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Summary: The Institut Français d’Archéologie Orientale (IFAO) has been studying since 1994 the site of Ayn Manawir. Human settlement is assessed on the site from the end of the Palaeolithic until the 3rd century AD. The Palaeolithic gatherers-hunters settled around artesian springs. By the end of the 3rd millennium BC, these springs dried up and men left the site.

Starting during the 5th century BC (the first Persian occupation of Egypt), the digging of a network made of approximatively 20 Qanats, a technical innovation in that time in Egypt, allowed resettling. A mud-brick temple and houses in which dated documents were found, gardens and open fields scattered at the bottom of the slopes of the ‘Ayn-Manâwîr hill. The excavation and the detailed study of one of these Qanats and of the connected irrigation systems gave us the keys for understanding the tunnel digging method, the water resources management, and the history of the attempts to maintain the supply of water as late as possible. In addition, the datas given by the demotic contracts and by the floral remains allow us to rebuild the ancient environment. The existence of the huge underground water table under the Egyptian Western Desert, the peculiar geomorphology of this part of its oases allowed and made necessary the digging of Qanats to secure human permanence in this arid region.

1. THE KHARGA OASIS : THE WATER RESOURCES AND THEIR USE DURING ANTIQUITY

The Kharga oasis is one of the four main oases of the Egyptian Western Desert. The nearest of the four to the Nile Valley, the oasis stretches for 150km along a north-south oriented depression cut in the limestone plateau (fig.1). The floor of the oasis is mainly formed of the so-called “Nubian formations” in which red clays and sandstone alternate, partially covered with Quaternary deposits which are re-depositions of wind eroded clays, sand dunes and sheets, playa sediments and paleosoils.

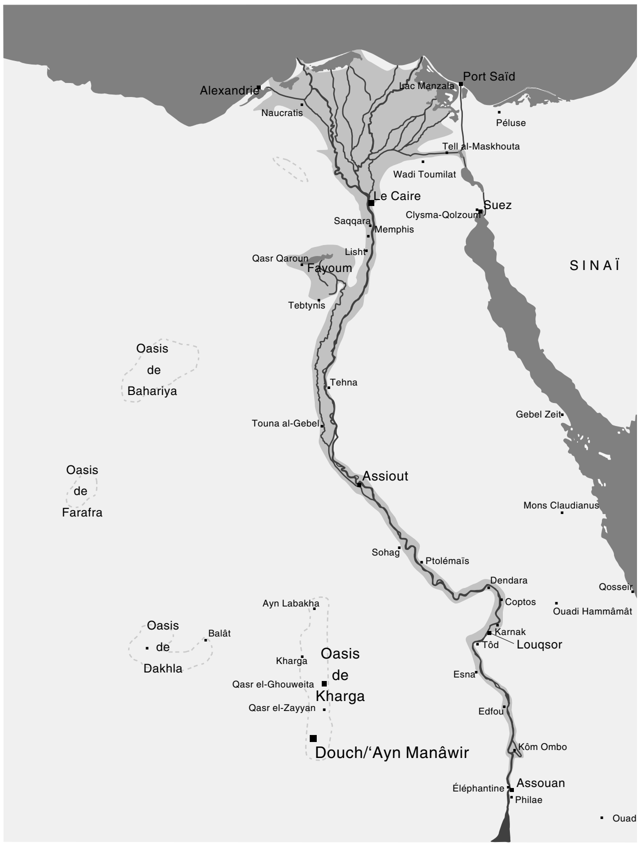

Figure 1: The location of ‘Ayn-Manâwîr.

The Kharga oasis benefited of the presence of artesian wells, bringing to the surface water from the huge Nubian Reservoir. This Nubian Aquifer System extends itself over some two million squared kilometers and is present under south eastern Lybia, north eastern Chad, northern Sudan and almost the whole western part of Egypt [1]. This aquifer was formed during the wet periods, the last of which ended between 8000 and 4000 years ago. Until recently [2] it was thought that the Kharga oasis artesian wells had dried up during the Palaeolithic period since no artefacts were known of dating between that period and the Persian rule over Egypt after 525BC, when new water collecting techniques were introduced. This assessment has to be revised at the light of recent excavations on different sites in the oasis.

