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Prehistoric Agricultural Water-Management on the Oman Peninsula

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The climate of the Oman Peninsula is characterized by low, irregular rainfall, high temperatures and a high evaporation rate. According to the little data at hand the last aridification process began around 3000 B.C. By 1000 B.C. the climate had reached the state which has lasted until today (Sanlaville 1992, 23). Due to these climate conditions crop cultivation is only possible with the support of ghayl-, falaj- or well-irrigation. Rainfed agriculture has not been accounted for, with the exception of the Musandam Peninsula and the Qara mountains in Dhofar. It is reliant on small oases, a situation due not only to the climate, but also to the shortage of arable land which is sometimes more difficult to find on the Arabian Peninsula than water (Costa 1983, 274).

Evidence of the earliest agricultural activities on the Oman Peninsula was found in the ancient settlement of Hili 8 in the modern oasis of Al Ain, in the form of imprints of grains in lumps of broken mudbricks and charred seeds of sorghum bicolor, two- and six-rowed barley, emmer, bread wheat, melon and dates (Costantini 1979, 70–71; Cleuziou/Costantini 1980, 245–251; Cleuziou 1989, 79–81). According to radiocarbon dating the earliest settlement phase at Hili 8 can be dated to 3100 B.C. ± 190. Serge Cleuziou (1982), director of the excavations at Hili 8, pointed out that already at this early stage a well-developed oasis economy of date palm trees with water melon planted at their base and fields of grain nearby existed at Hili 8.

Yet under the presumed climatic conditions, this form of agriculture was only possible with an additional supply of water. Therefore, the question arose as to which methods were used for irrigation in the early oases.

The main feature of third millennium B.C. settlements are large stone or mudbrick towers. In Hili 8 two wells were discovered inside the tower. The first one was dug to a depth of 4 m from the ancient surface in the centre of building III (Cleuziou 1989, 64 Pl. 21). In phase IIa building III was 'reshaped' to the then building IV. A new well was dug through the ruins of building V (Cleuziou 1989, 67–68 Pl. 13. 21). The upper part was included in the construction of the wall encircling building IV. This well remained in use for a long time until the beginning of the second millennium B.C. There is evidence of several re-diggings. The well was deepened to 8.5 m below the ancient ground level. This shows that the water table became 4.5 m lower over a span of about 1000 years. In the 1970s the water table was at a depth of c. 11 m, but now it has been almost destroyed due to the intensive pumping of ground water (Cleuziou 1998, 61).

Around the excavated tower at Hili 8 a system of canals was discovered. Sediments showed that the canals were filled with water at least part of the time. The system was interpreted "as the last section of an irrigation network designed to bring excess water from the gardens located upstreams" (Cleuziou 1998, 62). According to Cleuziou, it is to be assumed that the original irrigation network consisted of canals which brought water from the wadi gravels to the fields. Since the water table was low in the early third millennium, as the depth of the first well has shown, it must have been possible to dig the canals with the so-called 'cut-and-cover method', that is to cut low trenches in the soil and cover them with stone slabs. There was no need for long galleries and deep pits like today, since the water table is much deeper today. According to Cleuziou (1998, 62) "this is coherent with type and amounts of work that a society like that of Hili during the third millennium B.C. could carry out." However, he pointed out that there more detailed work is necessary to test this hypothesis.

East of the canals several trenches were observed. They were interpreted in the context of a lower water table in the second quarter of the third millennium. The original organic soil had been removed together with the upper silty loam in this area. This was done to reach a depth of 80 cm below the original surface. At this depth there was a 15 cm thick layer of ophilithic gravel. This removal of soil was visible in the excavated area of 900 m^2. The process of lowering the gardens is very common in the Oman oases. Organic soils are separated and re-deposited. However, such re-depositiong was not witnessed at Hili 8. Cleuziou (1998, 61) interpreted this lowering of the soils to the establishment of the gardens in the third millennium B.C.

