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The Man-Made Wadi Floors of Yemen
Les terrasses anthropiques dans les wadis du Yémen

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1. The irrigation system

Yemen is located at the southern border of the main desert belt. The fertility of this region from the tropical summer rains inspired its historical name, Arabia Felix, even though only in the central highland is the precipitation sufficient for rain-fed agriculture. Especially in the borderlands of the sand-desert, Ramlat as-Saba'tayn, irrigation was a necessity (Kopp 1981, p. 109). It was, however, exactly in these areas where the ancient kingdoms of Saba', Ma'în, Qatabân, and Hadramawt emerged and bloomed during the first millenium B.C. (Brunner 1997, p. 193). Every kingdom was centered in a big wadi using the periodical flood (=sayl), which normally rushed down in April and July/August. Irrigation was immediate. The sayl was caught by an earthen deflector dam which conducted the water into a main channel that led onto the level of the fields. Distributors made out of stones divided the water into secondary canals or were opened onto the fields. One field after the other was flooded knee-deep. The banks of the fields were twice as high. Surplus water safely flowed back to the wadi by massive overspills.

This simple method of irrigation was sustainable in a proper manner and had therefore a lot of advantages. First of all, the sayl irrigation always allowed silt to accumulate on the fields, thereby maintaining its fertility. The mean annual sedimentation rate was ca. 1.1 cm (Brunner 1983, p. 65). Second, the large amount of water that was conducted to the fields resulted in the leaching of salt. Because the retention of the soil was not big enough to hold all the water, some seeped through the soil into the aquifer, removing the salt crust of the former year with it. Third, the whole irrigation system was well adapted to the occasional occurance of disastrous flash floods. In these cases the earth dam - of which the middle part was the lowest like it is today - was washed away, but the whole irrigation network and the fields were left intact. Through cooperative work the dam was repaired and piled up again in a short time. Fourth, the whole system was easy to operate and ready to distribute the sayl day and night. It was therefore well adapted to handle unforeseen sayls. Another feature has to be mentioned which has proofen to be of major importance: The whole irrigation system was adequate for the centralized kingdoms in the wadis. The powerful kings were able to call on a labour force and to maintain it. The best example was the Wadi Dhana in which the capital of the Sabean kingdom was located. Here a large dam of 680 m long and about 15 m high blocked the whole wadi. Two outlets connected with overflows served as starting points of a complex irrigation scheme (Brunner &

Haefner 1986, p. 79f.). It has to be stressed that even this dam was not built for storage but to raise the water to the necessary level of the fields.

2. The identification of ancient irrigation

The most widespread remains of ancient irrigation are the shiny yellowish-brown sediments which accumulated during irrigation. They rest elevated as terraces on both sides of the main wadis. Their surface lies too high for modern sayl irrigation and is strongly dissected by gully erosion. The ancient irrigation sediments are uniform and consist of 10-20% clay, 60-80% silt and 5-25% fine sand. Their median size lies between 20 - 40µ and they are well sorted (fig. 1). The organic material content is quite low, after the method of Walkley and Black it counts for only 0.1-0.3%. Mica is the most common mineral, quartz appears in minor portions (Brunner 1983, p. 19). In this way ancient irrigation sediments are easily distinguishable from aeolian accumulations or from naturally generated sediments in the wadi bed. Nevertheless, until the seventies these sediments were interpreted as loess (Grolier & Overstreet 1978), due to the fact that coarser grain sizes are missing.

The explanation for their absence is as follows: The speed of the flowing water in the channels determined the coarsest sediments that could be taken along. Since the gradient of most of the canal systems was a mere 1-2‰, only fine sediments reached the fields. Most of the material shows no bedding owing to the effects of cultivation. Well defined stratification can be observed in old canal sediments. Further characteristics to determine irrigation sediments are diverse irrigation related structures in the sediments themselves, such as regularly arrayed tree-rings or -mounds, furrows from ploughing, burial sites, paths, canal-structures or remains of field banks (Brunner 1983, p. 25-42). In certain areas buried water distributors were found. Especially the course of the ancient canals shape the surface of the sediments. Gully erosion mostly followed the lines of former canals, so a well-defined rectangular erosion pattern characterizes ancient oases. This canal-network is well recognisable in aerial pictures, and can even be detected in satellite images.

