



HAL
open science

An absolute radiocarbon chronology for the World Heritage site of Sarvestan (SW Iran); a late Sasanian heritage in early Islamic era

Morteza Djamali, Manuela Capano, Alireza Askari-chaverdi, Nicolas Faucherre, Frédéric Guibal, Alastair Northedge, Elnaz Rashidian, Thibaut Tuna, Edouard Bard

► To cite this version:

Morteza Djamali, Manuela Capano, Alireza Askari-chaverdi, Nicolas Faucherre, Frédéric Guibal, et al.. An absolute radiocarbon chronology for the World Heritage site of Sarvestan (SW Iran); a late Sasanian heritage in early Islamic era. *Archaeometry*, 2022, 64 (2), pp.545-559. 10.1111/arc.12716 . hal-03380634

HAL Id: hal-03380634


<https://amu.hal.science/hal-03380634>

Submitted on 15 Oct 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

An absolute radiocarbon chronology for the world heritage site of Sarvestan (SW Iran): A late Sasanian heritage in early Islamic era

Morteza Djamali¹  | Manuela Capano² | Alireza Askari-Chaverdi³ |
Nicolas Faucherre⁴ | Frédéric Guibal¹ | Alastair Northedge⁵ |
Elnaz Rashidian¹ | Thibaut Tuna² | Edouard Bard²

¹Europôle méditerranéen de l'Arbois, Institut Méditerranéen de Biodiversité et d'Ecologie - IMBE (Aix Marseille Univ, Avignon Université, CNRS, IRD), Aix-en-Provence, France

²CNRS, IRD, INRAE, Collège de France, CEREGE, Aix Marseille Univ, Aix-en-Provence, France

³History Department, Shiraz University, Shiraz, Iran

⁴CNRS, Laboratoire d'Archéologie Médiévale et Moderne en Méditerranée (LA3M) - Aix Marseille Univ, France

⁵UFR d'Art et d'Archéologie Université de Paris I (Panthéon-Sorbonne), Paris, France

Correspondence

Morteza Djamali, Institut Méditerranéen de Biodiversité et d'Ecologie - IMBE (Aix Marseille Univ, Avignon Université, CNRS, IRD), Europôle méditerranéen de l'Arbois, 13545, Aix-en-Provence, France.
Email: morteza.djamali@imbe.fr

Funding information

Fondation Aix-Marseille Université; Agence Nationale de la Recherche; Centre National de la Recherche Scientifique; Aix-Marseille Université

Abstract

This study presents a new precise radiocarbon chronology for the World Heritage site of Sarvestan (SW Iran). The monument is a key construction in the history of architecture because it is a typical Sasanian construction built during the late Sasanian or early Islamic period. Previous attempts to date the monument have suggested the ages ranging from the middle Sasanian (fifth century CE) to early Abbasid (ninth century CE) era. These age estimations are based on the analysis of architectural plans and techniques, and a few radiocarbon dates with very large age uncertainties. This paper presents the results of a systematic radiocarbon dating of timbers in the walls and charcoals in plaster mortars used in the main dome of the monument. It further applies wiggle matching technique and R_Combine function to substantially reduce the age uncertainties in wood sections. The results indicate that a major construction work was undertaken

We proudly dedicate this study to Professor Touraj Daryaei (Maseeh Chair in Persian Studies & Culture, History School of Humanities, University of California, Irvine) in appreciation of his significant contribution to the history of the Iranian world during the Late Antiquity.

sometime between 658 and 683 CE, the century of the invasion of Fars by Muslim Arabs. This finding pushes back the age of Sarvestan for two centuries and suggests that the monument was built at the transitional period between Sasanian to Islamic era. Sarvestan would have been an architectural project designed and possibly initiated during the late Sasanian period but mainly accomplished during the second half of the seventh century CE. It can thus be considered a late Sasanian heritage in early Islamic period. Its construction at a time of political unrest further suggests that some areas of Fars may have benefited from certain socio-political stabilities during the expansion of Islam into the east at mid- to late seventh century CE.

KEYWORDS

Fars, Islamic architecture, Late Antiquity, radiocarbon dating, Sasanian architecture, tree rings

INTRODUCTION

The Sarvestan monument is one of the World Heritage sites of Iran (Sassanid Archaeological Landscape of Fars Region, Ref. no. 1568) that has long intrigued archaeologists and historians of architecture (Bier, 1986; Coste, 1878; Flandin & Coste, 1851; Grabar, 1969; Siroux, 1973). This well-preserved monument in Fars (Figures 1 and 2) is crucial to understand the history of Iranian architectural evolution in regard to its dating and function, both being a matter of long debates (Grabar, 2005).

Sarvestan is located on an inter-mountainous plain of about 1,000 km² between the northern mountain range of Kuh-e Ahmadi and the southern mountain range of Kuh-e Qara, about 75 km southeast of Shiraz and 45 km northwest of Fassa. The Sarvestan area is drained into Lake Maharlu, which lies in the northwestern entry of this plain (Figure 1).

The exact dating of the Sarvestan monument is not clear based on its architectural elements. On the one hand, it presents numerous elements reminiscent of the early Sasanian architecture including the ovoidal domes, elliptical arches, sawtooth moldings, and the use of mortared rubbles in walls (Bier, 2002; Coste, 1878). On the other hand, it displays several architectural features (e.g. the complex brick lays in cupola) that can be assigned to middle or late Sasanian and even a post-Sasanian period. Some authors go even further by assigning the monument to the Islamic period (Bier, 2002). The first attribution of the Sarvestan monument to the early Sasanian period was proposed by French architect Pascal-Xavier Coste after his visit to the site on 30 January 1841 (1878). His proposition was based on analogy with the Palace of Ardashir, an early Sasanian monument in Firuzabad (Djamali et al., 2017; Huff, 1978). In his *Mémoires d'un artiste: notes et souvenirs de voyages*, he writes: 'Having the same construction elements as those of Firuzabad, this monument is Sasanian' (Djamali & Faucherre, 2020). A Sasanian age for Sarvestan based on stylistic comparisons was thereafter adopted by other scholars (Creswell, 1914; Sarre & Herzfeld, 1910; Siroux, 1973). Creswell (1914) consider the architectural elements of Sarvestan to be an advanced version of the Ardashir Palace in Firuzabad and definitely belonging to the Sasanian tradition.

