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Nabataean Water Management Systems. From the 4th century B.C. till the 4th century A.D.

Praca doktorska

Praca napisana pod kierownictwem Pani prof. dr hab. Ilona Skupińska - Løvset

Łódź 2016

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3 *Introduction*

"Masters of the Desert" was a title stuck to the collective idea of a tribe living and the fringe of the Roman Empire in the lands known today as the Negev Desert (modern Israel) and the Hijaz (modern Jordan). The nomadic tribe was known for its skills in acquiring the most exotic of oriental of goods, myrrh and incense. Knowledgeable traders engulfed in a mist of mysticism and curiosity. Often, they would appear coming in from the desert, conducting their business and leaving back to the arid, unfriendly climate of the desert wasteland. Sometimes they would wait on the frontier of the desert for a scheduled meeting. As was the case with the famous Jewish – Roman turncoat Flavius, who arranged a meeting with the Nabataeans[1] in order to gather the newest of the lands gossip (valuable source of information in ages long past), and who will have the best information if not the land crossing tribe of the so-called Nabataeans. A tribe famous for its exotic trade. Made known to the world in the 1st century B.C. when it decided to join the ranks of the so called Hellenistic Kingdoms of the Middle East. Organized and setup by a hierarchy of rulers but in essence those who would call themselves "subordinates" couldn't feel a burden of monarchical rule bestowed upon them. Because in the Nabataean society freedom was the first and foremost imperative. Freedom defended by secrets, punished by death if someone was to betray them. Nabataean freedom was a very real idea during the times of the scattered tribes, long before Petra became the official capital of an official kingdom.

We may never know what inspired the tribe leaders to abandon their old ways and create an organized society based on a ruler. If Petra was their sacred and hidden place, why turn it into a cosmopolitan trade town? Why abandon the freedom of free trade as tribal organisms? It seems that every important Nabataean principle so carefully laid out by Strabo[2] has been compromised here. The secret of this very important change remains hidden. If this author is allowed to make a guess. He would say that it was just about the money. Trade was very prosperous and probably it was increasingly difficult to hide away any additional income (not to stash it in some caves) and then civilization theory took its course and Petra emerged from the sands of the desert as a rich Hellenistic metropolis. About 1st century B.C. and 1st century A.D. there was a massive influx of new people wanting to live in Petra. The city changed by the hands of architects from Asia Minor. Architecture became more Hellenistic (addition of a

[1] J. AJ. XII.

[2] Strab. XXVI, 5.

theatre, the odeum, and some instances of the so called Great Temple of Petra). With each wave of new settler's new challenges had to be met. And so, the legendary Nabataean water technology has been brought to life. Of course, the Nabataeans already had access to a water gathering technology from the 4th century B.C. but it was nothing more than a reuse of the advancements of the earlier people. During the modernization of Petra, the old combined with the new transforming the entire region of Petra into a water catchment area. From this point, onward Petra was supposed to have abundancy of water on a level that some researchers propose the idea of water fountains and gardens scattered across the city[3].

The mere thought that such people could exist sparked the imaginations of historians and travellers worldwide. Even today, Hollywood still uses the idea in many movies showing us imaginations of desert hidden tribes, very keen on excellent barter but not very happy with sharing their secrets.

Main idea of research into the Nabataean water systems came from the excellent stories about the Nabataean tribe that had been mentioned above. Absolute water sustainability in an arid climate of the deserts of the Middle East was no easy feat and in some cases, it could probably even cloud the Egyptian civilization and their success in taming of the water of the Nile. The differences of course are apparent. Age of the Egyptian Kingdom, its longevity and scale drastically dwarves the Nabataean accomplishments but the one main difference between them is the water availability of the Nile and the rain harvest of the nomads. The latter gathered water "out of thin air". Carefully planned water harvesting areas and waited for months for rain. Their cities could survive virtually in the arid desert.

In order to understand the idea of Nabataean water capture. We must learn every step of the Nabataean Water Technology. Beginning with the history of the Nabataean tribe as a whole in order to understand their motivations and choices. Through their technology in the Bronze Ages, the Iron Ages and the Roman Times. Archaeological discoveries of course are the main concern of this work, but additional help comes from scientific departments such as geology (very helpful in order to understand the choices Nabataeans made when selecting specific rock for their constructions). Research concerning climate changes and climate in the Roman and earlier times was helpful to establish what kind of environment was surrounding the Nabataeans. Ancient writers provided additional insight from the "eyes on" perspective, helpful

[3] Bedal, (2003).

when reconstructing the idea of searching for water and in some cases on the construction of some water systems borrowed from the Romans. Lastly there is a brief presentation of some of the most known and widely researched Nabataean water constructions scattered between the lands of today's Israel and Jordan. The material selected for this work should be enough in order to shed some new light on the entire idea of the Nabataean water technology.

The methodology of the work was to analyse the archaeological trace left not only by the Nabataean but also the earlier desert faring tribes in order to find a similar pattern of approach to the water problem. It was suspected that the Nabataeans were not the sole inventors of their water gathering systems and a pretty straightforward idea was presented, that they learned the technology from the earlier nomads and with additional help from outside sources - greatly expanded upon it.

Geographical borders have been set on the two most arid regions of the so called Nabataean Kingdom. The Negev and the Hisma deserts. Widely known as the most arid regions not only in the Middle East but in the entire world. No one would ever think of living in such areas, but the Nabataeans have created a bustling, alive civilization and that would be the main reason why we should focus on the most researched and known sites of those deserts. If we learn about the water technologies used on those sites we should have a clear understanding of similar practices used in different parts of this Kingdom.

Chronological borders have been setup to the 4th century B.C. when we notice the first pre-Nabataean tribes emerging from the pages of history until the 4th century A.D. when a giant earthquake destroyed some parts of Petra and in part the Nabataean tradition.

Ancient authors will provide a much needed "eyes on" approach on the life and evolution of the Nabataeans as well as their technology. Vitruvius will be our guide through the technological knowledge of the time.

Before we start I would like to express my greatest gratitude to professor Ilona Skupińska Løvset, professor Marion Meyer, professor Wolfgang Zwickel and dr. Hans-Peter Kühnen for their extraordinary help in completing this thesis. Furthermore, I would like to thank professor Michael Vickers and professor Vakhtang Licheli for their contribution to the authors archaeological growth.

3.1 First explorers and the beginnings of archaeology in the Middle East

Until the early nineteen centuries, middle east was mostly considered as *terra incognita* for the European people. The land and its history was mostly known through translation and studies of the ancient authors that wrote books and encyclopaedias in their ancient lifetimes. Europeans that had access to those works could revel at the world that was created so many years before them, and wondered on how the ancients could achieve so much in terms of creating culture and technology that was so fundamental for the creation of their very own reality. Europeans could not only read about the works of the ancients but could also witness them in many ruins of the once powerful Roman Empire, scattered across the plains, hills, valleys and mountains of the continent, so the sheer thought that in the mountains of Asia Minor and the deserts of Middle East not only dwell the ruins of the ancient Roman civilization but also their immediate neighbours sparked the imaginations of the adventurous. This notion alone undoubtedly brought a shiver of excitement to the people interested in the topic. Time passed and the times changed. The world was getting "smaller". People travelled the planet discovering new lands and civilizations. Reached the furthest lands of earth, but still their lust for discovery could not be quenched (and as the still undiscovered lost city of Atlantis electrified the minds of those who dreamt to find it one day). For what still remained unchecked were the lands of the Ottoman Empire. Stretching from the borders of the centre of European culture that was the city of Vienna in the 19th century to the far reaches of the Upper Nile in the south, and the Persian lands in the east.

This state of affairs was created with the fall of the Western Roman Empire in the year 476 A.D. by the hands of the ravaging barbarians that wandered the European plains, and the much later historical demise of its Eastern half, that in time transformed into a land known as the Byzantine Empire. The Byzantines held firm during the onslaught of the eastern European tribes and survived as a powerful entity for almost another 1000 years. Their demise came in the year of 1453 when the Ottoman Empire conquered the last defence of the Byzantines taking their finest city and the capitol – Constantinople. The battle solidified further advancement of the empire into Europe.

The fall of the western Roman Empire shook the foundations of the civilized world. Many Roman cities and settlements were either destroyed or abandoned. Cultural and technological heritage seemed to be lost in the chaos. Centuries later the lost Roman knowledge was found in the Christian monasteries and their newly established libraries. Monks and scribes working for a holy cause copied books and scrolls, so they could be preserved for the future generations. Those who later read them were armed with re-found knowledge that led the world in to the so called “Renaissance”. Religion proved to be a very important asset in expanding the curiosity for Middle Eastern travels and discovery. Additionally, the crusades provided the Europeans access to the Middle Eastern regions, after almost 500 years of isolation.

First European travellers willing to write down their journeys reached the holy land and its closest neighbours in the early 19th century. To find a very suitable set of words to describe their work we should look for a form of expression known as journal writing. A very systematic and thorough description of their travels filled with many references to their journey and all aspects of such an enterprise. Always full of observations and thoughts. In some instances, the books are filled with numerous sketches depicting visible ruins of ancient as well as modern constructions. Those journals were often very accurate in their measurements and descriptions. In fact, so accurate that many of those early travellers are today suspected of working for their respective government intelligence agencies.

3.2 Explorers

Ulrich Jasper Seetzen

Ulrich Jasper Seetzen started his long journey into Arabia in the year 1802. Going down the Danube into the Turkish empire, he stayed almost half a year in Constantinople. Then he continued further into the lands of the Middle East, where he arrived in Aleppo. There he remained from November 1803 to April 1805 to accommodate himself with the Arabic language and customs that would allow him to travel as he was a native. Seetzen's journeys were published in 1810 by the British Palestine Association. His work involved drawing sketches and writing descriptions of ancient cities and constructions that he encountered when on the road. During his pilgrimage to Mecca he converted to Islam. Travels took much of his later life until the end of his days when he was found dead, supposedly poisoned during one of his journeys.[4]

Johann Ludwig Burckhardt

A similar undertaking was conceived as soon as 10 years later by a man known as Johann Ludwig Burckhardt. The Swiss explorer was born on the 24 November 1784, in Laussane. After completing his studies in language and culture of the Arabian people, he became interested in exploring those areas and putting his acquired skills into use. Opportunity came in the year of 1806 when he journeyed to England with the intent to join an exploration enterprise aimed at travelling through Middle East and Egypt to the source of the river Niger. Burckhardt's proficiency in the Arabic language proved very valuable and so in the month of march 1809, the expedition journeyed east through Malta and into the same city that previously was home to Seetzen – Aleppo. In a very similar approach to his predecessor Burckhardt mastered the language and customs of the Arabian people in order to help him blend in with the local population. After leaving the city he joined up with various nomadic groups and travelled through the Middle East for almost two years. Time spent with the nomadic Arabs sharpened his language skills and broadened his knowledge on the Arabic culture and its habits. This brought Burckhardt very close to the religion of Islam, which he adopted taking the name - Ibrahim ibn Abdullah. He recorded explorations of the Nile river as far as the III cataract, with additional information about Abu Simbel. Journeys into the Sinai Peninsula and the Nubian desert, from where he took a boat to Jeddah and went on a pilgrimage to Mecca. He was also

[4] Seetzen, (1810).

the first European to see Medina. During eight years, Burckhardt constantly wrote letters and notes that he sent back to the African Association in England, securing the information and knowledge he gathered. This proved to be a very prudent activity when Burckhardt suddenly died of dysentery in Cairo in the year 1817.

In his lifetime, Burckhardt journeyed to very distant corners of the Middle Eastern region, but his most important discovery happened unexpectedly when accompanied by a guide he crossed the Siq and gazed upon the rock city of Petra. It was the 22nd of August in the year 1807. Burckhardt and he's guide were walking in the light of the incoming noon:

"In following the rivulet of Eldjy westwards the valley soon near rows again; and it is here that the antiquities of Wady Mousa begin. Of these I regret that I am not able to give a very complete account: but I knew well the character of the people around me; I was without protection in the midst of a desert where no traveller had ever before been seen; and a close examination of these works of the infidels, as they are called, would have excited suspicions that I was a magician in search of treasures"

Burckhardt (1922), p. 421.

"…The bottom of the Syk itself is at present covered with large stones, brought down by the torrent, and it appears to be several feet higher than its ancient level, at least towards its western extremity. After proceeding for twenty-five minutes between the rocks, we came to a place where the passage opens, and where the bed of another stream coming from the south joins the Syk. On the side of the perpendicular rock, directly opposite to the issue of the main valley, an excavated mausoleum came in view, the situation and beauty of which are calculated to make an extraordinary impression upon the traveller, after having traversed for nearly half an hour such a gloomy and almost subterraneous passage as I have described. It is one of the most elegant remains of antiquity existing in Syria; its state of preservation resembles that of a building recently finished, and on a closer examination I found it to be a work of immense labour…"

Burckhardt (1922), p. 424.

Nearly one millennia after its disappearance from the pages of history, the city built in rock, capital of the ancient Nabataean Kingdom, could be once again gazed upon with European eyes. At that time, Burckhardt was only 27 years old.

Edward Henry Palmer

"Can such a connexion between the scenery, the features, the boundaries, the situation of Sinai and of Palestine on the hand, and the history of the Israelites and on the other?" – question proposed by Dean Stanley sparked the idea of an accurate survey of the Sinai Peninsula.[5] The idea was first conceived by Rev. Pierce Butler who unfortunately died before the expedition could officially be arranged. According to the author a thorough survey should be made. One such will take into consideration a typical human trait of curiosity. So, while travelling through the land he can stray from the path and see everything that he wants to see and indulge his human virtues. And so, the expedition was planned to survey and identify the sites of the ancient world and bring back information that could be useful to Biblical critics. Opposite to the earlier visitors to the Holy Land, Palmers expedition was designed with a scientific approach, it was planned to answer questions and bring information.

Edward Henry Palmer was born in Cambridge on the 7th of August 1840. At the age of 19 he almost died of tuberculosis. Recovery made him think of a new idea for his life. Then he met Sayyid Abdallah who opened up to him the world of ancient cultures and their languages. This new world of opportunities inspired him to matriculate from St. Johns college in Cambridge and further study written text in Persian and Hindustani. Learned skills made him a natural candidate for the planned Palestine Exploration Fund survey of the Sinai Peninsula and its environs. He took it upon himself to record every step of the expeditions progress, additionally he was responsible for the translation of found artefacts.[6]

Palmer arrived in Suez on the 11 November of the year 1868. From where he began his journey through the Sinai Peninsula recording information ranging from ancient culture remains, the ways and cultures of the local inhabitants to the personal experience of a prolonged journey in a very complicated terrain and climate. The expedition remained in Sinai until the 16 of December in the year 1869 when they moved to the eastern parts of the Middle East – into the deserts of the Negev. Second part of the expedition visited the upper part of the deserts, focusing their efforts around the city of Beersheba but advancing further east in the lands of Edom, where they encountered hostile Arab tribes that declared war on them. The most interesting and valuable information came from their visit to the ancient city of Petra. Palmer

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[5] Palmer, (London 1871), p. 1.

[6] *Ibidem.*

recorded several descriptions of monuments as well as made an attempt to answer the question of the origin of the Khazneh (fot. 1). Then the party turned their interests to the northern part of the Middle East and journeyed into Moab.

The fruits of their journey were recorded in E.H. Palmers book, “Desert of the Exodus” that contained almost 700 pages of Palmers narrative descriptions of the land and its people, additionally the book contained almost 35 drawings and illustrations of ancient constructions. Book was published in 1871. Palmer died in service to his country when appointed as interpreter-in-chief for the Egyptian forces he fell into an ambush in August 1882. Much of his journey was completed on foot, which made him many friends with local Bedouin to whom Palmer was known as Abdallah Effendi. [7]

Fig. 1.Khazneh “Treasury” – Petra.

[7] *Ibidem.*

Alois Musil

Alois Musil was a Czech explorer and a professor at the University of Vienna, born 1868 to a numerous peasant family. After finishing school Musil went to study Theology at the Olomunec University where he got in touch with the Near Eastern languages and Old Testament Studies. In 1895 he receives his doctoral degree and leaves for the new Ecole Biblique et Archeologique Franceire de Jerusalem to continue his studies. Alois Musil was a man that constantly pushed his bounds and limitations and then he discovered that the only way to advance in the field of Arabic languages is to acquire empiric knowledge of the topics that he studied. This notion prompts him to go to Beirut where he could prepare for the most important journey, not only of his lifetime but also (as time would later show) for the entire European – Arab communication. Musil left Beirut in 1898 and begun his journey through the east shores of the Dead Sea, Moab, Petra, Palmyra, Sinai, Gaza an into the most acclaimed discovery as an explorer finding the 8^{th} century Ummayyad fortress called Qasr' Amra which was filled with mosaics. The visit ended abruptly due to hostilities that A. Musil made in his nomadic journeys. After fleeing from Arabia. Musil came back to Vienna and was branded a liar. I took him two more trips (1901 and 1902) and a company of an Austrian artist Leopold Alphons Mielich (who copied the frescos at 'Amra) to vindicate his claims. Second part of his journeys begun when he joined the nomadic Rwala Tribe in their migrations. The people were led by Ibn Sha'lan, a journey that inspired an ethnographic work of some 712 pages – "Oriental Exploration and Studies. The Manners and customs of the Rwalla Bedouins". Musil was constantly exposed to dangers when he rode with the Bedouins. Troubles and hardships earned him great respect with the leader of the Rwalla Bedouins. Musil became his close friend and always joined him in the front of the leading caravan.

Again, Musil came back to Vienna and became a professor at the University. His experience and contacts were once again called upon. This time in service to his country. In 1910 he left for the region of the Hidjaz and the Jordan River where he surveyed for geological and hydrological data. Two years later he joined Prince Sixtus Bourbon – Parma in his "tour" of the Mesopotamia were in reality it was another survey for mineral deposits along the planned railroad from Berlin to Basra. The Great War broke out in 1914 and Musil was once again called upon by his country. In 1917 he left for Arabia on a mission to discourage the Arabian tribes from further attacking the crumbling Ottoman Empire. [8] That was the official statement. In reality he was supposed to agitate for an increase in hostilities aimed against the Ottoman Empire, this way Austria could have easily negotiated a more beneficial peace agreement with the Turks. The plan was solid, but it didn't bear any fruits for its benefactors. During this mission Musil worked together with T.E. Lawrence, who was also known for his passion to ancient history. This was his last mission into the Middle East. After a stunning input as a worldwide known scholar he moved back to his home "Villa Musa" where he quietly enjoyed the rest of his life tending to his garden and still studying. Alois Musil died in 1944 leaving behind a tremendous feat of a lifetime, filled with adventure and scholarly insight.[9]

Thomas Edward Lawrence

Thomas Edward Lawrence was born on the 16 of August 1888 in Tremadog – a small village in the in the community of Porthmadog in Gwynedd, north west Wales. As a "out of wedlock" child of sir Thomas Chapman and Sarah Junner, a Scottish governess. In this situation, Chapman left his first wife and family in Ireland and in 1896 moved to Oxford where they lived calling themselves Mr and Mrs. Lawrence. Young Lawrence went on to study History in Jesus College at Oxford which he finished with first class honours and went on to become an archaeologist. Love for history and antics accompanied Lawrence since he was 15 years old. With his childhood friend- Cyril Beeson they visited medieval churches that littered Brittan's rural landscape, collecting information about their architecture and stored antiques. 1907 and 1910 were the years of Lawrence's education at Oxford. At this time, he ventured on an on foot three-month expedition in Syria to identify and describe the influence of crusader castles on the European architecture at the end of the 12th century A.D. After graduation, he did research on medieval pottery that was a form of a scholarship but quickly changed his mind when he was offered a spot as a practising archaeologist on a site located in central Syria known as Carchemish. In 1910 he sailed for Beirut and then travelled to Jbai (Byblos) where he studied Arabic. After one season of excavations in Syria he went back to England for a brief brake and after his return to the site for the second season he met Charles Leonard Woolley.

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[8] The Arab Revolt (1916–1918; Arabic: الثورة العربية *Al-Thawra al-`Arabiyya*; Turkish: *Arap İsyanı*) was initiated by the Sherif Hussein bin Ali with the aim of securing independence from the ruling Ottoman Turks and creating a single unified Arab state spanning from Aleppo in Syria to Aden in Yemen.

[9] Harrigan, (2009), pp. 8-16.

Charles Leonard Wooley born on the 17 of April 1880 as a son of a clergyman in Upper Clapton in London Borough and hackney. He began his education at St. John's School, later moved to Leather head and finally finished New College at Oxford. In 1905 he became an assistant in the Ashmolean Museum at Oxford. One year later in 1906 he was recommended by Arthur Evans to run the excavation on the Roaman site at Corbridge. While not having any archaeological knowledge nor experience in field work he proved to be a very methodological worker and in time he was called one of the first modern archaeologists who excavated with a methodological and careful approach. After several years, he was given the opportunity to work in Ottoman Syria at the archaeological site of Carchemish, where he met his future co-worker Thomas Edward Lawrence.

January 1914 the two archaeologists have been called upon to travel to the distant region of the Palestinian Southern Desert known as the Negeb (or Negev). Their assignment was to carry out a thorough survey of the desert region and prepare maps with accurate descriptions. Expedition was funded by the Palestine Exploration Fund. This was the official statement for the purpose of the expedition. In reality it was an archaeological smokescreen for the British military in order to have them two gentlemen prepare accurate maps of the strategically important battlefield of the Negev Desert in an event of an Ottoman Army making preparations to attack Egypt.

The expedition has left Carchemish for the port of Gaza were their journey was supposed to begin. From there, they left for Beersheba, further to: Khalasa, Esbeita, Auja, Ain Kadeis, Ein al Guderat. With a careful description and analysis of the finds at: Khalasa, Abda (Eboda or Oboda). Kurnub (Mamshit) and the so called "Northern Tells" – tell Abu Hareira, Abu Iregeig, Tell el Seba, Tell el Sawa, Khirbet Watan, Khirbet Hora, Tell el Milah, Imshah el Milah. In their survey, they journey as far as Wadi Musa and Aqaba.

The results of their journey have been published by the Palestine Exploration Fund in a book called "The Wilderness of Zin"[10] and are commonly commented as an "update on the state of antiques in the region of the Negev Desert since the early travellers". The book contains chapters on the history of the Southern Deserts form the earliest (archeologically observable) times till the Byzantine era. Additionally, it contains commentaries and ideas on the probable climate of the Middle Eastern land in the ancient times. Thoughts triggered by the observations

[10] Biblical term for describing the area of the Negev Desert.

made by the team during their inspection of early bronze and Byzantine age settlements. By assessing their sizes and infrastructural work required in order for the sites to survive. This encompasses any buildings used for probable administrative work as well as (and most importantly) water management systems with conjunction to any traces of agricultural work close to the settlement. Results of those observations have been often used as base for almost all future research done in this region in the time to come.

Most important work done for the scope of this dissertation was made in the Nabataean period settlements of Abda (Oboda or Eboda), Kurnub and Khalasa. Additionally, Abda and Esbeita contained rich Byzantine material that according to Lawrence was built on top of the Nabataean settlement hiding most of its remains. Kurnub was the site of a large water retention system.

Additional help of T. Wiegand involved a new method of acquiring pictures for archaeological usage – photographs made from a birds-eye-view by the use of the centuries new invention – the aeroplane.

In March 1914, Lawrence returned to work again at Carchemish. Following the outbreak of hostilities between the Ottoman Empire and England in August 1914 he was once again called into service with a special assignment – Acting as an English liaison to the Arabian revolt (known as the Kingdom of Hejaz) he was assigned to convince the Arabs to act as a support for the actions of general Allenby (who fought in Palestine), disrupting infrastructure and provoking skirmishes with local garrisons. For their help Arabs, have been offered a possibility to create their own independent state [11]. Desert guerrilla warfare disabled any possibility of movement for the Turkish troops that stationed on the Arabian Peninsula providing Allenby's forces much needed freedom of movement. This enterprise earned him the world renown name – Lawrence of Arabia.

Woolley continued his archaeological pursuits in Mesopotamia, where he worked at the site of Ur.

[11] Lawrence (1991).

3.3 Scientists

Michael Evenari

Born in Metz, 9th October 1904 into a Jewish family. Began his studies in Pythology in Frankfurt where he submitted his dissertation in 1926 with the title "The sheet development of Ligustrum vulgare and Plectranthus fruticosum and the theory of the Periklinalchimären ". Afterwards he worked as an assistant in Prague and Frankfurt. After his dismissal on 1st April 1933 he decided to emigrate and left Germany with his wife. Known for a life of scholarly pursuits. His most important work was done not only for sheer scholarly pursues but also for the improvement of the wellbeing of the new slowly developing country of Israel. Research done on the Nabataean water management systems was crucial for this task and could be widely re-used in the entirety of the Middle East. Fascinated by the Bedouin way of life he was a strong supporter of their cultural heritage.

Professors life's work was written down in: "Negev: The challenge of the Desert". Published in the 1968, a 345-page study of the Negev Deserts fauna and flora with additional remarks on archaeological finds scattered across the landscape especially those concerning the Nabataean water management systems. Observations alone are often too little in order to understand how complicated systems work. And thus, Evenari established several laboratory farms, based on the principle of runoff water farming in order to gain empirical knowledge. Professors team established solid foundations for Nabataean water technology research in the region of the Middle East, and this work is being cited to this day.

Avraham Negev

Born in 1923 as Avraham Eisenberg. He was interested in the life of ancient people since his childhood. Experiencing the drama of a typhus epidemic, that effected his friends, he decided to devote ten years of his life for the development of the Negev settlements and only later dreamt of becoming a brain surgeon. At the age of 20 he was appointed to maintain the water pumps and meteorological measurements in a second outpost in the Negev – Revivim. While working at the camp he got in touch with Nabataean antiquities. Elusa, Rehovot, Sobata Mampsis, Oboda and Nessana were as close as riding a bicycle. Negev's endeavours didn't go unnoticed. One of the visitors to the camp was Dr. Yehuda Leib Magness of the Hebrew University. Negev was promised a scholarship when he would decide to study archaeology. In 1948 war broke out between the newly formed state of Israel and Egypt. In response to the situation camps in the Negev have begun warfare training. During such an event A. Negev was severely wounded by a hand grenade explosion. Damage done to his hand was irreversible and it had to be amputated. Young Avraham's dream of becoming a doctor were shattered.

1953 A. Negev begins his studies at the Hebrew University. Five years later after finishing his M.A. joins the excavations at Oboda as an assistant director. A year later he takes over the research. From this point in time Negev becomes fully interested in the Negev desert research. He directed excavations at Mampsis, Oboda, Elusa and Sobata. Also, carried out a survey through the so-called "desert spice route". Nabataean pottery was very important for his research, so much that he wrote a Ph.D. in this subject being the first person to categorize and date the Nabataean pottery. Also, he was first to translate the many Nabataean inscriptions scattered across the Negev deserts. The most popular one being dedicated to King Obodas, found at the settlement called by his name - Oboda.

Tali Erickson Gini

Today one of the most known archaeologists working in the region of the Negev is Tali Erickson-Gini her PH.D. was published in 2010 in the BAR International Series[12]. It is a study of the Nabatean settlements in the central Negev described through the analysis of ceramic traces. Although it is a very thorough work on the aspects of the Negev trade it lacks any descriptions of the water management facilities.

[12] Erickson-Gini (2010).

3.4 Climate and geological conditions in the Middle East[13]

In order to have a better understanding of the technological processes that the Nabataeans employed in their desert faring activities, we need to turn to other branches of scientific work that handle different technological aspects recognized by the Nabataeans during their lifetime on the deserts of the Middle East. Basic aspects of geology are needed in order to recognize the building material used in water management construction. Knowledge of the Middle Eastern climate is important in the analysis of the water storing and usage capabilities on a yearly scope.

3.5 Geology

The Polish Scientific Publishers Encyclopaedia states that Geology is a science about the construction and history of the Earth, mostly the earth's shell. Additionally, the science covers the geological processes, by which the earth undergoes transformations.[14] Knowledge accumulated by the science of geology will be valuable when discussing the properties of the construction material available to the Nabataean engineer in the middle eastern deserts.

Due to the rocky and dry character of the Middle Eastern desert the most widespread and available material for the early Nabataean construction would be the rock cut stone. In the later periods the Nabataeans also included the quarried building stone. The building stone is a very durable construction material used since the earliest times of the human civilisation. Due to its capabilities, it could be stacked high enough to construct a safe shelter to hide from the changing weather. In the course of stone construction development, the extraction methods evolved and while moving further into the future they incorporated more technologically advanced designs and in the process becoming a very organized effort, which involved not only the initial stone extraction techniques but also their transportation and marketing. In one word –quarrying.

Stone is extracted from rocks. Solid materials of the earth, that are hard enough to withstand a hammer or soft like mud/sand/gravel. Those are traditionally grouped into three main classes according to their genesis. Igneous – connected with the cooling magma.

[13] Today the historical region occupied by the Nabataean Kingdom spans across two countries. Israel in the western side and Jordan in its eastern and southern part. Climate and geological conditions in those two countries could be very basically explained as "similar" in this bigger region of the so called "Middle East". That's probably the explanation for the homogenized constructions and technologies employed by the Nabataeans in the entire region. That's why for the purpose of this chapter Israel and Jordan will be treated as a one region – The Nabatean Kingdom.

[14] Encyclopaedia PWN Online

Sedimentary – formed by the breakdown of pre-existing rock. Metamorphic – morphed by action of heat and pressure on a pre-existing rock.

Igneous rocks.

Magma is a molten material with a source deep within the surface of the earth. On certain events and occasions, it may move through the earth's crust towards the surface. During the event, it may eventually cool down beneath the surface forming coarsely crystalline rocks. Such as granite or gabbro. In a dangerous and spectacular event of the magma breeching into the surface in form a volcanic eruption the incoming molten rock will quickly loose temperature and form crystalline or even glassy rocks.

Sedimentary rocks.

Formed out of detritus[15] of pre-existing rocks, which may be igneous, metamorphic or sedimentary in the process of weathering, erosion, transportation, and deposit. These rocks possess a wide range of particle sizes. From boulders to clay and chemical compositions – silica, lime or ferromagnesian volcanic detritus. Sedimentary rocks have a very characteristic feature for they are easily discerned by using stratification. They show successive episodes of deposition.

Metamorphic

The word comes from an ensemble of two words. "Meta" meaning altered and "morphos" translated into shape. In conjunction, they describe rocks of different origin changed by being exposed to high temperatures, pressure or both. Discerning two types of metamorphism. Regional and thermal/contact. Regional metamorphism is caused by temperatures and high pressures affecting the deposit during a deep burial, while the latter is caused by magma moving up the crust of the earth and thus creating a heat "aureole" that effects adjacent rocks.

Examples for thermal deposits are hanfelds and quaritze. Regional schist and greiss.

The limestone rock provides exception from this rule. It is a sedimentary rock that belongs to a group of anomalies called chemical sedimentary.

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[15] Debris.

The vast majority of rocks available for this region would belong the "sedimentary" category. Mostly because of the characteristic environment of the desert.

Characteristic rocks of the Nabataean environment,

Limestone

Limestone is a sedimentary rock that takes up to 10 % of the total volume of global sedimentary rocks. Composed largely of calcium carbonate ($CaCO_3$) its mineral form is calcite. High cemented limestone makes for an excellent building stone.

Sandstone is a sedimentary rock composed largely of quartz (SiO_2) and sand.

Deserts

Deserts are a barren area of land where little precipitation occurs and consequently living conditions are hostile for plant and animal life. The annual precipitation is less than half of the annual potential evapotranspiration[16]. About one third of the worlds land surface is arid or semi-arid. This includes areas with so called hyper arid conditions like Sahara, Arabia, Atacama and Namib. Largest deserts include the Saharan, Arabian and Australian, which are also known to have moisture-free air. Deserts are not always associated with high temperatures. As mentioned earlier, they are categorized by the lack of precipitation, which is the case in some polar deserts of Antarctica.

Desert Fluvial Systems

In most desert regions of the world the highest, yearly precipitation mark does occur in the so called "rainy periods" (different for each part of the world). The greatly increased amounts of water coming down the desert hills quickly accumulate in the valleys, creating temporary rivers flowing through deserts. Geological events that are closely linked with such an occurrence and define it, are recognized and described in Geology by the term "Desert Fluvial Systems". Temporary water systems called in Arabic: *Wadi*[17] or in Hebrew: *Nahal*[18]

[16] Moisture loss.

[17] Wadi (Arabic: وادي wādī, also vadi) is the Arabic term traditionally referring to a valley. In some instances, it may refer to a dry (ephemeral) riverbed that contains water only during times of heavy rain or simply an intermittent stream.

[18] Nahal (Hebrew: נחל) is the Hebrew term for a Wadi.

were the lifeline of some of the ancient civilizations that lived in the Middle Eastern deserts. Categorized in the Geological term of Ephemeral Rivers.

"This Wady Solaf was the scene of the great seil, or flood, in 1867, M^ien an Arab encampment was washed away, and forty souls, together with many camels, sheep, and other cattle, perished in the waters. Mr. Holland was in Sinai at the time of the calamity, and narrowly escaped losing his life on the occasion. He describes the scene as something terrible to witness; a boiling, roaring torrent filled the entire valley, carrying down huge boulders of rock as though they had been so many pebbles, while whole families swept by, hurried on to destruction by the resistless course of the flood. The marks of devastation which it caused are still too plainly apparent, and I have seen the trunks of large palm-trees lying in the wady-bed at a distance of more than thirty miles from the place where they had grown. A single thunder-storm, with a heavy shower of rain, falling on the naked granite mountains, will be sufficient to produce these dreadful effects, and to convert a dry and level valley into a roaring river in a few short hours…"

Palmer (1875), p.151.

Ephemeral rivers flow no more than few days in a year are usually fed by high – intensity but-short duration and in frequent rainfall events. Creation of a flash flood is possible due to exceeding the infiltration capacity of the substrate[19]. This enables the over land flow. The lack of vegetation and a high proportion of non-cohesive sandy sediment coupled with the low degree of bank stability and high rates of bed load transport tends to favour the existence of unconfined, braid plan, fluvial systems. Many desert rivers exhibit a downstream reduction in discharge due to transmission losses through a porous sandy substrate. The aforementioned lack of vegetation and that most of the ground level is covered by loose sediment makes fluvial transportation and deposition of sediment a very important geological process that occurs in the desert. There are two possible variations on the type of the desert fluvial system. Those can be:

- Endogenic: catchment areas within the boundaries of the desert region.

[19] Soil.

- Allogenic: catchment areas beyond the confines of the desert region. Such rivers may therefore be perennial in nature and provide a hefty water source in the arid environment.

Depositional Sedimentary Structures

Sediment transported by fluid in two ways:

- Carried along by fluid in suspension and Bed load. Bed load transport occurs in unidirectional currents and wave action. For the waves to affect sediment movement, the bed has to be above the wave base (within depth range of the waves)

- Suspension- Sediment could be carried provided that the turbulence within the fluid remains high. Deposit begins when the level of turbulence can no longer sustain all of the suspended grains. This happens when the current decelerates (channel expansion or waning of a high-energy event – storm or flood) Deposition produces effects of bedding[20] or lamination[21].

3.6 Climate

As mentioned earlier the historical region controlled by the Nabataean traders spanned across two modern countries of Israel and Jordan. Although the seized territory was really large we can't say it was big enough to have completely different climates or that it reached any territories that had a completely different climate. That being said we can describe the Nabataean Kingdom (speaking in general terms) as having a very dry climate with an annual rainy season usually from October till April[22]. With general differences in the northern parts of its territory – where there is usually more rain (495 mm in Irbid), and the southern parts – Negev desert and the Hauran[23], comparably a mean of 70 mm of rain. This gives us a mean of 250

[20] Bedding describes depositions where the layer is thick and is expressed in centimetres.

[21] Lamination describes depositions where the layer does not surpass values of few millimetres.

[22] Evenari, et al. (1971).

[23] Average annual rainfall for Jordan:

Jordan Valley – 50 – 300mm (5.7 %)

High Land – 400 – 600 mm (2.9 %)

Desert Area (Badia) 50 – 200 mm (91.4 %)

mm for the entire territory of the Nabataean Kingdom, which would be the lower limit at which drought faming can be undertaken [24] and would describe life sustaining capabilities of this region as arid[25]. Due to very low precipitation and a scarce availability of underground sources, water availability in the Middle Eastern regions of the Negev and Hauran deserts is highly dependent on rainfall which varies in quantities, intensity and distribution by every year. Research confirms yearly fluctuations in annual precipitation for the entire region. One year would have a very abundant raining season whilst the next year could have a marginal rainfall.

It should be emphasised that everything that has been said on the subject of annual rainfall applies to the state of research that has been measured for the modern time. This however is very helpful to the subject of the work, because any comparative material that could be confirmed unchanging for almost three millennia could be used in comparative studies for the Nabataean time. According to most scientist today's climate should be similar if not identical to the weather conditions of the 4th century B.C. and 2nd century A.D. This statement is based on a thesis that the climate in Israel and Jordan haven't changed in the last 5.000 years, although periodic fluctuations in the mean average are indicted[26] most of the scholars agree on this but Huntington[27] believed that the climate was periodically shifting from arid to much colder and wetter.

al- Kurdi (2008), p. 11.

[24] Natural Resources Authority 1977.

[25] Oliver, Arnold (1981).

[26] Rosen, Finkelstein (1992).

[27] Huntington, Visher (1922).

3.7 The Nabataeans

A dream. The fantasy of exploration and discovery. Ideas that guided man through the history of mankind. Man, bold enough to plan, fund and dream about the great discoveries that their vision could bring. Who decided to leave everything that they created, their families as well as their businesses and travel the unknown path of discovery. To look for places that history deemed forgotten or enshrouded those in a mist of secrecy sometimes even claiming that they are not even existent. Dreams and ideas were born when reading the manuscripts of old, written down by people living in the mythical times of the ancients. People who took on themselves the burden to collect and write down the historical and geographical knowledge of their times to preserve it for the generations to come. Monumental works of literature that described the lives of hundreds of people as well as the endeavours of entire kingdoms. Kingdoms that were not always easy to find on the map but sometimes even impossible to ascertain if they were real and not just a product of the writer's imagination.

