CSCanada
Management Science and Engineering
Vol. 12, No. 4, 2018, pp. 12-22
DOI:10.3968/11017

ISSN 1913-0341 [Print]
ISSN 1913-035X [Online]
www.cscanada.net
www.cscanada.org

Water Management in Petra: Nabataean Hydraulic Overview

Mansour A Shqiarat[a],*

[a]Department of Archaeology, Al-Hussein Bin Talal University, Ma'an-Jordan.
*Corresponding author.

Received 1 September 2018; accepted 4 December 2018
Published online 18 December 2018

Abstract
The study of Nabataean hydraulics has long been focused on the collection and distribution of water across the landscape and within the city of Petra. Traditionally, the collection, distribution and uses of water have been viewed from a purely practical standpoint: it is thought of as a resource, to be regulated and conserved and devoted to functional purposes. In his description of the Petra environment, the ancient Greek geographer, Strabo, pointed out two factors significant to the establishment of Petra as an urban settlement despite its arid desert environment. This paper concerning all the issues related to the water management in Petra. However, it starts by identification of Petra strategic location, followed by irrigation at Petra and storage of water. The Siq, which is the main entrance of Petra, is introduced for its importance role in managing the water during Nabataean period. Also this paper describes water management system used at Petra, this includes methods and controlling devices and all other sources utilised.

Key words: Petra; Nabataean; Water management; Irrigation; Waterfall; Methods devices.

Shqiarat, M. A. (2018). Water Management in Petra: Nabataean Hydraulic Overview. *Management Science and Engineering*, *12*(4), 12-22. Available from: URL: http://www.cscanada.net/index.php/mse/article/view/11017 DOI: http://dx.doi.org/10.3968/11017

INTRODUCTION

Petra, Sela, Reqem, and Pink city of the desert various names for that unique site situated, in the southern part of the actual Hashemite Kingdom of Jordan. Petra, as the capital of the Nabataeans, reflects by its monuments the prosperity their civilisation reached, especially between the 1st century BC and the 1st century AD. Most of the monuments of Petra and the other major Nabataean sites date to this period. Petra is situated to the south of the Dead Sea, about 100km to the North of the Aqaba Gulf. It is located, thus, in a transitional region between the Mediterranean basin and the desert.

On a visit to Petra in 1938, Robinson (1941) noted its urban character, describing the ruins of dwelling and other structures visible throughout the Petra basin. These ruins were so obvious to Robinson that he expressed surprise that they had gone unnoticed by previous visitors to the site. "Indeed the whole area…. was once obviously occupied by a large city of Houses…the whole body of the area. On both sides of the torrent, and especially on the North, is covered with foundations and stones of an extensive town. The stones are hewn and the houses erected with them must have been solid and well built. On looking at the extent of these ruins, it struck me as surprising, that they should hitherto have been passed over so lightly; although this may readily be accounted for by the surprising interest of the surrounding sepulchres. These foundations and ruins cover an area of not much less than two miles in circumference; affording room enough, in an oriental city, for the accommodation of thirty or forty thousand inhabitants" (Robinson 1941, p.424).

The sites under consideration are administratively included Petra within the Petra Development Tourism Regional Authority, a regional council founded in 1995 to promote the region of Petra. The sites consist sensustricto of Wadi Musa, Baida, Umm Seihoun, Taiba, Rajef and Dlagha. They extend about 900 km² around Petra and thus, constitute the periphery of the Nabataean capital (Al-Shqiarat, 2018).

Rome annexed Petra in 106 AD, motivated by the desire to ensure access to trading routes that linked the

Empire to the mid-east, India and Asia. A growing reliance on sea rather than land routes, as well as the ascendancy of Palmyra, eventually caused commerce through Petra to decline. Many buildings were never rebuilt after a severe earthquake in 363 AD, although, that not long after Petra was designated the seat of a Byzantine bishopric. Recent archaeological excavations at Petra have indicated a substantial complex of structures associated with this last function but, by the middle of the seventh century AD, Petra appears to have been largely deserted. In the twelfth century, Crusader forts were built and then soon abandoned. Petra was lost to the western world until its rediscovery during the early nineteenth century, an event not unrelated to European colonialism and perhaps a desire to capture in print the last parts of the world that remained unknown to and un-colonized by Europeans (Shqiarat, 2005; 2008).

The city has three main entrances: the first goes from the east, through Al-Siq (a natural gorge in Petra), extends for 1.216 kilometres and is the main passage the Nabataeans developed into Petra's formal entryway; it is hemmed in between cliffs up to 100 metres high and in places is no more than 2.19 metres wide. The others are from north and west through wadi Al-Torkmaineh and AsSiyyagh; they connect Petra with Palestine and Sinai (Shqiarat, 1999; 2005).

Irrigation at Petra

Most of Petra lies in an area of sandy stones in which there are many valleys, such as Wadi AsSurayi and Wadi Al-Matabha. This fact made the area around Petra dangerous in rainy seasons because of floods, especially the low areas, because of the many valleys and the high speed of the water that flows on the sandy stones. The Nabataeans were forced to build dams in many of these valleys for two major purposes. The first purpose was to make use of the rainwater behind those dams for drinking and irrigation.

The second purpose was to protect the various buildings and stations that lay in the low areas at times of floods and drifts. Petra is almost empty of springs and water, except the spring of the Wadi Siyyagh that lies in the western side of the city. It is a spring with a little water that lies in a low area of the city. There are some other areas that include a little water, such as the Qattar Al-Deir area, in addition to a small spring in the valley of Abu-Aliqah, but its water is salty and is not suitable for drinking. These sources are not of great importance in supplying Petra with water (Shqiarat, 2005; 2008).

The oldest reliable archaeological dating evidence for rainwater harvesting agricultural practices in the Negev has been found to date to Iron Age II 1000-539 BC (Aharoni *et al*., 1960). However, it was only in the Nabataean and Roman periods that rainwater harvesting agriculture reached its peak in terms of development and acreage covered around-4000 hectares out of 200 000 hectares available (Evenari, *et al*., 1971). In north Jordan, farmers built similar systems of runoff farming using cleared catchments and 'cross wadi walls' (Kennedy, 1995; Shqiarat, 2005).