2.‘AYN-MANÂWÎR : THE HISTORY OF THE SETTLEMENT

The “Institut Français d’Archéologie Orientale” (IFAO) has been excavating in Douch and its region since 1976. Douch is located in the Baris bassin, at the southern end of the Kharga oasis at a distance of 120km of the modern Kharga town, administrative capital of the New Valley Governorate. The Dush hill, on top of which was built a temple dedicated to Osiris and Isis, represents a fortress and a small town and belongs to a chain of five small heights oriented NNW-ESE extending over a 20 km distance along a group of parallel faults(fig.2). ‘Ayn-Manâwîr is one of these hills, excavated and studied by the IFAO mission since 1994 (fig.3). The peculiar geologic structure of ‘Ayn-Manâwîr and of the neighbouring hills, is formed of uplifted blocks of alterning strata of porous sandstone and clays, in a faulted band which allowed the constitution of a water reservoir overlooking the surrounding cul-

Figure 4: A dryed-up natural artesian venue.

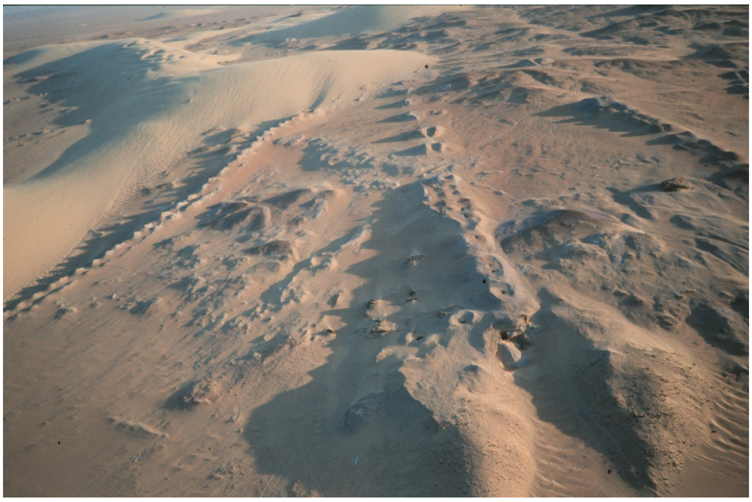

Figure 5: Three qanats on the northern slope of the hill. In the middle: qanat n°4.

tivable lands. These independent water tables were easily refilled during the rainy periods and water was prevented to seep into the depths thanks to the clay strata [3].

The remains of natural artesian water venues are still visible along the northern and eastern slopes of the hill (fig.4). Around some of them, we recently excavated small settlements and concentrations of lithic tools which belong to the epipaleolithic and neolithic civilisations. There is little doubt that these groups of hunter-gatherers and afterwards farmers were relying on the water resource provided by these artesian wells. Some scattered ceramic sherds dated to the end of the Old Kingdom (circa 2200 BC) may have been left by people staying for short periods around these wells. We have to assume, at the current state of our investigations, that there has been no consistent human presence on the site between the period of these Old Kingdom camps (by which most probably the artesian wells dried up) and the important resettlement which occured at least by the middle of the 5th century BC, under the reign of Artaxerxes the 1st.

As in such an arid region, human permanent presence cannot be granted without the mastering of water supply, the development of a totally new technique of water gathering and distribution was the key for the rebirth of the Dush region. Within a very short span of time, whole systems of tunnels, the qanats, were dug through the slopes of each one of the hills to drain the water trapped in these compartimented aquifers, and to bring it in a controlled manner to the cultivable lands at the foothills and beyond (fig.5).

Among the main features of the 5th century BC settlement, a mud-brick temple (60m x 18m) dedicated to the cult of Osiris [4] is surrounded by two groups of houses ("MMA" and "MMB") [5]. Two rooms of a building attached to the southern wall of the temple were in fact the office of the scribe and may-be priest whose archives were found, consisting mainly of contracts written on ostracas, some of them dealing with the distribution of the water collected in the qanats. These documents are dating the period of use (Artaxerxes the 1st, Darius the 2nd) and the leaving of the area (Amyrteos, Nepherites the 1st) [6]. The excavation of a small house with rounded walls, built on and covered with the damps of the digging and of the repairs of the uncovered terminal part of qanat n°4 gave us the definite proof that this qanat was in use by the second half of the 5th century BC [7]. This dating is given by a group of ostraca bearing the mention of the reignal year 29 of Artaxerxes the 1st.

