# New Radiocarbon Dates from the Edomite Highlands and the Hydraulic Systems of Southern Jordan

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**Summary: New Radiocarbon Dates from the Edomite Highlands and the Hydraulic Systems of Southern Jordan**

This study aims to interpret the recent radiocarbon datings of lime-based mortars from hydraulic structures of the archaeological site of as-Sila, in the northern Edomite plateau (Jordan). These radiocarbon dates suggest three main chronological horizons throughout a long period of time, but their interpretation is a difficult task. They present problems related to the nature of the mortar formation and to the discrepancies with the chronology provided by the local pottery, the 14C datings, and the archaeological evidence of other sites in the region. A cautious, interdisciplinary methodology is thus necessary, one in which the 14C datings are complemented by the contextual archaeological data. Following this approach, we suggest the hydraulic system of as-Sila would have been built during the Iron Age II and later reused during the Persian-Hellenistic and Early-Middle Islamic periods.

**Keywords:** Radiocarbon dating – Mortar – Water management – Southern Jordan – Edom

**Resumen: Nuevas dataciones por radiocarbono de la altiplanicie edomita y los sistemas hidráulicos de Jordania meridional**

El presente estudio tiene por objeto interpretar las recientes dataciones de radiocarbono de morteros a base de cal de las estructuras hidráulicas del sitio arqueológico de as-Sila, en la meseta norte edomita (Jordania). Estas dataciones de radiocarbono sugieren tres horizontes cronológicos principales en un largo período de tiempo, pero su interpretación es una tarea difícil. Éstas presentan problemas relacionados con la

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naturaleza de la formación del mortero y con las discrepancias con la cronología proporcionada por la cerámica local, las dataciones de C14, y los datos arqueológicos de otros sitios de la región. Por lo tanto, es necesaria una metodología prudente e interdisciplinaria, en la que las dataciones de C14 se complementen con los datos arqueológicos contextuales. Basándonos en esta aproximación, sugerimos que el sistema hidráulico de as-Sila se habría construido durante la Edad del Hierro II y habría sido reutilizado posteriormente durante los períodos persa-helenístico y el período islámico temprano y medio.

**Palabras clave:** Datación de radiocarbono – Mortero – Gestión del agua – Jordania meridional – Edom

## Archaeology of the Edomite Plateau and Excavations at as-Sila

The Edomite Plateau, located in the south-western part of Jordan, possesses a long history of human settlement that harks back to the Neolithic period. Although traditionally considered a peripheral region, far from the urban centers of the Levant and devoid of large agricultural resources, during certain periods the region experienced periods of settlement flourishing, particularly during the Iron Age, Nabataean-Roman, Byzantine and Midde-Islamic periods.[1] The region is known as the place where the Iron Age polity of Edom, mentioned by the Hebrew Bible and contemporary Mesopotamian sources, emerged and flourished.[2] Until recently, only three archaeological sites dating to the Iron Age had been properly excavated and published—Buseirah, Tawilan and Umm al-Biyara, which were dated according to their material remains (mostly pottery) and a few epigraphic texts.[3] Limited excavations have been recently carried out in the sites of Khirbat al-Malayqtah, Khirbat al-Kur, Khirbat al-Iraq Shmaliya, and Tawilan, which provided the first radiocarbon dates for Iron Age sites of the Edomite Plateau.[4]

[1] MacDonald 2015.
[2] See Bartlett 1989; Tebes 2013: 121–125.
[3] Bennett and Bienkowski 1995; Bienkowski 2002; 2011.
[4] Smith, Najjar and Levy 2014.


**Fig. 1**.
Map with the location of as-Sila and the main sites mentioned in the article (J. M. Tebes).

Since 2015 the site of as-Sila, a large 43 ha site located in the northern part of the Edomite Plateau (**Fig. 1**), has been being investigated by an interdisciplinary research group of the University of Barcelona led by R. Da Riva. According to the pottery found by this and previous investigations of the site, as-Sila presents evidence of occupation during the Iron Age, Nabataean-Roman, Ayyubid, Mamluk and Ottoman periods (**Figs. 2–3**).[5] The most notable archaeological feature is a large water system with more than a hundred structures comprising channels, tanks, and cisterns carved into the sandstone or

[5] Da Riva 2019; Da Riva *et al.* 2017; forthcoming.

cut into boulders, of an extent so far unparalleled on the Edomite Plateau (**Figs. 4–6**).[6] During 2015 and 2016 the Barcelona team surveyed and mapped all the site's hydraulic structures. Sixteen samples of lime-based mortars were collected from these structures and subject to petrographic and mineralogical analyses; 12 AMS radiocarbon dates were taken from them (**Table 1**; **Fig. 7**). The petrographic and mineralogical analyses were carried out by M. Soto, while the radiocarbon studies were done by F. J. Santos Arévalo.[7]

This is the first time that 14C dates are available from a mountain-top site on the Edomite plateau and the first 14C dating of hydraulic structures in this region. Although these dates are of enormous importance for unravelling the history of human settlement on the Edomite Plateau, their interpretation poses several methodological problems.

