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Ancient Tunnel Systems in Northern Jordan

Today water shortage is one of the main problems in Jordan.[1] However, obtaining water was also of utmost importance in ancient times, since Jordan is situated in a semi-arid region where a perennial water supply is only ensured by rivers or springs at a few places (Bienert 2000).

Different techniques were developed to obtain the required water:
1) Collection and storage of surface water.
2) Use of underground water from springs and aquifers.

In Jordan, water harvesting and storage in cisterns can be traced back to the Chalcolithic period as the example at Jāwa shows (Helms 1981). Cisterns can be found at different sites of the Bronze Age period, but more often at Iron Age sites. Later on, the Nabataeans were real masters in building elaborate water harvesting installations, e.g. at Petra. New water installations were constructed or older ones were expanded in Hellenistic, Roman and Byzantine times (Oleson 2001).

The principal aim of this paper is to focus on a special area of these water supply systems, i.e. the transport of underground water of springs and aquifers by means of tunnels. This area requires special technical knowledge and therefore deserves careful consideration. Until now, only few examples of this technique have been discovered in Jordan. These are at the sites of Gadara (modern Umm Qays), Abila (modern Quwaylibah), Khirbat az-Zayraqūn and Tall al-Fukhār at Wādī ash-Shallāla, as well as the site of Pella (modern Ṭabaqat Faḥl).

Two different methods were used for the construction of a tunnel. The first one is the so-called '*Gegenort*-technique' (Grewe 1986). The tunnel is built from two sides. The second technique is called '*qanat*-method'. In this procedure several vertical shafts were driven into the ground at short distances and then connected by the tunnel. This method is more labour intensive, but the chance of meeting is greater, because the distances between the shafts to control are shorter.

The Gadara Tunnel System

The first tunnel presented here is at Gadara/Umm Qays. This city was founded in the Hellenistic period. In 63 BC it was conquered and destroyed by Pompeius and afterwards built up again. In AD 636 it was conquered by the Muslims and settled into modern times.

Umm Qays is situated on a plateau with steep slopes on three sides: in the west towards Lake Tiberias, in the south to Wādī 'Arabah and in the north to the Yarmūk River. Only on the eastern side is there an easy access to the city (Kerner *et al.* 1997: 265).

There is a spring at about 100m to the south and 50m below Umm Qays. The outlet was probably within the walled city in Roman times (Kerner *et al.* 1997: 265), but the capacity was too small for a sufficient water supply. Therefore, another possibility was sought to obtain water for urban needs as well as drainage for agricultural irrigation.

There are three springs at about 12km to the east of Umm Qays, of which 'Ayn Turāb has the greatest water volume. Originally it was suggested that 'Ayn Turāb was the starting point of the tunnel system of Umm Qays. However, Kerner and her colleagues showed that the main tunnel system holds the water of another tunnel, which extends about 200m further east. Therefore, they suggest that the water of 'Ayn Turāb comes from a spring that is situated farther to the east, or that there is an aquifer and not a spring (Kerner *et al.* 1997: 268; Kerner in press).

Two parallel tunnel systems follow the contour lines of the hillsides over a distance of 23km. The tunnel transports not only the water from the spring of 'Ayn Turāb but, on the way between 'Ayn Turāb and Umm Qays, also collects water from smaller springs and even surface water. At the western end of the modern village of Umm Qays the tunnel does not follow the contours any more as

[1] This article came about at the suggestion of Dr. Hans-Dieter Bienert, whom I would like to thank.

the way is shortened by a bridge aqueduct that crosses the wadi (Kerner 1997: 283). Most of this construction is gone, but one arch and eleven piers are still preserved. Two small channels and a blocking system point towards a distribution outlet from the lower system on top of the aqueduct (Kerner 1997: 285).

From the aqueduct, both of these tunnels stretch from the east to the west for about 400m into the hill to the more densely built area of the city. The difference in altitude of the tunnels is 0.3m at the entrance and 1.5m at the end. For this reason we refer here to an upper and a lower tunnel system.

The lower tunnel was built in three stages in the Hellenistic/early Roman period (Kerner *et al.* 1997: 265-268; Kerner 1997: 286-287; in press). First, deep shafts were cut into the bedrock, which were connected by the tunnel. Then some parts of the tunnel were covered by a wall. Finally, the walls were coated with layers of plaster in order to diminish friction and loss of water into the ground.

