

Water Management and Rock-Cut Cisterns with Special Reference to the Region of Udhruh in Southern Jordan

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Abstract

Jordan has had a long history of water harvesting and water control systems, some of which are amongst the earliest examples in the world. These include dams, barrages, channels, qanat systems and cisterns. This paper focuses on the rock-cut cisterns of the region of Udhruh in southern Jordan where a group of 28 cisterns were recorded recently. The history of the rock-cut cisterns, their types and techniques of construction in Jordan, with a special focus on those of the Udhruh region will be presented. The evidence for water management systems in the study region suggests that water management in Jordan during the Nabataean-Roman-Byzantine periods was more sophisticated and less wasteful than that of today. Judging by the capacity of the cisterns, such as those at Udhruh, they covered daily needs throughout the year, in contrast to today. Renovating the cisterns would provide the local population with an additional supply of water.

Keywords: Southern Jordan, Udhruh, Water control systems, Rock-cut cisterns.

Introduction

Jordan is a country with an arid to semi-arid climate due to its location between the Mediterranean in the west and the arid regions in the east and south. In general, the climate of Jordan today is characterized by a long dry summer and short rainy

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winter season, with an average rainfall of about 395 mm per annum. However, there are regional variations across the country. The eastern Jordanian plateau receives the highest rainfall, ranging in average from 300 mm in the south to 550 mm in the north, while the eastern desert, Wadi Araba, Aqaba and the Jordan Rift valley areas receive very low rainfall, which in some areas does not exceed 50mm on average, and is one of the driest regions in the world (Shehadeh 1985: 25-31; Paradise 2005).

However, palaeo-environmental and archaeological research in Jordan, the southern Levant and the Near East in general have revealed that the climate of this region has been changing over time. This climatic shift is represented by fluctuations between a wet climate and semi-arid and dry climate (Klein 1982: 90-91 based on Dead Sea levels; Frumkin 1997: 244, based on deposition changes on salt caves of the Dead Sea, and Issar and Yakir 1997: 103 based on botanical evidence from Masada in Israel). Desertification is also attested in the history of this region (see for example Barker *et al.* 1998; Barker *et al.* 2000: 44). Moreover, studies have shown that periods of wet climate witnessed high settlement density and intensive agricultural activities (MacDonald 2001: 376; Al-Shorman 2002: 23). These periods of climatic changes have left various types of evidence related to settlement patterns, land-use and human-environment adaptation and interaction. Moreover climatic changes must have been, especially in past times, concomitant with changes in social organization, modes of production and social and regional dynamics (see for example Van Geel *et al.* 2004 for socio-economic adaptation to climatic change in Eurasia; see Finkelstein 1995 and LaBianca 1990 for socio-economic adaptation to climatic changes and other factors in the southern Levant). A prominent type of archaeological evidence dominating the landscape of Jordan and reflecting the human-environmental interaction is the historical water-control systems, of which rock-cut cisterns are a main type. In this paper the history, types and techniques of the rock-cut cisterns will be demonstrated with special reference to the region of Udhruh in southern Jordan.

Historical Survey

It is evident from archaeology that rock-cut cisterns have a long history in

Jordan. The first historical reference concerning the construction of cisterns is probably in the Moabite stele of King Mesha around 853 B.C. He initiated a national project when he said: “and there was no cistern inside the town at Qrhh, so I said to all the people, ‘make yourselves each one a cistern in his house’” (Ullendorff 1958: 197). However, cisterns, cut and built, seem to have been in use a long time before the Moabite period. Avraham Negev, for example, considers that the earliest examples of the rock-cut cisterns date back to the Middle Bronze Age (Negev 1972: 332). Other scholars (Oleson 1995: 709) believe in an even earlier use. The oldest house-cisterns found in Palestine are claimed to belong to the Chalcolithic period, before 3000 B.C. (Evenari *et al.* 1971: 171). However, at the Early Bronze Age site of Jawa, in the black-lava desert of northeastern Jordan, a sophisticated water-collecting system was planned and built before 3000 B.C. However, it did not involve man-made cisterns, but rather the utilization of natural caves, which Helms considered to be a natural prototype for the later artificial structures (Helms 1971: 160-177). Early Iron Age (1200-1150 B.C.) cisterns and a possible reservoir were uncovered at the biblical site of Hisban (biblical Hishbon) in central Jordan (LaBianca 1990: 149).