More evidence of early agriculture in the form of impressions of wheat and barley in clay on the Oman Peninsula was found in Bat (Frifelt 2002, 101), a settlement from the second half of the third millennium B.C. in the western foothills of the al-Hajar mountains (Frifelt 1976, 57–74; Frifelt 1985, 89–104). Trial trenches and soil samples made by Robert Brunswig on the northwestern periphery of the settlement mound revealed early cultivated terraces which had been irrigated (Brunswig 1989, 9–50). Umm an-Nar pottery found in the sondages dates the terraces to the second half of the third millennium B.C. Thereby Brunswig emphasizes that the results should not be interpreted as proof that date-cultivation, as it is practiced today, was necessarily a part of the Umm an-Nar economy. They only indicate that a similar garden environment with a relatively intense water regime must have existed in Bat (Brunswig 1989, 27). The discovery of several dams in Bat supplied further supportive evidence. Brunswig described his first ideas about the irrigation system at Bat in a footnote, as follows: "Essentially, Bat irrigation technology during the third millennium appears to have been based on a system of check and diversion dams designed to retard and divert floodwater for irrigation and silt accumulation." (Brunswig 1989, 28). Results of a more detailed analysis, which Brunswig purported to undertake, have not yet appeared.

Aerial photographs of the Maysar region in the western foothills of the al-Hajar mountains have disclosed remains of an old field system. It was dated by Gerd Weisgerber (1981, 197) to the end of the third millennium B.C. A charred date-stone and the impression of a mat made of palm leaves in the same context could suggest the cultivation of dates. Two flat dams in Maysar-19 and Maysar-24 (Fig. 1) (Hastings/Humphries/Meadow 1975, 18–19 [Maysar-19 = Samad 5; Maysar-24 = Samad 4]) have been interpreted by Weisgerber as diversion dams, to curb the flow of water and prevent the earthen dam from being washed away. However, in Maysar as well as in Bat the exact method of irrigation could not be determined.

The expanse, organisation and origin of the oasis settlements on the Oman Peninsula became a matter of lively controversy a few years ago. Jocelyn Orchard (1994, 63–100; 1995, 145–158; Orchard/Stanger 1999) was of the opinion that these settlements had been established by a tribe immigrating from the Marib region in Yemen and that some of the oases covered an area up to 400 ha. The large expanse of the oases would have required a system of underground and surface canals.

However, Orchard's supports for this theory are based on some willful or incorrect interpretations of archaeological material, as Daniel Potts (1997, 63–71) clearly pointed out. Nevertheless, although little can be said definitively about the origin of the oases-economy, none of the finds and contexts indicate that oasis settlements of the third millennium B.C. should be ascribed to an immigrant people.

Cleuziou (1997, 391) attributed the creation of oases to an external stimulus, which however does not mean that this creation was foreign to the area. Indeed, the destabilising factor was the demand of the Mesopotamian city states for copper from Oman at the beginning of the third millennium B.C. Although present in abundance, this ore had not been exploited intensively until that time. The ensuing increase in copper ore exploitation necessitated many changes. Among them was an increase in food production for workers employed in mining and metal working, which surpassed the existing food supplies. This led, according to Cleuziou, to an intensification of crop cultivation and animal husbandry.

At the beginning of the second millennium B.C. a cultural change took place, which is manifested in settlement patterns as well as in burial customs. Until recently it was still assumed that a deterioration in climate forced the inhabitants to abandon their sedentary way of life. However, at sites such as Hili 8 and Tell Abraq a continuity in the use of the towers can be observed, thus evidencing a cultural change rather than a break. Robert Carter demonstrated that a small number of large sites exist which testify to continuous sedentary occupation. In contrast, the broader picture points to a general decline in the intensity of settlement. Although various finds from the Wadi Suq period are usually found in the same areas that were inhabited during the Umm an-Nar period, they are usually comparatively sparse in structure and cultural deposits, or the remains are purely funerary in nature.

Only indirect evidence has been found for the consumption of grains or dates, in the form of grinding stones and a high incidence of caries in human remains in the second millennium B.C. Date stones were present in Wadi Suq levels at Tell

Abraq, whereas constructions related to irrigation are still lacking.