Studying them so many years later it's very hard not to imagine the places and events that had been written down on the many pages of Roman history. Fantasise about powerful Rome that was the light of civilisation for the unknown dark world of barbarians. Even now we couldn't put ourselves in the sandals of the Romans and imagine the same feeling as they had once their unstoppable armies brought the "light of Rome" to distant peoples living in the "dark corners of the world", a feeling currently incomprehensible for a modern human.

3.8 Roman literary sources on the Nabataean history

There are several main sources of Nabatean history, written down at the time when the Nabataean Kingdom still existed:

- Second Book of the Maccabees[28]
- Diodorus Siculus[29]

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[28] Second Book of the Maccabees is a deuterocanonical book which focuses on the Jews' revolt against Antiochus IV Epiphanes and concludes with the defeat of the Syrian general Nicanor in 161 BC by Judas Maccabeus, the hero of the work.

[29] Diodorus Siculus or Diodorus of Sicily was a Greek historian. Born sometime in the year 80 B.C probably in the city of Agria and died close to the year of 20 B.C. Known for writing the monumental universal history *Bibliotheca historica*, much of which survives, between 60 and 30 BC. It is arranged in three parts. The first covers mythic history up to the destruction of Troy, arranged geographically, describing regions around the world from

- Strabo[30]

- Titus Flavius Josephus[31]

- Pliny the Elder[32]

- Publius (or Gaius) Cornelius Tacitus[33]

- Lucius (or Claudius) Cassius Dio[34]

In order to shed some light on the Nabataean peoples we must result to the oldest known method of science which would be categorization or in this case; chronological differentiation.

Thus, we divide the time span of the Nabataean Kingdom into two time periods.

Egypt, India and Arabia to Greece and Europe. The second covers the Trojan War to the death of Alexander the Great. The third covers the period to about 60BC. The title Bibliotheca, meaning 'library', acknowledges that he was drawing on the work of many other authors. One of which was Hieronymus of Cardia that was a general in Alexander the Greats army and after many events finally settled as a subject of Antigonus I Monophthalmus who's later endeavours he written down. From these works come the earliest accounts of the Nabataeans.

[30] Strabo born 64 or 63 BC at Amaseia, Pontus (modern-day Amasya, Turkey) and died c. 24 A.D, was a Greek geographer, philosopher and historian. Strabo is most famous for his work Geographica ("Geography"), which presented a descriptive history of people and places from different regions of the world known to his era.

[31] Titus Flavius Josephus born Joseph ben Matityahu or Yosef ben Matityahu. First-century Romano-Jewish scholar, historian and hagiographer. Born in Jerusalem (part of Roman Judea) to a father of priestly descent and a mother who claimed royal ancestry. His most important works were The Jewish War (c. 75) and Antiquities of the Jews (c. 94). The Jewish War recounts the Jewish revolt against Roman occupation (66–70). Antiquities of the Jews recounts the history of the world from a Jewish perspective for an ostensibly Roman audience. These works provide valuable insight into first century Judaism and the background of Early Christianity.

[32] Pliny the Elder Gaius Plinius Secundus (AD 23 – August 25, AD 79), better known as Pliny the Elder was a Roman author, naturalist, natural philosopher, naval and army commander of the early Roman Empire, and personal friend of the emperor Vespasian. Spending most of his spare time studying, writing or investigating natural and geographic phenomena in the field, he wrote an encyclopaedic work, Naturalis Historia, which became a model for all other encyclopaedias

[33] Publius (or Gaius) Cornelius Tacitus c. AD 56 – after 117) was a senator and a historian of the Roman Empire. The surviving portions of his two major works—the Annals and the Histories—examine the reigns of the Roman Emperors Tiberius, Claudius, Nero, and those who reigned in the Year of the Four Emperors (AD 69)

[34] Lucius (or Claudius) Cassius Dio, c. AD 155–235 known in English as Cassius Dio, Dio Cassius, or Dio, was a Roman consul and noted historian. Dio published the history of Rome in 80 volumes, beginning with the legendary arrival of Aeneas in Italy; the volumes then documented the subsequent founding of Rome (753 BC), the formation of the Republic (509 BC), and the creation of the Empire (31 BC), up until AD 229. The entire period covered by Dio's work is approximately 1,400 years. Of the 80 books, written over 22 years, many survive into the modern age, intact, or as fragments, providing modern scholars with a detailed perspective on Roman history.

1. Period marking their first appearance on the pages of history sometime in the 4th century B.C till the 1st century B.C which was a turning point in the Nabataean history and their way of life.
2. Period starts at 1st B.C and goes through the vassalization of the Nabataean Kingdom by Pompeii till its complete annexation and creation of the province of Arabia Petrea in the year 107. A.D.

3.9 Arrival

The Nabataeans introduced themselves to the known world as able merchants supplying exotic goods to the peoples of the Mediterranean. Constantly travelling with their caravans trading incenses, myrrh and spices. They appeared like ghosts coming from the desert and after their job was done they again vanished into the desert. Much of their appearance and lifestyle they pursued came from their nomadic roots. Not only the knowledge gained by the nomadic lifestyle of the wandering tribe but also trade connections with other civilizations had deeply transferred into the technological ideas that helped them to harness the harsh environment that they came to live in and thus earn them a well-deserved title as the "Masters of the Desert."

The earliest traces of the Nabataeans appear in the Hebrew Bible and are linked with the sons of Ishmael, Nebaioth and Kedar who appear to be the founding fathers of the two tribes, Nebaioth and Qedarite which are again mentioned on several occasions in the inscriptions of the Assyrian King -Assurbanipal.[35] Their proposed origin of arrival was suggested as the lands of today's southern Jordan and northern Saudi Arabia. In later periods the two tribes; Nabatei and Cedrei are again coupled by Pliny the Elder. Then they disappear from the pages of history for several centuries to finally resurface as the Nabataeans. Diodorus Siculus who was living in the late first century BC mentions the Nabataeans, quoting Hieronymus of Cardia (323-272 B.C.)

> *[*They] range over a country which is partly desert and partly waterless, though a small section of it is fruitful... They live in the open air, claiming as native land a wilderness that has neither rivers nor abundant springs… It is their custom neither to plant grain, set out any fruit-bearing tree, use wine, nor construct, any house, and if anyone is found acting contrary to this, death is his penalty… Some of them raise camels, others sheep, pasturing

[35] Erickson – Gini, (2010).

> them in the desert… They themselves use food flesh and milk and those of the plants that grow from the ground that are suitable for this purpose.

Diod XIX, 94, 2-4.

This time period, mostly represented by the works of Diodorus Siculus (which is the main bulk of historical knowledge for this period), the second book of Maccabees, and Josephus Flavius. Is tightly linked with the nomadic lifestyles of the Nabataean tribe. The nomads made the region of today's central Jordan their home and harnessed the desert for an almost impenetrable safe fortress that stood against their enemies and provided a safe haven for all the tribe members that would require it. They live in the open air in a land deprived of any means of an easy to access water source such as rivers or springs. They do not build houses nor plant any seeds. Generally, they avoid everything that couldn't be later moved or taken with them. The Nabataeans share a strong belief that those who are in possession, could be easily turned against the other tribesman in order to preserve that possession[36].

Diodorus Siculus shows us a view of the Nabataeans as of Nomadic people that took herding as their main proficiency for survival. Coupling them with the word "Arabs" he describes a group of people with a pastoralist behaviour. According to Philip C. Hammond that information proved as a basis for the design of the Nabataean urban evolution model as a classical change from nomadic through agricultural transitions into a highly urbanized society. But following his theory we learn that it is not the case.

Hammond suggests that the Nabatu and Nabataean should be considered as two distinctively different words describing two different populations. Where the second term is derived out of combination of two populations living in the same time in the region of the settlement/city Petra.

This theory has been built on the analysis of the differences that appear in the descriptions of the Nabataean tribe that are visible when reading the source material coming in

[36] Diod. XIX 94, 4.

from the ancient authors as well as the notion of disappearance of the Nabatu[37] tribe sometime in the 6th century BC as well as contrasting descriptions of the ruling factor in Petra[38].

The first evidence for this theory are the titles given to the rulers of the Nabataean. The earliest account was written down in the Second book of the Maccabees[39] were Aretas I was called a "tyrant". The usage of this title was known from the earliest times and it was a legitimate description of a person who was in leadership of a "tyranny" and it was used in contemporary with the title "king" and according to Hammond it took place prior to the establishment of a proper kingdom. Historically a "tyranny" would be indeed frequently involved with two distinct populations united under one ruler. In the case of the Nabataeans those two populations were supposed to be: the Edomites and the aforementioned Nabatu tribe. [40] Some evidence for this argument could be seen in the works of Strabo[41] where the author claims that the Idumeans later became the Nabataeans when they joined the Judeans and shared some customs with them. Strabo shows evidence of a process where two desert tribes could become one tribal entity. This would lead us to the idea that the so-called Nabataean identity could be in fact established by a reoccurring process of tribe assimilation, were the stronger entity intakes the smaller one with its entire culture and knowledge. As the tribe expanded and came to live in different parts of the Arabian desert, more nomads probably joined their ranks[42].

Strabo's notion on Idumeans later becoming Nabataeans has been slightly widened by the earliest work done on the history of the nomadic tribe published by C.C. Torrey[43]. He argues that sometime in the late 7th century B.C. the "Nabataean" Arabs started to move into the territories of the Moabite peoples and this massive "encroachment" forced the aforementioned to finally subdue and gradually pull out of their previous settlements and move to the unsettled region between the Dead Sea and the lands of Judea thus creating a region that he called New

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[37] Most scholars have rejected the identification of the Nebaioth with the Nabataeans due the difference in the Assyrian and Hebrew spelling of the names (Na-ba-a-a-ti, Nebaioth or nbyt) with that of a later name (nabatu).

[38] Hammond, (1992) , p. 261.

[39] II *Macc.* V.9.

[40] Hammond, (1992) , p. 261.

[41] Strab, XVI.2.34.

[42] This work will not go into detail on the origin of the Nabataeans. This is a subject that requires its own dissertation.

[43] Torrey, (1898), p. 16-20.

Edom or Idumea. This notion leads us to believe that probably not every member of the Moabite population moved in to this new region and it could mean that they were living alongside their new neighbours who were in fact still pursuing their nomadic lifestyle.

According to Hammond the synergy of those different tribes has probably brought to life the one tribe named Nabataeans which (going along Hammond's theory) combined the best elements of the two. And so, the descriptions of Strabo and Diodorus were different because they described two divergent time periods where the Edomite-Nabatu synergy was supposed to be on a completely different level. Strabo depicts the Nabataeans as civilized people with a high understanding of culture and a love for making profit[44]. Which should relate to the Nabatu tribe being the more accustomed with trade and social interactions[45]. But also, it should be noted that Strabo depicts the tribe as a Nabataean Kingdom ruled and governed by a king. That would (in some extent) support Hammond's theory on the complete synergy of the two tribes.

Whilst Diodorus account is quite different. It comes indirectly from the report of Hieronymus dated to almost 300 years before Strabo[46] to the time period when the tribe is mostly engaged in nomadic activities as guiding merchants around the desert and raising sheep. Which should be connected to the Edomite tribe's expertise in agricultural matters. Following Hammonds trail we should see the first (post-synergy) Nabataeans living in the vicinity of Petra.

At this point in time their nomadic lifestyles enshrouded their customs in utmost secrecy. This fascinated Hieronymus who accompanied by an army travelled the Jordanian deserts. We can only imagine how fascinating it was too see a group of Nomads with hardly any water supply at all herding animals, standing at the empty slopes of the desert hills just watching as he passed by. Another point that added to the mysteriousness of these people was the death penalty for anyone who would give away their secrets to the foreigners. One of those secrets was discovered by Hieronymus[47]:

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[44] Strab, XVI. 4. 26.

[45] Hammond, (1992) , p. 261.

[46] (323-272 BC.).

[47] Most probably Hieronymus found one of those reservoirs that must have been empty at the time and that allowed him to write this report.

Whenever a strong force of enemies comes near, they make refuge in the Desert, using this as a fortress; for it lacks water and cannot be crossed by others, but to them alone, since they have prepared subterranean reservoirs lined with stucco, it furnishes safety… they make great excavations…, the mouths of which they make very small, but by constantly increasing the width as they dig deeper, they make them of such size that each side has a length of one plethrum (30 meters). After filing these reservoirs with rain water, they close the openings, making them even with the rest of the ground, and they leave sings that are known to themselves but are recognizable to others.

Diod, XIX. 94, 6.

Like any other Arabian tribe, they engage in pasturage, breeding camels or sheep. In the grand endeavour of living in a desert the Nabataeans didn't stand as unprepared. They dug holes in the ground that were narrower in their upper side but very wide in the bottom. Thus, creating a bottle like construction lined up with stucco that was filled up with water and then sealed for later usage[48]. Those types of instalments are called reservoirs and they fulfil the role of water storage for the travelling nomads. They are hidden in the desert, placed in adequately timed intervals that allow the Nomadic travellers to always be supplied with enough water for the ahead journey[49]. Only the Nabataeans should know the locations of those cisterns because they are vital to both safety and survival of the entire tribe. It looks like many taboos and secrets had to be preserved in order for the Nabataean tribe to remain hidden from its enemies and there is a death penalty issued for everyone who betrays those secrets[50].

Constructed reservoirs hidden in the ground and marked so *"that are known to themselves but are recognizable to others"* suggests that there was a trace of organization in their commission. It is no simple task to construct a water reservoir and it would be extremely hard for a group of unorganized nomads to fill the entire desert with those buildings. Hieronymus' account meant that already then the (still) Nomadic tribes of the Nabataeans were acting as a united conglomerate of people striving to achieve one goal that was probably the safety of their caravan trade.

[48] Keiholz, (2008), p. 207.

[49] Oboda, Sobata, Yotvata, Nessana. Nabataean camps settled close to the frankincense trade route between Aqaba and Gaza. Served as way stations for the caravan trade.

[50] Diod. XIX, 94, 3.

Hammond's theory helps to link the darkened tiles of the Nabataean history that exist between their arrival in the Middle East, disappearance and resurfacing in the 4th century BC., but it should also be taken into consideration when arguing on the probability that the Nabataean tribe could be formed as a conglomerate of not two but an even bigger number of nomadic tribes found living in the Negev, Hisma and the Hauran deserts. As the independent states of all periods of the Bronze and Iron Age eventually deteriorated and fell, their people must have again switched from their early farming activities into the old ways of the pastoralism. This way they probably met the merchant nomads, joined with them at the settlement of Petra, eventually merging together and thus creating a new tribe of the Nabataeans.

Shared knowledge and the identities of several tribes must have stirred the need for strong leadership that would ensure the freedom of all peoples in the conglomerate while providing a steady course for future enterprises. Evidence for this notion can be seen in the technological advances made by the Nabataeans in the course of their nomadic activities in the earlier periods between the 4th century B.C. and the 1st century B.C. As their influences and trade monopoly grew, there also appeared the need of expansion that would ensure the safety of their caravan trade. This way the Nabataean populations soon encroached on the lands of the Edomite, Moabite and later Idumean people, who eventually joined with them brining in their technological and land knowledge, that was later used into a large extent for the creation of the so called "nomadic kingdom".

3.10 Nabataean "takeover"

That being said one would ponder why did the Nabataeans put so much emphasis on their protection and safety. Weren't they only harmless merchants and animal breeders?

According to the works of Diodorus Siculus[51] the early Nabataeans often engaged in acts of brigandage, robbing peoples of adjacent territories and retreating back to their natural desert fortress. Chasing them or even considering a large-scale operation aimed against their wrong doings would require supplies and a thorough knowledge of the desert pathways. In a different scenario, any chasing force would lose their way and eventually break down from the intense heat and lack of water. Whilst the Nabataeans could travel through days without much trouble while maintaining a very steady storage of the priceless liquid. They also had a custom of watering their camels and herds frequently in case of an emergency situation (one that would

[51] Diod. II, 48, 2.

involve running away from any assailants). We could imagine them as mysterious people that appear out of the desert sands traveling with their little herds of animals, watching group of strangers trying to cross the dreaded paths and then disappearing into the unknown without a word. According to the written sources they were very fond of their freedom and they understood liberty. The fortress of the desert provided everything they needed to ensure that this state persists. No one could fight them nor would anyone even know where to look for them. The only real danger that could threaten the earliest still nomadic Nabataeans was a threat of an organized well supplied army marching towards their traditional yearly meeting grounds[52].

But not all Nabataeans were brigands or farmers. Some of them could be hired as desert guides for different groups of interest. As pointed out by Josephus in his *"Antiquities of the Jews"*[53] where he states that the Nabataeans awaited them on the fringe of the desert where they met them peacefully and provided help in explanation of the latest events and available gossip in the land. Those types of situations could be very common in the earliest times of the desert travel.

Despite all of that early background and other different enterprises the Nabataeans are mostly known for the skills of their merchants[54]. The early years of their newly found activity were mostly marked by first steps in the Arabian trade markets. In this period, they are still overshadowed by the Frankincense and Myrrh traders from the Sabaean. But as the Kingdom of the Sabaeans start to breakdown and their trade begun to wither on a yearly basis, the Nabataeans began to visit their kingdom in larger numbers and an increased frequency. Part of those visitors acted as guides for the new people that wanted to engage in the crumbling Sabaean monopoly but didn't knew the pathways of the desert that could lead them to one of the most important stops of the Frankincense trade route – Damascus. Other parties engaged directly in the trade, forming new Nabataean caravans and slowly starting to work their way into a new episode of the Arabian Peninsula trade. Their nomadic experience combined with the knowledge of the Sabaean trade routes and markets, enabled them to quickly fill in the void that the Sabaean trade left and become the sole rulers of the Arabian Peninsula exotic goods market.

[52] Chapter 4.4.

[53] J. AJ. XII, 8, 2.

[54] Diod. XIX, 94, 5.

Utilizing the fastest possible roads and the reuse of the Iron Age reservoirs the Nabataeans could travel several times faster than any trader that was not of the Nabataean tribe. Of course, the nomads also served as guides for other caravans, but as we develop this picture of the Nabataeans into the future periods we find them a tribe that highly prioritises their own will of survival over any other nation that had to work with them in any possible way. That's why we can safely assume that the Nabataean guides, were in no way obliged to show the easiest possible way to a certain destination but rather work their way around the desert so to extend the trip.

If the Nabataean tribe was really as organized as the archaeological community suspects them to be it was not long for them to see the great profits that their nomadic experience could give them while on the trade routes[55]. They knew the desert like the inside of their pockets and had already encountered a ready to use water assurance system that only they could locate and use, which gave them an unparalleled edge in terms of timed travel. Only a small portion of those water systems where reconstructed as parts of the trade routes way-stations or later *caravanserai*. The most notable and the earliest sites for desert way stations built on the length of the frankincense and myrrh trade would be: Nessana, Oboda and Elusa all founded at the end of the fourth or the beginning of the third century B.C.[56] as the stations on the junction of the caravan route from Petra and Aila to Gaza. According to the archaeological findings at the site of Oboda[57] (campfire remains) the fourth to third century B.C. stations where more like camp sites with drinkable water. The most common image of a *caravanserai* is that of a *Khan* or a *Khanat* which arrived possibly at the time when Nabataeans reconquered Negev after their "banishment" by Alexander Janneus at the beginning of the first century BC[58]. *Khan* is a square building with several rooms all encircling a central courtyard used as a place where one can rest and water your caravans. Way stations provided the security and safety much required on a

[55] The switch is however very puzzling because there is no apparent reason for a nomadic tribe to choose trading as their main proficiency instead of herding. Jane Taylor using the words of Diodorous Siculus states that Nabataeans where very fond of freedom and suggests that money could possibly help them maintain their independence as was later proved by several tributes that where paid to the Romans. But that statement doesn't really explain the switch itself.

[56] It is still an opened debate whether the way stations belonged to the Nabataeans in the earlier period or not. It could be proposed that those early settlers were the "pre-Nabataeans". Nomads that joined together in the creation of the later Nabataean tribe.

[57] Negev, (1993), p. 1133.

[58] J. AJ. XIII. 358-364; J. BJ. I. 87.

dangerous road that was the desert. In a way, the nomads where sharing the knowledge of their survival in the desert with the people that used the Nabataean *caravanserai*.

But the luxury of water and rest doesn't come for free and the Nabataean paths where known only to the Nabataeans till the discovery of flight. Also, one of the important factors of the successful Nabataean trade was their choice of animals for carrying trade goods. Although the described period of time is more famous for horse usage and breeding, the Nabataeans where not that much interested in horses, their animal of choice was the sturdy and patient - camel[59]. Those animals are without comparison in terms of desert traversing and water management. Much slower than horses but much more resilient and uniquely identical to the life of a Nomad in the desert. Speed is not a factor when your opponent doesn't know the way and is depending much more on built roads and way-stations, while camels forming caravans maybe move slow but the road covered is much more reliable and continuous then that of the horse. In addition, camels can move through rough, sandy terrain that horses cannot and that often was used to take hidden paths inaccessible to other kinds of pack animals. They don't need water very often and can be easily watered when arriving at a certain *Khan* or a hidden water supply being way ahead of their opposition. Camel breeding is evidenced at several sites in the Negev one of them being Oboda[60].

By closely guarding their own traditional rules and secrets they learned as much as they could about the proficiency of a trader not allowing anyone to grasp any knowledge of their paths nor the secrets of their mobility. Nomads are mostly known for the ability to adapt to certain changes in their environment that can ensure their survival. In the earliest stages of Nabataean history came the turning point when the Nomads took their opportunity and became one of the main players on the stage of the Arabian world. That point was the weakening position of the Sabaean Kingdom that (in their time) has monopolized the entire caravan trade of frankincense and myrrh.

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[59] Strab. XVI, 4. 26.

[60] Negev, (1993), p.1159.

3.11 The change of a lifestyle - Petra

According to Diodorous Siculus[61] the Nabataeans where established as famous and capable traders already sometime in the 4th century BC. Looking at the Nabataean tribe in its early periods of development we can't stand idle in the amount of work they have already accomplished being just a tribe of nomads. There is a sense of purpose in their actions a trace of organization that is being left by them every time we look at any of their endeavours. That means that they have to have a central point of rule that gathers every one of the Nabataean tribe and organises them in some way.

There is an old custom within the Arab community[62] that requires tribesman to gather once a year in a specific place in order to exchange experiences or trade goods. Everything that could be not taken with them should be left at a certain "rock". This place is hidden deep in the desert in a remote setting that is really hard to access and quite easy to defend. He estimates that this rock is as far as almost two days of travel from the nearest settled country.

The ancient writers called it simply "the rock"[63] which later transferred to a Latin name that was used in order to describe the capitol of Nabataeans - Petra. In the early days of the Nabataeans - Rakmu[64] was used as a starting point for every journey and filled the role of a storage deposit for all of the accumulated goods that the tribesman acquired. When troubles began to arise and the enemy has braved the deserts and threatened the entire tribe, they all withdrew to their desert refuge. Although not walled, it immediately turned into an impenetrable fortress which the tribe would protect until the enemy's water runs out and their spirit breaks from the intense heat. The main weapon of the Nabataean nomads was as always their knowledge of the dangers of the desert and the ability to overcome them.

One such a story[65] began when Antigonus I Monophthalmus has seized control over the Asian provinces in the year of 315 B.C and decided to invade the Arabian land that remained

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[61] Diod. XIX. 94, 4-5.

[62] Diod. XIX, 95, 1.

[63] Diodorus, Strabo.

[64] Nabataean name.

[65] Diod. XIX, 94, 1.

out of his control and was probably the home of the nomads that still raided his newly acquired territory for easy pillage.

The king must have thought that this will be an easy expedition because he armed his general Athenaeus with only four thousand lightly armed foot soldiers and six hundred horsemen for the entire campaign. Although the plan was to intimidate the nomadic people into submission by killing their cattle, Athenaeus had a different agenda. He's idea was to plunder the Nabataean rock for treasures and escape before the Nabataean men where made aware of this predicament and would leave the yearly gathering place in pursuit of his transgressions. While he did indeed rob the nomads of their wealth and withdrew from the rock, he still needed to gain time in order to escape safely, but once the Nabataeans discovered this treacherous act they began to follow him through the desert and thanks to their supreme path finding skills they found Athenaeus' camp and assaulted it in the night. After their decisive victory, they recovered all of their stolen possessions and brought them back to Petra, where they wrote a letter to the Greek ruler Anitgonus in order to inform him of the treachery that had befallen upon them on the behalf of his commander. The king's reply was swift and it held Athenaeus accountable for everything that has happened and excused them of his actions. As time, would later prove Anitgonus was merely trying to trick the Nabataeans into a false feeling of safety and then he would attack again and have his victory.

For this second campaign, he would designate a force of for thousand lightly armed foot soldiers and a cavalry support of almost four thousand, led by his son Demetrius.[66] Although Demetrius was known as a capable commander and his father trusted him in terms of warfare, this second campaign was proven to be even shorter and less successful than the first one. Nabataeans having learned a valuable lesson through the last defeat, prepared adequately. They setup desert look outs that spotted the incoming attack and signalled the rest of the tribe by pre-arranged fire signals. This message was then transferred to Petra were the Nabataeans gathered all of their belongings and mounted a defence. Additionally, they sent their flocks away into the desert in several different directions, cutting off any surplus supplies that Demetrius's army

[66] The author does not give us any time schedules for this enterprise but we need to take into account that between the years 314-311 B.C erupts a grand conflict between Antigonus and the alliance of three other Diadochi resulting in what was later called the Third War of the Diadochi. This struggle forced Antigonus to fight on two fronts; one of the developed in Asia Minor and the second was created in the year of 312 B.C. after the Battle for Gaza were Demetrius faces the forces of Ptolemy who launched an invasion on Syria. Ptolemy wins the battle and the escalating conflict successfully cuts of any future attempts that Anitgonus would take in order to subdue the Nabataeans.

could salvage. By the account of the author the siege lasted only to the evening and then the commander (while judging the futility of their actions) called for a retreat.

War with Anitgonus was a priceless lesson for the Nabataean people. Probably at that time they reconsidered the value and importance of the rock and shifted their main interest into its protection. At that time the Nabataean tribe started to expand beyond their initial borders of the central Jordanian desert. The accumulation of wealth and the steady monopolization of the Arabian Peninsula trade made them think of expanding the security to a bigger part of the soon to be Nabataean monopoly. With the expansion of trade comes the expansion of ideas and knowledge. And so approximately two hundred years after the war with Anitgonus a man named Jason[67] seeks refuge in the lands of a person who wore a title of a king of the Arabians, and that king was Aretas I. First noted ruler of the so called Nabataean Kingdom. This information comes from the Second book of Maccabees[68].

Archaeological evidence provided by the British School indicate that there was a building dated by the signs of lamps and black glazed ware pottery to the second half of the 3rd century BC. Constructed with foundations made out of rubble and pounded earth, with a clay floor. Also, they found coins of Phoenician, Ptolemaic and of Seleucid origin. With some repairs the building continued its existence until the end of the 2nd century B.C[69]. Although there is no definite proof that the site was occupied by Nabataeans there are still some visible traces of people that have enjoyed the shelter of this place for quite some time. The coins could

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[67] Jason of the Oniad family, brother to Onias III, was a High Priest in the Temple in Jerusalem.

Jason became high priest in 175 BCE after the accession of Antiochus Epiphanes to the throne of the Seleucid Empire. In an ongoing dispute between the current High Priest, Onias III, and Simon the Benjamite, Jason offered to pay Antiochus in order to be confirmed as the new High Priest in Jerusalem. Antiochus accepted the offer and further allowed Jason to build a gymnasium in Jerusalem and create a Greek-style Polis named after the king, Antioch. With the creation of Antioch, Jason abandoned the ordinances given under Antiochus III, which defined the polity of the Judeans according to the Torah. Jason's time as High Priest was brought to an abrupt end in 172 BCE when he sent Menelaus, the brother of Simon the Benjamite, to deliver money to Antiochus. Menelaus took this opportunity to "outbid" Jason for the priesthood, resulting in Antiochus confirming Menelaus as the High Priest. Jason fled Jerusalem and found refuge in the land of the Ammonites.

In 168 BCE Jason made a failed attempt to regain control of Jerusalem. Fleeing again to Ammon, he then continued to Egypt, then finally to Sparta, where he died and was buried

[68] 2 Macc, 5, 8.

[69] Negev, (1993), p. 1184.

indicate that they are engaged in a widespread trade enterprise engulfing the three most notable players of the political stage of the time.

Excavations at Petra indicate that the Nabataeans began to settle in this region sometime in the 3rd century B.C and begun to call this region their home sometime in the 1st century BC[70]. Remembering what has been said earlier about the earliest of the Nabataean settlements[71] we have to take into consideration that those where only the way-stations dominated by the view of tent housing. So, it is hard to count them as typical settlements. Most of the ideas for the settled life must have had come from no other place then Petra that was always the centre of the Nabataean rule and thought[72]. The Rock[73] leaves traces of the 1st century AD dwelling that was square in plan (30x30 m), built from local sandstone and limestone. No evidence of roof tiles has led to believe that the roof was flat in a classical Levantine manner that continues to this day. "Social" rooms where constructed and decorated in a highly Greco-Roman style which means that the Nabataeans where familiar with the dominating trend. The peristyle and the Corinthian capitals are the proof of this[74]. It also marks a path of cultural change that the nomads took for the future.

3.12 Halt of trade

This period of the beginnings of the Nabataean Kingdom and their prosperous trade came to a halt in the year of 100 BC, when Alexander Jannaeus destroyed the Nabataean emporium of Gaza and "expelled" the Nabataeans from the Negev[75].

Josephus Flavius is probably the biggest source of information about this time period of Nabataean political relations and many skirmishes that happened in between. In his work *"The Jewish War"* Nabataeans are cited multiple times in relation with their differences between their neighbours most notably the Jews. It covers the seventy years of Nabatean-Jewish history

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[70] Kolb (2003), p. 230.

[71] Elusa, Oboda, Nessana.

[72] Although A. Negev has also suggested that Petra was only a religious centre very close to what Jerusalem is now for the Israelis and in reality, a true Nabataean main city was founded in the sands of the Negev at the site of Oboda/Avdat (today Israel).

[73] Strab. XVI. 4, 21-22; simply states that the Nabatean metropolis is called Petra (means rock).

[74] Kolb (2003), p. 230.

[75] J. AJ. XIII. 358-364; J. BJ. I. 87.

begging from the reign of Alexander Jannaeus until the day that Herod conquered Petra while rejecting a bribe of 5000 talents to lift the siege of the city which in turn was starved into submission proclaiming Herod as their ruler forcing Nabataea to become a vassal of Rome.

Alexander Jannaeus (103 – 76 B.C) has waged war with the nomads taking from them the trade port of Gaza. This action was met with retaliation from the Nabataean king Obodas who ambushed the Hasmonean army in a valley stretching through the hills of the Golan. After they got surrounded the final blow was dealt by camel raiders. Another feat of battle readiness and the skill of using the desert to a military advantage happened when Antiochus XII Dionysus defeated the Hasmonean Kingdom in war and made a march against the Nabataean. After initial skirmishes fought against the armies of the Arabs he felt too confident about his chances to quickly end this campaign and followed the Nabataeans into the desert. Then realizing the grave mistake that his opponent did Obodas the king of the Arabs ordered his cavalry amounting to 10 000 men to turn back and assault the incoming Seleucid army. In the resulting battle, both of the kings died and the clashing armies were scattered. The price was high but Nabataea was saved. Two situations coming from the lifetime of one Nabataean king serve as examples contradicting the later notion that had been written down by Strabo.

Strabo's belief was that the:

> "Arabians are not very good warriors even on land, rather being hucksters and merchants, to say nothing of fighting at the sea."

Strab. XVI. 4.23.

thought also that;

> "Obodas the king, did not care much about public affairs, and particular military affairs."

Strab. XVI. 4.23.

According to him it is a trait common to all the Arabian kings. This would reflect the extent of how far did the Nabataean transformation go, from rugged almost savage like looters to calm, uninterested, peaceful merchants bound only to increase their income. This opinion is a product of Strabo's little knowledge of Nabataean history as well as the situation at hand that was noticeable in the Nabataean kingdom. At the time of Strabo's written account Nabataea was already a client kingdom subdued to the Roman Empire. It is somewhat understandable that at the time ruler did not care much for foreign affairs or fighting battles when he did not have any deciding power.

After the intervention of Pompeii who came to Arabia sometime in 67 B.C the Kingdom of Nabateans became a Roman client state. Treated as a vassal to the Roman Empire in a very similar (but in its depth), a bit different manner as the Decapolis was. This idea ensured that the bordering states will become strong enough to be able to defend their borders by themselves and thus work as a buffer zone between Romans and the Nomadic states of Arabia but also the most feared Roman enemy the Parthians. Retaining much of its independency (but forced to pay an annual tribute) the Kingdom once again grew and prospered thanks to the increased Roman demand and the unending need for Nabataean imported exotics.

Obodas III (30-9 B.C) recaptured the Negev for the Nabataean trade probably with the consent of Herod who levied considerable amount of tax money from the harbours of the Nabataean spice trade. Also in this time the Nabataeans established three new settlements (way-stations). Kurnub, Sobata and Rehovot(-in-the-Negev). The main difference between these new settlements and the earliest ones is the presence of public buildings which indicate a change in the Nabataean lifestyle from Nomadic to a settled one. Temples, military camps, pens for breeding camels and sheep or goat. The earlier settlements also begun to change and a theatre has been constructed at Elusa[76]and a temple at Nessana[77]. Mampsis[78] was supposed to have a gymnasium. Much like in the old settlements the population lived in the tents, but the army had probably their own permanent dwellings.

This period of Nabataean history is marked with changes that influenced the nomadic pastoralists to turn away from their nomadic lifestyles in order to select a sole ruler of a kingdom.

This change was probably an after-effect of the new lifestyle that they willingly undertook. Expansion of their exotic trade and the accumulation of wealth couldn't be further

[76] Musil (1907), p. 202.

[77] Colt (1980).

[78] Musil (1907), p. 25-28.

contained in a nomadic community and thus drastic changes had to be made. Another result of the expansion of their trade markets was the construction of several way stations on the deserts of the neighbouring region of the Negev that followed a secondary branch of the frankincense and myrrh trade road down to the ports of the Mediterranean Sea at Gaza[79]. There they could sell their exotics to bustling new trade markets in the entirety of the Mediterranean Sea and that meant trade with the rapidly expanding Roman Empire as well as the Greeks and Northern Africa. These new organisational feats required more additional control and authority that the Nabataeans put on themselves and that was probably one of the few elements that influenced a rise of the higher society inside the tribe that later took upon themselves the role of the supposed leaders. And thus, with the new ruling authority significant changes had to be made in the seat of power of the newly formed Kingdom that was Petra.

For this enterprise, Petra was turned into a bustling metropolis redesigned in a Hellenistic fashion. The city was planned on a flat terrain but fortified by surrounding rock formations seen all around the site. According to Pliny[80] there was a river flowing through the centre of the city[81]. Furthermore, Strabo[82] mentions; abundant with water springs that are found inside that provide drinkable water as well as water used for the great number of gardens that could be found in the desert city. Buildings carved out of shear stone filled the metropolis. They could be found in several places around the main centre of the capitol which was marked as in most Hellenistic cities by the colonnaded street. The city itself remained not walled as it was a more peaceful time for the reborn Nabataeans.

As their city changed in the 1st century B.C the nomads slowly adopted their new Hellenistic lifestyles and the tribesman turned into citizens, but still the nomadic way of life followed. Petra opened up to new markets and to visiting people; merchants and diplomats. It no longer remained as a hidden secluded place. But while their city changed immensely they

[79] Nabataean nomads that lived close to Gaza would from time to time engage in acts of piracy.

[80] Being past them you find the Nabataei, who inhabit a Town named Petra, in the Valley, little less than two Miles large; environed with very steep Mountains, and having a River running through the midst of it. It is distant from Gaza (a Town of our Coast) 600 Miles; and from the Persian Gulf, 122. And here meet both the Highways, that is, the one which Passengers travel to Palmyra in Syria, and the other wherein they come from Gaza: Pliny The Elder, Book 5 Chapter 28.

[81] Most probably the writer was referring to the Wadi Mousa, which runs alongside the colonnaded street at Petra. Significantly changed by the Nabataeans, today it resembles more a canal than a natural riverbed.

[82] Strab. XVI. 4, 21.

adopted accordingly and held many nomadic traditions in high regard and cultivated them in this new reality. From a tribe that resented any types of possessions that could hinder their freedom of movement, to tough merchants that exchange and accumulate those possessions. After the change of the 1st century B.C the nomads turned into Hellenistic citizens, but still they held the highest regard for the traditions of their ancestors.

Not everything changed in the Nabataean lives. The one thing that could be connected with their Nabataean ancestors could be seen in their everyday activities in the life of the common folk as well as at the king's courts. The Arab's prepare and consume their meals together, in groups of thirteen people. Strabo recollects that in most part they are served by their own kinsfolk or simply by one another or sometimes the host of the dinner serves his guests and this custom was also visible at the Kings court were the ruler himself served his guest at the table. They also drink from golden cups, were the kings assumes the role of the ceremony master and holds many drinking bouts in magnificent style. They drink no more than eleven cup lifts, each time using a different cup. In Tacitus *"Annales"*[83] the writer mentions that Germanicus Julius Caesar and his wife Agrippina visited the Nabataean King where they have been received with great splendour and luxury. So much luxury in fact that it outraged a man named Piso who did not like the notion that a Roman prince should be honoured like a Parthian monarch.

The Nabataean ruler's administrator is also one of the king's closest companions and is being called "brother". Which would easily indicate very close relations that occur between the members of the Nabataean community. Further evidence is provided by the account of Strabo's close friend Athenodorus, (who was supposed to visit Petra). He recollects a big number of lawsuits being decided at the time of his visit between foreigners as well as natives. But there wasn't even one argument that was held between the Nabataeans. If we judge by our initial observation, it may look like the Nabataeans are money hungry fanatics, but Strabo describes them as sensible people that take their new-found job very seriously and they will prosecute anyone who diminished their wealth, but will also greatly reward any help provided in its expansion. Prosecution by lawsuits and the general idea of being careful with whom you may and may not do business with is strictly linked with the strange transformation that happened to the Nabataean people.

[83] Tac. Ann. II, 57.

The common life looked more or less the same as it was described in the earlier period. Though the number of sheep pasturages has diminished adequately that does not mean that this type of life was entirely extinguished[84]. There was still the need to herd sheep and oxen as well as the main source of transportation for the Nabataeans that they took in higher regard than any horse that they could buy – Camels.