In the north, several outlets from the main chamber were built. These channels are smaller in diameter and have pipelines for water transport. Water transport and distribution was controlled by different systems, which cannot be explained here in detail (see Kerner *et al.* 1997: 286; Kerner 1997: 267).

At the western end, the channel was blocked by a weir in order to control the distribution of water for public use outside the acropolis. The channel continues through an older cistern and the water was distributed by smaller channels and pipes.

At the end of the Byzantine period the system fell into disuse, it was no longer cleaned and debris accumulated in the cistern at the end.

The upper tunnel is 2.5m high and 0.8-1.5m wide. This tunnel was never finished (Kerner 1997: 285-287; Kerner *et al.* 1997: 269). In the western part the tunnel is blocked by debris that accumulated after the middle of the third century AD. Presumably, the upper tunnel was intended as an extension to the lower tunnel, but could not be finished for financial reasons.

The Abila Tunnel System

The site of Abila (modern Quwaylibah) is situated about 20km east of Umm Qays. Like Umm Qays, Abila was one of the Decapolis cities. Also at this place an extended tunnel system for water transportation was built. The settlement area lies on the northern *tall* of Abila, that is on the left side on the slope, with Umm al-'Amad to the south of it, that is on the right side on the slope and on the saddle depression in between (Mare 1990: 309). Due to its favourable situation with respect to agricultural and pastoral potential, economic possibilities, and defense the place was inhabited continuously from the early Bronze Age to the Ottoman period, although the intensity varied throughout all periods.

Three different sources were available for the water supply of the city: the spring called 'Ayn Quwaylibah situated at the southern edge of Umm al-'Amad, the spring of 'Ayn Khurayba situated south of Abila and an underground spring in the heart of the hill south of 'Ayn Quwaylibah (Mare 1995: 730).

Presumably — according to Mare (1995: 730) — water transport into the city was managed by a tunnel since the Iron Age. Mare suggested that the tunnel system was constructed in two main phases. In the first phase during the Iron Age, Persian and Hellenistic periods, the lower Umm al-'Amad tunnel was built, which was repaired and re-used in the Roman period. The tunnel starts north of the spring of 'Ayn Quwaylibah below the eastern foothill of Umm al-'Amad, in the direction of the centre of Abila. In the second phase during the Roman and Byzantine periods the upper tunnel was built, which runs like the lower tunnel along the hillside of Umm al-'Amad only 1-3m higher, and the Khurayba tunnel that runs through the hill south of the spring of 'Ayn Quwaylibah for a length of 2.5km.

The *qanat*-method was used in constructing the older, lower Umm al-'Amad tunnel. The shafts were dug into the bedrock at an average distance of 25m (Mare 1995: 732 fn 3). This tunnel was repaired and extended in the Roman period. For the construction of the younger, upper Umm al-'Amad tunnel the *qanat*-technique was also used, but in this case the shafts were dug into the ground at an average distance of 32m. In order to centralise the whole system and to obtain a better water flow, the upper Umm al-'Amad tunnel and the Khurayba aqueduct were connected.

Presumably, there was a fourth tunnel system, according to Mare (1995: 732). Possible mouth-holes were discovered at the southwest edge of Umm al-'Amad and in the west transect 15, about 1.5km west-southwest of Abila. Until now it could not be determined how this tunnel fits into the Umm al-'Amad/Khurayba system, but Mare (1995: 732) has suggested that it transported water from the springs west-southwest of Abila into the city centre. According to Mare, it is even possible that the Abila water system is connected with the Umm Qays tunnel system.

Beside this main water system, minor installations like small channels and cisterns have been discovered which give a first impression of the water distribution in the city area. After the 1995 investigations and excavations, Mare determined that this system was well planned and more extensive than thought before. Mare (1996) determined that this system was essentially constructed on the Roman model described by Sextus Julius Frontinus (first century AD). However, until now there are not enough finds to make a detailed analysis of the water supply of the buildings and the fields.

The Pella Tunnel System

An extended network of tunnels and caves in the western Wādī Jirm, ca. 600m from Pella, was discovered during the investigations in the years 1994-1996 (Watson 2001). It can be dated to the Roman period, however its specific purpose is still under discussion.

