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READING ANCIENT LANDSCAPES IN YEMEN: THE USE OF REMOTE SENSING AND GEOMORPHOLOGY TO MONITOR HISTORICAL CHANGE

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1. The Beginnings

The term Yemen is a native title. Since Islamic times it has meant a cultural region stretching over the whole south of the Arabian Pensinsula. The modern borderlines of the Republic of Yemen confine an area much smaller. As a result of the colonial history, Yemen was divided into two countries till 1990: the British Protectorate had become the People's Democratic Republic of Yemen with Aden as its capital, and the Osmanic province had turned into the Arab Republic of Yemen with Sana'a as its capital. The Swiss activities started in the Arab Republic in the early seventies, so this country is discussed first (Fig. 1).

Until the revolution in 1962 the country, ruled by a religious and political leader called Imam, followed a policy of total isolation. Only a handful of western medical experts were allowed to enter and to serve the royal family. The revolution led to a seven-year civil war. With the help of Saudi Arabia, conservative tribes in the north and east supported the overthrown Imam, the rest of the country fought on the side of the Republicans which got military support from Nasserite Egypt. The stalemate situation ended in 1969 in an agreement between both parties to form a government of national unity with Republicans as well as Royalists. So the main characteristic of the country, the tribal division into small entities, did not disappear.

Nevertheless, after the reconciliation the country opened the doors for multi- and bilateral aid. It was within this liberalisation that the first Swiss scholars entered the Arab Republic of Yemen in the year 1973. The pioneer was Toni Hagen. He was engaged within the UNDP and was eager to promote

development aid to this poor country.[1] The geographer Hermann Escher conducted an economic and social study on the Wadi Mawr in order to imbed an irrigation scheme which was already under construction into the local tribal customs.[2] It was especially Toni Hagen who established firm ties to his host country, and after a prospective mission of three scholars in 1975 the Yemen government signed a bilateral agreement with the Swiss government concerning the realisation of an airphoto interpretation project to complement Yemen's population census programme. Under the auspices of Professor Haefner of the Department of Geography, University of Zurich, Hans Steffen and his team succeeded in working out excellent reports and maps on the population situation in the Arab Republic of Yemen.[3] The fact that remote sensing was applied to support the population census sheds light upon the political situation in this country during the seventies.

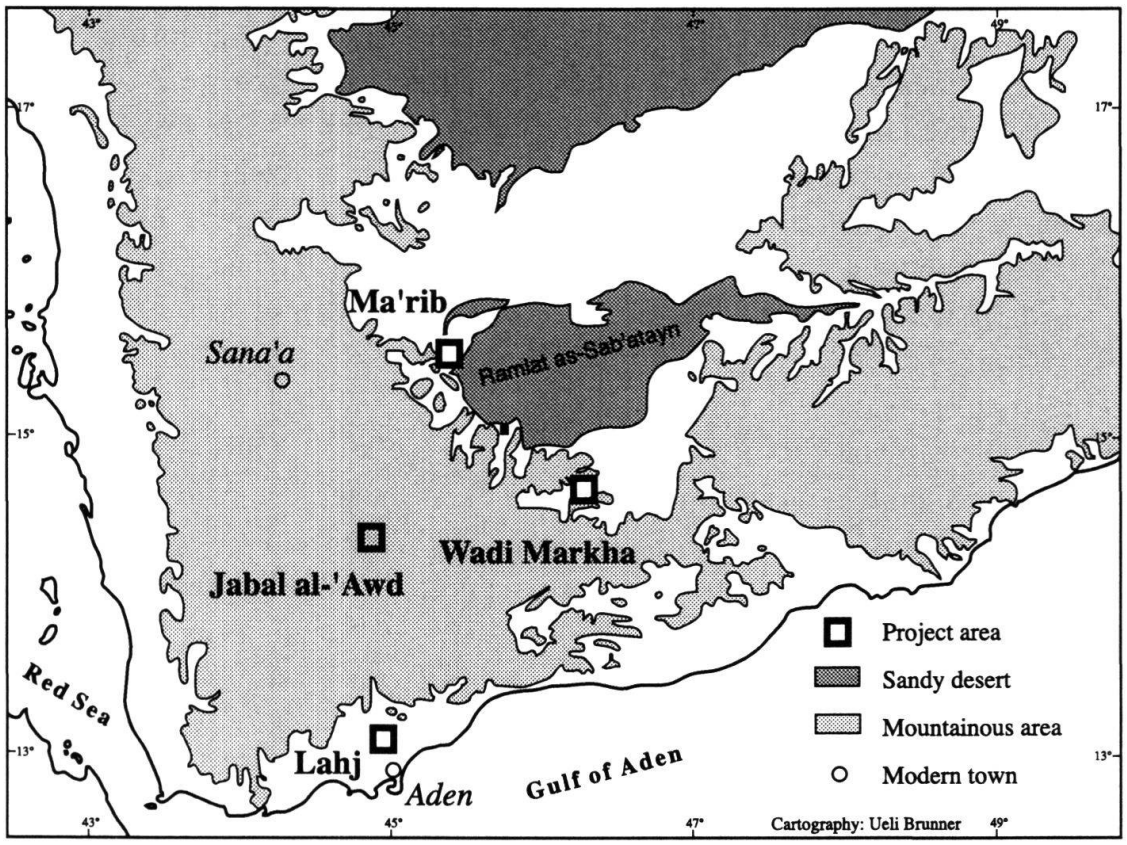

Figure 1: Sketch map of Yemen

1 HAGEN, 1971.
2 ESCHER, 1976.
3 SWISS TECHNICAL CO-OPERATION SERVICE, 1978; GEISER et al., 1977; DUBACH, 1977.

It was divided into tribal territories. Many regions were still inaccessible without the permission of the local *shaykh*. Furthermore the infrastructure for the traffic consisted in most parts only of tracks, most of which happened to be in a very bad state. The knowledge of the geography of the land or of the pre-Islamic history was on a low level, partly because the centres of the ancient cultures were located in the tribal areas of the east, along the borderlands of the sand desert Ramlat as-Sab'atayn.

A later result of the Swiss cooperation in conducting a population census was the dissertation of a team member on land-cover studies and crop acreage estimates south of Taiz.[4] During their field work the Swiss airphoto interpretation team came across hundreds of archaeological remains during their field trips as well as in the aerial photographs. Therefore it was really not by chance that it got in contact with the German Archaeological Institute, which started their activities in North Yemen with a short visit of Ma'rib in 1977. The research done by Swiss scholars in the then emerging cooperation is the central topic of this paper.