Dress code for the common folk was mentioned for the first time and it described a person with a naked chest wearing a girdle around his thighs with slippers on his feet. Supposedly the king had a similar dress code with one real difference being the colour of the girdle which in this case was purple[85].

The most interesting notions that found their way into the works of Strabo are that the Nabataean people lived in houses made of stone and that they treat their dead like dung. Although this notion is very interesting it was found to be very distant from reality. The idea of was closely linked together by the account of the archaeological work done in the Nabataean capitol on the topic of Nabataean funerary practices.

For many years, there was a popular belief that Nabataeans lived in rock carved houses that Strabo described in his work and attributed them a residential character. On the account of our today's knowledge coming in from the archaeological dig sites, we can safely disband Strabo's ideas and conclude that due to his limited knowledge of the Nabataean culture (available to him through the account of Athenodorus) he made false assumptions.

Those rock cut structures served as burial tombs for the Nabataean Kings as well as their subjects[86]. The Nabataeans themselves still lived in tents, scattered around the city of Petra. Of course, masonry cut buildings also appeared in the city[87] but they should not be mistaken with the monumental rock constructions so characteristic for the Petraean background.

The second notion concerning the Nabataean burial practices comes with the words borrowed from another historian by the name of Heracleitus. Who wasn't aware of what took place in that peculiar situation. Most of the contemporary scholars agree that this was an

[84] Evenari. et al. (1997).

[85] Strabo. XVI. 4, 26.

[86] Perry (2002).

[87] Kanellopoulos (2001).

element of a widely spread eastern mortuary practice that encompasses the ritual exposure of the body and secondary burial practices. After its exposure, the relatively clean body was gathered and buried in an enclosed tomb (mentioned earlier)[88].

As far as trading of goods go there is also the exchange of knowledge and thought. In addition, a big number of Roman citizens settled in Petra[89]. Most of them where probably merchants keen on being in the centre of the oriental trade. One and a half century later after the death of their last king Rabbel II (70- 106), in the year 106 AD the Romans annexed the Nabataean client kingdom and re-established it as the province Arabia Petrea[90].

Last entry connected with the Nabataean Kingdom comes from the works of Cassius Dio. He writes:

"About this time, Palma, the governor of Syria, subdued the part of Arabia around Petra and made it subject to the Romans."

Dio LXVIII, 14, 5.

This event is linked with the year 106 AD, when the annexation of the Nabatean Kingdom helped to create the Roman province of Arabia Petraea in 109 AD, definitely erasing the existence of the so called Arabian Kingdom.

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[88] Perry (2002).

[89] Strab. XVI. 4, 21.

[90] Whereas this change was done by peaceful means or by the act of war is still a question of debate. Researchers like Schmid propose that the destruction layers uncovered in Petra belonging to the early second century AD are not (like previously thought) earthquake derived but they were caused by a Roman Nabatean war where Trajan personally led the siege of Petra. This idea is supported by two poorly dated sigils that many researchers would rather date to the 135 Jewish revolt. Apart from that many sites in the entire Nabatea bear the signs of earthquakes all dated to the early second century AD. Which puts more emphasis on the peaceful takeover scenario. The Annexation was probably a reflection of the new defensive doctrine that was setting root in the Roman minds from the time of Domitian. First triggered by Varus defeat in Teutonburg forest when he lost three Roman Legions in his fight against the German tribes. This decisive Roman defeat prompted Augusts not to engage further into the German territory and by his advice the following Tiberius did the same.

Breeze, Dobson (1976).

3.13 Arabia Petrea

Arabia Petrea spans from the south-eastern parts of the Golan Hills going south through Gilad. At this point the city of Bostra is extending the borders too far to the east and the city of Abila is the Syro-Palestinian border in the west. The territory expands further south passing Gerasa and running through Ammon straight to Philadelphia. From here it goes south with a brief border on the Dead Sea straight to the arid regions of the Negev. Then it encircles Samaria and expands further into what we call today the Suez Channel. With this territory, the province covers some parts of the Roman city establishment called The Decapolis and the dry areas of the Negev where Nabataeans built their famous desert fortresses and of course the capital of their Kingdom Petra. Annexation brought a complete change in the culture of the past kingdom. Roman bureaucracy arrived bringing in Roman administration and the Roman construction ideas that now have been employed on a larger scale. When incorporating new lands, it is vital to ensure the best possible infrastructure that will connect the old roads with the new. This was the main idea of building the *Via Nova Trajana* road which spanned through the entire province of Arabia Petrea in a North to South motion. Most of Nabatean way-stations where either destroyed or abandoned during the switch to the Roman province in the years 106 -111[91] and then partially reconstructed as watchtowers for the Roman military.

Nabataea flourished under Roman rule during the Pax Romana of the second century AD. Many cities accumulated wealth when being connected to trade network coming through the Via Nova but the Nabataean spice trade diminished greatly over the years by the influence of the Roman Empire who wanted to control the trade routes without any additional “peddlers”. This turn of events forced the Nabataeans to turn to agriculture and animal husbandry. Workings of the last king of the Nabataeans slowly prepared the nomadic trade nation to a completely, new lifestyle that they will have to adapt to in order to survive the roman change. He was honoured by the tribe with the title: “Rabbel II who brought life and deliverance to his people”.[92] Signs of significant agricultural and animal husbandry facilities like stables at Oboda, Sobata and Rehovot are the testimony to the legacy of the last king of the Nabataeans. The biggest part of this area is affected by a very low annual rain precipitation of about 100 – 200 mm of rain per year.

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[91] A significant amount of archaeological excavations confirms this trend.

[92] Negev (1963), p. 115.

Cities where slowly absorbing the Greco-Roman culture as they were constructing typical Roman buildings that were connected with the main centre of every city – the Forum. Theatres, Odeons and even baths where of commonplace in every major city[93]. Also, this "assimilation" has influenced the Semitic cults of the Nabataeans where the deified king Obodas III has assumed the guise of Zeus Obodas, as attested by several inscriptions found at Oboda[94]. And lastly the switch from living in tents to moving into constructed buildings. The 22 papyrus of Nessana is a certificate apportioning inheritance dating from the year 566 AD. It describes a typical Nabatean dwelling in the Negev as a two-story high building with a central courtyard. In addition, the second-floor rooms where used as a bedroom with doors opening into the courtyard[95]. The description of typical Nabatean house (a very comfortable one in that matter) combined with the adoption of an advanced form of the desert agriculture was the last major change in the lifestyle of the past Nomads.

3.14 Summary

Almost six hundred years of existence of the Nabataean tribe was marked by the overall success and splendour of their enterprises. Much like their desert living counterparts the Egyptians they strived to survive the harsh environment that has fate imposed on their lives. But with one considerable difference. Egyptian had excess to a vast amount of water that came from the river Nile. Nabataeans had to learn how to find water, store it and finally use it and in the best way possible. Maybe that was the most important part in their rise to power on the trade routes. They knew how to deal with the little amounts of things that they got and how to make the most of them. Also, their unprecedented knowledge of the surrounding terrain gave them an edge in their voyages across the Arabian Peninsula. As their travels expanded so did their overall wealth. Times changed and the merchant's proficiency had become more dangerous. New rising powers sought to claim what they have created. Forcing the Nomads to do what they can to best - to adapt. So they built way-stations to look out for their caravans and ensure that they are safe, which came with another way of gaining funds. After the annexation of the Kingdom and the diminishment of the Nabataean trade they turned to farming. Using their vast knowledge of water collection, they created a very extensive system of food production that could sustain a population of 20 000 peoples living in the Negev desert. When they converged

[93] Gardens and baths at Petra.

[94] Negev (1991).

[95] Kraemer Jr. (1958).

to farming they finally left their Nomadic lifestyles to live in houses so they can tend to their fields.

It’s hard to ascertain as if their main rule about not sharing the tribe’s secrets was ever broken or not, but the visible Greco-Roman cultural additions point out that the Nabataeans “opened up” in some way to the new trends coming down to their region. In fact, Petra was home to a considerable number of Romans that could have influenced this cultural change.

The Nomadic lifestyle of the Nabataean people came a long way from the first days since their arrival in The Middle East. After examining the history of those people one could say that they never stopped adopting to the new challenges that arose in the extent of that six hundred years of their history.

The Nabataean tribe (as well as all of the peoples living in the Middle East) are not considered to be a popular topic in the amazing number of surviving literature works created by the numerous group of world known ancient artists. Most of the literature that describes the Nabataean people as well as the geographical background that they lived in comes from the 1st century A.D and is derived mostly from observations communicated by travellers (not the authors themselves) or it was frequently copied from earlier authors.

This meant that that all information available to us has to be carefully examined and cross-checked with available archaeological material in order to setup the most plausible path of history. Examples can be seen in the works of Pliny the Elder who describes in very brief words the Nabataean city of Petra and suggests the existence of a river that was supposed to be flowing in the middle of the city. This statement was based on the words of his acquaintance that was supposed to visit the city and probably mistook the Petraean water canal (Siq al-Mudhlim) for an actual river or there is also a possibly that he was describing Wadi Mousa which on the other hand can be found in a considerable distance from the actual city centre. In Strabo’s – “*Geographica”* pages concerning the Middle East are frequently referred to as based upon the knowledge of a certain Artemidorus whilst Diodorus information about the Nabataeans came from Hieronymus of Cardia.

On the other hand, there was one author that wrote about the Middle East from a very “close” perspective. Josephus (native to the Middle East) conveyed a large amount of information about the Jewish history of the Middle East as well as the history of the close relations between the Nabataeans and the Jewish king Herod. His work is one of the biggest archives of historical knowledge attributed to this period and it’s very useful in setting up the political stage of that time. The Nabataeans are very frequently mentioned on various occasions which makes this account one of the richest positions concerning the Nabataean history and the actions of their rulers.

4 *Water Management Systems in different time periods of the Nabataean Kingdom*

In order to understand the puzzle of Nabataean water supply technology we need to recreate every single element involved in their creation and later usage. 200 years of exploration and archaeology combined with the works of the ancients, should help us in better understanding of the entire puzzle of the Nabataeans. Vitruvius, Hero, Strabo and Diodorus will serve as our guides through the survey, construction and usage of the water supply systems. Their knowledge is of course quite different from what the Nabataeans accomplished but with many differences the overall ideas are outstandingly quite similar and striking resemblances also appear. This said we will be also looking at the technology exchange that occurred between Romans and the Nomads sometime in the 1st century AD.

4.1 Early Bronze Age

The history and development of water catchment and control systems in the Middle East begins in the years attributed to the Early Bronze Age[96]. People living in that period had been steadily abandoning the hunter-gatherer way of life in favour of a much predictable lifestyle of a farmer. There are also several different views upon the reasoning of the settlers. One of them connects the change to sedentary lifestyle with the increased need for copper from the northern cities of the Middle East[97]. Therefore, in order to excavate and transport the mined copper they had to establish permanent or semi-permanent settlements. This change had to bring along some additional ideas and technological advancements in the fields of providing food resources to the growing desert communities in order to ensure their survival. This of course led to the creation of an early agricultural land and the birth of the deserts most advanced technological phenomena; that of the desert rain farming.

Before the transition was complete and much later after it many people that lived in the deserts of the Middle East often engaged in sheep raising. Small flocks of sheep could traverse the desert in search of water wells or catchment areas in order to stay supplied and survive. Sheep pens scattered across the region testify to that notion. Considerable evidence suggests

[96] Between 3330 and 2300 B.C.

[97] Haiman (1996), p. 14, 16, 18.

Finkelstein (1984).

Finkelstein, Perevolotksy (1990), p. 74-75.

that sheep grazing was greatly diminished due to the arrival of agriculture but never has been extinguished completely and in some parts of the region survives till today.

The pursuits of an agricultural worker meant that the transforming population had to establish permanent settlements in order to frequently tend to their fields. The most desirable locations would be those close to water sources of the perennial springs. The size and population density of the erected settlements was directly linked to their distance to the water sources. The biggest available sites could be located in the direct vicinity of the perennial water springs. The smaller encampments placed in a considerable distance of the water source were mostly labelled as "daughter" settlements dedicated for seasonal usage.

Water sources in this period come mostly from the rugged and not very effective technological ideas such as the well or rain water collection (still very primitive in this period).

*4.1.1 **Thamila***

The Nomadic wells called "Thamila"[98]can be found at the banks of the wadis. They are usually 3 to 6 meters deep with a narrow throat 50 to 60 centimetres in diameter. They have been invented on the basis of animal imitation. After the infrequent smaller rains occurring in the desert the wandering nomads could discover small mud patches that, when excavated fill themselves up with water. Imitating the ways of the desert animals that often find their drinking water in a similar fashion. Human ingenuity took the nomads one step further and encouraged them to widen and deepen the water bearing location in order to expand its possibilities of water accumulation. The downside of this enterprise was that this newly created water well was filled up with gravel and it often was destroyed during the desert rainfalls. This forced the nomads to look for different location for the digging of wells and in time they moved closer too to the banks of the temporary wadi rivers where the well could be protected from the incoming flash floods. If the bottom of the well is additionally widened, it could produce as much as 200 to 300 cubic meters of water per year.[99]

Wells had been further developed when the nomadic population discovered that the water coming from underground could be found in a water bearing layer found above the impenetrable stratum. Close to Nahal Zin one can find a deep well dug almost 2000 years ago,

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[98] "A place where the water dwells."

[99] Evenari. et al. (1997), p.152.

it is 3 to 4 meters in diameter and measures the amazing depth of 70 meters. On the place of the well there is a Roman bathhouse that served the caravans travelling from Petra to Gaza.[100]

4.1.2 Runoff water & Wadi terracing

Run-off water is a term used for the description of the most commonly used water source of the nomadic and later Hellenised people living in the arid and semi-arid conditions of the Middle East. The name itself is derived from the appearance of the water source that originates during heavy rain storms that come in the yearly rain season sometime between September and February. The most usual situation in the water gathering scenario includes the collection of a low rainfall that is usually measured up from 3 to 10 millimetres. Rain storms occurring from time to time provide a hefty percentage of the overall yearly water precipitation for this region. The amount of coming in rain creates powerful water torrents racing down the dry hills of the deserts. This water source has been utilized by farmers that used to live in its direct vicinity.

In the Middle East, the most prevalent land forms are rocky hills and mountains devoid of any continuous soil coverage. The only fertile soil available in those regions would be the Loess. Additionally, to have any meaning in agriculture it has to be of sufficient depth and continuity (span on a large area). This means that in order for the farming facilities to produce sufficient (if any) crop they have to be placed in regions where the fertile soil could be accumulated and irrigated. According to M. Evenari[101] the most widespread idea of farming could be attributed to the group of Individual terraced narrow wadis.

Wadi terracing is an idea based on the assumption that the water coming in from the hilltop (by rain or any other torrential water source) would fill out one singular plot of agricultural ground and then by means of the terracing walls built around this levelled terrain the water would be contained in this singular field until by means of small water outlets dug under barrages the excess water is directed onto the lower field of the system. This step like construction ensures that water reaches every point of the terraced field, soaking up with moisture and depositing slit, which was collected from the mountains surface by the water coming down the hill during the flash flood. Channels diverted the incoming water onto the surface of the wadis where the terracing system was prepared – farming squares were cleaned up from any additional debris and in order to surround the squares with barrages and/or dams

[100] *Ibidem*, p.156.

[101] *Ibidem*, p. 97.

the land had to be flattened. Researchers of the subject had often stumbled upon the practice of desert stone pilling. A significant number of archaeological sites contained elements of land terracing and spire like constructions built of piled up stones[102]. This occurrence produced a significant riddle that still troubles researchers. Stone heaps placed in not a very large distance of the cultivation plots and sometimes found even on the catchment fields themselves. One of the theories suggests that those stone heaps had been used for vineyards in order to ensure that grapes can get sufficient amounts of water. This theory was rejected by several scientists[103] on the grounds that the amount of rainfall was insufficient for growing vineyards. The second idea focuses on the process of preparing the selected terrain for water catchment usage and it claims that the stone heaps are merely a product of gathering stones from the catchment area and were piled up in random fashion. [104]

Spacing between the terraced walls is usually 12 to 15 meters with a length of the wall of some 6 to 20 meters. The average height of such a wall differs around 60 to 80 centimetres. They are built of 5 or 7 layers of stones. There are also reported low inedible shrubs that could assist in the stabilizing of the watered area. Although it would be hard to ascertain if those

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[102] Modern authors: Oleson, Evenari.

This notion is also witnessed in the ancient times: 2 Kgs 3,25.

[103] Kedar (1957), p. 184-185.

Kedar (1967).

Evenari. et al. (1997), p. 106, 110, 112-113.

[104] One word should be used to describe a perfectly working Nabataean water catchment system – Efficiency. In arid and semi-arid conditions were rainfall is a rather scarce occurrence people trying to accumulate enough water that would ensure not only their mere survival but some additional usage capabilities (animal herding or in some cases manufacture) would want their system to transport as much water as it can possibly accumulate. Cistern and reservoir lids or any other forms of insurance that water evaporation has been limited are the fruits of that fought. In water accumulation and transport, channels and terracing are often cleared to ensure that the water is travelling without any additional obstacles. Stone pilling is the probable outcome of the terrace cleaning activities that were undertaken in order to broaden and flatten the ground upon which rain water would drop. We should also remember that the rain fall averages for this region are being produced in a set amount of time. The so called rainy season spans from the month of October until the last of February. In this window, turbulent and heavy rain storms may happen once or twice – efficiently filling up the entire system with water. During any other day, the water catchment systems rely on “light” rainfalls and calm rain drops that last for a few minutes. This means that in order for the system to be as efficient as possible, water needs to be collected at every possible point in time on the biggest available surface. Expanded and thoroughly cleaned catchment areas enable the possibility that every rain drop will be collected and moved to their appropriate zones of irrigation or storage.

shrubs prevailed as an original idea or they are just a by-product of abandonment and temporal usage by the modern-day Bedouin.[105]

M. Evenari suggests that the earliest traces of agricultural activities should be attributed to the Israelites (Iron Age). His argument is that the early Middle Bronze population confined themselves mostly to the plateaus and he presumes that the early people couldn't wield the knowledge of developed agriculture since there are no definitive discoveries that could confirm this statement[106]. However later surveys and multiple excavations proved[107] that the development of agriculture[108] started in the earlier times of the so called Early Bronze Age and it happened not only in the regions of the later Kingdom of Israel but also in the territories of their future neighbours - the Edomites.

Water management systems at the Early Bronze Age settlement of Jawa.

Jawa is an archaeological site belonging to the Early Bronze Age located in the northern part of the Kingdom of Jordan. It stretches from the basalts of Jebel Druze to the northern Hejaz, on the edge of the arid zone where the annual precipitation does not exceed 150 mm per annum. With no natural nearby water supply and only a slight winter water surplus the people living in the Jawa had to find a way to supply themselves with a bigger storage of water.[109]

Three separate water systems have been designed in order to supply the site with the valuable resource. The most important and the best dated one, fed rain and run-off water from the main wadi of this region – Rajil as well as an additional 2 square kilometres of run off area situated very close to it. The water was transported by means of two water channels. One was essentially carved in stone and relied on gravity flow through a distance of 1.4 kilometres. For the second part of the channel the local wadi was used for a distance of 1 kilometre. The water was transported into a reservoir built next to the town. All three-water supply system provided

[105] Evenari. et al. (1997).

[106] *Ibidem*, p. 119.

[107] Israel Antiquities projects of archaeological surveying.

[108] Sickle-blades found at several settlements in the region of Har Hamran point to grain agriculture, but in a very marginal spectrum. M. Haiman, *Map of Har Hamran - Southwest (198)*, Jerusalem, 1986

[109] Roberts (1977), pp. 134-146.

water for drinking as well as for irrigation purposes. Different channels transported water into different places.[110]

There is also the question of usage of the main water suppliant in the region the wadi Rajil itself. According to Neil Roberts the water run-off occurring in the wadi is too powerful for a dam to hold water and further water collection. Evidence of this notion are the remains of a dam found on the site that according to the author was destroyed after several years of use by incoming water run-off. In order to by-pass those difficulties and figure out a way how to provide more run-off water for the settlements storage, the population decided to build a dam in a side wadi at the other side of the town. By doing this they did not block the coming water but rather deflect it so that it continued to flow in downstream and increase the overall yield of the water that was being trapped by other diversion structures[111].

The run-off water gathering complex has been dated approximately to 3000 B.C. which means that it heavily predates any of the Nabataean systems that they built in the Negev or the Jordanian deserts for that matter. On top of that it was already fully developed and reused in the Middle Bronze Period when the settlers returned to once abandoned Jawa[112].

Further examples from Early Bronze Age dated farm sites at Wadi Faynan, Jordan.

Wadi Faynan is mostly known as a late Roman (2^{nd} to 5^{th} century A.D.) Nabataean - Roman site with an extensive field system that is supplied by Nabataean water distribution technology. Excavation and surveys done in the last twenty years brought more information about the earliest periods of the sites existence. Dated by pottery finds that could be traced back to the Early Bronze Ages.

Pottery was identified on the surface of the entire Wadi Faynan field system[113], but in several places, it formed large concentrations of sherds that strictly dated the neighbouring constructions. The eastern end of the field system is occupied by a water mill dated to the Roman-Byzantine period. The accumulation of pottery sherds could be discerned as almost 90

[110] *Ibidem*, p. 142.

[111] *Ibidem*, p. 142.

[112] *Ibidem*, p. 143.

[113] This work chapter: 6.2.7.

% of the material was wheel-made and thus considered Nabataean/Roman-Byzantine in date. While only 10 % of the remaining finds where identified as handmade, probably Early Bronze Age. The south-central part of the field contains archaeological remains of a series of bigger walls and in this area, there have been found assemblages of pottery sherds with an opposite percentage of datable finds. Close to 95 % of the found potteries are firmly dated to the Early Bronze Age and with conjunction to the available terrain which is mostly terraced and heavily walled, the researchers came to a conclusion that the surveyed field was probably first founded in the Early Bronze Age setting[114].

Additional work involving the finds of Chalcolithic and Early Bronze age pottery coupled with a story of a local Bedouin farmer, who complained that he had to uncover deep wall foundations in order to expand his fields, gave more evidence that the surveyed terrain was long in usage since the Nabataean period[115].

Archaeological work at the site is still mostly ongoing but there wouldn't be any surprise if we learned that the Wadi Faynan water system was largely inspired by already available remains of a similar idea left by the earliest builders of the Early Bronze Age.

The sedentary lifestyle also expanded the means and possibilities of trade with the neighbouring communities. The Middle East was always considered as transit zone where incoming traders often stopped to rest and engaged in trade with the local populace on their way to the shores of the Mediterranean. Trade Routes going through Negev are a very important factor in the socio-economic pattern of the region[116]. Although no direct traces of the aforementioned trade exist in the archaeological picture of the land, this idea is widely accepted as very plausible due to the rich mercantile traditions appearing through the entire regions history from the Bronze Age up until modern times.

When this proposed trade diminished the settlements of the Early Bronze Age slowly began to crumble and fall. At the end of this period many settlements have been abandoned and the populace had returned to their nomadic roots

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[114] Ruben, et al. (1997), p. 444.

[115] *Ibidem*, p. 444.

[116] Rosen (1987), p. 45–58.

Rosen (1988), p. 498–506.

4.2 Middle Bronze Age

In most areas of the Middle East the Middle Bronze Age didn't bring any significant changes to the water harvesting scenario.

The sedentary way of life gave way to the nomadic. This does not mean that the permanent settlements have been entirely abandoned. In fact, the number of the smaller settlements grew considerably. Their locations and survival dependent entirely on the high trade value of the region which is known for its long history and proven so on multiple occasions (as discussed earlier). The settlements had to be again abandoned due to power struggles of political entities. This resulted in a settlement void that lasted till the time that is considered to be known as the Iron Age. The pastoralist lifestyle still prevailed in this region but as such it did not leave any archaeological material behind.

4.2.1 Tunnels for spring water

The Chain of Wells also known in the Semitic language as "Qanats", the Arabic language as "Foggara" and the Persian "Karez" is a system of wells built in a considerable distance from each other designed in a straight line for the purpose of conveying water. Originated in the Armenian[117] regions of the Iranian Plateau about 2500 years ago, in 7th century B.C Ecbatana the capital of Media was supposed to be supplied with water from the chains of wells, and the Persian capital of Persepolis founded by Darius I (522-485 B.C) allegedly received all of its water from the "qanats", they also helped to fuel with water the oasis at Kharga that inhabited the Hibis temple[118]. The ancient idea of the "qanat" is not confined only to the regions of the Middle East. Systems could be found all around the regions of: China, Afghanistan, Pakistan, North Africa, Spain and even Chile. In the Middle East, they are often dated by the presence of Persian potsherds dated to the Persian rule of Palestine (537-332 B.C) which indicates either their construction by the conquerors or Jewish exiles returning from Babylonia[119].

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[117] Based on the analysis of the inscription portraying the military campaign of Sargon II on the king of Ulhu. Where the author describes the multitudes of water outlets that irrigate the fields in the conquered kingdom. The inscription appeared in; "the irrigation system at Ulhu (eight century B.C)" in J. Cuneiform Studies, vol. V, 1951, 1, 21-32). This analysis confirmed the earlier assumptions contained in the work;" Lehmann-Haupt (1910), p. 111.

[118] Forbes (1955), p. 154.

[119] Evenari, et al. (1997), p. 176.

Its main design features are grouped in three parts.

1. The first one are the so called “mother wells”. Wells built at the start of the system that tap to the water bearing stratums of the region. The depth is dependent on the geological profile of the region.

2. The second part consists of the digging of a gently sloping canal that leads the water to the desired point of its destination.

3. The third part of the system consists of vertical shafts built on the entire length of the underground canal in order to provide maintenance for the tunnel.

In overall the entire designed tunnel looks like a chain of interconnected wells that convey water from the water bearing stratum to the usage spot.

Examples of this could be found near the later Nabataean settlement of Yotvata, where the chain of wells fell into disuse and in course of time it was largely destroyed. The water level could be found six meters’ underground, in the same depth as the entrance to the “qanats” tunnel. The tunnel was lined with stones in order to prevent its collapse[120].

4.3 Iron Age

The recuperation of the region after a several thousand-year absence of any form of organized settlement patterns was started by a massive organizational body in a form of the newly founded Israelite Kingdom. The founding of new settlements could be arranged in two ways.

The first one would be come from the organizational powers of the Israelite kingdom where the newly founded settlements fulfilled the role of desert fortresses on the very border of the southern kingdom of Solomon. The second possibility was foundation by the civil communities that wished to live on the edges of the Negev Deserts. This new age introduced the Middle East to several new ideas of water capture and control.

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[120] Evenari, et al. (1997), p. 175.

4.3.1 Cisterns, reservoirs, settling tanks.

Water storage systems such as the reservoir or a cistern are the most vital elements of every water supply facility (as well as singular constructions for smaller settlements) in any civilization thanks to their most important role of water storage. Commonly known all over the world and widely researched they are the most usual background of any water absent human occupied territory. But not only used in water scarce regions. “Dewponds” of the chalk hill tops of Sussex and Dorset could be the most primitive idea for the storage of rainwater but some people believe that they should be dated to the Roman times[121]. Prehistoric Europe built timber-lined shafts that were sunk into the impenetrable clay strata in order to catch rainwater[122]. Water has been collected in the rainy season either by direct rainfall into the cistern or it was channelled in from rain water that was coming down the hilltops by the means of conduits (run-offs).

With the influx of new settlers willing to live in the desert parts of the Middle East new agricultural advancements had to be considered in order to sustain the incoming population boom. New ideas in the development of agricultural and water supply technologies, such as the hallmark of the desert water supply systems of the Israelite period, the stone-lined cisterns. Often circular, excavated in impenetrable Turonian marl ground with stone walls built for ensuring water capture and prevention of water seepage. The vertical marl had to be additionally lined with un-cut stone walls because of the unstable nature of marl that could easily collapse when wet. Although the bottom of the cistern was as equally unstable when wet it did not need any reinforcing. Steps leading down to the bottom of the cistern were constructed for easier water collection as well as maintenance.

The widest spread idea of the period was the open cistern (not roofed) with a water catchment conduit entering the construction from the top. It was fuelled by water, gathered from the surrounding terrain. The water catchment area consisted of several hectares of artificially cleaned ground that gathered the falling rainwater and by means of rock-cut channels diverted the run-off to the open cisterns built significantly lower than the water gathering areas. Water inlet for the open cistern was designed at the top of the construction. Water that gathered in the rock-cut run-off channels in all certainty should be considered unclean and unfit to drink. That’s

[121] Adam (1999), p. 236.

[122] Forbes (1955), p. 148.

why right before the channel entered the main cistern, people that used the cistern built an additional tank that served the main purpose of "settling the water".

Settling basins are small rectangular structures used for water purification purposes. They contain all of the slit and sediments that are carried in with the incoming water. They operate on the basic understanding of the behaviour of sediments and loose material in an aquatic environment.

Every sediment and loose material coming down the aqueduct had to arrive in the settling basin where the water outflow was placed a few centimetres above the bottom of the tank. This solution prevented the sediments and loose material from exiting the settling basin which in turn made them drown to the bottom of the tank. This mechanism ensured that only clean (or rather sediment derived) water could exit the settling basin and flow further to the cistern. According to author H. Chanson sediment catchment rate for those devices should oscillate at around 50 %[123]. That being said we can understand how did the purification mechanism work.

The open cistern ensured an easier approach on water collection as it was not very deep and the gathered water could be easily extracted by a simple bucket. A great number of those constructions could easily sustain a densely-populated settlement[124]. Its drawback was the absence of the covering lid that increased the evaporation rate of the stored water. This situation created an archaeological debate whatever those types of constructions could have originated in the desert areas or had they been brought from neighbouring regions and later adapted for low precipitation regions as means of temporary water collection sites.

The civilisation of the Moabites.

In the earliest times of history and archaeology known only from the descriptions in the bible, the civilization of the Moabites was finally identified in the Archaeological view of Jordan in an article written by Nelson Glueck in the year 1934[125]. The author described a civilization that thrived on the east bank of the river Jordan which created developed art and

[123] Chanson (2000), pp. 52.

[124] According to the model of Evenari's calculations based on a "typical" nomadic family

Evenari, et al. (1997), p. 148- 150.

[125] Glueck (1934), p. 212-218.

architecture that could easily be measured as equal to its western counterpart (kingdom of Israel).

The Moabite civilization started out as a nomadic tribe (as almost every known kingdom in the Middle East) that settled the eastern bank of Jordan sometime when the Israelites occupied Palestine. The end of the Moabites as a lasting archaeological body is being dated to the Assyrian conquest in the 8th century B.C.

The Moabite city of el-Medeiyineh stands on a large, well defined tell, setup on an isolated knoll commanding the approach to the Wadi eth-Themed. Water on this site could be found less than half metre digging underground and could easily be used for a large group of people if they decided to setup a settlement here.[126]

The later Nabataean encroachment could be noticed by the ruins of a Nabataean settlement left inside the Moabite city of El-Medebi[127]

Nakhl is a site containing several cisterns connected to a water retention system based on the idea of a series of water retaining dams built for the purpose of surface run-off collection[128].

Fajj al-‘Useikir contains a long channel cut in the rock to drain winter run-off from a steep slope of the Fajj into a large cistern near the wadi’s floor[129].

Al-Mraygha reveals a concentration of large cisterns, located high on a slope just north of the settlement.[130]

Short characteristic of the earlier periods of the Negev Deserts (before the Nabataeans) shows groups of early settlers that were very capable of supplying their settlements in water and even setup the first run-off agricultural plots in the desert. This corresponds very well with Hammond’s theory on the synergy of the two tribes that lived very close to each other in the vicinity of today’s site of ancient Petra. According to the theory the water knowledge acquired

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[126] *Ibidem*, p. 213

[127] *Ibidem*, p. 216

[128] *Ibidem.*

[129] *Ibidem.*

[130] *Ibidem.*

by the Idumeans was assimilated and resulted in the emergence of the Nabataean tribe of nomads.

4.4 From the beginning of the 4th century B.C to the 1st century B.C

The beginning of the 4th century was marked with the arrival of a new tribe of nomads. Their appearance in the deserts of the Middle East meant a completely new start for the desert region.

The Nabataeans established themselves as capable traders and knowledgeable guides. Their vast knowledge of the surrounding desert coupled with their mysterious capabilities of finding and maintaining a steady water supply destined them to become one of the most notable players on the Middle Eastern political stage for the incoming six hundred years.

Not much information can be gathered for the early years of the future kingdom of the Nabataean. Aside of few remarks that appear in the works of the ancient writers our knowledge of the tribe is limited only to acknowledge them as a very active group of Nomads (until the first century B.C. when they decided to finally make their big appearance on the political map of the region). Still their motivations for transforming from a group of nomadic people into citizens of a kingdom remain unclear[131].

The most prolific form of water collection facilities in the Nabatean landscape would be the runoff water collection system that was later used as a part of the aqueduct water systems, but it's still very crude in its design and its entire plan is based on the Early Bronze till Iron Age ideas for water accumulation. This shows that not much has changed in the water technology that the Nabataeans used in the early times of their rule in the Negev and Jordanian Deserts.

Vitruvius[132] knowledge on rain water capture is almost non-existent. He describes only how water in its perforated state is moving through the air, and how it "snatches" moisture from every hot place in its path. To illustrate it a little bit more vividly he uses the Roman bath as a

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131 Although it was speculated that their ambition was a direct result of their „close" relationship with the Israeli Kingdom that encouraged both sides to surpass their immediate rival.

As described by Josephus in his "*Antiquities of the Jews".*

132 Although Vitruvius was a Roman architect his views were more or less used in the entire region of the Roman Empire not only in the 1st century A.D. but also earlier. This was due to the fact that Vitruvius did not exactly invent any new methods of architecture or water capture and storage, but he collected this entire already existing and used knowledge in one book that he dedicated to Octavian August. And thus it is possible to observe several similar methods as being used in the Nabataean region of the Middle East.

comparison. Also, he tries to prove that the blowing wind determines the quality of water that is going to come down. For example, Auster (accompanied with other winds that begin their road at the suns course) will probably always bring rain because they venture through very hot regions that give away moisture (evaporate). And thus, he gives a long description of every river in the known world and concludes that they all have springs that begin their journey in the north. Following the words of Vitruvius rainwater is much healthier because it contains more healthful qualities that are composed from perforated springs which percolate through movement of air and storms. Thus, Vitruvius knowledge on rain water must by subsided with our current archaeological knowledge on the subject.

Rain water would be the most often used water source in the entirety of the Nabataean Kingdom. Its usage capabilities greatly outrange those of the water springs, because in conjunction with adequate technological ideas it could be collected anywhere in the entirety of the Nabataean Kingdom. Ranging from mountain hilltops to wadi beds.

Technology used to build similar systems in the 4th century B.C. is greatly carried over from the Early Bronze age and appear only as a direct transfer of perfectly executed ideas onto the new time period. This means that the rain water catchment system of the early Nabataeans closely resemble the Early Bronze Age constructions described and dated by M. Evenari[133].

4.5 Sabaeans in the works of the old.

As it was mentioned earlier the first appearance of the Nabataean people recorded on document was already after they became widely known for their trade capabilities and the technology to create and sustain cities in one of the most water derived areas of the world.[134] That of course begs the question on the source of their knowledge. Did they already knew about the hidden water supplies when they came into the Middle East? Was their Edomite heritage (proposed by Hammond) their only source of water supply knowledge or have they learned about some of those ideas through their many long-range trade contacts and relations? The most widespread and mostly agreed upon idea states that the Nabataean gained their knowledge from an older Arabic kingdom that ruled over the far south side of the Arabian Peninsula.

[133] Evenari, et al. (1997).

[134] Chapter 4: The Nabataeans.

Sabaean is the name of the language used by the people of the Kingdom of Saba that the scholars refer to as Sabaean[135]. They were an Arab kingdom which borders spanned trough the lands of today's Yemen in the Arabian Peninsula. Described by Strabo as an agricultural land of prosperity inhabited by four kingdoms. The already mentioned Sabaeans with their main metropolis Mariaba[136], the Minaeans inhabiting lands close to the Red Sea with their main city Carna or Carnana. Then the Cattabanians who settled near the passage across the Arabian Gulf where they built their city of Tamna and produces their most valuable trade resource: frankincense (the gum of the libanus tree) and most fathers to the east the kingdom of Chatramoititae with their city of Sabata (today Sawa)[137].Their specialty being the production of myrrh. Four kingdoms ruled by four kings with a very interesting system of inheritance. According to Eratosthenes's account[138] the current ruling king's son wasn't immediately placed in the front of the inheriting line but rather had to participate with other attendants (coming in from the entire high level society of the Kingdom) in a race that begun long before they even got born into their world. The rules were quite simple: The first child that has been born after the appointment of the new king succeeds to the throne. This idea requires a lot of resourcefulness and community awareness to be arranged, in order to correctly evaluate and (if found) protect the future king of any foul play that could be directed at his life. Strabo writes that eligible pregnant women where registered and placed under guard security[139]. It's very hard to imagine how this system could have worked perfectly, when it is very susceptible to human infringement and it probably caused the social elites to be in a state of constant competition. After the new king was born he resided within the palace with the ruling king of that time and the ruler held supreme power but was forbidden to leave the palace by the penalty of death. Conducted by the people of the Kingdom by throwing rocks at the king who would be unwise to not heed to this warning. This arrangement brings thought about the deification of the current ruling monarchs. As long as they exercise their power while unseen the common folk could assume that they are gods and their decisions and influence: godly and undeniable. Wealth and

[135] Beeston (1989).

[136] Today Ma'rib.

[137] Strab. 16. 4. 2.

[138] It is common knowledge that not all works of antiquity have survived until today as standalone volumes. Some of them like Eratosthenes's (and many others) account of Arabia Felix was preserved in the works of Strabo.

[139] Strab. 16. 4. 3.

luxuries of their seat of power assumes the gaze of a temple representing gods living on earth. This notion is backed up by Strabo in his texts

> *"Both he himself and those about him live in effeminate luxury…"*

Strabo Geography 16. 4. 19.

