HYDRAULIC ENGINEERING AND SITE SIGNIFICANCE IN NABATAEAN-ROMAN SOUTHERN JORDAN: BA'JA, AS-SĀDAH, ṢABRĀ, UMM RATĀM[1]

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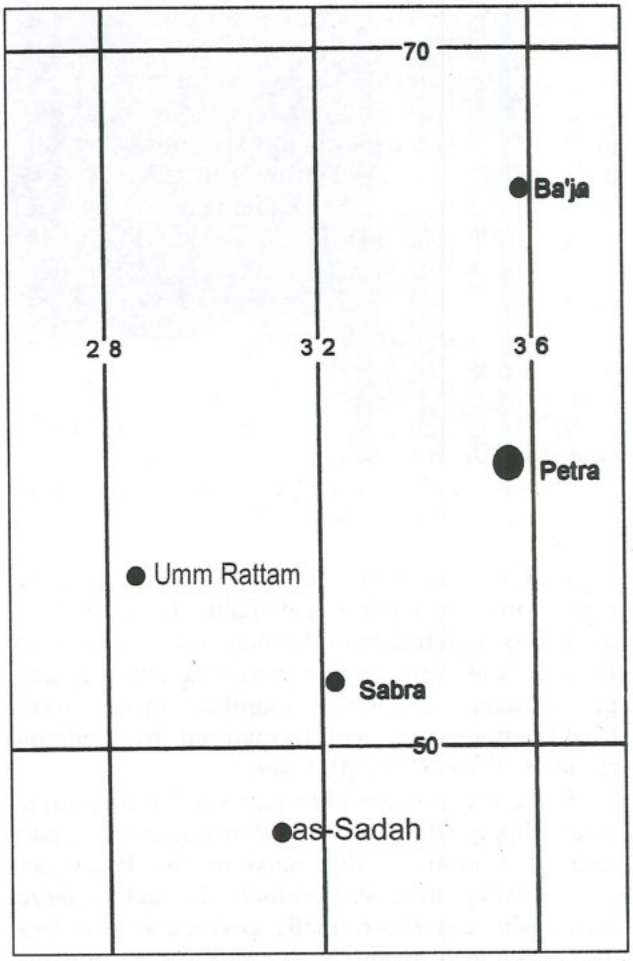
Introduction

Engineering achievements in collecting, stor-ing and conducting run-off and spring water in Nabataean-Roman southern Jordan have been several times described during the past decades. In addition, it seems promising to evaluate the significance of the supplied sites according to the dimensions and particularities of the hydraulic installations. Such a point of view may shed more light on places like Ba'ja (بعجة), as-Sādah (السّادة), Ṣabrā (صبرا) and Umm Ratām (أم رتام), all of them explored by the Naturhistorische Gesellschaft (NHG) Nürnberg under the author's direction (**Fig. 1**).



1. Sketch map with the localisation of the analyzed sites after Jordan map 1:50 000.

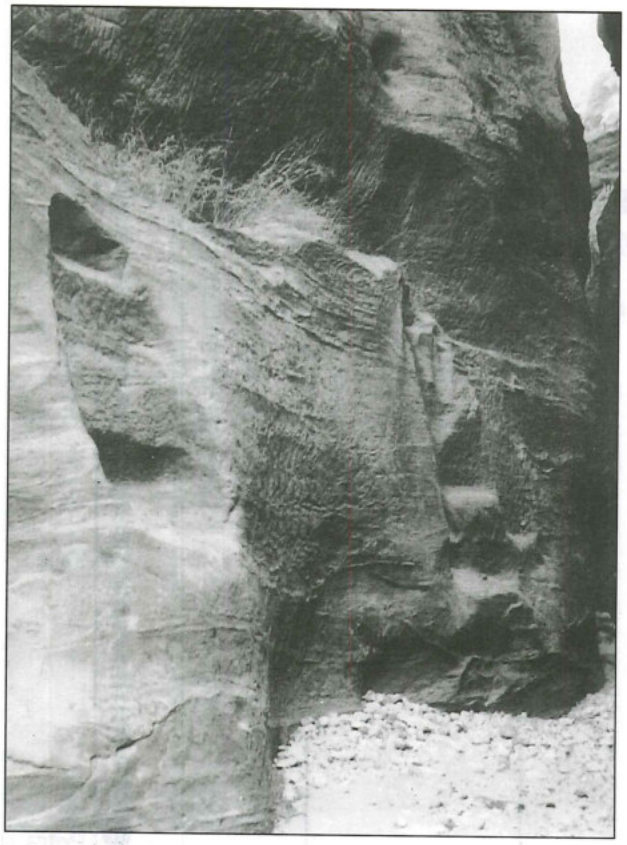
The Channeling System of Ba'ja

Beside a PPNB settlement (Ba'ja II) and an Iron II (Edomite) mountain stronghold (Ba'ja III), the Ba'ja massif ca. 10km N of Petra features an important channelling system. Exiting from the end of a narrow gorge, water from the Ba'ja massif could behind storing walls be dammed, stored and transferred into two main channels running to both sides of a ruined village (Ba'ja I), which is perched on a rocky outcrop at the foot of the massif (**Figs. 2, 3**). Nabataean inscriptions date the partly rock-cut, partly built channels to the Nabataean (-Roman) period (Lindner 1986; Bi-enert *et al.* 2000) (**Fig. 4**). There may have been a few cisterns hidden in the village ruins that were filled from the northern channel (Muheisen 1990), but most of the water coming out of the partly du-plicated southern channel ran into a canyon-like section of the wadi, which was originally and is now fed by the water coming out of the gorge. Here it may have been additionally stored before it was used for irrigating fields and gardens to the west of it.