The hinterlands surrounding Petra and other Nabataean settlements throughout the desert region show signs that the Nabataeans practised agriculture on a large scale to feed their growing population. They devised elaborate and intricate systems for water catchments and irrigation as a means of extending the boundaries of agriculture farther and farther into the desert (Shqiarat, 2005; Al-Muheisen, 2002, p.107; Evenari and Koller, 1956; Glueck, 1959, p.201). The effects of this massive terracing system on the landscape were so great that, centuries later, Nelson Glueck identified many settlements along Wadi Araba and in the Negev desert as "garden cities", whose extensive field and hydraulic systems demonstrate the Nabataean efforts towards "the fructification of deserts" (Glueck, 1959, p.202). The only written evidence for land organization in the plateau region before the Byzantine periods comes from a short Nabataean dedication stone of eight BC from the large cult centre at Khirbet at-Tannur, dedicated by the 'curator' of the source of Wadi La'aban. Villeneuve suggests this may hint that there was a local organisation for the control of spring water and irrigation within the valley (Villeneuve, 1992, p.281). However, the curator may have been the keeper of the spring water.

Because the region's limited rainfall comes only in the winter, the emphasis of the Nabataean system is rain catchments and storage for use through the long arid summer months. When the rainfall does come, it is usually in the form of sudden outbursts and the hard soil and impermeable rock are unable to absorb the water quickly enough. Instead, it flows rapidly across the surface and into the dry wadis where flash floods often develop, carrying topsoil along with rocks and debris, which are deposited in the wadis and catchment basins. In an effort to conserve precious resources, the Nabataeans built walls and terraces along entire wadi systems in order to trap silt and water on the slopes and spread it out for wider use (Shqiarat, 2005; Shqiarat, 2018).

The main wadis were converted into u-shaped terraces to divert the water and silt into the side plots. Upstream conduits and collector walls led the water to downstream plots that might otherwise have been missed when the floodwaters rushed by (Evenari and Koller, 1956, pp.42-44). Dams were constructed across wadis to slow the water and reduce its force and to store it for subsequent use (Hammond, 1967, p.39).

This system allowed for the irrigation and cultivation of large field crops (mainly grain), as well as orchards and vegetable gardens, enough to fulfil the demands of a growing population (Evenari and Koller, 1956; Glueck, 1959; Shqiarat, 2005). Furthermore, Strabo states that the

Nabataeans have mastered the arts of irrigation and enjoy rich harvests of cereal and fruits from across the kingdom (Strabo 16.4.21). A good indication of the farming practices of the Byzantine period of the sixth century AD has come to light recently with the unearthing of the carbonised papyri from the storeroom of a Petra church (Koenen, 1996).

According to papyri found at Nessana in the Negev, the Nabataean water system permitted the successful cultivation of barley, wheat, legumes, grapes, figs and dates (Evenari and Koller, 1956). Many of the ancient channels and terraces are still extant and some continue in use by the local population. Also, they are still using the water from Muse spring: everyone has two hours to irrigate his field. They manage this between them, depending on the size of the land, sometimes allowing more then two hours.

A good indication of the farming practices of the Byzantine period of the sixth century AD has come to light recently with the unearthing of the carbonised papyri from the storeroom of a Petra church (Koenen, 1996; Shqiarat, 2005). Although not fully published yet, these papyri, most of which are in the form of legal contracts, have provided a wealth of information concerning the administrative organisation and agricultural methods of the plateau region. The most important evidence in this regard has come from roll number ten, which is concerned with the division of property and land between three brothers (Koenen, 1996). Mention is made in these papyri of sown lands for wheat; vineyards; and houses with adjoining orchards which would have been irrigated by hand and which are common in Jordan today. A further roll fragment mentions a "regular orchard" which has been interpreted as referring to an irrigated orchard, as seems to be the case with similar papyri from Nessana in the Negev (Koenen, 1996; Shqiarat, 2005). It is also interesting to note that the land divided up in roll ten was scattered in plots across a relatively large geographical area, and that the individual fields were small in size, from around 2.6 acres up to an occasional maximum of around sixteen acres. As Koenen suggests, this reflects well-known methods of risk management where the availability of water could fluctuate wildly from year to year at different location within a very localised area (Koenen, 1996).

Documents in the Nabataean language from the Wadi Habra west of the Dead Sea, give us an idea how the distribution the water between of worker farmers in Nabataean period was arranged.

Document (1), known by P. Yadin 2 line three from Verso as mentioned:

"one that day (He) purchased (namely) Archelaus, Son of ‘Abad-‘Amanu ……..,The commander , from me, I, Abi-Adan daughter of ‘Atah, son of Manigares, a plantation of date palms which is in Mahoz ‘Eglatain, including irrigation ditches and assigned watering periods" (Yadin, et al. 2002: P.Yadin, 2).

Document (2) known by P.Yadin 3 lines 1-4 from Verso as mentioned:

"On that day he purchased (namely) Shim'on, son of ….of Mahoz ‘Eglataion, from on one, I, ‘Abi-‘adan daughter of ‘Aftah son of Manigares, a date palm, Called GH…., which is in Galgala, which is in Mahoz ‘Eglataion, including irrigation ditches and assigned watering periods, half of one hour on the first day of the week every single week and forever."(Yadin, *et a.l* 2002: P.Yadin, 3). By default it seems to most commentators that irrigated, no directly attributable evidence has been found to ascertain a specifically Nabataean date to a particular system or even to the specific nature of the irrigation methods employed by the Nabataeans.

Storage of Water

The Nabataeans displayed the greatest intelligence in their selection of location through several different geographical and geological aspects.

Once the demands of field irrigation were met, surplus water was diverted into cisterns and reservoirs for storage and domestic use. Water collected in the winter had to be stored for use through the dry season at least 12 and up to 24 months for irrigation and for drinking water. It is estimated that a minimum of 10-20 litres per day per inhabitant was required for drinking and washing (Garbrecht and Peleg, 1994; Shqiarat, 2005). Fall-off points and natural catchment basins were enlarged. Channels were cut into the side of every hill and rocky outcrop to collect water and conduct it to established storage sites. Small reservoirs were established along the wadis and shielded from the sun by rocky outcrops and trees to slow evaporation (Evenari and Koller, 1956; Shqiarat, et al., 2010). However, in order to fulfil the demands of large populations in a desert environment, large underground cisterns were a necessity. Some cisterns were enlarged caverns with pillars to support the roof; others were entirely man-made, dug into the limestone strata which are naturally water bearing, and lined with plaster for additional waterproofing. Nabataean cisterns were typically roofed over with long stone slabs supported by transverse arches to prevent evaporation and pollution (Glueck, 1959; Oleson, 1990; 1995; Shqiarat, 2005). (The overall dimensions of the cisterns were limited by the arch span. A study of Nabataean roofed cisterns in Jordan and southern Palestine shows that their wide was limited to 6 to 7 metres maximum, and their deep was 5 to 6 metres maximum. This led to an elongated, rectangular design for public cisterns in order to obtain the desired capacity (Oleson, 1995).