**Fig. 2.**
Panoramic view of as-Sila (photo: Sela Archaeological Project).

[6] Marsal 2020: 75–81.
[7] See Da Riva *et al.* 2021, for the details of these analyses.

**Fig. 3**.
Panoramic view of as-Sila (photo: Sela Archaeological Project).


**Fig. 4**.
As-Sila: water deposit 36 (photo: Sela Archaeological Project).


**Fig. 5**.
As-Sila: water channel 29 (photo: Sela Archaeological Project).


**Fig. 6**
As-Sila: water deposit 27 (photo: Sela Archaeological Project).

| CNA# | User Code | Age BP | $\delta^{13}C$ | Calibrated ranges |
|---|---|---|---|---|
| 4192.1.1 | SL16.D16.2 | 3150±30 | -11.5 | 1498–1382 BC (*90.0%*)<br>1340–1310 BC (*10.0%*) |
| 4191.1.1 | SL16.D38.9 | 2980±30 | -8.7 | 1371–1359 BC (*1.2%*)<br>1297–1113 BC (*98.8%*) |
| 4393.1.1 | SL16.D03.5 | 2890±30 | -4.6 | 1192–1170 BC (*3.3%*)<br>1165–1144 BC (*3.3%*)<br>1131–977 BC (*93.4%*) |
| 4193.1.1 | SL16.107.13 | 2660±30 | -12.2 | 895–868 BC (*8.7%*)<br>857–854 BC (*0.6%*)<br>850–794 BC (*90.7%*) |
| 4394.1.1 | SL16.D57.10 | 2650±30 | -9.6 | 894–870 BC (*6.3%*)<br>849–792 BC (*93.7%*) |
| 4392.1.1 | SL16.D22.8 | 2500±30 | -13.0 | 787–699 BC (*27.9%*)<br>696–540 BC (*72.1%*) |
| 4396.1.1 | SL16.D91.6 | 2300±30 | -6.5 | 404–356 BC (*82.1%*)<br>286–235 BC (*17.9%*) |
| 4395.1.1 | SL16.D59.11 | 1260±25 | -8.1 | 670–778 AD (*92.9%*)<br>791–805 AD (*2.1%*)<br>812–826 AD (*1.7%*)<br>840–862 AD (*3.3%*) |
| 4391.1.1 | SL16.H1.UM3.2 | 1000±30 | -18.1 | 983–1049 AD (*82.2%*)<br>1086–1124 AD (*14.5%*)<br>1137–1150 AD (*3.3%*) |
| 4189.1.1 | SL16.H1.UM3.1 | 980±30 | -21.1 | 993–1055 AD (*51.0%*)<br>1077–1153 AD (*49.0%*) |
| 4190.1.1 | SL16.H1.6.169 | 970±30 | -21.7 | 1018–1059 AD (*36.3%*)<br>1065–1154 AD (*63.7%*) |
| 4397.1.1 | SL16.D13.1 | 910±25 | -12.7 | 1035–1189 AD (*99.1%*)<br>1199–1202 AD (*0.9%*) |