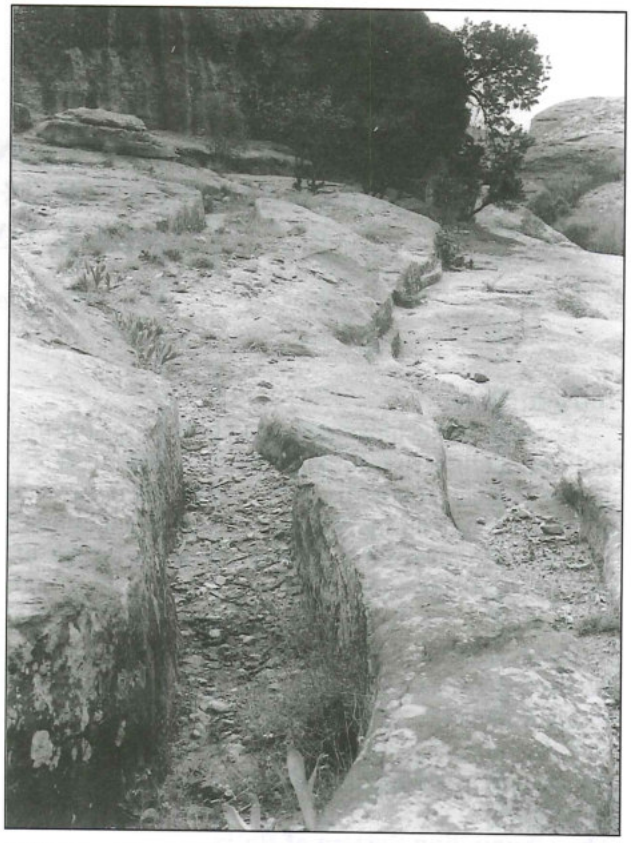
The hydraulic system had, every year, to be newly adapted to the conditions of rock fall in the gorge and the water level behind two walls at the exit of the gorge[2] . All that supply cannot be sufficiently explained by advantages for the Nabataeans who may have seasonally camped here or for later oc-cupants of the Late Islamic village (Bienert and Lamprichs 1999; Bienert *et al.* 2000). Moreover, a large cistern constructed in a natural

1. This paper is a revised version of a contribution to the Symposium "Men of Dikes and Canals. The Archaeology of Water in the Middle East" 1999. The author uses "conduit" for the whole installation, con-ducting water and "aqueduct" or "aqueduct arch" for an arch carrying the conduit.

2. Observations during the last 10 years showed that the water level in and in front of the gorge exit changed from year to year. Some changes are due to the diligence of the Bedouin who tried to renew agricultural work between the exit of the gorge and the canyon-like section of the wadi.



2. Exit of the Ba'ja gorge with abutments of two walls and the beginning of one of the conduits (1992).



3. Section of the southern conduit, which was du-plicated either according to the purpose or to the water-level (1986).

cleft of the mountainside with a long staircase leading into the depth was available. It was first regarded as a Nabataean (-Roman) reservoir but, in fact, an Arabic inscription marks the entrance and geometrically decorated Mamluk sherds were found among the sand thrown-out by Bedouin (Lindner 1999: 491; 2003: 249)[3] .

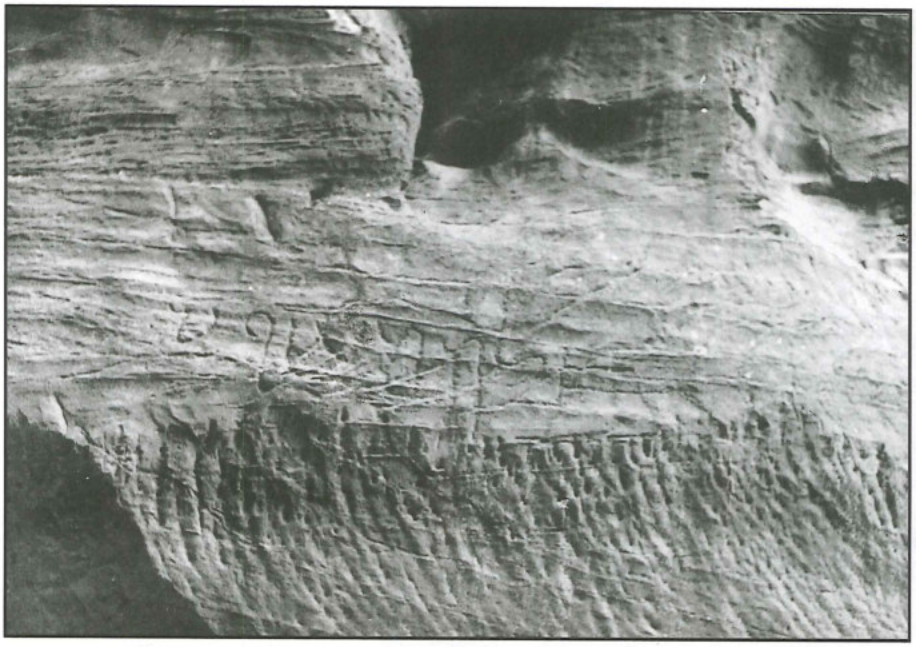
There are two possible reasons for the ample water supply. Ba'ja I was a Nabataean (-Roman) caravan station at the outskirts of Petra accommodating men and animals. In fact, a large rectangular cistern originally covered with arches in the Petraean manner is located where caravans could rest and pass outside Ba'ja I proper. The second function of Ba'ja I was to produce food as is done even today. As a large winepress attests there was also wine produced for the Petra region. Both functions may have alternated or were a matter of course all the time.