2. Developing New Interdisciplinary Methods

The most surprising fact for the archaeologists visiting Yemen was the abundance of archaeological sites and features all over the land. In many places it was as if the ancient landscape had survived into modern times. For once the problem of the archaeologists was not to find a site for digging but to survey all the innumerable remains. The best method to do so was by means of remote sensing. Aerial pictures with a scale of 1:60'000 were at hand from most of the regions from the population census. The task consisted in working out an interpretation key for the structures and objects in the aerial pictures. It was quite easy to see outlines of ancient buildings or city walls. But there remained thousands of other features of the ancient cultures. Most of them appeared in rural areas and belonged to the former agriculture or were lines in the outback, difficult to identify.[5]

The most prominent feature in the aerial pictures were light shining, rectangularly textured sediments in nearly all the *wadis* debauching into the Ramlat as-Sab'atayn. It was neither clear where these sediments originated

4 SCHOCH, 1982.

5 GERIG, 1982:40f.

from nor why they showed a rectangular pattern. So it turned out to be necessary to investigate these sediments by a geomorphologist. His method to determine the origin of the sediments was to take samples in the field, to test them in the laboratory by grain size, content in organic matter, mineral analyses and observation of the particle surface under the microscope. In this manner it became possible to differentiate airborne sediments from water-borne sediments and to define sediments accumulated by irrigation.[6]

Based on the idea that under the climatic conditions of Yemen with its periodic rainfalls twice a year, the amount of sediment accumulation by irrigation does not fluctuate very much, a mean annual sedimentation rate on the ancient fields was calculated. This figure turned out to be a very useful instrument to date structures out in the fields where charcoal for radiocarbon dating is lacking. A further goal of the geomorphologist was to explain the diverse structures on the surface of the sediments like e.g. the rectangular pattern by sampling and observation.

A third method of understanding the ancient situation was to study the present one. One of Yemen's pecularities is its permanence. So the old wisdom that the present is the key for the past was taken into account. A study of the present day irrigation system and cropping pattern was undertaken in order to better understand the agriculture of the old South Arabian Kingdoms. These investigations helped roughly to calculate the population of the oases in ancient times. So at the end of their research the new team ended up doing the same work as the old team, viz. conducting a population census.

In the following pages four case studies done during the last 25 years are presented.

3. Case Studies

3.1 The Sabean Oases of Ma'rib

Ma'rib is a very well known town in Islamic countries because the Qu'ran Surah 32, verses 14-16 tells the story of the breaking of the dam as a punishment for the impious people in this fertile oasis. As a consequence the inhabitants had to leave their homeland. This was the final decline of the

6 BRUNNER, 1983:18.

once most famous city of Southern Arabia, the capital of the kingdom of Saba: Ma'rib. The story explains clearly why the ancient landscape survived up to our days. People were forced to leave their homes not because of a war but because their fields fell barren due to the lack of water. Almost everything beside the dam was preserved in a good state.

This favourable situation was perfectly retained in the aerial pictures of the Swiss airphoto interpretation team (Fig. 2). Furthermore there existed aerial pictures on an even larger scale, i.e. 1:30,000, which were taken in order to get a basic knowledge of the region for the modern Ma'rib Dam and Irrigation Project. The goal of this project consisted in reestablishing the mythical fertility of the former Sabean oasis. The Abu Dhabi Fund of Shaykh Sultan an-Nahyan, who claimed that his ancestors were among the victims of the dam catastrophe mentioned in the Qu'ran, was the financing party. The Yemeni government supported this idea for several reasons. It was a good opportunity to open up new agricultural land for the fast growing population. Furthermore the government saw the possibility to establish a stronghold of the state in a hardly accessible tribal area. To reach this goal, an asphalt road was built to link Ma'rib directly with the capital Sana'a. And finally the government was fully aware of the historical importance and the legendary myth still alive in the Yemen people so by implementing the project the newly founded Arab Republic of Yemen hoped to become the legatee of the famous Queen of Sheba.

It was in this very famous and almost perfectly preserved oasis that the research of the new Swiss team started. Schoch, in a short article, had already pointed out the promising possibilities of geographical methods.[7] Together with Gerig he drew an inventory of all the ancient and medieval structures on the basis of airphoto interpretation. The result were two maps of Ma'rib and its environment on a scale of 1:30,000; one showing the region in a puzzle of aerial pictures with about fifty place names and the other depicting the abundance of archaeological structures seen on the surface. Altogether twenty different types could be distinguished, ranging from large forms such as roads and *tells* to tiny structures such as graves or water distributors.[8]

7 SCHOCH, 1978.

8 GERIG; SCHOCH, 1982.

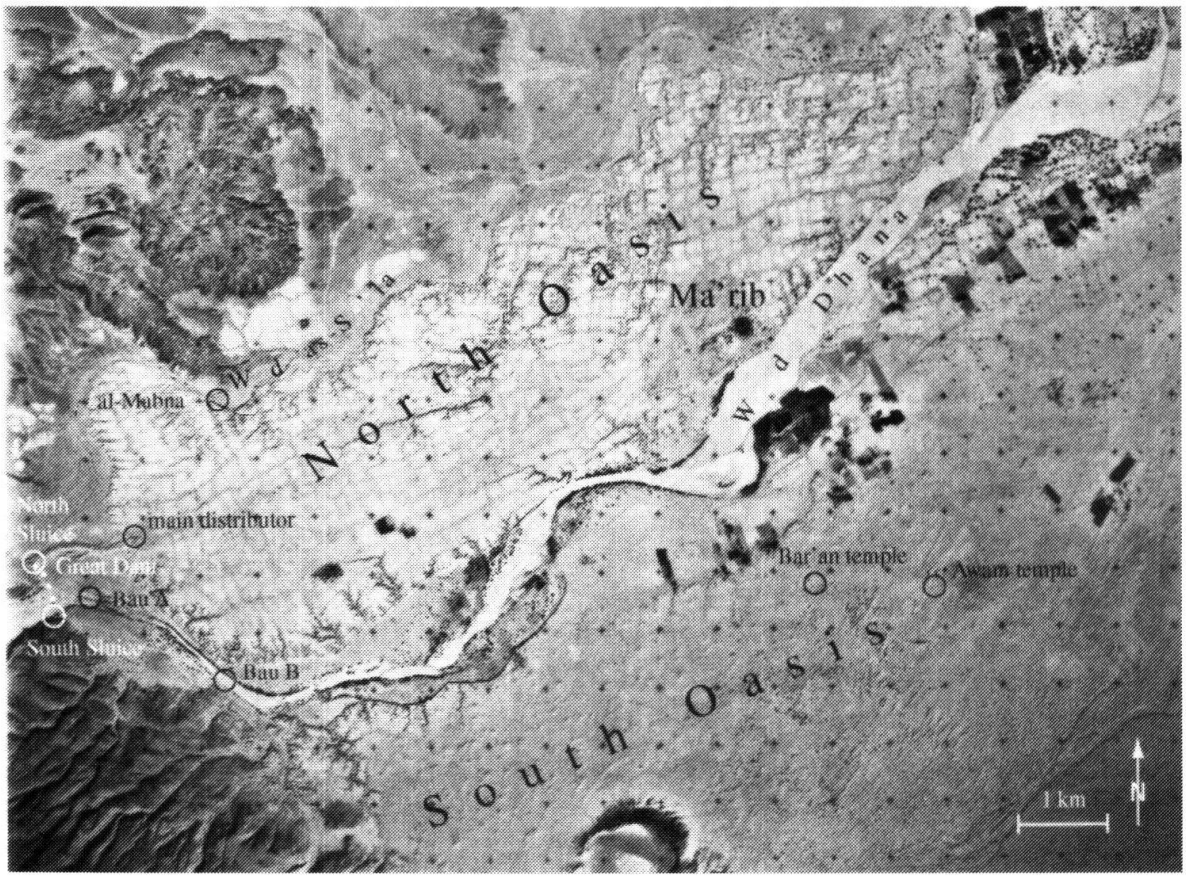

Figure 2: Aerial photograph of the oasis of Ma'rib showing the two ancient gardens (Royal Airforce 1971)