**Table 1**.
Radiocarbon dates from mortars from as-Sila (CALIB3.0; IntCal13)
(F. J. Santos Arévalo).

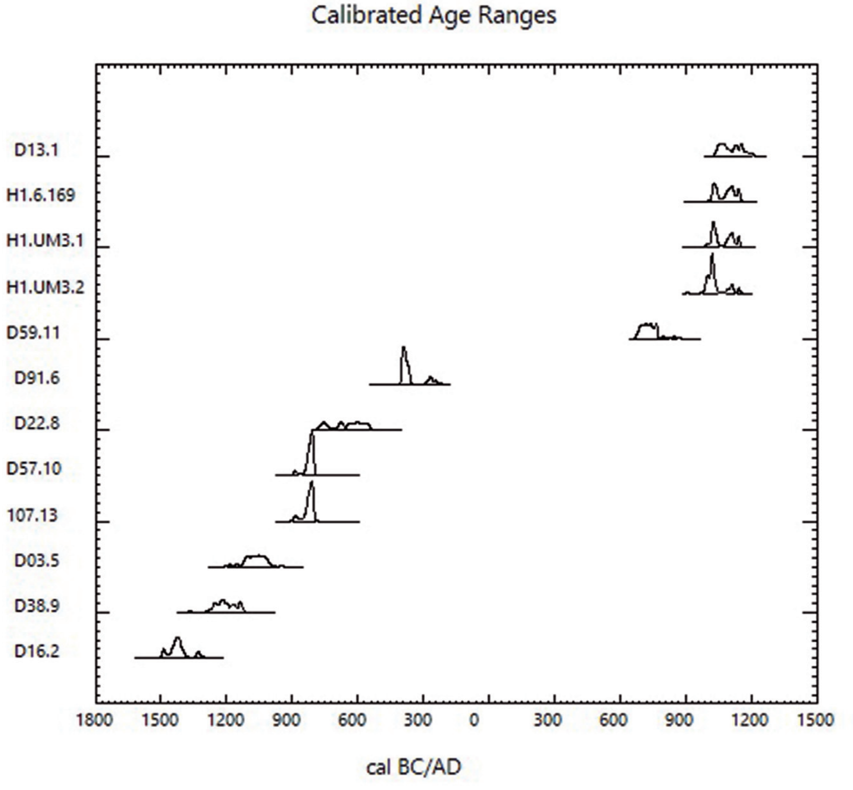


**Fig. 7**.
Calibrated age ranges of the as-Sila Radiocarbon Dates
(F. J. Santos Arévalo).

## The as-Sila Radiocarbon Dates: Problems and Interpretation

Since the 1960s, scholars have used radiocarbon dating to determine the date of lime-based plaster and mortar and the date of construction or renovations of buildings and structures. The age of ancient structures from Europe, the Middle East and the Americas have been determined with this method.[8] This type of radiocarbon dating involves the study of the carbon from the atmosphere that is fixed to the mortar during the

[8] See Al-Bashaireh 2008: 106–114; Urbanova, Boaretto and Artioli 2020.

hardening process, which can theoretically point to the mortar's period of creation. As observed in a recent reassessment of this method:

> *This dating method assumes that after the emplacement of the lime binder the carbonation process occurs rapidly (i.e. weeks or months) with respect to the architectural history of the building. Therefore, the measurement of the $^{14}$C content of the binder should yield the age of the corresponding construction phase.*[9]

The interpretation of the 14C dates of the mortars from the as-Sila hydraulic systems poses several problems. These can be grouped into two types: a) problems related to the process by which the mortars are formed; and b) problems regarding the relationship between the 14C datings and the site's overall archaeological evidence.

Problems of the first kind arise from the same process of mortar formation. Several issues can cause incorrect radiocarbon readings, including: the hardening process can take a long time to finish (years or decades), altering the relationship with the original date of the mortar formation; interaction with water may alter the deposits of carbonate and thus alter the age of the mortar; contamination with limestone, under-burned calcareous raw material or any other form of old calcareous inclusions would produce incorrect older ages; and the presence of aggregates containing inorganic carbon can interfere in the dating.[10]

On a more general level, the 14C datings from mortar are also subject to issues related to the presence of fluctuations in the radiocarbon calibration curve. Particularly significant for the Iron II is the flat calibrated radiocarbon curve from 800–400 BCE ("Hallstatt plateau"); although high resolution dendrochronological measurements have greatly improved calibration for this period,[11] extreme caution should still be taken on dates falling within this period.[12]

[9] Urbanova, Boaretto and Artioli 2020: 505.
[10] Al-Bashireh 2012: 11–12; Urbanova, Boaretto and Artioli 2020: 505–506; Da Riva *et al.* 2021: 58.
[11] Fahrni *et al.* 2020.
[12] For an overview of the problems associated with dendrochronology, see Porter 2015.

The second type of problems involve the relationship between the resultant mortar 14C datings and the chronology based on the archaeological evidence, particularly when there exist wide discrepancies (that is to say, beyond the margin of error) between both. This is precisely what happens with the as-Sila datings.

The mortar 14C dates from as-Sila are distributed through a long-time range—even though some trends can be discerned. Taking into account the widest calibration ranges, three main chronological horizons can be discerned:

- Mid-late 2nd mill. BCE: Late Bronze, with two 14th–12th cent. BCE dates (CNA# 4192.1.1, 4191.1.1); and Iron Age I, with one 12th–10th century BCE date (CNA# 4393.1.1);
- 1st mill. BCE: Iron Age II, with three 9th–6th cent. BCE dates (CNA# 4193.1.1, 4394.1.1, 4392.1.1); and Persian-Hellenistic, with one 4th cent. BCE date (probably extending into the 3rd cent. BCE) (CNA# 4396.1.1);
- Mid-1st–early 2nd mill. AD: Early Islamic, with one 7th–8th cent. AD date (CNA# 4395.1.1); and Middle Islamic, with four 10th–12th cent. AD dates (CNA# 4391.1.1, 4189.1.1, 4190.1.1, 4397.1.1.)

The question is if these three chronological groups correspond with the actual dates of construction and potential reuse of the hydraulic system. To begin with, interpretations should be taken as tentative, since the mortar samples used for 14C dating comprise only a limited corpus of more than a hundred structures comprising the hydraulic system of as-Sila.