Two examples of roofed cisterns at Humayma (Auara). Nabataean roofed cisterns are found at virtually every known Nabataean site: Petra (Kennedy, 1925; McKenzie, 1990); Humayma (Oleson, 1990),Ramm (Horsfield and Conway 1938), Ain el-Khalde (Kirkbride and Harding, 1947); Jabel Ratama (Kirkbride and Harding, 1947);

Mahmal (Meshel and Tsafrir, 1975); Qasr Wadi es-Siq (Glueck, 1953).

This roofing design was borrowed from Hellenistic architecture and continued in use throughout the Byzantine and early Islamic periods (Oleson, 1995). Sedimenation basins placed at the narrow entrances to the cisterns helped to purify the water of silt and other pollutants. A small opening in the roof allowed water to be drawn by means of buckets (Evenari and Koller, 1956; Shqiarat, et al., 2010). (Writing about the Nabataeans in the late 4th century BC, Diodorus [Hist.XIX.94.6-8] described subterranean reservoirs with small opening and concrete lining.

Larger open-air reservoirs were less practical because they were more subject to loss by evaporation-between 3 and 4 metres per year- than a closed cistern or covered reservoir. In addition, open reservoirs require constant upkeep due to the introduction of pollutants such as insects, animal waste, plant debris and the growth of algae under the hot sun. As a result, the occurrence of larger reservoirs is generally restricted to the outskirts of settlements where they were probably used as watering holes for livestock and passing caravans, or as a resource for filling nearby domestic cisterns when necessary (Oleson, 1986; Oleson, 1995). Glueck describes large rectangular reservoirs (Birkeh) at et-Telah (Toloha) in Wadi Araba (Glueck, 1959) and at Umm al-Jimal (Glueck, 1965; Shqiarat, 2005) that date to the Nabataean period. At Humayma, a reservoir measuring 27.6 x 17 x 1.75 is located at the northern edge of the city (Eadie and Oleson, 1986; Oleson, 1995). The use of seven alternating courses of headers and stretchers in the wall construction and diagonal dressing on the ashlars and stretchers in the wall construction is noted. The second reservoir at Humayma cistern 1, dates to the Roman period (Eadie and Oleson, 1986, pp.58-59).

The walls are topped with stone paving to form a walkway around the perimeter. The interior of the reservoir is lined with hard, sandy stucco. Water was fed by an aqueduct that entered the reservoir through an opening at the centre of the northern wall (Eadie and Oleson, 1986). Nearby, a large stone was found with a basin and several covered diverting channels leading into it (Eadie and Oleson, 1986). A similar basin found in situ at Sobata functioned as castellum-diverted water to another smaller cistern once the main reservoir had reached its capacity (Eadie and Oleson, 1986).

At Petra, the Nabataeans, conquest of the desert went well beyond the practical needs of crop irrigation and drinking water. As with all of their settlements, the Nabataeans constructed extensive water collection and supply systems for their capital city. As Hammond observed: "In a land of high cliffs and deep fissures, as well as desert wastes, the stonecutter became the engineer's ally, and the abilities formerly devoted to tomb facades and sculpture were diverted to the production of runnels, diversion channels, cisterns and water control system" (Hammond, 1967).

In his description of Petra, Strabo stated that, there are abundant springs of water for domestic purposes and for watering gardens (Strabo.Geog, XVI.4.21). An extensive system of channels and aqueducts carried water from spring and catchment areas to numerous cisterns and public works throughout the city (Strabo.Geog. XVI.4.37). At many points along the way, arches were constructed to carry the aqueducts across deep crevices and uneven terrain. The use of arches and the installation of the pressure pipe allowed the Nabataeans much freedom in their design of hydraulic installations and ultimately enabled them to virtually disregard the topography (Hammond, 1973, p.73).

The main water source for Petra is 'Ain Musa (Spring of Moses), which tradition honours as the spring that burst forth from the rock when Moses struck it with a staff. 'Ain Musa is located in the eastern hills approximately 7 kilometres from the City Centre. Downstream from 'Ain Musa, above the entrance to the Siq, a large freestanding reservoir collected the spring water for controlled distribution into the city and its environs. One route was via a channel cut into the southern wall of the Siq and covered with stone slabs. Later, a deep groove was carved along the Siq's northern wall and installed with interlocking high-pressure ceramic water pipes (Hammond, 1967; Shqiarat 2005). The pottery pipes are later than the Siq paving. (McKenzie, 1990); Hammond (1967) dates them to the reign of Aretas IV.

The narrow Siq, however, proved to be a dangerous place during the rainy season. Water flowed into it through nineteen faults and inlets resulting in dangerous flash floods carrying earth and debris and anything else in their path along with them. The Nabataeans designed an intricate hydraulic system in order to control the life-threatening floodwaters.

The paved road through the Siq was laid at a gradual decline to lessen the water velocity. Dams were erected across smaller side wadis along the Siq to contain the water and create small reservoirs for use in the dry season. The construction of a diversion dam and a tunnel, 40 metres long, at the entrance to the Siq diverted the bulk of the water around the base of Jabal al-Khubtha where it emptied into Wadi al-Matabha (Gunsam, 1980). From there, the water headed downstream to converge with Wadi Musa, where additional diversion channels and erosion control walls kept the flow in check as it passed through the centre of the city (Hammond, 1967; Shqiarat, 2005).

Two other springs, in addition to Ain Musa, are known to have served Petra in antiquity. Ain Braq, located in the eastern hills a few kilometres south of Wadi Musa, was of secondary importance, mainly serving the agricultural lands and residences south of the city centre. The spring in Wadi es-Siyagh probably never played a major role in supplying Petra's civic needs, due to its location west of the city centre at a significantly lower elevation. When the demands of the thriving city outgrew the output of the three local springs, an aqueduct was constructed that carried water from Dibdibeh-several kilometres northeast of Petra, across a bridge spanning a deep ravine and into the northern section of Petra. A group of more than thirty French tourists were killed during a visit to Petra in the 1963 when a wall of water crashed through the Siq following a rainstorm. Since then, the restoration and reconstruction of the ancient Nabataean water control system has prevented similar tragic events (Shqiarat, 2005; 2008; Al. Muheisen 2002; Hammond, 1967; 1973).