The other curiosity of the Sarvestan monument is its function upon which no consensus has yet been achieved. Most of the debate has been caused by the uncommon architectural plan of



FIGURE 1 Geographical location of the Sarvestan monument as well as the major Sasanian cities in seventh century CE mentioned in this study. The extension of the Sasanian Empire at 3rd century CE is shown in the inset map

the monument. This monument has been considered a palace/residential building, garden pavilion, and ceremonial complex (Bier, 1986, 2002; Coste, 1878; Grabar, 1969, 2005). The possible function as a Zoroastrian fire temple, first mentioned by Coste (1878), has more recently been elaborated by Grabar (1969, 2005) and Bier (1986, 2002) after detailed analysis of the building layout and spatial configuration of different rooms and halls. Lionel Bier goes further by suggesting that not only would the monument have functioned as Zoroastrian fire temple, but it was used by Zoroastrians during the first centuries of Islam, when Persia was under domination of the Muslim Arab Califate (Bier, 1986, 2002). He thus put Sarvestan out of the ‘canon of Sasanian architecture’ and presented it as an Islamic construction in which architects were possibly influenced by Umayyad and Abbasid architecture (Bier, 1986).

Obtaining an absolute age for Sarvestan monument is thus key to understand its position in the evolution of architecture in southwest Asia during Late Antiquity and its possible links to emergence of Islamic architecture, which has its own roots in Sasanian architecture (Bier, 1993; Labisi, 2018). A preliminary radiocarbon dating of the monument on the basis of three ^{14}C ages of wood samples already provided an age of late seventh to late ninth century CE with over 200 years uncertainty, the latter being a typical feature of calibrated radiocarbon ages obtained from this interval of medieval time (Askari-Chaverdi & Djamali, 2019; Djamali et al., 2017). These radiocarbon ages do not help determine the precise construction date of the building. The question of the absolute age of the Sarvestan monument remains thus open to the archaeological community and needs a more systematic and precise absolute dating, which constitutes the main goal of this study.

Presence of numerous timbers used during the construction and/or restoration of the monument provides the possibility of establishing a detailed absolute chronology for the whole site. We apply the wiggle matching to timbers showing a tree-ring sequence longer than 10 rings with



FIGURE 2 The Sarvestan monument from different angles. (a) Looking to the second dome in NNE-direction through the eastern hall. (b) Looking to the internal courtyard from the opening of the western *eyvan*. The western columned hall is located on the left. (c) a view to the north showing the two main domes as well as part of the eastern columned hall. (d) the southern wall of the western *eyvan* with the position of one of the oldest wood samples (S39)

the aim of increasing the dating precision. Indeed, the technique combines in one model, the information concerning annual rings with ^{14}C dating (Bronk Ramsey et al., 2001). Further, to support the wood-based radiocarbon dates, we also dated a few charcoal grains found in gypsum mortars used in the construction of the monument's major dome.

The present research was thus designed to:

- i. undertake a systematic radiocarbon dating of wood samples used in the walls of different sections of the monument and charcoals in gypsum mortars,
- ii. increase the precision of dating to a decadal scale, and
- iii. to discuss the historical and architectural implications of dating results.

THE MONUMENT

The architecture of the Sarvestan monument has been documented in a number of drawings, articles, and books (Coste, 1878; Creswell, 1914; Siroux, 1973. Bier, 1986, Grabar, 2005). The monument, located in the middle of the Sarvestan plain, 300 meters away from other structures (Askari-Chaverdi, 2009), is a $45\text{ m} \times 37\text{ m}$ rectangular construction with NE–SW oriented longer axis with a large central hall with a high cupola (number 1 in Figure 3) between a monumental entrance and an open courtyard (Figure 3). This central axis is bordered by two basilical

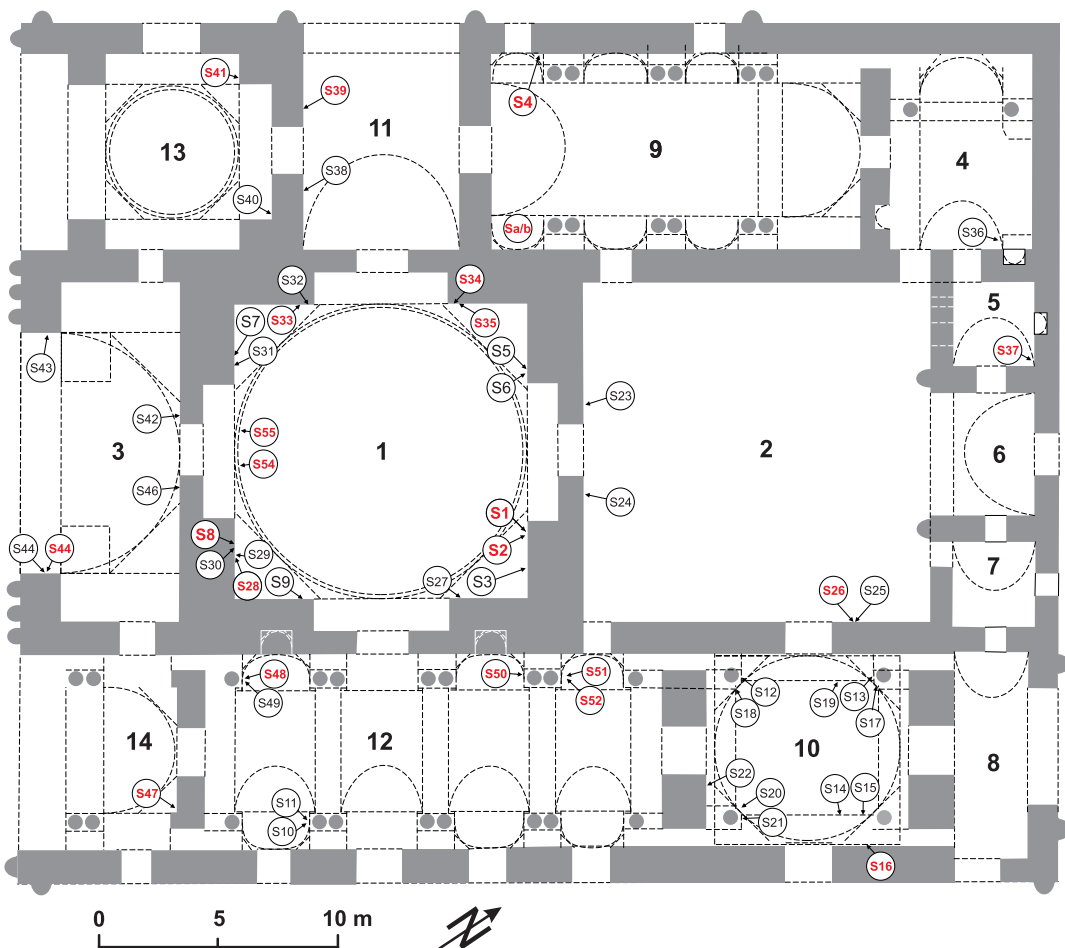


FIGURE 3 Architectural plan of the Sarvestan monument after Bier (1986) with the position of all sampled timbers Notes: 1. Main domed hall, 2. Internal courtyard, 3. Main *eyvan*, 9. Western columned hall, 10. Northeastern domed hall, 12. Eastern columned hall, 11. Western entrance *eyvan*. Wood samples S07, S33, and S42 are Montpellier maple (*acer monspessulanum*) and all other timbers were identified as cypress (*Cupressus sempervirens*)

naves carried by double columns. Two other halls with cupola occupy the opposite angles east and west. Five porches, two (perhaps three) domed halls, two colonnades, three rooms, and a nave are among the most important sections of the building. The monument's walls are of stone, the domes of brick, and an advanced vaulting technique is observed here (Creswell, 1914).