If we suppose that at least 5 years were needed to excavate a whole tunnel [8], we have to wonder about the planning and the decision making. As it seems that the resettlement we are noticing at 'Ayn-Manâwîr is at least a phenomenon at the scale of the oasis, is this resettlement a decision issued from the court at Memphis? In this case, the land reclamation in such an

Figure 2: 'Ayn-Manâwîr and the neighbouring hills. The faults system (after BOUSQUET 1996, fig.6).

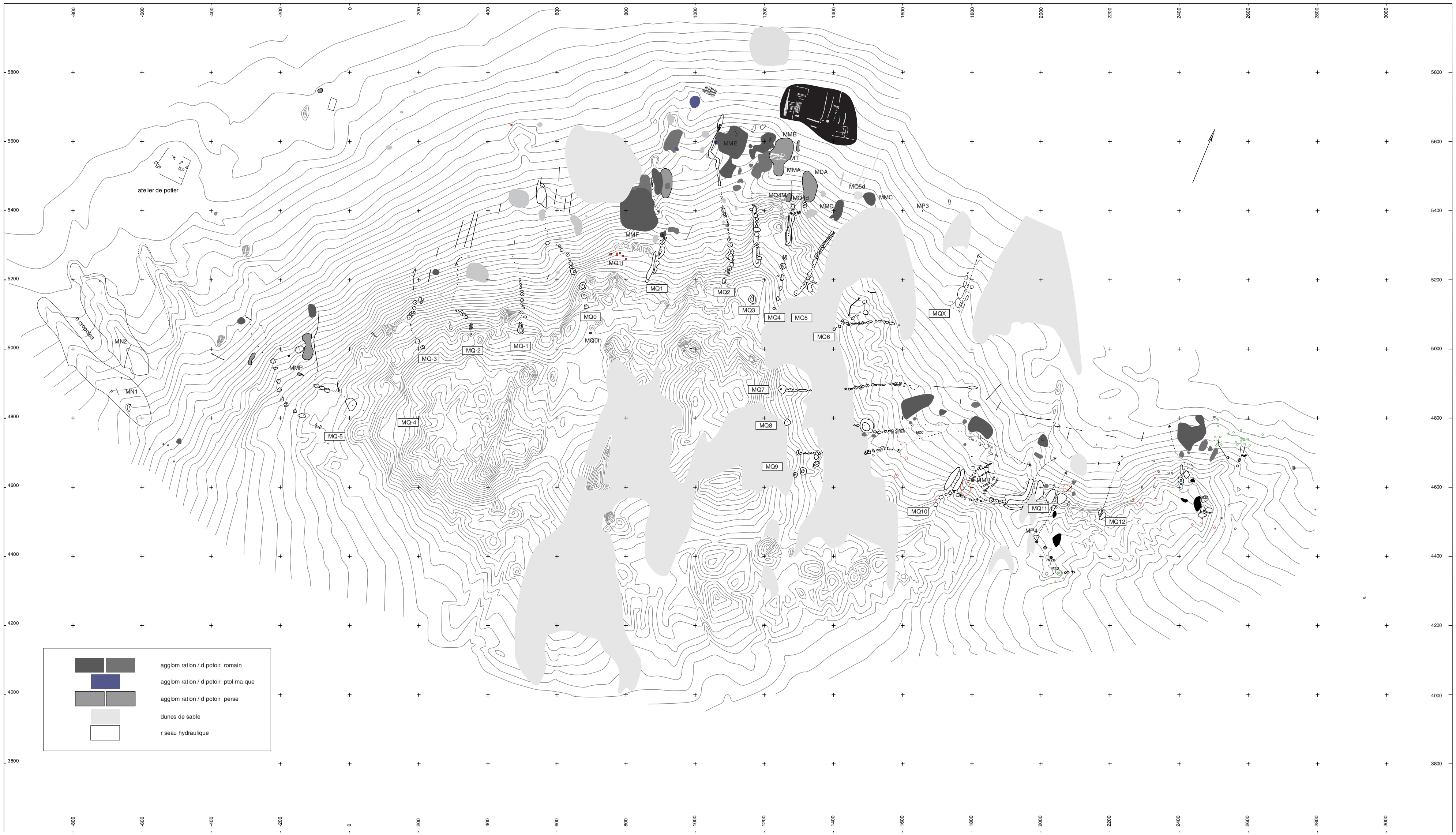

Figure 3: Topographical map of the ‘Ayn-Manâwîr hill showing the different qanat systems and the settlement areas. Grid of the map: 200m.

