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HYDRAULIC INFRASTRUCTURES IN SOUTH-WESTERN IRAN DURING THE SASANIAN PERIOD: SOME ARCHAEOLOGICAL REMARKS

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On account of the peculiar geomorphological and geographical features of the Iranian territory, water has always been a fundamental element of the Iranian landscape. Surface water and groundwater reserves were extensively exploited during the Sasanian period - for freshwater supply and to enhance the agricultural productivity - by means of public as well as private programmes of management of the hydraulic issues. Focusing on archaeological evidence from South-western Iran and stressing the extent to which the cultural landscape of Sasanian Iran was influenced by the importance of water, this paper deals with topics related to the architecture and chronology of some hydraulic infrastructures in Fars and Khuzestan.

Keywords: South-western Iran; Sasanian period; water management; irrigated farming; hydraulic infrastructures

1. WATER MANAGEMENT IN SOUTH-WESTERN IRAN DURING THE SASANIAN PERIOD

From a hydrological point of view, the area of South-western Iran, including the modern Iranian Provinces of Khuzestan,[1] Kohgiluyeh and Boyer-Ahmad (only to a limited extent), Fars and Bushehr (fig. 1), mainly falls within the large Persian Gulf exorheic drainage region,[2] with the exception of some territories in the north-eastern sector of the Fars Province, pertaining to the Niriz endorheic drainage basin.[3]

This area can be considered as a hydrologically favoured one due to the presence of major river catchments areas (e.g. those of the Karkheh, Dez and Karun - the latter being the longest river in Iran and the only navigable one, albeit partially), of rich groundwater reserves as well as of an average annual amount of rainfall reaching approximately 500-600 mm per year.[4]

During the Sasanian period (*c.* 224-651 CE), South-western Iran was administratively subdivided into the Provinces of Xūzistān and Pārs. The latter, 'cradle' of the Sasanian dynasty, was an administrative entity much larger than the modern Iranian Province of Fars,[5] possibly encompassing coastal areas of the Persian Gulf and some islands in front of those.[6]

In the archaeological literature on the Sasanian empire, great emphasis has always been given to the agricultural intensification and maximisation of agricultural output attested in

1 Toponyms, hydronyms, oronyms and personal names are reported according to the variants more commonly used in the international scientific jargon.

2 In this area, therefore, surface water is mostly collected and discharged through exterior drainage, whilst most of the Iranian territory is characterised by interior drainage (Ehlers 1996, 527, fig. 27; 2004, 596).

3 Beaumont 1985, fig. 3.

4 Ehlers 2004.

5 On the evolution of the geographical concept of Pārsa/Pārs/Fars see de Planhol 1999.

6 On the administrative geography of Sasanian Pārs see Gyselen 1989, 70-73 (mainly based on sigillographic evidence); Miri 2012 (taking into account epigraphic and numismatic evidence as well).

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that period. As stressed also in some recent syntheses,[7] these results have been often considered as a direct consequence of the fruitful policies pursued by the dynasty in the field of water management, testified by the realisation of a huge number of hydraulic infrastructures in several areas of the empire, particularly South-western Iran.

In this frame, the tradition of studies about socio-economic issues in the Sasanian empire started to attribute - especially after the mid-twentieth century - an excessive role to a supposed dynastic 'centralisation', allegedly attested in every administrative and economic aspect of the empire. Such 'paradigm' of the 'Sasanian administrative centralisation' was retained as extremely convincing, especially when scholars compared the results achieved by the Sasanians in terms of agricultural productivity and management of the agricultural policies with those attained by the Arsacid dynasty (considered by far less 'centralised') or with the ones documented in the same economic fields during the first centuries after the Islamic conquest of Iran. In short, the Sasanian period was considered as a sort of 'golden age', when agricultural productivity, settlement and population density reached an unparalleled zenith. That was followed by a period of marked decline - especially in the areas formerly representing the empire's agricultural backbone - due to natural disasters (plagues and huge destructive floods), over-exploitation of resources as well as the 'collapse', after the Islamic conquest, of the Sasanian 'apparatus' in charge of the irrigation-based farming strategies.[8]

Without going into further details about these long-debated issues, one should stress that such a somewhat 'distorted' view of both the 'Sasanian administrative centralisation' and the following 'collapse' during the Islamic period basically originates from two main reasons. On one hand, it derives from an overestimated confidence in the written sources at disposal - the majority of which are from the Islamic centuries, thus quite late with respect to the Sasanian period and therefore not completely reliable.[9] On the other hand, it probably stemmed from the popularity gained in the past decades by the notorious theories about the 'Oriental Despotism', developed by the German sociologist and sinologist K.A. Wittfogel.[10]