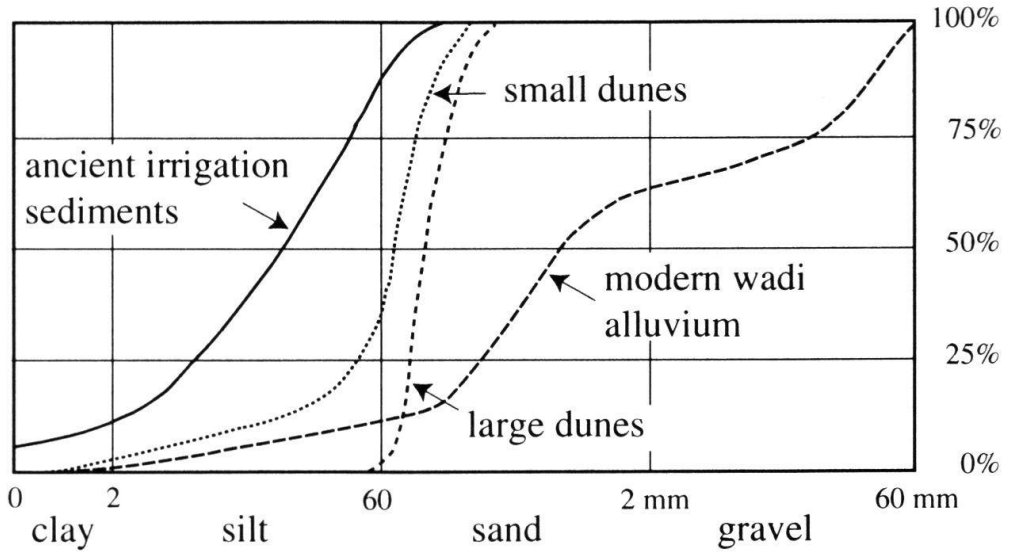

Figure 3: Grain sizes of different sediments in the oasis of Ma'rib

After the first research campaign it became obvious that the interpretation of aerial pictures could not lead to substantial explanations for many of the ancient structures. To find out the distribution system of the irrigation water, Schoch concentrated on the remains of water distributors on the northwestern part of the North Oasis. Here a main channel coming from the ancient dam ended up in a basin from which more than a dozen outlets fed secondary canals which covered the whole North Oasis. He numbered and measured all the water distributors in its elevation, capacity and direction. This work resulted in a proposal as to how the distribution of water in ancient times may have functioned.[9]

The other pioneer, Gerig, worked on the differentiation of the linear structures and on the understanding of the irrigation system as a whole.[10] After one season it became evident that the functioning of the Sabean irrigation could only be determined if the sediments were tested and classified. It was within this setting that the author of this article joined the team as geomorphologist in 1979. My programme consisted of four different subjects. First of all I wanted to discover the origin of the Quaternary sediments in the region. Second, based on these results, I hoped to find out more about the functioning of the irrigation. Third, I undertook a detailed study of diverse small structures on the surface of the loess-like sediments and fourth, I intended to write a history of irrigation in the oasis of Ma'rib with the Great Dam as the central subject. Here are some of the results.[11]

The oasis of Ma'rib has to be seen as on organism which functioned in space and in time. This means that the visible surface of the oasis must not implicitly reflect a single stage. It may well be that some parts belong to another time period than others because erosion might have been uneven on the oasis since its abandonment. Questions like this are primary subjects of the geomorphologist's work. So I started investigating the sediments. By field methods and especially by determining their grain sizes in the laboratory, four different sediment types were differentiated (Fig. 3). The most relevant result was that the loess-like sediments could surely be identified as accumulations laid down by irrigation. These sediments were man-made and therefore a direct cultural heritage of the Sabeans. At this point the research shifted into geoarchaeology. By investigating the extension of the

9 SCHOCH, 1982, table 17.

10 GERIG, 1982.

11 Details in BRUNNER, 1983.

irrigation sediments, the area of irrigated land in the ancient oasis could be determined. A mix of interpreting aerial pictures and sampling in the field led to the astonishing result of 9'600 ha; 4'300 ha on the North Oasis and 5'300 ha on the South Oasis.[12]

In some places it was hard to differentiate between modern and ancient irrigation sediments. But this meant that modern irrigation still functioned in the same way as in antiquity. The irrigation of today is called *sayl*-irrigation. The *sayl* is the episodic waterflow in the *wadi* which appears after heavy rainfalls in the Yemeni mountains to the west. By an earthen diversion dam, a part of the *sayl* is conducted into a channel from where the tamed water flows into large empoldered fields. The fields are irrigated only once before the seeding but therefore by large quantities.[13] The farmers say that the water must cover the soil knee-deep, which corresponds to about 60 cm. If you get the same accumulations in modern *sayl*-irrigation as you find in the ancient oasis, this means that the Sabeans used the same technology as today; they practiced *sayl*-irrigation. This new idea led to important conclusions concerning the functioning of the Great Dam. The task of it was by no means to store water, but to raise the water to the level of the fields, where it was distributed immediately.

Easy calculations verified this conjecture. The 9'600 ha needed about 50 mio m3 of water. The yearly flow in the Wadi Dhana is given with about 100 mio m3. The two outlets of the Great Dam had a capacity of about 120 m3 /sec. This means that the two oases could be fully irrigated within less than a fortnight. Normally there are two rainy seasons in the catchment area, one around April, the other one in July/August. So two annual irrigation periods may be taken as granted. The sediment load of the water in *sayl*-irrigation can be assumed to be about 1%. This leads to a sedimentation rate on the fields of a little bit more than 1 cm/year. Radiocarbon dating of the irrigation sediments confirmed this figure with 1.1 cm/year.[14]

A fascinating subject was the broad variety of structures on the surface of the irrigation sediments. The forms ranged from small fossilized imprints of raindrops to kilometer-long outcrops of ancient canals. A culmination in my research was the discovery that flat ring structures and regularly arranged mud mounds had the same origin: palm trees. Dates were basic food for the

12 BRUNNER, 1983:90.

13 BRUNNER; KOHLER, 1997:175.

14 BRUNNER, 1983:65.

members of the caravans. Inscriptions told of palm tree gardens and now I found them in the fields.[15] How could it happen that they were preserved up to our days? Date palms needed water the whole year round. So *sayl*-irrigation was not sufficient, they needed further irrigation. This was effected by water from wells which was poured into small circular depressions around the tree. In that way the soil got harder than in the field. When erosion attacked the oasis after its abandonment, the rootstock resisted and was carved out as a mud mound. Tree rings on the flat surface show a higher level of the palm tree, the darker ring represents the higher degree of organic material in the soil originating from the fibre (Fig. 4).