Thus, even a quick look at the architectural plan of the monument shows its first puzzling aspect, which is its asymmetry (Grabar, 1969). Although the main façade composed of one monumental central *eyvan* and two smaller lateral *eyvans* displays a symmetrical aspect, the internal arrangement of the building is peculiarly asymmetrical (Grabar, 1969). The central *eyvan* leads to the main domed square hall which forms the turning plate of the monument and contains the largest concentration of timbers (n = 17) used both in the walls and in the cupola. The major domed hall leads, in turn, into the internal courtyard (number 2 in Figure 3), which is not a walled space but is delimited simply by the outer walls of the surrounding halls and rooms. Remains of four timbers are still in place in this part of the building. The right-lateral *eyvan* of main façade (number 14 in Figure 3) leads to a 20 m long columned vaulted hall that

connects to the main domed hall on its western side and a small domed hall in the northeast corner of the building (hall number 10 in Figure 3). This latter hall contains the second highest numbers of timbers after the main domed hall ($n = 11$). The left-lateral *eyvan* of the main façade leads to another *eyvan*, which opens up to the northwest from the main domed hall (number 11 in Figure 3). This space is then connected to another long columned hall (number 9 in Figure 3), which ends in a small semi-domed room (number 4 in Figure 3).

MATERIAL AND METHODS

Wood sampling

In June 2018, a systematic sampling of all timbers found in the walls of different compartments of the Sarvestan monument was undertaken. In total, 52 wood pieces were sampled for dating and taxonomic identifications (Figures 3 and 4; Table 1, Supplementary Materials). The main strategy was to sample the last tree ring of the timbers. When the timbers were protruded from the walls, a transversal section was cut using a hand saw in order to subsample tree rings for wiggle matching dating. The wood samples were taxonomically identified by examining the transversal, tangential, and radial sections of timbers under the light microscope ($\times 40$ to $\times 1000$

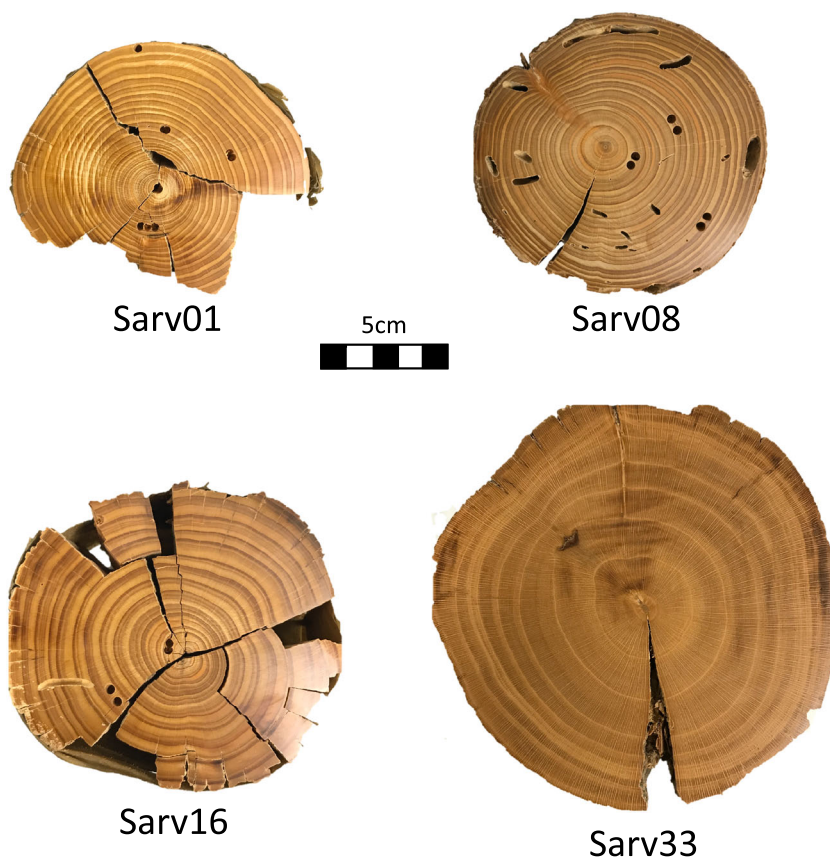


FIGURE 4 A selection of wood sections including those used in wiggle matching (Sarv01, Sarv08, Sarv16) identified as *Cupressus* and Sarv33 identified as *Acer monspessulanum* Note: See Figure 3 for positioning in the monument and Table 1, Supplementary Materials, and Figures 5 and 6 for dating results

magnification) when the size and anatomical preservation of samples permitted (Table 1, Supplementary Materials). Tree rings of wood sections were counted and sampled in the dendrochronological facilities of IMBE (France).

Plaster charcoal sampling

The use of gypsum mortar and plaster was widespread in Sasanian architecture (Huff, 1986). Most gypsum mortars and plasters contain charcoal fragments of the fuel burnt during the process of dehydration of gypsum (Stoops et al., 2017). The dehydration is done by heating the gypsum between 130 and 160°C to generate the calcium sulphate hemihydrate or ‘plaster of Paris,’ which when mixed with water is transformed again into gypsum and consolidates the stones or bricks (Rapp 2002; Stoops et al., 2017). Two charcoal fragments were directly hand picked from the mortars between the bricks of the main dome (S54, S55). We also picked some tens of microcharcoals under a stereomicroscope from a plaster sample used in the foundation in the southeast corner of the western columned hall (S a/b in Figure 3).