During the last two decades, however, thanks to advancements in the historical reconstruction and archaeological research, the idea of an alleged centralised and 'monolithic' Sasanian empire, reverberated in all its socio-economic and socio-political achievements, has come under a strong criticism. In particular, the results of some

7 See e.g. Mousavi - Daryaee 2012, 1082-1083; Farahani 2013, 6465-6466.

8 See especially Adams 1962, 116-120; 1965, 80-85; Wenke 1975-1976, 131-139; Christensen 1993, 67-112.

9 In those written sources, the effectiveness of the Sasanian agricultural and water resource policies tends to be somewhat exaggerated (see Soroush 2014, 72).

10 Although making reference to geographic and chronological contexts different from that of the Sasanian empire, Wittfogel postulated that the ancient 'oriental autocracies', developed by virtue of the prosperity of their artificial irrigation systems, represented a model of 'hydraulic societies' based on major hydraulic infrastructures, which were directly planned, built and maintained by the central administration through specific bureaucratic organisations and the utilisation of forced labour. Such model required the firmness of a highly centralised state power, with an absolute sovereign at its top, provided with the necessary authority, strength and economic resources to manage large-scale and labour-demanding activities connected to hydraulics (Wittfogel 1957).

archaeological researches carried out in south-western areas of Iran partially dismissed the traditional chronological attribution to the Sasanian period of some hydraulic infrastructures, moreover testifying, at least to a certain extent, for a continuity of investments in the hydraulic issues during the Parthian, Sasanian and Islamic periods. A similar continuity was also attested (albeit partially) in the settlement as well as in the population density, thus weakening the idea of a 'peak' reached during the Sasanian period.

For instance, recent researches carried out by M. Soroush on the area of the Miyanab Plain, south of the city of Shushtar, in the Khuzestan Province (fig. 1), pointed out that the Sasanian investments in the hydraulic issues were probably followed by similar investments during the first centuries after the Islamic conquest.[11]

In the same area, moreover, Iranian archaeological activities carried out in 2001-2002 revealed two settlement peaks during the Parthian and Early Islamic periods (*c.* 7th-11th century CE), divided by a rather striking shrinkage during the centuries of the Sasanian political control over the area.[12] In the light of the archaeological evidence, moreover, the construction of the Darioon irrigation system (a major hydraulic feature of the area) was attributed to the Parthian period on the basis of «the linear distribution pattern which the Parthian settlements exhibit along the irrigation canals that emanated from Shushtar in antiquity».[13]

Also the area east of the Karun river (i.e., the so-called 'Eastern Corridor') revealed «the lack of substantial occupation […] during the Sasanian period», while, during the Islamic centuries, it featured a peculiar development of *qanat* irrigation networks.[14]

Other researches, moreover, outlined a less rigidly centralised picture, in which investments for hydraulic infrastructures built for agricultural productivity were carried out not only by the dynasty but also by some members of the aristocracy as well as private entrepreneurs, sometimes provided with a noticeable degree of autonomy and often with the participation (to different extents) of local farmers.[15] This aspect was particularly stressed in a paper summarising the scholarly views emerged during a workshop organised in 2011 at Durham University by D. Kennet and T. Wilkinson. From the talks delivered on that occasion, it became clear that «just because a system appeared large in scale, it was not necessarily a product of imperial management» and «many hydraulic systems were probably local enterprises resulting from local investments, for purpose of tax-farming, or simply […] representing the continuation of long-held practices that were then incorporated into the economic regimes of whatever empire held sway at the time».[16]

A more remarkable 'centralisation', indeed, would seem documentable only during a later phase of the Sasanian history (between the end of the 5th and the beginning of the 6th

[11] Soroush 2014.
[12] Moghaddam - Miri 2003, 103-104, figs. 7-9.
[13] Moghaddam - Miri 2003, 103.
[14] Moghaddam - Miri 2007, 51.
[15] For a different view, more adherent to the paradigm of the centralised Sasanian dynastic control over irrigation systems, see Montakab 2013. Moreover, a paper with a rather provocative title was recently published by M. Vidale, who, partially following C.C. Lamberg-Karlovsky, stressed the possible necessity to re-evaluate, although to a limited extent, some of Wittfogel's intuitions (Vidale 2018).
[16] Wilkinson *et al.* 2012, 172-173.