Based on this knowledge about the function of the irrigation system, the cultivation on the fields, the extension of the agricultural zone and the sedimentation, a history of the irrigation in the oasis of Ma'rib could be drawn. In the North Oasis more than 30 m continous irrigation sediments demonstrate a *sayl*-irrigation of at least 3'000 years. Since its end is fixed by

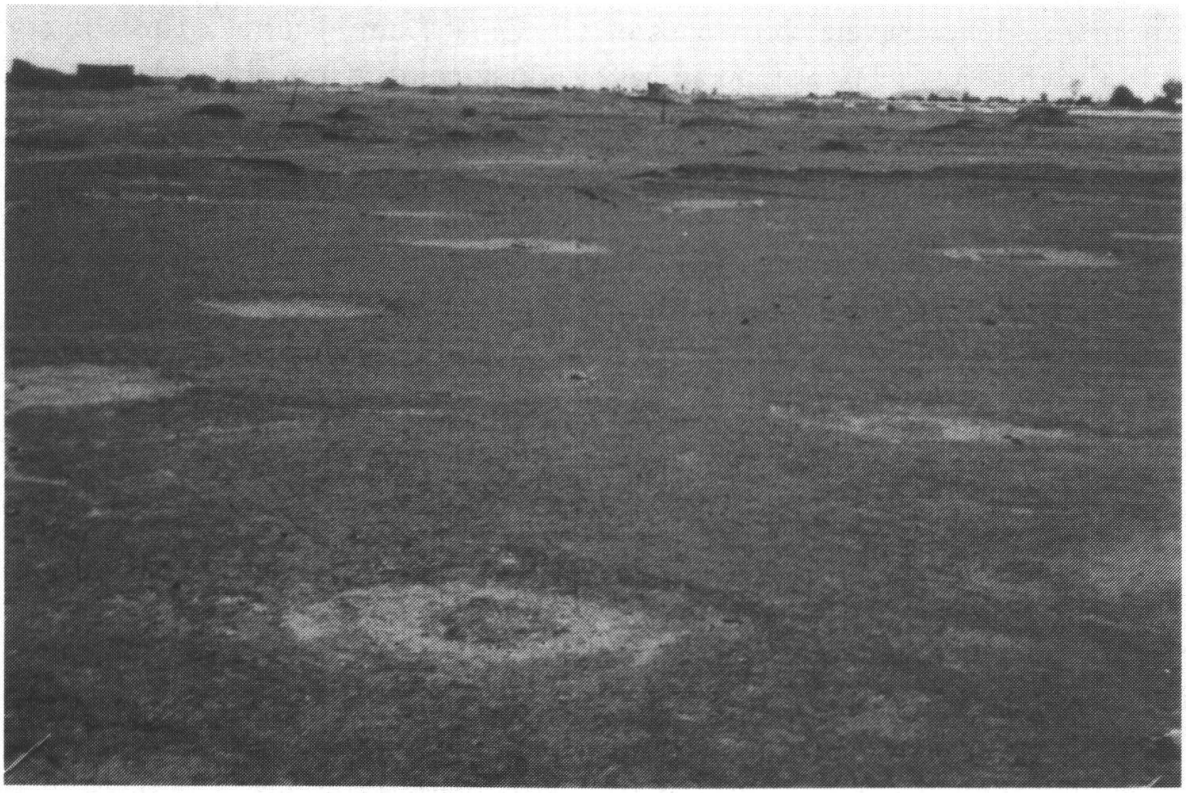

Figure 4: Mud rings on the surface of the ancient oasis of Ma'rib representing palm gardens of the Sabean time

15 BRUNNER, 1983:29.

the Qu'ran to the early 7th century AD, the beginning reaches into the 3rd millenium BC. At the time this result was published, the history of Yemen started only in the 8th century BC. Nothing was known of the Bronze Age or Neolithic cultures.[16] Therefore the irrigation sediments of Ma'rib proved for the first time the existence of a well-organized society in Yemen in the 3rd millenium already. Newly discovered massive stone structures turned out to be predecessors of the Great Dam. Their skilled masonry is as impressive as their age. By a comparison of the level of the outlets with the level of the fields, they could be dated into the late 2nd millenium BC. This was the first proof of a highly advanced society in the homeland of the legendary Queen of Sheba at her time in the 10th century BC.

The existing remains of the South Sluice date from about 530 BC.[17] This fits very well the level of the oasis at this time. Troubles with the dam started in the first centuries AD. The continuous sedimentation of the fields required a higher dam. To raise the water onto the level of the fields, the *sayl* had to be stowed almost to the top of the dam. Safety was not guaranteed any more. Hence several breakages of the Great Dam occurred. The society in Ma'rib had lost its power, so an easy and economical possible solution was looked for. It was found at the end of the 6th century AD, when the overflow of the North Sluice was lowered so the whole *sayl* could pass into the neighbouring Wadi as-Sa'ila. About five kilometers downstream the *sayl* was caught again by a quickly built dam arrangement called al-Mabna. In this part the North Oasis was lower, so it was easier to reach its level and to serve the area around the capital with irrigation water. As detailed studies of discordances in the barrage area of the Great Dam show, the final destruction happened to be at the beginning of the 7th century AD.[18]

3.2 The Unknown Wadi Markha

Ma'rib was the place to gather experiences in the field of researching irrigation by discovering archaeological signs in aerial photographs and geomorphological investigations in order to get an intimate knowledge of Yemen history. It became obvious, that as late as in the 1980s the knowledge of South Arabian cultures was based mostly on inscriptions and on a few excavations. It was therefore a matter of course to extend our activities to

16 DE MAIGRET, 1996:127.
17 WISSMANN, 1982:241.
18 BRUNNER, 1983:119.

other ancient oases. The best way to start with it consisted in the application of remote sensing in the heartland of the South Arabian kingdoms in the borderlands of the Ramlat as-Sab'atayn. The work based on images with a resolution of about 20 m x 20 m, recorded by MOMS (modular optoelectronic multispectral scanner) aboard the Space Shuttle flying at an altitude of 296 km.

The interpretation was undertaken in the analogous manner, and it became clear, that the MOMS images were very helpful for the task. They covered the southern borderland of the Ramlat as-Sab'atayn, excluding the two large and fertile valley systems of Jawf and Hadramawt. Ancient irrigation could be detected in at least ten *wadis*, covering a total area of 44'500 ha.[19] Thus the legend going around in Yemen that in antiquity a horseman could ride for seven days without leaving fertile gardens has become a true story.

Among all the *wadis* observed by remote sensing, the Wadi Markha was the bright star. It contained the largest ancient oasis with around 12'000 ha and the images marked three archaeological sites, unknown so far. The reasons for this was the political situation in the valley. The lower part belonged to the People's Republic of Yemen. The borderline in the valley was unclear and the local tribes tended to be independent from governmental influence. So it was almost impossible to enter the *wadi*. The situation rapidly changed after the unification of the two Yemens in 1990. In cooperation with the Staatliches Museum für Völkerkunde in Munich a project was launched to explore Wadi Markha. In May 1991 a first short mission visited, as the first scholars in general, the valley. The high expectations were exceeded by far. The Wadi Markha was really an archaeological treasure.