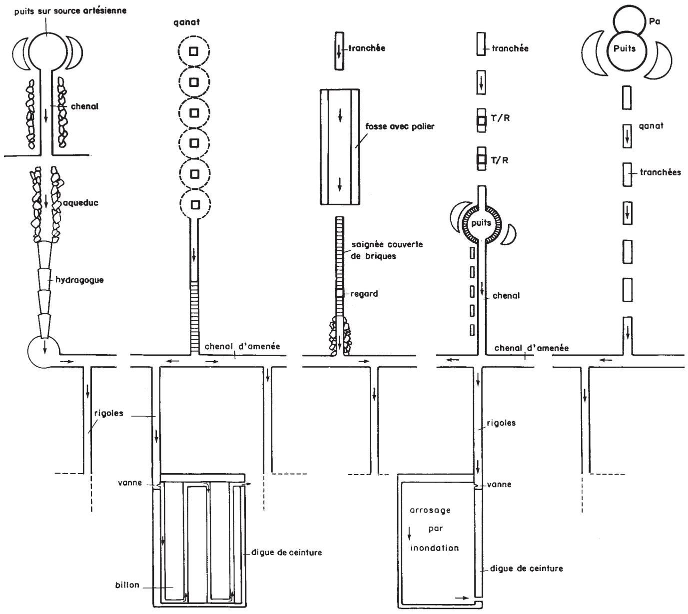

Figure 6: The different kinds of water collecting and irrigation systems (after BOUSQUET 1996, fig. 24).

pioneer front in a dry desert zone could have been the decision of the Persian central power under the control of the Satrap of Egypt and his administration.

Along with the depletion of the water level in the aquifers, the qanat system aknowledged many changes: repairs, drilling etc until the progressive drying up of the aquifer between the 3rd and the beginning of the 6th centuries AD. As the different aquifers under the hill of ‘Ayn-Manâwîr dried up, the last trials to get water were the digging of wells in the bottom of the plain (during the second half of the 2nd century AD). Once again the Douch region was almost totally abandoned by its inhabitants until the 19th century when the availability of new mechanical devices made the drilling of artesian wells through the bottom of the plain possible.

3 . THE DIFFERENT SYSTEMS OF WATER GATHERING AND IRRIGATION AT ‘AYN-MANÂWÎR (fig 6) [9].

The water gathering and irrigation systems at ‘Ayn-Manâwîr are combinations of elements resulting from different technical choices which, in most cases, are relevant to the geomorphological environment. In all these different systems we can identify:

- the water source: the water-filled bed-rock or a well bringing water to or near the surface by the artesian pressure
- the transportation of the water from the source to the cultivated plain: underground tunnel or open ditch eventually equiped with ceramic pipes or flat ceramic ducts.
- the flow control system: bassins and dams
- the distribution devices
- the irrigation channels and the cultivated areas (open fields or gardens).

The water collecting techniques:

The well on an artesian source:

Wells have been dug through clay or sandstone layers to open the way for artesian outcome of water. This is the most simple technique used on the site. The outlet of water may be an open trench. In some cases there is no dug nor built outlet and we have to suppose the use of a lifting system.

The traditional qanat (draining tunnel)[10]*:*

The traditional qanat is a draining underground gallery (fig.7) dug through the sandstone water bearing strata. Water is seeping from the walls of the tunnel, collected at the bottom of the gallery and driven by a smooth slope to the outlet, usually an open trench, and collected in a bassin behind a small dam. This dam has one or more outlets allowing the control and the distribution of water to different irrigated areas (gardens, open fields).

The local type qanat (draining open trench)

In some cases, the qanat is an open trench dug through the water bearing levels, draining water in the same way as the traditional qanat. This type is met only in short length systems.

The qanat/well combination

A progressively drying up well is connected to a newly dug water draining tunnel in order to increase the quantity of water collected.

The well/qanat combination (these last two types as modifications performed on existing systems).