The Sabaean kingdom was a very fertile place, ruled by a very large tribe. According to Artemidorus it was very abundant with different types of tress: frankincense and myrrh being the most common one but also those rarer like cinnamon and balsam which could be found on the coast. There are also palms and reeds that have a sweet smell. Their abundance is so great that people often tend to use them as firewood. By the account of the writer the Sabaean people look like they don't work very hard nor care about anything. Their system of trade is presented as a mere "pass to the nearest neighbour" type of trade. Which according to Artemidorus enables them to trade with lands as far as Syria and Mesopotamia. But that would be a real understatement. Because when trying to imagine a merchant traveling through the lands of the Arabian Peninsula it would be extremely hard to picture a man or a group of people exercising an easy job. Extreme risks do often payoff in extreme gains. Their long-distance trade routes made them very rich and enabled them to live in luxury.

> *"…and they have a vast equipment of both gold and silver articles, such a couches and tripods and bowls, together with drinking –vessels and very costly houses; for doors and walls and ceilings are variegated with ivory and gold and silver set with precious stones."*

Strabo Geography 16. 4. 19.

But as all human enterprises engulfed in high "risk-award" scenarios could eventually fail so did the Sabaean trade decline and the Kingdom finally moved to the side of the historical mainstream to make place for a new contender of the Arabian people.

Today the kingdom is widely known for their water management systems one of them being the great Ma'rib dam that was presumably built as a 750-meter-long stone faced earth wall that accumulated water through the rainy season and stored it for the dry periods. Two sluice gates where used to unleash a water torrent capable of watering an area as large as the 72-square kilometre Wadi Dhana[140].

The design of this water collection system was purely based upon the climatic conditions of the Southern Arabia Peninsula which is located on the edge of a tropical zone. Which means that the land is experiencing rain twice a year and the incoming downpour could be different at any given occasion. Sometimes the rain comes very gently but frequently one could expect a very heavy downpour several times as big as the last. The inhabitants of the Arabian Peninsula call this rain *suyul* (sg. *sayl*). In order to catch this water and use it to their own needs a water collection system was devised. It consisted of a series of dams built a bit higher that the fields that they were collecting water for. The main idea of the dams was to slow the incoming torrent of water so it does not come in full force to the fields and flood them. This in turn would cause the accumulated fertile soil to be washed away and hinder any farming whatsoever. The dam system slowed the incoming water torrent and diverted it to the channel system that continued down the slope to its minimal gradient where the main agricultural level can be found. The dams were built with a lower part in the middle which was designed for a possibility of a very big rain downpour. Thanks to this idea the excess water was going through this lowered part dispersing in a short time. This means that the height of the deflector dam determined the amount of water which could enter the canal network[141]. The second part of the system consisted of walls built around the farmable areas which served as means of holding the water in the field. The walls were around 3 to 4 cm tall which means that the incoming water would quickly overflow the first field and then pour over the wall to the second field that is placed slightly lower than the first one, filling it in the same manner as the first one did. Thus, creating a terraced agricultural system. This idea solved some water availability problems listed by U. Brunner[142]

1. The immediate irrigation minimized the loss of water by evaporation
2. The weak deflector dam saved the system from being destroyed

[140] J. Taylor, *Petra and the Lost Kingdom of the Nabataeans,* 2001 p. 22.

[141] U. Brunner, *The Great Dam of Ma'rib as a Part of the Hydraulic Culture of Southern Arabia,* H.D. Bienert and J. Häser (eds.), *Men of Dikes and Canals: The Archaeology of Water in the Middle East.* Orient-Archäologie, Band 13, 2004. Rahden: Leidorf. Deutsches archäologisches Institut, Berlin 2004, p.405.

[142] *Ibidem,* p. 405.

3. Small communities as well as very organized Kingdoms could install and adequate size of their system.

4. The very simple way of distribution did not need permanent supervision. A *sayl* occurring during the night could irrigate the oasis as well

5. The huge amount of water entering the field prevented the soil from salinization. The salt from the former irrigation was leached by new flooding.

6. The irrigation water carried suspended sediments with it. These were deposited on the fields, thus guaranteeing the fertility of the oasis.

7. As open water sources were abundant for only a short time of the year, water-related diseases like malaria and bilharzia did not occur.

Despite all of its advantages the Southern Arabian floodwater irrigation system had one major problem: the sedimentation of the fields. The incoming water brought down sediments which it dragged along thus increasing the height of the fields by one centimetre per year. Which in turn in a perspective of several decades made the fields too high for irrigation and so they have been abandoned.[143]

4.5.1 Sabaean Agriculture

The earliest date of Sabaean agriculture was setup by the discovery of a terraced wall that was dated by radio carbon readings to as early as the 4000 BC[144]. As the terraced wall being the pinnacle of the water usage technology in the ancient times, involving several other different technological resolutions to perform as one object in a harmonically combined water delivery system. It is safe to assume that they wielded the knowledge to build the most traditional ideas of the water management systems as: wells (*b'ir*) and springs (*ghayl)* (that are sometimes transformed into underground tunnels) (*ghayl* or *kidamah* that are very similar to the Persian *qanat*) also the surface run-off, cisterns (*birket*) and rainfall management, even before the time of the terraced wall. Despite all of the aforementioned advantages of terraced farming this system was very hard to maintain. It required maintenance once a year which involved in the complete levelling of the entire terrace in order to make sure that water floods every part of the

[143] *Ibidem*, p. 405.

[144] T. J. Wilkinson, *Agriculture and the countryside. in Queen of Sheba Treasures of Ancient Jemen,* 2002.

field equally. The mud and terrace walls had to be reinforced and the eroded soil had to be returned on the backs of donkeys from far away.[145] In the drier regions of the Yemeni mountains the collection of water was of course more difficult and required more work from the farmers. In this case the idea was to expand the catchment area to all available hills and mountains that could be cleaned up from debris and allow the water to come down the hills and be directed by simple stonewalls to the underlying fields.[146]

All of those types of water collection and usage systems could be (with the same degree of success) used to collect drinking water for the domestic users working on those fields. The runoff water coming down the hills filled large cisterns built not very far away from the supplying houses. Every cistern had a sedimentation basin which main purpose was to capture water before it entered the main cistern and clear it of any flowing sediments it collected on its way down[147]. The impenetrability of the cisterns was improved in the late Sabaean period by using hydraulic mortar.[148]

According to Brunner the decline of the Yemeni kingdoms came in two distinct geographical and political occurrences. First one being the deterioration of the weather conditions with even smaller precipitation per annum. The Second change was the decline of the inland frankincense road. Substituted by less dangerous and cheaper Red Sea maritime trade. Changes compelled more and more people to move into the mountains (increasing the population density of the settlements) where the water collection system provided water for both agricultural and drinking purposes which in turn affected the agriculture forcing farmers to expand their fields and water collection areas. In course, of time the fields became too large to maintain and the population had to migrate to new places[149].

As it was mentioned earlier the Kingdom was also famous for their merchants trading frankincense and myrrh across the Arabian Peninsula to the regions of the Mediterranean. About 400 BC the Sabaean Kingdom fell apart and divided into four different states with each one taking apart that that once made the old Kingdom strong. Strabo relates that Qataban stayed

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[145] Kopp (1981).

[146] Brunner (2004), p. 407.

[147] *Ibidem*, p. 407.

[148] Brunner (1989), p. 39.

[149]Brunner (2004), p. 408.

with myrrh trading and Hadhramaut sold frankincense[150]. Saba was derived of any of those goods but still had access to their vast water management facilities. At this point in history the trade routes where free of monopolized power and in a state of re-establishing. Eratosthenes of Cyrene who lived in the 3rd century BC wrote a work similar to Strabo's *Geography* (but it was never found and it only remains partly in Strabo's work) gives a hint about the main operatives of the old Sabaean trade route in his time[151]. Not only we know who was operating those routes in the 3rd century BC, but we also learned that the trade routes converged very close to the future Nabatean lands.

Connecting that with our present knowledge of the Nabatean trade routes[152] we can come to a conclusion that the Nabataeans probably learned how to and what to trade at the times when they were escorting or guiding the caravans that passed by Nabataea and where looking for a safe passage to the Mediterranean. Strabo also states that the Nabataeans knew about the location of the Sabaean kingdom, which would suggest that they visited those locations on several occasions[153]. Strabo's account says that the Romans wished to conquer the entire Arabian Peninsula and in order to do so, they needed someone that can show them they easiest, fastest and safest way across to the lands of the Arabs. And so, they asked the Nabataeans for support which was helpfully granted. Upon these considerations, Gallus set forth on an expedition guided by a man known as Syllaeus who was a Nabataean administrator. Upon he's guidance they reached the southern most parts of the Arabian Peninsula straight into the lands of the former Sabaean Kingdom[154]. The abundance of life and riches that the Romans could witness during their journey was described by Diodorous Siculus in his work.

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[150]Strabo. XVI. 4, 4.

[151] Strabo. XVI. 4, 18.

[152] Graf, Sidebotham (2003).

[153] Strabo. XVI. 4, 22-25.

[154] By the relation presented by Strabo the furthest city they have reached was Mariaba.

“Now adjacent to this waterless and desolate land is another Arabia so much superior to the first that, from the great profusion of foodstuffs and other material goods produced therein, it has been named Arabia the Fortunate. For it brings forth reeds and rushes in abundance and every other aromatic shrub besides and, in general, all manner of fragrant foliage.”

Diod. II. 47.

In order to understand the Nabataean water supply technology and propose a general idea on the history of the Nabataean water supply and its origins we need to recreate every single element involved in their creation and its later usage. We need to acknowledge the fact that water supply technology of the Middle East was developing long before the arrival of the Nabataeans. Several ideas, very similar to the Nabataean ones were already working in the region of the Middle East.

4.5.2 The Ma’rib Dam

The Ma’rib dam lies on the border of the Wadi Dhana, one of the largest wadis in Southern Arabia with a catchment area of 8033 km^2 and a yearly flow of about 90 million m^3.[155] According to Brunner’s description the course of Wadi Dhana has a special character. The Wadi runs within the mountainous region which is building into a narrow valley. At the border of the mountain it cuts through the ridge of the Jibal Balaq and then, suddenly spreads out onto the vast plain of the Ramlat as-Sab’atayn. This characteristic of the wadi offered only one good place for irrigation: the point where the wadi left Jibal Balaq. It was only natural that the Great dam was built exactly in this place. Well known from the verses of the Holy Qu’ran, Surah XXXIV 14: ‘A sign there was to Saba, in their dwelling places: -two gardens, the one the right hand and the other to the left”.[156]

The Great Dam had a length of 620m spanning the gorge of Wadi Dhana between the Jabal Balaq al-Qibli and the Jabal Balaq al-Awsat and in its central part a height of 16m. Some parts of the waterside have been protected by unhewn lava and limestone rocks. North Sluice consists of two outlets that divert the water into a stilling basin, from where it flowed into a

[155] The Water Resources of Yemen – a Summary and Digest of Available Information. Report Water Resources Assessment Yemen 35. Ministry of Oil and Mineral Resources & TNO Institute of Applied Geoscience. Sana’a and JA Delft. 1995

[156] Brunner (2004), p. 406.

primary canal. As it was mentioned earlier the amount of incoming water was determined by the height of the spillway, which was a 12m. wide stonewall connecting the central structure of the North Sluice with the slope of Jabal Balaq al-Qibli. One big outlet guided the water into a deep stilling basin, from where the primary canal was fed[157].

The northern primary canal expands over 1.1 km, at the beginning of the North Oasis, where it ends in the round main distributor. It has 15 outlets, which led to secondary canals. Those canals have been linked together by a series of stone structures acting as distributors for the smaller tertiary canals which in turn distributed water into the terraced fields. As in similar terraced arrangements found in the lands of the Yemeni Arabs here also the fields have been walled off with stone structures about 60 cm high and similar to all of the *sayl* fed water irrigation systems it had a very high sedimentation rate calculated by Brunner[158] to 1.1 cm per annum. He also uses those numbers to discern between a fast, seasonal floodwater irrigation system, and a perennial irrigation system fed by a reservoir.

4.5.3 Concerning Nabataean cisterns in the early period.

Majority of the cisterns found in the Negev deserts could be safely dated to the Iron Age period[159] when they first appeared and quickly spread all over the entire region of the desert. Very characteristic and easily distinguished in the background of the desert regions they served the purpose of water storage for over 700 years. Their role slowly begun to diminish between the 4th and 1st century B.C. with the arrival of the Nabataean tribe of nomads. Although the Nabataean nomads developed new ideas for water storing and introduced their own technological take on the construction of cisterns, we cannot reject the possibility of the re-usage of the Iron Age cisterns in the time period between their arrival in the Middle East and the creation of the Nabataean Kingdom.

According to the latest work on the possible dates for the Nabataean rule[160] we must take into consideration that the Nabataean have probably reused much of the water technological knowledge from the Iron Age. They either found those constructions in the desert or they learned about them from their contacts with the Idumean, Moabite and Edomite tribes

[157] *Ibidem,* p. 406

[158] Brunner (1983), p. 96.

[159] Based on the works of Israeli archaeologists working in in the field of the Iron Age Israeli Kingdom.

[160] Erickson-Gini, Israel, [online] Acadaemia.eu

of nomads that probably joined with the Nabatu (along with other tribes) before they appeared again on the map as the Nabataeans in the 4th century B.C.

It is difficult to ascertain the ideal time period for the arrival of a truly Nabataean constructed cistern but when coupled with the fact that the Nabataeans started to engage in the Southern Arabian Frankincense and myrrh trade sometime in the 3rd century B.C. and the general conclusion that most of the Nabataean cisterns were built along the Sabea – Damascus – Gaza, Frankincense trade route, we can safely assume that the Nabataean constructed cisterns providing water for the caravan trade that was slowly being taken over by the Nabataeans.

The shape and the general idea of constructed cistern varied considerably from what has been achieved in the Iron Age. From the location of the construction do the very material of which the cistern was constructed. At this point, Nabataean knowledge on water gathering and its later storage was already sufficient enough not only construct a cistern but also to predict its later refill and prolonged water storage. Of course, the Iron Age cisterns also included those elements but with significant differences.

Similarities between the Iron Age cisterns and those of the Nabataean are to be found in the main idea of water gathering that was utilized on the basis of a large area run-off. Examples can be seen in the region of Avdat where 13 cisterns received water from an area around 60 hectares[161]. Those cisterns are considered to be much older than their Nabataean counterparts scattered across the region of Avdat. Mainly because they don't follow the bottleneck scheme that is usually attributed to the Nabataean constructions[162].

Differences between two constructions are multiple and they seem to "adjust" the construction to their nomadic, desert travelling lifestyle.

Typical Nabataean cistern is excavated out of the soft chalk found on the side of the Middle Eastern desert hills. With its water inlet built at the side of the cistern it enabled the Nabataean nomads to utilize a very thin 1-meter layer of hard limestone that covered the soft penetrable chalk. This way the inlet could be easily dug and the limestone served as a natural

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[161] Evenari, et al. (1997), p. 166.

[162] Notion that the Nabataeans constructed the first geometric cisterns is being questioned by Israeli archaeologists. They argue that a big number of the Negev cisterns are not accurately dated using correct and precise scientific methods and thus their dating cannot represent a true trend that was supposed to appear in the Negev desert between the 4th century B.C. and the 1st century A.D. Furthermore, the cistern that was described by Diodorus to have a geometric shape is widely considered to be a statement referring to a 4th century B.C. construction.

roof that covered the construction. This way the cistern was safe from water evaporation and contamination by algae. Contradictory to their Iron Age counterparts that (unusually for desert constructions) were open cisterns and probably struggled with those problems. Rock cut cistern were usually very big with an average size of 36 square meters and a depth of about 4 to 6 meters. That's why cistern pillars are a very common sight. Built out of soft chalk 1 to 2 square meters were left as supports.[163] Water refilling in those kinds of cisterns is identical as in their Iron Age counterparts. Water channels gather water from previously arranged water catchment areas.

The entire prospect of finding, identifying and using a desert water source comes from the direct experience that the Nabataean Nomads gained across their many travels and contacts with new and more knowledgeable groups of nomads. The idea of a cistern should be directly linked with the limited possibility of setting up reliable, clean and constantly rechargeable safe water sources otherwise known as wells.

4.5.4 Wells

One of the major sources of information for the methods on water well construction would be Vitruvius. Who realizes that even in the human friendly environment of European Italy, gaining access to water could be difficult and sometime even dangerous. In a possibility of a total lack off ground level springs that can be utilized for the water supply, it is highly recommended to dig for underground water supplies and construct wells. While this seems very easy and one may think it doesn't require advanced techniques, Vitruvius suggests not to undervalue the methodical and scientific approach to the well digging. That's mostly for the safety of the diggers working on such assignments. Because sometimes they can encounter poisonous gases coming out of the ground like sulphur or bitumen. To counter act this situation people that are digging should light a lamp and send it down the shaft. If the light stays on then the way is safe, but if the light gets blown away that means the builders have to construct additional air shafts on the sides of the dig to dissipate the incoming vapours. When the digging is finished (the location of the water vein) the dig should be lined with masonry.

Numerous surveys and ethnographical research conducted by M. M. Evenari provide information about a nomadic method that could be used in the earliest of times in digging up very shallow wells used by the Nomadic people. European definitions and ideas on the topic of

[163] Evenari, et al. (1997), p. 159.

the well should be discarded and thoroughly changed when approaching the nomadic methods of creating similar constructions. Nomadic wells are rarely rock cut or lined with masonry. Mostly they resembled the ideas of water holes such as the aforementioned ***Thamila.***

4.6 From the 1st century B.C to the 1st century A.D

In the earliest stages of its development the Nabataean Kingdom utilized very raw methods of water supply and transportation (much of them coming from the earlier periods of Middle Eastern history). This trend was beginning to evolve when the Nabataean Kingdom came in close relations with the Roman Empire in 67 B.C when Ptolemy the Great arrived in the Middle East and established Roman control over the region. Roman takeover opened up the Nabataean capitol to Roman influence and the incoming wave of Roman settlers. They made Petra their new home due to its close distance to the important trade routes coming through the city. This influx of interest made the city a very popular place to live and conduct business, which in turn was reflected by the growing wealth of the city and its inhabitants. The newly established cosmopolitan capitol in the desert probably had to adapt to the new socio-economic environment that grew around it. That's why sometime in the 1st century B.C during the rule of Aretas IV (9 B.C.-40 A.D.), the city became to change from a tent littered peaceful Nabataean retreat into a Hellenistic capital. It underwent a complete Hellenistic makeover with a strict net of urban planning and the construction of many new technological advancements that either replaced or upgraded the technologies used in the old Nabataean settlement. That of course also applied to the old water supply system that still remained in usage through the whole of the Nabataean rule. Much of the water channelling technology that was used in the renovation of old the Nabataean capitol also radiated across the rest of the Nabataean lands influencing most major settlements to change and/or upgrade their water systems.

4.6.1 Spring Water

In a semi-arid climate that spans through the entirety of the Nabataean Kingdom (with a bit lighter climate in the northern part of it) water was the most valuable resource available. It fuelled the growth of the Nabataean tribe and their spice trade. It sustained the growing population of many settlements and flowed freely through countless human's technological advancements created for the sole purpose of collecting and transporting this priceless resource. Flowing like blood through the veins of the cities channel systems. Filing up cisterns, basins and even fountains as big and majestic as the Nymphaeas built in Gadara, Amman or Petra.

Very often the water came from distant places, located as far as 30 km[164] away from the desired place of storage.

Vitruvius has written a lot about water collection and its later usage. Most of those methods found in his “Ten books on Architecture” are used in every corner of the Roman Empire with great success. The same thing applies to the region of the Nabatean Kingdom that assimilated many new technological ideas in the beginning of the 1st century B.C. (during the renovation of Petra) and after its annexation by the Roman Empire in 107 C.E.

The first step in supplying a city with water would be the finding of a suitable water spring ideally in high hills or even better in the mountains[165]. According to Vitruvius the water is sweeter there and is much more abundant than anywhere else and it’s also linked with the sophisticated methods of channelling the water down the hill used by the author which I will be describing later. According to Vitruvius the easiest springs to manage are those that flow freely in the open air. But if the search party doesn’t encounter any of those then they have to start looking for underground water sources. Which are easy to identify by remembering several important facts and methods:

The easiest actions that should be done before any other more complex searching methods, is to lay down and set the chin to the ground thus making it still and motionless. Thanks to this exercise the observer’s eye sight will not wonder higher than it should and will enable him to spot the moisture rising into the air. When rising, steam is noticed the observer should dig on the spot because the sign cannot occur in a dry location. The observation should be done at sunrise, it is very simple to perform, does not require much time nor any specialized equipment. The searching party should also acknowledge the type of vegetation it encounters. Traces of rushes, wild willows, alder, agnus custus, reeds, ivy and other similar plants cannot occur without water. But in multiple circumstances they can occur in standing ponds where water accumulated during winter, which by all means are not a valid sign of an underground water spring because they can be just holes in the mountains crust.

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[164] Forbes (1955), p. 148.

[165] *Ibidem.*

Eastern springs are found in the Desert Mountains. But their number is rather underwhelming.

When the observation team finally aggress on a place that is suspected of having water. Then it is time for the testing phase. At this point we look into Vitruvius and find several interesting methods of water testing all involving digging a pit three Roman feet wide on each side and five feet deep. At sunset, the survey team's needs to place a bronze or leaden boat shaped vessel or a basin in the dug hole, coat it with olive oil, place it upside down and cover the dig with reeds or leaves. The last step is to cover the entire thing with earth. On the next day, the team removed everything to check If there are droplets of seepage in the vessel. If so we have water. Of course, this is not to only method that has been used. Vitruvius lists a few more. Instead of the boat vessel you may also put in unfired clay pot which will begin to damp and fall apart thanks to the moisture, also you can use a piece of wool which will wrung when affected by moisture. Next there is the lamp test. Prepare a lamp and put it in the aforementioned test dig and cover it up. When uncovered at sunrise the lit should be on fire and the lamp itself should have some of its oil left and also when water is present the lamp will be covered by moisture[166]. Similar is the test of the fire pit. Start a fire in the test pit. When steam comes out of the pit then the presence of water is confirmed.[167]

Once all of the required test are completed the surveyor-architect team can now proceed in transforming the native water source into a full-fledged water supply. The first step is to build a well in your test dig and locate the water table.

The second step involves the construction of several new wells around the primary well. This creates a base for water capture that should be diverted to the place where the accumulated water is needed. The diversion is done by constructing water channels (rock or masonry cut) that sometimes travel down the hilltops through many kilometres to their final destination place. Everything that's has been written here so far is contained in the first chapter of the eight book of Vitruvius "De re Architectura".

A construction closely resembling that what Vitruvius suggests could be found in Wadi Musa at the spring of al-Birka. On the east part of the site on a mountain slope there is a chamber built at the spring (still flowing) called the "dar". The chamber is roofed by ten vaulted arches with additional three supporting columns probably built later. Opposite the entrance there is a northern wall, cut from the limestone rock with a niche in it. The rock-cut floor contains

[166] According to Vitruvius heat attracts moisture.

[167] Vitruvius VIII, 4, 1-2.

channels carved into them that connect with the main channel that travels to an open cistern in the terraced orchards to the west[168].

More examples of used springs are available in several water technology abundant sites that span in the entirety of the Jordan landscape. Humeyma, Sabra, Wadi Fanyan to mention a few. Humeyma is a very characteristic site for water technology development and usage. Four springs found outside the site; Ain el-Qanah, Ain el-Jaman, Ain Sharah, Ain Abu Insor had been used as the main water supply for the Nabataean city. But only three of them (besides Ain el-Jamam) have been connected to the aqueduct line. The latter spring probably had a lower discharge than today and it could be already exhausted in the times of the Romans (although the spring was used till the year 1983)[169] and therefore not suitable for connection. The only spring found in the direct vicinity of the site is located one kilometre south-west of the town. Dry in summer it must have produced a considerable amount of flowing water in antiquity, a Dushara niche carved into the rock wall a few meters of the spring give notice of cultic representations of places connected with water. Ten meters in front of the spring stands a water cistern.[170]

The site of Qa'1 (Close vicinity of Wadi Mousa) provides additional examples of Nabataean second period water well design. A round rock-cut water well with internal steps (one step at a depth circa. 1m). Built on the flat top of a low hill, surrounded by remnants of ancient structures with one course of stones preserved above rock-cut. The well is connected with a square settling tank that is placed to the northwest of the well (uphill). Water channel leading from the well to the south-east.[171]

At Qa'6 there is a round water well with a ceramic water pipe leading into the west (uphill)[172].

Vitruvius states that not all springs have good and tasteful water and sometimes they can be even dangerous. It is common knowledge that water tainted with some particular heavy

[168] 'Amr, et al. (1998), p. 522.

[169] Meyers, O'Connor (1983).

[170] *Ibidem.*

[171] 'Amr, et al. (1998), p. 540.

[172] *Ibidem*, p. 541.

metals is hazardous to human life. Springs affected by sulphur, alum or bitumen whatever they are hot or cold, it will come with a bad odour and taste. But does not mean that they can't be utilized in any other way. The cold springs could be used for washing or manufacture and the hot ones for more healthful practices. We know for certain that those types of springs could be used in the ancient times, and are still used today as a part of rehabilitation clinics or as an overall tourist attraction where one can relax and forget about the troubles of life. Just as the ancients did two thousand years ago, the most famous Roman hot spring working till today would be the Hammam Essalihine[173]. According to Vitruvius Sulphurous waters refresh strain on muscles by thoroughly heating and burning off the harmful humours from the body. Alum saturated waters heal the feeble limbs affected by paralysis, entering their open pores and warming their chill with the opposing force of the heat.

Stumbling upon the topic of water taste Vitruvius begins to clarify the many possibilities.

> "These waters then are made to have differing tastes because of the characteristics of the earth, as can also be seen in the case of fruits."

Vitruvius VIII. 3, 12.

This means that the taste of water is closely tied to the type of soil that is flows through. For his example, Vitruvius used the wine production (he singles out every wine known to him, including the type of soil) to show that every wine has its own taste and flavour that corresponds with the type of the ground it grows in. Concluding that if his theory is not true then everything in the world would taste the same[174].

Aside of healthy or heavy metal tainted waters the authors also describe multiple peculiarities that he encountered in the ancient world. Rivers and water banks that have significantly changed the composition of its waters, by running through a particularly characteristic terrain. Here we have salty lakes: Himerias that divides into two which on part flowed north in the direction of Ertruria and it had sweet water and the other part that flowed

[173]Hammam Essalihine (Aquae Flavianae) is an ancient Roman Bath situated in the Aurès Mountains in the El Hamma District in the Khenchela Province of Algeria. As the Latin name suggests, it dates from the time of the Flavian Dynasty.

[174] Vitruvius VIII, 3, 26.

through the places where they once mined salt and thus It became salty. In Egypt, there was a lake so salty that it had salt crystalized on its surface. Lakes that were tainted with oil. Soli a town in Cicilia had a river Liparis where bathers are covered in oil once they leave the river, also in Ethiopia we had a similar situation. In Babylon, there was a lake called "linume asphalitis" with liquid bitumen floating on its surface. Between Mazaca and Tyona in Cappadocia there is a lake that has a petrifying effect on everything soaked with it. Same thing can be said about the lakes on Hierapholis in Prygia. River Hyponis (Bug) in Pontus runs for 160 Roman miles from its spring and in that place it encounters a little spring which joins with its waters making them bitter. Alongside those peculiar and very unlikely waters there are also those types that can kill a person who mistakenly drunk or bathed in them. The fountain of Poseidon has been blocked due its deadly capabilities. In Thrace, there was a lake called Chrobs. That killed those who drank and bathed in it. More rivers come with their own stories, encased in their own mythology and legend. But they all bare one distinctive warning. Not all water is safe water.

That brings us to the next topic of Vitruvius work. How to test water. The easiest way was to locate a group of people that had lived around the spring earlier and take note on their health conditions. If they are healthy and well build the water passed the test flawlessly. The downside of this test is that when you are surveying a very low population density region (like the one discussed in this work) it will be very difficult to locate a group of wandering nomads to ask them about the water that they use. It's not impossible but still it would extend the water supply constructions time till unforeseeable future. The more likely method un-reliant to outside sources would be to sprinkle the water into a bronze vessel and check it for any stains that the water droplet could leave. If there are no stains the water is clear. Another similar test was to boil the water in the vessel and let it cool down. After that you poured the water out and looked any remaining's of sand and mud. If there are no such traces the water is good. On the other hand, Vitruvius states that:

> *"If the water in the future fountain is limpid and bright, and neither moss nor rushes grow where it emerges nor is the place tainted by any source of pollution but instead preserves a pure appearance, on the basis of these signs it is given the nod as being light and of the highest healthfulness"*

Vitruvius VIII. 4, 2

Fig. 2. Plastered water pool at Gerasa.

4.6.2 *The design and construction of the Nabataean water system in the 1st century B.C. and the 1st century A.D.*

Nabataean knowledge on how to construct and maintain buildings of similar usage like the water conduit or water channel although being agreed upon that could have originated in their large-scale trade contacts with the Sabaeans[175]should be confronted with Hammond's theory on the duality of the Nabataean origin and again considering suggestions of the architectural work that was supposed to be done by the architects from Asia Minor or vastly inspired by them, but made by Nabataean architects[176]. Whatever would be the case of the origin of this technology, there is no doubt that it significantly changed and developed into new and advanced usage methods as the Nabataeans made their change from a nomadic gathering of tribes into a kingdom.

This particular period in the lifespan of the Nabataean rule in the Middle East was characterized by a very active colonization movement that setup few distinctive and important

[175] Brunner (2004).

[176] al-Salameen (2011), p. 55-78.

settlements on the nomadic trade route[177]. Many of them possessed new and previously unseen in (Middle East) water collection and control facilities that ensured their prolonged survival granting the caravan traders new way stations on their road to Gaza.

In the most frequent scenario the water distribution system had to be built from "root", because of the tent littered character of the earlier settlement. There is also the possibility that the enclosure thrived as a nomadic campsite long before the Nabataean kingdom emerged with its centralised ideas for water administration. Growth of those settlements was possible due to their nomadic experience with water collection and the proposed idea of re-usage of the Iron Age cisterns left on the desert trade routes coming in from Arabia Felix to Damascus. In this case the newest ideas in water collection constructions had to be designed into the settlement grid with great care. Water collection systems of the 1st B.C. and 1st A.D. could transport great amounts of water that could be even multiplied by connecting the channels that gathered the run-off water with the incoming spring water channels. This could create a very dangerous water torrent that would easily destroy a poorly designed water conveyance system[178].

A Nabataean water collector is a broad term describing a construction that utilizes terrain that is built upon and its surrounding environs in order to collect as much water as it possibly can. Deserts of the Middle East although being one of the driest places on earth or not derived of water sources. Yearly precipitation is measured on an average of 200 mm of rain fall, which occurs in the "rainy period", the time frame between October and February. Rain coming in the "rainy period" is also not consistent. Heavy downpours (or flash-floods) that could create torrential water flows are very rare, they appear two or sometimes three times in a year. Most of the rain available in the Middle East comes from light showers that last for few minutes. This amount of water is easily absorbed into the rocky surface, with the exception of limestone which proves that it can be quickly saturated by water. This tendency creates water impermeable crust that prevents from further water absorption into the surface thus enabling the water to flow freely through the ground.

[177] Avdat (Oboda), Nessana, Shvita, Mamshit (Kurnub), Rehovot.

[178] This sentence refers to the flooding incident at Petra that happened in the year 1963. French tourists suffered deaths in the incident due to the destruction of the times current Patrean water system. The accident brought more awareness to the condition of the sites archaeological remains and our poor knowledge of the Nabataean water convenience and retention system.

Aqueducts or water channels the most advanced and widespread form of water transportation in the Middle East as it incorporates several different technological ideas available in that time for the engineers of the old. Widely known and used around the world it developed into a massive system of water carrying lifelines for many cities of the ancient times[179]. Originated as the "Qanat" in the region of Armenia in the VIII century BC[180]. It was primarily used as means of providing water for agricultural irrigation. Then it spread across the region into the Assyrian Empire[181] and from there it travelled across the Middle East to the Greeks and Roman[182] people. The Mycenaean's were the first people to use this technology as means of transportation for water that they desired to use for drinking. They created elaborate water supply systems because they preferred spring water (found in the mountains) to well water that wasn't considered healthy. In the region of the Nabataean Kingdom the solution of a water channel or a conduit was applied more often than that of a typical Roman aqueduct, which was for the first time built in Rome by the censor Appius Claudius and was called Aqua Appia.[183] At this point it is worth mentioning that the water supply systems consisted of very various elements and planning ideas all suited for the terrain and water expectancy for the selected region of the settlement.

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[179] Petra, Rome.

[180] Forbes (1955), p. 153.

[181] Large water-supply system built by Sargon's son Sennacherib to provide water for the city of Ninviveh and the royal palace of Chorsabad but primarily used as means of field irrigation for the old and the new capital. Built in three stages:

Started in 703 B.C by building a weir or a dam across the Khosir River near Kisiri, north of Niniveh. The purpose was to increase productiveness of the low-lying fields.

694 B.C Establishment of a water reservoir in the hills of the modern Jebel Bashiqah north-east of Niniveh with an adjacent water canal that brought the water down the hill to the orchards below.

690 B.C canalizing the Atrush River up to Bavian where the new canal met the older one. A weir placed across the stream dammed the gorge of Bavian turning it into a reservoir. The south-wester corner outlet was converted into a canal that leads the water down the hill to the older system of Niniveh for a distance of over 55 km.

[182] The Roman history of the aqueduct construction begins with the Aqua Appia.

[183] Forbes (1955), p. 162.

4.6.2.1 Surveying tools.

In 1995 Jean-Pierre Adam began research[184] on Roman surveying and construction in a more empirical sense. In order to understand the Roman engineering methods, he decided that archaeology needs to go a step further than only uncovering inventories of the ancients, but it should also encourage to recreate them in order to acquire knowledge concerning their usage. The experiment was meant to recreate the usage of the Greek measuring mechanisms of the dioptra and the chorobate (following the research data it could be discussed that the chorobate easily combined the capabilities of the dioptra and the water level).

The purpose of this experiment was to test the aforementioned devices in (what Vitruvius called) the first principle of good construction and planning - the art of levelling.

Levelling can be done by several techniques using different tools. Descriptions presented by Hero later reappeared in the work w Vitruvius. Despite giving clues on how a chorobate should be levelled and why is it much better than the dioptra Vitruvius doesn't give real advice on how does these tools work in an actual surveying scenario. This statement reflected the need for such experiments.

The research team used the recreated surveying tools in order to setup efficient measurement methods for the most elementary form of angle measurement, universally applied in the ancient times for the squaring off a baseline that enabled the formation of a buildings ground plan essential in every designed construction.

This can be achieved by two methods.

- The right definition of an angle that starts from an already known line that should be marked by pole. This action is described as raising a perpendicular.
- Secondly, while starting from a singular point we are joining it with a straight line. This action is known as dropping a perpendicular. The rest of this work is completed by measurements of the distances which are always horizontal. To complete such a work there is a need of an instrument that can set down two axes of perpendicular sightings, dividing the space into four quadrants. The surveying square of antiquity called the *groma.*[185]

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[184] Adam (1999).

[185] *Ibidem,* p. 10.

The instrument is built on a perpendicular cross with all four arms having the same reach, making up the so called directional square. Every arm of the cross ends with an attached and suspended plumb line. These four lines make up the *perpendicula,* forming the two sighting planes. The directional square is suspended on a positioning bracket that in turn is attached to the base (or upright) of the instrument. This arrangement made it possible to attach another plumb line onto the bottom centre part of the cross which was responsible for setting up the central point for the entire measurement. The positioning bracket also made the entire cross movable for easier handling and more precise instrument tuning. Finally, the base is provided with a point so it can be fixed in the soft ground; while in a rockier environment there was probably a tripod that could stabilize the instrument or one of the *agrimensor*'[186] had to hold it through the entire measurement. To setup the instrument the mensor had to inject the upright into the ground (or secure its standing position by using a tripod) so the centre plumb line would point at the location where the measurement begins or is being continued at. The positioning bracket could be additionally moved to pinpoint the exact location of the measurement while working in rocky or inaccessible ground conditions. Finally, the plumb lines have to be aligned with the proposed dimensions of the planned square[187].

The *groma* was tested in several experiments conducted in the area of la Villase by Jean Pierre Adam and his crew. The results were really satisfying and they confirmed that the ancient instrument is by no means less accurate, then its contemporary counterpart of the alidade[188]. Their setup time is comparably similar and both of the instruments work at the same rate in hard environmental conditions. The only downside of the *groma* is that it has problems to setup and take good measurements on a windy day. The plumb lines are affected by the wind and it was suggested to increase their weight. This experiment confirmed that the *groma* could have possibly had many operating possibilities in the ancient times. It could easily be used for designating two positions for opposite ends which in turn meant the surveying capabilities to plan a tunnel[189].

[186] Agrimensor was a position at a building site that was connected with taking measurements for the planned constructions site.

[187] Adam (1999), p. 11.

[188] No sufficient information could be collected on the topic of this item.

[189] Adam (1999), p. 15.

If those were the prevailing instruments used for survey in the ancient world at the time of the 1st B.C. and 1st century A.D. and taking into consideration the highly probable outside help that the Nabataeans hired for the reconstruction of Petra, we can safely propose that the first spring water aqueduct constructed in Petra could have been designed by the use of those aforementioned instruments or their very similar equivalents.

To design a tunnel or underground channel the *groma* was usually complemented by a *chorobate*. Described by Vitruvius[190].

A *chorobate* consists out of a horizontally aligned piece of wood that measures up to 20 roman feet. At the both ends of the board there are two perpendicularly attached planks of wood that serve as legs for the entire establishment which are additionally enforced with sloping wooden elements that are connecting the main part of the instrument with the side elements. The working elements of the instrument that are used for levelling purposes are the two plumb lines attached to the main board that are hanging down the instrument bypassing the additional enforcing planks. On the sides of those planks facing directly the plumb lines are the carved marks that when perfectly aligned with each other signify an ideal horizontal position of the instrument. The usage of the plumb lines signifies that in the event of a heavy wind the measurements could be done not adequately or it could be nearly impossible to even manage such an operation. Especially for those situations the instrument was also equipped with a water hole, carved at the top of the main horizontal board. The carving is about 5 roman feet long, 1-inch-wide and 1.5-inch depth. The water hole will act as a modern-day water line. Signifying if the entire instrument is perfectly horizontal or not. In this case the *mensor* has to check if the water is on the same level on the left side of the hole and its right side. If there are noticeable differences between the two water levels the user has to level, it up by putting chocks under that peculiar leg. One thing that requires mentioning about this instrument is its amazing size that could easily be a big downside and a problem for the crew that is working with it. Moving it from place to place and levelling such a big object would be very time consuming. The levelling itself is done by looking in from one to the other end of the main board, through the axis of the instrument.