During the early phase of the Iron Age, around 1100 B.C. there was a distinct increase in the number of settlements. Continuity in certain areas is notable, whereby shifts in settlements of 100 to over 1000 metres can be observed, for example in Maysar, Hili, Wadi Bahla and Bat. John Craven Wilkinson presumed that the shift in location was due to the introduction of a new method of irrigation, the falaj-system.

The origin and the time of emergence of the falaj-system on the Oman peninsula have been a matter of lively debate in recent years. The falaj is an irrigation system, through which water is directed by means of canals to fields to be cultivated. Whereas springs and wadis carrying water are easy to recognize, the search for and localization of aquifers is a task for specialists. In Oman the 'Awāmr tribe is specialized in this area (Birks/Letts 1976, 93–100). Water can be transported in various ways. The simplest method is by means of open canals. Water in wadis, usually only a few metres below the surface, can be acquired through the so-called 'cut-and-cover' technique, in which narrow ditches are cut into the sediment and covered with large stone slabs.

The most complicated way of building a falaj is the drainage gallery. This entails driving a shaft hole from the surface to an aquifer (the so-called mother-well). From there a tunnel leads off, built at a slight decline to enable the flow of water. This infers that the surface of the land must be steeper than the tunnel, so that water can be directed from the underground to the surface. In order to remove the dirt resulting from building the tunnel and to ventilate it as well, vertical shafts are placed in regular intervals of 5 to 20 m.

This method of water transportation is also designated 'qanat' (Goblot 1979, 25–36; Beaumont 1989, 13–31; Hodge 2000, 35–38). In Oman the word 'falaj' is used for all kinds of irrigation systems regardless the technique of transporting the water or the source of the water. According to Wilkinson (1977, 74) in Oman this term refers to the organized distribution of water to those who have a right to it.

Today the hypothesis that the falaj-system was introduced to Oman from Iran is still frequently supported. This opinion is based mainly on Wilkinson's work, which he published in 1977 and in which he asserts this hypothesis. He was influenced by the works of H. E. Wulff (1963) and Paul Englisch (1968), who saw the origin of the falaj-technique in Iran. Englisch maintained that the aflāj was introduced into Arabia by the Achaemenids in the 5th century B.C. In 1983 Wilkinson himself modified his opinion slightly. Accordingly, he placed the beginning of this technique in the 8th/7th century B.C. and dated only the major impetus behind the expansion of the falaj-system in Oman to the Achaemenid period. Thereby Wilkinson based his position on the reports in the Annals of Sargon II. In his interpretation of the text Læssøe (1951, 21–32) argued very cautiously that Sargon might have seen a qanat in Urartu. On the other hand, Bagg (2000, 127–146) presented a new interpretation of this passage, concluding that the collection and transportation of ground water by means of qanats in Urartaian times is still not confirmed. Daniel Potts (1990, 390–392) expressed the view that falaj technology on the Oman Peninsula could be of pre-Achaemenid date, but none the less of Iranian origin. Further, its introduction may have been part of the same process of contact with the Iranian side of the Gulf which accounts for the marked similarity between certain Iranian and Omani pottery and metal types.

Iron Age falaj-systems can be confirmed in various places on the Oman Peninsula. On the plain of al Madam in the Emirate of Sharjah in the western foothills of the Oman mountains, one of the most fertile places in the United Arab Emirates, several Iron Age settlements were discovered near al Thuqaibah as well as three underground canals which lead to this area. In a trial trench dug across the earth debris downhill from the large well of the falaj Am.21, two ceramic bowls were found, one almost complete, both characteristic of the Iron Age. The excavators A. Benoist, J. Cordoba and M. Mouton (1997, 64–65) cautiously dated the falaj in this period but advising that more studies were needed to establish the relationship between these settlements and aflāj exactly.