Radiocarbon dating

Nineteen pieces of wood were sampled for ^{14}C analysis. Only three wood samples showed tree-ring series long enough for wiggle matching dating: wood no. S01, 33-years long, wood no. S08, 11-years long, and wood no. S16, 14-years long (Figure 3; Table 1, Supplementary Materials). Several annual rings from the three wood sections were subsampled for dating. These included rings no. 1, 20, 24, 28, and 33 from S01; rings no. 3, 6, and 11 from S08; and rings no. 3, 9, and 14 from S16 (Table 2, Supplementary Materials). For the remaining 16 timbers, the last ring was subsampled for ^{14}C measurement. Rings were sampled using a scalpel or a micro coring system and sliced into small pieces. About 50 mg of wood was treated for cellulose extraction using the ABA-B method at CEREGE (Aix-en-Provence, France). This method consists of a classical ABA treatment, with solutions of HCl and NaOH at 4% concentration, followed by a bleaching step performed with 60 g of NaClO_2 in 1 L of ultrapure water in acid solution (HCl) at pH 3 (Capano et al., 2018). The ABA-B method omits the resin extraction with organic solvents, as several studies demonstrated that NaOH is sufficient to remove resins from conifers (Capano et al., 2018). Approximately 0.3 and 8 mg of charcoal, respectively from samples Sarv-a/b and Sarv54/Sarv55, were treated with the ABA method described in Capano et al. (2018).

After chemical pretreatment, the dried residues of wood and charcoal (Sarv54 and Sarv55) were weighed in tin capsules and combusted with the elemental analyzer. The evolved CO_2 was then transformed into graphite with the AGE III system. The graphite target was finally analyzed for its $^{14}\text{C}/^{12}\text{C}$ and $^{13}\text{C}/^{12}\text{C}$ ratios using the AixMICADAS system (Bard et al., 2015). Standards (OxA2 NIST SRM4990C) and blanks (VIRI-K, chemically treated like the other wood samples) were processed together with unknown-age samples and used for normalization and blank correction, respectively. In addition, IAEA-C3 (that underwent the chemical pretreatment like the other wood samples) and IAEA-C8 standards were pretreated and measured for ^{14}C in the same batches, serving as control standards. High precision ^{14}C measurements were performed with long AMS runs to reach at least 800,000 ion counts for each OxA2 standard target on the same magazine. An additional uncertainty of 1.6‰ was propagated in the ^{14}C analytical errors and background correction following the convention described in Capano et al. (2018). The data are reported in terms of conventional ^{14}C age in years BP (Stuiver & Polach, 1977). The precision and accuracy of ^{14}C ages measured on tree-rings at CEREGE has been verified in the frame of an international intercomparison (Wacker et al., 2020).

The sample Sarv-a/b consisted of a few μg of charcoal with inclusions of gypsum mortar. The sample was separated in three subsamples: One subsample was directly ^{14}C measured with the aim of testing the contamination derived from gypsum inclusions; the other subsamples separately underwent the ABA chemical pretreatment (hitherto called Sarv-a and Sarv-b or Sarv-a/b) in order to check for the contamination removal efficiency (Capano et al., 2018). Ca. 100 μg of carbon from the three subsamples was weighed into silver capsules and combusted with an elemental analyzer connected to the gas interface system (GIS), which allows to transfer the evolved CO_2 directly into the ion source of AixMICADAS system (Bard et al., 2015). Standards (OxA2 NIST SRM4990C) and blanks (VIRI-K, chemically treated like the other samples) were processed together with samples and used for normalization and blank correction. In addition, two cylinders of gas standards are connected to the GIS in order to monitor the blank and to perform the measurement normalization with OxA2 (Tuna et al., 2018).

The ^{14}C ages were finally calibrated with the IntCal20 calibration curve, which is based on annual-resolution records for the period of our interest (Reimer et al., 2020). OxCal v.4.4 program was used for calibrations: D_Sequence model was used for wood samples S01, S08, and S16 (Bronk Ramsey, 1995; Bronk Ramsey et al., 2001), and R_Combine function for the remaining 16 samples based on the youngest tree ring (Bronk Ramsey, 2009).

RESULTS AND INTERPRETATIONS

Wood preservation and taxonomic identifications

Timbers are found in all of the compartments of Sarvestan monument with highest concentrations in the domed square halls in which $n = 17$, and $n = 11$ wood samples were counted in the larger and smaller domes, respectively (Figure 3). They are inserted into the walls as deep as 30 cm and are mostly located at a height of 2 to 10 meters from the ground surface. Some wood sections and pieces are extremely well preserved due to their content in essential oils and the dryness of the climate. Indeed, well-preserved essential oils were successfully extracted from wood chips of the Sarvestan monument (pers. comm. with Dr. Frédéric Poitou, Laboratoire SIGNATURE, Aix-en-Provence, France). Nevertheless, in a few wood sections, traces of xylophagy as gallery networks partly filled with fecal pellets were observed (Sarv08 in Figure 4). Over 52 wood samples examined, 49 were taxonomically identified with *Cupressus sempervirens* (cypress), accounting for 94.2% of samples. Besides cypress, three samples were identified as *Acer monspessulanum*.

Radiocarbon dating results

Calibrated radiocarbon ages of all dated wood samples (mostly the last tree ring) with 2σ -range provided a large time interval from 1,343 to 1,176 cal BP corresponding to 645–775 cal CE (Table 2, Supplementary Materials) covering a long time interval of 130 years. However, despite this large uncertainty, ^{14}C ages of all wood samples are in agreement within almost the same error uncertainty permitting to use the R_Combine function of OxCal to combine the obtained ages and to reduce the associated uncertainty. To do this, we excluded the samples Sarv01, Sarv08, and Sarv16 because of their longer tree-ring sequences that could allow for the utilization of wiggle matching technique (see later). The χ^2 test on the weighted average was successful, validating the results of the R_Combine function (see "All wood" in Figure 6). The results revealed two distinct intervals of dating at 2σ -range: 658–683 cal CE and 748–759 cal CE with the first showing the highest probability. The long-time spanning interval of dating (i.e. 658–759 cal CE) cannot, however, help to precise the chronology of construction of