Tunnel Systems in Palestine

In the same region, but outside of Jordan, we can find some analogies for the tunnel systems at Umm Qays and Abila. These are the water management systems — for example — at Acre and Caesarea Maritima.

An Acre the water system consists of a tunnel, which transports the water from the springs of Kabri into the city area of Acre. Three shafts have been excavated. They were constructed with steps that lead down to the tunnel. This is a feature that is only found at Caesarea Maritima according to Frankel (1985: 135). However, very similar shafts with steps are also known at Gibeon and Hazor. The tunnel at Acre was built using the *qanat*-method. This underground aqueduct included a rock-cut tunnel and a vaulted masonry tunnel. An unusual feature of the tunnel at Acre is the use of ashlar blocks to build a vault inside the tunnel. With the help of two oil lamps that were found in the fill of sand and silt and were believed to have been used during the construction work, this tunnel was dated to the end of the fourth or the beginning of the third century BC (Frankel 1985: 137-138).

The water management system of Caesarea Maritima can clearly be dated to the Roman period. It is typical for the Roman water systems that used different components like bridges aqueducts, open channels and tunnels. The tunnel, which was dug in Caesarea Maritima, transported water from the spring of Ṣabbārīn to Nahal Senunit over a length of 6.5km. From there an open channel leads the water to the so-called 'high level aqueduct'. This tunnel was constructed using the *qanat*-method just like the tunnels at Gadara and Abila. Some of the shafts are provided with steps, as mentioned above (Olami and Peleg 1977: 127-137).

Tunnel constructions have a long tradition in this region. Recent excavations in Jerusalem showed that the Gihon spring was incorporated in a system of fortifications, rock-cut tunnels and channels already in the Middle Bronze Age II period (ca. 18th-17th century BC) (Reich and Shukron 2000a: 327-337; 2000b: 5-17). This so-called "Warren's Shaft System" was deepened in the eighth century BC, presumably to create a different approach to the spring. These activities were stopped for unknown reasons. The excavators suggest that these works were brought to halt because a better solution was found, which was the construction of a new water supply system for Jerusalem, the so-called "Hezekiah Tunnel" (Reich and Shukron 2000: 337). The "Warren's Shaft System" as well as the 537m long "Hezekiah Tunnel" were built with the *Gegenort*-method. Recent geological investigations by Gill (1996) supported the idea that the "Hezekiah Tunnel" was not planned but constructed by using the natural crevices. Grewe (1998: 50-51) objected to this opinion maintaining that the existing crevices might have led to the construction of the tunnel, but that at the encounter point the work was done very systematically. This can be observed by several projections in the wall, which are signs of continuous control measurements and corrections of direction. This shows, on the one hand, that the engineers were able to control the direction over short distances, but on the other hand, that there was a great uncertainty about the course of the tunnel.

There are other examples of tunnel systems like these at Gibeon, Hazor and Megiddo. They can be dated from the tenth to the eighth centuries BC. All have differing layouts according to their geological and topographical setting as well as the special needs of the settlements, but they share the same idea of creating an access to underground water by means of shafts and tunnels.

The Tunnel Systems at Khirbat az-Zayraqūn and Vicinity

With the above in mind, the tunnel system of Khirbat az-Zayraqūn shall be looked at more intensively. The site is situated on top of a spur above Wādī ash-Shallāla, which is surrounded by steep slopes on three sides. This topographical setting as well as a city wall ensured the security of the inhabitants of the settlement which had a size of 9 hectares. Based on previous investigations, the settlement can be dated to the Early Bronze Age (2950-2350 BC) (Ibrahim and Mittmann 1989).

A modern entrance to the tunnel system was discovered in the steep slope on the northeastern side, at about 60m below the edge of the hill that rises about 100m above Wādī ash-Shallāla (Grewe 1998: 52). The horizontal shafts into the bedrock could only be partially investigated, that is for a length of 200m (Bienert 2000: 21). First they run along the exterior slope, but then turn into the hill almost at right angle (Grewe 1998: 52). The modern entrance into the tunnels from the slope was made at a later time by cutting through the wall of the tunnel (Bienert 2000: 21; in press).