Several significant ideas have been suggested and experimented upon in order to establish; how the chorobate was used in the measurement systems. The overall conclusion was

[190] Vitruvius VIII, 5, 1.2 and 3.

that the chorobate works in one particular way but the changing terrain could indeed impose additional methods of gaining measurements. The usage of a chorobate bears a close resemblance to today's methods of work with the theodolite and the markings pole.[191]

The measuring process begins at the source point for the planned channel, which often finds itself in the upper parts of any hilly landscape. Here we place the chorobate with its main axis pointing at the direction of the planned aqueduct. Due to the slopping character of the hills a marking pole is a useful item that adequately complements the chorobate. The measurement requires the co-work of two surveyors that use the aforementioned equipment were the chorobate user acts as the lead and establishes the distances between the chorobate and the marking pole. Thus, looking through the axis of the instrument the lead surveyor catches the top of the markings pole and in doing so he establishes that the height of the slope is equal to the length of the spotted instrument when excluding the height of the chorobate. The maximum measuring distance is restricted to the visible height of the pole. On a lightly slopped terrain this method needs to be adjusted accordingly. In this case the measurement system depends entirely on the sightings of the markings placed on the markings pole. In a fashion, very similar to the workings of a theodolite. One surveyor looks through the axis of the chorobate, the other marks the point on the pole and writes down the results.[192]

Although the Dioptra was not considered as an experimental tool in Jean-Pierre's research we must acknowledge it as a viable tool of design and survey by the premise of Vitruvius who mentioned it in his work.

Dioptra is a surveying device using the principles of triangulation. Hero of Alexandria uses it to construct a tunnel through two opposite points in a mountain. He takes a point close to the first entrance B and another point E. Then uses the Dioptra to obtain the perpendicular line EF and through a set of other perpendicular segments get line segment KL the point M for which DM is perpendicular to KL, where D is the other opposite entrance point. Using DN and NB estimate the angle alpha necessary to connect points B and D. The tunnel of Eupalinos is shown as an example of the measurement work done by the *dioptra*.

[191] Adam (1999), p. 18.

[192] *Ibidem,* p. 18.

4.6.2.2 Water channels by Vitruvius and application of the method

Vitruvius' knowledge corresponds to the state of the Roman technology that has been in use sometime in the 1st century AD but it should be treated very carefully as if used to try and picture a realistic view of the water supply systems that had been use in his lifetime. Vitruvius' account is more of an idealistic take on the subject, a handbook if you will. Visions and ideas collected in his work found resolution in the enterprises conducted by his ruler and patron- Octavian August as shown in the regulations of Venafrum[193] and by Agrippa's reorganization of the water-board of Rome[194].

Whatever the case may be. Many of the ideas that Vitruvius described found their way to the Nabataean Kingdom of the 1st century A.D. and while consulting his account on the many decisions made while implementing them one cannot seem to wonder how close they are to the vision of the architect.

4.6.2.3 The Masonry cut watercourse

According to Vitruvius there are three ways of designing a watercourse each with its own set of rules. First would be the most frequent arrangement available in the ancient world - the masonry cut watercourse with an open canal.

It should be constructed out of the most solid masonry available and the floor of the watercourse should have a slope no less than half a foot every hundred feet. The masonry should be vaulted so the sunlight doesn't reach the water table warming it and triggering the growth of algae. Which is of course dangerous for a safe and continued water flow as also for the overall state of the water. Channels coming down from cliffs will not always have a long and uninterrupted run. Sometimes they will encounter hills or mountains. Vitruvius advice is to cut through the obstacle and thus create an underground tunnel. If the obstacle is of tufa or stone, the engineers should cut the water channel directly in the rocky surface. If it's earthy or sandy they should construct the same masonry water channels that had led the water earlier inside into this underground passage. It is also important to include airshafts in the construction of this underground tunnel. They should be spaced one actus (35.5 meters) of every two air shafts. They are important for providing a constant flow of oxygen into the underground tunnels that prevents the growth of algae. In case of emergency they could also be used for any maintenance

[193] Forbes (1955), p. 165.

[194] *Ibidem,* p. 165 .

work necessary. After its long journey the water finally reaches the walls of the city. Here Vitruvius recommends building a *castellum aquae*[195]. It should be placed just inside the city walls at their highest point. This construction is responsible for accumulation and the diversion of water around the city. It is based on a plan of a reservoir which contains three tanks that are interconnected with each other. The water coming in the reservoir is flowing to the three tanks equally. Every tank is connected with a pipeline that diverts the coming water to a specific branch of users inside the city. For the middle tank, it should always be water for public usage (fountains, *nymphae*) the other two tanks should divert the water to public baths and private houses separately. In case of an overflow the two outermost tanks will spill their excess water into the middle tank. The idea of the central tank is to ensure that public water will not stop flowing even in the driest of seasons.

The main principle of a water conduit is to carry spring or run-off water for a (very often considerable) distance from its original source (preferably a hilltop) to a storage space in a settlement. The Nabataean methods of water conveyance show us a tribe of people that are very capable of providing fresh spring water for their settlements from considerable distances.

Water conveyance by means of an aqueduct is really a straightforward idea. Capture water at point A and deliver it to point B. Problems often emerge when the land is rocky and littered by hills and valleys that provide natural obstacles for the planned water line. Additionally, the changing aspects of the terrain in which the aqueduct was built it had to be substantially rebuilt and reimagined to create an environment for a steady water flow. In this regard, H. Chanson undertook empirical research on several artificially constructed, laboratory style, water courses. This research brought him to a conclusion that on contrary to popular belief that water in aqueducts maintained a fluvial flow, he[196] states that the usual 3 degrees' downward water flow would in fact create a superficial flow, that would require a technological response to ensure a normalized, steady water flow. Techniques applied would mean the construction of chutes followed by stilling basins, stepped channels and drop shafts.

In water conveyance, a chute is characterized by a steep bed slope that is associated with torrential water flow. During construction, the terrain plays a crucial role in discerning whether

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[195] In the Nabataean desert *castellum aque* was a very rare occurrence. So in most cases the water line ended at a cistern or reservoir built close to the city or sometimes in the centre of the settlement.

[196] Chanson (2000), pp. 47-72.

the chute will be smooth or stepped. Roman designers used both designs as well as single drops along aqueducts. Water lines with smooth chutes are recorded at Brevenne, Cherchell, Corinth, Gorze, Anio Vetus, Claudia, Marcia and Anio Novus at Rome. Stepped channels (although really scarce) found at Andriake and Bealieu. Construction of dam spillways also incorporated smooth and stepped – chute designs. One of the oldest built around 1300 B.C. in Greece and the famous Ma'rib dam in Yemen. Built with an unlined rock chute on the left bank to spill flood waters.[197] In several instances the design of the chutes differed from that of the main channel. Those differences appeared in steep chutes wider that the rest of the main channel. It has been suggested that this design was introduced to maximize water flow resistance[198]. Steep chutes that had a narrower width than the main channel had been connected with a rock – cut channel/ aqueduct bridge transition.

Along the route of an aqueduct we can frequently find settling (mentioned earlier) and stilling basins. Differences appear in their general usage. Chanson proposes to identify some of the basins as stilling basins. Not built to capture sediment but to decrease the incoming water torrent. The concept of the stilling basin has appeared as early as the 5th century B.C. downstream end of the aqueduct at Priene (Ionia). The construction measured 3.23 m long, 0.8 m wide, and 0.8 m deep, its main purpose – to dampen undulation and surge wave energy that could cause a threat to the integrity of the water channel. Stilling basins work best when the basin itself is deep and long. In a modern hydraulic jump stilling basins is about three to six times the downstream flow depth although, for oscillating hydraulic jumps, the basin length must be longer (in a length to depth ratio of about 6:1).[199]

Another element used in water channel constructions was the idea of a dropshaft. In Rome, it was used as means to connect new aqueducts with the older ones. In modern hydraulics, there are three recognized purposes of constructing a dropshaft[200].

- When topography is especially steep
- Decrease of kinetic energy

[197]*Ibidem,* p. 47.

[198] *Ibidem,* p. 56.

[199] *Ibidem,* p. 52.

[200] *Ibidem,* p. 54.

- Aeoration or reoxygenation of the water flow by means of water bubbles. Occurs by introducing plunging jet action on the shaft pool

This last principle of modern hydraulics stands as Chansons hypothesis for similar ideas being used in the Roman times. As common knowledge states – most aqueducts had to be covered up in order to minimize water loss due to high temperatures prevailing on the biggest part of the Roman Empire. One of the side effects of this action, would be the low oxygen content in the flowing water. And thus, the need for dropshafts cascades. Water falling down could easily dissipate some of its energy flow and additionally be enriched with oxygen.

Vitruvius' descriptions are not fully accurate and they should not be treated as such, but in some cases, they do represent a rather accurate view of changes that had been utilized in the 1st century B.C. in the Nabataean Kingdom.

On special occasions Nabataeans, didn't build any water channels at all. With a little help of their technological proves they utilized the rock faces of the hills to transport water from the top to the cisterns built below. Such is the case at the site of ancient Sabra, were the water is being guided by the flattened terraced surfaces of the mountains close to Sabra. In this case the face of the mountain acts as a water channel guiding the runoff to the theatre at Sabra. This should be also considered as an example of a cascaded water transport line. Water is free falling from one terrace to another until it reaches the improvised reservoir of the theatre.

4.6.2.4 Terracotta (Ceramic) Piping

Piping is a pre-designed system of long cylindrical objects bound together in order to convey fluid material from one location to another. Widely used in all regions of the world where fresh, healthy drinkable water is abundant, but infinitely more required in lands were water is scarce and had to be transported by means of such water conduits. Known from areas of mainland Greece, Indian Chandu Daro, Mohenjo Daro and Mesopotamian cities such as Mari that are still in perfect working condition.[201] In Mesopotamia clay pipes were constructed at a standard of 30 cm. high and 11 cm. in diameter.[202] This issue found itself as a topic of a strong debate in Rome (as reported by Frontinus[203]).

[201] Forbes (1955), p. 147.

[202] *Ibidem*, p. 147.

[203] Frontin. Aq.

The palace of Cnossos contained water pipes 72 cm long, 2 cm thick and slightly tapering towards one end (17 cm – 8.5 cm). This contracting tendency creates a possibility on which two clay pipe sections could be connected with each other. This design has its name derived from a very anthropogenic point of view and is being called the Male/Female joint. This enables the attachment of a second pipe and form a working clay pipe conduit. During the dawn of this technology joints where very incompatible and required additional "help" in order to retain water successfully. For this purpose, mortar (or any other hydraulic plaster) was used. To ensure a firm connection of the joints and cancel out any leaks of water. Additionally, if the clay worker possessed a high understanding of the material and an adequate workshop, he could create clay pipes that can be connected without any need for mortar.

Terracotta piping was used as a method of transporting fresh water directly from its (mountains or hill) source found on high ground by means of earlier prepared water pipes made out of dried or burned clay. It allowed the water to flow in a rather secured way, blocking off any additional debris that could contaminate it. Due to its relatively low construction price and manageable (skill to material) maintenance costs it quickly became of the widest spread ideas for water transport. Earliest traces are found in the lands of mainland Greece; their construction is probably connected with a requirement for a healthier water source than the available surface water. Terracotta conduits built by the Mycenaes of Tyria and Philacopi, (who were the first to construct such mechanisms) were mostly designed as open channels. On contrary Cretans of Knossos preferred closed ducts to prevent the accumulation of slit.[204] That being said Greeks were by no means the first to construct aqueducts.

Terracotta piping remains the cheapest of the methods and also easy to use. Because ceramic damage could be repaired by any team sent to make the necessary repairs, in opposition to lead piping where you need specialists in lead casting. The method of construction is similar to the water systems where water is conveyed by lead pipes, but with some differences. Those are mostly visible in the event of encountering a valley. In this situation, there are two easily penetrable rokcy blocks placed in the bottom of the valley in places where the pipes would normally bend. It's different from the lead constructed ones where the architect should avoid bending pipes at high angles. Those blocks should be drilled so they can house the two sides of the pipe that are going to be attached to the top and at the side of the drilled block. The block of stone will fulfil the task of reinforcing the installation against high water pressure values that

[204] Forbes (1955), p. 149.

are going to be present in the drilled stone. From here the construction looks like a usual water line that carries the water to the opposite side at the valleys ascent to a second identical drilled rock. This one works similarly to the ascending one. Retaining a high water pressure, it enables the water level to rise and overflow the pipe in order to flow up the valley and further to its desired point of destination. The speeding water current will be slowed down by the joints of the pipes themselves because they will create a bottleneck at every connection with another element. Also the “knee bend” is stone so it should hold out a moderate amount of incoming water. The rest of the construction is made the same way as the lead piping.

In the Nabataean region of the Middle East, ceramic piping is not a very popular method of water conveyance. It is of course used on several archaeological sites around the Negev and Hauran but its appearance is very seldom and mostly associated with the late period of the settlement development and thus mostly connected with the Nabataean trade contacts from the direction of Asia Minor and the Romanisation of the Nabataean people. Pipes appear in the new civic designs and reconstructions of several Nabataean buildings that are directly linked with the ongoing process of desert settlement urbanization. Ceramic channels appear in the early first century B.C. until the fourth century A.D.[205] Laid in shallow trenches excavated in the foreground, some are often replacing hydraulic plaster in the rock-cut water conduits. Similarly used in masonry infrastructures (buildings that provide passage through uneven topography). Water pipes were laid on a bedding of mortar, mud plaster or just plainly over sandy ground. Additional reinforcement was required at points of maximum stress such as the elbow and the Y-joints (fot. ??), the pipe was packed with small cobbles and mud on either side and below.

Terracotta pipeline development at Wadi Musa could be presented as an example on how the technology changed in the vicinity of the Nabataean city. Ceramic pipes are all wheel made and they show development in time. In the first century B.C. the pipes were plain and long, with one narrowing rim to fit inside the wider end of the next pipe. Many pipes had vertical trimming marks on their surface. Early to mid-first century AD hey developed “collar rims” with curving pronounced shoulders, making for a variety of internal dimeters along the length of the channel. Early second century A.D. pipes had more singular shoulders and uniform body diameters. Third century A.D. brought smaller and sharper shoulders thus making for smaller differences between the diameters of the two ends of the pipe. Early to mid-fourth century A.D. pipes had much better fitting joints and “wasted” bodies. Additionally, potters produced harder

[205] ’Amr, al-Momani (2001).

and stronger fabrics neglecting the quality of the finished material, ensuring that the ceramic pipes withstand an increased water pressure.[206] (Fig.3)

Fig. 3. Terracotta water pipes at the Siq – Petra

[206] *Ibidem*, p. 270.

4.6.2.4.1 Lead Pipe Water System

The second pipe conduit method of transporting the collected water would be the construction of a lead pipe water system. Metal cast pipes where known since the earliest periods of human history. As shown in the temple of Sahure (Abusir, Egypt) that contained copper pipes which spanned for 400 m. Each individual section measured 40 cm. and was made out of 1,4 mm hammered copper strips. Ends of those pipes were joined without soldering. Explanation is offered that they have been connected by hammering the ends on a wooden core.[207]

The idea behind this method is completely different then in the masonry cut channels. First off Vitruvius suggests to construct a *castellum aquae* at the source (where the water is accumulating) and cast lead pipes that are no less than 10 feet long with a set diameter for the entire route, until the planned destination of the water distribution. This destination would be the second *castellum aquae* constructed as usual on the highest point of the cities walls. Basically, in its main idea it's the same system as the masonry one but the real significant difference occurs when the lead pipe encounters a valley. [208]

According to Vitruvius we got three possible choices of fixing this problem but they all depend on the type of the valley. If the valley is rather small and not deep the builders should construct underpinnings in masonry and match them to the current level of the pipes, just like in the canals and channels. If the valley is not long and can be bypassed the pipes should be carried around to low spot. But if the valley is long and very step the pipes must be lowered inside the valley. When doing this the engineer has to avoid placing the pipe in a parallel design very close the valley walls. This way he can avoid the growth of pressure caused by the racing water in the vertical pipe which would eventually burst it open and destroy the water transport. Instead the pipe should be placed on the bottom of the valley on a very low angle that gradually descents and then ascends at the end of the troublesome terrain. This type of construction is called by the Greeks *coelia* which translates into "gut" but Vitruvius decides to call it the "belly". The idea of this establishment is to slow down the water current so it does not damage the pipes themselves but accumulate so much of its pressure that it will push the water up the valley.

[207] Forbes (1955), p. 149.

[208] Vitruvius, VIII, 6, 5-6.

Taking into consideration everything that has been said about Vitruvius' work and further examples of very essential archaeological finds[209] in the world of Roman engineering we can say that lead piping was frequently used for high pressure water lines. Sometimes in conjunction with such elements as the water siphon. This setup ensured constant movement of water within its line of transport. Low lead particle saturation within the storage water ensured its later usage as a drinkable water source. In their history of usage in the Roman world led pipes have undergone a process of size and measurement standardization, described by Frontinus and Vitruvius in the 1st century AD. The introduction of the *quinaria*[210] was disputed between Agrippa and the plumbers that had been influenced by the works of Vitruvius the architect[211]. According to Frontinus it was named *quinaria* after the fact that a spread sheet of lead 5 digits wide, could be made up into a water pipe, however he declines this method because a pipe built in this way would be extended on the exterior surface and contracted on the interior surface. Despite Frontinus' doubts about the usefulness of the so called Vitruvian water pipe, an identical system was described by Pliny[212] Explanation presented by Frontinus would be that the *quinaria* received its name from having a diameter of 5/4 of a digit.[213] Those who stood by the notion that Agrippa popularised the *quinaria*, reason that it was because the old system used five small sections (ajutages/punctures) that the new system connected into one.[214]Be that as it may this idea became a standard by which all future lead pipes were constructed and fitted into the water line.

[209] Chapter 8.

[210] „a fiver".

Quinaria was a measure not of volume but of capacity i. e. How much water would flow through a pipe one and a quarter digit in diameter, constantly discharging under pressure.

Frontin. Aq. I. 22-24.

[211] Frontin. Aq. I. 24-25.

[212] Nat Hist 31, 57-58.

[213] Frontin. Aq. I. 25-27.

[214] Frontin. Aq. I. 24-25.

Roman Inches	SI Metres	Roman Pounds	SI Kilograms
100	2,46	1200	392,602
80	1,96	960	314,082
50	1,23	600	196,301
40	0,984	480	157,041
30	0,738	360	117,780
20	0,492	240	78,5203
15	0,369	180	58,8902
10	0,246	120	39,2602
8	0,197	100	32,7168
5	0,123	60	19,6301

Tab. nr.1. Measurements given by Vitruvius as proportional for the construction of water transport pipes. Modern values are given for more comfortable orientation.

4.6.2.4.1.1 Lead pipe poisoning?

There is essentially one drawback of using lead piping and it may be the most important one because lead is considered poisonous to human life. It looks like Vitruvius knew of this fact, stating that he sometimes observed people that work in lead mines and he saw that their skin is turning paler from inhaling the lead particles every day[215]. It seems that he was not alone with his observations about this essential drawback for water systems that use lead piping. But how does this affect the state of the water?

Jean Pierre-Adam thinks that only harsh water can partially dissolve lead, mixing it and thus making it toxic (but only when it exceeds 0.1 mg dissolved lead per water litre.)[216] Based on that statement we can safely assume that if we have continuously running water in a system of lead pipes then it should remain healthy. Even when it gets contaminated by lead particles it's still too much water for the contamination to take effect. The water would have to stand still in the lead pipes for weeks, which is of course not possible by looking at the nature of its work. But even this statement would be incomplete without more research on this subject.

[215] Vitruvius. VIII, 6, 11.

[216] Adam (1999), p. 346.

Professors Horsford's take on the subject is quite similar but it is complemented with few additional remarks. According to this work- lead dissolves in some water but not in other. Everything depends on the amount of calcium carbonate mixed in the flowing water. In other words, it's so called "softness ", which in turn is affected by the geological structure of the catchment area. Lead is soluble in water but if the water runs over sedimentary rocks (limestone) and not ingenious rocks (granite), then it acquires a calcium carbonate content which, when mixed with water causes the so called hard-water effect. Water enriched with calcium carbonate will eventually lose its additional mineral content, which will in turn start to accumulate on the sides of the lead pipeline. This reaction will lead to form a shell of incrustation inside the pipes and water channels, effectively insulating them from the water flowing inside. In this case water and lead can't get into direct contact.[217]

There were also scientists that considered lead to be not as a safe construction material for water transport as others had. One of those declarations came from the year 1909 form a man known as R. Kobert who made a firm statement that lead is in all cases poisonous. This statement was based on the assumption that if people are widely being diagnosed with lead poisoning all over the world the culprit must be the lead waterworks that were constructed in most major cities at that time. Following that statement, he presumed that if the early 20th century is boggled with those types of nuisances and they only use lead in the construction of the main water line (where other divergent lines are made from iron), then in the ancient times (that constructed the entirety of their water works with lead piping) lead poisoning had to be an even bigger issue or perhaps even a disaster[218].

Considering the research on lead poisoning and its probable causes several facts must be taken into consideration. Lead is poisonous. The ancient knew it. Vitruvius explicitly warns that the use of lead water pipes is dangerous and with that we also have to consider that the Romans did use a great deal of lead water pipes and they poisoned themselves by drinking from it. But in the light of all the research done till this day we can assume that; they knew how to neutralize the dangerous aspects of lead piping with the overall design of their water works that provided water that flowed constantly which was in addition secured by the lime scale coating that appeared in the time of its usage.

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[217] Hodge (1981), p. 488.

[218] Kobert (1909).

4.6.2.5 Water channel maintenance

Damage or destruction of water pipes forces the upcoming question. How is this system maintained and what protections does it have against damaged piping?

According to Vitruvius it is a good idea to setup water reservoirs along the piping's road. They will ensure that there is no water loss during the maintenance work and that the destruction of a single pipe tube doesn't alter the entire system useless. Also, it is easier to look for any signs of damage when you can count out entire fragments of a system. One thing to remember is that the reservoirs shouldn't be placed on a downward fall nor at an ascent not even inside the aforementioned "bellies" only on flat continuous ground. This is directly linked with the water pressure inside the pipes. In any of those situations where you place the reservoir incorrectly, the water current slows down and loses the entire momentum it has built up when coming down its source. Making it unable to overcome any obstacles on its way. The reservoirs should be placed at two hundred actus (7 100 metres) of one another.

Generally, Frontinus divides every water carrying construction into two classes of supposed usage decay[219]. Sections that carry water through sides of hills, gorges and generally are passing over obstacles being suspended in air by the means of bridges or arches are the most affected by the "time decay" (erosion and weathering) and are contained in the first group.

The second group gathers all of the constructions that are hidden underground or simply not exposed directly to the effects of harsh or constantly changing weather conditions. He also uses two groups to classify the type of damage inflicted on the water system. The first group would include damage that can' be remedied without turning the water flow off which in turn means that the maintenance group will have to make a detour for the water system (damage inflicted on the water channel itself). The second group contains all of the damage that doesn't force the workers to close off the water supply (superficial damage). There also exist a third group of possible problems. That group contains maintenance issues that are a direct result of how the water supply system works and had been foreseen in the maintenance plan of the aqueduct, the accumulation of slit and the calcium carbonate washed away from the limestone's surface can create a hard crust of materials that will lower a channels capacity or even block it of completely and that in turn could cause catastrophic damage to the entire channel system. Maintenance work should be planned ahead of time with additional observations made in the

[219] Frontin. Aq. II. 118-121.

affected section of a water system. The additional work is required for the preparation of any materials or entire sections of the system that could be replaced on spot. Because with larger waterworks attached to big city centres one cannot afford a prolonged time of maintenance work. Considering the materials that are to be used in the planned work there is also a need to select the best time of the year for the work to be most efficient and successful. Frontinus suggest not to plan any construction works to the time of Summer (which is a very good suggestion taking into consideration the fact that Summer is the most water hungry time of the year) and to focus more on the time of Spring and Autumn. The same case would be with the repairs done in masonry work which are suggested to take place sometime in the time span of the first of April till the end of November (again excluding summer). The hottest possible environment is not very suitable for drying masonry mortar (it shouldn't dry fast).

Taking it all into consideration and moving all of the aforementioned conditions into the dry and hot lands of Middle East we can safely assume that the Nabataean people have more or less kept to those guidelines. The dry season in the Nabataean lands covers exactly between the time span proposed by Frontinus and of course summer (due to its high daily temperature) would be excluded from any maintenance work whatsoever. Of course there would be differences associated with the origins of the acquired water, like the question of spring fed waterworks or run-off sources. The spring fed aqueducts could have been easily repaired during this period, because the main idea on how the aqueduct works is not different from what Frontinus knows and so the spring fed channels would have to be repaired using a detour or by closing off one of the sections. But in this environment springs are a very rare commodity and not all settlements could benefit from their waters. Most of the settlements acquired water from the mountain run-off which was only working in the rainy season. And so the proposed work schedule is very appealing because in the dry season there is no precipitation whatsoever and that means that the maintenance workers don't have to block or reroute any channels in the run-off collection systems.

4.6.2.6 Construction methods and circumstances

This observation gives us significant clues on the design ideas chosen in the construction of a Nabataean water capturing system.

- Setting up the entire water collection facilities on hill slopes

Hill slopes are the best place to setup water collection facilities thanks to their average height and their sloppy texture. Rain fall coming down the desert hills is easily manageable and can be guided to the required location. Most of the hills in the Negev and Jordan deserts are built of marl sandstone which could be easily cut and transformed into a water diverting channel. In case of heavy downpours large amounts of water coming down the mountains can create a flash flood of remarkable strength. Controlling these water torrents was a vital element of the catchment system.

- Terracing the hilltops and wadi canals to store water

As mentioned earlier most of the water that was collected by the system comes from small not long lasting rains. Knowledge of the chemical reaction between water and the limestone that creates limestone crust enabled the desert dwellers to utilize this opportunity by constructing large carefully prepared water capture zones at the foot of the hills. These water catchment terraces were explicitly built in order to utilize the nomadic knowledge of the chemical interaction that occurred between desert soils and flowing water. It also served as a way of slowing down the water torrents. Secondary role involved water diversion and extensive agricultural usage.

- Water conduits (either rock cut or masonry cut) used to transport water

Those would be any means of transporting water from its source to its designated location. Channels can be rock cut or masonry built. In some cases, the water ways are created by a system of dams and barrages used to lockout different sections of the hill slope in order to divert the incoming water to the desired place of usage.

- Dams and water barrages to hold off vast amounts of water and for water diversion purposes.

The idea of dam building is not an entirely new notion for the nomadic populace of both deserts. It existed as soon as the Iron Age period and it was very successful till the times of the

Nabataeans (fig. 4 and 5), when it was copied by them and essentially upgraded by adding additional technological ideas coming in from the world of Sabaeans.

- Stilling and settling basins for water run-off control and its further sanitation.

Another idea coming in from the earliest of ages available in the both deserts. Stilling basins and settling basins share an almost similar name, but their construction purposes are quite distinct. Settling basins are square like constructions often built as attachments to the water gathering cisterns and sometimes even as a part of the water transporting chain of canals as an additional method of preliminary water cleaning. Stilling basins on the other hand are square like constructions used in water transport for the sole purpose of controlling the incoming water discharge. Built in the chain of water transport the basins could be used to work in tandem with dams and terraces in order to dissipate the incoming water torrent, to ensure the safety of the water transport.

- Water cisterns and reservoirs for storage and usage.

The last part of the water catchment system. Water flowing in from canals or water conduits was essentially stored in those square-like stone cut or masonry constructed buildings. Here it was available for extraction.

- Water retention basins

Built for the purpose of capturing vast amounts of water that very often proved to be fatal for the water catchment and regulation installations as for the people that occasionally could drown in such an uncontrolled event.

This overall plan shows that the Nabataean water technology wasn't created in a cultural and technological vacuum. Many ideas used by the Nabataeans have been recycled from earlier periods, like the overall scheme of the hill terracing, reservoirs and rock cut water conduits. Some of them like dams, leave traces of Sabaean origin. Second Period Aqueducts could be inspired by the works of engineers from Asia Minor. Many later additions are easily discerned as to have Roman origin.

Facilities may vary in size and construction methods but they all pursue the same goals and similar design choices.

Fig. 4. Water dam at the Nabataean Siq

Fig. 5. Water dam at the Nabataean Siq

4.6.3 Cisterns

The cistern finds itself in the Middle East represented by all different sizes and styles. Built for the sole purpose of collecting rain and spring water that could be used later for drinking. In the Middle East cisterns were most commonly cut in the rocky subsoil of the earth in shape imitating the texture of a bottle. With a very thin bottleneck and a much bigger core of the water reservoir. This solution proved to be very successful in the arid regions of the Israeli Negev and Jordanian Southern deserts because of its low building material dependency. P. Keiholz gives examples of four different shapes of water cisterns found in the city of Gadara[220]:

1) In a form of a pear
2) In a form of a funnel
3) In a form of a bottle
4) In a form of a playing dice

This means that they could have been easily hidden underground and that possibility was a great factor in designing the sizes of some of those bigger cisterns.

Constructed in different shapes and dimensions that varied through the ages with the main ground plan that stayed more or less the same.

In cities and wherever possible reservoirs could have also been built from stone cut masonry[221]. The most commonly used shape would be that of a rectangle and from there the ideas reached over to the most obvious plans such as squares and in some cases cisterns are shaped in circles[222]. Sizes of such constructions varied from those very little ones of approximately 0.50 m. in length, 0.33 m. in width and 0.30 m. in depth to those that their enormous sizes awake naming issues. Great examples for this situation could be seen in the two cisterns of Humayma found in the so-called habitation centre[223]. They are measured to have

[220] Keiholz (2008), p. 207.

[221] Stone slabs, and sometimes marble.

[222] Oleson (1988), p. 166.

[223] *Ibidem,* p.166.

capacities of 445 and 487 cubic meters respectively, and according to P. Oleson[224] they are almost large enough to be called reservoirs.

Looking at those numbers one must realize that in order to achieve a capacity of 445 and 487 m^3 the cistern should have had approximately 20 m. in width, 15.00 m. in length and a supposed depth of about 1.5 m. and further reading Oleson we can see that they:

> *"…have been narrow enough to be roofed with flat stone slabs carried by sixteen transverse arches".*

Oleson (1988), p. 166.

Sadly, the author doesn't give any measurements of the width of those cisterns in order to assume what is the allowed upper border for construction of such a roof. However, taking into account the researchers statement we can assume that the border for the construction of cistern vaults would be somewhere close to the value of 14 to 16 m in width.

Every construction of a cistern should have to acknowledge the incorporation of a lid that would enable the user to close the water storage after use to ensure that no light will enter the cistern and trigger the growth of algae also it prevents the loss of water by evaporation (which was frequently not the case in the Middle Eastern water management facilities[225]). Another standard addition to any cistern was a flight of steps that were used for two different tasks. One was the cleaning and maintenance of a cistern, secondly it helped in the drawing of the water with a bucket when any other water lifting mechanism was unavailable. Furthermore, every cistern should be built with a settling basin preceding the point where the water enters the tank.

Cisterns can be built anywhere thanks to their design which takes into account all of the possible places of their construction. But in the case of the Middle East and its water derived terrains there are only a few places where a cistern could be built and perform its intended usage to the fullest:

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[224] *Ibidem,* p.166.

[225] Early Bronze age open cisterns. Discussed in this work.

Aqueduct lines

Cistern usage in an aqueduct line is very common and widespread across the Middle East. They accompany the aqueduct water line in its journey to the main tank of a targeted settlement. In some instances, those additional basins served the purpose of water drawing cisterns for the people that live around them[226]. Settlers or shepherds. In other situations, they would fulfil the role of settling basins[227].

Vitruvius on cisterns

First of all, to construct a cistern or reservoir we need to have knowledge about the making of the opus signinum which would be the hydraulic plaster. Essentially, it's just a mix of pure sand with broken limestone. (Lime and mortar)

Next is to dig a trench to the desired depth and then lime it with rods sheathed in iron. The best idea is to make those cisterns double or triple. That means that they should be connected with settling pools. Two or (for a better efficiency) three of them. Settling pools are little basins where the water is being filtered out of unnecessary filth that could accumulate before it reaches that last cistern where the water should be perfectly safe to drink. They work in the same fashion as they are called. Settling of the water enables the heavier particles (that have earlier mixed with it) to sink down to the bottom of the basin. Thus, ensuring the water doesn't have any unpleasant sights of mud or anything else. Otherwise Vitruvius suggests filtering it with salt.

4.6.4 Reservoirs

The difference between a water cistern and a water reservoir is that of its intended usage, construction methods and volume of resource accumulation. Water cisterns are most commonly designed with a lid that would enable the user to lock it after usage as was mentioned earlier.

A reservoir on the other hand is an open water source that strongly resembles an artificial water aquifer. An open character of this constructions presents new difficulties for water storage. Water evaporation and algae growth are uncontrollable in this environment and this in all probability cancels out the possible usage as drinking water. Water reservoirs fulfil the role

[226] Oleson (1988).

[227] *Ibidem.*

of very large water storage areas. In some cases, they also fulfil a secondary role of water retaining basins, collecting excess amounts of water that would endanger the existing transporting lines or even human lives (tragic event at Petra on 1967)

The open character of the reservoir makes it a daily water source that must be frequently refiled either by any means of water engineering or frequent rain which is not the case in the desert or semi-desert conditions of the region of the Nabataean Kingdom. The most famous reservoir complex in the Middle East would be the "Pools of Solomon"[228]. Apart of the Pools of Solomon complex all of the aforementioned reservoirs where mainly used in smaller communities. Small reservoirs but in a large number. The biggest reservoirs ever built in the ancient times are those that supplied the biggest cities of the period and they had been divided into three separate groups according to the type of construction by Jean Pierre Adam. Chambers and Pillars belong to the first group. Rome has built the Prisicina Mirabilis at Misenium (present day Bacoli)[229] that is the final point of the Augustan Aqueduct that went from Serino to Misenium passing by and supplying cities such as Pompeii and Naples. Barrel-vaulted cisterns create the second group. Its main representation is the great cistern of Domitian's villa at Albano 11m wide and 123m long.[230] Parallel chambers, consist of a series of parallel and interconnecting vaulted galleries, and arrangement that can be seen in the towns of North Africa (Bulla Regia or Thugga)[231]. Province administration centres like Alexandria and Byzantium also built their own reservoirs. In the latter city the largest one measures 141 by 73 m and has 420 columns. These huge cisterns built by Valens and Justinian still serve the city of Constantinople.[232]

In terms of construction the reservoirs and cisterns are reasonably very easy to build and maintain.[233] Archaeological evidence suggest that they were used from the earliest times and

[228] Three large reservoirs, following each other in line, stand several dozen meters apart, each pool with a roughly 6 metres (20 ft) drop to the next.

[229] Adam (1999), p. 249.

[230] *Ibidem*, p. 249.

[231] *Ibidem*, p. 250.

[232] Forbes (1955), p. 148.

[233] The knowledge of construction of a water reservoir is available to us mainly through the works of Vitruvius

even by the most primitive peoples. In the Middle East, they have been often used by all available members of the society. Starting from the greatest of kings going down to the smallest of agricultural land. Built by Empires such as the Assyrians that built them for the people of Israel.

Finally built by the nomadic tribe of the Nabataeans long before they could be called a kingdom but just in time to make a great use of them in their trade road takeover.

4.6.5 Dushara and sacred water in Nabataea.

Lifestyle of the nomadic desert travelling tribe of the Nabataeans is very closely related to their skills of rainwater capture, which stood for the biggest part of their available water supply. But even in a desolate desert one can find a relevant water source. Utilized and upgraded it could be used for variety of different activities. The nomads could not ignore a blessing of fresh water in the desert and so they thanked Dushara for it. Associated with flowing water the goddess Dushara appears as the most important god in the Nabataean pantheon. Considered to be the chief national god of the Nabataean Kingdom[234]. Pillar idols, votive tablets, niches and sometimes even sanctuaries have been frequently raised in the immediate vicinity of the water or transport line.[235]

According to the Byzantine writer Suidas, Dushara was worshipped at Petra in a form of a square aniconic stone, but anthropomorphic representations of the goddess are also known especially on coins that appear at Bostra (Commodus – 2 A.D.) and on some final issues at the last years of the Independent Nabataean Kingdom.[236]

The Cult of Dushara was not exclusive to Petra[237] but it also spread across the entire territory of the Kingdom. In 1937 the Colt Expedition uncovered ruins of a temple at ‘Avdat, with painted plaster walls. Nabataean character of the site was confirmed by the usual north-

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[234] Negev (1963), p. 114.

[235] As evidenced in important Nabataean settlements such as: Humeyma or Oboda.

[236] al.-Salameen (2011), p. 70.

[237] Also, it was not exclusive to the Nabataeans. According to A. Negev it is no surprise that the Thamudic E inscriptions from the Hisma desert of southern Jordan contain numerous invocations to Dushara, for he was after all the local deity, taking his name, or rather epithet, from the Shara range of mountains near Petra. 270 It is therefore highly probable that his worship predates the settling of the Nabataeans in this area and the authors of the Thamudic E texts from this region, or their ancestors, may well have been worshipping him long before the coming of the Nabataeans.

south axis alignment of the walls known from Nabataean architecture as well as a direct parallel with a similar ground plan of tripartite Nabataean temples from the region of Moab. With a porch, hall and adyton. Difference lies in the unusual division of the adyton in the ‘Avdat temple. The crew setup an idea that the largest west part of the construction was devoted to the traditional Nabataean gods as Dushara and Allat. The smaller east part was dedicated to a regional god. Probably Obodas II who was deified after death.[238] The construction also included a drainage channel for removing rainwater from the foundations that crossed the southern wall.[239]

Humeyma is home to a tremendous number of Nabataean Water Management devices. Also, a shrine that held an aniconic representation of a Nabataean deity, used in the Roman period (2nd and mid-3rd century A.D.) The shrine was a single room (6 by 6 m.) located in the centre of the southern side of the Roman Barracks and oriented to the east. Two mudbrick bias and a shelf were constructed along the west wall facing east. Remains suggest that only the eastern part of the room was roofed, leaving the space above the cult objects open to the sky, an arrangement known from a contemporary house shrine at Mampsis (fig. 6). The shrine was dedicated to the local” God of Hawara” [240]. Years later its dedication has been read a new by Oleson and his team[241]. This new interpretation was taken from an inscription visible on an altar located just north of the shrine. As mentioned earlier Dushara was connected to the Nabataean water abundancy. Many water gathering constructions had been dedicated to the goddess. Example being the famous ‘Avdat water dam dedicated by its builders during some kind of a yearly festival or possibly the festival cold be held for the special occasion of commemorating king Rabels II great water management project that included the construction of the mentioned dam. The dedication is connected with the popular inscription “That brought deliverance to its people”.[242]

[238] Negev (1991-92), p. 108.