The Conduit of as-Sādah

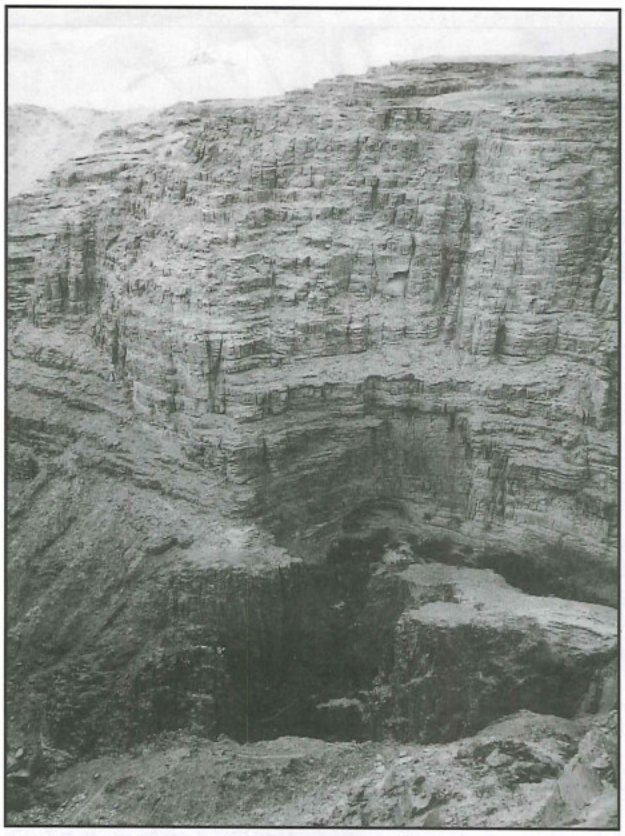
The valley of as-Sādah ca. 15km to the SWS of Petra became archaeologically known when Bedouins reported on "arches" to be found there[4] . Invited by the Department of Antiquities, an expedition of the Naturhistorische Gesellschaft (NHG) Nürnberg under the author's direction discovered an Early Bronze and an Iron II (Edomite) site above Wādī as-Sādah in 1984 and 1986 (Lindner *et al.* 1988 and 1989). The Nabataean (-Roman) inhabitants had no need to take refuge on the heights and lived openly near the wadi banks and in a village at a small tributary of Wādī as-Sādah (W. Umm Sheb) below a large structure of un-known significance. A spring higher up in the mountainside had already supplied the Iron II stronghold as is attested by a strong tower watch-ing over the plateau with the settlement and at the same time over the access to the spring. The pre-cious gift was

3. The sherds were from juglets or pitchers, the adequate vessels to carry water from a cistern. The reservoir (and its inscription) should be re-examined. It may have been constructed by Nabataeans and reused in the Late Islamic period.

4. Much too late, in 1997, Z. al-Muheisen and D. Terrier reported on a visit to "as-Sādah" in 1984 and described cursorly the "aqueduc" and "les arches hautes de 5.80m" . At the time of their visit, Bedouin from Petra took specimens of grape-vines and fig trees and brought them to Petra where they planted them in Wādī as-Siyyagh and Wādī Turkmaniya. (Al-Muheisen, Z. and Terrier, D. 1997: 148). Both plants were also found and identified by I. Künne in her botanical survey of as-Sādah (Lindner et al. 1988: 77; idem 1990: 220).



4. Nabataean inscription (founder? sponsor? ar-chitect?) at the wall of the gorge (1986).



5. Upper section of the natural drain from the spring at as-Sādah with a tributary from the rock wall above (1987).

not stored at that time and got lost rapidly in short bursts of flash floods after it had rained. The team of the NHG experienced such a sudden flood during the survey of 1987.

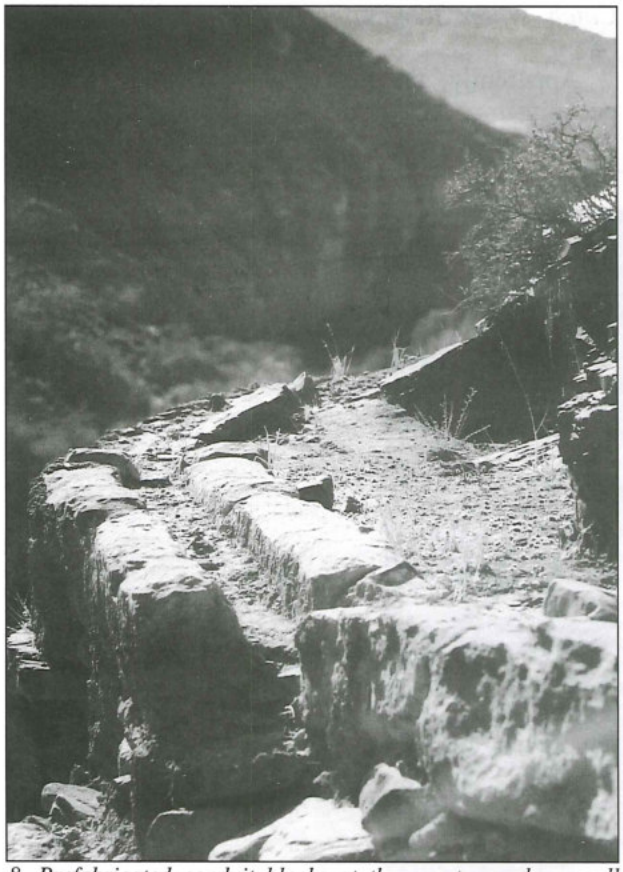
In the Nabataean (-Roman) period the natural course of the spring water was tapped in its last third and conducted over some 200m into a reservoir of 18 x 9m and into natural cavities in the rock bottom of the valley (**Figs. 5, 6**). Two aqueduct arches of ca. 5m height, one of them well-preserved in 1989, had to support the conduit where no rock could be cut and no channel affixed to the quartz-porphyry wall (**Fig. 7**). Where it was possible, the conduit was composed of pre-fabricated blocks of white Ordovician sandstone with a groove in the middle (**Figs. 8, 9**). These conduit stones can be compared with others used for the same purpose at various sites of Nabataea. The arches compare well with the best structures of the same kind spread all over the Roman sphere of influence. They correspond to Roman engineering whether done by Roman architects before or after the annexation of Nabataea in 106AD (Lindner *et al.* 1988: 97)[5] .