centuries CE),[17] coinciding with the agricultural reforms part of a wider fiscal renovation probably initiated already by Kavad I (r. *c.* 488-531 CE) and completed to a fuller extent by Khosrow I Anushirvan (r. *c.* 531-579 CE).[18]

Unfortunately, however, the overall archaeological picture of South-western Iran during the Sasanian period is far from being completely clear and homogeneous. For instance, in a recent publication about the American archaeological activities carried out during the 1960s in the Deh Luran Plain of Khuzestan (sponsored by Rice University and directed by F. Hole), a noticeable growth in the number of sites during the Sasanian period was evidenced. Moreover, an expansion of canal and *qanat* systems in nearly all portions of the plain was registered during the same period, to such an extent that «Sasanian and 7th Century Islamic times appear to have been the apex in terms of the total amount and intensity of land use as well as the maximum population density on the plain».[19]

In the 2000s, archaeological surveys were carried out in the Kur River Basin, i.e. the area around Persepolis (Fars Province; fig. 1), by a joint team of the Iranian Center for Archaeological Research, the Parsa-Pasargadae Foundation and the University of Chicago. Results of those activities suggested that the exploitation of the area's agricultural potential began only during the Sasanian period, as the result of the creation of a wide irrigation network created under the patronage of the dynasty and the consequent development of related sites.[20]

A similar picture of increased settlement and population density, as well as of major 'centralised' agricultural investments during the Sasanian period, seems to be provided also by the results of other archaeological researches carried out in the hinterlands north of the Persian Gulf, recently reappraised by a team of Iranian scholars.[21]

2. Hydraulic infrastructures in South-western Iran during the Sasanian period

Due to the peculiar geographic and climatic features of South-western Iran, the farming model predominantly adopted in that area has always been based on irrigation techniques aimed at managing the surface water at disposal.[22] Unfortunately, the torrential character of rivers in South-western Iran (as well as of the Iranian rivers in general) has always represented a major obstacle in this regard. In fact, the noticeable seasonal fluctuations in

[17] Even during the late Sasanian period, however, some forms of cooperation in the management of the hydraulic issues between the monarchy, aristocratic landowners and local farming 'managers' seem to be attested, at least in some areas of the empire (see Campopiano 2017, with related bibliography).

[18] Rubin 2009.

[19] Neely 2016, 246.

[20] Hartnell - Asadi 2010; Hartnell 2014. The hypothesis put forward by the surveyors was firmly criticised by S. Gondet, since it did not take into due account the evidence for an Achaemenid canal system (fed by the Kur river) discovered in the area and pointing to a much earlier exploitation of its water resources for agricultural productivity (Gondet 2013). In the same area of the Kur River Basin, moreover, albeit closer to the site of Pasargadae (fig. 1), a series of five dams attributed to the Acheamenid period (firstly documented in the 1980s) were the subject of a recent geo-archaeological study carried out by Iranian, French and Belgian scholars (De Schacht *et al.* 2012).

[21] Asadi *et al.* 2013, with related bibliography.

[22] Spooner 1985.

the rivers' flow rate[23] have always been in stark contrast with the specific water needs during sowing, growing and harvesting periods,[24] especially as far as cereals are concerned.[25] Therefore, irrigation strategies have been mainly aimed at obtaining the seasonally desired amount of water and preventing the excessive salinisation of the soils, a phenomenon caused by intensive irrigation, significantly worsened in arid and semi-arid climates as the Iranian one.[26]

During the Sasanian period, therefore, hydraulic infrastructures as canals, *qanat*s,[27] watermills,[28] dams, weirs and weir-bridges[29] represented intertwined elements of a complex irrigated landscape, specifically designed and built in order to mitigate the torrential nature of the Iranian rivers, to minimise silting, to avoid avulsions, to prevent salinization of soils, etc.; i.e. with a main hydrogeological concern and an ultimate economic goal related to agricultural productivity.

