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The Dez-Karun-Confluence in Lower Susiana (SW Iran) in the Last Millennia; a Case Study for the Human-Environment-Interaction

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Abstract

Dez and Karun are two perennial rivers originating from the Zagros mountains in highland Iran, flowing into the riverine landscape of the Susiana Plains in southwestern Iran. They are crucial elements of the landscape and central to the region's archaeology, especially regarding agriculture and trade, at least since the late Neolithic. The oldest known settlements of the Susiana date back to the seventh millennium BCE in the flood plains of these two rivers. This long and continuous interaction of rivers and human settlements is worth understanding. The current Dez-Karun-confluence is assumed to be very young, especially given the very straight channel of the joint rivers directly after their confluence – for about 20 kilometers (km) to the south – before it regains a meandering character.
In this paper, I propose that their current confluence is recent and explore this proposition based on archaeological evidence, historical accounts, and newly generated geoarchaeological data, as well as OSL dating. Then, I discuss the implications of this environmental change, making a case for the hybrid nature of this change as an event within the framework of human-environment-interaction.

Keywords: Dez river, Karun river, geoarchaeology, Riverine Landscape, Iran, Susiana, OSL dating, River confluence.

ArticleType: Research Article

Introduction

The rivers Dez (Gaube 1982) and Karun (Borjian 2011) flow in a dynamic and geologically young riverine landscape in southwestern Iran (Fisher 1968), archaeologically known as the Greater Susiana (Moghaddam 2012; Wilkinson 2003). Currently, Dez joins Karun's two tributaries – Shoteit and Gargar[1] – at the small village of Band-e Qir (~ 31° 39' N, 48° 52' E) and continues as the Karun-e Bozorg (Great Karun) river. A few kilometers to the southwest, it meets Arwand (Shatt-Al-Arab) – the junction of Tigris and Euphrates from the Mesopotamian plains. Together, they form a delta of brackish water and a landscape of sabkha at the current head of the Persian Gulf (Figure. 1).

Dez and Karun (Table. 1) are crucial elements of the Susiana landscape with a settlement tradition from at least the seventh millennium BCE (Adams 1962; Alizadeh 2003 & Moghaddam 2012). These rivers have been subjected to several manipulation projects in the recent past and have shifted from their original shape and flow beyond recognition (FAO 1957; Ehlers 1975 & Veenenbos 1958).

The confluence of two rivers is a crucial element of their biography (Benda *et al.* 2004 & Rice *et al.* 2008), especially if it has shifted, as is the case here. Historical accounts indicate a hydraulic shift in the region leading to the emergence of the current confluence (Le Strange 1873 & Verkinderen 2015). Their strikingly straight channel immediately upon joining is another indication of the young age of their confluence.

[1] Karun is divided into two separate watercourses Gargar and Shoteit by the Shushtar Historical Hydraulic System registered by UNSECO [no. 1315, since 2009]) and is subject of several investigations by others (Moghaddam, 2012; Verkinderen 2015).