In the Iron Age, the use of cisterns appears to have increased considerably, and their walls were lined with a waterproof plaster, which might have affected the quality of water and the period of storage (Negev 1972: 332; Wåhlin 1997: 233-249). In the Negev, for example, cisterns from the Iron II period were dug into loess soil and lined with large stones to ensure the stability of their walls. Also in Petra and the Negev, rock-cut cisterns began to appear in the Nabataean period (Al-Muheisen 1993 and 2009: 83-89; Evenari *et al.* 1971: 14-17, 159). It seems that the preferred type of cistern at that time was the rock-cut bottle cistern. As the name suggests, these were shaped like a bottle with a small neck but widening out below the lip to an interior width of three to four meters in diameter (Al-Muheisen 2009: 146; Oleson 1995: 709).

The archaeological record from southern Jordan shows that rock-cut cisterns were used in major ancient settlement sites. At Petra, many rock-cisterns were found on the top of Jebel Umm al-Biyara, an Iron Age settlement site (Al-Muheisen 2009: 83-124; Oleson 1995: 709; 2001: 606). At Humayma Oleson

(1997: 176; 1992: 207-617) recorded 41 rock-cut and built cisterns, and at Petra Al-Muheisen recorded more than a hundred examples in Petra and its vicinity (Al-Muheisen 2009). Diodorus Siculus (XIX.94.7) described how the Nabataeans make a cistern: “they have prepared subterranean cisterns lined with plaster...As the earth in some places is clayey and in others is of soft stone, they make great excavations in it, the mouths of which they make very small, but by constantly increasing the width as they dig deeper, they finally make them of such size that each side has a length of one plethrum” (30 metres or 100 feet). Nabataean rock-cut cisterns in Petra, for example, were filled with rain water through surface channels incised in the rock. These cisterns were placed on the top side of the hill, in order to prevent contamination, and the interiors were divided by rock partitions into reservoirs. From a spatial point of view, they are very well arranged so as not to lose extra water, because when a cistern was full it would overflow into another. Huge volumes of clean and cool water were collected in these cisterns (Forder 1923: 44-46).

In the study area (the region of Udhruh), cisterns remained in use from the Nabataean period throughout the following centuries until they were totally abandoned or rarely used by the second half of the twentieth century. However, the shape and construction techniques as well as the intensity of use and distribution varied with time (Wåhlin 1997: 233-249; Oleson 2001: 606). The rock-cut cisterns, however, are most commonly bell-shaped, with a narrow opening at the top and widening symmetrically below (Murray 1939: 63; Hill 1899; Evenari *et al.* 1971: 156-171). The cisterns in Samad in northern Jordan, for example, range in volume from about 35 to 200 cubic metres (Khammash 1986: 35). The pear- or bottle-shaped cisterns on top of Umm al-Biyara in Petra are 4 m deep (Lindner 1974: 107; 1997).

The use of cisterns reduced the loss of water through evaporation, an important consideration in arid regions. Many cisterns also show evidence of plastering to lessen seepage. In addition, such cisterns, whether open to the air or underground, were usually located at the centre or base of a suitable catchment basin. The only visible evidence for many underground cisterns, for example those located at Humayma, is the presence of runnels cut into the rock of the catchment area. Such