As the reservoir is exactly placed where it was possible to irrigate cornfields and gardens, there is no doubt that spring water was mostly used for this purpose. Remnants of an aqueduct or dam in a tributary that failed or was destroyed, would have irrigated more fields in the valley (**Fig. 10**). There

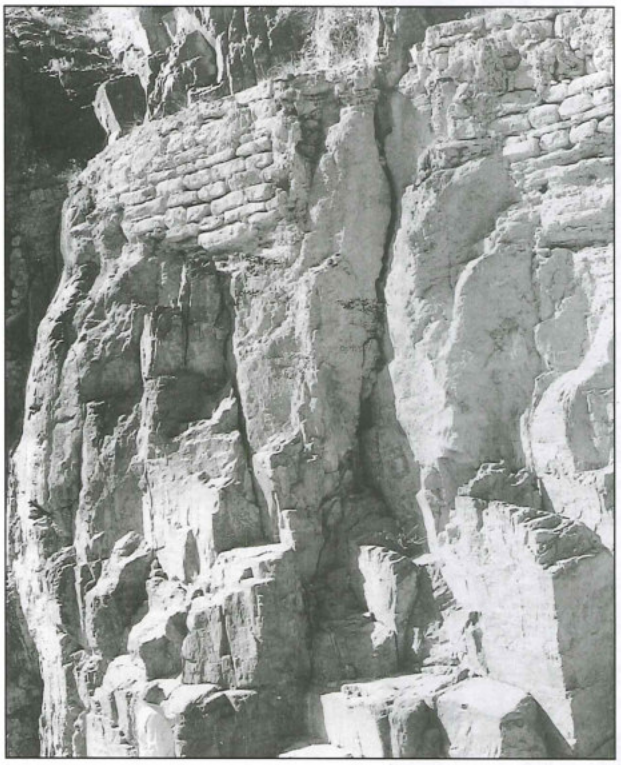
5. The answers of experts asked about their opin-ion on the aqueduct arches of as-Sādah differed somewhat between "reminiscent of aqueducts in Aspendos and Caesarea Maritima" (Prof. Dr. Ch. Börker), "Blüte der Bossen- und Spiegelquader in herodianischer und vorherodianischer Zeit" (Prof. Dr. A. Schmidt-Colinet), "parallels in Pisidian Antiochia" (Dr. K. Dornisch), "an impressive monument of Roman engineering in the Nabataean realm" (Prof. Dr. E.M. Rupprechts-berger).

6. Lower section of the original (and present) drain from the spring (right) and the conduit (middle left) (1988).

7. Aqueduct arch at as-Sādah, an important part of the conduit (1988).



8. Prefabricated conduit blocks at the quartz-porphyry wall high above the wadi (1988).



9. Substruction of the as-Sādah conduit above a quarried rock wall (1988).

10. Remnants of a hydraulic installation in a tribu-tary rock wadi of as-Sādah. Substruction of a con-duit or abutment of a dam (1988).

were footpaths from the east passing by the spring and still used by present day Bedouin. As-Sādah is located a few kilometres from Wādī 'Arabah plain where caravans might have passed, but it offered little room for caravans and no easy access for camels to be watered. So caravan trade and control of it were probably rather minor functions of as-Sādah. At another route (through Wādī Umm Sheb) a Bedouin had already installed a garden in 1986, before the greater project at the foot of Umm al-'Ulā had begun. It was from that garden that Dakhlallah brought delicious grapes when he reached the NHG camp on foot from the aṭ-Ṭayyiba road. Considering the historical changes in the Nabataean area, food production may have been added to or may have superseded the ques-tionable profits of caravan trade between the first and second century AD and may have done so till, according to the as-Sādah pottery, the third century AD.