A qanât type tunnel is dug to collect the water coming out of an artesian well. As the level of the water in the

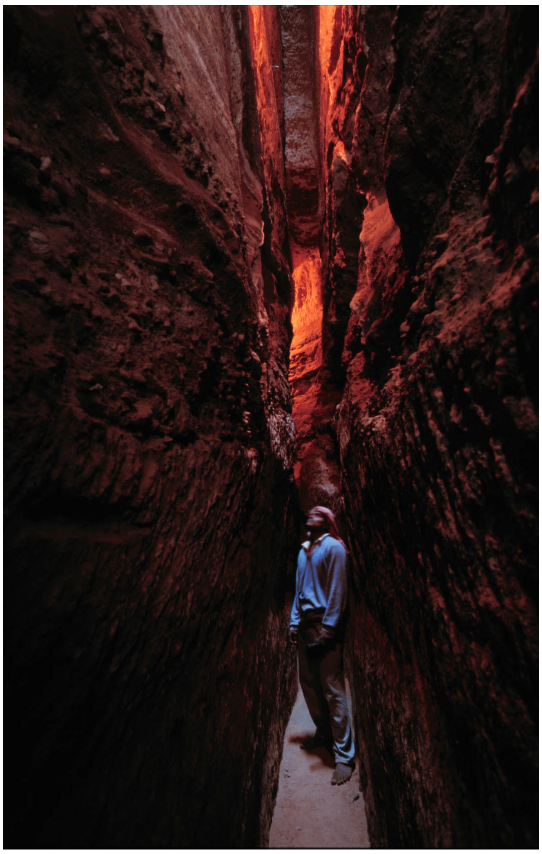

Figure 7: A part of the tunnel of qanat n°4.

well doesn't allow free flowing of the water upon the ground level, an underground tunnel is dug. The floor level of this tunnel is chosen as to allow free-flowing. In such a system the underground tunnel has the same physical characters as the traditional qanat but, it has no draining properties.

Water transportation

The transportation part of the system is generally adapted to the geology and morphology of the areas encountered on the way to the cultivated areas. In all cases where the geological layers encountered are sandstones or clays with good mechanical properties, water is driven in tunnels, in direct continuity with the draining tunnels (the "qanats" stricto-sensu). In depleted or sand filled areas, the tunnel changes into an open ditch fitted with pipes or U-shaped ceramic elements. Over pipes the ditches are most often filled up with sand and equiped, at regular intervals, with mud-brick built pits in order to allow easy cleaning and repairs.

In the lower parts of the hill, where wind driven sand doesn't build up and doesn't consist a threat, the open ditch is preferred. In this case water flows through U-shaped ceramic elements.

In the flat areas in the plain, up-lifted channels are built with the use of stone bound with clay mortar. This elevation above the surrounding ground levels is a protection against wind-driven sand and allows the control of the water-flow.

Flow control systems

In order to manage with the quantities of water to be directed to the different cultivated places, the flow has to be controlled. Water is collected in small ponds, the outlets of which are fitted with devices such as standing stone slabs in which circular openings have been drilled as to be equipped with removable stoppers. Small earth dams have been built at the entrance of these ponds, possibly to establish a two-stage control system.

The distribution systems

To each outlet of the flow control system corresponds one or more channel leading directly to the irrigation bassins. The main branches may be built with stone but most usually the secondary branches are small channels cut in the irrigated soils.

The irrigated areas

Two types of irrigated areas are known on the site: open fields and enclosed gardens. Besides these cultivations we noticed isolated plantations (palm trees and bushes) on the banks of the water channels even in locations near to the outlets of the underground tunnels.

4. THE UNDERGROUND PART OF THE QANATS AT AYN MANAWIR : THE CHOICE OF THE PLACE AND THE DIGGING.

Describing the geology of the site is essential for the understanding of the qanats and their providing of water. The tank's stone is sandstone of different qualities depending on the studied area of the qanat. In some places the grain is very fine, in others it's very big, and could reach the size of a pebble. The lower stone at the northern limit of the hill is made of wind transported clay.

After five seasons of excavations and surveys on the site, we now have a clear image of the technical choices made before the digging of the qanats. On the northern and north-eastern sides of the hill, the qanats (and especially the underground parts, which drain water) are relatively regularly dug. Every 150/200m, we can find a tunnel. On the eastern part of the site, this disposition is less regular, due to geomorphologic data. From the case of two qanats we have entirely or partly excavated, we can say that the places chosen to dig were, in a small part (qanat n°4) or in a larger part (qanat n°13), on a geological fault. But the two cases are very different:

- in the first case (qanat n°4), the axle of the fault is the same than the axle of the aqueduct
- in the second, the axle of the fault is almost perpendicular to the aqueduct's axle.