NEALH.

[239] Negev (1993), p. 109.

[240] Oleson (2003), p. 47.

[241] Oleson et al. (2002), p. 112, 116.

[242] Negev (1963), p. 115.

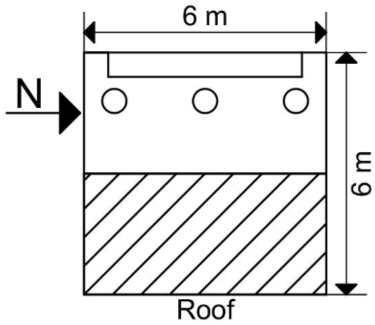

Fig. 6. Dushara shrine at Humayma

As a very mobile nation. Nabataeans often infiltrated other cultures and often they "brought" back some ideas that they later assimilated in to their lifestyle. As it was once done with their water management technology. Cult of the "sacred water" often connected with Dushara bears striking resemblances with similar practices coming from the territory of Asia Minor. Phrygians share the same kind of architecture (rock carved) that the Nabataean tribe and thus this sparkled the rise of an idea that there is some chance of people from Asia Minor to have worshipped water in the same way as the Nabataeans did.[243] Small rock-cut basins are found in some Phrygian cultic sites and some of them are found inside the shrines and some are lined with channels to transfer water to the basin to be used in the sacrificial rites. Similar Examples are attested in the vicinity of Petra probably used for ritual purification.[244] This Nabataean – Asia Minor connection is evidenced by Zeyad al-Salameen, who points out that the:

[243] Leigh – Ann Bedal supports this assumption saying that "it is not surprising that the Nabataeans perceived water as sacred and that the many examples of ornamental water display in Petra held religious significance. Numerous religious icons, inscriptions, and sanctuaries are found in association with springs, catchments pools, and channels throughout the city and its environs".

Bedal 2003, p. 99.

[244] Healey (1993), p. 10.

Phrygian rock-cut architectural remains include rock-cut facades, niches, idols, stairs, platforms in addition to other structures mostly cultic in character. Rock-cut niches and idols common in Phrygia are mostly linked with the rock-cut step monuments which are concentrated in the Phrygian highlands and appear in many forms some of which are surrounded by a large imitation of façades. These rock-cut features were constructed close to water sources and they have been interpreted as waterside shrines. Additionally, there are rock cut holes or cavities inside the Phrygian niches and these were cut to receive sacrifices and votive offerings

al-Salameen (2011), p. 58.

Close connection between sanctuaries and built elements of the Nabataean infrastructure has already been demonstrated by the excavations in the Siq carried out by Bellwald.[245]

4.7 From the 1st century A.D to the earthquake of 363 A.D.

The fall of the Kingdom was anticipated by its last king Rabel II. Upon the discovery of new water trade route around the Arabian Peninsula, through land caravan trade routes (controlled mostly by Nabataeans) suffered a heavy blow and already brought tidings of things to come. Analogously, the Nabataean conflict with Alexander Janneus over the Mediterranean Sea port at Gaza exemplified what would Nabataea suffer if cut off from its merchant revenues. Closer to the year of 106 A.D. nomadic trade was already almost entirely controlled by the incoming Roman administration and so the last king of the Nabataeans begun his grand program of recreating the nomadic economy in a completely new way. Re-using the water technology of the past, the king built farms that had been watered by the run-off water system once used only for water collection. For his revitalization of the Nabataean spirit the king was honoured a title “Rabbel who brought life and deliverance to his people”[246]

Full Roman administration favoured further Romanisation of the Middle East. More and more roman citizens came to live in the rich- trade driven region of the world. Petra lost its position as the main city of the Nabataean people and gradually declined. Gravity of the remaining Nabataean influence and lifestyle has shifted much closer to the waters of the Mediterranean Sea. Nomadic waystations built in the years before had begun to change either

[245] Bellwald (2003).

[246] Negev (1963), p. 115.

into full-fledged roman towns or they have been reconstructed as Roman watchtowers[247]. New settlements construct buildings typical for a roman type urbanisation. Square street plan, theatres, artificial fountains, baths and Roman temples are but just few elements of the change that engulfed the once independent lands of the Nabataean. New water management and usage technologies were incorporated. Some of them were already available, but few in number[248].

The so called Late Nabataean period is considered to be the most successful episode in the entire history of the Nabataean people. Ironically its beginning is dated to the year that the independent entity of the Nabataean Kingdom ceased to exist as it was annexed by the Roman Empire and turned into the province of Arabia Petrea with its main city moved from Petra to Bostra.

The gradual fall of the independent Nabataean state is a wide topic encompassing an enormous spectrum of different variables that would easily go beyond the frames of this work. That is why we will focus only on the Nabataean water systems in their last period.

4.7.1 Caravanserai and Baths

The Nabataean Caravanserai are probably the most important element of the Nabataean Kingdoms economy. Originally built as way-stations on the frankincense – spice trade route. They helped tired desert travellers. Here you could buy some food, have a drink, resupply your caravan, water your animals, generally speaking rest and prepare for the road ahead. The caravanserai was a way of sharing their Nabataean water collection secrets with strangers, but of course for a small fee. A typical Nabataean caravanserai was a rectangular (close to square) construction with sets of rooms located around a central courtyard. Parallel and perpendicular rooms create a fortress type location. The configuration of rooms depends solely on the designer, but in most cases a typical caravanserai contains several rooms for guests, kitchen facilities, storage halls and stables. Better financially suited sites even contained elements of a bathhouse. Caravanserais strengthened their position further after the fall of the Nabataean

[247] Israeli (1991-92), p. 102.

An archeologically observed trend of reconstruction of some of the old Nabataean buildings and their re-usage as watchtowers or parts of some fortress utilities.

[248] First Nabataean bath constructed in the 1st B.C.

Bikai, Kooring (1995), p. 507-533.

Kingdom and the creation of the Roman province of Arabia Petrea. Then they remained as one of the last witnesses of the Nabataean rule.

Imperial and private bathhouses widely spread across the entire dominium of the Roman Empire. The most successful branch of the imperial entertainment system. Used by a plethora of different people, separated by wealth and political status. Everyone could enjoy the benefit of attending a bathhouse only by paying a small entrance fee. Open from the earliest time of the morning till the evening the bathhouse offered a wide range of activities ranging from physical exercises to lazy sun-bathing. Roman favourite time to spend time in the bathhouses were the evenings, after the end of their daily duties they could enjoy their free time, talking and relaxing in the sacred halls. After that it was often time to go to an evening's dinner at a friend's house. Some bathhouses had fixed hours for woman and man attendance, but in most cases bathhouses were places for community gathering unrestricted by gender or social level. They were the greatest weapon of Roman propaganda, here everyone could feel equal when spending their time naked and in the same room as the Roman elites. In the Bathhouse, everyone was "he's own man".

Bathhouses didn't have standardized ground plans. This means that their overall design and architecture was placed in the hands of the employed architect. Only thing that should be true for those types of constructions were the types of the rooms available for their guests.

Apodyterium – entrance and the "locker room". Here guests would undress and store their personal belongings until they are done with their bathing pleasantries.

Caldarium – a room were bathhouse guest could use a hot water basin.

Frigidarium – the cold-water room. Basins filled with cold water.

Tepidarium – the warm water room. Basins filled with a moderately hot water. Warm if you will. The *tepidarium* served as a room where the bathhouse attendants could relax. Hot air that raised the temperature of the room was coming from the floor heating system called the *hypocaustum.*

Hypocaustum – floor and wall heating system that used hot air means of raising temperature. Consisting of a system of terracotta or lead pipes that converged hot air coming from an oven to a raised floor. The floor was built higher than the ground level by means of square bricks laid one on another and forming columns. Stone pillars are very rare in the southern Jordanian parts of the Nabataean Kingdom and are based on their Near Eastern parallels (Masada, Jericho or Ramat Hanadiv)[249]. This idea ensured air circulation beneath the floor. Any bathhouse could also have some additional secondary features, such as:

Paleastre – exercise grounds

Sudatoria or laconica – Sweat baths

Destrictaria - strigiling[250] rooms.

Sphaeristeria -ball courts

Natationes or piscinae – open air pools.

According to the author Garrett G. Fagan those additional rooms could be found in a roman bath, but are not the defining features of one.

It was theorized that after using the apodyterium, which would be the first logical choice of a man who doesn't want to bathe in his garments on, the bathhouse client would go straight away to the *tepidarium,* after that he would visit the caldarium, finishing his ceremonial venture in the frigidarium. Despite this theory of "arranged movement", bathhouse clients enjoyed a complete freedom of movement through the available rooms. This idea appeared during the analysis of several bathhouse ground plans that showed no intention coming from the designer to force a unitized system of movement through the facility. Some plans showed an apodyterium at the entrance and the other rooms were scattered across the construction allowing for a complete freedom of choice. Of course, some people always have their favourite ceremonials that they like to routinely undertake but that would belong to the client's personal choice. [251]

In the region of the Nabataean Kingdom bathhouses appeared after its transformation to the roman province of Arabia Petrea during the years 106/107 A.D. when roman administration and their urbanisation plans came to work in greater effect. It is a well-known fact every person's favourite place in the world is their home where they can feel safe and comfortable. Even while traveling we like to feel everywhere at home. So often when during our travels, we

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[249] Bikai, Egan (1997), p. 518.

[250] Strigling is a word describing the action of scraping off dead skin with a tool called a strigil.

[251] Yegul (2009).

take something with us that would bring back that feeling. This also what hotel and hostel owners have to strive to achieve if they count on a profit. And of course, this also applies to the wealthy people. Surrounded by luxury during their normal day to day activities they also would like to experience the same while on the road. Being relaxed and feeling comfortable makes good for business. Nabataeans being a very resourceful tribe fixed on expanding their wealth probably decided to borrow some of the ideas from the European part of the Roman Empire and made sure that this little site in Wadi Ramm has the best conditions for a wealthy Roman merchant to conduct his business.[252] This could be a reason for the earliest traces of a Nabataean bathhouse installations built on the Aqaba – Damascus- Gaza trade route. But that doesn't mean that the idea of the bathhouse wasn't used in private, residential setting. Evidence can be found at the site of Khirbet edh – Dharih[253].

4.7.2 Gardens

Gardens are a very unique occurrence in the Middle East. They do exist but in a very scarce number and their availability is stretched through time. They could be seen in the cultures of Mesopotamia and Egypt. The Neo-Assyrians Kings established the royal garden as a way of a symbolic re-creation of the expanding Assyrian empire. Later connected to the Achaemenid royal palace architecture. The Mediterranean world learned of the Persian *pairadaeza* after the conquests of Alexander the Great. Described by Xenophon (Oeconomicus 4.13, 4.20-24) who introduced a new Greek word *paradeisos.* Subsequently it became to describe one of the most important constructions in the Greek palace architecture. Recreational facilities which included pavilions, zoos, theatres, promenades, pools etc.[254]

Discovery of such a garden facility made by Leigh-Ann Bedal in 1998 came as a tremendous surprise even to the digging crew. Although by the account of Strabo (mentioned earlier) it should not come as a surprise.

[252] This notion is not a complete innovation in the Nabataean world. See chapter Caravanserai.

[253] Chapter 6.2.10.

[254] Bedal. (2001), p. 33.

4.7.3 Farming, agriculture

Up until this point the Nabataean water engineering prowess was shown almost to its full extent. Despite their enormous knowledge of water management, farming and the overall idea of agriculture was completely neglected in favour of increasing the overall trade revenue of the Kingdom. Water accumulation systems were mainly used for the purpose of capturing able drinking water. Farming was never considered as a big part of the Nabataean economy[255]. But that does not exclude the existence of small earth patches that could have been irrigated and cultivated for the usage of small communities living in the close vicinity of valleys or run-off facilities. Despite this possibility, the Nabataean means of survival were as always largely based on the nomadic lifestyle that mostly considered sheep/goat breeding. After the death of the last king of the Nabataeans in the 2nd century AD the Kingdom was incorporated into the Roman administration. Previously Nabataean monopolized trade routes have been taken over by Imperial merchants, successfully pushing off Nabataean control and destroying the main revenue of the nomadic economy. By this change farming and agriculture had been enforced on the Nabataean people. It comes with no surprise (looking at the environmental conditions of the Middle Eastern desert as well as the preserving nature of the nomadic Nabataeans) that this change should be considered a milestone in the Nabataean history. The aforementioned king Rabbel II (76 – 106 AD.) foresaw the lurking change in the economic situation of the Nabataeans and its later escalation at the time of his death. Sometime in the middle part of his rule he began to develop large scale agricultural facilities based on the already existing principle of water collection and management systems built around the region of the Nabataean Kingdom.

Ideas implemented by the nomads were long known before they begun to monopolize the Arabian trade routes. Nabataean achievement was largely based on the scope of the enterprise. It required almost an entire “nation” of nomadic people to change their pastoralist behaviour into an agricultural sedentary lifestyle. The “agricultural revolution” most probably affected the richest of the Nabataeans who previously acquired and sustained their wealth by engaging in the Arabian trade routes. The “city” dwellers became land owners that hired people to work on their farms while other groups remained nomadic. The archaeological view of the

[255]Nabataean economy was heavily based upon the revenues acquired from the trade routes coming in from the port of Aqaba. Food production was based on a typical nomadic lifestyle - Camel and sheep/goat breeding.

Nabataean settlements changed completely. From only a handful of heavy populated cities to a massive dispersion of little settlements that engaged in farming and animal breeding. The most pressing issue with this technological and social change would be the massive scarcity of land usable for agricultural activities and that it had to expand rapidly over a significant region. This problem was solved long before the nomads transition and is attested in the Nabataean water management practices through their entire existence in the Negev, Hauran and Hisma deserts.

Nabataean water systems were largely based upon their bronze/iron age counterparts, already extensively used in early agricultural activities. The same principles of water use and catchment applied when considering their usage. Channels brought water from the top-hills to the wadis beneath were previously prepared terraces contained the water in several rectangles by usage of barrages and dams. This enabled the Nabataeans to grow plants in the desert, which became their new economy and once again brought life to the desert

Desert run-off agriculture could be easily divided into two categories.[256]

- Constructed within the wadi beds proper with the aid of dams
- Constructed on the wadi banks with the aid of dams, walls and canals.

The most archaeological and iconographic material attested site for the development of the Nabataean agricultural technology would be the biggest and the most important settlement in the central plain of the Negev Desert. Oboda (or ’Avdat) probably held the great function of the “capitol” (administration centre) of the Negev in the late years of the kingdom, but it flourished still in the later Byzantine times. Excavations held by A. Negev in the early 50's of the past century proposed a view of the Nabataean tribe as a very nomadic population, concentrated on sheep and goat breeding with a high dependency on brigandage for the amassment of luxury goods. Additionally, the excavations shown a very advanced water collecting facility established in the settlement – by that time it was the only water system found in the entire Nabataean Kingdom. Archaeological reports published by Negev show a very different picture of the Nabataean conglomerate as we know today.

[256] Zohary (1954), p. 21.

4.7.4 *Epigraphic evidence*

Apart from what can be seen in the land the excavations also revealed parts of destroyed artefacts containing written language of the Nabataeans. Upon analysis, they have been discerned into three categories.[257]

1. Dedications engraved in marble or in building stone, most of which were found in the western part of the acropolis of ‘Avdat, where a Nabataean temple is supposed to have stood.

2. Inscriptions on large stone objects, found mainly in the tributary gulley of the ‘Avdat Valley; fragments of such stones were found in the large courtyard of the Byzantine citadel, certainly not in situ.

3. Inscriptions on small finds discovered in the acropolis area – city dump No.1 and in the Nabataean potter’s workshop.

The most interesting finds for the scope of this work consist of several inscriptions that define the elements that carry them as they could (in spite of their discovery places) be used earlier in the water management systems. Inscriptions have been translated by A. Negev’s team.[258]

4.8 *Nabataean mortar*

Chemical compound widely used in stone construction, valuable for its solidifying characteristics that enabled people to build high raising constructions is called mortar. Not only known in architecture but also very often used in a variety of water conveyance methods for its unique capability to seal of the water channel and prevent water seepage. This special type of mortar is called hydraulic mortar.

Nabataean usage of the so called hydraulic mortar[259] is considered as an effect of the most widespread human ingenuity development process – the trial and error method. By the help of the science of mineralogy we have determined that on some sites the Nabataeans used local

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[257] Negev (1963), p. 127.

[258] Negev (1963), p. 133.

[259] The name derives from a type of mortar that can „dry” itself while underwater. On contrary to regular mortar that dries on the wind.

rocks in order to prepare the hydraulic mortar mix. A mix of sandstones and carbonate rocks is required. Due to the process of raw material grinding we can observe sandstone, silicate rocks and quartz grains. While carbonate fragments could be used mainly in form of loose sediments.[260]

The hydraulic property of the mortar can be increased by the addition of pottery fragments and charcoal, while the presence of clay with lime makes the mortar more water resistant.[261]

4.9 Hammonds Theory as a probable answer to the Nabataean success.

Nabataeans were indeed one of the most fascinating conglomerates of people living in the Middle East. They settled in the most dangerous environment that was unfit for the survival of a human being and changed into a sprawling caravan highway. Abundant with the most important resource of water, the Nabataean trade could prosper and travel the desert regions of the Arabian Peninsula, Jordanian deserts and the Negev desert, without any fear of a diminishing water supply or a hostile caravan raid. No one knew the routes of the Nabataeans nor their hiding locations. In face of danger they usually turned to their desert fortress hidden from the eyes of strangers.

Abundant with water supplies they prospered as a nomadic tribe and later due to their Hellenistic transformation they became a meaningful player of the Middle Eastern political stage.

Different theories concerning their technological prowess in the field of water management have been proposed in order to answer the question of its origin[262]. Considering the theory proposed by Hammond[263] for the origin of the Nabataean people as a tribe we could also go a few steps further and (in light if what we know so far) suggest that Hammond relates to an actual state of knowledge that the early Nabataeans possessed in their first years of the 4th century B.C. that was possibly later only further enhanced through their long trade contacts with not only the Sabaeans but all of their trade contacts, and thus the Nabataean water management technology was born as a synthesis of knowledge and practical skills brought to

[260] Bonazza et.al. (2013).

[261] Goffer (1980), p. 107.

[262] Tali Erickson gini described one, Hammond the second.

[263] Discussed earlier as a part of the origin theory.

the Nabataean Kingdom before the 1st century B.C., by their long range contacts with multiple ancient civilizations of the Arabian Peninsula and the Mediterranean world.

Their water knowledge was chronologically differentiated by M. Evenari into three stages that occurred over three different periods of time.

Although built in different time periods they all work on the same pattern of rain water collection and its later distribution on the terraced fields. The same system that had been in use the far away land of the Sabaeans was already at work in the Negev deserts as soon as the Early Bronze Age (although it was not as technologically advanced as the Sabaean one and not so carefully planned). This notion makes it clear that Hammond's theory on the origin of the Nabataean tribe contains elements that could be agreed upon as highly probable. Like the idea of inheriting the agricultural knowledge from the Idumeans and thus the creation of the agricultural terraces that could be tied with M. Evenari's first group of farming constructions.

Whichever was the case the (proposed) combined strengths of the two tribes, were probably already reinforced by newcomers from the lands of the Negev. Kingdom states that ruled over the region in the earlier times periods, withered and fell apart in the wake of the diminishing trade or military conflicts. Populations of those kingdoms had to revert back to their nomadic roots. This was probably one of the elements for the creation of the so-called Nabataeans.

Populations that lost their initial states wandered around the desert and eventually met the trade faring nation and upon contact decided that they should join with them to increase their chances of survival. We cannot also not take into consideration the idea that many of these new nomads already knew the trade faring, soon to be called Nabataeans and had the knowledge were to find them. In this way, the gathering nomads could exchange knowledge and in course of passing years, eventually merge together. Thus, creating a new identity for themselves. Those contacts allowed for the exchange of the water gathering and storage technology that the Nabataeans slowly started to apply. Most of the cisterns that the early Nabataeans used were of Iron Age origin and heavily predated any of the purely Nabataean constructions. This leads us to the idea that most of the early water technology of the trade route was reused from the already existing frankincense trade that was previously run by the Sabaean merchants coming in from the southern parts of the Arabian Peninsula. The fall of the Sabaean kingdom and their diminishment in frankincense trade allowed for new players to enter the merchant game. Creating a conduit of new ideas that had flowed into the Nabataean community establishing the agricultural farmstead that was grouped by M. Evenari as the second possible farming construction in the Negev.

The Hellenisation of the main settlement of the Nabataeans named Petra expanded their water technological ideas even further. The water transfer and storage ideas that the Nabataean already possessed from their assimilation with the Idumean and Edomite tribes has been greatly expanded thanks to their merchant work in the basin of the Mediterranean. Knowledge gathered from around the Nabataean kingdom later served its purpose in the grand scheme of reforming Petra and the entirety of the Nabataean tribe into a Hellenistic Kingdom. This huge scale enterprise slowly introduced The Nabataean people to: Aqueducts, reservoirs, ceramic and lead piping, all visible in the new Hellenistic image of Petra.

Hammond's theory could be used to describe a wider range of the Nabataean development. When taking into consideration the overall success of the Nabataean tribe as a whole and by closely discerning the development factors that are easily argued to have arrived as a foreign addition to the starting population of the soon to be Nabataeans, we arrive at a probable conclusion that the origin of the tribes identity should be closely linked with the merging of the nomadic tribes that roamed the regions of the Negev, Hisma and Hauran deserts in the close vicinity of the nomadic gathering place of Petra.

4.10 Conclusions

Our current knowledge on the Nabataean history and their archaeological remains leads us to believe that the water accumulating technologies solely created by the Nabataean technological thought should be dated to the second period of the Nabataean rule. Their early period is still dominated by nomadic lifestyle and many of the technological ideas utilized by them should be considered as a second-hand reuse of the already available construction left by the previous nomadic and kingdom-like dwellers. Archaeological evidence confirms this overall attitude of the Nabataean settlers.

5 Archaeological Sites

5.1 Israel

5.1.1 'Avedat (Oboda)

Visited in the early XX century by P.P. Jaussen, Savignac and Vincent who drew a site plan through careful examination and later published their work in the Reuve Biblique (Nouvelle serie I, 1904, pp.403-424).[264] Oboda was a settlement named in celebration of a Nabataean King, whose name preserved in the Arabian 'Abdah. It was erected at the main Alia (Elath/Aqaba)- Jerusalem road, in the first wave of colonization. Identified by scholars with Eboda of Arabia Petrea.

Site is famous for its temples built in the Middle Nabataean period, at the times of Obodas (30 – 9 B.C.) and Aretas IV (9 B.C. – 40 A.D.) It was also a very important site for sheep/goat pasturage as well as later camel breeding. Nabataean pottery manufactures were important during the years of Malichius (40 – 70 A.D.). Destroyed by nomadic Arab raids. The settlement rejuvenated during the rule of Rabbel II (70 – 106 A.D.) - the last Nabataean king. The king's policy was to invest in agricultural technology across the lands of the Nabataean. This action was a direct result to the changing economic situation in the region – vanishing or moving trade routes disrupted the main economical target of the Nabataean people. After the Roman annexation Oboda prospered. In time the population Romanized even further to the point where the city had two temples consecrated to the roman gods – Zeus and Aphrodite. Rabid expansion of the cities borders enforced further construction on the Nabataean ruins. With the construction of a fort, emperor Diocletian incorporated the city to the new defensive line.[265]

In its earliest period Oboda (as every Nabataean settlement) was a nomadic encampment built as a waystation on the Eliat/Aqaba to Gaza merchant route. Dated by Hellenistic stamped rhodian jar handles (320 – 280 B.C.) No dating available for the 1st century B.C. The most possible explanation for this situation would be the fact that Alexander Janneus has conquered the port at Gaza and expelled the Nabataeans from the territory of Negev for almost 100 years. After the arrival of the roman general – Pompey, Gaza is returned to Nabataean possession and the Negev encampments are reoccupied. Earliest construction activities in the settlement are

[264] Lawrence, Wooley (1936), p. 95.

[265] NEAHL.

dated to the times of Obodas III and are built from hammer-dressed stones, as opposed to the much later ashlar construction.[266]

Nabataean military camp

The Nabataean military camp is a large structure located northeast of the acropolis. Built on a square plan 100 m. by 100 m. with singular towers on every corner, coupled with two additional towers between them. All erected by using hammer-dressed stones. The main gate could be found on the southern wall of the fort. In addition to the typical constructions that inhabited a Nabataean fortified enclosure, the fort at Oboda included camel pens. A water reservoir was reported some distance west of the construction. It was supposed to be very similar with the construction at the site of Sobata and similarly stored water for the camels. A large cistern located north of the camp was gathering water from an adjacent slope. The water was probably brought to the fort by means of camelback.

Number of walled enclosures were found in the close vicinity to the settlement. They are linked with a high amount of sheep/goat breeders that lived around Oboda and produced a significant amount of meat for the travelling caravans as well as the army.

Khan (Caravanserai)

Caravanserai built at Oboda was located north of the so called "potter's workshop". Planned as a rectangular construction. 22.5 long and 31 m. wide, constructed out of ashlar masonry with a central courtyard 12 m. long and 19 m. wide. Adjacent to the walls of the construction are rows of rooms and halls. The eastern wall houses six rooms where one of them acts as a

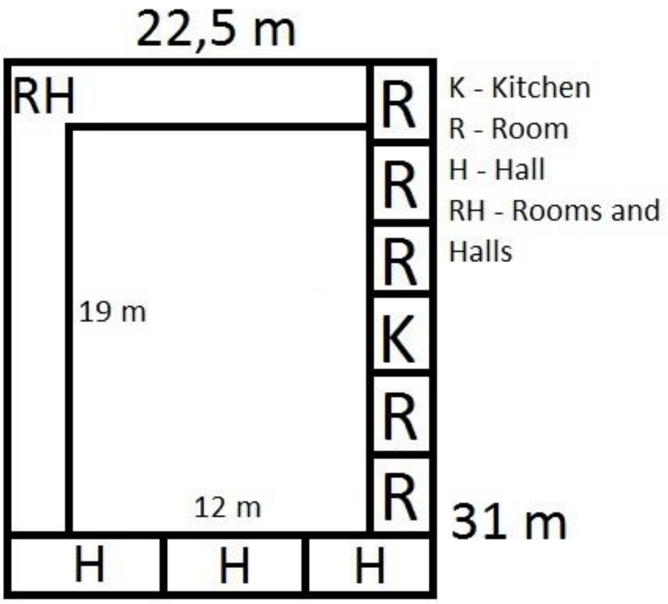

Fig.7. Schematic view of a Caravanserai

[266] NEAHL.

kitchen. Three big halls were identified on the southern wall. Rows of rooms and halls are available in the entire north-western side of the caravanserai. Steps built along the eastern wall lead to an upper story. Construction dated by coins and pottery (Nabataean cups and bowls) to the Late Nabataean period.

Close to the settlement on the Mizpe Ramon – Sede Boqer road there were two adjoining pools found. One of them was placed on the south measuring 6.8 m. in length was partially excavated. The second pool measuring 7 x 7 metres was found entirely plastered.

Fig. 8. Water conduit at ʻAvdat. Photo courtesy of Dominik Elkowicz.

Fig. 9. Water conduit at ‘Avdat. Photo courtesy of Dominik Elkowicz.

5.1.2 Halusa (Elusa)

Elusa was a Nabataean settlement founded in the so called first wave of colonization to serve as a waypoint on the frankincense trade route that connected Aqaba with Damascus and Gaza. In its first years, it was probably used as an encampment spot for the merchants and their supporting guards or guides. Archaeological evidence for the existence of such a camp could be found one kilometre west of the settlements borders.[267] Its ancient name survived in the Arabic name el-Khalasa.

The entire city layout could be divided into three occupational zones, described by their period of existence; western part existed in the Late Roman period while the eastern part should be linked with its Nabataean period. The entire region was protected by watchtowers (which is a usual occurrence in the Nabataean history). During the settlements lifetime, it grew considerably and in Middle Nabataean Period the city consisted of a residential quarter and a theatre.[268]

Remains of a preserved house were identified to the full height of its ground floor. Architectural elements found close to its vicinity encompassed the very popular Nabataean capitals. Elements found ranged from the earliest classical types to the later Nabataean Byzantine. [269]

The theatre was constructed on even ground in the eastern part of the settlement. Built of limestone masonry with a *cavea* measuring 35 m. in diameter and with the orchestra 13 m. long. In the middle part of the orchestra adjacent to the *cavea* there was a separated small area circa 2.8 by 2.9 m. that was probably used as a box for the representatives of the city's community (priest or an administrative bodies). The *cavea* has two vaulted entrances. Construction dated by pottery finds onto the 1st century A.D. In Nabataean times theatres were connected strictly with cult activities. Parallels could be found at the site of Sahr in the Ledjaa, additionally funerary rites have been also conducted at the site of Petra.[270]

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[267] NEALH.

[268] Negev (1976).

[269] *Ibidem*.

[270] *Ibidem*, p. 93.

The Late Roman western part of the city contains archaeological evidence of the settlements water supply. It was a chain of rectangular reservoirs one of which measures 10 m. long, 5 m. wide and 2 m. deep built in a close vicinity to the Nahal Elusa. The wadi itself had wells built on its side that acted like upgraded versions of a *Thamila* with additional capabilities for gathering water. With the lack of archaeological evidence suggesting a technologically planned transfer of the accumulated water storage to the cities limits, we must take into consideration the notion of a manually coordinated action of transporting the water by camel or horseback to the aforementioned cistern. The mentioned cistern was used to transfer the water by means of lead and clay piping to a Byzantine bathhouse and private dwellings in its vicinity.[271] The cistern was constructed out of thick large ashlars consisting the wall of the construction. The survey observed three distinct phases of usage.

1. The original structure was covered on the inside by a thick layer of grey plaster that was applied directly to the inner face of the large stones.
2. A thick rubble construction covered by a thin layer of the same grey plaster, built against the northern wall of the reservoir. Described as an attempt to repair damage.
3. Still another repair of the northern wall, recognizable by its poor workmanship and by the reddish plaster (fig. 9), typical of the Byzantine period in the Negev.

Additional water transporting system conceived of an underground tunnel and shaft system. One shaft was fond in the remains of a courtyard described as a small cylindrical shaft, 15 m. deep, heavily covered with limestone. Upper parts of the system were built out of limestone fragments set in mortar. The lower part was broadend (probably to form a tunnel) and plastered with a thick layer of water proof plaster. The surveyors except it to be a part of a more elaborate water system. Water was gathered from the upper water table near Nahal Haluza in the south of the settlement and it was sent towards the Nabataean city. Water could be drawn directly through the shafts.[272] Taking into consideration the design of the system it could be compared to similarly designed constructions of a khanat.

[271] NEALH.

[272] Negev (1976), p. 94.

Fig. 10. Reddish hydraulic plaster at the site of Gadara

5.1.3 Mamshit (Kurnub)

15 September, 1956 marked the beginning of the first season of excavations started under the direction of A. Negev (Hebrew University), under the auspices of the National Parks Authority. Work later continued in the summer of 1966.[273] Mamshit (fig. 11) known today by its Arabic name Kurnub was a Nabataean town established as a waypoint on the Aqaba – Gaza trade route in the first wave of the Nabataean colonization. Building activity is recorded to begin in the Middle Nabataean period when the inhabitants constructed a fort, several residential buildings a marketplace and a watchtower. The site was described by Lawrence and Woolley in their work - “The Wilderness of Zin”.[274]

[273] Negev (1966), p. 145.

[274] Lawrence, Woolley (1936), p. 122-128.

Fig. 11. Kurnub – General view. Photo courtesy of Domink Elkowicz

The fort was built in the highest part of the city, placed on a rectangular plan with a square construction in the middle to which an adjacent oblong terrace was attached. Around the terrace there are visible traces of additional rooms surrounding the construction. Everything was closed with heavy outer walls.

Residential constructions where placed at various spots across the settlement. Foundations of building XXIV underlie a street while the construction of the building marked as XIX was partly placed on the northern city wall. This building consists of a large courtyard with two rows of rooms. It was demolished in order to build a Late Nabataean water pool (building VII).

The Late Nabatean period saw a great age for the increased prosperity of the town due to the construction of the Via Nova Trajana. Although new trade routes have been built the Nabataean trade could no longer thrive under the Roman influence and so the Nabataeans switched to agricultural activities such as animal breeding. Weak and water less soils could not be taken into account when setting up properly functioning dry farming plots – and so the idea had to be abandoned.

The public pool measured 18 m. long, 10 wide and 3 m. deep. Constructed of large hewn stones with pillars indicating a roofed construction. A. Negev suggests wood planks due to a significant distance between the walls of the pool, which a masonry cut construction could not reach. The eastern wall of the pool houses a square tank that gathers water from a conduit transporting water from the cities walls. The conduit was filled manually by means of horse or camelback transport. The water was brought from water collection systems found in the wadi to the west and subsidiary water collection system from the east.

The south-western part of the marketplace (building IV) was occupied by a very common (for this region) staircase watchtower, built on a square plan measuring 10 x 10 m.

Near the city wall, very close to the aforementioned pool (building VII) stand the remains of a construction very typical to the discussed region, but not very typical for the discussed time. The bathhouse was built on a rectangular plan with two rows of three rooms. The plan of the building could be divided into two parts. The north and the south one. The entrance to the bathhouse was located on the west side of the construction and as in most cases of such buildings it led directly to the *apodyterium.* The room was surrounded by benches and in the middle stood two columns that supported a roof (in situ). Going further into the east side of the bathhouse we enter a room with plastered walls that was identified as a *tepidarium* and by going even further we encounter a door leading to a room described as a *frigidarium*. The room contains two baths and could be reached by means of stairs. One of the baths was octagonal, while the other of circular shape. The entire northern part of the building was dedicated for the construction of the *caldarium*. The caldarium took three separate rooms. The first one on the west side of the bathhouse was designed for the water heating stove. By means of a canal dug beneath the *hypocaust* (fig. 13 and 14) floor of the adjacent room the heated water could be transported further to the last room (also housing the *hypocaust* floor) on the east side of the construction. Water supply and disposal systems were still present at the site at the time of the excavation, as well as the *hypocaust* floors of the northern rooms. The construction of the Bathhouse is dated by means of Nabataean pottery to the Late Nabataean period but was used until the end of the Byzantine. This would mean that the Mamshit bathhouse is one of the few Nabataean constructions of this type available for this period.

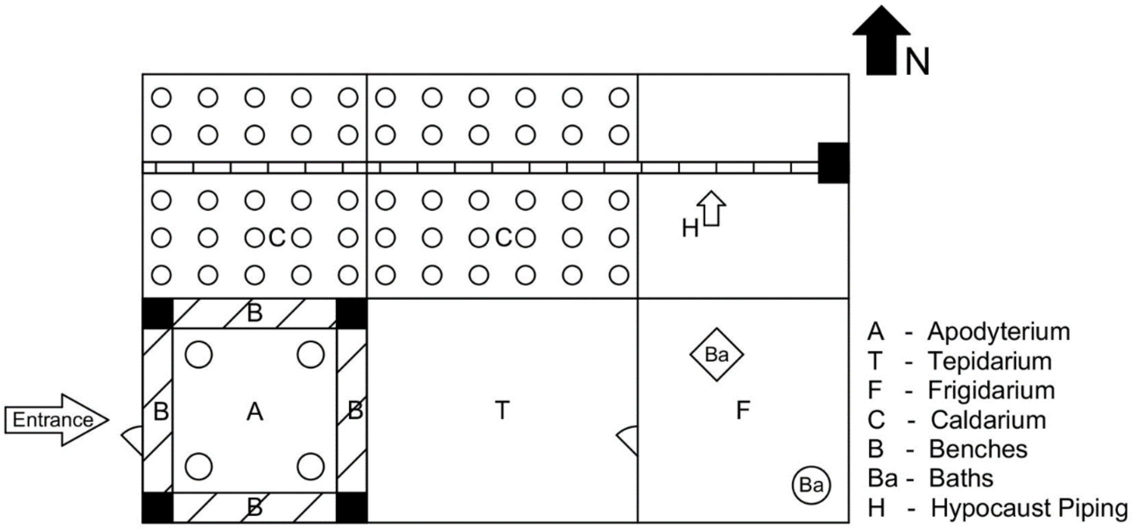

Fig. 12. Schematic view of the Mamshit Baths.

Not far from the remains of the city stands a construction that reminds of the nomadic times of the Nabataean – when the Aqaba-Gaza trade route still flourished.

The Caravanserai (named building VIII) is a rectangular structure measuring 42 m. of longitude and 23 m. wide. With a central courtyard, it paints a perfect picture of a very classical setting for a Middle Eastern caravanserai. The courtyard is surrounded by additional buildings dividing up the plan into two separate sections. The northern and eastern parts of the building contain rooms, while the south-western sector is made up from long halls. One of the rooms contain debris of a hypocaust installation that could mean a possible *caldarium* for additional relaxation value for a travelling guest. Archaeological information could be also acquired about the construction method of the roof. Remains of two different types of roofing were discerned on the basis of the prevalent material found in the construction. Earlier period of the buildings existence was marked with the north-south alignment of the roofing. The southern part of the caravanserai brought archaeological remains that suggest a significant change to the roofing's construction in the later periods where it was made out of wood and changed its construction style to the east-west alignment. The building was dated to three phases on account of the excavated rooms and courtyards.[275]

- Phase A: Middle Nabataean Period. Badly preserved clay tiles paved rooms identified as a small bathhouse. Dating based on pottery finds in adjacent rooms to the Nabataean times of Malchius II.