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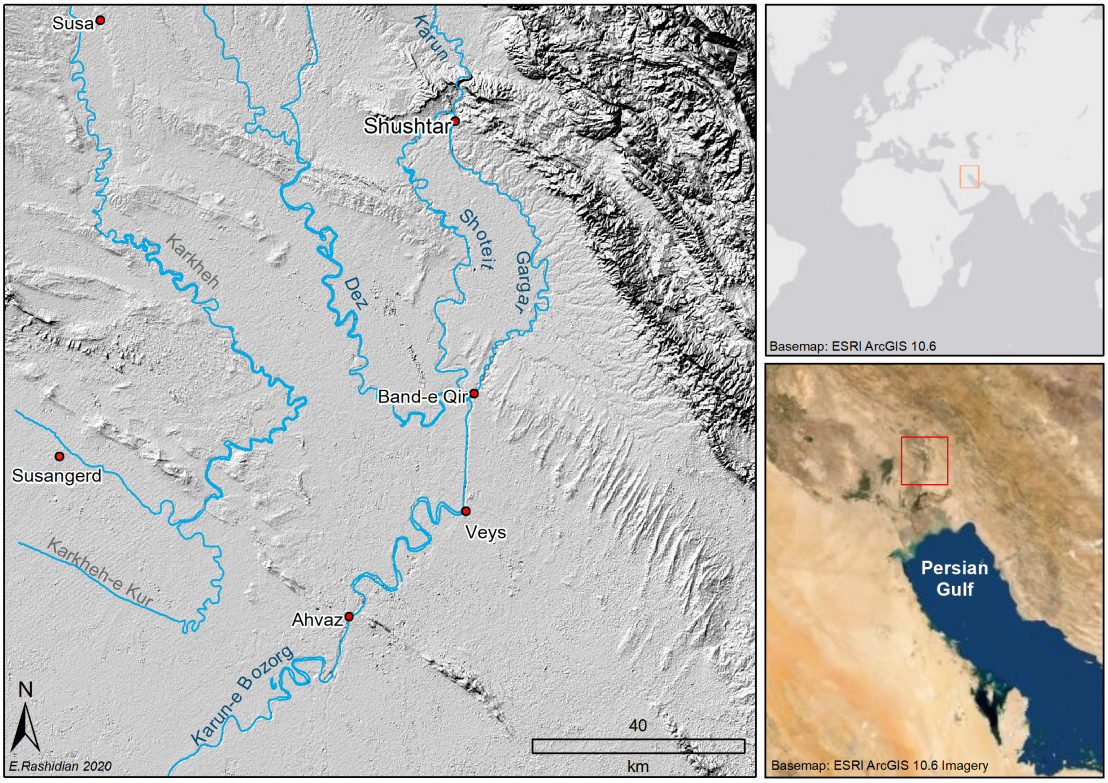


Figure. 1: *Study area showing the mentioned rivers and sites (illustrated by the author)*

Despite their immense archaeological importance, the existing indications of past confluences of these rivers have been neglected. A comprehensive biography of their confluences is missing to date. This paper fills this gap and provides a framework for further reconstructing the landscape in their environs.

Theoretical Framework

Rivers are mostly illustrated on maps as two-dimensional blue lines. On detailed maps, one can guess the direction of the flow based on the relief and contour lines or at the mercy of additional data on the legend. However, rivers are three-dimensional spatial spaces with all the characteristics of an ecosystem. Rivers rather resemble over-dimensional earthworms than static lines. They are living beings interacting with their environments and adapting to their habitat.

For a long time, the rivers' view as waterways flowing in one direction – as a blue line on the map – has persisted. Until that time, humans' intervention and manipulation of rivers were thought to be a one-way change. The riverine continuum concept (RCC) challenged this traditional view (Vannote *et al.* 1980). By defining rivers as continuous systems in a dynamic equilibrium with their environment, one could study the current waterway embedded in its floodplain in holistic terms. Therefore, the river system's response to human-made changes in its course or the river's evolution of the immediate landscape could be studied and determined as an interaction of the river and its environment.

Table 1: *Key data on Dez and Karun in their current form*

River name	older name	Ancient name	River Source	Actual length	Average volume
Dez	Ab-e Diz/ river of Gondīšābūr	Coprates	Near Boroujerd in central Zagros	400 km	140 m3/sec
Karun	Dujail / Little Tigris	Pasitigris	Near Isfahan in Bakhtiari Zagros	890 km	481 m3/sec

However, the concept of rivers as continuums was coarse-grained and could not address current issues of riverine studies in the framework of the ever-changing landscapes of greater rivers. In another view, rivers seemed not to be a continuum but rather consisted of a flexible mosaic of micro-zones, which all together enabled the river system to respond to external challenges from humans or the environment.

The Riverine ecosystem synthesis (RES) has further established the idea that rivers are dynamic living beings and subject to interaction with their habitat (Thorp, Thoms & Delong 2006). The utmost important aspect of the RES is the notion that rivers are not two- or three- but rather four-dimensional ecosystems: lateral, longitudinal, vertical, and temporal dimensions shall be considered. This concept integrates the biography of a river (and its settlement history) into its spatial evolution and enables us to comprehend the river as a waterway throughout history.

This history gets even more complicated at the point where two already tangled waterways join and create a larger river. The location of their confluence affects the rivers in both directions, as well as in their four mentioned dimensions. Therefore, the confluence of two rivers is crucial for studying these two waterways (Benda *et al.* 2004 & Rice *et al.* 2008), especially if the confluence has moved throughout their existence, as is the case here.