"Just as their resources were smaller, Nabataean applications of running water were fewer, and the physical arrangements for distribution correspondingly less elaborate than those for a Roman metropolis. Instead of being divided up into pressurised pipelines serving public fountains, public baths, and private homes– as Vitruvius recommends 8.6.1-2)— the water splashed quietly into public reservoirs to which access was arranged by Nabataean deity. The overflow from the primary storage tanks probably was conducted into private cisterns and small agricultural plots in accordance with similar arrangements" (Oleson, 1995).

The Siq

As described earlier, the narrow Siq, the first leg of via sacra leading into Petra, was installed with a water channel and ceramic pipeline along its south and north faces, respectively. Their primary purpose was to help control floodwaters and to provide an easy means of transporting unpolluted water into the city. In addition, it is likely that the presence of these hydraulic features served a secondary, symbolic role. The sound of the water that flowed, unseen, inside the covered channel and pipeline, would surely have been audible to passers by, as a continuous murmur reverberating off the towering walls of the narrow Siq (Shqiarat, 2005).

Many religious symbols are found in the Siq, thus, there is a close association between them and the waters that flow through it. At the entrance are three-square towers or "god blocks" carved from the sandstone, and more than 60 god idols, or stelae, are carved upon the walls at various points along this long, winding passage (Brunnow and Domaszewski, 1904-9; Dalman, 1912; Patrich, 1990). Most of the representations of Nabataean deities are aniconic and thus presented as simple carved blocks of stone or stelae. Anthropomorphic representations of Nabataean gods began to appear in the 1st century BC as a result of Hellenistic influence but are few in number (Patrich, 1990; Mettinger, 1995; Ball, 2000; Shqiarat, 2005).

Particularly notable is a relief sculpture discovered during the recent excavations in the Siq. Two pairs of camels (1½ times life-size), each led by a male guide, are carved into the rock on the southern wall of the Siq. Only the lower half of the guide is preserved showing his draped garments, sandals and a staff. Of the camels, only the feet and lower portions of the legs are well preserved. Although their bodies are badly eroded, one can make out their general outline in the rock face above the water channel (Shqiarat, 2005).

This relief was carved either before, or at the same time as, the water channel that is credited with the existence and success of the city; the specifics of its design suggest a less functional meaning. First of all, these camels do not appear to be carrying burdens and, thus, are not represented in their role as pack animals. Secondly, the arrangement of the scene, with each pair of camels and their guides facing each other, is more reminiscent of ritual scenes where a venerated subject, god, icon, king or altar stands at the centre of a symmetrical arrangement of worshippers or participants. It has been suggested that an altar once stood between the two sets of camels (Shqiarat 2005; 2008; Taylor 2005).

A similar scene, also badly weathered, is depicted in a relief near the ed-Deir monument, in which a carved niche is flanked by two guides, each leading a single camel. Nearby are channels and a small collecting pool carved into the bedrock. In these scenes the camels appear to be part of a ritual procession, possibly leading to their own sacrifice (Taylor, 2005; Shqiarat, 2005).

Fountains

The veneration of water, especially springs and rivers, is one of the most ancient and universal forms of worship. It is a universal phenomenon that persists through the time and space due to role further as a basic human need. Because of its crucial role as a life giving resource for the desert nomads, it is not surprising that the Nabataeans perceived water as sacred and that many examples of ornamental water display at Petra held religious significance. Numerous religious icons, inscriptions and sanctuaries are found in association with springs, catchment pools and channels throughout the city and its environs (Shqiarat, 2005; 2008; Al-Muheisen, 2002; Al-Muheisen and Tarrier, 1996; 1997; Brunnow and Domaszewski, 1904-9.; Dalman, 1912; Patrich, 1990; Lindner and Gunsam, 1995).

One Nabataean deity in particular may be associated with springs and water. This is the goddess Al-'Uzza, consort to the patron deity Dushares. Al-'Uzza is most commonly represented as a rectangular stele on which two schematic eyes and a nose are carved (Patrich, 1990). In inscriptions, Al-'Uzza is associated with the Greek fertility goddess, Aphrodite, as well as the Syrian fertility goddess, Atargatis (Patrich, 1990). The decoration on a gold earring found in a Nabataean grave at Mampsis (Mamshit) in the Negev, combines the features of "eye idol" with an image of a standing female nude that is more commonly associated with Aphrodite Anadyomene ("rising from the sea") in Hellenistic Roman iconography (Patrich, 1990).

Atargatis is the goddess of fertility and the life-giving forces of earth and water. In the Nabataean temple at Khirbet et-Tannur, anthropomorphic representations of Atargatis show her against a backdrop of abundant flowers and fruits wearing a headdress of dolphins or fish (Shqiarat, 2005; Glueck, 1965; McKenzie, 1988). Atargatis is also represented at Khirbet et-Tannur in association with lions, a common attribute for the chief female details of Near Eastern and Classical religions (Glueck, 1965; Browning, 1973).

The use of carved lions in the architectural details of the Temple of the Winged Lions at Petra, and the discovery of an especially well carved "eye idol" inside that temple, allows this structure to be identified with the veneration of Atargatis/Al-'Uzza (Patrich, 1990; Hammond 1996b). Although there is no known water source or water installation in the vicinity of this temple.

Direct associations between water and the veneration of Atargatis /'Uzza are found elsewhere in Petra. A stele carved into the rock face above the spring in Wadi es-Siyagh is accompanied by a dedicatory inscription to Al-'Uzza (Milk and Starcky,1975). En route to the "High Place of Sacrifice", the site of ritual sacrifice on the rocky summit of Jabal Attuf, a votive fountain, in the form of a lion (4.5 metre high), with its body in profile and its head frontal, is carved in relief on the mountainside. Water was transported down from the summit via a deeply carved channel and poured out through an opening in the lion's mouth into a basin below. Other representations of lions in association with water are found at Qasr Rabbah and Khirbet et-Tannur in the form of lion-headed waterspouts (Glueck, 1965; Shqiarat, 2005).

During the Roman period, the Nymphaeum, a monumental public fountain, was constructed near the confluence of Wadi Muse and Wadi al-Matabha, at the eastern end of the Colonnaded Street. Only the foundations of the Nymphaeum's semi-circular plan remain, so the details of its appearance are lost to us (Bachmann, et al., 1921; Mckenzie, 1990). Based on examples at other sites in the Roman East, the Petra Nymphaeum can be reconstructed in the shape of an exedra, its face decorated with carvings of water nymphs to whom the monument was dedicated (Browning, 1973; Segal, 1997; Shqiarat, 2005).