runnels lead to a small drain hole, which is the entrance to the cistern and often located in the face of a natural cliff or low hill (Eadie 1984; Oleson and Eadie 1986: 56). These bottle cisterns were easy to design, though probably difficult to construct. Another type of cistern common in the east is the *ma'agura* cistern, which are usually found cut into a soft chalk layer, non-porous when wet, immediately below a layer of hard limestone or flint that acts as the roof (Rubin 1988). These *ma'agura* tend to be rectangular, the larger examples having uncut chalk pilasters as additional roof supports. However, both the bottle and the *ma'agura* types of cistern were restricted in their use, for they required either a suitable position within a particular catchment area or appropriate bedrock. Using improved construction techniques taken from the Hellenistic world, larger square cisterns lined with stone ashlar walls were built. These could be placed close to a settlement site and linked to the catchment area by aqueducts, of which there are many varieties within the Middle East (Costa 1983; Eadie 1984). To conserve the maximum amount of water, many of these cisterns were roofed over with transverse arches across the reservoir. Such reservoirs can still be seen at many locations across the east, and often continue in use as cisterns for an entire community. Examples of such roofed cisterns are still particularly common within what was the Nabataean kingdom. From studies of these cisterns, it seems that the maximum effective span they could achieve was six to seven metres (Oleson 1995: 717). For private use, some Nabataean residences had circular cisterns up to five metres in diameter placed underneath their houses to collect rainwater from the roof. In this way, the development of earlier roof collection systems continued, and many examples of these later cistern types have been recorded throughout the ancient Near East (Rubin 1988: 233).

The Evidence from the Region of Udhruh

Udhruh lies about 15 km east of Petra and approximately 25 km northwest of Ma'an (Fig. 1). It is mentioned in Islamic sources alternately as the capital of the district of ash-Sharah or al-Jibal (Schick 1997: 75). In the late 10th century 'Adhruh and Mu'an (Ma'an) are mentioned as townships in the ash-Sharah region in the account of al-Maqdisi (al-Muqaddasi) (Schick 1997: 75; Walmsley 2001:

517). However, archaeological records show that the region of Udhruh was densely populated and thriving for long periods of time. For example, Killick (1986; 1987) surveyed the surroundings of Udhruh, concentrating on the Roman to Byzantine periods. He found around 200 sites in the survey, most of them not previously known (Killick 1986: 432), but unfortunately there is very little information about them available, as the results of the survey have not been published. Graf (1992, 1995) has surveyed mainly Nabataean to Byzantine sites in the eastern plateau in connection with his survey of the *Via Nova Traiana*. While the periods between the Iron Age and the Byzantine period have thus received considerable attention, a palaeo-environmental investigation led by Gebel in the early 1980s is the only example of a survey of Epipalaeolithic and Neolithic settlement in the Petra area (Gebel 1988). At the same time, however, it has been reported that new settlements were established east of the *Via Nova Traiana* and in the surroundings of 'Udhruh after the 4th century A.D. (Killick 1986: 438; Graf 1992: 259; 2001).

Rock-cut cisterns were one of the main sources of water in the study area. Twenty eight rock-cut cisterns were documented at twenty-three sites. During field work, it was observed that there is a strong relationship between the location of the rock-cut cisterns and both the topography and geology of the location. It is worth mentioning that this type of water resource depended mainly on rainwater run-off. In other words, no springs or ground water races were associated with the cisterns. At the same time, without rain, these features would have been useless and unsustainable. This type of cistern developed from natural cavities in rocks which were artificially enlarged and improved by cutting into the native rock and revetting parts of the enlarged perimeter with walling.

Technical and theoretical factors combined with topography and geology to make rock-cut cisterns important. A rock-cut cistern would not be valuable if it was not located at a point where large amounts of run-off water can be naturally or artificially collected. Not every point on the ground was suitable, and this explains why topography was important (Oleson 1995: 710). Theoretically, the people who initiated this strategy either were unable to build cisterns for that purpose, or imaginatively requisitioned the landscape around them by using the cheapest

material, which is naturally available, to make their cisterns. Geologically, the area in the highlands and interior deserts where most of the cisterns were found contain limestone and flint. In many cases, the limestone contains significant amounts of hard chert (or flint) which is less easily eroded than the limestone itself. Cutting the limestone layers is easier than cutting other types of stone. Therefore, most of the rock-cut cisterns in the region of Udhruh were cut into limestone layers, and that also occurs elsewhere in Jordan.

The 28 rock-cut cisterns recorded at sites of the study area vary significantly in design, size, means of access, and architectural components and construction methods.