The main idea behind the project was an approach by different remote sensing products. It had started from a distance of 300 km with the MOMS images from space shuttle, the next step consisted in organising aerial photographs from about 3 km above ground, and a last approach should go to a mere 30 cm by magnetic prospecting of special sites.[20] The reason for this unusual proceeding was the political uncertainty and the partly hostile tribal population in the Wadi Markha. Starting by an excavation would have endangerd the archaeological remains because it seemed impossible to safeguard the site, and because some people were eager to look at our activities in order

19 BRUNNER; HAEFNER, 1990:151.

20 KOHLER et al., 2000:238f.

to find out the best places for robbing statues and selling them on the black market.

It became a difficult task to organise a flight to shoot aerial photographs. During 1993 the unity of the Republic of Yemen was in danger. The former South Yemen had become dissatisfied and was trying to regain independence. By the beginning of 1994 the armies had got in line in Wadi Markha, too. It was a great surprise when we got the official permission to undertake the flight in February 1994. We do not know whether the pilot (of a private company) was aware of his hazardous job when several times he flew over the armies poised for battle. For us the result was worth the risk; we got in possession of 210 excellent aerial photographs on a scale of 1:30'000 (Fig. 5). The flight and the photographs were financed by the Staatliches Museum für Völkerkunde in Munich.

Field work started not even a year after the civil war in January 1995. Two students of the Department of Geography of Zurich surveyed the entire Wadi in order to document the ancient and modern situation.[21] Two experts from the Bavarian Conservation Office started ground magnetics at the largest *tell* Hajar Yahirr, which is located in the lower part of Wadi Markha. Their goal was to draw a city map of this 17 ha settlement of which most structures were buried under aeolian sands.[22] The author as head of the team conducted endless discussions with different tribes to ensure safe work, and he tried to trace the outline of a history of the valley by dating the irrigation sediments and settlements.[23] In November and December 1995 a second campaign took place. Later attempts to work in the *wadi* failed due to armed attacks by local people.

Nevertheless the two campaigns showed marvellous results. Twenty new *tells* or large sites could be revealed and – with the exception of one – all be named.[24] Hajar Yahirr turned out to be by far the largest town with 17 ha. Five *tells* are of an area of around 3-6 ha, and the other sites were smaller than 3 ha. The airphoto interpretation of modern settlements allowed safely to distinguish ancient sites from recent villages. The diversity of house constructing was documented as well as the different methods of modern irrigation agriculture.[25]

21 BOSSHARD, 1996; FECHTIG, 1996.
22 BECKER, 1997.
23 BRUNNER, 1997a.
24 BRUNNER, 1997:193.
25 FECHTIG, 1996: Figure 26.

The identification of ancient dams, canal systems, water distributors, irrigation sediments, field arrangements, tree rings and mud mounds allowed to reconstruct the way of irrigation in antiquity and the large extension of it.[26] A few radiocarbon datings led to a rough picture of the history of irrigation in the valley. It seemed to have started in small lateral *wadis* at the beginning of the 3rd millenium BC. During the middle or the end of the 3rd millenium BC the irrigation shifted to the main *wadi* in its lower reaches. It is exactly in this region that the capital of the kingdom of Awsân, Hajar Yahirr is located. In the 2nd millenium water must have been scarce in this heartland with at least 6'600 ha so the *sayl* water was conducted over a canal 20 km long from the neighbouring Wadi Hammâm. At the beginning of the 7th century BC the centre of the kingdom of Awsân was totally destroyed by the Sabeans. In consequence irrigation moved upstream and there it shows the Sabean pattern with rectangular field arrangement. These oases and the corresponding settlements were abandoned by the end of the South Arabian period, i.e. in the middle of the first millenium AD. In Islamic times only small parts along the main *wadis* were irrigated.[27]

Altogether the investigations in Wadi Markha brought to light another ancient cultural landscape which has survived into our days, and whose surface in the lower *wadi* parts was much older than the one in Ma'rib. Now we were eager to focus on another valley in a different region. The chance came when the German Archaeological Institute started a project in the Lahj oasis north of Aden.

3.3 The Coastal Oasis of Lahj

In the 1990s the focus of interest shifted to the Gulf of Aden. The German Archaeological Institute and the Russian Academy of Science, in cooperation with the General Organization of Antiquities, Museums and Manuscripts of Yemen started excavating a so far totally unknown Bronze Age culture which today is called Sabir Culture after the place. This culture is characterized by a highly differentiated society: a city centre with houses on a large scale, and suburbs with huts, and, especially, an enormous production of pottery.

26 BOSSHARD, 1996:34f.

27 BRUNNER, 1997a:79.

Figure 5: Aerial photograph of Hajar am-Lajîya in the Wadi Markha (Maps geosystems 1994)

It was obvious that trade played an essential role in its economy; it was even suggested that with Sabir the well known land of Punt may have been found.[28]

The question our team was asked by the archaeologists was: What was the basis of the local economy of the Sabir culture? Sabir is located about 30 km from the coast. It lies 50 m a.s.l. at the southern fringe of the fertile oasis of Lahj, which is watered by the *sayl* of the Wadi Tuban. The catchment area of Wadi Tuban covers the southern escarpment of the Yemen mountains, a region with an annual precipitation of more than 1'000 mm in some parts. Therefore the Wadi Tuban is a safe water source; in the upper part the water even flows all year. This permanent flow in the *wadi*-bed is in Arabic called *ghayl*.

Beside the climatic difference, there was another basic distinction between Lahj and the regions of Ma'rib and Wadi Markha. The oasis of Lahj was not abandoned in the late South Arabian period. It shows a permanent

28 VOGT; SEDOV, 1998:133.

farming that has covered an area of 20'000 ha in recent years. During all the Islamic period it was the fertile hinterland of the important sea port of Aden. As a consequence the archaeological remains were not to be found on the surface and could therefore hardly be detected in satellite images or aerial photographs. So research in ancient agriculture had to be conducted in sections along the *wadis* or in wells.

The preparation for the fieldwork was undertaken by the author in November 1995. Old, but accurate aerial photographs taken in 1947 by the Royal Airforce could be purchased from the Survey Authority of Yemen. An image from the French satellite called Spot was helpful to establish an overview of the oasis with its complex nature. The concept that the research should be conducted on two levels was adhered to; one subject consisted in documenting recent agriculture, the other in searching for remains of ancient irrigation. In March and April 1997 two students and the author surveyed the oasis of Lahj. Already the fieldwork clearly showed the contrast to the work in Wadi Markha. The local people helped the foreigners in every way to succeed in their task. No hostile activities were undertaken against us.

The investigations on recent agriculture conducted by Grolimund and published in a master thesis, demonstrated the importance of the political system for the way of irrigation, the variety of products and the extension of the fields.[29] Till 1950 the oasis was watered by *sayl*-irrigation from April to September, and in smaller parts by *ghayl*-irrigation for the rest of the year. Mostly millet was grown. Most of the land belonged to the sultan of Lahj and his family members, who leased it to farmers. The British established a well-built irrigation scheme in the fifties. Starting from a weir at the head of the oasis, a permanently installed network of canals and outlets was drawn over the upper part of the oasis. The production of cotton was boosted, it was so profitable that the sultan family got involved into cultivation. As a result many small farmers lost their land and hence their income.