This difference is due to the difference of location. In the first case, the fault, and the general axle of the tunnel, are perpendicular to the front of the hill whereas in the other case the fault is parallel to the front of the hill. In this peculiar case, the fault is even the result of the uplifting of the hill. It seems that almost all the qanats of the site were dug following a fault that can be seen on the ground. On that particular site, the rock can directly be seen because there isn't any floor on the hill due to the windy deflation. The faults can be seen because the rock, at the contact of these geological facts, are more crystallised, due to compression and glide during the uplifting of the hill. This important crystallisation presents characteristics of a white and hard rock. Therefore, along with the windy deflation, the mirror of the fault, more resistant than the other parts of the rock, appears very clearly with a difference sometimes up to 50 centimetres above the surface.

In the underground, the mirror of fault takes two different aspects:

- the fault can be seen at the roof of the gallery as in qanat n°4.
- the mirror of the fault has not been dug and so is one of the walls. In that case, the shape of the gallery looks really like the shape of a metal mining area.

We can suggest that the position of the qanat be chosen for technical reasons. The main two reasons observed are:

- the fault may be at a point where the water as a better drainage, and this point can be verified thanks to the peculiar aspect of the mirror of fault ;
- or it may be a point where the rock could be attacked with the tools more easily.

These two points are probably parts of the explanation.

The digging: technical layout

We are dealing here with the upper part of the qanat, where the water is collected.

When the outside fault is chosen for exploitation, work can begin and we can suggest that the first thing to perform for the digging is to place the pits which allow multiple access to the qanat, and therefore make the work easier. The pits are generally 3 to 4 meters long, whereas their width is about 0,6 meters (just like the galleries). We think that these great dimensions should be used in order to help following an easier direction while beginning to dig the mentioned gallery.

When the digging is over, the main part of the pit should be covered with vaults made of mud-bricks. A small access (60cm width, 60 to 80cm long) remains, generally where the notches for climbing the pit are the easiest. The pits aren't really vertical, but their direction should turn and make an angle with the vertical (fig.8).

As for the tunnel, as soon as we see the qanat we have mainly been studying, we realise that the underground way isn't linear (fig.9). By analysing the trajectory of the qanat and the tool traces on the walls (showing the progress direction of the job), we conclude that the workers have begun the digging of the gallery from different pits, and sometimes therefore have followed a partially wrong direction, making curves. It seems that the construction of the gallery has begun by the digging of the higher meter of this gallery and was followed by the remaining parts of the qanat. But analysing this aspect, there might be confusion regarding the evolution of the qanat during that time period. This could particularly be noticed in the gallery near pit 10, where the first meter (more precisely 1,2m) is directly regarding the axle of the pit and the lower parts of the gallery are turning to join in the upper pit. Similarly, within the joining parts (clearer in the lower sections of the qanat 4), we can see that the roof is a little lower than elsewhere in the gallery. This work process is similar as the one used for mining, and called «in degrees». The actual high of the galleries (for the qanat n°4) is between 5 and 9 meters, depending on the situation of the gallery. The width is the minimum that can be allowed for working easily, approximately 60cm (and sometimes less: down to 40cm in a very small area). The main reasons for such a disproportion between high and width is that the qanat's good working depends on the total surface of the walls and the roof, and that this surface grows up faster by having an higher gallery than having a larger one. It also seems, regarding the case of the qanat n°13, that this high isn't the original high , but rather the result of the whole history of water draining and of the re-digging of the galleries in order to get more water.

Unfortunately, we have not found any of the tools used for the digging of the qanat but studying the walls, we can determine some of these tools. Notice that the traces of the tools can only be seen on the sandstone, whereas the wind blown clay, much more faultable presents very rare traces. In one particular case, in the qanat n°13, between pit 1 and pit 2, the shape of the tools have been preserved, allowing us to make some kind of reconstruction. The tool, probably a sort of pickaxe, has a square section of at least twenty cm long but we can't tell whether this tool has been used for picking directly the rock, or to put on the rock and hit it later on with a hammer.

Another essential matter regarding the work inside the qanat is the light. In that case also we have not found any fragments of lamps, neither Persian nor roman (except in houses, but for house use only). On the walls of the galleries, we were able to see some little recesses more or less regularly dug. They aren't very large (10cm long, 5 or 6cm high and 5 or 6cm width) and can't receive any ceramic roman lamp we know of, from the site. The stone doesn't show any traces of soot. We can suggest, since we have not found any remains, that the workers used metal lamps with hooks and rods to suspend from the recess. This idea is based on models known from modern mines (16th century AD).