In 1983 a falaj-system, called Hili 15, was discovered in the north of the Hili Park in the oasis of Al Ain (Al-Tikriti 2002, 120–124). It was excavated during five seasons of work. The main canal was lined with stones along one side and sluices were found in situ. Additionally, two subcanals were uncovered and at the southwestern most part of the excavations a bifurcation was excavated. All of them were built in the cut-and-cover technique. In the northeastern most section a shaft hole was found, which was built on the cut-and-cover-canal. The area closer to the mother-well could not be investigated; therefore it is not clear, whether more shaft holes exist. The falaj heads in the south towards the Iron Age site Hili 14. This site was interpreted as caravanserai. With this new discovery in mind Al-Tikriti now interprets this large building complex as place for the administration and controlling of the falaj system, that is as bayt al-falaj (Al-Tikriti 2002, 124). Even if the connection between the site Hili 14 and the falaj is not proved, the dating of the irrigation system is clear, since in and around the falaj pottery sherds of Iron Age II date (1100–600 B.C.) came to light.

Recent excavations at Bida' bint Sa'ūd, 1 km west of the famous outcrop Qarn bint Sa'ūd revealed a public building dated to the early first millennium B.C. (Al-Tikriti 2002, 124). In the course of the search for the water supply system in the surroundings of that building and following excavations 11 shaft holes forming two lines came to light. Excavations between the shafts revealed the tunnel of the falaj. Some pottery sherds were discovered between the shafts, which are clearly of early Iron Age date. However, the excavators have not been able to confirm this date for the falaj for the time being.

Another site with an ancient falaj-system was found at al-Jabeeb, about 25 km north of Bida' bint Sa'ūd (Holmes 2001, 23–24). A series of shaft holes were excavated but could not be traced to the bottom, since the great depth was too dangerous for the excavation team. Therefore, the tunnel was not reached. There was no pottery but the excavators date the falaj to the early Iron Age in view of the shape and architecture of the shaft holes.

From a later time but with a relatively secure date is the falaj Maysar-46 near the settlement Maysar-42. Based on pottery comparisons Gerd Weisgerber and Paul Yule (1999, 101) assigned Maysar-42 to the Lizq/Rumeilah period, that is the early Iron Age. A storage vessel was dated by thermoluminescence to 280 ± 170 B.C., a date at the end of the early Iron Age and the beginning of the Samad period after the terminology of Weisgerber and Yule. The falaj is adjacent to the settlement which Weisgerber and Yule (1999, 100–101; Weisgerber 1981, 245–247) consider as proof of their association and a similar dating.

On the basis of several Iron Age falaj-systems, Walid Al-Tikriti (2002, 137) concluded that the earliest examples are not attested in Iran but on the Oman Peninsula and therefore held southeastern Arabia as the origin of these irrigation systems. Rémy Boucharlat (2001, 157–183; 2003, 162–180) pointed out that concerning the origin of falaj-systems not only differences in technique of the acquisition of the water but also the origin of the water itself must be considered. Followingly, he shows that all falaj-systems attested for the Iron Age used water from wadi-beds. By contrast, the use of deeper aquifers is not confirmed at such an early date. Thusly, Boucharlat concludes that the use of aquifers in southeastern Arabia occurred in Islamic times.

Once introduced falaj technology has remained until today **the** determining element for water management on the Oman Peninsula.

Wilkinson (1977, 131–132) presented a detailed study about aflāj in Sassanian and Islamic times. During the Sassanian period there was probably a fairly extensive development either under direct or indirect Persian influence. According to Wilkinson the intensification of the old-established falaj-network took place notably within the mountain area, with a possible extension southeastwards to the outer limit of reliable water supply and a development of water resources on the plateau of Jebel Akhdar. He also dates technical innovations such as the inverted siphon to the Sassanian period (Wilkinson 1977, 132).

Wilkinson (1977, 124–127) sees two periods of development during Islamic times. In the opinion that the aflāj's growth could only have taken place in times of relative political rest and economic prosperity, Wilkinson dates the first period of development, the "Golden Age" of the first Imamate, to the 9th century and the second to the Ya'ariba dynasty of the 17th/18th century.