After the communist regime took over in 1967, the land reform was among their most urgent political objectives. The land was confiscated, 60% handed over to cooperatives, 40% to public farms. The British irrigation scheme was renewed and the rest of the oasis was covered by concrete canals and endless weirs. This progress was supplemented by diesel pumps using the abundant groundwater. In this connexion the surface of the oasis was totally remodelled, as the old aerial pictures show, and the traditional *sayl*-irrigation

29 GROLIMUND, 1998.

disappeared. Cotton became less important, in demand was now the production of fodder for the large public dairies. Since the unification of Yemen in 1990, Lahj established a highly diversified agriculture. The farmers shift from *sayl*-water to groundwater in order to cultivate the whole year round and also to be independent from the canal system badly maintained by the government. The developments during the last fifty years have shown clearly that none of the new irrigation agriculture is sustainable. The British system supported the sultan's income and deprived many a farmer of his land. The socialist system killed the farmers' motivation, and pump irrigation overuses the aquifer. How must have been the *sayl*-irrigation in ancient and Islamic times—for it to last 5'000 years?

The geomorphological research on the history of the oasis yielded interesting results.[30] It brought to light that the smaller valley, Wadi Saghir, is quite recent, and that the main water course, Wadi Kabir, shifted continously westward. Therefore the new Wadi Saghir cut deeply into the ancient oasis and exposed perfect cross sections of past soil and sediment layers on both sides. Analysis of the sediment samples proved their origin from irrigation, although the grains were slightly coarser than in Ma'rib or Wadi Markha. This may be explained by the slightly steeper gradient of the valley floor of Wadi Tuban. The cliffs along Wadi Saghir showed several sections of two different ancient canals. One type is less than a meter in width, the other is 4-15 m wide.

This fact can be interpreted in the way that also in ancient times *sayl*- and *ghayl*-irrigation were practised together. Measurements along the *wadis* and in wells led to a map showing the thickness of the irrigation sediments and their extent.[31] The maximum size reaches about 18 m; in many parts it is only half of that. The extent of the irrigation sediments is, especially to the east, much larger than that of the modern oasis. These two findings supported the idea that in the course of time the cultivated fields moved westward. A few radiocarbon datings and an excavation in Ma'layba at the southern fringe of the oasis of Lahj provided evidence concerning the history of irrigation (Fig. 6). In Ma'layba it certainly started in the 3rd millenium BC, maybe already at the end of the 4th.[32] Further upstream along the middle course of Wadi Saghir, its beginning lies in the middle of the 2nd

30 LOHER, 1999.

31 LOHER, 1999: annex, map 2.

32 VOGT et al., 2001.

millenium BC. So the trend is the same as in Wadi Markha: from the lower reaches to the upper part.

Summing up the results of the investigations in the oasis of Lahj, it can be stated that for the first time ancient irrigation could be ascertained in the coastal region of Southern Arabia. The beginning dates back to the early Bronze Age and—as a contrast to the *wadis* bordering the Ramlat as-Sab'atayn—food production of the Sabir culture based on two different ways of irrigation agriculture: *sayl-* and *ghayl*-irrigation.

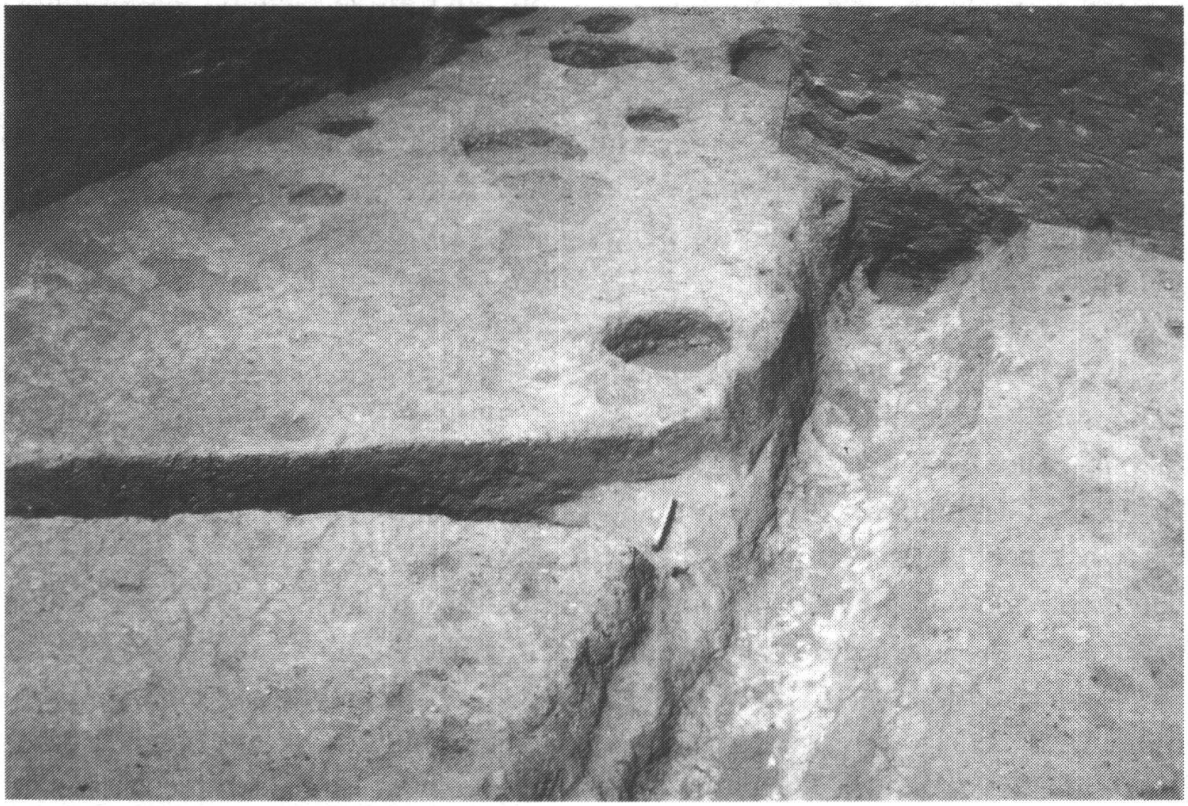

Figure 6: Early Bronze age canals in Ma'layba, oasis of Lahj

3.4 On Top of the Mountains

A new challenge was the request of the German Archaeological Institute to join their project on the Jabal al-'Awd in 1999. So far our favorite terrain had been the arid regions where the broad *wadis* debauch in the flat Ramlat as-Sab'atayn or in the coastal plain. The Jabal al-'Awd is situated in the southeastern part of the Yemen mountains and reaches an altitude of 3000 m a.s.l. Because of its easterly location it already lies a little bit in the rain shadow, so the annual precipitation can be expected to amount to less than 1'000 mm. During winter months frost occurs during night time. A four-kilometer-long but narrow plateau, running east to west, forms the top of the

mountain. The whole plateau is full of ancient structures, and almost in the middle the remains of a town of about 4 ha can be seen. The remains can be dated to the 1st to 3rd century AD. According to the martial time, when the Qatabanian kingdom slowly disappeared, the Himyars started their rise to power and the Abyssinians roamed the country, the town was safeguarded by a wall.[33]

The settlement on the Jabal al-'Awd must have been a thriving town with quite wealthy inhabitants. This can be seen from the very well built houses and streets, large store vessels, shops and grave chambers and—most striking—hundreds of bronze objects. The style of these objects show the close ties to the Mediterranean cultures of Egypt, Rome and Greece. The town was destroyed by a fire at the end of the 3rd century AD, maybe by the Abyssinians. The mountain slopes are terraced and still in agricultural use, but not so the top. The agriculture depends on the wet season, so mostly rain-fed agriculture is practised (Fig. 7). In some areas rainwater harvesting is undertaken.