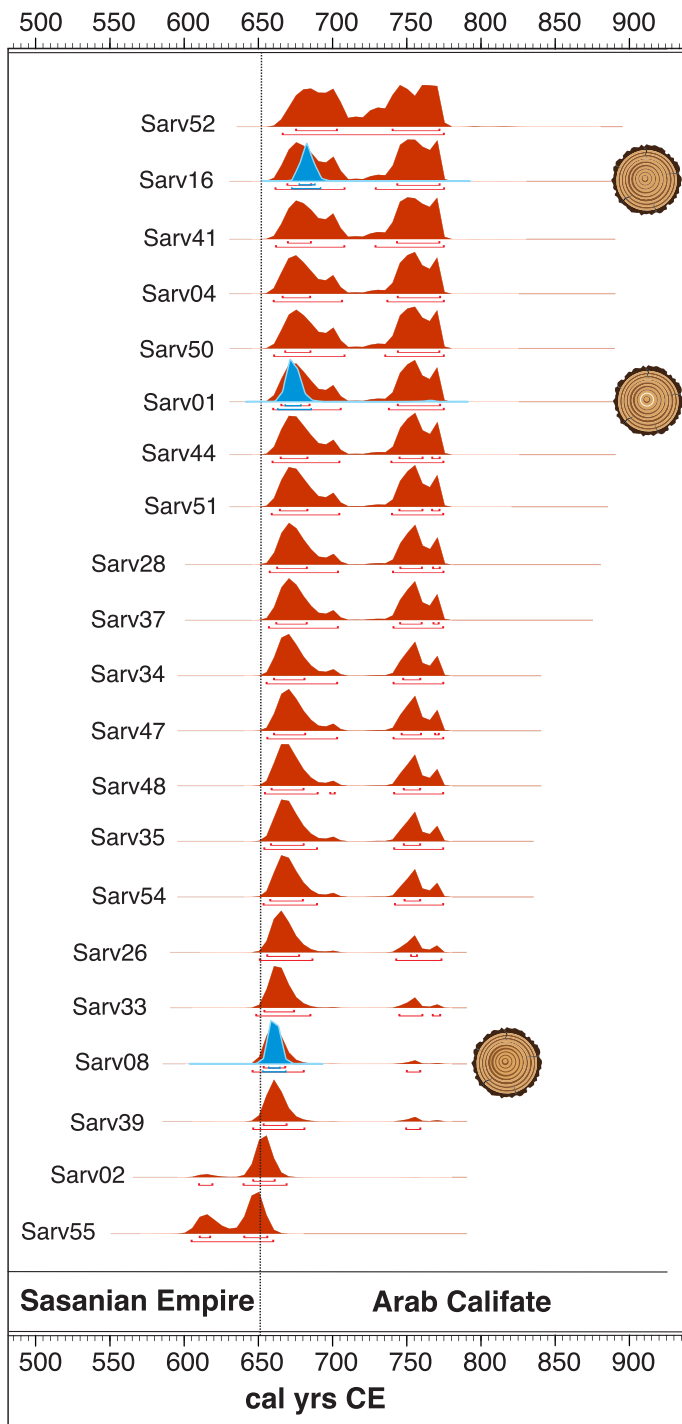


FIGURE 5 Probability distribution curves for calibrated radiocarbon ages of 19 wood samples from the walls and two charcoal samples from the main dome (Sarv54 and 55) Notes: The presented red curves for Sarv01, Sarv08, and Sarv16 represent the radiocarbon age of the last (youngest) tree ring, whereas the three constrained wiggles are displayed in blue. See Table 1 for more details about samples and ^{14}C dates

the monument in relation to the important geopolitical events in southwest Asia including the heartland of Persia during the Late Antiquity (Hinds, 1984).

Therefore, to further reduce the age uncertainties, we applied the wiggle-matching technique to the wood sections displaying the longest ring series. Despite the relatively short tree-ring sequences, the results of wiggle-matching dating of Sarv01, Sarv08, and Sarv16 successfully reduced the dating uncertainty and clearly indicated the timbers dating to the second half of the seventh century CE (see Figure 5 [blue curves]). The results of samples dated by wiggle matching let thus to restrict the dating of the other 16 wood samples (marked in red in Figure 5) to the first age interval obtained with the R_Combine function, that is, 658–683 cal CE (Figure 6). Indeed, ^{14}C ages of all 19 timbers are in agreement within the error uncertainty (Table 2, Supplementary Materials), giving the 658–683 cal CE as the time interval during which the major construction phase was undertaken in Sarvestan monument. ^{14}C age of Sarv54 charcoal fragment is fully in agreement with the ^{14}C ages of all wood samples (653–774 cal CE, 2σ), whereas the results of ^{14}C dating of charcoal Sarv55 shows a slightly older age (605–660 cal CE, 2σ), which is still in agreement with the ^{14}C ages of all wood samples and Sarv54, and can be considered as a further confirmation of monument construction to the

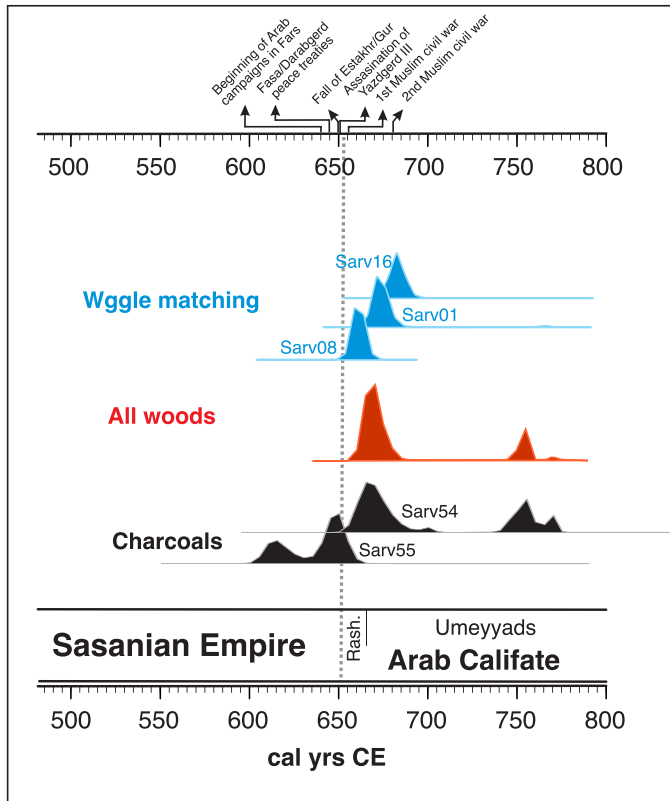


FIGURE 6 A summary of the wiggle matching, R-combine function of OxCal of all wood samples and the charcoal dating depicted against the timeline of major historical events during the construction phase of Sarvestan monument. Notes: All distribution curves refer to 2σ -range probabilities. S01, S08, and S16 (in blue) show the refined radiocarbon ages based on wiggle matching. The charcoal sample of S55 is the oldest radiocarbon age with relatively small age uncertainty. Based on wiggle matching, we attribute the age of 658 to 683 as a major construction phase of Sarvestan monument. All ages fall within the second half of 7th century CE during the invasion of Persia by Arab Muslims. Rash.: Rashidun caliphate

mid- to late seventh century CE (very late Sasanian and first decades of Arab Caliphate (Figure 5; Table 2, Supplementary Materials).