However, although human impact has always affected many rivers in Iran, fluvial landscapes in the region have always remained areas prone to more or less radical changes,[30] as demonstrated by some recent geo-archaeological researches concerning Lower Khuzestan.[31]

Among the hydraulic infrastructures considered to be of Sasanian date, bridges (in fact 'weir-bridges')[32] have particularly attracted the scholarly interest,[33] especially because they have been often considered as the most glaring example of the direct activity of Roman captives (military engineers and architects, as well as common legionaries) deported to Iran

[23] Rainfall does not represent the main source for the majority of Iranian rivers' flow rate. Their water is provided to a larger extent by the seasonal melting of the snow on the mountains during mid- and late spring, producing discharge peaks in March, April and May (Beaumont 1985, 32).

[24] Ehlers 2004.

[25] Bagg 2012, 263.

[26] Over-irrigation may often raise the level of the aquifer in an area. In arid environments, when the aquifer is too superficial, the evapotranspiration index increases enormously and a noticeable quantity of mineral salts is left in the upper soil layers. A concentration of salts in the soil around 0.1-0.2 % can be already dangerous for the crop, while a concentration near or over 0.5 % can threaten it irremediably (Bagg 2012, 264).

[27] The technology of underground water channels used for irrigation - known as *qanāt* or *kāriz* on the Iranian territory - represents one of the main subjects extensively discussed in the scientific literature concerning ancient water management in Iran and adjacent areas. For brevity's sake, only two prominent works recently published on that topic are mentioned: (Angelakis *et al.* (eds.) 2016; Charbonnier - Hopper (eds.) 2018).

[28] For an overview of water milling techniques in Late Antique Iran see Neely 2011, dealing with Sasanian gristmills in the Deh Luran area.

[29] See *infra*.

[30] Fluvial landscapes are 'ever-changing environments', continuously disturbed by river dynamics. Flooding, bank erosion, silting up of channels, avulsions, may occur on annual to decadal time scales. All these issues have always required human adaptation, like shifting production areas, changing land-use practices and methods of subsistence or even abandonment of settlements and of cultural practices.

[31] Mainly based on two Iranian-Belgian geological campaigns carried out in 2004 and on remote sensing analyses, those researches were able to identify and map the shifting paleochannel belts of the Karun, Karkheh and Jarrahi rivers, the networks of ancient irrigation canals, avulsions and ancient field patterns (Heyvaert - Verkinderen - Walstra 2013; Woodbridge *et al.* 2016, with related bibliography).

[32] See *infra*.

[33] Publications about Sasanian bridges in Iran are rather scanty, limited to a few main works (Kleiss 1983; 2015, 157-160; Bier 1986; Huff 1990, 450-452).

after the famous battle of Edessa in 260 CE and supposedly forced to build those infrastructures[34] from that moment onwards, during the reign of Shapur I (*c.* 239-270 CE).[35]

Unfortunately, the majority of the alleged Sasanian bridges (not only in South-western Iran, but also elsewhere in Iran as well as in other neighbouring areas subject to the Sasanian political control during Late Antiquity) was heavily restored or rebuilt during the Islamic period, thus making the chronological attribution of their original layout a very questionable issue,[36] especially since building inscriptions are usually unattested. The only exception in this respect seems to be represented by the bridge (nowadays in a very poor state of preservation; fig. 2) crossing the Tang-e Ab river in correspondence of the famous rock relief of Ardashir's investiture near Firuzabad (Fars Province; fig. 1), accompanied by a building inscription of Mehr-Nareseh, *wuzurg framādār* ('grand vizier') of Yazdgerd I (r. *c.* 399-421 CE), Bahram V (r. *c.* 421-439 CE), Yazdgerd II (r. *c.* 439-457 CE) and Peroz (r. *c.* 459-484 CE). The architectural features displayed by the remains of this infrastructure have therefore become 'paradigmatic' of Sasanian bridge architecture: its only extant pier - on a pentagonal plan, by virtue of the presence of a triangular cutwater pointing upstream[37] - shows a mortared rubble core, faced with cut stone blocks held together by metal clamps.[38]

The majority of Sasanian bridges, however, were not built solely for traffic,[39] but were mostly designed for reasons related to water management, being in fact 'weir-bridges', i.e. bridges laid on weirs provided with adjustable sluice gates. The construction of similar hydraulic infrastructures, representing a partial barrage of a watercourse, had the purpose to produce a limited hydric 'regurgitation' within the riverbed (without overflowing the river embankments), with the aim to raise the upstream water level and thus facilitating the derivation of water for irrigation. Being very versatile, they represented the perfect 'tool' to

[34] See e.g. Huff 1990, 450. The Polband-e Shadorwan (also known as Band-e Kaisar, i.e. 'Caesar's Dyke') at Shushtar, in Khuzestan Province, is commonly cited as the alleged most prominent example of Sasanian bridge built in Iran by Roman prisoners.