Across the front of the Nymphaeum is a large basin that would have been filled by water flowing from at least one fountain built into the façade. The Nymphaeum was a standard feature in all Graeco-Roman cites that was adopted into the Hellenised Near East. The origins of the Nymphaeum can be traced to religious sanctuaries located near natural springs or streams; an offering was made in honour of the water nymphs that were believed to inhabit these secluded watering holes. Although the sacred significance of the Nymphaeum was somewhat lost in its Roman transformation into a public monument, its role as a symbol of the water upon the Nymphaeum of Petra provided passersby with a convenient resting spot and gathering place, where one could refresh oneself with a drink and cool spray from the fountains. As a place of congregation for citizens and non-residents alike, the Nymphaeum stood as a symbol of the volume of water entering Petra and, thus, held an important role as a status marker for the city. The so-called "South Nymphaeum" has not been excavated and may not be a Nymphaeum at all. Its plan is that of a small temple or shrine (Browning, 1973).

Waterfalls

It is to be expected that many waterfalls, both natural and artificial, could be witnessed throughout the Petra region during the rainy season as running water navigated the rugged landscape. In many cases, the Nabataeans constructed arches across deep gorges to act as bridges for aqueducts and, thus, maintained the flow at a desirable gradient. Elsewhere, water was channelled to the cliff's edge, where it dropped off into basins or catchment pools. Such waterfalls would have made a lovely sight but were unremarkable as natural features in any mountainous landscape. One waterfall at Petra, however, falls into an entirely different category. Carved into the sandstone cliffs adjacent to the Palace Tomb is a monumental niche standing approximately 20 metres high. Water was channelled around the northern edge of Jabal al-Khubtha to the top of this niche and cascaded over the edge to from a magnificent waterfall. At the base of the Waterfall is a series of terraced basins and a cistern (Laureano, 1994; Shqiarat, 2005).

It has been suggested that the water from the cistern near the Palace Tomb may have been used to feed the Roman period Nymphaeum (McKenzie, 1990, p.110).

This man-made waterfall is remarkable not only for its size, but for its negative impact on the Nabataeans' efforts towards water conservation. Although splendid to behold, the amount of evaporation off water of such magnitude was unnecessarily wasteful of the city's most precious resource. Therefore, the creation of the waterfall, a feature of purely ornamental value, must have held enough significance to its creator and/ or the inhabitants of the city to justify its existence.

Another artificial waterfall is documented in the theatre at Wadi Sabra, a suburb located approximately 7 kilometres south of Petra. An investigation of Sabra's catch water regulation system, by Manfred Lindner (1982), provided information about its hydraulic installations. According to Lindner, the theatre functions as the terminus for the runoff from the mountains surrounding Wadi

Sabra. A dam constructed on the slopes above the theatre formed a reservoir with a holding capacity of 370 cubic metres of water. A small outlet at the base of the dam functioned as a drain emptying water into the theatre in the same manner as a fountain spills into a basin (Lindner 1982a; 1982b). This cascade of water out of the mountains and into the theatre is an overt example of water display. The ultimate destination and use of the water after it entered the theatre is not, known, since excavations have not yet been undertaken within the theatre proper.

Early explorers speculated that the orchestra of the Wadi Sabra theatre functioned as a large water basin used to re-enact maritime battles, similar to the Roman naumachiae (Laborde, 1830; Lagrange, 1998; Shqiarat, 2005).

Water Management at Petra

The considerable role of water in the design and character of cities throughout the classical world is summarised in the following quote from a recent study of water supply and water technology in the Roman world:

"Water was everywhere in cities across the Graeco-Roman world. A metaphor for Life itself, it gave an underlying structure to the ancient city. It shaped urban topography and even local history. Water was hidden in deep wells and cisterns and gushed unseen through the conduits and armatures of aqueducts, to be distributed by the castellum aquae or to be used for irrigation outside the city. It bubbled openly in nymphaea, public fountains, baths and the labyrinth sewer networks that served them.

Invisibly and visibly it lent form" (Koloski-Ostrow, 1997).

The function of water in these cities was something much greater than providing drink to the inhabitants and nourishment to plants. In the public realm, waterworks, such as fountains and baths, formed the backdrop for communal activities. In Public Square, at the entrances to the theatres, assembly halls and religious sanctuaries and at major intersections of the streets, the presence of water increased the amenity of the space (Crouch and Rinne, 1996; Shqiarat, 2005).

In addition, the attention lavished on such public installations would remind the citizens and foreign visitors alike of the quality and generosity of the local leaders. The same is true of the waterworks at Petra. All of the examples of water display at Petra previously listed, with the exception of the Nymphaeum, date to the Nabataean period (pre-annexation) and, therefore, cannot be attributed merely to the Romans, whose passion for spectacular waterworks is well documented (Crouch and Rinne, 1996; Jones and Robinson, 1998; Al-Shqiarat, 2018).

Despite the great efforts in the area of water display by the Romans, Vitruvius writes surprisingly little regarding the incorporation of water into architecture for aesthetic purposes. His chapter on water is focused on the very practical methods of locating water sources, testing it for quality, transporting and storing it (Vitruvius, VIII.1-6).

Due to the generous supply from the Tiber and the luxuries of their waterworks, no villa was complete without is baths, fountains, pools, channels and fishponds (Jashemski, 1979; 1993; Eisenberg, 1998; Farrar, 1998). At Hadrian's Villa at Tivoli, arguably the most famous and extravagant of all Roman villas, the single most unifying element is water (Erhlich, 1989; MacDonald and Pinto, 1995). The exhibition of water at Petra belongs to a much larger phenomenon of human psychology, in which water's aesthetic and symbolic values are used to provoke emotions and make statements regarding wealth, status and power. In addition to its aesthetic appeal, water has a way of exciting human emotions. Water is simultaneously the most docile and the most powerful of visible elements, and it is these two qualities that form the basis of the art of water display. "One stimulates the mind the other the eye" (Jellico and Jellicoe, 1971).

Due to its cleansing qualities, water is almost universally attributed with the value of purity. Throughout the near eastern and classical worlds, religious sanctuaries were fitted with pools and basins of water that permit both priests and worshippers to attend to their religious duties in a state of purity. Most notable, perhaps, are the sacred lakes and pools of the ancient Egyptian temple complexes known, through their depiction in wall paintings (Shqiarat, 2005; Hyams, 1971; Gallery, 1978; Wilkinson, 1998).