¹⁴C results of microcharcoal grains extracted from the gypsum foundation that did not undergo the chemical pretreatment show an older age than the other analyzed samples: 2301 ± 68 years BP. This ancient date could be the result of a fossil contamination material. The two subsamples of microcharcoal grains (Sarv a/b) that underwent two independent chemical pretreatments consistently show the same ¹⁴C date, which allowed for the weighted average calculation (298 ± 41 cal BP; 1,480–1,662 cal CE) and confirmed the reliability of results. This youngest date is totally out of the range of all other ¹⁴C dated materials and belongs to a recent phase of restoration of the monument in the 15th century CE.

DISCUSSION

The abundant wood samples used during a major construction and/or restoration work in the Sarvestan monument provide us with an exceptional opportunity to establish the first precise absolute radiocarbon chronology for an ancient monument in Persia. Most of the wood samples were identified as the Mediterranean cypress (*Cupressus sempervirens* L.). This finding is not surprising as the timbers of this tree have also been reported from two other Sasanian palatial monuments in Firuzabad dating to the beginning of the Sasanian Empire (Djamali et al., 2017). Cypress stands with very old trees dating at least to the 15th century CE have been described from the Firuzabad region suggesting an old tradition of cypress cultivation in the region (Arsalani et al., 2021). Indeed, the word ‘Sarvestan’ in Middle and New Persian languages means the ‘garden of cypress’, suggesting that this tree has been a major planted tree since the medieval and older times. The young age and high radial growth rate of most of the collected wood sections of Sarvestan monument also suggest that the trees either grew on deep well-watered soils or were most probably irrigated at the time of their cutting. For a detailed account on the archaeobotanical implications of our finding of the cypress wood in the Sarvestan monument, the reader is referred to Djamali, Askari-Chaverdi, Balatti, Guibal, and Santelli (2017). The finding of three wood samples belonging to Montpellier maple (*Acer monspessulanum* L.) is also expected as it is possibly the third most important deciduous tree (after *Pistacia atlantica* and *Amygdalus scoparia* [*Prunus scoparia*]) found in the pistachio-almond scrub communities dominating the mountain areas around the Sarvestan. It is still not clear whether the utilization of two different woody taxa (cypress and maple) was linked to their different functions and properties or simply because of the shortage of available cypress timbers during the construction/restoration or a modification phase in the building at a later time. In any case, the age of the Sarv-33 (maple) coeval to the other *Cupressus* wood samples excludes the possibility that these samples belong to two separate construction/restoration phases. Figure 5 shows that all timbers date almost to the same decades but to slightly different years of the same period. We can, therefore, suppose two different possibilities where the second is not contradicting the first prospect. The timbers could indeed be included in the monument in different years within a period of ca. 40 years or having been stored for a while before being included in the monument.

Our new constrained chronology for the Sarvestan monument has significant implications to understand (i) the role of Sasanian architecture in emergence of the Islamic architecture and (ii) the process of the conquest of Persia by Muslim Arabs.

Sarvestan and the emergence of the Islamic architecture

Our results indicate that the Sarvestan monument is one of the first important constructions, if not the very first one, built and completed during the Sasanian to Early Islamic transitional

period in Iran (Figure 6) (see Grabar, 1986 for this transitional period). It has been an architectural project designed and most probably initiated during the late Sasanian period and accomplished during the second half of the seventh century CE when Persia was subjected to frequent incursions by Arabic tribes partly coordinated by the newly established caliphate in Basra (Hinds, 1984). It is thus logical to argue that the Sarvestan monument represents an architectural style developed and practiced in Iran during the late Sasanian era. Common presence of typical Sasanian architectural elements (Huff, 1986) observed in Sarvestan monument has convinced a number of archaeologists and historians of architecture to propose a Sasanian age for this monument since the 19th century (Coste, 1878). This Sasanian age had recently been criticized by Bier (1986, 2002), who attributed the monument to ninth century CE and relocated it from Sasanian to Islamic architectural corpus. His dating of the monument was not, however, based on absolute dating (Bier, 1986, 2002). In his analysis of the influence of Sasanian palatial architecture on the Umayyad and Abbasid buildings, Bier (1993) further noted the near absence of archaeological evidence for the late Sasanian architecture to investigate the continuity in palace design during this transitional period. Indeed, some of the Umayyad palaces (e.g. in Amman) seem to have been built and decorated in a deliberately Persianising (Sasanian) style (Northedge, 1993), whereas others start to differ in general plan and functionality but continue to use Sasanian decorations (Hillenbrand, 1981). Although few late Sasanian buildings in Mesopotamia have been reported (Finster & Schmidt, 2005), their poor preservation state and their later restoration and re-use, especially during Abbasids, does not permit to draw any picture of late Sasanian architectural tradition (Northedge & Kennet, 2015; Simpson, 2018). The Sarvestan monument is thus a key construction to understand the continuity of Sasanian to early Islamic architecture.

The monument has a number of features that seem to be precursor of the ways Iranian architecture would evolve in the Early Islamic era (Grabar, 1986). For instance, as Bier (2002) mentions, the projection of the entrance arches on the southern and western façades suggests the presence of a primitive form of tall rectangular masonry frames known as *pish taq*, a typical feature of the post-ninth century Islamic monuments. Furthermore, 'the combination of bricks laid radially in doubled stretcher courses alternating with a course of pitched brick in vaults whose finely finished undersurfaces were unplastered and meant to be seen, seemed to prefigure the more elaborate brick lays which later became characteristic of Islamic architecture in Iran' (Bier, 2002).

The exact chronological position of Sarvestan in the Late Sasanian-Early Islamic era is thus fundamental for understanding the Iranian architecture during the post-Sasanian era and the roots of the so-called Islamic architecture. Our findings indicate that some features characterizing the Islamic architecture (e.g. *pish taq*) were already developed during the late Sasanian to very early Islamic period. The new chronology, in clear contradiction with the ninth century age proposed by Lionel Bier (1986, 2002), brings the Sarvestan monument from an Abbasid to Buyid construction at least one century back during the socio-political instability of the mid-seventh century when the Arab Caliphate was trying to establish its domination in the Iranian plateau (Hinds, 1984).

