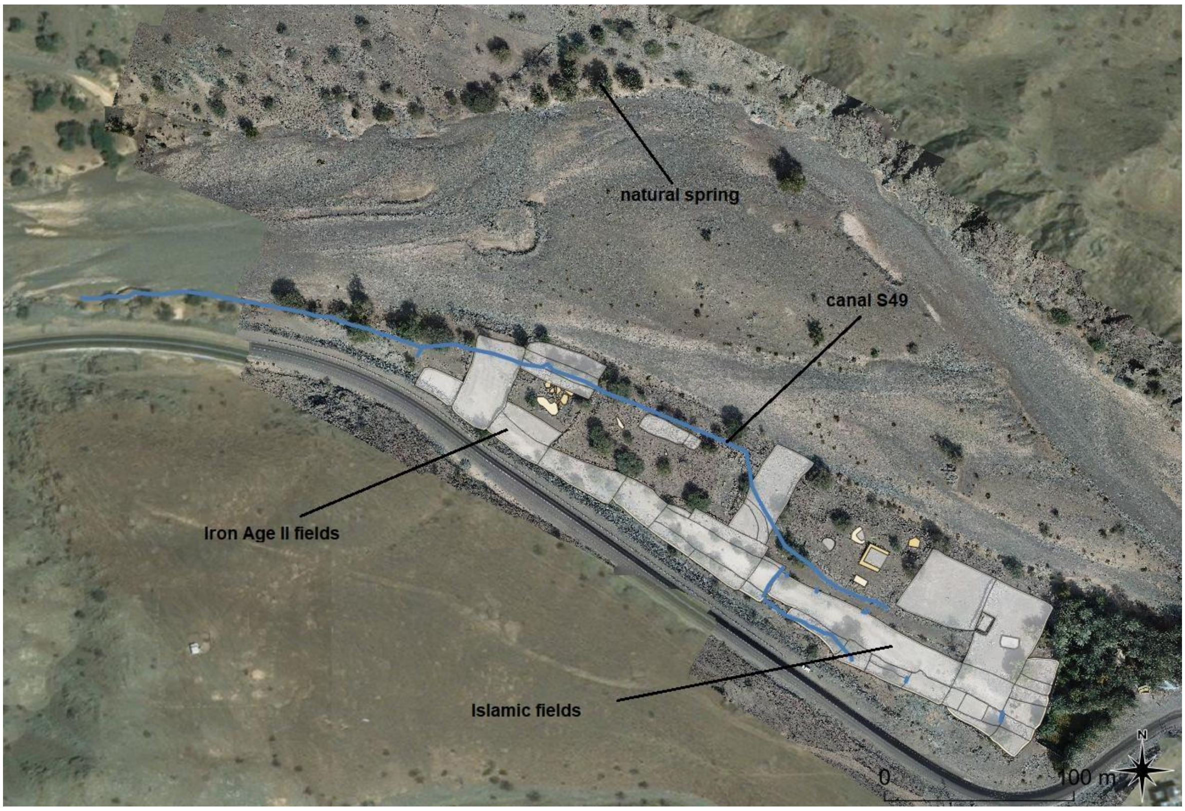

Figure 45: S48 and S49 (Map created by Anna Lipp, © WAJAP)

One hypothesis on how the fields were irrigated will be put forward. Bleda Düring suggests, that water could have been taken manually from the wadi or from the spring and carried manually to the fields to irrigate it. Manual irrigation is a straight-forward procedure and a good preliminary hypothesis on how irrigation was conducted at S48, as there is yet no further evidence.