Water Controlling Devices

Runoff water can damage properties and public buildings. For this reason, protective devices were established. At Petra theatre, the excavation revealed a hydraulic system which was applied to protect the theatre against water. The theatre itself was constructed beside the slope of a mountain and the rainstorms which occur in the area made such a system necessary. A channel was chiselled in the upper gallery in order to prevent the water from falling down to the summa cavea. About 60m of the canal is still preserved. In other parts of the theatre runnels were located, one of which is rectangular in shape (16 x 24cm). In trench 1.22B three superimposed drains were located. The upper one which is known as drain A is built of undressed stones. The stones were smoothed on two sides. The canal rests on rubble fill and its pieces are connected with mortar and plastered. Canal B is located underneath canal A. The canal is made of tiles in the form of a circle; many parts of the canal were destroyed when canal A was constructed. One of the pipes is 37cm long 22cm in diameter and 1cm thick. The ends are thicker than the other parts. The tiles are of reddish ware with white grits and a black core. The tiles were connected by mortar between the overlapping. Canal C is the lowest and in good shape. It was laid in cut red bedrock. Contemporary with this canal is a retainer wall built in the shape of stairs. It served two purposes, the first to prevent water from going inside and the second as stairs to the exit. The tiles of the drain are about 44cm long, 18.5m in diameter and 0.75m thick. It was made of reddish ware with white grits and there is a black core. The parts of the canal were held intact by black mortar, which contained charcoal, the same as the mortar, used in the earlier phase of the theatre (Hayes, 1965).

At the southern temple of Petra, a water management system was discovered in the area of the temple forecourt. It consists of various channels which are labelled A-G. The main channel runs north south and is called channel A. It was covered by top soil followed by a hexagonal pavement. The main and original phase of the structure was followed by a second phase in which more courses were added at the top of the wall in order to contain a greater amount of water. The walls consist of 5-7 courses, which are built without mortar, of dressed sandstone 60-70cm long and 30-40cm wide. The walls of the second phase were not as good as the older ones as regards the shape of stones and courses. The tunnel parts were covered by slabs of limestone 0.75m long, 0.57m wide and 0.18m thick, which were in turn covered with sand and then top soil.

Channels B and C are connected to the main channel A on its two different sides to the east and west with a space of 0.75m between them. They are narrower than the main one (about 0.5m wide) and their level is 0.3m higher than channel A's floor. Strangely, the slope of these two channels is contrary to the slope of the main one, which could be explained by the fact that they served as alternatives in case the main one had overflowed.

The way in which the system is executed regarding the connections of the branches suggested that the whole system was constructed at the same period. The channel wall was supported from behind by a filling of rubble and stones. The water which ran inside the channels was of a high percentage of calcium, as is clear from the lime deposits on the inside walls. The purpose of the tunnel system is to drive the water from inside the temple area and protect the area from flooding (Joukowsky, 1997).

At tomb 825 in Petra there was a ceramic pipe installed in the façade. An opening of a size larger than the pipe was made; then the pipe was inserted. The space was filled with smaller stones and mortar. The pipe continued before and after the tomb and was supported by a stone structure (Shaer and Aslan, 1997).

BATHS

At Petra, south of the Temenos Gate, the bath is located; it is dated to the first century BC. The bath consists of a circular room about 5.12m in diameter adjoining another square one. The structure is at underground level. The circular room has eight half columns with an Attic base. The roof is of a dome shape and was built of stone slabs with a circular window at the top. Remains of red stucco and coloured marble were found in the rubble. Connected to the wall of the circular room is a large staircase with stucco of red and yellow paint (Mackenzie, 1990).

At Khirbet Edh-Dherih was discovered a unique area that consists of two rooms No16 and 17, which formalise the bath. The caldarium No17 was tiled and warmed by a hypocaust system and consisted of upper and lower parts, the latter is the cauldron that is supplying the upper one with a high temperature to get bioled water. The other room, No 16, is receiving the water vapour to be the Sauna room. The fuel's storage room No3 was approached by a passage located in the southern part of the building and had a direct link with the cauldron. What distinguishes the bath of Dharih that it is only one in the Nabataean sites that was discovered except Petra (Al-Muheisen and Villeneuve, 1993, p.10; Villeneuve, 1990).

CONCLUSIONS

Petra's urban centre is located on the sloping banks of Wadi Musa, covering an area of approximately 650x500 metres between the confluence of Wadi al-Matabha to the east and the rocky knoll of el-Habis to the west. Little is known about the early Nabataean settlement along the banks of the wadi prior to the 1st century BC. This is due primarily to the monumental architectural programs of the late 1st century BC through to the early 2nd century AD, Petra's classical period that dramatically altered the landscape and obliterated from view all signs of earlier occupation. Only a few excavation trenches have been sunk below the foundations of the monumental structures to provide a narrow glimpse of the early settlement.

Petra is located in a wide basin bordered by deeply eroded mountainous ridges of sandstone, with outcrops of the limestone highlands of Jabal Shara. The presence of several natural springs meant abundant water for the demands of a large population and agricultural fields in an environment where the annual rainfall is approximately ten centimetres (four inches). However, the development of Petra as an important political, economic and cultural centre in the Middle East during the classical period was ultimately the result of its strategic position on the crossroads of the major trade and communication routes that cut through the region. At Petra, the major north–south route, King's Highway that created a link between the Gulf of Aqaba and Syria intersected with the trans-Arabian routes (to southern Yemen and the Arabian Gulf) and the trans-Negev route to Gaza and the Mediterranean Sea. The Wadi Musa, the narrow valley along which Petra developed, provided one of the few convenient and negotiable routes through the mountainous barrier allowing caravans to pass between the high desert plateau to the east and Wadi Araba to the west (Browning, 1973, p.15).

The desert environment in which the Nabataeans lived is characterised by a limited period of rainfall in the year, making it difficult for agriculture and crops to prosper. The Nabataeans had to find other sources of livelihood such as raising herds and trading. As regards water resources, each raindrop caught was transferred through a canal to a cistern for use.

Spring water was carried for long distances until it reached the towns, as mentioned by Strabo when discussing Petra: "The inside parts have springs in abundance, both for domestic purposes and for watering gardens" (Geography 16.4.21), referring to artificial springs or fountains rather than natural outlets.

Nabataean knowledge of water resources, and how to conceal them from other people, was mentioned by Diodorus: "The eastern parts are inhabited by Arabs, who bear the name of Nabataeans and range over a country which is partly desert and partly waterless …they have dug wells at convenient intervals and have kept the knowledge of them hidden from the peoples of other nations" (Diodorus. His. II, 48). The water system which they established contained various different elements.