The following is a brief explanation for the variation in these elements:

- Design: Four shapes were identified: bottle-shaped, rectangular, circular and irregular cisterns. The account of Diodorus (above) obviously applies to the bottle-shaped form. Oleson (2001: 606) identifies this type as 'a deep, round, rock-cut reservoir that tapers upwards to a small entrance hole'. The irregular cisterns were originally natural caves but modified into cisterns after being carved and plastered.
- Size: Size usually varies according to the design. Bottle-shaped cisterns, for example, have roughly the same dimensions, a height of 6 m and a diameter on the floor of 3-4 m.
- Access: Cisterns that were cut vertically into the rock, including the bottle-shaped form, were laid out without access. The cisterns cannot be entered by such normal means as steps or permanent ladders. However, other cisterns had steps, by means of which access was available to the core of the cistern.
- Architectural Components and Construction Methods: Cisterns vary in the way they were constructed. Bottle-shaped cisterns were usually cut vertically into bedrock, whereas others were cut horizontally. Architectural elements were usually found in association with the latter since a side-wall or a roof was necessary to keep the water clean. Sometimes a terracing wall was built and raised in front of the cistern to direct the run-off water into it. This technique is particularly noticeable in the cisterns located on slopes. Settling basins were

also constructed in front of many cisterns in order to stop sediment. This is clear from the condition of the cisterns from the point of view of sediment. Due to the relatively large number of rock-cut cisterns recorded in the study area, a full discussion of every single cistern cannot be presented in this study. Rather, the discussion below considers some significant examples.