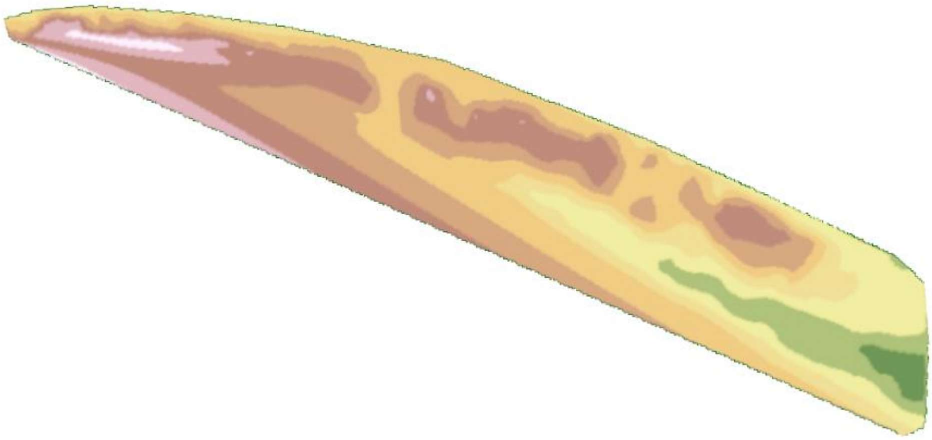

Figure 46: DEM of the fields at S48 (DEM provided by WAJAP)

The third research question and therefore the dating of the fields S48 will be assessed in this paragraph. Bleda Düring suggests, that fields S48 have been irrigated and cultivated in the Iron Age II for three reasons. First, some Iron Age II sherds have been recorded on the fields. However, most of the pottery found within the fields dates to the Islamic period. A first use in the Iron Age II period and later reuse of the fields is thinkable. Reuse of the fields is furthermore suggested by the different height levels of the fields and the pottery dispersal.

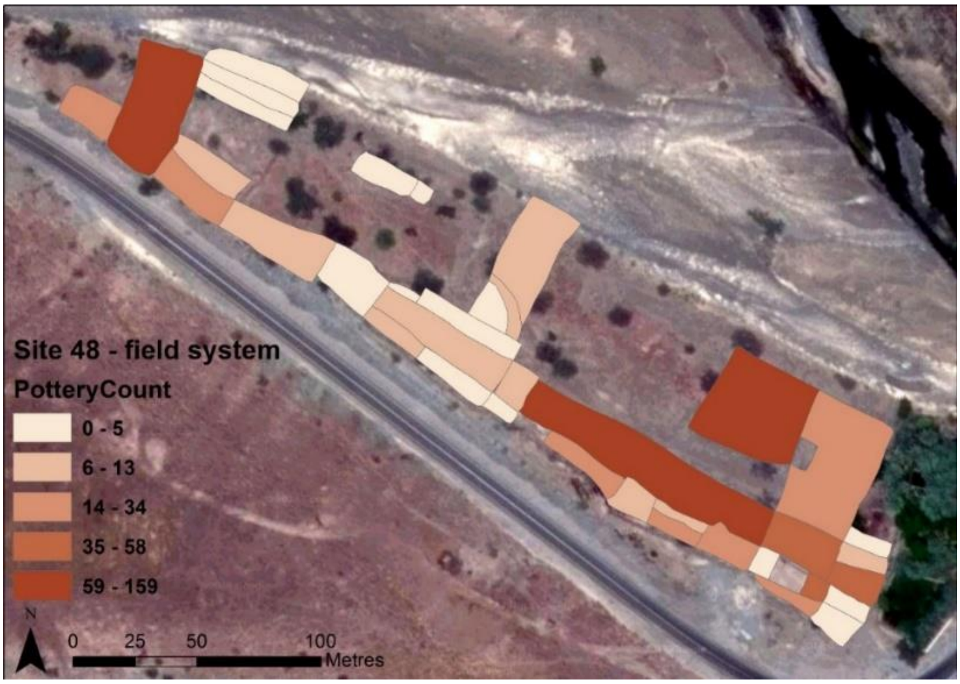

Figure 47: Pottery count at S48 (Picture provided by WAJAP)

Secondly, when digging test pits below the field separation walls to retrieve OSL samples during the 2018 WAJAP campaign, two prehistoric sherds were found (Figure 48). The tespits were small and the sample is too, but it it is possible that prehistoric activities took place at S48.