3. New knowledge about Yemen history

On the basis of the interpretation of satellite images, Brunner & Haefner (1990) pointed out that in almost every big wadi in Yemen ancient irrigation on a large scale existed (fig. 2). Not only is the horizontal extension of the irrigation sediments striking, but also the vertical dimensions are surprising. In most of the wadis the sediment lies between 10 and 20 m deep. In the Sabean oasis it surpasses 30 m. Since the annual sedimentation rate is 1.1 cm it can be deduced that sayl-irrigation lasted here for almost 3000 years, a time period testifying to the success of this kind of irrigation.

It is possible to date this period because the end of irrigation is described in the Holy Koran, sura 34, verses 14 and 15: *"Eat ye of your Lord's supplies, and give thanks to Him: Goodly is the country, and gracious is the Lord! But they turned aside: so we sent upon them the flood of Iram; and we changed their gardens into gardens of bitter fruit and tamarisk and some few jujuba trees."* This killing event for the Sabean irrigation culture can be dated to the beginning of the 7th century A.D. A simple calculation leads to the astonishing result that irrigation started in the Sabean oasis of Ma'rib as early as

the 3rd millenium B.C. (Brunner 1983, p. 66). Resarch in other wadis confirm this dating (Brunner 1998, in press). The importance of this fact for the history of Southern Arabia is immense because so far the evolution of a genuine Yemen culture has been put at the first half of the first millenium B.C. (Audouin et al. 1987, p. 64).

4. The coming of Islam

During the period of South Arabian civilization humans changed the face of their country in a significant manner. The most prominent evidence of this are the shiny yellowish-brown sediment terraces in the wadis. They build up most of the lower parts of the wadi floors in central Yemen. They overlie the natural fan with its aquifer. These wadi floors are therefore almost free of vegetation. This is in strong contrast to wadis in other dry areas where there was no ancient irrigation. There acacia low open-woodland normally exists.

Furthemore the ancient irrigation sediments show over all a very flat surface, not only in the cross section but also in the longitudinal section (Brunner 1983, p. 21). The modern wadi bed is deeply eroded, most of the time it has already reached again the level of the natural fan. As a consequence high cliffs on both sides of the wadi are a further characteristic of wadis leading through an area with ancient irrigation. As a conclusion it can be said that the irrigation in ancient times has modelled the landscape of central Yemen in a similar manner to Middle Europe's formation by Pleistocen glaciation. There is a special reason why they have not been destroyed since their construction.

After the great turnaround in South Arabia during the coming of the Islam in the 7th century A.D., the well organised supraregional kingdoms gave way to the small-scale tribal system which has lasted to this very day. These small societies were no longer able to reach the level of the ancient oases with their irrigation water. A fine account of this fact is the above cited story of the Holy Koran. A great exodus of Yemen people took place which led them to northern Arabia, North Africa and even to southern Spain. Only a minor part of the former population remained in the wadis bordering the Ramlat as-Sab'atayn.

The expanses of the irrigated land diminished rapidly into small eroded patches within the ancient oases. Therefore the majority of the irrigation sediments were kept untouched by agriculture for almost a millenium and a half. The people still practised sayl irrigation, but in a simplier way, and closer to the wadi on a lower level (Brunner, in press).

5. Modern developments

It is only in the last 20-30 years that the ancient oases have come under cultivation again. In the process of looking for new land for the fast growing population, farmers as well as the government discovered the ancient irrigation sediments as the most fertile land reserve in their country. Finally, they possessed the technical and financial possibilities to use the water of the aquifer for irrigation on a larger scale. Yemeni workers abroad sent home the necessary money to buy diesel driven pumps. Between 1977-1990 the area of

pump irrigated land in Yemen doubled every five years (Brunner & Kohler, in press). As a result, the water table in the ground sunk rapidly so many wells have already fallen dry.

In Ma'rib the government tried to reestablish the former wealth of the region by building a dam with an accompanying irrigation scheme. A firm analysis of the ancient irrigation sediments by the planning company confirms their good soil quality. Hydraulic conductivity ranges between 1.0 and 1.5 m per day, and the infiltration rate is about 50 mm/hour. The values for available water holding capacity are in excess of 20% by volume (Electrowatt 1978, p. 30).

Unfortunately the farmers did not like to be integrated into this scheme. They prefer the well irrigation. Reasons for this are many: The farmers are foremost tribal people who prefer to remain independent. With their pump they can irrigate their land whenever they want, produce whatever they want, and do not have to pay any taxes. They further explain that the water quality of the aquifer is better than the one of the reservoir. The provision of water from the lake is insufficient due to high percolation between the dam and the diversion structures.