Fars during the first decades of Arab invasion

The realization of a major construction project in Fars region (SW of Iran) during a period of war and power transition between the Sasanian Empire and Arab Caliphate arises a fundamental question about the socio-political situation of Iran at the beginning of the Arab invasion as well as the religious stability of the mainstream Zoroastrian beliefs systems (Pourshariati, 2008). It necessitates a certain stability, at least locally, which is hard to imagine during the wartime. The last Sasanian ruler was crowned in Estakhr, at the heart of the Fars

region in 632 AD, probably due to security and loyalty issues (Daryaei, 2009). A detailed analysis of the available historical accounts shows that the Arab invasion of Fars was an overly complex process that was not accomplished until 650 CE (Morony, 2012). The first incursions were carried out solely by tribesmen from Oman and Bahrain independent of the newly established Caliphate in Basra (Hinds, 1984). Although the cities in the coastal plains of the Persian Gulf were more easily conquered, the repeated attempts to capture the major mountain strongholds of Estakhr and Gur failed until 650 CE (Hinds, 1984). In the other hand, the governors and religious leaders of a number of cities preferred to make peace agreements with the invaders rather than to combat. For instance, the Arab commanders made a peace agreement with the *herbadh* (a Zoroastrian priest leader) of Darabgerd and the Lord of Fassa (Hinds, 1984; Morony, 2012). The Sarvestan monument is very close to the city of Fassa and would have administratively belonged to the territory of Fassa (Figure 1). It can be postulated that under a peace treaty, the Persian ruler of Fassa and/or Sarvestan could quietly continue finalizing the project of the Sarvestan monument on the basis of the architectural plans dating to the late Sasanian era.

Furthermore, the seemingly convincing proposition of Grabar (1969) and Bier (2002) on the religious ceremonial functionality of Sarvestan provides new information on the history of Zoroastrianism at the advent of Islam. If Sarvestan has really functioned as a fire temple, it seems that when the peace treaties were agreed, the Arab rulers left the local people to practice their ancient religion after tribute arrangements. The strong resistance of many highland cities of Fars left no choice to Arab invaders to accept the peace agreements with some rulers to be able to continue their eastward and northward military operations into the Persian territories.

CONCLUSION

New radiocarbon-based chronology constructed for the Sarvestan monument has significant implications for understanding the history of architecture and the socio-political situation of Iran at the transition of the Sasanian Empire to the Islamic period. Detailed analysis of the architectural design and innovations in the monument informs us on the late Sasanian architecture and its continuation during the early Islamic period before the emergence of the so-called 'Islamic architecture'. However, although a comprehensive architectural documentation is available for the monument (i.e., Bier, 1986), the subsequent interpretations are based on the assumption that the monument belongs to the ninth century CE at the time of Abbasid Caliphate (Bier, 1993, 2002). Our new chronology urges to reconsider Bier's interpretations and re-interpret the monument and its religious function in the context of the mid-seventh century CE.

Finally, although the present study provides a minimum age of mid-seventh century CE, this age may represent a restoration phase or the resumption of the construction works already initiated during the Sasanian period. The foundation and walls of the monument may have been built before the occupation by Arab armies. Hence, there is room for further constraining the chronology of Sarvestan construction by absolute dating of gypsum mortars used in the foundation and in the walls of the building.

ACKNOWLEDGEMENTS

The project leading to this publication has received funding from Excellence Initiative of Aix-Marseille Université - A*MIDEX, a French 'Investissements d'Avenir' programme. Fieldwork and radiocarbon dating were also supported by LIA project entitled 'HAOMA' supported by Centre National de la Recherche Scientifique (CNRS) and 'PALEO-PERSEPOLIS' project (2015-2019) funded by the Agence Nationale de la Recherche (ANR-14-CE35-0026-01). This work has also been supported by the Center for International Scientific Studies &

Collaboration (CISSC), Ministry of Science, Research & Technology, Iran. Dahvya Doum-Belkacem and Maryse Alvitre are thanked for extraction of microcharcoals from gypsum plaster. Nassim Komjan is thanked for her precious help in positioning the timbers in the architectural plan of the monument. We are grateful to the staff members of the municipal library of Marseille (the Alcazar) Olivier Polère and Thierry Conti (Fonds rares et précieux) for their generous help and cooperation to give access to Pascal-Xavier Coste's archive. AixMICADAS and its operation are funded by the Collège de France, the EQUIPEX ASTER-CEREGE, and the ANR project CARBOTRYDH (PI E. B.). We thank two anonymous reviewers for their thoughtful and constructive comments.

PEER REVIEW

The peer review history for this article is available at <https://publons.com/publon/10.1111/arc.12716>.

ORCID

Morteza Djamali  <https://orcid.org/0000-0001-7304-7326>

REFERENCES

- Arsalani, M., Griebinger, J., Pourtahmasi, K., & Bräuning, A. (2021). Multi-centennial reconstruction of drought events in South-Western Iran using tree rings of Mediterranean cypress (*Cupressus sempervirens* L.). *Palaeogeography Palaeoclimatology Palaeoecology*, *567*, 110296. <https://doi.org/10.1016/j.palaeo.2021.110296>
- Askari-Chaverdi, A. (2009). Archaeological excavations in the building known as the palace of Sarvestan. *Iranian Journal of Archaeology and History*, *23*, 36–65.
- Askari-Chaverdi, A., & Djamali, M. (2019). Sasanian palaces of Persis according to the absolute chronology: Qal'a-ye Doxtar and palace of Ardashir I (Ātaškada) at FirūzĀbĀd, and the so-called palace of Sarvestān, Iran. *Archaeology Journal of the Iranian Center for Archaeological Research*, *3*, 23–32.
- Bard, E., Tuna, T., Fagault, Y., Bonvalot, L., Wacker, L., Fahrni, S., & Synal, H.-A. (2015). AixMICADAS, the accelerator mass spectrometer dedicated to 14C recently installed in Aix-En-Provence, France. *Nuclear Instruments and Methods in Physics Research B*, *361*, 80–86. <https://doi.org/10.1016/j.nimb.2015.01.075>
- Bier, L. (1986). *Sarvistan: A study in early Iranian architecture*, College Art Association Monographs, Monograph on the Fine Arts 41. Pennsylvania State University Press, University Park.
- Bier, L. (1993). The Sassanian palaces and their influence in early Islam. *Arts Orientalis*, *23*, 57–66.
- Bier, L. (2002). Sarvistan reconsidered. In E. Ehrenberg (Ed.), *Leaving no stones unturned: Essays on the ancient near east and Egypt in honor of Donald P. Hansen* (pp. 43–51). Winona Lake: Eisenbraunus. <https://doi.org/10.5325/j.ctv1bxh4bc.8>
- Bronk Ramsey, C. (1995). Radiocarbon calibration and analysis of stratigraphy: The OxCal program. *Radiocarbon*, *37*, 425–430. <https://doi.org/10.1017/S0033822200030903>
- Bronk Ramsey, C. (2009). Dealing with outliers and offsets in radiocarbon dating. *Radiocarbon*, *51*, 1023–1045. <https://doi.org/10.1017/S0033822200034093>
- Bronk Ramsey, C., van der Plicht, J., & Weninger, B. (2001). "Wiggle matching" radiocarbon dates. *Radiocarbon*, *43*, 381–389. <https://doi.org/10.1017/S0033822200038248>
- Capano, M., Miramont, C., Guibal, F., Kromer, B., Tuna, T., Fagault, Y., & Bard, E. (2018). Wood 14C dating with AixMICADAS: Methods and application to tree-ring sequences from the younger Dryas event in the southern French Alps. *Radiocarbon*, *60*, 51–74. <https://doi.org/10.1017/RDC.2017.83>
- Coste, P. (1878). *Mémoires d'un artiste; notes et souvenirs de voyages (1817-1877)*. Marseille: Tome I, Typographie et Lithographie Cayer et Cle.
- Creswell, K. A. C. (1914). The history and evolution of the dome in Persia. *Journal of the Royal Asiatic Society of Great Britain and Ireland*, *46*, 681–701. <https://doi.org/10.1017/S0035869X00047067>
- Daryae, T. (2009). *Sasanian Persia: The rise and fall of an empire*. London: I.B. Tauris & Co. in association with the Iran Heritage Foundation. <https://doi.org/10.5040/9780755694174>
- Djamali, M., Askari-Chaverdi, A., Balatti, S., Guibal, F., & Santelli, C. (2017). On the chronology and use of timber in the palaces and palace-like structures of the (Sasanian empire in "Persis" SW Iran). *Journal of Archaeological Science: Reports*, *12*, 134–141. <https://doi.org/10.1016/j.jasrep.2017.01.030>
- Djamali, M., & Faucherre, N. (2020). Sasanian architecture as viewed by the 19th century French architect Pascal-Xavier Coste. *Dabir*, *7*, 91–100.
- Finster, B., & Schmidt, J. (2005). The origin of 'desert castles': Qasr Bani Muqatil, near Karbala, Iraq. *Antiquity*, *79*, 339–334. <https://doi.org/10.1017/S0003598X00114139>