The use of lime plaster cannot be used for purposes of chronology, because the technology of lime plaster is one of the oldest building techniques, appearing in the southern Levant as early as the Neolithic period.[13] In the southern Levant, the earliest plastered cisterns are known from the Middle Bronze Age, although the use of plaster in cisterns only became widespread in the Iron Age II.[14] In the regional

[13] Rollefson 1990; Iriarte *et al.* 2016.
[14] Faust 2006: 2231.

context, lime plaster has been documented as a waterproof application at Ramesside Timna (southern Arabah) for lining stone basins,[15] at the ‘Ain el Qudeirat Valley (north-eastern Sinai) for coating a Middle Bronze II or Late Bronze aqueduct,[16] and for lining water reservoirs in Petra and Udhruh in southern Jordan and at Negev sites during the Nabataean, Roman and Byzantine periods.[17]

The relationship between the 14C dates and what is known about the history of settlement of the Edomite Plateau is more complicated, particularly with respect to the pre-8th cent. BCE dates. According to the most recent research, there is no archaeological evidence of human settled occupation in this region during the 2nd mill. BCE (Middle-Late Bronze periods). At most, the area was inhabited by nomadic pastoral groups, based on the references of New Kingdom Egyptian texts to the *shasu*-groups of Edom (although these may very well be references to their living in the Negev or Sinai).[18] The modern chronology of Iron Age Edom was established by C.-M. Bennett, who following her excavations at the Edomite sites of Umm al-Biyara, Tawilan and Buseirah during the early 1960s-early 1980s, established that the beginning of settled life occurred in the later phases of the Iron II (7th–early 6th cent. BCE). This view hinged upon the dating of the local decorated pottery and chronological synchronisms with Neo-Assyrian history. This overall dating was slightly modified by Bienkowski in the final publications of these sites, extending the range to encompass the whole of the Persian period.[19] During the 1990s, Finkelstein suggested the presence of Iron I occupation based on his identification of pithoi and cooking pots with parallels in Iron I assemblages from Israel and central Jordan, and the findings of Midianite/Qurayyah pottery in sites of the Edomite Plateau.[20] This

[15] Avner 2014: 119–120.

[16] Bruins and van der Plicht 2007: 489.

[17] Shaer 1997; Al-Aseer 2000; Akasheh *et al*. 2004; Meir, Freidin, and Gilead 2005: fig. 5; Al-Bashaireh 2012; Bonazza *et al.* 2013; Driessen and Abudanah 2018; Ore, Bruins, and Meir 2020: 4.

[18] MacDonald 2015: 22.

[19] Bennett and Bienkowski 1995; Bienkowski 2002; 2011.

[20] Finkelstein 1992; 1995: 127–137.

interpretation was contested by Bienkowski, who argued that all excavations at the Edomite sites reached bedrock and therefore all "Iron I" sherds should be dated to the Iron II, while the parallels with Cisjordanian pottery were regarded as irrelevant to the archaeology of Edom.[21]

During the 2000s most scholarly attention was redirected to the several archaeological projects taking place in the Faynan region of southern Jordan. As a ramification of its research at Faynan, in 2006–2007 a team of the University of California San Diego surveyed and carried out soundings at four Iron Age sites of the Edomite Plateau.[22] At three of these sites, Kh. Al-Malayqtha, Kh. Al-Kur and Tawilan, the first 14C dates from the Iron Age of the Edomite Plateau were taken (**Table 2**). Most of these dates fall in the 8th–6th cent. BCE, with the exception of Tawilan, that extends mostly in the 9th cent. BCE.

| **Site Name** | **Sample #** | **Material** | **Age BP** | **Calibrated ranges** |
|---|---|---|---|---|
| Kh. Al-Malayqtha | OxA-18322 | seeds | 2572±30 | 810–578 BC (*95.4%*) |
| Kh. Al-Malayqtha | OxA-18323 | seeds | 2589±30 | 820–612 BC (*95.4%*) |
| Kh. Al-Malayqtha | OxA-18344 | seeds | 2491±27 | 776–511 BC (*95.4%*) |
| Kh. Al-Kur | OxA-18345 | seeds | 2539±30 | 799–545 BC (*95.4%*) |
| Tawilan | OxA-18346 | seeds | 2642±28 | 890–785 BC (*95.4%*) |

**Table 2**.
Recent Iron Age radiocarbon dates from the Edomite highlands (OxCal 4.05; IntCal04). Adapted from Smith, Najjar and Levy 2014: Table 3.2.

It is clear that the first chronological horizon (mid-late 2nd mill. BCE) of the 14C dates from as-Sila falls completely outside the range of these Edomite Plateau 14C dates. Regarding the pottery evidence, a short report made by Zayadine of the sherds Lindner collected at the site briefly describes the presence of pottery "from the Early Bronze I (3rd

[21] Bienkowski 1992.
[22] Smith, Najjar and Levy 2014.

millennium BC) until the Mamluk period (14th/15th centuries AD)," noting the finding of a sherd from the Late Bronze Age.[23] However, other surveys in the site did not report any pre-Iron Age pottery. Although the existence of nomadic groups living in the as-Sila area cannot be discounted during the mid-late 2nd mill. BCE, it is unlikely that these groups left any archaeological evidence of their presence. Most importantly, such technology of water management can be better associated with sedentary communities whose economies were based on agriculture, such as the ones that inhabited as-Sila since the Iron Age.