Figure 48: Two sherds, dated to the Iron Age II period, which were found below the separation wall of the fields at S48

Thirdly, S45 and S47 are in approximately 400 metre distance to the fields further south. The proximity of fields and settlements, is a third reason why Iron Age cultivation at S48 is thinkable. Furthermore, several grinding stones were found at S45. It is possible that edibles were processed on these, but they could have been part of other activities, too. To conclude, the fact that some Iron Age II pottery was found within fields S48 and the two prehistoric sherds found below the separation walls and the proximity to the Iron Age II settlements, builds up the hypothesis that the fields of S48 were irrigated and cultivated in the Iron Age II.

The evidence can however be refuted. Iron Age sherds can be found on the fields for other reasons than manuring or being traces of cultivation activities. Instead, they could be transported from the settlement by soil erosion or, vessels could have been carried down by inhabitants of the settlement to the general area of the fields. The prehistoric sherds found below the separation walls indicates that some prehistoric activities took place in the area. But this is not a reliable post quem date for the building of the separation walls. Other material than edibles could have been grinded at S45 or edibles that were growing wildly and were not cultivated at the fields. It is at this point neither possible to prove, nor disprove what exactly was processed at S45. Overall, I suggest the evidence is not sufficiently strong yet to provide a clear dating of the fields to the Iron Age II, nor to Iron Age II cultivation taking place. It is more certain that the fields were cultivated in the Islamic period, based on the dating of canal S49, running from the Wadi towards the fields and secondly, due to the high amount of Islamic pottery found in situ. Further research on the fields could test the hypothesis on Iron Age II cultivation further.

IV.5 Discussion

In this section, I will state, interpret and discuss the results from the four case studies along the three research questions. I will discuss the results with arguments from other scholars from Arabian Archaeology.

1. In which areas are the irrigated fields located (e.g. in desert-like, coastal, mountainous regions)?

Here, I would like to address three aspects: Dryfarming possibilities at the four sites, their inland location and drop of local water tables during the Iron Age II.

As several palaoclimatic studies show (Fleitmann et al. 2007, Fuchs and Bürkert 2008, Van Rampelbergh et al. 2013), the climate in Southeastern Arabia did not change considerably since 6ka BC until today. Therefore, modern precipitation data can be considered as an approximate indicator for precipitation conditions during the first millenium BC. As shown in the previous chapter, precipitation at all the four locations ranged between 5,52 and 22,06 mm per year during the last five years and secondly, varies. Therefore, if communities intended to cultivate plants, routinized dry-farming was impossible in the region and irrigation became necessary. The importance of tapping groundwater for the Iron Age II communities due to the climatic conditions, was put forward by several archaeologists (Potts 1993, 165, Charbonnier 2018, 232).

Secondly, the four sites considered are all located in the inland, not at the coast. Is their inland location a characteristic of Iron Age II irrigation?

Possibly, desalination of groundwater at coastal regions was a danger and tapping water for agricultural purposes would have overexhausted resources more quickly than only domestic water use did. Another argument would be that coastal communities were mainly consuming and processing wild plants and receiving imported cultivated plants from elsewhere. However, communities inhabited the coastal settlement of Tell Abraq from the late Umm an Nar period (2600-2000 BC) until the late Iron Age (600-300 BC). A high number of date stones was found in all layers of the site (Potts 1993, 68). It is possible, that date palm gardens have been close by. Excavations yielded however neither evidence for fields nor irrigation activities and they might be imported. Evidence from the four sites and from other sites – for example Bida Bint Sa'ud, Jabeeb, and Maysar (Yule 2017), suggests, that irrigation during the Iron Age II seems to have been practiced rather inland. But, since there is clear presence of date stones at Tell Abraq, date palm gardens could have been close by. The inland position of the four case studies discussed is yet not a sufficient criterion to suggest an inland focused agriculture in Iron Age Southeastern Arabia. Research thusfar did not identify any fields, but evidence for irrigation at the coast could potentially be found.