Presumably not for the first time, in the eighties of the last century Bedouins of Sa'īdiyyīn tribe started a project of cultivating the valley in the same way as the Nabataean-Roman people had done two thousand years before. As was observed

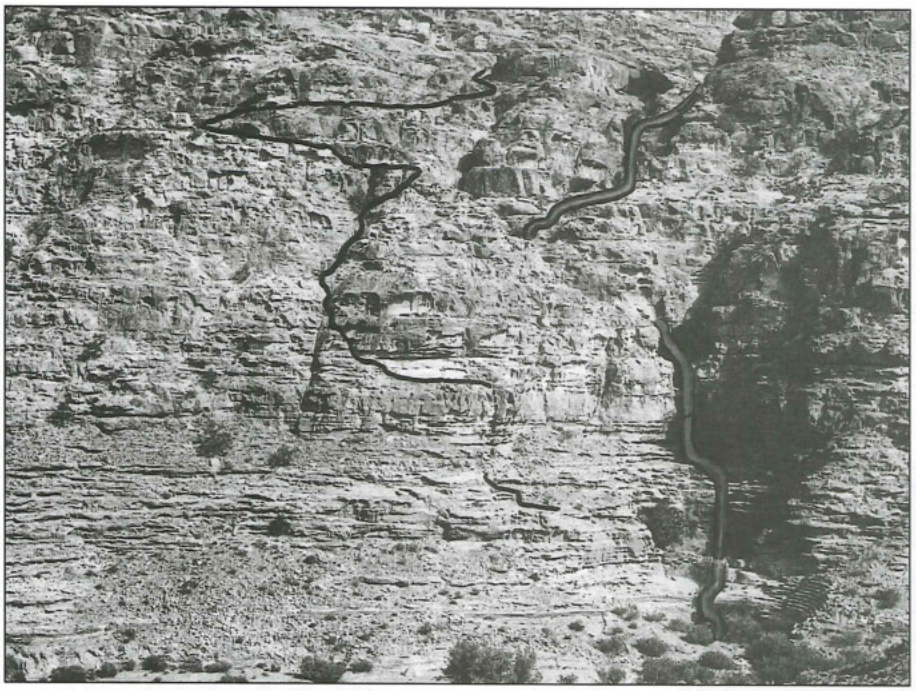
in 2003, the new occupants refrained from building conduits and aqueduct arches and used plastic hoses instead. Also observed in 2003 were grape-vines and fruit bearing trees (**Fig. 11**). The arch was broken down in the meantime (pers. comm.) (**Figs. 12, 13**).

Catch Water Regulation System and Conduit at Ṣabrā

Apparently, the provision with water was especially important at the oasis settlement of Ṣabrā located ca. 6.5km to the SW of Petra (Lindner

11. Natural verdant slope (left). Fruit trees and grape vines on the wadi bank (2003).

12. Broken-down aqueduct arch (2003).



13. Courses of the Ṣabrā *hydraulic works. Conduit from the dam (left), Catch Water Regulation System down to the Theatre (right).*

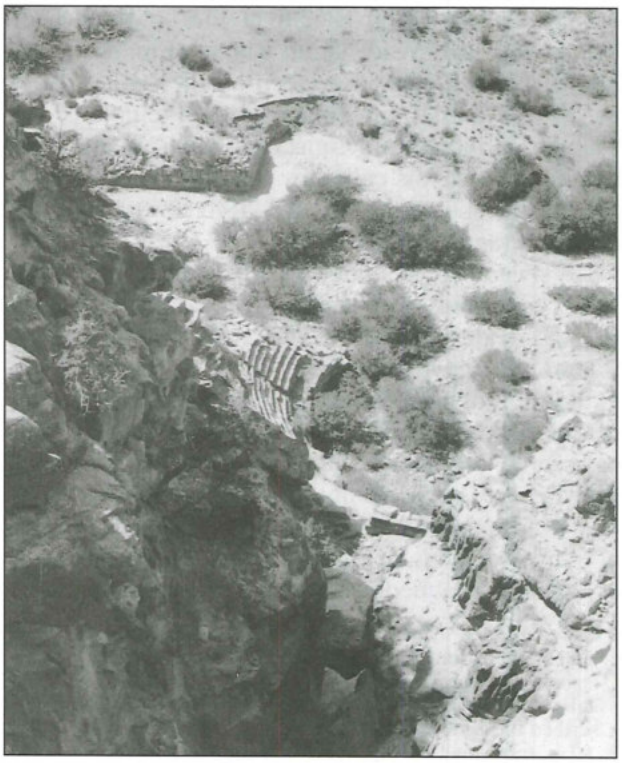
1982; 1992; Lindner and Zeitler 1997/98). Run-off from the Jabal al-Jathum massif was diverted from flashing down directly into the wadi of the same name and conducted instead through a maze of gullies, gorges and waterholes into a large reser-voir behind a strong masonry wall above a small theatre. Lacking maintenance for some 1500 years, the totally destroyed *skene* bears witness to the tor-rents that pour down from the mountainside after occasional winter rains (**Fig. 14**). As in these days, rain is scarce in the Ṣabrā area "between steppe and dessert" (Künne).

The "Catch Water Regulation System" from the upper slopes into the reservoir above the Theatre shows an ingenious use of the steep slopes and gorges of the Jabal al-Jathum. Constructing the Theatre was only possible after the downpour from the mountain was controlled. Another supply with run-off water was received from a reservoir behind a large dam of excellent masonry, installed about 100m above the wadi floor with an audaciously constructed partly rock-cut, partly built conduit running down to the settlement (**Figs. 15, 16**).

The high quality execution of these two hydraulic projects is explained by the needs of a growing resident or passing-through number of people. Of course, there might have been a series of draught years, though that will never be ascertained. There is another thinkable reason for the need of water: Smelting of ore on the Acropolis Mountain is attested by slag that was found by and under the temple platform.