[35] The direct involvement of engineers, architects and masons from eastern areas of the Roman Empire in the Sasanian building activities had already started, instead, during the reign of Ardashir I (*c.* 224-240 CE), as testified by the peculiar masonry technique documented by D. Huff at the Takht-e Neshin of Ardashir-Xwarrah (Huff 1972), i.e. the fire temple of the famous capital city built by Ardashir I near present-day Firuzabad, in Fars Province (Bosworth 1987; Huff 1999). This important point was stressed by P. Callieri in a paper specifically devoted to the use dressed stone masonry in Sasanian architecture (Callieri 2012). The same scholar, moreover, hypothesised an earlier and direct involvement of sculptors from the eastern provinces of the Roman Empire also in the change of style detectable in the last rock reliefs (four out of five) carved under the reign of Ardashir I (Callieri 2017).

[36] Kleiss 1990, 453.

[37] Piers on a pentagonal or hexagonal plan, by virtue of the presence of triangular cutwaters pointing upstream and, in later examples, also downstream, seem to be typical of Sasanian bridges, although they are attested on Islamic examples as well; on the other hand, rounded projections or semi-circular buttresses seem to appear only during the Islamic period (Huff 1990, 452).

[38] Bier 1986. Metal clamps are still visible at some Sasanian bridges, as the one close to the north-western gate of Ardashir-Xwarrah (fig. 3), considered of Sasanian date, although possibly «overbuilt by another bridge with hexagonal piers in later Sasanian or, more probably, Islamic times reusing ancient material» (Huff 1990, 451).

[39] Huff 1990, 452.

control the extremely variable flow rate of torrential rivers, ensuring the possibility to keep a sufficiently raised upstream level during periods of water shortage and, conversely, with their gates entirely open, ensuring the discharge of huge hydric volumes during flooding periods.

In one of the articles summarising the results of the aforementioned joint Iranian-American archaeological project carried out in the 2000s in the area of the Kur River Basin, T. Hartnell stressed that Sasanian irrigated farming «relied on weirs or other methods that maintained the flow of water, rather than on reservoir dams that seek to contain bodies of water behind large dam walls».[40] On the basis of the evidence at disposal, he hypothesised that the main reasons for the alleged absence of reservoir dams during the Sasanian period and, conversely, the remarkable number of weirs or weir-bridges, were to be found in the religious prescriptions concerning the cult of Ardwīsūr Anāhīd,[41] a Zoroastrian *yazatā* celebrated as the river-goddess and water-divinity in *Yašt* 5 (so-called *Ābān Yašt*: 'Hymn to the Waters').[42] In Hartnell's opinion, Sasanian irrigation networks were based on weirs because these allowed a constant water flow (thus mimicking Anāhīd's attribute of flowing), while reservoir dams, 'entrapping' water and causing stagnation, were instead abhorred from a religious point of view.[43]

However, at the present stage of our archaeological knowledge, at least two ancient reservoir dams, both in South-western Iran, seem to be possibly attributed to the Sasanian period, although their chronology is still somewhat debated.

The first one is the Jarreh dam, located on the Zard river, in the Ramhormoz County of Khuzestan Province (fig. 1). This hydraulic infrastructure (fig. 4) was the subject of a salvage archaeological project carried out in the early 2000s, in view of the construction of a huge modern dam in the area.[44] The archaeological activities consisted of a survey in the whole area of the Zard River Basin as well as the excavation of seven trenches located at strategic points around the ancient monument. On the basis of preliminary studies carried out on the archaeological finds retrieved during those activities, the dam was tentatively dated to the Early Islamic period.[45] Very recently, instead, a chronological attribution to the Sasanian period was established in the light of more in-depth studies of the same materials[46] and by virtue of 14C analyses.[47]

A second possibly Sasanian barrage is the Gompu dam, located at about eight kilometres south-west of the city of Fedagh, in the Gherash County (Fars Province; fig. 1). Although a significant portion of its western section is missing, this hydraulic infrastructure is rather well-preserved (figs. 5-6) and displays evident signs of rebuilding activities during