It is in the second radiocarbon horizon (1st mill. BCE), and particularly the three Iron II dates, where we find a perfect correspondence with the archaeological data. The three Iron II 14C dates are supported by finds of so-called "Edomite" pottery, also known as "Southern Transjordan-Negev Pottery" (STNP) or "Busayra Painted Ware," in Edomite highlands sites and the northern Negev between the late 8th and the early 6th cent. BCE.[24] This characteristic pottery was found in as-Sila by Glueck's survey of Eastern Palestine ("EI I–II sherds"), Hart's Edom Survey, Lindner's survey, and MacDonald's Tafila-Busayra Survey[25] and again by the present project.[26] Finkelstein identified a few Iron I sherds from Hart's survey of the site,[27] although as we have seen his interpretation has been contested. The only Persian-Hellenistic date is supported by the Hellenistic pottery reported by Zayadine's report.[28]

The use of 14C dates for delineating the chronology of Iron Age southern Jordan is not without problems, particularly the presence of fluctuations in the radiocarbon calibration curve.[29] Thus, some scholars have attempted to build a chronology of Edom completely independent

[23] Lindner 1997: 282; Lindner, Hübner and Gunsam 2001: 269–270.
[24] Tebes 2011; 2013: 71–109; Singer-Avitz 2014.
[25] Glueck 1939: 32; Hart 1989: 110–111; Lindner 1997: 282; Lindner, Hübner and Gunsam 2001: 269–270; MacDonald *et al*. 2004: 276–277.
[26] Da Riva *et al.* 2017: 632; Da Riva 2019: 163.
[27] Finkelstein 1992: 161; 1995: 129.
[28] Lindner 1997: 283; Lindner, Hübner and Gunsam 2001: 270.
[29] Smith, Najjar and Levy 2014: 287; Tebes 2021: 6–7.

from the radiocarbon dating, based only on epigraphic sources and pottery finds, reaching later dates for the climax of the Edomite polity.[30]

One of the most surprising aspects of the mortar 14C from as-Sila is that there are no 14C dates from the Nabataean-Roman period. There is one 14C date from a grave pointing to occupation during the 1st cent. AD,[31] but it is not related to the hydraulic system. This contrasts with the wide evidence of Nabataean pottery found at the site[32] and the well-known works of water management made by the Nabataeans in the Petra area and elsewhere (see below).

The third radiocarbon horizon (mid-1st–early 2nd mill. AD) is clearly supported by the Medieval pottery found at as-Sila,[33] although 14C readings from timber coming from a house gave three later dates, ranging between the 15th and the 17th cent. AD.[34]

In order to test the problems and the efficiency of the 14C datings of mortar from as-Sila, we will briefly discuss recent 14C and OSL datings of mortar in southern Jordan. These studies have involved the 14C and OSL datings of mortar and plaster from archaeological assemblages at Petra and Uhruh, in some cases from samples coming from hydraulic systems, such as Petra's Great Temple bath complex, High Place of Sacrifice water cistern, and as-Siq canal; and two of Udhruh's *qanat* reservoirs[35] (**Table 3**).

[30] van der Veen 2020: 106–115.
[31] Da Riva *et al.* forthcoming.
[32] Glueck 1939: 32; Lindner 1997: 283; Lindner, Hübner and Gunsam 2001: 270; MacDonald *et al.* 2004: 276–277.
[33] Da Riva 2019: 163.
[34] Da Riva *et al.* forthcoming.
[35] Al-Bashaireh 2008; 2012; 2013; Al-Bashaireh and Hodgins 2011; 2014; Driessen and Abudanah 2018.