Water from the Moses Spring into Wādī ʻArabah

All water from the Moses spring (ʻAyn Mūsā) (عين موسى) at al-Jayy (الجيّ) (present-day Wādī Mūsā) plus an ample amount of run-off from the bordering slopes but minus what evaporated on the way arrived in the basin of Petra and ran through the Siyyāgh gorge as its only exit into Wādī ʻArabah. Part of that water was caught in conduits and



14. Lower section of the Catch Water Regulation System with the reservoir above the Theatre (1982).

15. Dam, 17m long, 4.30m wide and 5.30 high some 100m above Wādī Ṣabrā (arrow) (1987).

16. Section of the Ṣabrā conduit originally bridged by masonry or a conduit block (arrow) (1982).

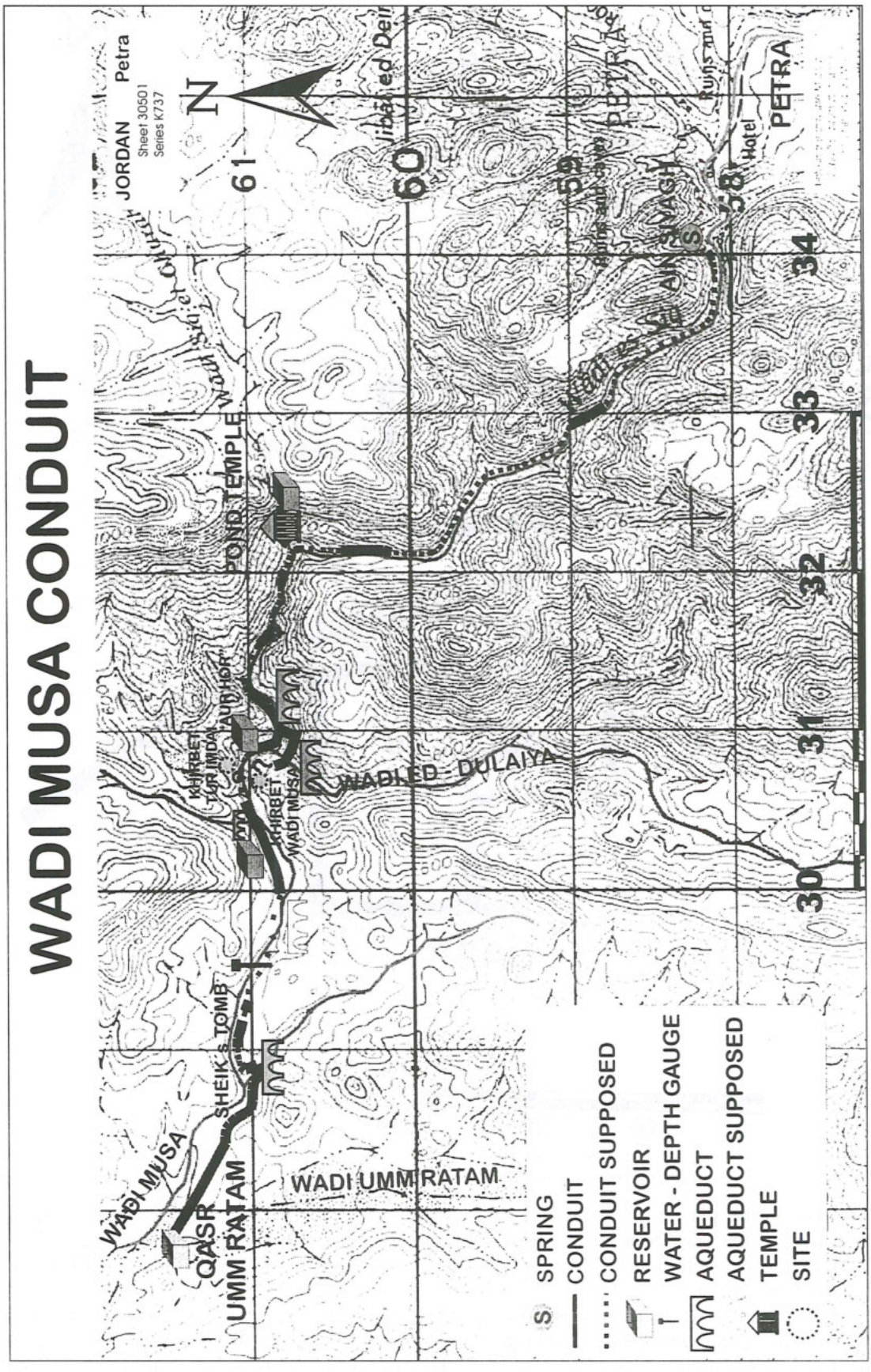
cisterns and was eventually conducted to the reservoir of Qaṣr Umm Ratām at the confluence of Wādī Mūsā and Wādī Umm Ratām (Lindner *et al.* 2000) (**Figs. 17, 18**). Enriched by the run-off from the Slaysil massif and enhanced by a temple (Pond Temple) (Lindner and Gunsam 1995), "Wādī Mūsā Conduit", as it was called by the NHG, passed with a total altitude difference of 440m through an extremely craggy terrain.