Three entrances to shafts are situated in the southeastern corner of the city (Grewe 1998: 52-54). They run diagonally into the bedrock. One of them could be investigated for a length of 60m. Presumably, they were the original entrances to the tunnel system. Between these shafts and the shaft at the exterior slope, a distance of about 100m has to be traced in order to prove that both of these tunnel systems belonged to one complex system. According to Grewe (1998: 53) the zone of water extraction and the zone of water supply in the city should have been connected by a zone of water transport.

The shafts inside the city are furnished with steps with gradients of 45°. The shafts are cut in the bedrock, where the course of the tunnel changes direction. In view of this layout of the shafts, Grewe (1998: 53) draws the conclusion that they are actual shafts for construction and that from these shafts the tunnel was built. Also the transmission from the ground level to the underground of the direction of the tunneling must have been made by means of these shafts.

The tunnel in the water extraction zone, that is the one close to the steep slope, has three smaller tunnels. They run partially parallel to each other, but in other parts they cross another shaft and in some cases they cross each other as well.

Analogies to the tunnel system can be found in Jerusalem, Gibeon, Megiddo and Hazor. As mentioned above, the earliest can be dated to the tenth century BC. Also the *qanat*-method, which was used for constructing the tunnel at Khirbat az-Zayraqūn, does not start earlier than the tenth century, perhaps even later. And here lies the main problem. Khirbat az-Zayraqūn can clearly be dated to the Early Bronze Age and was not inhabited after this time. However, the earliest possible date for the tunnel system is, according to the mentioned parallels, the tenth century BC.

Additionally, Grewe (1998: 54) thinks that the dimensions and the carefully planned work of the tunnel system are so outstanding that the earliest date for it is the first half of the first millennium BC. This opinion is supported by some analyses of plaster from the tunnel at Khirbat az-Zayraqūn, which, according to Grewe, point to correlations with the Early Iron Age water tunnels at Megiddo and Hazor. However, even a date in the Roman period is not excluded by Grewe. The presence of Romans at Khirbat az-Zayraqūn is evidenced by a Roman bridge found at a distance of only 500m from the tunnel system. Therefore, Grewe (1998: 54) suggests that the bridge and the tunnel system might be the construction of an infrastructure for a planned Roman settlement which, however, was never realised at this place.

Two sites have been discovered in the neighbourhood of Khirbat az-Zayraqūn, which should be seen in correlation with this settlement and water management system. One of them is Tall Umm al-Jurn, a small hill that rises about 20m above the surrounding valley (Kamlah 2000: 21-24). A small, fortified settlement of Middle Bronze Age date has been found on top of it. This settlement existed for about two hundred years. At the beginning of the Late Bronze Age the settlement shifted to the neighbouring Tall al-Fukhār on the eastern side of Wādī ash-Shallāla (Strange 1997). In the Hellenistic period a settlement was established in the plain around Tall Umm al-Jurn. the occupation of which decreased in the Roman period. A precise date for its abandonment is still not determined.

A tunnel system was discovered close to Tall al-Fukhār but not yet investigated in detail (Bienert 2000: 21). Bienert pointed out that according to previous results, the method of construction is very similar to that of the tunnel at Khirbat az-Zayraqūn. Therefore, he suggested that both tunnels were cut at the same time. It is still unclear whether this tunnel system belongs to the occupation of the Tall in the Late Bronze and Iron Age periods. A connection to the settlement of Tall Umm al-Jurn and its neighbourhood, which is situated only 200m from the tunnel entrance to the eastern system, cannot be excluded (Bienert in press).[2]

Conclusion

It can be concluded that the beginning of the construction of tunnel systems for the water supply of settlements in northern Jordan can be dated at least as early as the Iron Age, and that it continued into the Byzantine period. These tunnel constructions fit well into the context of water management systems of the region.

Whether or not the tunnel system of Khirbat az-Zayraqūn actually belongs to the Early Bronze Age settlement is still questionable according to our knowledge of the general development of tunnel construction and water management in the region.

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2 Recent investigations at the spring cave of the Lower City of Troy have brought astonishing results (Korfmann 2000: 32-37). The original use of the rock cut tunnel system could be assigned with a high degree of certainty by dating sinter layers to the early third millennium BC. According to Korfmann (2001: 37) these tunnels resemble a *qanat*-system. Therefore, an Early Bronze Age date for the tunnel at Khirbat az-Zayraqūn is no longer that improbable (I thank H.-D. Bienert for this reference).

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