For the moment, we do not have any idea about the organisation of the work outside: neither of the machines that were used to take away the wastes produced by the underground work nor about the repairs of the pickaxes, such as forge remains.

The evolution in time of the qanats

The structures we are studying have a very long history: in the mentioned cases, the first dig was performed during the Persian occupation (5th century BC) and its last use was during the roman period, and especially during the first and second centuries AD, a total of seven centuries.

During this long time frame, the main problem was the daily cleaning of the galleries, in order to conserve and control the quality of the water. The two sources of water pollution were:

– the degradation of sandstone with the floodtide of waters making the stone alternatively dry and wet. This degradation has given, for a large part, the actual shape of the gallery. The variation of the shape (and therefore the degradation) was due to the difference in resistance to water degradation. This degradation has produced white sand.

– the other source is the sand winds. During a period of three days of such wind (not very strong during the '99 campaign of work), about 1,5m of sand fell at the bottom of the pit 3 of the qanat n°13 (this pit is in a sort of corridor which amplifies the effects of the wind).

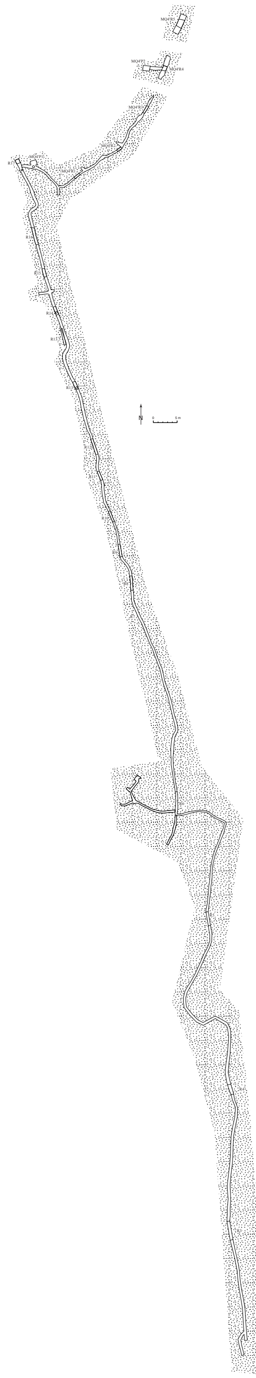

Figure 8: Plan of qanat n°4.

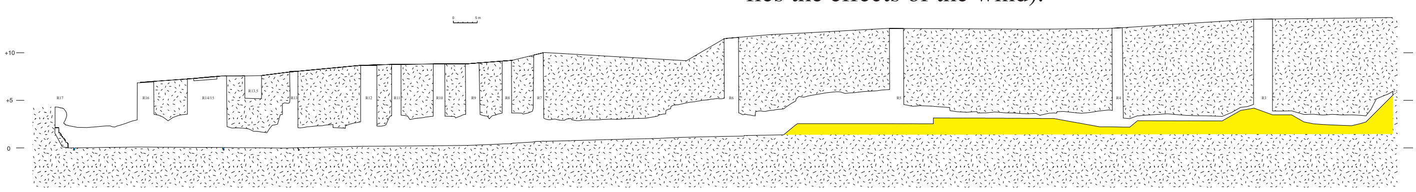

Figure 9: Projected section on the main axis of qanat n°4.

Thanks to all this data, we were able to conclude that there must have been relatively frequent cleansing of the gallery and of the pits. We have not found any archaeological evidence of such work.

During the mentioned time period, the level of water contained in the rock decreased to end up nil after a certain time (that we can't evaluate). The qanat didn't give away any water any more. Consequently, the floor of the gallery was lowered again, to allow the qanat to work again. This operation could be performed until the level of the floor at the coming out of the tunnel was higher or at the same level than the external floor. In the qanat n°13 case, it is very clear: in the Persian period, the first qanat was about 6m deep from the plateau floor, and the water drain came out in the middle of the foothill. A small part of the external drain still exists, containing ceramics, which allows us to determine the period of use. Later on, probably in the roman period, the galleries are dug deeper by 4m, but the connecting galleries of the first period were not: the workers dug new galleries of 3m high, and therefore leaving about 1m of stone between the two galleries. There may have been another digging, but it is not very clear.