This system of water-management has survived for over 2500 years, and today the government of Oman endeavours to preserve the aflāj despite radical measures of modernization. Migration of rural populations to the cities, light-weight hand-pumps and modern irrigation systems as well as the supply of drinking water by means of trucks with water tanks all represent a serious threat to the ancient system. The Ministry of Water Management in Oman has therefore gathered information on all falaj, including their respective owners, technical details, and quality and quantity of water. In pilot projects such as that in Wadi Bahla various and new techniques for improving the present water irrigation system are being investigated and tested. Modern methods of irrigation are planned, which supply the exact amount of water needed for the particular soil and plants, and old irrigation canals have been refurbished. A project of the Sultan Qaboos University is concerned with the improvement and less complex production of sarooj, the traditional sealing material for aflāj. Great support is given from the side of the State to the training of young Omanis, which attempts to develop new and adjustable systems of water-management.

ABSTRACT

Climatic conditions on the Oman Peninsula have made agricultural activity possible only with ghayl-, falaj- or well-irrigation systems. Even the earliest cultivation at the beginning of the 3rd millennium B.C. was based on irrigation, since at that time aridification had already set in. By c. 1000 B.C. aridity had reached the state which has continued until today.

Although diverse finds and contexts from the 3rd millennium B.C. provide evidence of well- and ghayl-irrigation, no detailed conclusions can be made as yet about their actual function.

Proof of field irrigation from the 2nd millennium is absent, although some finds of date stones and the carious condition of the teeth of the population could be an indication of date cultivation.

The falaj-irrigation system was introduced during the 1st millennium B.C., whereby recent finds indicate an earlier date than assumed until now, that is the first half of the 1st millennium B.C. If this is confirmed by further finds, the theory on the introduction of the falaj-system in Oman by the Achaemenians in the mid 1st millennium B.C. must be reviewed.

Since then the falaj has become the characteristic water-management system in Oman today. Despite the recent employment of water pumps and other new techniques, the state is endeavoured in preserving the long proven falaj system and in making it more attractive for usage.

ملخّص

جعلت الشروط المناخية في شبه جزيرة عمان ممارسة الزراعة ممكنة فقط بمساعدة أساليب الري بالينابع والأفلاج والأغيال. حتى أن أبكر أعمال الزراعة في أوائل الألف الثالث ق.م كانت قد اعتمدت على الري لأن الجفاف كان قد بدأ منذ ذلك الحين وبلغ الحد الذي ما زال مستمراً عليه حتى اليوم حوالي ١٠٠٠ ق.م.

وعلى الرغم من أن العديد من اللقى الصغيرة وحالات السياق الأثري من الألف الثالث ق.م تقدم دلائل على الري بالينابع والأغيال، فإنه لا يمكن وضع أي استنتاج تفصيلي حول وظيفتها الفعلية حتى الآن. ولا يوجد برهاناً من الألف الثاني ق.م على ري الحقول على الرغم من أن العثور على لقى صغيرة لبعض الحجارة المؤرخة، وكذلك حالة نخر أسنان السكان، يمكن أن تشكل مؤشراً لزراعة البلح.

أما أسلوب الري بالأفلاج فقد استُخدم للمرة الأولى خلال الألف الأول ق.م، ولكن هناك لقى حديثة العهد تدل على تأريخ أبكر لما كان مسلّماً به حتى الآن، وهو النصف الأول للألف الأول ق.م. وفي حال البرهنة على ذلك التاريخ الأبكر من خلال لقى أخرى فإنه من الواجب إعادة النظر في النظرية القائلة بتطوير أسلوب الري بالأفلاج في عُمان من قبل الأخمينيين في منتصف الألف الأول ق.م.

منذ ذلك الحين أصبح الفلج أسلوب إدارة المياه المميز لعُمان في يومنا هذا. ورغم الاستخدام الحالي لمضخات المياه وتقنيات حديثة أخرى، فإن الدولة تسعى للمحافظة على أسلوب الري بالأفلاج الذي اختُبر لفترة طويلة ولجعله أكثر إغراءً للاستخدام.