40 Hartnell 2014, 203.
41 Boyce 1985b; Chaumont 1985.
42 Boyce 1985a; Darmesteter 1882, 52-84.
43 Hartnell 2014, 203-206. The deep ideological and religious roots of the relationship between water sources (rivers and springs) and several artistic and architectural achievements of the Sasanians had been already highlighted in previous years (Callieri 2006).
44 The ancient dam and the area surrounding it are nowadays completely submerged.
45 Sharifi - Motarjem 2013; personal communication by M. Sharifi (April 2016).
46 Sharifi 2018, 215.
47 Approximately 1800 BP; personal communication by M. Sharifi (June 2018).

the Islamic period. The overall height of the dam reaches 15 metres, while its thickness tapers from 6 metres at the base to 4 metres at its middle-upper section. The core is made by a rubble concrete of sandstones and lime mortar, although some parts reveal the absence of a binding agent. The structure is faced with cut blocks of sandstone, apparently without the use of metal clamps.[48] An important feature of the dam is represented by the presence of three rectangular outlets aligned along its vertical axis, roughly in correspondence of its central section. In the downstream side, these outlets are sealed with stone blocks in dry masonry, possibly to facilitate their removal in case of need.[49] The chronological attribution to the Sasanian period of the Gompu dam was retained as unquestionable by M.J. Malekzadeh, who visited the monument in May 2010.[50] More cautiously, instead, A. Askari Chaverdi, on the basis of the ceramic evidence collected during a survey carried out in the area of the dam and surrounding sites, prefers to date this impressive infrastructure to the first centuries of the Islamic period, without excluding, however, the possibility that further studies and stratigraphic excavations may reveal an earlier dating to the Sasanian period.[51]

In any case, the contrast between the alleged evidence for only two examples of Sasanian dams in Iran and, on the other side, plentiful archaeological attestation for other types of Sasanian hydraulic infrastructures is rather striking and raises serious doubts and several questions about the actual level of our knowledge about Sasanian technologies of water management. Although a series of hypotheses can be put forward in this respect, taking into account different arguments (e.g. possible archaeological biases,[52] erroneous chronological attributions of the attested evidence, different hydrological, environmental or socio-economic needs in some specific areas of Iran), those questions are likely to remain unsolved until further evidence is available.

48 Malekzadeh 2013, 2.
49 Malekzadeh 2013, fig. 4.
50 Malekzadeh 2013, 1.
51 Askari Chaverdi 2013, 283-284, tab. on p. 391.
52 As stressed by M. Vidale, we should keep in mind that «the archaeology of canals, dams and reservoirs is made difficult by the very scale of observation, by the burial of hydraulic constructions under later flood events and violent destructions […]. In short […] relevant evidence is destroyed by abandonment and deflation, or remains sealed under meters of silt, and […] results of surface surveys may be totally biased by large-scale environmental transformations» (Vidale 2018, 36-37).