- Phase B: The team had some difficulty to determine the exact extent of the second phase building whose construction was dated to the Late Nabatean period (2nd – 3rd centuries A.D.) and continued into the 4th century with some repairs.

- Phase C: The addition of a courtyard marked the beginning of the third phase of the buildings lifetime which in turn was dated to the Byzantine period (5th century A.D.)

Water system accompanying the site was of typical Nabataean origin. Three dams were erected in order to halt the soil of the agricultural land found at the North-western part of the close wadi. The lower dam is 24 m. long, 11m. high and 7,8 m. wide at its upper part. Built of large stones embedded in mortar and additionally reinforced by hewn stones set in a hard mortar with an oblique shape. Face of the dam is covered by layers of flint mixed with mortar. The middle dam can be found 50 m. upstream and it measures 20 m. in longitude and 5 m. in width. The upper dam is 35 m. further away from the middle one. 53 m. long and 3.4 m. wide. Shape of the dam constitutes a rectangle.[276]

Additional water systems located west of the city, consisting of a small pool gathering rain water brought in from a 2km. long canal built in the hills and a dam 20 m. long and 3 m. high collecting water from a waterfall.[277]

[275] Israeli (1991-92), p. 102.

[276] NEALH.

[277] NEALH.

Fig. 13. Hypocaust heating system at Mamshit. Photo courtesy of Dominik Elkowicz.

Fig. 14. Hypocaust heating system at Mamshit. Photo courtesy of Dominik Elkowicz.

5.1.4 Mizpe Shivta

The site of Mizpe Shivta is a witness to different mechanical solutions for water capture that existed in the Nabataean lands that were settled further from the central part of the Kingdom.

Site located in the Negev made use of technologies that probably originated independently in this region and were later adopted and changed by the settling Nabataeans. The example of the water supply system consisting of the three circles connected by means of passage that transported the water to its final resting destination that of a reservoir. The first so called circle gathered the incoming water that was then transported over to the second circle placed right beneath the first one. This area acted as a sedimentation pool for the entire system. From here the water flowed down to the so called lower terrace where it was collected by a system of bell cisterns. If those cisterns would overflow with excess water, they could divert it further it in an additional rectangular construction measuring 5 m. by 7m. with a supporting column in its centre. This cistern also accommodates a sedimentation pool.

This description could be probably attached to the terraced water system were the so called “circles” are probably terraces collecting the runoff water. In this case the first “circle” should be substantially larger than the further two. Its surface should be polished clean and flat with additional sightings of several stones, scattered in a random fashion all over the terrace (usual sight for water collecting terraces as was explained above). The second terrace is (as explained) a sedimentation pool, which acts as a cleaning mechanisms for the gathered water. It removes any sediment that is flowing with the water. Last “circle” is the cistern entrance, were the water flows for its storage for later usage.

5.1.5 Nessana

Nessana (fig. 15) was a Nabataean settlement built in the first wave of Nabataean colonization as a waypoint for the Nabataean trade. Dates were based on the identification of the Hellenistic pottery handles. Additional dating was available through the finds of coins: Ptolemy IV (212 B.C.), Ptolemy VIII (127 – 126 B.C.) and John Hyrcanus (134 – 104 B.C.).

Second period for the growth of the settlement into a Hellenistic city was established to the Middle Nabataean period. Dating by Nabataean ware and early Roman pottery. Additional finds of coins minted by Aretas IV (9 B.C. – 40 A.D.), Malchius (40 – 70 A.D.) and Rabbel II (70 – 106 A.D.).

Fig. 15. Nessana – general view. Photo courtesy of Dominik Elkowicz

Temple

A square like building measuring 27 m. long and 25 m. wide built in the eastern end of the cities acropolis was also dated to this second period of the Nabataean rule. Similar in construction with other square like buildings built in the Hauran, Edom Moab and Ledja marked as temples. A middle court measuring 8 m. by 5m. served as a shrine in a typical plan of a Nabataean temple. According to A. Negev[278] the temple at Nessana would be the biggest in the Nabataean Kingdom (fig. 16).

278 NEALH.

Fig. 16. Nessana Temple. Photo courtesy of Dominik Elkowicz.

Late Roman Fort

The ground plan for the Late Roman Fort at Nessana is almost identical with other forts built around the Negev in the late years of the Roman Empire. It is a rectangular structure (85 by 35 m.) placed on the greater part of the acropolis hill. Two towers guard the junction spots of the walls located on the western side and two additional towers were raised closer to the middle. The same configuration applies for the southern wall with the addition of an entry gate between the two middle towers. The eastern side of the fort contains an entrance gate in the middle of the wall. A set of rooms could be found inside the fort adjoining the western wall. The fortifications have been dated by A. Negev to the time of Diocletian (245–311). Similarities in planning could indicate that the fort was designed in the same place as the fort in Oboda. Probably abandoned in the sixth century when Justinian (c. 482 –565) held back funds for the garrisoned soldiers.

Nabataean farms at Nessana

Oded and Almond farms are a typical site for this archaeological region. Fed by water incoming from the surrounding hills that appears either in a powerful rain storm that causes torrential water flows or during a more usual occurrence of delicate rain drops. The gathering water is then transported by means of rock cut tunnels down the hills until it reaches the flat terrain where additional walls or barrages guide the water into the wadi fields themselves. The usage of dams and barrages not only diverts the water to their indented places of usage but also (and furthermost) slows down the incoming water torrent in order to prevent the wash away process of the accumulated fertile soil that is used for agricultural purposes. Sluice gates used in the wadi damming helped to slow the water and enabled it to slowly flow through the wadi. Both farms were shaped into a seven-part terrace system.

5.1.6 Sobata

Sobata in the central Negev desert situated about 40 km of Beersheba. It was founded in the Middle Nabataean-Early Roman period and flourished mainly in the Late Nabataean – Late Roman and Byzantine periods. The Arabic name preserves the ancient one.

The first person to discover the ruins of the ancient city and describe them was E.G. Palmer in 1870. The year 1901 was marked with the arrival of A. Musil who portrayed Sobata in his drawings of the most important constructions available at the time of his travels. Only 4 years later the site was again visited by an expedition from the Ecole Biblique et Archeologique in Jerusalem with the participation of A. Jauseen, R. Savignac and L.H. Vincent who located the Byzantine time cemetery.[279] In 1914 C. L. Wooley and T. E. Lawrence drew more precise plans of the town and churches. 1916 was marked by the expedition of W. Bachmann, C. Watzinger and T. Wiegand, who made an aerial photography of the site. 1934 and 1938 were the first years of archaeological excavations that were carried out on the site on the behalf of the New York University and the British Archaeological School in Jerusalem led by H.D. Colt but never published. Almost 30 years later, A. Negev undertook new surveys in the vicinity of the site (between 1970 and 1976). Work done by Negev later resulted in archaeological excavations carried out by A. Segal with the Ben-Gurion University in the years 1979-1982. In

[279] NEALH.

1985 the North Church was examined by S. Margalit and the city plan of Sobata was analyzed by J. Shershevski.[280]

Occupation at Sobata began in the Middle Nabataean peiod. It was established in the early part of the reign of Aretas IV (9 B.C. – 40 A.D.) or perhaps even earlier in the time of Obodas III (30 B.C. – 9 A.D.) The town prospered in the times of Rabbel II (70-160 A.D.) when the Nabataeans began to engage in desrt farming and horse breeding. Roman times at Sobata are not very well known. Probably the town was re-established when Diocletian fortified Nessana, Oboda and Mamshit, but there is no positive evidence for that.

Excavations found a large water cistern halfway between Mizpe Shivta and Sobata. In the town itself researchers excavated a double reservoir. The water was collected by runoff channels that sloped down the mountain according to the excavators the city followed the Nabataean town plan to ensure water availability.

Water systems were not only used for obtaining drinking water. Sobata (Subeita) would be the one of the most prominent sites for Late Nabataean run-off water farming alongside the Nabataean ‘Avdat (Oboda). Although those two sites are very similar in urban planning and methods used for water irrigation they contain significant differences in scale and difficulty of the enterprise. Main differences could be seen in the location of the two settlements. ‘Avdat was placed much higher than Sobata and thus received more rain and moisture through the year because Sobata was almost 300 hundred metres lower than its counterpart.[281] Additionally, Sobata was surrounded by flora classified as “desert” (Saharo – Sindian) while Oboda occupies a centre of a steppe like vegetation (Irano – Turanian) enclave.

As mentioned earlier, the Negev water management systems fall into two categories (or stages)[282]. The most advanced and complicated are the wadi bank agricultural systems which are very nicely presented in the region of Shivta – The Lavan Valley located 3 km. in the south – eastern direction of Shivta. The valley is 760 metres long and 140 metres wide. Consisting of a total of 20 plots laid out on several levels, and covers an area of 11 hectares. The installation

[280] NEALH.

[281] Kedar (1957), p. 178.

[282] Chapter 5.7.5.

is entirely fuelled by episodic rainfall[283]. Built on two different levels. The upper one obtains its water from a gully that channelled the runoff from the slope above and is laid out on the same height as the gully's alluvial fan. The 3 hectares of fields was divided into eight plots lying at various sub-levels and was irrigated by a runoff form the drainage area of 65,5 hectares.[284]

The lower field encompasses an area of 8 hectares that obtained water from the wadi flow itself and in order to provide that proper hydrostatic head the wadi flow had to be tapped 700 metres upstream. Three canals brought water to the field – localized on the left, right and central part of the field. Right canal supplied water to an area of 2,35 hectares. Central area of 3.6 hectares divided into 8 fields and the left canal close to the wadi bed that supplied the lowest part of the field which was almost 2 hectares. Typical measurements for the canals located in this area are up to 1.5 km long, width of 3 metres and their depth never less than 2.5 metres. In some instances, the canals were up to 12 metres wide. [285] Wadi bed walls were measured to a height of 4 and 4.5 metres and fulfilled their general role of holding up deposited slit.[286]

5.1.7 Rehovot

D Rehovot

1986 excavations by Y.Tsafrir and K.G. Houm on the behalf of the Hebrew University and the University of Maryland.

Area B.

The houses placed very close to each other and divided up according to the location of the central courtyard. One of the courtyards revealed a drainpipe draining water form one of the roofs. Into a small channel that was built of stones and plaster that led towards a cistern in a courtyard. Part of the town dated to the 5th and 6th centuries A.D.

[283] Kedar (1957), p. 182.

[284] *Ibidem,* p. 183.

[285] *Ibidem,* p. 183.

[286] *Ibidem,* p. 183.

Area C (Stable house)

Consisting out of 4 groups of rooms placed around a central courtyard with a typical so called Nabataean capital and a bilingual Nabataean – Greek inscription indicate that the building was constructed sometime in the 2nd and 3rd century A.D. The typical plan of the construction could betray the usage of that of a caravanserai. Other possibilities proposed are that of a barracks or a mansion. Resemblance of the types of the constructions with Mamshit and Shivta. Pottery fragments found under the floor dated the establishment as early as the 1st century B.C.

5.2 Jordan

5.2.1 Es- Sadeh

Es – Sadeh is located 13 km south of Jabal Harun in a valley stretching for a few kilometres between the usual sandstone, limestone and quartz poryhpry of the Edomite upland. The settlement has been placed 640 meters above sea level, close to a wadi going in from the east to the west, between the massif of Jabal Barrat Salama and a not named one on the map, but called Umm el-‘Ala by the Bedouins. Altough there are no signs of a visile road in the bottom of the valley it is considered as a camel caravan track. The most interesting discovery (for the scope of this work) is a spring that comes down the valley in a series of cascades. The water supply was deemed to be perennial because of a waterfall that was seen in the first week of October 1987. The coming down water was gathered in a small pool.[287] Flash floods carved and continue to carve a deep gorge with still deeper waterholes in the upper third of the valley. Drinkable water was fetched out of those holes in October 1987.[288]

Iron Age II water supply limited to a cistern on the Um el’- Ala plateau.

Completely new and improved water system was later added by the Nabataeans. It was added above the Es-Sadeh water fall. On the sheer porphyry cliff. The hard and brittle rocks could not be penetrated by available tools and thus no rock cut channels were available. This minor inconvenience led to the construction of the masonry cut water channel. Setup from prefabricated guttering stones made of limestone and placed upon additional well mortared limestone structures. The guttering stones are 0.70 m long with the gutter opening of 0.12 x 0.10 m. The construction faced significant problems when it encountered the first bend of the

[287] Lindner et al. (1988), p. 75.

[288] *Ibidem,* p. 77.

cliff. The proposed solution was to build two lean-to-arches of well-hewn mostly bossed ashlars with an abutment of projecting slabs either as a decoration or for a more practical usage which would be the installation of a scaffold[289]. The conduit ends in a sand-filled cistern measuring 17 x 8.60 m.

5.2.2 Aurara (Humayma)

Aurara (Humayma) was the only Nabataean settlement between the al-Sherā escarpment, 15 km to the north and the major centre of ancient Hegra in the Hejaz. It was setup by Aretas the III (87 – 52 B.C.) within a triangular catchment area irrigated by seasonal run-off from the al-Sherā and the water bearing mountains of the Jibāl Humayma. The entire region is also very water abundant (for its desert location) and receives almost 100 mm of rain water per annum.[290] This makes this region a very popular place not only for early irrigation practices but also for the local pastoralist groups that lived in the vicinity of site. The city encompassed a catchment area of 1416 km^2 [291]

In the 1st century B.C. Humayma witnessed a time of prosperity linked with the Nabataean Kingdoms trade routes covering almost the entire region of the Middle East and the northern parts of the Arabian Peninsula. The settlement quickly rose in population and status. Soon it was to become one of the most important cities in the region. Mostly due to their innovative approach to the creation of their water systems.

Awara's water supply is almost entirely based upon incoming aqueduct transportation from remote springs. The only spring that is found in the direct vicinity of the town could be found one kilometre south-west of the town. A Dushara niche carved into the rock wall attests its importance. The opening of the spring is coated with thick layer of crust of calcareous tufa, very characteristic for water highly charged with calcium carbonate. The spring water systems had been slightly renovated and the water transportation was almost

The water brought into the city came from two springs of Jebel al Ghana and Jebel Jaman which are both are utilized in the channelling system. Their waters are transported for more than 15 km to the main settlement through an elaborate chain of stone cut masonry

289 *Ibidem,* p. 84.

290 Eadie, Oleson (1986), p. 49-76.

291 *Ibidem.* p. 71.

channels. Water flowed in conduit hollowed out from cretaceous limestone escarpment that begun its journey at 1400m above sea level. Gradually shifting into a ground level aqueduct between the spring and its destination which is necessary for levelling and water control.

The aqueduct was constructed out of blocks of two different geological materials. Closer to the city the Nabataeans used fine grained, friable white sandstone and while moving away from the main encampment the building material changed to yellow marl and muddy limestone. The material was cut into rectangular blocks measuring - 0.30 – 0.35 metres of width and 0.30 metres thick, usually 1.10 metre in longitude with a central cut water transporting channel of ca. 0.10 m wide and 0.13 m deep. Made by using a chisel[292]. Conduit blocks were set in packing of mortared rubble and trimmed blocks. Fist sized stones packed in grey mortar ran along both top edges of each conduit block. Everything was framed by two roughly squared blocks of sandstone placed along each side of the conduits line. Roughly 0.88 metre apart. On a substantial part of its road the aqueduct was built on the ground level where natural soil was used as a foundation for the construction. When encountered a problem of different elevations the construction technique would change slightly in order to keep a correct gradient for the incoming water and thus ensure the safety of the aqueducts construction. Heavy rubble was used as a foundation for the slightly elevated aqueduct. Taking into account the Nabataean water management ideas the aqueduct was probably covered from sunlight on the entirety of its long road. One example could be seen at the junction with the so called Cistern 2. Surviving slabs of reddish sandstone circa 0.22-metre-wide and 0.12-metre-thick were found covering the chiselled canals. Mortared rubble that was mentioned earlier was used to secure the covering slabs in place. This engineering method applies to the entire length of the aqueduct and it's unique to the Nabataeans. [293]

Main line (known as Ghana line) of the Nabataean aqueduct reached for as much as 18.900 m from the Ghana spring (elevation 1425 m) to the reservoir built in the centre of the settlement (elevation 955 m). The branch line came from the spring at Jebel Jaman. It spanned for a distance of 7,625 km leading from the Jamam and Sharah springs (elevation 1425) and it

[292] Additional information on Nabataean chisel marks could be found here:

Paradise (2014).

[293] Eadie, Oleson (1986), p. 62.

joined the main line of the Ghana aqueduct at the 6.557 m. mark (elevation 1180 m)[294]. Archaeological surveys encountered a reservoir that was proposed to fulfil the role of a *castellum dividicullum*[295]. This discovery portrays Roman changes that slowly influenced the Nabataean Kingdom.

The Jamam branch (fig. 17) was constructed by the same principles that were used in the construction of the main aqueduct line, but some minor design differences appear at various locations of the water line. What stays constant in its construction is the usage of cut yellow marl that is used for conduit blocks. At 1770 m., the marl conduit blocks were measured 0,95 m. long, 0,34 m. wide and 0,36 m. high supported on sides by bands of fist sized stones mixed with grey mortared rubble framed by large partially trimmed blocks. The channel contained series of inverted terracotta roof tiles made from brick-red clay. Similarly, to the Ghana section the channel was covered by flat unworked capping stones. The width of the structure was 0,90 m.[296]. Another section (not specified by the author) was built on the same design ideas but it was accurately measured and given completely different dimensions. The marl conduit blocks were 0,35 m. across and 0,25 m. thick, the mortared space between the blocks and the canal was measured to be 0,35 m wide, and the canal inside the conduit blocks was 0.11-metre-wide and 0.12-metre-deep. Roof tiles placed inside 0.015-metre-thick and 0.41 metre long. The overall width of the construction was measured to be 1,35 m. This means that the width of the construction differed outstandingly from the previous section [297]**.** It is very hard to ascertain why does the author give different measurements for the same construction. Was he referring to different sections of the aqueduct or was it a mistake in measurements?

[294] Oleson (1986), p. 257.

[295] Eadie, Oleson (1986), p. 63.

[296] Oleson (1988) p. 159.

[297] Eadie, Oleson (1986), p. 66.

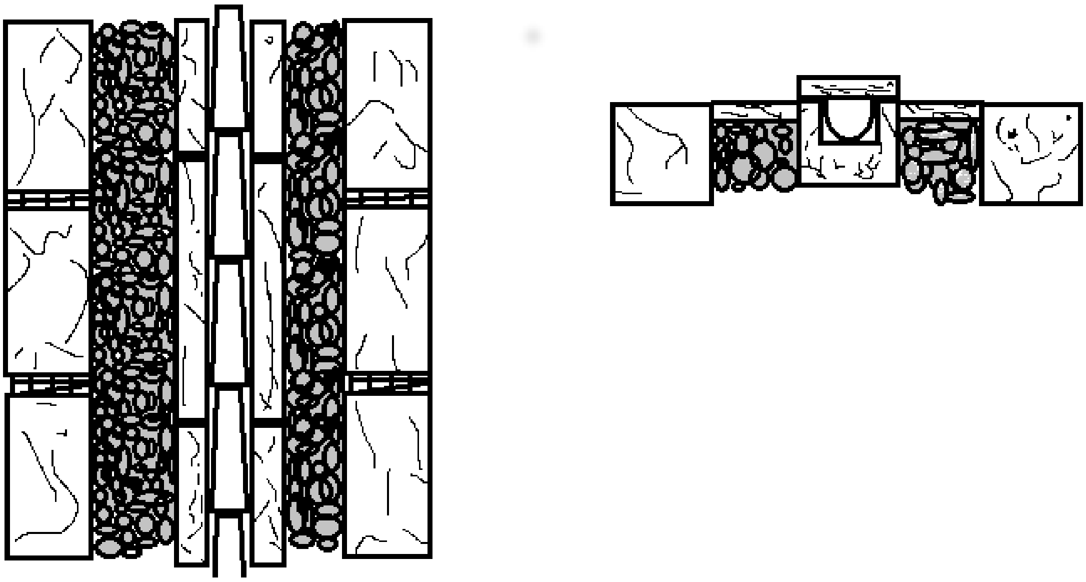

Fig. 17. Schematic representation of the Jamam Branach of the Humayma aqueduct line. Based on Oleson.

In spots were roof tile coverage was lacking the calcium carbonate (coming in from spring water) coating was visible. Apart from the roof tiles and the last 3 km of channel that was plastered by a layer of fine, hard, white sandy stucco 0.004 m thick, there are no additional signs of water proofing. This probably means that the fine-grained yellow and muddy limestone is a great water proof material with does not need any additional reinforcing. It is however very prone to flaking when exposed to changing weather.[298]

Various conduits across Humayma

The construction method of the Ghana aqueduct was later used as a pattern for most of the water conveyance across the city of Humayma. Marl and stone conduit blocks have been carelessly lined up down a gentle slope nearby the end of the settlement without any rubble packing or framing blocks (no connection)

Another example of those types of channel constructions was built out of marl blocks roofed with stone slabs that followed an irregular southward course from a courtyard in front of a small domestic structure. Conduit blocks are identical to those used in the Ghana aqueduct,

[298] *Ibidem*, p. 62.

which brings up the possibility of salvaged reuse, since two identical blocks were re-used as doorjambs.

Above mentioned channels not only are identical in the material and technology used in their construction, but also, they have the same slopes – that is close to 3 percent. This may show a consistent rule of thumb that the Nabataeans used in creation of those drains. Another important element concerning those water drains is that they are all connected to a settling tank. This means that the water flowing through the drains was not waste water but should be considered clean enough to drink. Rooftops and the paved streets themselves could be also considered as run-off collectors, when adequate methods are used[299].

Cisterns

A total of 51 cisterns were found in the direct vicinity of Humayma. The difficulty of the task was considered on the correct dating of the cisterns. Not enough dating material was uncovered to determine the exact time periods for the found cisterns. 32 could be discerned as ancient in origin. 2 of them were built of masonry cut stones rather than rock cut. 16 were unroofed or roofed in a non-Nabataean fashion. 14 were covered by a singular stone slab carried by arches belonging to the side walls of the cistern basin[300].

Dam

Large dam found in a small canyon in the southern part of the city. Construction made of blocks of limestone set in mortar in a header-stretcher technique. The dam was 10.66 m long, 4.36 wide and at the time of the measurement it stood at 3, 65 m tall. The spillway of the dam was cut in the bedrock. Rock cut stairs gave access to the upper parts of the dam coming in from the bedrock. It is presumed that this was the only method of acquiring water from this artificially created water source. The dam was dated to the Nabataean period thanks to a Nabataean inscription found on the side of the enclosed canyon[301].

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[299] Oleson (1988), p. 165.

[300] Oleson (1986), p. 256.

[301] *Ibidem*, p. 257.

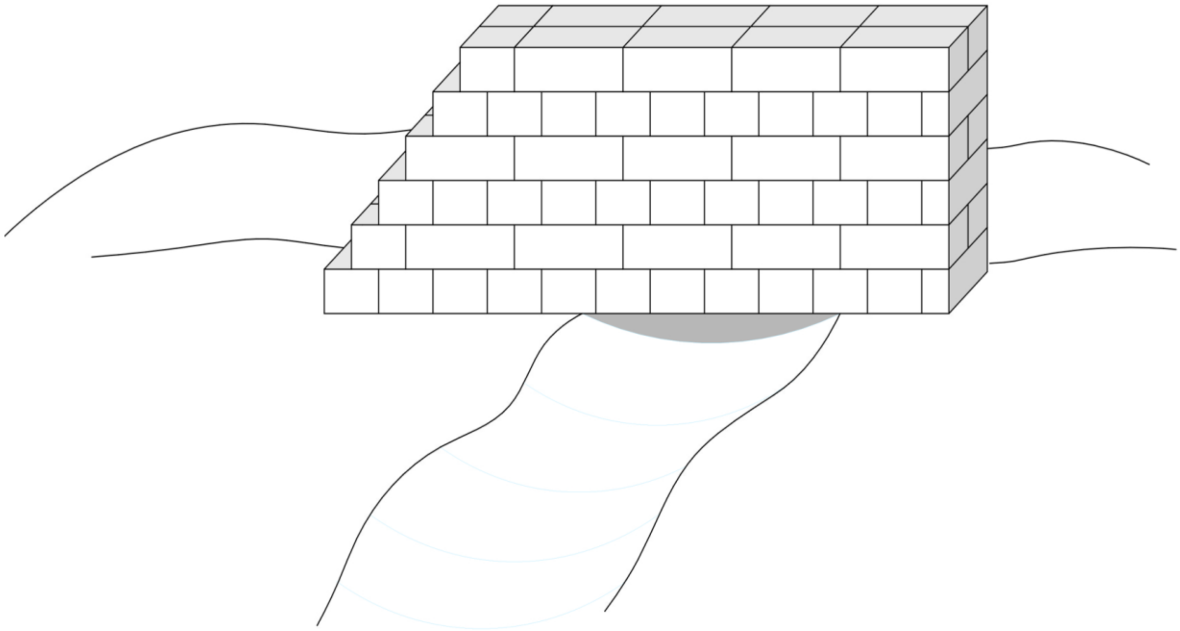

Fig. 18. Schematic representation of the Humayma dam.

Wadi Barriers.

Difficulties in identifying ancient remains of wadi barriers is closely related to their general idea of construction. Stone and earth constructions could be easily destroyed or moved by the overall influence of the climate and the activities of any later groups of settlers (tractor ploughing in the modern Humayma).

Two constructions have been dated for possible ancient origin. One was discerned solely on the fact that it is quite different from the other constructions, because it was built from large boulders rather than small ones. The other barrier is dated on its close vicinity to other ancient constructions[302].

Terraces

Not many terraces found in the immediate vicinity of Humeyma due to the very steep nature of its slopes. Only six terraces were identified. One terrace was cleared out its covering stones which were later heaped up in an orderly row of piles. According to the author the work

[302] *Ibidem*, p. 257.

was probably intended to free some more ground for agricultural activity or it was done so to increase to runoff to the fields lying below. Examples of the second activity could be seen in the earliest traces of Nabataean activity in the Negev[303].

Tanks/Stilling basins

The surveying team identified six different constructions that stood adjacent to the main Jamam branch. The structures were placed on the aqueduct line or next to it. Built mainly of stone slabs and lined with water proof plaster they contained water tanks of average sizes 0.50 meter to 0.76-meter-long, 0.33 meter to 0.70-meter-wide and with a depth of 0.30 meter to 0.50 meter. Measurements taken from four tanks that were viable for excavation. Two tanks were in a very poor condition that cancelled out any possibility of excavation. Their location on the aqueduct line fits well with their interpretation as settling basins. They appear at distances of 1.182, 1.790, 1.925 and 2.495 m from the source of the Jamam branch. Two damaged tanks are placed 1.373 and 2.260 metres from the source. This means that the tanks were used for water cleaning purposes for the first 2.5 km from the source of the spring. Theory is backed up by further evidence from the last tank of this assemblage (2.495 m). It is closed off by a very big and heavy covering slab, which would provide difficulties if the tank was used as a continuous water supply for the wandering nomadic sheep herders from the region. Also there is one tank that was placed on a very steep cliff that effectively cancels out any access to it (1.182 m.). Those are the only tanks that are built before the aqueduct reaches the city. The Ghana line doesn’t have any additional constructions that could fulfil a similar role to that mentioned above. According to the surveying team this could possibly indicate that the As-Sherah and Jamam springs gave a very sediment heavy water flow that had to be cleaned as quickly as possible[304].

Reservoirs

Reservoirs at Humayma belong to one of the most spectacular water transmission structures in all off the Middle East. The last part of the water catchment mechanism at Humayma they stand in the northeast edge of the so-called Habitation area. Recognized and documented by every group of travellers and researchers that came across Humayama.

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[303] *Ibidem*, p. 258.

[304] Oleson (1988), p. 159.

The larger reservoir is 29.49 metres long, 14.20 metres wide, and 3.05 metres high was built in the northwest corner of the roman military camp or *castrum*. Built of seven courses of large carefully trimmed sandstone blocks set in hard white mortar and waterproofed with plaster it had a capacity of 1252 m^3 Dimensions of the reservoir are really close to the Vitruvian 10 by 50 by 100 Roman feet, which would indicate a Roman or Byzantine date for the setting up of such construction. The surrounding construction of a *casrtum* and the overall availability of similarly dated Nabataean, Roman and Byzantine pottery sherds around the camp signifies the belonging period[305].

The second reservoir is located 77metres west of the west wall of the roman camp and by archeologically probing it was established that this reservoir was constructed in the same time as the Ghana aqueduct main branch and was the direct receiver of its water. Additional dating was made by taking into consideration the building techniques and solutions employed in its construction. The header stretcher technique used in masonry construction coupled with diagonal surface trimming of used blocks is very characteristic for Nabataean craftsmanship. Built of seven courses of the local brown and red sandstone using the aforementioned header stretcher technique. Topped by a circumferential paving of sandstone slabs 0.12 metres thick and 0.40 metre wide. Masonry of the Ghana aqueduct was bonded with that of the reservoir. The interior was waterproofed with a layer of hard, sandy white plaster. The inlet of the aqueduct can be found at the midpoint of the north wall, 1.75 metre from the paving slabs. Just underneath the inlet there is a rock slab projecting 0.04 metres higher than the pavement. In its centre an eroded circle 0.06 metre in diameter with a depth of 0.04 m. According to the researchers the level of erosion could be associated with a low amount of water reaching the reservoir only been able to reach the additional height of the stone slab (0.04m) (but this would be the case only in the years after the abandonment of the site and its further decline). Remains of the 0.02 m. thick layer of hard white sandy stucco is still visible at the height of 0.60 m. which means that the reservoir was designed to hold at least as much water as it measured height. Measurements of the reservoir came up at - 27, 60 metres long, 17, 00 metres wide with a depth of 1.75 metres, with a capacity of 821,1m^3. The size of the reservoir cancels out the possibility to construct a typical Nabataean vaulted roof.[306]

[305] *Ibidem*, p. 161.

[306] Eadie, Oleson (1986), p. 59.

Pipes

Ceramic pipeline transported the water to a shrine that was possibly dedicated to the Nabataean god Dushara. It was placed through the constructions of the city, in a 25, 6 m. irregular route to a modern destruction area. Then it was traced further along the same route closer to the upstream where It sharply goes downwards as if it wanted to avoid an obstacle by going underground (possibly Via Nova). From here it continued north to a probable fountain or bath it fed.

Constructed out of wheel-made ceramic pipes with an external diameter of ca. 0.095 m. Singular pipe section varied in length from 0.14 to 0.30 m. and when combining the data from an overall sample of 58 sections, the average section length was measured to 0.227 m. Pipes combined with male and female joints and plastered over with white or light grey mortar. At most lengths they were placed on a bedding of grey mortar or mud plaster laid over sandy ground. At specialized sections involved in high pressure water transmission the bedding was additionally reinforced by packing up small stones and cobbles with mud under and on both sides of the pipe. The pipelines were hidden from the eyes of people by covering them up with slabs of stones (as seen with the pipelines going under buildings) or simply by hiding them under a thin layer of mud[307].

Well

Roughly shaped limestone blocks arranged in a circle ca. 2.5 m. placed in some distance away from the city. Probably used by farmers or pastoralists[308].

Oleson (1988), p. 161-163.

[307] Oleson et al. (2003), p. 42.

[308] Eadie, Oleson (1986), p. 70.

5.2.3 Petra

Petra was considered to be the main city of the Nabataean people and most of their cultural and technological heritage could be found in its closest environs. The site of Petra is located in a very dry region of the Jordan southern desert. The yearly precipitation is measured to only 150 mm of rain. A good deal of the used water was accumulated during heavy thunderstorms that additionally have a catastrophic influence on the soil surfaces and sedimentation structures in this area. Average type of soil available in this region is the so called yellow soil that appears in the regions of a yearly precipitation between 100 and 200 mm. The absence of well-developed soils mean that erosion and accumulation are quicker than soil formation[309] (fig. 19).

Fig. 19. Water erosion processes as seen in the Siq - Petra.

[309] Frosen et. al. (1999), p. 395.

The earliest and ongoing excavations in the city of Petra, conducted by Bellwald, Schmid, Graf and Bedal. Bellwald's[310] research revealed underground sections of a gravity flow channel which was the first spring water aqueduct constructed in Petra. It followed the surface of the trampling path before the construction of the paved road straight to the city centre. More detailed work established that the channel was plastered. Archaeological surveys conducted during the modern building activity in the town of Wadi Musa show no signs of a water channel thus rendering the identification of its original source close to impossible. But based on the wide cross section of the channel it must have been a spring with a great capacity, hence it was most probably Ain Musa.[311] Further excavations in the Siq area confirm that the first spring water aqueduct was destroyed by a flash flood in the middle of the first century BC[312]. The constructive characteristics of the first spring water aqueduct as revealed by the excavations in the Siq and near the Temenos Gate are clearly showing that the aqueduct was built as a completely hidden underground construction. Such buried aqueducts were common in the archaic period of the Greek civilization and widely adopted by the Hellenistic cities in Asia Minor[313]. Also this model was adopted for the first aqueducts built in Rome, as seen in the Aqua Marcia[314].

The Khubhta North Aqueduct

The first spring water aqueduct built for the purpose of developing the urban city centre. It was built to replace the destroyed oldest channel in the Siq and was the first completely visible structure above the ground, with imposing arched bridges up to span of more than 13 m. from the spring to the inlet of Wadi Al Zhurraba into Wadi Al Musa and it most probably followed the conduit of the first spring water aqueduct. New research suggests that on the contrary to some older ideas the Khubhta aqueduct was indeed fully covered. Which of course prevented any loses of water thanks to evaporation[315].

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[310] Bellwald (2008), p.48.

[311] *Ibidem*, p.49.

[312] *Ibidem.*

[313] Garbrecht (1991).

[314] Fahbusch (1981).

[315]Bellwald (2008), p.52.

The Siq Aqueduct (fig. 20, 21,22)

Compromised out of two essential parts. The first one being the terracotta pipeline constructed in the first century BC[316] which due to its gradient was a high-pressure waterline which was never used to reach places higher than the conduit of the pipe. The second part of the water system built in the Siq was the gravity flow channel built in the mid first century AD following its southern cliff it supplied the Khazne Plaza with drinking water[317].

Fig. 20. The Siq aqueduct covered by stone slabs.

[316] *Ibidem.*

[317] *Ibidem.*

Fig. 21. The Siq aqueduct.

Fig. 22. The Siq aqueduct.

Fig. 23. Dam and the visible Siq aqueduct.

The Ain Braq Aqueduct

Provided the South-western quarter of the city with drinking water. Constructed as a double aqueduct, consisting of a terracotta pipeline and a gravity flow channel[318].

The Ain Abu Olleqa Aqueduct

Connects the spring on the lower Wadi Turkmanyie with the sacred area of Petra, the Temenos of Qasr el Bint. Unfortunately, this area was completely destroyed by the flash floods. The destroyed remains give a close resemblance to the same construction ideas as were used in the Ain Braq Aqueduct, a double aqueduct of terracotta and gravity flow channels[319].

318 *Ibidem*, p. 56.

319 *Ibidem*, p. 58.

The Ain Debdehbeh Aqueduct

It brings the water from the spring above the actual village of the Amarin Bedouins in the city basin supplying the north-western quarter of the city with drinking water. Again, the construction pattern of this aqueduct follows the general idea of the Ain Braq Aqueduct.

The construction of those five water supplying channels begun at the middle of the 1st century BC. And ended with the construction of the last one in the late first century AD. Three aqueducts were destroyed during the 363 AD earthquake and have been never rebuild.

Three springs provided water for the settled populace with the main one being the Wadi Musa. Numerous rock cut and plastered cisterns have been used as storage places for the water that has been brought to the city by the means of a water channel but the springs are not the only source of water in Petra. Water catchment systems identical to those seen in the other Nabataean sites were collecting and directing the rain water coming down the slopes of the hills during the October-February rain storms that sometimes could cause flash floods. This type of water catchment solution proved to be dangerous when a group of French tourists drowned in an occurrence of a flash flood in April 1963. The tragedy took place in the narrow two-kilometre-long Siq gorge that leads to the site.

The accident could be probably averted if our knowledge of the Petra water catchment system would be greater. In this case the abandonment of the sites ancient dams and irrigation systems proved fatal. Hundreds of years of rain and wind eroded the catchment systems thus in result the torrent of water coming down the hill approaching the site was too strong and couldn't be sufficiently decreased by the damaged flood control systems closer to the Siq in result drowning the entire zone. Flash flood control systems were developed for the sole purpose of protecting the city from strong, uncontrollable water torrents racing down the hills of Petra. They consisted of series of water diverting dams with stilling basins built right under them. Sometimes like in the example of the Petrean Siq the system also incorporates a retention basin for the storage of the extra water. Four aqueducts of Petra were incorporated into the flash flood control system and were protected by a series of dams[320]. Water catchment systems captured rain water and diverted it into basins or covered reservoirs backed up by settling basins where the water could be preliminary cleaned out of any floating debris.

[320] *Ibidem,* p. 67.

Fig. 24. "Hellenistic" Petra – general view.

Flash flood retention system - Siq al Mudhlim

Probably one of the biggest enterprises in the entirety of the Nabataean Kingdom in terms of water management. The Petrean Water Detention basin stands at the very begging of the legendary main access road to Petra – the Siq. Built not only to collect usable water for the city but also (or even more important) to protect the city and its inhabitants from the devastating effects of flash floods that from time to time happen in the area of Petra. This system is a great example of every technological idea that the Nabataean people conceived or learned from other cultures put to use in one massive enterprise. Built at the curve where the course of Wadi Mousa changes from east-west to south-north and its size limited by the cliff of Jebel Madrass. Closed by a dam on the high-level road built by the Nabataeans sometime between 50 and 25 BC.