The irrigated agriculture of today is quite different from the ancient one. In ancient times irrigation was seasonal with abundant water linked to the tropical rains. Today the farmers irrigate the whole year with small quantities of water. Hence the danger of salting the soils is prevalent as can be observed in many places. The permanent existence of water allowed the anopheles fly to spread. Over the last few years the risk of malaria - hitherto unknown in this region - has become very high. In the reservoir of Ma'rib, bilharzia has appeared a new (Abdulsattar 1995, p. 34). Another issue signals the changing local climate. The humidity of the air increased and weakend the formerly hard mud bricks. Together with the more frequent rains it poses a severe danger to the houses and for many archaeological sites. These are also threatened by bulldozers preparing new arrable land.

The miraculously expanding irrigated agriculture made Yemen - especially in fruits and vegetables - an almost self-supporting country. If the old water rights and the irrigation methods do not change, the wonder might only be with us for a short time.

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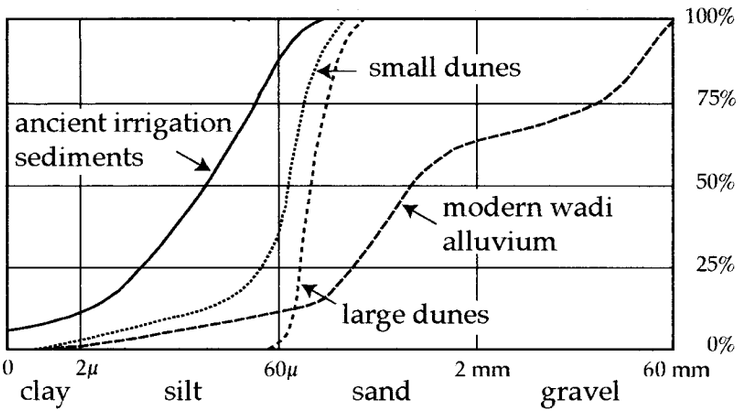

Fig. 1: Grain sizes of various recent accumulations in the wadi floors of Yemen

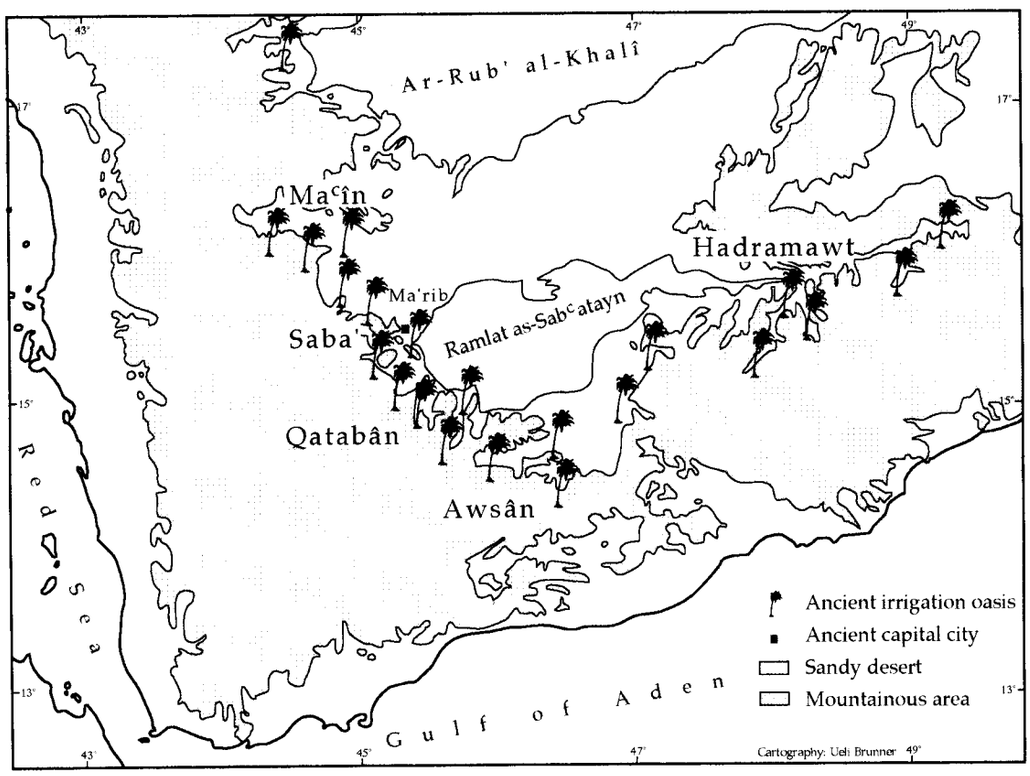

Fig. 2: Distribution of ancient irrigation oases at the borderlands of the Ramlat as-Sab'atayn in Yemen