In several spots, aqueduct arches of 1.50m width with presumably 3 or 4 piers crossed wadi beds up to 30m wide (**Fig. 19**). The complicated line of 9.3km must have presented serious problems to the hydraulic engineers and, actually, to the surveyors of the NHG in 1995-1998[6] . Of the aqueduct arches, scarce but convincing remnants of abutments are visible. The vulnerability of the conduit is obvious. Earthquakes and devastating flash floods do not and did not happen every year. When they did, channels and aqueducts were severely damaged or entirely destroyed. I was reliably informed that a few years ago the whole of Umm Ratām including the so-called Roman gardens was inundated. Even in normally dry years, maintenance was necessary. A relatively simple section from the foot of the sandstone mountains to the Qaṣr Umm Ratām evidenced serious damage. A conduit of ceramic pipes in that stretch was abandoned and substituted with a plaster bed that was strengthened with the fragments of pipes[7] .

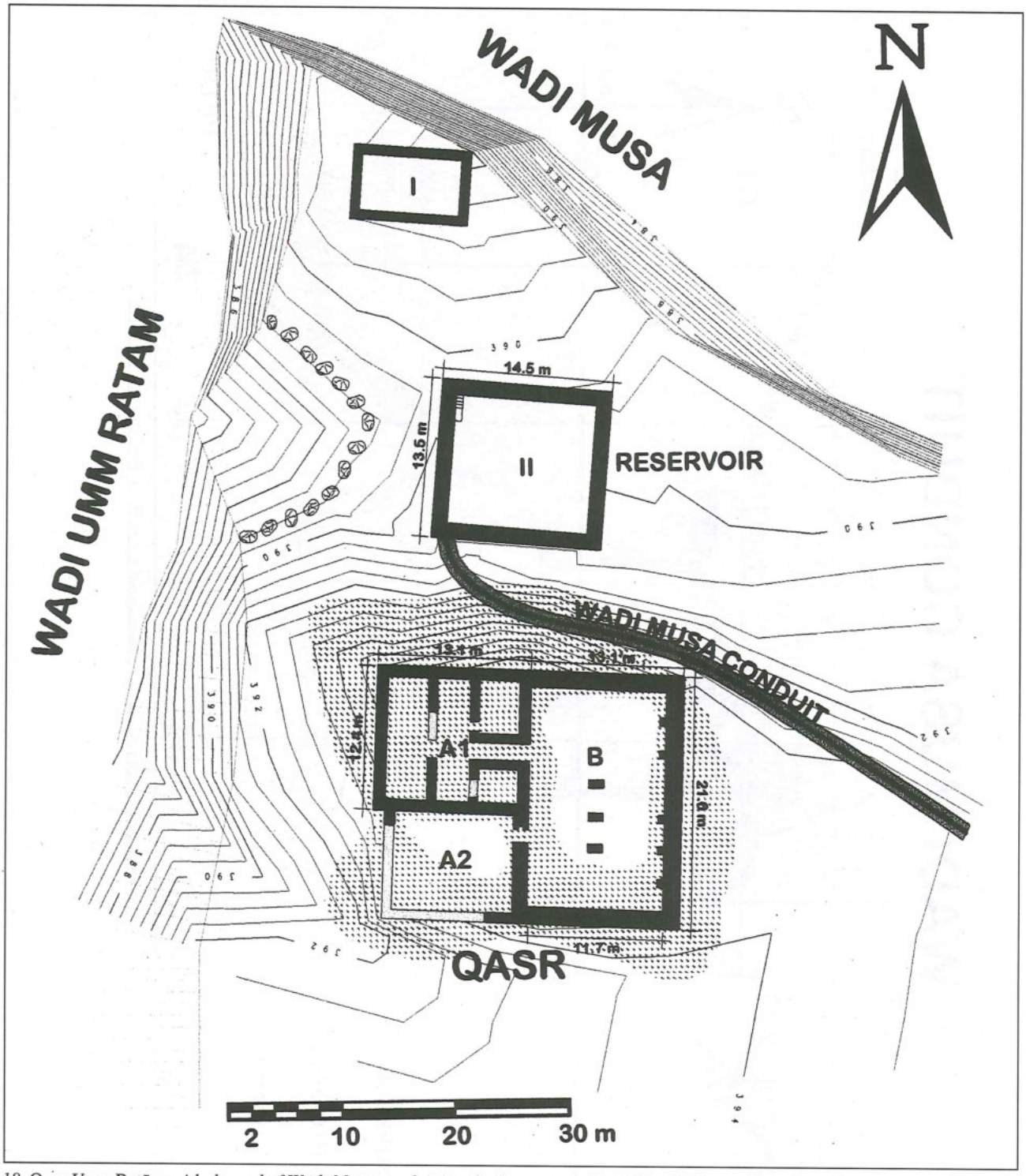
Was Umm Ratām with the *qaṣr* of the same name, so important that a costly and at the same time ex-tremely vulnerable system was constructed? Ac-cording to surface finds a small settlement was oc-cupied originally by Nabataeans since the end of the first century BC. They camped there probably only seasonally respectively after inundations in order to tend the "Roman" and "Nabataean" gar-dens. The *qaṣr* with its reservoir and the conduit was built in the Late Roman era and

6. The examination of Wādī Mūsā Conduit was prepared by Elisabeth Gunsam and Antonie Schmid who contributed excellent photos, and later by J. Hübl and U. Hübner, who described the whole course (Lindner *et al.* 2000: 554-558).

7. Clay fragments of pipes from Wādī Mūsā Con-duit were drawn by M. Lindner (Lindner *et al.* 2000: 235-567, fig. 24, 25). One year later K. 'Amr and A. al-Momani (2001: 270-71, fig. 24) published a note on the Development of Ceramic Water Channels at Wādī Mūsā including repre-sentative examples of ceramic water pipes from the first century BC to the forth century AD. They were all wheel-made and show a development toward "sharper shoulders" and "harder ware". The pipes from Umm Ratām seem to coincide with the second/ third century pipes of 'Amr and Momani.