Petra grew in the first centuries BC and AD. This was made possible in an extremely arid environment by the engineering of a sophisticated hydrological system. The system brought water in channels and clay pipes from a spring at present-day Wadi Musa, outside the sandstone canyons in which the city was set. The system also harvested the meagre yearly rainfall and mitigated the effects of the rare downpours that would otherwise have produced destructive flash floods.

The Nabataeans handled this problem by supplying their city with water from springs outside the city. The most important of these springs is Ain Musa (7 kilometres to the southeast of the city). In addition, other springs inside the city of Wadi Musa, such the spring of Umm Sarab, supplied Petra with water crossing the Siq area and Shi'b Qais in the middle of the city. There is also Brak spring (about 5 kilometres south of the centre of the city) which covers the areas of Jabal Mad bah, Wadi of Farsa and the southern side of the city centre. Also, there is Dibdiba spring situated 6 kilometres north east of the city centre, which feeds the northern and northeast areas. The water of these springs is distributed through a group of networks of ducts carved in the stone or built on the aqueducts or walls. It was also distributed carefully, to supply all residential areas in Petra with water. This network showed the precision of its workers and their great ability to slow the speed of water flow, especially in the long channels that lead the spring water outside the city.

The Nabataeans also preserved the beauty of the areas through which the channels passed, especially in front of the tombs, temples and residential buildings. They camouflaged these channels by digging deep tunnels and laying the pottery pipes inside them. After that they covered these tunnels in coloured clay (between red and grey) to go with the natural colour of the covered stone. They installed filters of different types in most of the channels to keep out various impurities. They also built dams and cisterns, and used them for the purposes of irrigation and cultivation. Some of the major examples are the valley of Farsa, Mu'airah (eastern and western), Al-Matabha, the valley of Turkmaniya and the Al-Deir area.

The Nabataeans' most important achievement in preserving Petra was the protection of the city from flood and drift during rainfall, by changing the direction of the Wadi Musa out of the Siq area, to Wadi Al-Muzlem in the north. Also, they built the dams in most of Petra's valleys as in the Siq area, such as Al-Khazneh dam. The ancient water control of Petra has to be considered as one of the monuments of Petra. The Nabataeans created a magnificent real attraction by constructing their hydraulic control in Petra. There have been some trials of the restoration of Nabataean hydraulic control in Petra to protect the monument from floods and help to provide water to the local people; also, the hydraulic control has a beauty itself. And its restoration would attract tourists.

REFERENCES

Aharoni, Y., Evenari,M., Shanan, L. & Tadmor, N. (1960). The ancient desert agriculture of the Negev V: an Israelite agricultural settlement at Ramat Matred, *Israel Exploration Journal*, *10*, 23-36.

Al-Muheisen, Z. (2002). *Hydrology and Irrigation at Nabataean Period* [in Arabic]. Petra: Biet Al Anabt.

Al-Muheisen, Z., & Tarrier, D. (1996). Menaces d'eaux et mesures preventives à Petra à l'époque nabatéenne. Paris : *Syria* 73, 1-4.

Al-Muheisen, Z., & Tarrier, D. (1997). Ressources naturelles et l'occupation du site de Petra. *Studies in the History and Archaeology of Jordan, 2*, 45-57.

Al-Shqiarat, M. (2018). *Water management in Jordan past, present and future*. Lambert Academic Publishing.

Bachmann, W. (1921). *Petra*. (Wissenschaftliche Veroffentlichungen des Deutsch-turkischen Denkmalschutz-Kommandos, 3). Berlin and Leipzig.

Ball, W. (2000). *Rome in the east*: *transformation of an empire.* London: Routledge.

Browning, I. (1973). *Petra*. London: Chatto and Windus.

Brunnow, E., & Domaszewski, A. (1897-1898). Published an ambitious three-volume mapping project in their. *Die Provincia Arabia* 1904-09.

Crouch, D., & Rinne, K. (1996). Aquae Urbis Romae: An historical overview of water in the public life of Rome. In N. de Haan & G. Jansen (Eds.), *Cura Aquarum in Campania* (Proceedings of the Ninth International Congress on the History of Water Management and Hydraulic Engineering in the Mediterrannean Region. Pompeii, 1-8 October 1994): 145-151. Leiden: Babessch.

Dalman, G. (1912). *Neue petra-forschungen.* Leipzig.

Eadie, J., & Oleson, J. (1986). The water -supply systems of the Nabataean and Roman Humeyma. *Bulletin of the American Schools of Oriental Research, 262*, 49-76.

Eisenberge, E. (1998). *The ecology of Eden*. New York: Knopf.

Erhlich, L. (1989). The water works of Hadrian's Villa. *Journal of Garden History, 9*(4), 161-171.

Evenari, M., & Koller, D. (1956). Ancient masters of the desert. *Scientific American, 194*(4), 39-45.

Evenari, M., Shanan, L., & Tadmor, N. (1971). *The Negev: the challenge of desert*. Cambridge MA: Harvard University Press.

Farrar, L. (1998). *Ancient Roman gardens*. Gloucester: Sutton.

Gallery, M. (1978). The garden of ancient Egypt. In D. Schmandt-Besserat (Ed.), *Immortal Egypt* (pp.43-49). Malibu.

Garbrecht, G., & Peleg, Y. (1994). The water supply of the desert fortresses in the Jordan Valley. *Biblical Archaeologist, 57*, 161-170.

Glueck, N. (1953). Exploration in Eastrn Palestine. *Bulletin of the American Schools of Oriental Research*, 131, 6-15.

Glueck, N. (1959). *Rivers in the desert: A history of the Negev***.** New York: Farrar, Straus and Cudahy.

Glueck, N. (1965). *Deities and dolphins*. New York: Farrar, Straus and Giroux.

Gunsam. E. (1980). De nördiche Hubta-Wasserleitung in Petra. In M. Lindner (Ed.), *Petra. Königreich der Nabataer*, 302-312. Munich**.**

Hammond, P. (1967). Desert waterworks of the ancient Nabataeans, *Natural History, 9*, 36-43.

Hammond, P. (1973). *The Nabataeans: Their history, culture and archaeology.* Gotheburg, Sweden: Paul Astroms.

Horsfield, G., & Conway, A. (1938). Sela-Petra, the rock of Edom and Nabatene, *Quarterly of the Department of Antiquities of Palestine, 7*, 1-42.

Hyams, E. (1971). *A history of gardens and gardening*. New York: Praeger.

Jashemski, W. (1979). *The gardens of Pompeii: Herculaneum and the villas destroyed by Vesuvius*. New Rochelle: Caratzas.