A third aspect I would like to discuss is the drop of the Iron Age II water table at Hili and Al Madam. Iron Age II communities, deepened the canals at Al Madam and Hili, which Al Tikriti (2010) and Del Cerro and Cordoba (2018, 93) interpreted as dropping of the local water tables. The canal at Al Madam was lowered from 1,50 to 4,80m. Jorgensen and Al Tikriti state a difference in well depth from a well dating to the Bronze Age to a well dating to 1600 BC. According to Jorgensen and Al Tikriti the water table at Hili dropped by 3,8 metres between 2500 BC and 1800 BC. It is not clear how deep the water table was at Hili during the Iron Age II. But the ancient water table is a relevant subject further exploration, because as for example Del Cerro and Cordóba argue, the settlement of Al Madam was suddenly abandonded - perhaps due to water scarcity (Del Cerro and Cordóba 2018, 97). Gathering more information on the water table during the Iron Age period and its end is helpful to better understand the groundwater situation and irrigation possibilities at the time.

2. What are characteristics of the irrigation technology (e.g. fields and channels)?

The four Iron II communities applied three different technologies: Irrigation by means of a *qanat*-type *falaj* system, runoff irrigation and manual irrigation. Here, I would like to discuss five aspects. First, more specifically on the two *qanat*-type *falaj* systems at Hili and Al Madam, the tunnel shapes and size, temporality of use and tools. Then, more generally on the four irrigation systems, aspects of knowledge and limitations of this research question.

Firstly, Hili and Al Madam: The two zigzag canals are similar in their shape (Figure 29, Figure 31), but they differ in their depth. The builders at Al Madam built the underground water gallery first at 1,5 metres depth and later deepened the canal to 5,6 metres (cf. Figure 32), as suggested by Córdoba, based on traces of potential scooping and ersosion at a depth of 1,5 metres (cf. Figure 32). Al Tikriti (2010) did not publish the depth of the zigzag section specifically, but from the published pictures (Figure 29), I would assume they are approximately 1-1,5 metres deep. The difference in depth of *qanat*-type *falaj* canals however depends on where the part of the section is located. It will lie higher if its closer to the mother source and lower, the closer to the fields where the canal reaches the surface. How can the similar zigzag shape of both canals at Hili and Al Madam be explained?

Al Tikriti (2010) explains, that building canals in a zigzag line is easier for the *falaj* diggers, because they are less likely to miss each other. Del Cerro and Córdoba (2018) suggest the canals at Al Madam were carved out along the underlying geologic formation and thereby attained their shape. Both arguments are discussed in the respective case studies. It is remarkable, that both canals are bending in a slight zigzag shape and yet the shaftholes are lined up finely straight.

Secondly, there are differences in how the canals were dug. The gallery at Al Madam is carved in bedrock with a pick-axe like tool, according to Córdoba and Dell Cerro. This seems likely looking at the *falaj* walls of AM-2. Al Tikriti does not give suggestions for how H15 was built. But looking at the pictures, stones seem to make up the walls of H15. They seem to be built differently, perhaps due to the environmental conditions (different levels of bedrock). How the *falaj* canals are built, can be a suitable subject for further research.

Eventually, as all four case studies show, members of the communities had a good knowledge of the hydrologic conditions and were skilled in exploiting the water resources in situ. At Hili, parts of a *qanat*-type *falaj* irrigation systems have been identified, that were carved in bedrock. In addition to the *qanat*-type *falaj* system and the sophisticated irrigation channel system at Al Madam, a mudbrick production site, carved in stone was found. The community members at used their water resources for different purposes and constructed thusfar singular installations for mudbrick production and irrigation purposes. Runoff irrigation at Masafi seems to have occurred and several channels showed traces of repair. Charbonnier et al. suggested that these point towards a seasonal irrigation pattern (Charbonnier et al. 2017).

Limitations to answering this research question yet lies in the water management activities of prehistoric communities. Maincanals and subcanals were found at Hili, Al Madam and two different canals at Masafi, secondly sluices were found at parts of the *qanat*-type *falaj* system at Hili and at Masafi. It seems that the communities at Hili and Al Madam divided their water up in shares, but it is still not clear how the divison took place and might not be answered with a sound hypothesis.