| Site Name | Dating Type | Material | Periods indicated by 14C-OSL | Bibliography |
|---|---|---|---|---|
| Petra – Main Theater | 14C | charcoal inclusions | Nabataean | Al-Bashaireh and Hodgins 2011 |
| Petra – Qasr el-Bint | 14C | wood inclusions | Nabataean | Al-Bashaireh and Hodgins 2011; 2014 |
| Petra – Temple of the Winged Lions | 14C | charcoal inclusions | Nabataean | Al-Bashaireh and Hodgins 2011 |
| Petra – Great Temple | 14C | plaster & mortar | Nabataean, Roman | Al-Bashaireh 2012 |
| Petra – bath complex at Great Temple | 14C | mortar | Byzantine | Al-Bashaireh 2012 |
| Petra – Florentinus Tomb | 14C | plaster & straw inclusions | Nabataean | Al-Bashaireh and Hodgins 2011; Al-Bashaireh 2013 |
| Petra – al-Siq canal | 14C | charcoal inclusions | Nabataean, Roman | Al-Bashaireh and Hodgins 2011 |
| Petra – Painted Room | 14C | plaster & straw inclusions | Nabataean | Al-Bashaireh 2013 |
| Petra – cistern at High Place of Sacrifice | 14C | plaster | Nabataean | Al-Bashaireh 2012; 2013 |
| Petra – Petra Church | 14C | plaster | Byzantine | Al-Bashaireh 2013 |
| Petra – Petra Pool Complex | 14C | plaster & charcoal inclusions | Nabataean, Roman | Al-Bashaireh 2013 |
| Udhruh – Ottoman Castle | 14C | plaster & charcoal, seed inclusions | Ayyubid-Mamluk, Ottoman | Al-Bashaireh 2013 |
| Udhruh – Tower 1 | 14C | plaster & fibres inclusions | Early Frank-Ayyubid | Al-Bashaireh 2013 |
| Udhruh – North qanat reservoir in Wadi el-Fiqay | OSL | mortar | Nabataean, Roman | Driessen and Abudanah 2018 |
| Udhruh – South qanat reservoir in Wadi el-Fiqay | OSL & 14C | mortar & charred twigs | Roman, Byzantine, Umayyad | Driessen and Abudanah 2018 |

**Table 3**.
Radiocarbon and OSL datings of mortar and plaster and other organic inclusions within them in southern Jordan.

The methodology followed by Al-Bashaireh and Hodgins in their 14C datings of Petra and Udhruh is important, as they radiocarbon dated both the lime binders and organic inclusions found within them, such as wood, charcoal, straw and fibres. There was an almost complete agreement between the 14C dates of the mortar and the organic inclusions.[36] In other words, these organic inclusions, and in some cases inscriptions found in the same structures, served for checking the accuracy of the 14C datings of mortar.

Following the success of these analyses, we can take a cautious, but proactive approach to the interpretation of the evidence. By using an interdisciplinary methodology, we can assess the data coming from the 14C datings on mortar by complementing them with information from the contextual archaeological data. This data comprises:

- The pottery assemblage collected at the site.
- The inscriptions found in or close to the site.
- The architectural layout of the hydraulic system and similar works of water management.

With due caution, we suggest that the construction of at least part of the hydraulic structures of as-Sila dates to Iron Age II, thus agreeing with the large quantities of Iron II pottery sherds found in the site. The post-Iron II 14C dates would correspond to later adaptations and renovations of the water structure during the Persian-Hellenistic, Early and Middle Islamic periods. Earlier 14C dates should not be easily discarded, as they would correspond with recent evidence of water management in the Negev and north-western Arabia in the 2nd mill. BCE and earlier (see below). However, until new evidence is presented to the contrary, all contextual evidence points to the Iron II as the initial phase of construction of the hydraulic system of as-Sila.

No inscription was found directly associated with the water installations. There are some inscriptions inscribed in Arabic, some of them containing *wusūm* or tribal marks. The most significant inscription is the famous relief of Neo-Babylonian king Nabonidus, which

[36] Al-Bashaireh 2012: 24.

was carved sometime between 553–543 BCE. However, the relationship between the relief and the hydraulic system is not straightforward, as the inscription is not easily accessible or visible from the site.[37] What is noteworthy is the absence of Nabataean or Roman-Byzantine inscriptions associated with the hydraulic system, as was customary in the water works built in Petra and the Negev.[38]

We can now proceed to the third contextual archaeological data, the architectural layout of the hydraulic system and similar works of water management in the southern Levant and north-western Arabia.

## The as-Sila Hydraulic System and the Southern Levantine-Northern Arabian Water Management

The hydraulic system found at as-Sila is unique among the sites of the Edomite Plateau. Although rock-hewn hydraulic features are common in Nabataean sites in and around the Petra area, few have been found to the north. Sites on the Edomite plateau should be considered part of a larger geographical and historical area comprising the southern arid margins of the Levant and north-western Arabia. Dry farming was possible in certain ecological niches with limited precipitation levels, particularly the highlands of Edom[39] and the loessical valleys of the northern Negev,[40] or with access to underground water, especially the oasis towns of the northern Hejaz.[41] Access to water was of primary significance for the mountain-top sites in the Edomite highlands such as as-Sila. Limited precipitation levels, with a 200–125 mm of average annual rainfall, but with high variability from one year to the other, implied that storage of water was essential for daily living and the limited agriculture production that is possible in this area. Several technologies were used throughout history to capture, transport and store

[37] Da Riva *et al*. 2017: 633; Da Riva 2019: 168–171.
[38] Bedal 2002; Ore, Bruins and Meir 2020: 2.
[39] Oleson 2018.
[40] Bruins 2012: 32–36.
[41] Kürschner and Neef 2011: 30.

water, including rock-cut or built reservoirs and cisterns, terracing of agricultural fields, earth or masonry dams, open earth or stone water channels and aqueducts, terracotta pipes, and *qanats*.[42]