Our research focused on the economy of this settlement at the beginning of the Christian era. In autumn 2000 three students travelled to Yemen and took part in the campaign of the German Archaeological Institute. Two students (Corbellini and Peter) studied the modern agriculture. They asked questions such as: When is the growing season? How many yields can be obtained in a year? What plants can be grown? How big is the risk of a drought? How are the terraces maintained? The third student (Brühwiler) searched for all kinds of clues related to the ancient situation. Soundings in terraces helped to determine their age. The architecture of the terrace walls also indicates a certain age. It seems that in ancient times large and heavy rocks were used; today the farmers prefer the easy way with smaller and hence lighter rocks.

The evaluation of the field work has only just started. The results of this new engagement will be three master theses submitted to the Department of Geography at the University of Zurich in early 2002.

33 VOGT et al., 2000:145.

Figure 7: Terraced fields on the slope of Jabal al-'Awd

4. Further Swiss Research

The more than twenty years of intensive scientific research in Southern Arabia have yielded a rich harvest. Starting with the most famous ancient structure in Yemen, the Great Dam of Ma'rib, step by step a unique hydraulic culture was revealed. As we could prove, their roots are going back to the early third, possibly even to the late 4th millenium BC. Irrigation emerges in many valleys as a response to the drier climate of this time period. The Yemeni flood water irrigation system was perfectly adapted to the harsh conditions of this arid region. The farmers did not fight the disastrous *sayl*, but used it. By taking only part of it and leading the water in a large channel with a very low gradient, they succeeded in reducing the energy of the flood. The immediate and single flooding of the fields accumulated fertile silts and leached the salt of the former farming season. The Yemeni flood water irrigation system was a simple method which corresponded to the tribal

society and which had a rich return of the investments. Thus it may be called sustainable in every manner, e.g. social, economical and ecological.[34]

Remote sensing showed the widespread application of the Yemeni flood water irrigation in Southern Arabia in ancient times. The visible remains are the light shining silt terraces along the *wadi* courses. The fertile soil accumulated by the former irrigation in most of the *wadis* could be placed at the disposal of the modern fast growing population as urgently needed farmland. This chance has been taken during the last twenty years but almost exclusively by installing diesel pumps and therefore irrigating with groundwater.[35] This led to overusage of the aquifers because traditional moslem water rights do not take into account the capacities of diesel pumps. This special, but for the Yemen Republic essential, problem of the common-property discussion is surveyed in depth in the dissertation by Kohler. He establishes a link between the institutional framework of resource management and the overuse or misuse of these resources. He concludes that if a solution is desired and a sustainable condition again reached, changes to the institutions must be adjusted to that system.[36]

The satellite images and aerial photographs not only indicate the potential agricultural land reserve of the young nation, they furthermore comprise thousands of pieces of information about its history. However, the recultivation of the ancient oases by the use of large bulldozers and scrapers destroys all the archaeological remains on the surface. The Sabean oases of Ma'rib has totally changed in appearance since 1970 (Fig. 8). Two master thesis analysed the changes on agriculture and ecology in this time span.[37] So the images and photographs have become most precious documents of the history of Yemen. Many archaeological structures and even sites are only documented by aerial photographs. We were lucky that the Yemen Government realized this side effect of our research quite early, so it gave us every possible support in taking aerial photographs.

The documentation of ancient Yemen led to a cooperation with the IREMAN (Institut de Recherches et d'Etudes sur le Monde Arabe et Musulman) in Aix en-Provence, France. The result was a map of ancient Yemen on a scale of 1:1 mio containing all topographical and tribal names

34 BRUNNER, 2000:58.
35 BRUNNER; KOHLER, 1997:189.
36 KOHLER, 1999:191.
37 CHERCHI, 1998; JUZI, 1999.

known from South Arabian, that means pre-Islamic inscriptions.[38] The map was so much appreciated by the Yemen government that the president of the republic, Ali Abdullah Saleh, personally ordered and funded an Arabic version that will hopefully be published in 2002.

In 1997 an exhibition about Yemen's past was initiated by the Institut du Monde Arabe in Paris. It was inaugurated in November 1997 in Paris. Since then it has been shown in Vienna, Munich, Rome, Turin and is now on the way to The Hague. Our contribution to the initial catalogue consisted in