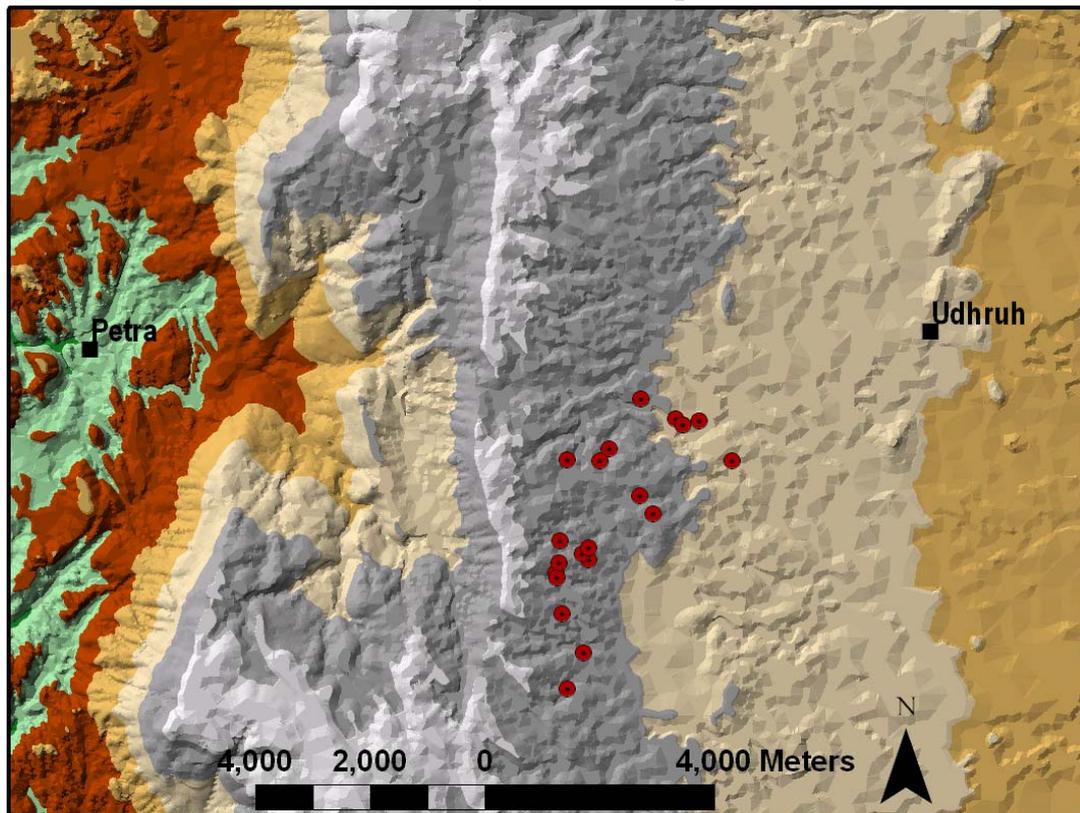


Figure 1: Distribution of the rock-cut cisterns in the study region

1. Site no. 059: Three cisterns were found at this site; one of them will be considered here. It lies just on the southern base or slope of the low hill where the site is located. The cistern seems to have been originally a natural cave converted into a cistern after being vertically deepened, and because it had a side opening, a wall was built to prevent any sediments or debris from entering it (Fig. 2). The latter was fed by rainwater via an earth channel running east-west along the southern slope of the hill. The walls of the cistern were coated with a white waterproof layer. The height of the cistern is approximately 3 m whereas the interior diameter is 2 m.



Figure 2: The wall of a rock-cut cistern at site no. 059



Figure 3: A rock-cut cistern in the courtyard of site no. 069.



Figure 4: The shaft of the rock-cut cistern at site no. 070

2. Site no. 069: The main feature at this site is a two-room traditional house. However, there is strong evidence that this house was built on the substructures of an ancient farmstead; some of the original walls are still visible in its lower courses. The farmstead was obviously associated with a roughly square bedrock courtyard. A cistern was cut vertically within this courtyard (Fig. 3), approximately 3 m high and 3 m in diameter on the floor and an opening of 2 m. The walls of the cistern were coated with waterproof or hydraulic plaster. The cistern appears to have been fed seasonally, mainly from rainwater. Two possible sources might have supplied the cistern with this water; the courtyard itself and/or the roof of the ancient building. This technique of collecting water is attested elsewhere in Jordan and in the Middle East in general (Wählin 1997: 233-249).

3. Site no. 070: This is a very typical bottle-shaped rock-cut cistern located on a moderate slope of a hilly area. A long earth channel clearly fed this cistern with rainwater; the same channel seems to have fed other nearby cisterns. The cistern was cut vertically into limestone bedrock with a flat floor and small opening shaft (Fig. 4). The height and the diameter of the shaft were measured, whereas the

diameter at the floor was not measured as there is no access to the floor. The height is 6.5 m, the diameter of the opening shaft is 0.70 m, whereas the diameter on the floor may be approximately 3-4 m.



Figure 5: Steps inside the rock-cut cistern at site no. 095

4. Site no. 095: This cistern is probably the most significant rock-cut cistern in the study area. It was located on the moderate slope of a rocky hill, where the elevation gradually decreases from southwest to northeast. The cistern was found near the northeastern base of the hill, and the area where it was cut consists of relatively soft limestone layers associated with chalk. A long earth channel (about 150 m) running southwest to northeast along the slope of the hill must have directed the rainwater to the cistern. The course of the channel is very clear near the cistern where the exposed rock was cut to lead the channel. A rectangular settling basin was built at the end of the earth channel in front of the cistern to clear the water from sediment and debris, and finally a short stone channel fed the cistern from the settling basin. The cistern appears to have been cut from the side between two horizontal bedrock layers. The diggers cut a large, round and deep

hole into the bedrock. The cistern is partly roofed by the bedrock, and a wall, approximately 1m in height, was built on the edge of the hole to carry the artificial part of the roof. The short stone channel and the only entrance to the cistern were located in the north side of this wall. The entrance is quite small, approximately 80 cm high and 50 cm wide. However, it gives access to the floor via 17 steps cut into the right-hand side of the bedrock (Fig. 5).



Figure 6: The interior of a rock-cut cistern at site no. 099

The interior of the cistern is roughly circular and is about 9 m in diameter including the side with the rock-cut steps. The diameter at the bottom of the cistern is approximately 7m. Although some debris has collapsed from the roof and stones have been thrown on the floor by local shepherds, the cistern is 6 m high. Apart from the roof, all of the interior, including the steps, were coated with a waterproof layer. It is therefore highly likely that the water level would have reached a point close to the entrance in a good rainy season. The steps must have given access when the water level was low or during the dry seasons when the cistern was being prepared for the next season.