Jashemski, W. (1993). *The gardens of Pompeii: Herculaneum and the villas destroyed by Vesuvius* (Vol. 2). New Rochelle: Caratzas.

Jellicoe, S., & Jellico, G. (1971). Water: The use of water landscape a srchitecture. New York: Martin's press.

Jones, R., & Robinson, D. (1998). Water Wealth and Status at Pompeii: the House of the Vestals in the First Century AD, *Paper for 100th Annual Meeting of the Archaeological Institute of America December*, 27-30, Washington.

Kennedy, D. (1995). Water supply and use in the Southern Hauran, Jordan. *Journal of Field Archaeology, 22*(3), 21-32.

Kennedy, W. (1925). *Petra. Its History and Monuments*. London: Country Life.

Kirkbride, D., & Harding, L. (1947). Hasma. *Palestine Exploration Quarterly, 79*, 6-26.

Koenen, L. (1996). The carbonised archive Petra. *Journal of Roman Archaeology, 9*, 177-188.

Koloski-Ostrow, A. (1997). Water in the Roman town: New Research from Cura Aquarum and the Frontinus Society. *Journal of Roman Archaeology, 10*, 181-190.

Laborde, D. (1830). *Voyage de l'Arabie Petrée.* (Reprint 2001, Paris: Pygmalion.)

Lagrange, J. (1998). Recherche épiger, à Petra à M. le marquis de Vogue, *Revue Biblique, 7*, 165-182.

Laureano, P. (1994). Abitare il deserto: il giardino come oasi. In A. Petrucciolo (Ed.) *Giardino Islamico*: *Architettora, natura, paesaggio* (pp.63-84). Milan: Electa.

Lindner, M. (1982a). An archaeological survey of the theater mount and catch water regulations system at Sabra, south of Petra, 1980. *Annual of the Department of Antiquities of Jordan,* 26, 231-342.

Lindner, M. (1982b). Über die Wasserversorgung einer antiken Stadt: Sturtzwasserführung, Talsperre und Wasserleitung im "Theaterberg" von Sabra. *Das Altertum, 28*, 27-39

Lindner, M., & Gunsam, E. (1995). A newly described Nabataean temple near Petra: the Pond Temple. *Studies in the History and Archaeology of Jordan, 5*, 199-214.

MacDonald, L., & Pinto J. (1995). *Hadrian's villa and its legacy*. New Haven CT: Yale University Press.

McKenzie, J. S.(1990). *The Architecture of Petra*. Oxford: Oxford University Press.

Meshel, Z., & Tsafrir, Y. (1975). The Nabataean road from 'Avdat to Sha'ar. *Palestine Exploration Quarterly, 107*, pp.3-21.

Mettinger, D. (1995). *No craven image? Israelite aniconism in its ancient near eastern context*. Stockholm: Almquist and Wiksell.

Milik, T., & Starcky, J. (1975). Inscriptions recerment decouverts a Petra, *Annual of the Department of Antiquities of Jordan, 20*, 111-130.

Oleson, J. (1986). The Humaima hydraulic survey: preliminary report of the 1986 Season, *Annual of the Department of Antiquities of Jordan* 30: 253-260.

Oleson, J. (1990). Humayma hydraulic survey. *Classical Views / Echos du Monde Classique, 34*(2), 145-163.

Oleson, J. (1995). The origins and design of Nabataean water supply systems, *Studies in the History and Archaeology of Jordan, 5*, 707-719.

Patrich, J. (1990). *The formation of Nabataean art: Prohibition of a graven image among the Nabataeans*. Jerusalem: Mangnes Press.

Robinson, E. (1941). *Biblical researches in Palestine*. London.

Segal, A. (1997). *From function to monument*: *Urban landscapes of Roman Palsestine, Syria and Provincia Arabia*. Oxford: Oxbow Books.

Shaer, M., & Aslan, Z. (1997). Architectural investigation on the building techniques of the Nabataeans with reference to Tomb 825. *Annual of the Department of Antiquities of Jordan*, *46*, 219-230.

Shqairat, M. Abudanh, F. & Twaissi, S. (2010). Water management and rock-cut cisterns with special reference to the region of Udhruh in Southern Jordan. *Journal of History and Archaeology of Jordan*, 4(2), 205-227.

Shqiarat, M . (1999). *Water systems in the site of Al-Yasileh during the Roman and Byzantine Ages*. Unpublished MA thesis, Department of Archaeology, Yarmouk University, Irbid, Jordan. (In Arabic).

Shqiarat, M. (2005). *The archaeology of water management in the Nabataean and Roman-Byzantine periods in Jordan: Overview and case studies from key sites*. University of Bradford, UK. PhD.

Shqiarat, M. (2008). The Archaeology of Water Control in the Nabataean and Roman-Byzantine Periods in Jordan: Overview and Case Studies from Key Sites, Cura Aquarum in Jordanien . pp.21-45. Siegburg.

Shqiarat, M. (2018).Abandoning Shammakh: Historical Archaeology among the Villages of Southern Jordan and its Ethno-Archaeological and Modern Economic Potential. *Journal of Anthropology and Archaeology, 6*(1), 1-14.

Siculus, D. (1960).Bibliotheca historica. *Loab Classical Library* (C. H. Oldfather, Trans.). Cambridge MA: Harvard University Press.

Strabo. (1982). *Geography*, (Vol.1) H. Jones. Loeb Classical Library, Cambridge MA: Harvard University Press.

Taylor, J. (2005). *Petra and the lost kingdom of the Nabataeans*. Harvard University: Harvard University Press.

Villeneuve, F. (1992). Le Peuplement nabatéen de la Gobolitide (al Jibal). **État** critique de la question. In M. Zaghoul, K. Amr, F. Zayadine, R. Nabeel, & N. Rida (Eds.) *Studies of the History and Archaeology of Jordan, 4*, 277-290.

Vitruvius, (1962). *De Architectura* (F. Granger, Trans.). Loeb Classical Library. Cambridge: Harvard University Press.

Wilkinson, A.(1998). *The garden in ancient Egypt*. London: Rubicon Press.

Yadin, Y. (1963). *The finds from the bar Kokhba period in the cave of the letters*. Jerusalem: Israel Exploration Society/ Hebrew University.

Yadin, Y. (1966). *Masada: Herod's fortress and the Zealots' last stand*. London: Sphere.

Yadin, Y., Greenfield, J. Yardeni, A., & Levine, B. (2002). *The documents from the bar Kolrhba Periods in the cave of letters: Hebrew, Aramaic and Nabataean-Aramaic papyri*. Jerusalem: Israel Exploration Society/Hebrew University.