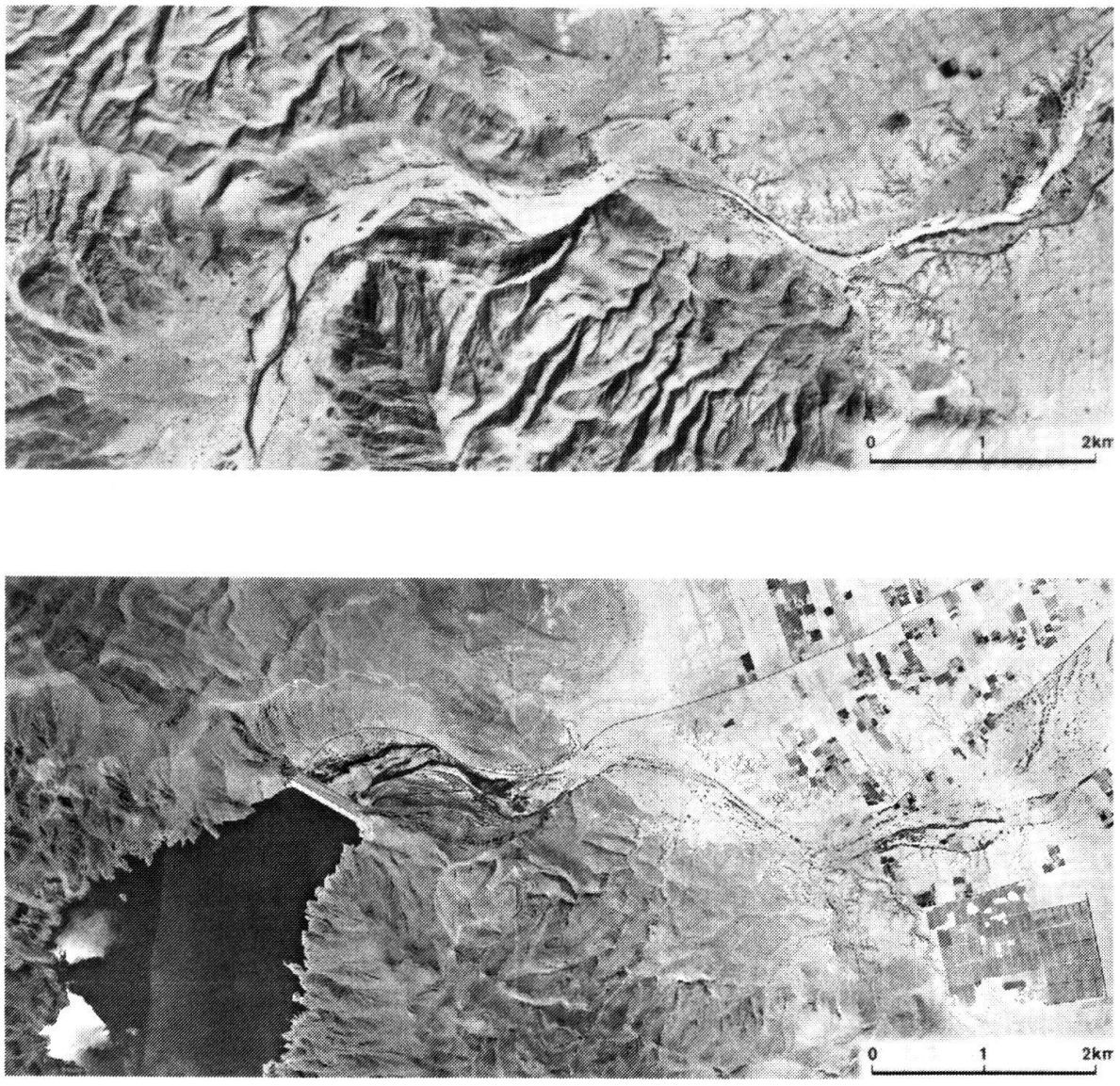

Figure 8: Changes of the landscape in the western part of the Ma'rib oasis between 1973 and 1989

38 ROBIN; BRUNNER, 1997.

two articles.[39] A special effort was made for the exhibition in Munich. In a separate room which was entered by a platform, the approach to the archaeological remains by remote sensing was demonstrated. Furthermore three additional articles were contributed[40] and a model of the Great Dam at a scale of 1:2'500, 6 m x 4 m in size, constructed after plans and under the scientific supervision of the author was installed. The model was taken to the Yemen pavillon at the world exhibition in Hannover. Now it is planned to present it to the Yemeni people and to exhibit it either in the National Museum in Sana'a or in the newly opened archaeological museum in Ma'rib.

The systematic research in, and the presentation of, the ancient irrigation methods of Yemen woke the interest of engineers and environmentalists. The indigenous Yemeni knowledge in hydraulic affairs has become well known and is today a symbol of sustainability. As a consequence we were invited to different symposiums on the subject of water. In June 1999 the traditional Yemen flood water irrigation system was presented in Petra, Jordan,[41] and in March 2000 at the Second World Water Forum in Den Haag[42]. In June 2000 there was a conference in Sana'a entitled "The place of ancient agricultural practices and techniques in Yemen today: Problems and perspectives", which was attended by Kohler and Brunner. A last remarkable yield of twenty years of research in a broad variety of subjects in Yemen is the publication of a book giving for the first time an entire overview of the geography and the history of this fascinating country.[43]

5. Future Activities

The German Archaeological Institute is very much interested in further joint programmes similar to the current one on Jabal al-'Awd. The reason for this is that our team works on a low-cost budget but delivers highly appreciated results which archaeologists themselves would not be able to reach. On the other hand we can profit from the almost perfect infrastructure of the Insti-

39 BRUNNER, 1997c, d.
40 KOHLER et al., 2000; BRUNNER et al., 2000; BRUNNER, 2000.
41 BRUNNER, 2001.
42 BRUNNER, 2000.
43 BRUNNER, 1999.

tute, their close relationship to the Yemen government and from the fact that it is willing to pay the expenditures for travelling and staying abroad.

This year the German Technical Cooperation (GTZ) decided to finance the preservation of the Great Dam. We will be part of the scientific team planning and supervising the work. Furthermore we initiated and now participate in a multidisciplinary discussion group based in Berlin, whose goal is to augment the knowledge of the dam by gathering engineers, archaeologists, geographers, architects and epigraphists at a single table. A geomagnetic sounding and dating in Ma'rib will hopefully give new facts about the history of the Great Dam.

The extensive knowledge gained of ancient irrigation in Yemen during our long presence could successfully be applied in some other countries. Invited by GAME (German Archaeological Mission to Eritrea) of Humboldt University, Berlin, we went to Eritrea in autumn 1997. Our task consisted in a general viewing of the remains of ancient irrigation on the territory of this young state and to investigate the national symbol called the Dam of Safîra. Safîra is located about 3'000 m a.s.l. on the Qohaito-Plateau in the south-eastern province of Akele Guzay. According to the school books of Eritrea, this dam is said to be related to the Queen of Sheba and therefore to date as far back as the 10th century BC. The result of our research greatly disillusioned the Eritrean authorities: We showed that the function of this structure was not the one of a barrage dam to collect water for irrigation. It is rather a massive wall of a cisterne in Yemeni style. The characteristics are a small catchment area of less than a square kilometer, a small sedimentation basin above the cisterne and an augmentation of the reservoir by hewn-out rocks. Seen from the point of water engineering the wall is constructed in a poor manner. Alternating layers of the wall consist of horizontally applied schists which gives it a nice appearance but undermine the stability of every dam. This architectural detail is one of several hints to an axumite origin. Since the culture of Axum flourished in the first centuries AD the wall could be dated to this late period. This new interpretation of the Dam of Safîra was very hard to accept by the Eritrean officials. This fact and the respect of GAME towards their local counterparts are the reason why these results remain unpublished so far.

In another study close relations could be established between the Yemeni rainwater harvesting system and the Nabatean way of irrigation in the Negev semidesert as well as the rainwater collecting system in its capital Petra in

Jordan.[44] The origin of this transfer of knowledge is given by the frankincense route which connected South and North Arabia till the beginning of our era.

We further expanded our activities in early 2001 when a short mission was undertaken in Belochistan, on the request of the Joint German-Pakistani Archaeological Mission to Kalat. The main object of study were the *gabar-bands*, large dams and wall systems found in several valleys in the south-eastern corner of this semiarid region. The study of the geomorphological processes lead to a definitive relation between the *gabarbands* and the archaeological sites in the vicinity. Therefore the dams seem to date to the late 4th and early 3rd millenium BC. Regarding their function and construction it is obvious that there does not exist any connection to South Arabia. The *gabarbands* seem to be an indigenous development in order better to use the diminishing amount of rainwater at that time. The water basin behind the dams became, after getting dry, the fertile farmland.

The latest request comes from the Commission for General and Comparative Archaeology in Bonn. They decided to set up the subject "water management for agricultural and household purposes" as a main topic. With our help they intend to study the treatment of water in different cultures. The project would entail sending scholars to Peru, Guatemala, Benin, Ethiopia, Sri Lanka and China. If this project is implemented, the methods developed and the knowledge gained in a small region in Yemen will spread to many countries all over the world. The seed sown in the nucleus of Ma'rib will have grown to maturity.

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44 BRUNNER, 2001.

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