The first chronological horizon (mid-late 2nd mill. BCE) represented in the as-Sila mortar 14C dates would fit into the evidence of the spread of new water management systems in the arid southern Levant and north-western Arabia in the late 2nd–early 1st mill. BCE, but does not find correspondence with the archaeological evidence found in the site and the region. During this period, the arid southern Levant and north-western Arabia experienced large socio-economic transformations—a true "revolution in the desert" that included the earliest evidence of Bedouin agriculture in the Negev desert and the construction of the earliest hydraulic works in the Hejaz.[43] There is some debate as when agriculture started to be practiced in these areas, and despite some scholarly hesitations,[44] there is wide evidence of runoff and floodwater farming in the central Negev and the Faynan lowlands of southern Jordan during the Iron Age, if not before. We have already cited the radiocarbon dating of an aqueduct mortar from the 'Ain el Qudeirat Valley to the Middle Bronze II or Late Bronze Age. To this should be added analyses of phytoliths and sherulites taken from ancient agricultural terraced fields from Horvat Haluqim in the central Negev highlands that have been radiocarbon dated to the Late Bronze-Early Iron Ages.[45] The construction of cisterns in the central Negev Highlands has been traditionally dated to the Iron Age,[46] although the high spatial correlation between open cisterns and Early Bronze Age and Middle Bronze Age I sites would re-date the construction of at least some of them to the 3rd mill. BCE (see below).[47] The still visible field systems surveyed and excavated in the Wadi Faynan contained dense concentrations of Iron Age sherds within their walls and enclosures, reflecting their use as part of

[42] See Oleson 2018.
[43] Tebes 2020.
[44] Gilboa *et al*. 2009: 91–92; Shahack-Gross and Finkelstein 2017.
[45] Bruins and van der Plicht 2007; 2017.
[46] Haiman 1994: 49–53; 2002; 2003.
[47] Ore, Bruins, and Meir 2020.

complex run-off farming regimes.[48] During the 2nd mill. BCE, complex irrigation systems were erected in north-western Arabian oasis-towns such as Qurayyah and Tayma, consisting of retaining walls to divert runoff or underground water to nearby farming fields.[49]

As we have seen, the second radiocarbon horizon (1st mill. BCE) finds a reasonably good correspondence with the site's pottery assemblage and the 14C and pottery evidence from other sites on the Edomite Plateau. However, few similar rock-cut installations are known in the Edomite highlands during the Iron Age II. These include those surveyed at Ba'ja III and Umm el-Ala and probably Kutle II,[50] but they are comparatively smaller than the one found at as-Sila. Surprisingly, although rock-cut hydraulic features will become plentiful with the Nabataeans, particularly at Petra, but also Umm al-Biyara(?), Ghrareh, Humayma, Udhruh and Wadi Ramm,[51] none of the mortar 14C dates from as-Sila point to use during the Nabataean period.

On a more transregional level, there is some archaeological evidence of water management at Iron Age Jordanian sites such as Hisban, Amman, Sahab, and Tell Es-Sa'idiyyeh (cisterns, reservoirs, wells, channels). In the Moabite Stela, the building of water pools is one of the deeds attributed to king Mesha.[52]

There is, however, a closer if often overlooked, parallel for the as-Sila hydraulic system. This is provided by the water installations located close to the large number of settlements established in the central Negev Highlands during the Iron Age II, traditionally dated to the 10th or late 10th–early 9th cent. BCE. According to some scholars, these sites, numbering around 350 and variously identified as fortified posts, towers, farms and corrals, were founded by a central Cisjordanian entity (the Israelite or the Judaean kingdoms);[53] while others consider

[48] Mattingly *et al.* 2007: 282–285.
[49] Hüneburg *et al*. 2019; Wellbrock *et al.* 2018; forthcoming.
[50] Lindner 1992: 144–145; Bagg 2006: 615–617.
[51] Bedal 2002; Shqairat, Abudanh and Twaissi 2010; Mithen 2012: 111–114; Oleson 2018; Driessen and Abudanah 2018.
[52] Wåhlin 1997; Bagg 2006: 617–623; Khaleq and Ahmed 2007: 85–86; Shqairat 2019: 46–47.
[53] Cohen and Cohen-Amin 2004.

them as part of a long-term process of sedentarization of the local nomads.[54] Haiman has dated two types of water cisterns to this period:

1. Rock-cut cisterns, of which a dozen were found in proximity to the sites.
2. Open reservoirs, 3–20 m in diameter and 2–5 m in dept dug into sealed earth, paved with stones and unplastered.