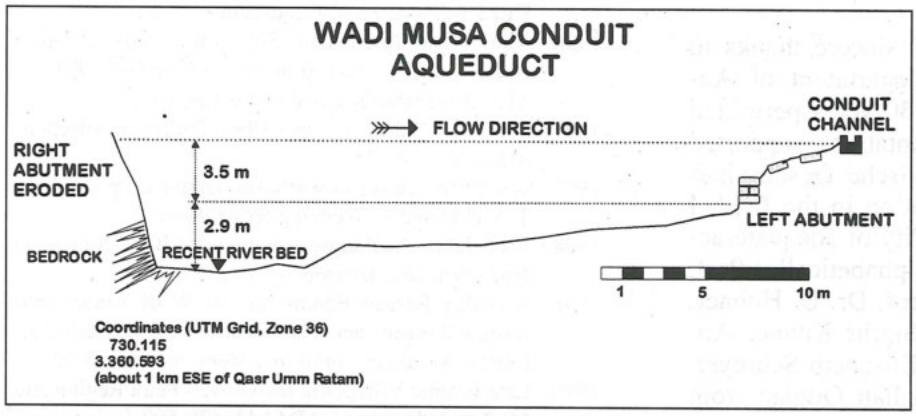
17. Sketch map of Wādi Mūsā conduit from Petra to Umm Ratām (J. Hübl) (2000).



18. Qaṣr *Umm* Ratām *with the end of Wādī Mūsā conduit in a built reservoir (J. Hübl) (2000).*

modified in the Byzantine period. The rests of a *mansio* or *khan* add to the post-Nabataean architecture of Umm Ratām as well as a tower (Uli's Tower) at the settlement entrance.

Obviously, the fact that the conduit was constructed at all indicates the significance of Umm Ratām. The *qaṣr* controlled a route from Petra into Wādī 'Arabah and from there into all other directions e.g. to Khirbat aṭ-Ṭilāḥ (خـــربة الطلاح), which was sup-plied by another conduit and Bīr Madhkūr (بئـــر مـــذكـــور) with a *qaṣr* and water of its own. The Qaṣr Umm Ratām may have housed an auxiliary unit of cohorts or at times perhaps a centuria (Hübner). Charged with the control of a crossroads



19. Measurements of an aqueduct ca. 1km from Qaṣr Umm Ratām (J. Hübl). Note the width of the valley that had to be bridged (2000).

20. Re-used section of the northern conduit of Ba'ja I (1986).

and of a large agricultural area, the Roman-Byzantine garrison had to be provisioned with a constant supply of drinkable water. The Wādī Mūsā Conduit was most probably included in planning and constructing the *qaṣr*.

Summary and Conclusions

In this paper it was attempted to draw conclusions from hydraulic engineering at sites with an artificial water supply. The hydraulic system of Ba'ja I clearly attests that it was planned and con-structed in order to supply a large agricultural area. The sporadic bursts of flash floods out of the gorge would not have allowed for reliable crops every year. For caravans passing through and for watering flocks there was a cistern in the Jabu Plain. In the valley of as-Sādah, spring water conducted to the valley bottom over aqueduct arches and conduit blocks was mainly used for irrigating cornfields and gardens. With water stored in a large reservoir and in rock holes, the settlement was rather an agricultural haven in the Nabataean-Roman period than a caravan station.

Without the catch water management, a large res-ervoir behind a strong wall and an audaciously constructed conduit, Ṣabrā would have suffered from rare but devastating floods at one time, and thirst at another. The spring in the wadi was just sufficient to preserve the natural oasis and a small number of people but not enough to supply residents and caravans passing through. Wādī Mūsā conduit, as it was called by the NHG, to Umm Ratām was not constructed by and for indigenous Nabataeans. Its planning, constructing and maintaining on a high technical level was done for military reasons, i.e. for the Roman garrison at the crossroads of Umm Ratām. The conduit accentuates the *qaṣr's* significance in the second/third century AD and later despite its relatively minor size. It is a pity that we do not know when precisely the different conduits were constructed, who financed them and when they ceased to function.

Generally, the conduits were built either in the framework of a greater plan or when an authority changed or after a catastrophe. Hopefully this paper can add a few hints as to the missing dates. The author suggests that at least the Nabataean inscriptions in Shu'b Qes (Milik and Starcky 1975: 12; Lindner and Gunsam 1970/97: 332), at the upper conduit of Jabal al-Madhbaḥ (Knauf 1997 Pl. 12B); in Sadd al-Maagin (Knauf 1990/91: 154) and at the conduit of Ba'ja I (Lindner 1986: 121; 1996: 255) should be epigraphically analyzed for dating the conduits. Malfunction of the water supply by destruction or lack of maintenance of conduits or other hydraulic works hastened the decline of a site. There is no evidence that the annexation of Nabataea by the Romans in 106AD caused a gap in constructing and maintaining conduits. Significantly, at Ba'ja I (**Fig. 20**)and as-Sādah people tried to reuse the conduits up to a much later, even the present time. Due to their technical complexity, the ancient conduits of Ṣabrā were not reparable and only certain sections of Wādī Mūsā Conduit to Umm Ratām were reused – in one spot as a grave.

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