- Flandin, E. N., & Coste, P. - X. (1851). *Voyage en Perse*, Tome 2. Paris: Gide et J. Baudry Librairies Editeurs.
- Grabar, O. (1969). Sarvistan, a note on Sasanian palaces. in O. Aslanapa & R. Naumann (Eds.), *Forschungen zur Kunst asiens, in memoriam Kurt Erdmann* (pp. 1–8). Istanbul: Baha Matbaasi.
- Grabar, O. (1986). Architecture; v. Islamic, pre-Safavid. *Encyclopedia Iranica*, 2, 339–345.
- Grabar, O. (2005). Chapter XVII: Sarvistan, a note on Sasanian palaces. In O. Grabar (Ed.), *Early Islamic art, 650–1100* (pp. 289–297). Hampshire: Ashgate Publishing Limited.
- Hillenbrand, R. (1981). Islamic art at the crossroads: East versus West at Mshatta. In A. Daneshvari (Ed.), *Essay on Islamic art and architecture in honour of Katharina Otto-Dorn* (pp. 63–86). Malibu, CA: Undena Publications.
- Hinds, M. (1984). The first Arab conquests in Fars. *Iran*, 22, 39–53. <https://doi.org/10.2307/4299735>
- Huff, D. (1978). Ausgrabungen auf Qal'a-ye Dukhtar bei Firuzabad 1976. *AMIF*, 11, 117–147.
- Huff, D. (1986). Architecture: III: Sasanian period. *Encyclopedia Iranica*, 2, 329–334.
- Labisi, G. (2018). Squinches and semi-domes between the late Sasanian and early Islamic periods. *Iran*, 58, 236–249. <https://doi.org/10.1080/05786967.2019.1633241>
- Morony, M. (2012). ARAB ii. Arab conquest of Iran. *Encyclopaedia Iranica*, 2, 203–210.
- Norhedge, A. (1993). *Studies on Roman and Islamic Amman, vol. 1: History, site and architecture, British Academy monographs in archaeology no. 3, British Academy/OUP*. Oxford: Oxford University Press.
- Norhedge, A., & Kennet, D. (2015). *Archaeological atlas of Samarra, Samarra studies II, 1*. Exeter: The British Institute for the Study of Iraq, The Short Run Press.
- Pourshariati, P. (2008). *Decline and fall of the Sasanian empire: The Sasanian-Parthian confederacy and the Arab conquest of Iran*. London: I.B. Tauris. <https://doi.org/10.5040/9780755695270>
- Rapp, G. R. (2002). *Archaeomineralogy, Natural Science in Archaeology Series*. Springer.
- Reimer, P., Austin, W., Bard, E., Bayliss, A., Blackwell, P., Bronk Ramsey, C., Butzin, M., Cheng, H., Edwards, R., Friedrich, M., Grootes, P., Guilderson, T., Hajdas, I., Heaton, T., Hogg, A., Hughen, K., Kromer, B., Manning, S., Muscheler, R., ... Talamo, S. (2020). The IntCal20 northern hemisphere radiocarbon age calibration curve (0–55 cal kBP). *Radiocarbon*, 62, 725–757. <https://doi.org/10.1017/RDC.2020.41>
- Sarre, F., & Herzfeld, E. (1910). *Iranische Felsreliefs, Aufnahmen und Untersuchungen von Denkmälern aus alt- und mittelpersischer Zeit*. Berlin: wasmuth Verlag.
- Simpson, S. J. (2018). Christians on Iraq's desert frontier. *Abstracta Iranica*, 39, 2–30.
- Siroux, M. (1973). Le palais de Sarvistan et ses voûtes. *Studia Iranica*, 2, 49.
- Stoops, G., Tsatskin, A., & Canti, M. G. (2017). Gypsic mortars and plasters. In C. Nicosia & G. Stoops (Eds.), *Archaeological soil and sediment micromorphology* (pp. 201–204). Oxford: John Wiley & Sons Ltd. <https://doi.org/10.1002/9781118941065.ch24>
- Stuiver, M., & Polach, H. A. (1977). Discussion: Reporting of ¹⁴C data. *Radiocarbon*, 19, 355–363. <https://doi.org/10.1017/S0033822200003672>
- Tuna, T., Fagault, Y., Bonvalot, L., Capano, M., & Bard, E. (2018) Development of small CO₂ gas measurements with AixMICADAS. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, 437, 93–97.
- Wacker, L., Scott, E. M., Bayliss, A., Brown, D., Bard, E., Bollhalder, S., Friedrich, M., Capano, M., Cherkinsky, A., Chivall, D., Culleton, B. J., Dee, M. W., Friedrich, E., Hodgins, G. W. L., Hogg, A., Kennett, D. J., Knowles, T. D. J., Kuitens, M., Lange, T. E., ... Tuna, T. (2020). Findings from an in-depth annual tree ring radiocarbon intercomparison. *Radiocarbon*, 62, 873–882. <https://doi.org/10.1017/RDC.2020.49>