Over 100 open reservoirs were found. These cisterns were designed to collect the limited amount of rain water that this desert area could provide, both for drinking and for engaging in agriculture. The findings of sickle blades, silos and threshing floors confirm the presence of dry farming in this period.[55]

Recently, Ore, Bruins and Meir carried out an in-depth spatial analysis of these cisterns, leading them to re-date some of these installations to the Bronze Age.[56] They concluded that the Negev cisterns comprise three main types:

1. Open cisterns dug and constructed in relatively soft clayey marl (Haiman's type 2). They present revetting walls built of limestone blocks, without plaster. Their spatial correlation with local sites suggests they were built in Early Bronze Age and Middle Bronze Age sites, and reused during the Iron Age.
2. Cisterns hewn in limestone (Haiman's type 1). They are subdivided into:
   2.1 Bell shaped cisterns, hewn mostly in hard limestone, with narrow, square openings (diameter: 1,1 m) and wide bottoms (5–6 m) (**Fig. 8**).
   2.2 Small bowl-shaped cisterns hewn into soft limestone, with circular circumferences of about 3,9 m and shallower depth (2 m). Found in the vicinity of Iron Age II, Roman, Byzantine and Early Islamic sites.

[54] Finkelstein 1995: 103–126.
[55] Haiman 1994: 49–53; 2002; 2003.
[56] Ore, Bruins, and Meir 2020.

3. Roofed rock cisterns hewn in soft chalk, are larger and plastered. They present Roman-Byzantine inscriptions on their walls.

A comparison with the water system of as-Sila shows some interesting results. First, Type 2 cisterns are similar to the square and circular cisterns cut on limestone found at as-Sila. While their date is not clear, they evidently do not seem to date earlier than the Iron Age. Since they are hewn into hard rocks, they required quarrying tools stronger than those currently available in the Bronze Age (flint, copper, bronze). Therefore, they were probably built with iron tools.[57] The size of the as-Sila cisterns, with diameters of opening between 0,60 x 0,40 m and 1,60 x 1,30 m,[58] is similar to the Type 2.1 cisterns. Second, Type 3 plastered cisterns usually present inscriptions that date them to the Roman-Byzantine period, which is not the case at as-Sila. Therefore I would tentatively suggest that the Negev Highlands cisterns provide a well-dated parallel to the water system found at as-Sila.

The Negev Highlands cisterns also look similar to the hydraulic installations at Umm al-Biyara. These installations, located on a mountain-top site overlooking Petra, pose similar problems to as-Sila. Eight rock-cut piriform cisterns associated with rock-cut rainwater channels were recorded here, but they cannot be conclusively associated with the nearby Iron II Edomite settlement nor with an adjacent Nabataean building (**Figs. 9–10**).[59] But if they do not date to the Iron II period, it is difficult to know how and where people obtained water in this isolated place.

For the third radiocarbon horizon (mid-1st–early 2nd mill. AD), there is ample archaeological evidence of the use of different technologies of water management in Jordan during the Early Islamic and particularly the Middle Islamic period, such as cisterns, aqueducts and *qanats*. Many of these features had been built in Roman and Byzantine times and were reused later, such as in the case of Udhruh, sites in the

[57] Ore, Bruins, and Meir 2020: 2.
[58] Marsal 2020: 77.
[59] Bienkowski 2011: 140.

southern Jordan Valley and Jerash in northern Jordan.[60] Therefore, the Medieval 14C dates of the as-Sila mortar can be understood within the context of general reuse of older hydraulic systems throughout the Early and Middle Islamic periods.

**Fig. 8**.
Bell-shaped cistern with narrow opening, central Negev Highlands (photo: G. Ore).

[60] Driessen and Abudanah 2018: 146, 148; Al Karaimeh 2019; Kaptijn 2019; Boyer 2019; Lichtenberger and Raja 2020.

**Fig. 9**.
Rock-hewn cistern at Umm al-Biyara (photo: J. M. Tebes).

**Fig. 10**.
Rock-hewn cistern at Umm al-Biyara (photo: J. M. Tebes).

## Conclusion

The study of the hydraulic system of as-Sila is of the utmost significance for understanding the history of human settlement on the Edomite Plateau. The 12 14C datings taking from mortar indicate three main chronological horizons: mid-late 2nd mill. BCE, 1st mill. BCE, and mid-1st–early 2nd mill. AD. However, the 14C dating of the mortar presents several methodological problems, some related to the nature of the mortar formation and some associated with the discrepancies with the chronology provided by the local pottery and the 14C and archaeological evidence of other sites in the same region. Given these problems, we prefer to be extremely cautious in the interpretation of this data, taking an interdisciplinary methodology by which the 14C datings are complemented by the contextual archaeological data. We have followed the successful example of similar 14C datings of mortar carried out in southern Jordan, some of them coming from hydraulic systems, that have arrived at chronologies grossly matching the associated 14C datings of organic inclusions, archaeological and epigraphic evidence. With due caution, we can date the construction of at least part of the hydraulic system at as-Sila to the Iron Age II, with later adaptations and renovations in the Persian-Hellenistic, Early and Middle Islamic periods. However, the earlier radiocarbon dates should not be easily discarded.

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