The most visible part of the entire system could be found at the beginning of the Petrean Siq. A large geometrical shaped basin (fig. 25 and 26) has been dug out in the very close vicinity of the so called "high road" at the height of some 30 cm above the modern-day pathway into Petra. Shapes used in its construction betray its purpose. The area was created as a settling basin for the sediment that would arrive with the flash floods coming down the Petrean hills. Any big rocks or even trees would eventually sink down to the basins bottom and allow the clear water to pass through the Al-Mudhlim Canal that was dug some 2 metres above the pools sedimentation level. The high walls of the basin were created in order to withstands the impact of the flash flood water and hinder its dangerous movement into the centre of the city by the means of the Siq[321].

Between the Siq entrance and the al – Mudhlim tunnel there are visible traces of two abutments, which could belong to a collapsed arch. It does not appear as to what purpose had it served. It was probably not a supporting arch of any kind. The proposed idea of it having a commemorative inscription is overturned by its relative distance to a probable observer (it would be not visible).

The design and ground plan of the Siq is attributed to the Hellenistic influence of the Nabataean technology.[322]

Fig. 25. Settling basin at the entrance to the Siq.

[321] Petra National Trust (2004), p. 119.

[322] *Ibidem,* p. 119.

Fig. 26. Settling basin at the entrance to the Siq

The Siq tunnel was constructed as means of connecting the Wadi Musa and Wadi al – Mudhlim in order to divert the flash floods from the first one into the latter. To achieve this the constructors had to bypass a bedrock obstacle that completely blocked off the two wadis. The easiest way to bypass this sort of problems and not getting involved with additional technological struggles is to go by the advice of Vitruvius and simply dug out a tunnel. Taking into account the work of Siq al Mudlhim Survey team we come to a conclusion that the survey work for the tunnel itself was made not in a very technological matter but rather by empirical knowledge based on years of experience. The proposition is that the work done in order to connect both of the canals ends was done by observing the natural faults between the brown sandstone and the white Dishi sandstone. As shown in the correction of the tunnels line at the point of 13 meters downstream of the mouth of the tunnel. The surface of the left wall consisted of the same material as the aforementioned fault. Downstream of the tunnel doesn't follow the earlier procedure but it goes in a perfectly straight line, hence the visible signs of tooling that cover the both walls for more than 30 m[323].

More examples of underground tunnels in Petra.

Excavations conducted by Nabil I. Khairy[324] have identified three water tunnels that conducted water across Petra. They have been found south-east of Qasr el – Bint in the el – Katuteh area under a paved terrace supported by podium. Their main characteristics are vaulted roofs finished up with keystones.

Channel A was measured to have a probable (because this channel was not fully excavated) depth of about 3,20 m. in its northern part and about 1,50 m. in the southern part. Constructed out of natural sandstone we varying width from 0,90 m. in the upper part to about 2,20 m. below. The channel was covered by a vaulted roof, evidence of those supports was visible in specially cut grooves. The vault diameter is 0,90 m. with a keystone surrounded by three coarses on either side[325].

Channel B is located on the eastern side of channel A and it's a bit smaller in size. During the time the channel was not excavated but its proposed depth was measured from the upper surface to the accumulated deposit of 2,20 m. The width of the canal varies from 0,80 m. in the upper part to the 1,80 m. below. The channel is covered in the same way that channel A is. The same vault diameter of 0.90 m. with eight coarses separated by a keystone. Several columns found from the times of Justinian I were probably stored in the canal, a practice very common in the 5th phase of the settlement[326].

Channel C located east of the channel A with vertical sides covered with notches made with a mallet and a chisel. Excavated length of the channel is about 2,5 m. The height is about 2,5 and a 1,00 – 1,1 m. of height. Regular width in the entire channel measured to 1.15 m. This

[323] *Ibidem*, p. 120.

[324] Khairy (1984), p. 315 – 320.

[325] *Ibidem*, p. 315.

[326] *Ibidem*, p. 315.

channel was not covered in a similar manner to the previously mentioned ones. Most probably it was covered by large and thick regular sandstone slabs[327].

Channels A and B were sealed off by covering the top of the vaults with a layer of rubble about 0,35 m. thick, when the mason laid down irregular slabs of fragments on the rubble as a foundation for the regular pavement that was 0,04 – 0,7 m. thick. The overall thickness of the cover up was about 0,90 m[328].

Great Temple Excavations

The plaza of the Great Temple was equipped with several different canalization systems.

One of the canals was dug in the bedrock, covered by a shallow slab and sealed with hydraulic plaster. It was used to remove waste water, but the intended place for the removed water wasn't determined. In the southern part the canalization measures 5,69 m. in length and 0,48 m. width, the channel itself is a 0,20 m. wide and 0,51 m. deep construction[329].

Second water system was built in the parent bedrock sealed with hydraulic plaster of 0.012 m in depth and set under the paved East and South Perimeter Walls. When more of it was cleared, the trench released an unpleasant odour which was linked with its immediate usage of water removal. Later phases uncovered a series of limestone lined channels. Constructed with reused ashlars, bonded in into the pavement with plaster. One course of 10 rows of segmented limestone ashlars measuring 0.67 x 0.60 m. Another segment on the opposite side of six ashlars measuring 0.67 x 0.60 m. Five ceramic pipes remained in situ used either as means of brining portable water to the site or rebuilding the defunct canalization system. They measure 0.34 m in length and 0.10 m. in diameter[330].

The last system is mostly unrecognized. It consists of a basin and a platform built right beside it. The platform measuring 2,36 m. east-west and 2,65 m, north-south with a height of 0,76 m. is built of small ashlars bonded together with hydraulic cement. Further north a basin cut into the bedrock with a diameter of 0,72 m. and a wall thickness of 0,05 m. and a depth 0,40

[327] *Ibidem,* p. 317.

[328] *Ibidem,* p. 317

[329] Joukowsky (2001), p. 335.

[330] *Ibidem,* p. 335.

m. A small section of a lead pipe was visible in the proximity. The pipe measuring 0.60 m. length and 0.07 m. in diameter[331].

Additional water systems are hidden in the southeast plaza of the Great Temple. Excavated by Christian F. Cloke. It was carved out of bedrock with several rock elements left to fulfil the role of column supports. There are also visible signs of an voussoir arched roof. The dimensions of the cistern where measured to have 8,50 m. in the north-south and 7,80 m. east-west and 5,80 m. high, which was estimated to hold up to 390 cubic meters[332] (during the next season of 2002 the estimation was corrected to 327,64 cubic meters[333]). The cistern was not of uniformed depth but it was shallower on its west side. The entirety of the room was sealed off by hydraulic plaster[334]. It was fed with water coming in by a piping installation located on the southwest opening of the cistern the channel was cut in the bedrock expanding over 36 m. from north to the south with a width of 13 m. east-west [335]. The southwest part of the cistern had a cylindrical shaft topped by an arch used to remove the overflow water by a bedrock channel extending 35,30 m. into the north end of the East Plaza. The channel is measured to be 0,26 m. at its bottom to 0,63 m. at the top, with a depth of 1,00 m.[336]

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331 *Ibidem,* p. 335.

332 Joukowsky (2002), p. 323.

333 Joukowsky, (2003), p. 399.

334 Joukowsky (2002), p. 323.

335 *Ibidem*, p. 323.

336 Joukowsky (2003), p. 399.

Fig. 27. Siq al – Mudhlim canal beside the colonnaded street.

Fig. 28. Wadi Mousa canal bridge.

5.2.4 Sabra

Sabra Water Draining systems

One of the most interesting and peculiar water draining systems could be found at the site of ancient Sabra. Researched by the group of Naturhistorische Gesellschaft Nürnberg between 1978 and 1980[337] and earlier found and described by L. de Abrode in 1828[338].

Surviving ruins of the theatre (fig. 29) are directly linked with the water draining system found at the rock face of the hill called J.al-Jathum. Above the *cavea* of the theatre there is a large crevice that was covered with a construction of a dam wall. The wall is 1.80 meters high, 14 meters long and wide for 2.20 meters. Constructed out of diagonally cut masonry stones, arranged in the binder-stretcher technique with additional coats of hydraulic mortar applied on the inward and outside walls. This arrangement artificially dammed an area of 14 x 12 metres and taking into consideration the overall size of the area and the additional space that could be used when the base level was cleaned of debris, it was estimated that it could store around 380 cubic metres of water. A little opening found between the ashlars in the lowest layers of the dam enabled the accumulated water to gently flow down to the orchestra of the theatre. Remains of a small water fountain could mean that the water flowed gently into the direction of the orchestra by means of a fountain basin. The water fountain was regarded as a commodity and suspected to be used seasonally or in some cultic ceremonies.

[337] Lindner (2005), p. 33 – 52.

[338] *Ibidem*, p. 33.

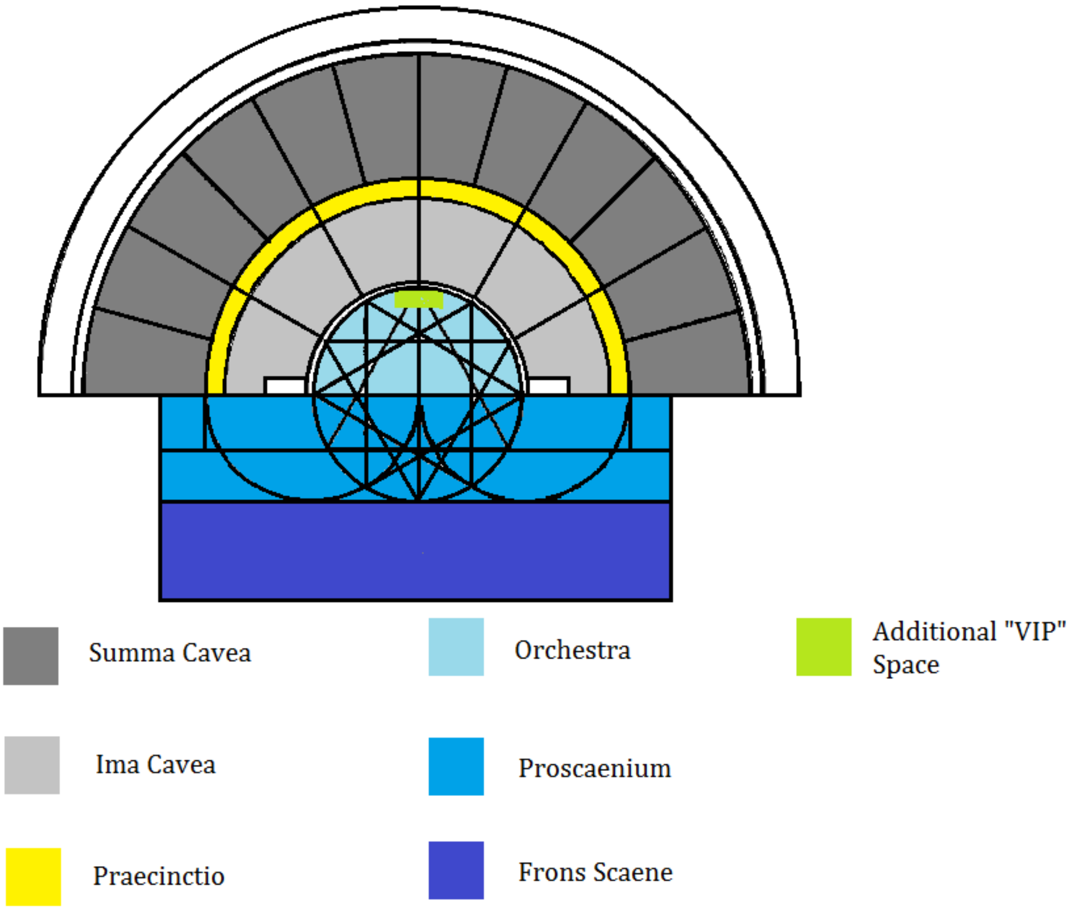

Fig. 29. The Theatre at Sabra built by using "Vitruvian" standards.

The water course coming from Wadi er - Raqi was designed in mind with the natural flow of the surrounding terrain. Stretched through four terraces it brought water to the Sabra theatre. The highest terrace is the beginning of the catch water regulation system and as reported in the first years of the survey – it was a rocky, water polished surface, retreating 30 m. into the mountainside. Called the "niche" terrace thanks to a niche like opening. Additionally, the terrace is filled with water basins measuring 2 x 2 m. From here the water discharges into a steep inaccessible gulch. Circa 30 m. downstream there is a large kettle and water basins that could be closed off for water storage. Going further we reach a "third terrace" located 10 m. below in a place of a wedged in rock. This terrace also could be closed off in order to gain another reservoir, but no masonry survived the years of uncontrolled coming down water. 16 m. below the point of the wedged in rock there was a "second terrace" surrounded by very thick masonry built walls, creating yet another possible reservoir. Lindner states that this enabled the architects to direct the coming in water to the Sabrean theatre and that creates the possibility that the construction of the theatre was conceived as a joined project. Because the theatre itself could not be built without the construction of the water system.[339]

Upon looking at this mechanism that directed the water to the orchestra, its discoverer L. de Abrode presented an idea that the theatre could be flooded in order to setup very exotic presentations, of the Naumachie. This idea was abandoned due to the size of the theatre which according to most researchers was too small for such presentations. Researchers did not take into consideration the sheer amount of water that this kind of entertainment needed in order to work properly. Also, it should be considered that the Nabataeans did not have a habit of wasting water for such trivial entertainment. The sheer thought of the possibility to display an event of the *naumachie* in the middle of the desert should be considered as a romantic thought of its discoverer that came with the knowledge of the existence of similar events often held across the entirety of the Imperium Romanum.

The Sabra Dam.

The eastern valley of Sabra runs parallel to the western but ends in a large natural basin which was originally eroded by a natural run-off and with it brought a fill of sand and rock debris. The Surveyors discovered that the valley was closed off by a dam located some 100m. above the wadi bed of Sabra. Running from South – West to North – East measured to be 17 m. long, 4.30 m. wide and at its deepest point 5.30 m. high, creating a reservoir of 30 x 30 m. that was capable of storing almost 3.6 million of litres of water, about 4 m. in depth. Constructed of greyish, very hard, carefully hewn sandstone ashlars in the header – stretcher technique. Hydraulic mortar was mixed with stone chips. A water outlet 0.7 m. in square and 3 m. in depth was observed at the north-eastern end of the wall.[340]

Discovery of an ancient dam in Sabra indicated the existence of a water conduit that had lead the water in a gentler inclination towards the settlement. The earliest traces of this conduit have been built from masonry cut stone, later the system was exchanged for rock-cut. The width of the channel varies between 0.19 to 0.25m. Due to the difficult terrain that surrounds the ancient dam and the entirety of length of the channel. According to the Lindner there must have been a lot of problems with its design. Rock outcrops made it almost impossible to build the channel in a moderate incline so they were bypassed by means of settling tanks that

[339] *Ibidem,* p. 38.

[340] *Ibidem,* p.40.

accompanied steep inclines. Water coming down the valleys that was going in the direction of the Theatre had to travel by almost vertical sections of the water conduit. It is not possible to determine were the conduit terminated. There is a possibility that it could be connected with masonry cut channels that lead to the edges of the settlement close to the buildings of the theatre[341].

5.2.5 Shamasa

The area called Shamasa by the local populace extends over ca. 1x1.5 km. and is located very close (only about 3 km) to the ancient city of Petra.

The Cistern

A Nabataean rock cut cistern is used today as an orchard. This second usage of the cistern is not a singular event. The same activity takes place at the site of Khirbat an-Nawafla (‘AMr et.al 2000 234, 238). The cistern was originally covered by a roof that was supported by eleven arches on a space of 13.50 x 10.0 metres. [342]

Flight of sixteen steps provided access to the water storage, at the depth that was noted in 2002 as 3metres and an additional 1.80 m. beyond it.

Another cistern was found 44m. Southeast of the first construction. Measurements at the opening of the cistern were fixed at 3.70 x 4 metres and then the cistern began to stretch accordingly to its depth. Measuring a 4 x 3.30 m. at the first stretch in the upper parts of the building to a final 5.5 x 5 m. in the bottom of the excavation. Sizes verify the number of arches needed in order to sustain a built roof. In this example, only three arches have been prepared which have later supported slabs that were used for cover. The cistern was fed by a channel running form a settling basin measured 3.50 x 2.10 m.

5.2.6 Umm Ubtullah

A Nabatean Roman military installation which probably was associated with a line of Nabataean and/or Roman fortresses and watchtowers along the south side of Wadi el Hasa. The name of the site Umm Ubutlah was provided by the local Bedouin. Crop being grown on this

[341] *Ibidem,* p. 41.

[342] Cisterns as big as this one would be; the cave cistern at Bayda and the oarched-overr cistern at Jabal Harun and Jabal al-Khubta.

good agricultural land is wheat. In 1-983 they grew tomatoes there. Abundant water supplies have been noted in the year 1982 and 1983. A pool directly below the site to the east called Birkat Umm Ubutlah by the land-clearing crew, contained a great deal of water. Mostly supplied by the modern gas pumps. The led up a field on the south side of the wadi to the east of the site. A concrete foundation for a pump was noted on the north side of the wadi, also to the east of the site. Moreover, an aqueduct, chiselled out of bedrock, was noted leading from the pool to a field along the north side of the wadi immediately below Umm Ubtulah. Other pumping stations and irrigation canals were noted both to the east and north-east of the site. Very lush vegetation. Natural erosion carved runoffs used for water collection. Cisterns are built right under the run-off erosion for water collection like in Umm Ubtulah lower segment[343]

Lower segment

The so called lower segment of Umm Ubtulah is irregular in shape measuring 250 metres (east-west) and 230 metres (north-south) of longitude. The rock-shelf that separates the lower and the upper segment is measured to be 115 metres long. The entirety of the zone is located on a steep slope leading down to the Wadi el Hasa. Additional structures are found in the area of the site. Measuring from 2.60 to 3.20 metres with walls 0.90 metres thick. Aligned in rows running down the slope arranged in a terrace step like fashion. Those arrangements measured from 7.90 to 8.30 metres from on terrace-face to another. Identification of those structures remains unclear. [344]

Topography of the entire area is that of natural run-off heading into the south-eastern direction. There are speculations as to the purpose of the remains left at the line of this run-off but the clear recommendation should be that of a cistern for the capture of any incoming water.[345]

5.2.7 Wadi Faynan

Wadi Fayan water system is located on the south bank of Wadi Ghuwayr, facing Khirbat Faynan. The system covers an open channel an aqueduct that goes across Wadi Ushaykir and

[343] MacDonald (1984), p. 186-187.

[344] *Ibidem*, p. 187.

[345] *Ibidem*, p. 187.

ends in a large sunken reservoir. Watermill and an extensive filed system used the water gathered in the reservoir.

Water sources at Wadi Faynan come from two sources: One would be the run-off water coming in from the Ash-Shara Mountains and the flash-flood water from side wadis and springs. The incoming water was channelled by two conduits. One is rock- hewn and the other is a thickly plastered U-shaped channel butted against the wadi side. There are also remains of an aqueduct that originally spanned the Wadi Ushkyar over a distance of 120 meters. It is built of faced sandstone blocks bonded with cement like mortar around a core of rubble and pebbles bonded with mud mortar. The aqueduct probably carried water from east across the wadi to the western side through a currently buried area and then it emerges further west going into the settlement tank of the reservoir.

Reservoir

The water reservoir is a partially stilled up sunken reservoir that measures c. 30 x 33 m. with a 4 m. of wall face exposed (in the year 1997). The sides of the reservoir are constructed of sandstone blocks and a partially demolished stone staircase, supported in a clearing arch is still visible in the north west corner. The eastern and southern walls are almost totally destroyed while the western wall and the western end of the north wall are still standing to the level of the uppermost course. Towards the centre of the eastern wall and abutted to it is a settling tank that would have collected the water flowing from the aqueduct and open channel. The basin measures approximately 1.6 x 1.7 m. Its plastered floor is 1.2 m. lower that the incoming channel, allowing the water to fall and the residue to settle. There is no evidence, however, for the position and the level of outlet from the settlement tank. Along the top of the northern half of the west wall are the remains of a channel 0.5 m. wide and 0.3 m. high. No physical evidence remains as to the starting point of this channel of whether the water arrived directly from the settling tank or from higher up in the system. Nor indeed is it clear whether this channel is contemporary with the reservoir. There is some evidence for an outflow near the middle of the western reservoir wall perhaps leading to the mill.[346]

Analysis of plaster samples from the channel leading onto the settling tank, the channel on the west reservoir wall and the channel leading to the watermill suggest that they are roughly contemporary and of Roman date. It would be logical to assume that the aqueduct and water

[346] Ruben et al. (1997), p. 445.

channels to the east form an integral part of this water system and are therefore also Roman in origin. However, penstock mills in Jordan are generally thought to be Islamic date and if the Fanyan mill proves to be Roman it will be a unique example. Bochum mining museum dated the enormous heap of slags of the east bank of the Wadi Ushyakir that overlay the channel flowing west of the Roman period between the 2nd and the 5th century AD.[347]

5.2.8 Wadi Ramm

Wadi Ramm is a vast desert valley located approximately half way between Petra and Aqaba. It is considered to be the biggest wadi in Jordan. Through history it was populated by different cultures (nomadic, semi-nomadic or settled), the most recent ones being various Bedouin tribes. Wadi Ramm was popularized around the world by the enterprises of the aforementioned T.E. Lawrence (aka. Lawrence of Arabia).

The Wadi Ramm Recovery Project was undertaken in August 1996 to document the so called Eastern Complex that consists out of a Nabataean house and bathhouse partially cleared by the DAJ (Department of Archaeology in Jordan) 30 years prior to the project. Additionally, it encompasses a survey of the neighbouring Nabataean temple.

The Eastern Complex consist out of 28 rooms and they divide between those that are designated as the "Villa" and the bathhouse. 12 or 13 rooms belong to the bathing facility (5 or 6 central bathing rooms that are linked by doors and 7 maintenance rooms). The bathhouse facility assembled out of a typical *caldarium, tepidarium* and a *frigidarium* design. In 1996 excavations commenced in the *caldarium* and a circular room. The caldarium measured 4,40 x 4,58 m. laid upon stone slabs (ca. 0,13 m.) covered with six layers of plaster, below the room was a hypocaust chamber that supported the *caldarium* with a set of pillars built of sandstone [348]. The *frigidarium* was excavated in the second season of the project in the year 1997. In its centre: an immersion pool 1,24 m long, 2,59 m. wide and 0,94 m. deep. Steps partially covered in plaster at the north-eastern corner gave access to the northern part of the room placed on a higher podium.[349] The frigidarium was placed between those two rooms. The excavation team

[347] *Ibidem*, p. 446.

[348] Bikai, Egan (1997), p. 518.

[349] Egan, Bikai (1998), p. 592.

failed to identify a hypocaust heating system, but due to evidence of soot encrusted on the remains of the wall plaster found in a soil fill suggests that the room was heated by a brazier[350].

The entire Eastern Complex was described as a construction designed to be used in a private and public section. Dated by the team to the 1st century B.C. till the 1st A.D. by the comparative analysis of the Nabataean dressing stones used in the bath as well as the hypocaust. The discovery makes it the oldest bath in Jordan. It is disputed if the bath belonged to the public part of the complex or the private one. Its proximity to the public parts could be evidence of its free access, but there is a possibility that the bathhouse was closed off by a door.[351]

5.2.9 Qasr al- Hallabat

Site located 25 km to the northeast of the city of az-Zarqa. Stretching an area of almost 20 hectares, with a castle (*qasr*) placed on a top of a mound. The castle was erected in the Roman time and functioned continuously thorough the Byzantine. The most interesting elements for the scope of this work consist of the settlements remains of its water system and reservoir.

The core construction of the reservoir was placed directly on bedrock partly carved up in bedrock and partially made up of rubble walls of local limestone blocks, which had been probably quarried from the same site, sealed together with hydraulic mortar. The core of the reservoir is consisting of small stones and concrete. The external blocks betray adequate skills of their masons, but have different shapes. The reservoir encapsulates and area of 2059,905 square metres. Number of masonry stones are considered to be prepared only to fit in certain spots of the construction. Also, there are stones covered with decorative elements – probably reused from earlier constructions.[352]

During 2002 excavations, the digging team wanted to establish the exact depth of the construction in order work out its probable capacity. The depth was assumed to a 2.5 m. which gave the quantity of stored water to an 8107 m^3. The existence of two additional wells on the north-eastern side of the reservoir was explained as an overabundance of coming in water that had to be stored in surplus tank. Additionally, the entire perimeter was bound by earth. Both

[350] *Ibidem*, p. 592.

[351] *Ibidem*, p. 592.

[352] Ghrayib (2003), p. 65.

the wells and the ground reinforcement served the process of securing the constructions integrity during a heavy water income.[353]

5.2.10 Khirbet edh – Dharih.

Settlement located approximately 30km. south of the Dead Sea containing visual remains of a temple and a residential building. At some point in time the residential building had its main axis modified in such a way it enabled the excavators to identify two main phases of occupation. The main entrance to the building was found on its eastern side, straight into a paved court. Two reception rooms visible to the right side, paved and covered with arches. Visible marks of pained plaster. Second part of the occupation was marked with the changes made to the northern side. As evidenced by the "intrusion" of one room on the courtyard. Rooms meant for domestic purposes. The north-western area is the one that is the most interesting. Two rooms were identified as a bath setup one of which could be easily identified as a caldarium. Identification was based on the hypocaust floor found under the room. Construction was dated to the timespan of 1st century A.D. till the Byzantine period, when it was destroyed in an earthquake.[354]

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[353] *Ibidem*. p. 65.

[354] el – Muheisen, Villeneuve (1993), p. 521.

Fig. 30. Nabataean and Bedouin transport – Camel.

6 Probable machines that convey water that could be used in the Nabataean Kingdom

A machine is a continuous piece of joinery that has outstanding capacities for moving loads. It is moved systematically by the revolutions of circles, which the Greeks call "kuklike kinesis" – circular motion

Vitruvius acknowledges three types of machines. Mounting machines those that enable the user to supervise a construction in high places (scaffolding). Pneumatic machines that work on the principle of pressurized air and the Tractor machines that enable workers to drag heavy loads of cargo from one place to another.

6.1 The "Drum" or the Compartment Wheel

Vitruvius describes it as a low-lift how-output water wheel. Much similar to the medieval and modern time water wheels but with slight differences. The water wheel itself is designed as a catchment place for water. Ii divides into eight compartments and it's in its quarter drowned in the water source. Those aforementioned compartments have SQUARE like openings that are placed on the rim of the wheel which are used to catch the water when the compartment is submerged. Then the water is being transported up thanks to the perpetual motion of the wheel. When approaching its highest point on the wheel the water is being drained from the compartment by a hole made in the centre of the wheel. The water falls on a channel that is placed slightly below the hole (to avoid any unnecessary water splashing) and transports the water further.

6.2 The "Bucket Wheel"

The same principle can be used to raise the water even higher. Constructing a wheel that could reach the desired place. But instead of using compartments Vitruvius suggests to attach square buckets on the rim of the wheel. Those can fill up when they are down in the water tank and empty when they reach the top.

6.3 The Bucket Chain

The Bucket chain is a mechanism derived on the same principle as the water wheels. The exception being that you don't construct big wheels that convey the water but two small wheels. One at the bottom and the other one at the top of the place we want to move the water. Then you connect them with a chain to which you attach buckets that can hold water. The rotation of the mechanism will ensure that the buckets will fill up with water once they reach the bottom and then pour its contents into the channel before it reaches top.

6.4 The Water Screw

The water screw is more commonly known as the Archimedean screw pump and its invention was traditionally ascribed to the Greek scholar as early as the third century B.C. Still we cannot assume that it wasn't used earlier before Archimedes. Vitruvius describes it as a machine that can move a great quantity of water but not as high as the wheel. The construction if fairly easy and cheap. A beam should be as long as needed to perform the required operation but the diameter of that beam shouldn't be higher than 1/16 of its length. That of course also hinders the maximum size of the beam itself still if the machine gets longer then the blades will become too large and it will require a lot more power to operate. Ends of the beam should be divided into eight identical parts corresponding with the parallel lines drawn along its length. Next the length of the beam should be divided into similar sections equal to the 1/8 of the circumference. Thus, creating a well-drawn pattern on the entire surface of the beam. This pattern sets a "road" on which the future blade will have to be placed in an angle of 45 degrees. The blades are made out of slender willow or cut agnus castus which is dipped in liquid pitch.

Then the blade is fixed at one selected point of the drawn intersections at the beginning of the beam and carefully its making its way around the beam to the next intersection. When it finally reaches the eight-drawn point away from the begging it should made a round trip through this section of the beam and should be fixed at the aforementioned point that is exactly on the same level as the point we stared from. This is then continued through the entire length of the beam. The operation is repeated until the blades are stacked to the point that their thickness reaches one-eighth the length of the rotor. After the construction of the bladed beam it is covered up by wooden panels bound together with iron beams. The ends of the rotor are sheathed with iron. According to Vitruvis the best angle for this machine to work at would be the one corresponding with the Pythagorean triangle. Which is approximately 37 degrees.

The question is how this machine works in practical use. In his work, Vitruvius, has stated that he has done a drawing of the machine with added instructions on how to operate it at the end of book. Sadly, that part of the work has not been preserved till the medieval times when it was discovered. So, the pictures that we see in today's edition of the book are done by medieval scholars who assumed that there was a treadmill installed outside the box placed halfway down and tilted in the same angle as the machine which would be the aforementioned 37. Landels states that it's not a very comfortable angle to work at in the long hours of water pumping which is not hard to agree on.

6.5 The Water Pump of Ctesibus

This machine is the first one described by Vitruvius that is not entirely made of wood. Those water pumps are constructed from bronze and they ensemble from two cylinders, standing slightly apart and connected by a forked pipe which leads to a central tank located between the earlier mentioned two. The two side cylinders accumulate water by the usage of a disc inlet valve built on the bottom of every cylinder by which water passes through and into the tank. There is also a similar disc used for the outlet valve that is attached to the side of cylinder where it connects with the fork pipe that leads the outgoing water to the central tank. Ideally the two cylinders should be half submerged under water which of course would make the pumping much easier. The central tank should be connected to a pipe that is leading the water to the desired place. Additionally, the two cylinders have big discs with their diameter being equal to the diameter of the tanks that contain them which are then attached to a rocker system that is being worked by two people. The horizontal motion of those two discs compress the water and whatever air that is inside and forces it to go outside the tank and into the central one and then up to the desired point of transportation.

7 Vitruvius

Vitruvius belongs to the world's most famous Roman architects whose work influenced many generations of future builders during the late Medieval and Renaissance periods all the way up to English eighteen century architecture. "De Architectura librii decem" is the only surviving roman document about the duties and (according to the author) required knowledge of the ancient Roman architect. The work itself was dedicated to the achievements of Emperor Augustus who had undertook an intense rebuilding program of the destroyed Rome after the civil war that ended at the battle of Actium in 31 B.C.E. This date sets the first possible time frame in which the document was written. The second-time frame can be deducted from the treatise itself. Vitruvius is not using the title Augusts while turning to the Emperor which means that the document was written before Octavian got the title in 27 B.C.E.[355] Another proposed time frame wold be the year before 14 B.C. and it is based on the grounds that Vitruvius would not dare publish a work praising Octavian until he finishes establishing peace.[356]

Before writing his book, he collected some practical knowledge while possibly working for Julius Caesar. He wrote about this in the document stating that he was known to the ruler and he even received some recognition from him. We don't know where Vitruvius has worked before him and three other Romans: Marcus Aurelius, Publius Minidius and Gnaeus Cornelius where moved to be in charge of the construction and maintenance of catapults, scorpions and all sorts of siege equipment. In other words, he was appointed to the technical section of the army the *fabri*[357] (engineers). This section of the Roman army was responsible for maintenance, building bridges, transport and other such matters. According to Landels[358] he probably never became *preafectus fabrum* (which would mean the head of the engineers) because he does not claim to have that post. For this work, he and the other two men received a stipend awarded by Augustus and then extended by the supposed recommendation of the Emperors sister

[355] Howe (1999).

[356] *Ibidem.*

[357] Landels (1978), p. 209.

[358] *Ibidem,* p. 209.

Octavia[359]. The acquired stipend must have been a very large sum of money because it enabled Vitruvius to write he's life's work uninterrupted.

The main purpose of this work was to gather all possible knowledge and construction principles used in the times of the Roman Emperor Octavianus Augusts and write them down so they can be used for future generations.

More information about the author himself can be found in various parts of the treatise. Most of them are written in the prefaces for the individual books. The second book begins with a story of a young architect from Macedonia called Dinocrates, who wanted to meet the great Alexander of Macedonia and share with him his vision of establishing a great city. According to Vitruvius's description the young architect was of great beauty of his face and dignity of his physical presence. The combination of his ideas and the physical appearance made him an irreplaceable architect at Alexander's side. The most glorious of his achievements was the fulfilment of his great vision: the planning and creation of the Egyptian city of Alexandria. Vitruvius told this story as a representation of his personal ambitions. But as he said he was not blessed with imposing stature, age has ruined his face and bad health made him weak. In spite of all that he hopes that his work will gain him the Emperors approval.

Vitruvius "Ten works on Architecture" isn't just a handbook about theoretical (reasoning) and practical (practice) knowledge of engineering. It also acts as a codex of the architect's morality and it states the amount of knowledge required of the architect to perform his work at his best. Often people in Rome wanted to learn the basics of construction, so they can build their own buildings by themselves. This situation was caused by unskilled architects designing buildings which devoured a lot of funds for the construction alone and then they constantly required maintenance which was exhausting the financial possibilities of their owners denying them the luxury of having their own family home. Vitruvius blamed the young architects whose only concern was to become famous and attain glory in life. According to Vitruvius they lacked the expertise (reasoning and the practice) to perform any work of

[359] In his commentary Thomas Noble Howe states that Octavia who was a full sister of Octavian and not only a big patron of arts but also an active politician and could have handled Octavian's lesser clients, like the architect Vitruvius. This statement accompanied with the translation stands in a contrary to what Landels wrote in his book in 1978 where he states that Octavia's influence helped Vitruvius in the promotion of his career. According to Howe's commentary and Rowlands translation this sentence looks more like Vitruvius is trying to express he's gratitude to the Emperor for extending his stipend. The extension was probably awarded by Augustus and later announced by Octavia and thus Vitruvius is being polite writing the phrase "at the recommendation"

construction on their own. That's why his treatise puts so much emphasis on education. Finally, the author states that a bad architect is the one that is looking for assignments by himself. His logic is that when someone wants to deceive you they come to you asking you for a favour (In this situation it's the favour of constructing something). On the contrary of a good architect who always has clients that come to him asking for a favour. According to Vitruvius the main reason why he is not known to the people in his time, it's because he didn't seek false fame nor glory.

"Since, therefore, few men are thus gifted, and yet it is required of the architect to be generally well informed, and it is manifest he cannot hope to excel in each art..."

Vitr. I. 1, 18.

Vitruvius suggests that a good architect should learn from all branches of available science so his work could be done to perfection.

And so, he should understand letters – so he can read what others have to say about architecture. Next, he should know craftsmanship so he can describe anything he is working on. Geometry is useful for designating squares, lines and levels. Optics is what you need to design the windows properly. Arithmetic is useful to determine the total price of every enterprise. Knowledge of History is very valuable when working with ornaments which are often connected to certain past events like the *Caryatids*[360]. He also should know the basics of

[360] The origins of the term are unclear. It is first recorded in the Latin form caryatides by the Roman architect Vitruvius. He stated in his 1st century BC work De architectura (I.1.5) that the female figures of the Erechtheion represented the punishment of the women of Karyæ, a town near Sparta in Laconia, who were condemned to slavery after betraying Athens by siding with Persia in the Greco-Persian Wars. However, Vitruvius' explanation is doubtful; well before the Persian Wars, female figures were used as decorative supports in Greece and the ancient Near East. Whatever the origin may have been, the association of Caryatids with slavery persists and is prevalent in Renaissance art.

The ancient Karyæ ("Walnut Trees") supposedly was one of the six adjacent villages that united to form the original township of Sparta, and the hometown of Menelaos' queen, Helen of Troy. Girls from Karyæ were considered especially beautiful, tall, strong, and capable of giving birth to strong children.

A caryatid supporting a basket on her head is called a canephora ("basket-bearer"), representing one of the maidens who carried sacred objects used at feasts of the goddesses Athena and Artemis. The Erectheion caryatids, in a shrine dedicated to an archaic king of Athens, may therefore represent priestesses of Artemis in Karyæ, a place named for the "nut-tree sisterhood" – apparently in Mycenaean times, like other plural feminine toponyms, such as Hyrai or Athens itself.

Philosophy so that he will be fair, trustworthy, not arrogant and most importantly free from greed. The most important knowledge for a water supply designing architect would be: physiology. Building pipes and water channels requires the knowledge of basic facts of nature like natural water pressures. The most surprising branch of basic knowledge used for the construction of the most surprising things would be the knowledge of music. Vitruvius states that in terms of constructing a catapult, *ballistae* or a *scorpion* the engineer needs to have a very good ear while "tuning" the "strings" that are holding the headpieces of those machines. They should not be wedged in place until they deliver a distinct and identical sound that the engineer must recognize. Only then the machines will fire in a straight line and in the right angle. This knowledge is also used when constructing the roman theatre or an Odeon of course. Bronze vessels which the Greeks call *echea* are placed underneath the seats according to the mathematical principle based on their pitch. Thus, enhancing any sound by a double octave. Any architect trying to be the best in his work should also study medicine. Therefore, he knows where the ground, air and water are most healthful to setup a safe settlement or a construction. But furthermost he needs to know the law. This knowledge will help him to avoid unnecessary law-suits and create quality contracts that will release the contractor and the contracted without any further disputes. Astronomy in its most basic sense, for the ability to find oneself on the construction plan. The knowledge of east, west, north, south and of course the locations of the constellations of stars.

In spite, all of what was written here. Vitruvius vision of the perfect architect wasn't so ideal. All of this knowledge should be learned at its most basic level. He realizes that no man on earth can be a master at everything only because mastery of certain skill takes time and practice and even then, only a few reach the pinnacle of their individual disciplines and yet they still don't get the recognition they deserve.

The mere existence of such people is a testament to mankind's skills in adaptation and its abilities to claim even the most unfriendly of environments for its own usage.

The later male counterpart of the caryatid is referred to as a telamon (plural telamones) or atlas (plural atlantes) – the name refers to the legend of Atlas, who bore the sphere of the heavens on his shoulders. Such figures were used on a monumental scale, notably in the Temple of Olympian Zeus in Agrigento, Sicily.