5. Site no. 099: This cistern was partly cut out of a natural cave. Some parts of the cave seem to have been cut to make a roughly rectangular cistern. The cave

was located on the southern lower slope of a low hill. A wall was built on the southern side or the opening of the cave to close the cistern. However, a small entrance was left in this wall to give access to the cistern. A round stone column was built inside the cave, near the east wall, to support the roof (Fig. 6). The column as well as the walls of the cave were coated with a waterproof layer. Traces of an earth channel can be seen on the slope of the hill to the east of the cistern. The channel ran east to west and entered the cistern through the roof near the southeast corner. The cistern was 8 m in length and 6 m in width, its current height is approximately 2 m, but it could be more as the floor of the cistern has some sediment and debris.



Figure 7: A settling basin outside at site no. 104

6. Site no. 103: This is another significant rock-cut site, consisting of two cisterns and a settling basin. The site is located on a moderate slope in a hilly area. The most recognizable feature at the site is the square settling basin (5×5 m), which was built of large flint blocks. There were two openings in the walls of the basin: one in the north wall close to the northwest corner and one in the south wall near the southeast corner. The first opening allowed the rainwater, brought by an

earth channel running east-west along the hilltop, to enter the settling basin, whereas the second opening directed the settled water into a cistern just behind the southern wall of the basin. This cistern was vertically cut and had a waterproof layer. It is now full of debris, therefore, no measurements were taken. To the east of the basin and cistern, a few meters apart, another cistern was found. It is also a vertical rock-cut cistern. The opening shaft of the cistern is currently closed by many slabs, accordingly, the dimensions of this cistern were also could not be obtained. About two meters to the east of this cistern, a stone wall was built to form half a circle or a curve. This wall, although shallow, seems solid enough to prevent any water leakage as it might have worked as a collecting basin for the second cistern.



Figure 8: The interior of the rock-cut cistern at site no. 125

7. Site no. 104: This is a bottle-shaped rock-cut cistern associated with a settling basin, located on the upper slope of a rocky hill. The cistern is approximately 6.5 m in height and 5 m in diameter at the bottom. The settling basin was constructed very close to the opening shaft at the end of an earth channel running south to north (Fig. 7). The walls of the cistern were coated with a waterproof layer.



Figure 9: A rock-cut cistern west of Udhruh used in the 20th century

8. Site no. 125: This is a round cistern cut into a limestone layer on the lower slope of a rocky hill. It was cut from the north side of the limestone façade. It is 5m in diameter and 3m in height and the walls had a hydraulic plaster layer, as indicated by the remnants of the plaster on the inside walls of the cistern (Fig. 8). A wall appears to have been originally built to close the north opening of the cistern. Three rock-cut steps were seen in the northeastern part of the cistern. It also appears that this cistern was fed by a channel that led water from the catchment area. The course of this channel can be seen on the south-eastern slope of the hill, particularly after a rainy season.

Notes on the Date, Distribution and Use of the Rock-cut Cisterns

Date

As already mentioned, the technique of cutting cisterns into rocks was known at least from the Middle Bronze Age (Negev 1972: 332). In southern Jordan, this technique was attested in Petra, Auara and elsewhere from the Iron Age till the classical periods (Oleson 1995: 708; 1997: 176; Wåhlin 1997: 233-249). No

dateable materials were found in association with most of the rock-cut cisterns. Therefore we should rely on general conclusions and some observations from the field work. Geographically, the cisterns lie within the hinterland of the Nabataean capital, Petra.

The archaeological evidence from the study area clearly demonstrates that the region reached its peak during the Nabataean period. The Nabataeans also developed unique water management systems suitable to the area in which they lived in (Koenen 1996: 179). Therefore, it is quite reasonable that this technique of water supply, rock-cut cisterns, was initiated in this region by the Nabataeans.

The GIS mapping of the cisterns allows us to relate each rock-cut cistern in the study area to an ancient settlement site. They were found either within the site itself or nearby. It should be taken into consideration that the location of the cistern is subject to topographic and geological factors; therefore, it is not unlikely that the founders of these sites looked closely at the landscape before they chose a site to build their dwellings. The ceramic evidence shows that the Nabataean period is the earliest and best documented at the sites that have direct connections with the rock-cut cisterns ('Amr *et al.* 1998: 540-543). A Nabataean inscription was also seen, but could not be reached, on the walls of the cistern at Site no. 095.