3. How were irrigation structures dated by archaeologists?

All in all, Iron Age II pottery was present at all four sites und used as proxy. AM 2 was further dated by a Radiocarbon sample and Canals A and B by a sample of microcharcoal analysis. Secondly, three of the irrigation systems were undisturbed contexts. This seems so far, a good indicator for more secure dating.

Dating *falaj* canals and irrigation systems in general, remains a challenge. Further absolute dates from rather securely dateable contexts and for example, systematic analysis of soil layers of potentially cultivated areas as conducted at Masafi (Charbonnier et al. 2017), can hopefully contribute further to render dating more precise.

V. Conclusions

The three research questions assessed the regions, where the four irrigation systems were located, their characteristics and by which method they were dated. The four irrigation systems are located in hot arid environments with modern annual rainfall below 22, 06 mm; therefore, irrigation becomes necessary to sustain agricultural fields. The four irrigation systems are located inland and the water table at Al Madam and probably Hili, decreased during the Iron Age II. Groundwater is easily available at all four sites.

The *qanat*-type *falaj* systems at Hili and Al Madam are similar in their shape, but if they are built with similar tools remains to be seen. Diggers of all four irrigation systems were skilled and knew the hydrologic conditions well. Traces of repair and sluices point towards longterm use and water management activities.

Iron Age II pottery was present at all four sites. The fact that the contexts at Hili, Al Madam and Masafi were undisturbed, dates from Radiocarbon samples from Al Madam and a microcharcoal sample from Masafi, further supported the irrigation systems' dating.

V.1 Reflection on the research

Doing a literature review was a useful approach, because much has been published on the subject of *qanat*-type irrigation during the Arabian Iron Age II and its earliest use on the Arabian Penisula. A difficult taks was to come to sound conclusions on the paleoenvironment of the four sites. I considered modern precipitation data in order to better understand the surface water conditions during the Iron Age II. But there are limitations to that and better another approach might be more suitable. Considering precipitation data from the four sites was one way of comparing climatic conditions at the four sites with the same indicator.

V.2 Future research

Coninuing to investigate prehistoric wells to reconstruct ancient water tables and ways of building irrigation systems can be promising future avenues of research. Reconstructing the ancient water table can help us to understand the groundwater situation better and how the prehistoric communities dealt with the retrieval of water and what they used it for. Secondly, the material that was used for building irrigation canals and their surfaces can be investigated to hypothesize, what kind of tools were used, how the surfaces were treated and how the canals were built. There might a ‘profession’ of *falaj* digging already in prehistory, similar to contemporary *falaj* diggers, as the Omani ‘Awamr tribe.

As the examples of the *falaj* systems at Hili and Al Madam, the runoff system at Masafi, the mudbrick working at Al Madam and other examples show, there is much more to find out about, how Southeastern Arabian communities tapped, collected, used and managed water in the Iron Age.

VI. Abstract

Irrigation technologies and more particularly *qanat*-type *falaj* irrigation and its first emergence, are one of the key topics of Arabian prehistory. Magee suggests that *falaj* systems and the domestication of the camel considerably facilitated the Iron Age II population boom in Southeastern Arabia (Magee 2004).

Here, four irrigation systems are systematically discussed along three research questions addressing their location, characteristics and how they were dated.

The four sites are located in regions, were hot desert climate prevails and groundwater was easily available. The communities conducted *qanat*-type *falaj* irrigation (Hili, Al Madam), runoff irrigation (Masafi) and potentially manual irrigation (Wadi Fizh). Modification traces (Al Madam, Masafi) indicate a continuous use of the structures and sluices (Hili, Masafi) point towards water management activities. All systems were dated based on Iron Age II pottery; the system at Al Madam was furtherly dated by radiocarbon dates and the system at Masafi by dates from microcharcoal analysis. The absolute dates from Al Madam and Masafi were strong indicators for a dating to the Iron Age II period, showing that *falaj* and runoff irrigation were conducted at the time. Reconstructing past water tables and studying construction techniques will be suitable approaches, to further research how Iron Age II communities were irrigating.

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VII. Figures

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