When the lower level was reached, and when the water level decreased, there were some ultimate research for underground springs. Two searching methods were used: when there was a spring coming out from the ground, a drill was made to make an easier passage for the water, increasing the flow. These drills were quite deep (the most deep was 80cm for about 15cm of diameter). In the main course of the qanat 4, we found 3 of these drills, as well as one in well n°1. The other method was to dig a new gallery, perpendicular to the main axle of the qanat. It has been done in qanat 4 pit 6. We found some small galleries (1,2 to 1,5m high, 0,6m width) representing 15m in total. These galleries ended in a small "room" where we can find a double drill, 80cm deep. The shape of this gallery was very different to the one seen in all other parts of tunnels. It's oval and this peculiar shape shows that these galleries weren't finished.

5. THE IRRIGATED AREAS (GARDENS, OPEN FIELDS) AND THE SETTLEMENTS:

As seen here above, the qanats are driving water from the hill through the settlements area to the surrounding plain where cultivation took place. The terminal part of qanat n°5, excavated during 1997 and 1998 seasons [11], gave us a well preserved example of the transition between the water collecting part and the final irrigation. It consists in an open ditch turning progressively into a shallow water channel ending by a dam. This dam allows water running through. The speed of the flow is limited by 4 successive changes in direction at straight angles. This dam is also a bridge making possible to cross the ditch. After the dam a first stone assembly makes possible to stop temporarily the flow. Just after this device begins the main water collector: a pond. This pond is dug in the clay, is 60 to 80 cm deep. The banks are are not proeminent above the general ground level. At the opposite end (to the north) a sandstone slab erected in the upright position (fig.10) prevents water to get out freely from the pond. A circular opening is drilled in the slab near its upper end. We can imagine that a stopper could have been fitted in this opening in order to allow or prevent the flow. After this outlet water can be directed to any of the main irrigation channels leading to the open fields stretching to the north, in the plain. The pond is surrounded by an enclosed garden. The remains of the trees and other plantations have been collected and documented during the excavation. The garden was benefiting from direct irrigation: water could have been taken from the pond in jars and poured directly around the plants. We can assume that this gardening activity needed only a small proportion of the available water. This example shows us also that these ponds and gardens were set in the middle of the settlement zones.

Figure 10: The sandstone slab erected to control the water flow out of the bassin of qanat n°5.

6. ARCHAEOLOGY AND EPIGRAPHICAL DOCUMENTATION

The main difficulty in rebuilding the history of the site by its different components: the digging of water collecting system, the cultivated areas and the settlement units consists in the actual need to classify chronologically these different elements which are often not physically connected. Stratigraphy is of no help to date the digging phase of a qanat. The key discovery was that of archives written in demotic on ostraca in different locations. An important part of these documents consists in contracts dealing with land and water use property or leaning. Some of these describe elements of the water collecting and distribution system [12]. Above all, most of them bear dates and as a consequence date also the ceramic artefacts from which these ostraca were made from. This dated material gave us the tools for dating structures in contact with parts of the water collecing system. This is the reason why we can date some of the qanats and some the changes that occured in parts of them over the 5th century BC – 3rd century AD span of time. This is also the reason why we can assume by now that at least a part of the qanats network over the ‘Ayn-Manâwîr hill was in use by the time of the first Persian Domination, the Egyptian 27th dynasty and only fully dried up at the very beginning of the 3rd century AD, under the Roman rule.

7. THE AREA OF ‘AYN-MANÂWÎR TODAY

Nowadays the ‘Ayn-Manâwîr hill and its surroundings is a merely bare arid landscape with half dried up remains of tamarix and palm trees around what was a 19th century dug well at one end of the hill. However at Dush, 3km far from ‘Ayn-Manâwîr, gardens and fields benefit from water pumped out of wells drilled in the 1960's with mechanical devices through 800m of the Nubian sandstones and clays.

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See also the paper given here by CHAUVEAU M.

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which would be specially devoted to Achaemenid Studies?

☐ no

☐ yes ☐ on line ☐ paper

☐ do you think it would be useful to organize conferences around the field

relating to achemenet. com?

on which topics?

thank you

for sending this form back

either, after having printed an filled it,
by post sent to
Pierre Briant, Collège de France,
place Marcelin-Berthelot,
75231 Paris cedex 05, or by
fax send to **33 (0) 1 44 27 17 13**

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of Acrobat at your disposal,
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