The fact that these cisterns were reused in later periods cannot be denied. Many of them, especially the bottle-shaped cisterns were in use until the 1980s. Proper doors or covers were made for them and small square openings replaced the original circular opening shafts using small stones and cement (Fig. 9). Therefore, there is no reason to believe that this type of water supply system was not reused during the

Roman and Byzantine period ('Amr *et al.* 1998: 540) as the region seems to have flourished during Byzantine times in particular (Killick 1987). A variation in the colour and material of the waterproof plaster was noticed in many cisterns, and this could illustrate later reuse of these features. The diversity in the colours, the mortar types of the hydraulic plaster and the methods of plastering have been used in an attempt to date aqueducts in Palestine based on those differences (Porath 2002).

Distribution and Use

The recorded rock-cut cisterns in the study area are concentrated in one area to the southwest of Udhruh, as is clearly shown in figure 1. This phenomenon might be explained according to the following observations:

1. The area was relatively far from natural water resources; therefore, the ancient people had to look for alternatives.
2. The landscape of the study region, in terms of geology and topography, was suitable for this type of water supply. The region of Udhruh lies between the limit of the eastern Jordanian Desert and the southern part of the ash-Sharah plateau and is divided into small ridges by shallow valleys and gorges along with a few small rounded hills.
3. The abundant presence of natural caves in this area near natural catchment areas encouraged the ancient people to utilize this technique.
4. Having a water source near a settlement site or farm would have saved the time and effort required to bring water from a remote natural water source.

The storage capacity of most of the rock-cisterns in the examples given above is small. Although many of them were found near ancient agricultural fields, it seems that they were not used for irrigation due to their small capacity. Moreover, these cisterns were seasonally fed as they are mainly dependant on winter rainwater. Thus, a seasonal water source would not sustain a continuous irrigation system. Furthermore, a considerable number of the cisterns recorded show that the quality of water was very important to the ancient people. This fact can be seen in the cisterns themselves as their walls were carefully coated with waterproof plaster, settling basins were constructed, and roofs and side walls were added whenever it was necessary. This degree of care might reflect the nature of use, and it can be said that the water stored in those cisterns was consumed for domestic purposes such as drinking, cooking etc. A settling basin would have guaranteed that at least no considerable quantity of sediment or debris entered the cistern. Minor material would most likely stay at the bottom of the cistern as the water stayed still in it for a long time before it was totally consumed.

The majority of these cisterns can be rehabilitated and reused again to aid in overcoming the problem of water shortage that we suffer from nowadays. They

would be of great benefit at least for agriculture and animal stock in a dry area like the region of Udhruh, particularly during the hot and long dry summer season.

Conclusions

This paper has presented a sample of the rock-cut cisterns of the region of Udhruh in southern Jordan. The study has revealed that there was a strong relationship between the location of the rock-cut cisterns and both the topography and geology of the location, i.e. this type of cistern developed from natural cavities in rocks, which were artificially enlarged and improved by cutting into the native rock and reveting parts of the enlarged perimeter with walling. Moreover the study has shown that rock-cut cisterns in the study region can be classified into four types according to their designs to include bottle-shaped, rectangular, circular and irregular cisterns. Comparative study and parallel examples from other Nabataean sites in southern Jordan along with epigraphic and ceramic evidence, all suggest that this technique of water supply, rock-cut cisterns, was initiated in this region by the Nabataeans. The ceramic evidence shows that the Nabataean period is the earliest and best documented at the sites that have direct relations with the rock-cut cisterns. Furthermore, the evidence for water management systems in the study region suggests that water management in Jordan during the Nabataean-Roman-Byzantine periods was more sophisticated and less wasteful than that of today. Judging by the capacity of cisterns, such as those at Udhruh, communities may well have had more water available per person per year than is the case now, considering the time scale, demographic figures and development. Furthermore this paper has shown that cisterns in the study region remained in use from the Nabataean period throughout the following centuries until they were totally abandoned or rarely used by the second half of the twentieth century.

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