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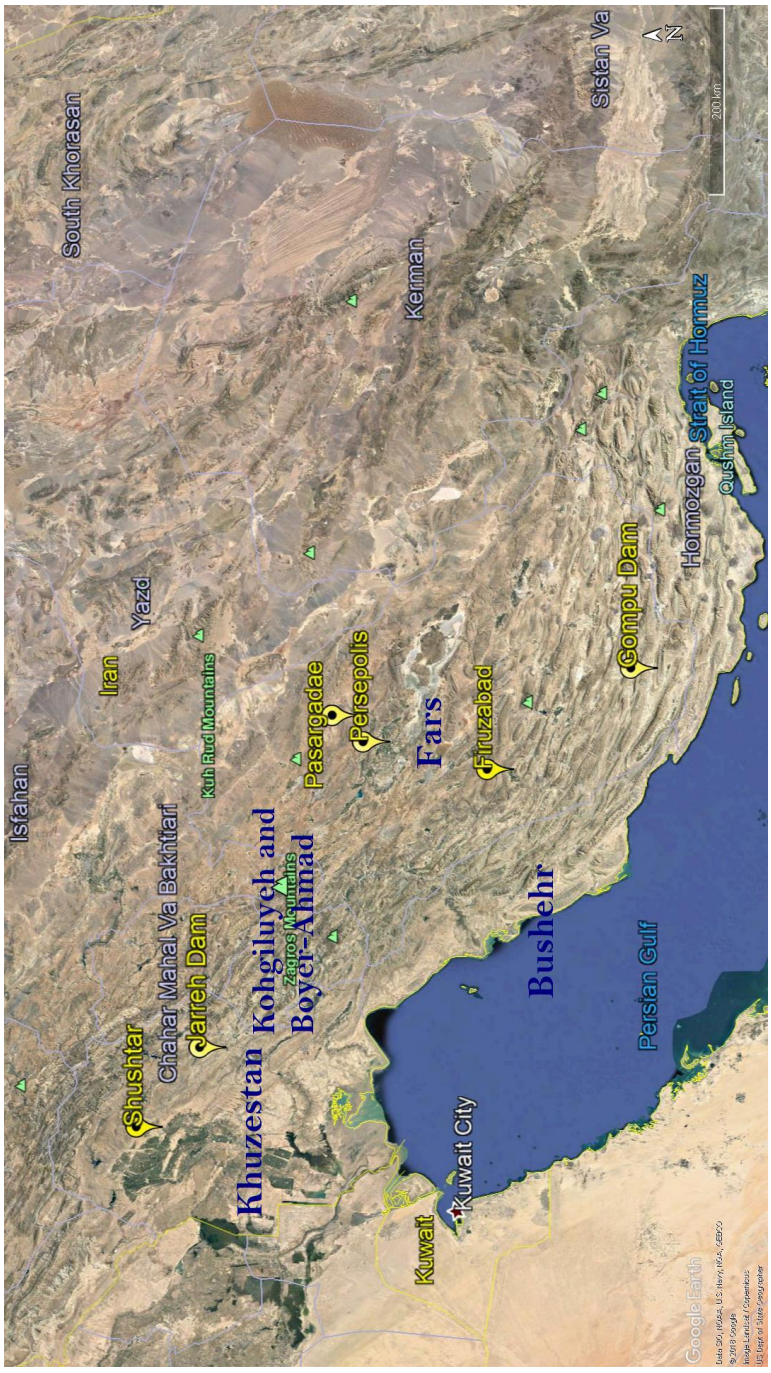

Fig. 1 - Map of South-western Iran showing the location of major archaeological sites mentioned in the text (satellite view after Google Earth™)

Fig. 2 - Remains of a pier of Mehr-Narseh's bridge on the Tang-ab River, Firuzabad County, Fars Province (photo by the author).

Fig. 3 - Remains of a pier of the ancient bridge located west of Ardashir-Xwarrah, Firuzabad County, Fars Province; in the red frame: detail of a socket with traces of a metal clamp joining two cut-stone blocks (photo by the author).

Fig. 4 - Panoramic view of the Jarreh dam in the Ramhormoz County, Khuzestan Province (after Sharifi 2018, fig. 9).

Fig. 5 - Panoramic view of the Gompu dam in the Gerash County, Fars Province (after Askari Chaverdi 2013, fig. 73).

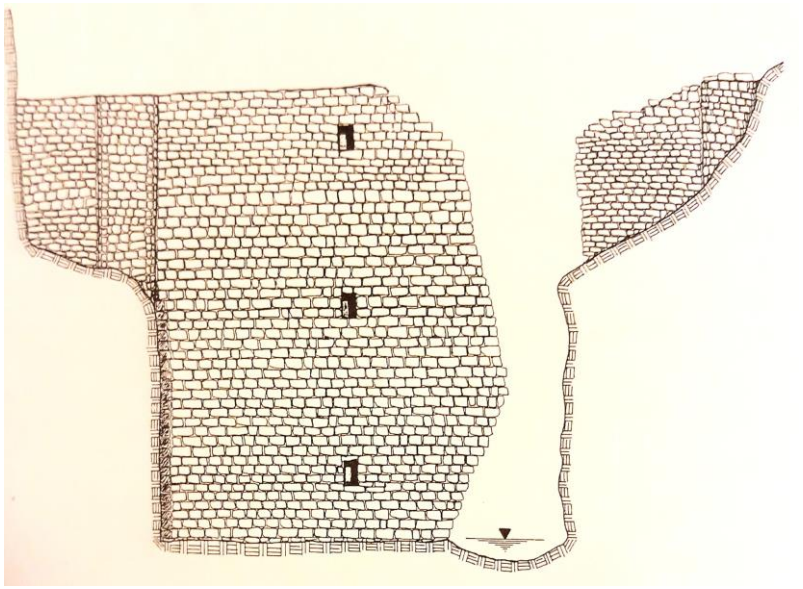

Fig. 6 - Drawing of the Gompu dam in the Gerash County, Fars Province; not to scale (after Askari Chaverdi 2013, ill. on p. 313).