Methodology

As an interdisciplinary study, this paper combines data from different sources to address the question of the Dez-Karun-confluence. Three essential elements are at play: (1) the possibilities based on geohydrologic terms, the geological conditions and availabilities; (2) the archaeological indications of human activity alongside the current watercourses as well as historical accounts and textual evidence regarding particular changes in human and environmental conditions in the environs of these rivers; and (3) new data produced through geoarchaeological investigations including sedimentology and absolute dating.

For (1), the available data were studied and integrated into ArcGIS (standard version 10.6 from ESRI) to visually categorize the possible indications of the confluences at different locations. A digital terrain model (DEM) was produced based on data from past surveys and available data from GSI and USGS[1] . The relief, as well as soil classes, were considered for categorizing the surface. This data provided a basis for further investigation, including a field survey.

For (2), available data on known archaeological sites and their dating were integrated into the geo-database. Here the emphasis was not on details of the sites but rather on their physical location and spatial relation to the current and possible past confluences of the rivers. Others have already studied historical accounts in this regard, and their interpretation was exceedingly helpful in filling the gaps of the archaeological data for the medieval times upwards. Special climate events were also considered to present a framework for possible global changes with local indications.

For (3), spatial data analysis has made a significant contribution. After georeferencing the available data in step (1), several floodplains were prioritized for field study. Based on the soil characteristics and relief, certain areas were excluded as possible hotspots for the study. Then, the author carried out a geoarchaeological investigation in 2014 in two campaigns. The first campaign focused on an extensive survey to identify immediate human traces at the current confluence. In the second campaign, the author conducted a stratified sampling survey, and soil cores were taken in different locations using a mechanical cobra drill hammer. Bulk samples were subject to further laboratory study. Samples of fluvial sand at one core were chosen for OSL-dating.

Current Evidence; a Summary

In geomorphologic terms, the plains of the Greater Susiana are relicts of aggradation, which presumably started around the ninth millennium and ended sometime around the second millennium BCE (Lees & Falcon 1952; Veenenbos 1958, pp. 26-27 & Fisher 1968). This regime change has probably resulted in the incision of the paleo-rivers in their flood plains, changing their nature from braided riverbeds with vast floodplains into meandering rivers with river valleys (Krikby 1977, p. 281).

During the Holocene, the paleo-rivers were shifting westwards gradually, probably due to a

[1]Geographical Survey of Iran, United States Geological Survey

slight elevation of the Zagros folded area, changing the slope of the plains from east to west (Veenenbos 1958, pp. 38-39). Based on this reconstruction, the Dez river – or one of its braided channels – joined Karun probably directly to the south of modern Shushtar (Kouchoukos 1999, p. 73), near the site of Chogha Mish[1]. Unfortunately, traces of this probable confluence of paleo-Dez and paleo-Karun are not visible on the surface due to intensive land use of the area since at least Late Antiquity.

The current incised riverbeds of Dez and Karun are undoubtedly young, being initially braided (Alizadeh *et al.* 2004; Krikby, 1977; Kouchoukos, 1999; FAO, 1957; Hansman, 1970; Veenenbos, 1958). However, a few traces of their past flows are recognizable on the satellite images and the ground. For example, Karun-e Kur (Blind Karun) seems to be a paleo-riverbed of Karun, which was abandoned due to a historical dam-collapse in the fifteenth century (Hansman 1970; Heyvaert & Baeteman 2007 & Verkinderen, 2015).

The finds of a recent geoarchaeological survey in the area between Shushtar and Band-e Qir suggest a higher level of riverbeds in the last millennia up until Medieval times. One of the most visual indications is the so-called "hanging wadis" – traces of canal sediments found in the riverbanks of the current rivers, up to 3 m higher than the current level (Alizadeh *et al.* 2004, 72-73). In addition, traces of Arsacid to Islamic material culture in the riverbanks of Shoteit – 2 m above the current river flow – indicate a dramatic incision in the last two millennia (Alizadeh *et al.* 2004, 76). Some have suggested that Gargar is the direct descendant of the historical Masruqan[2] canal, a completely artificial channel built around the first millennium BCE (Alizadeh *et al.* 2004, p. 80 & Moghaddam 2012, p. 43).

However, the nature of the east banks of the modern Gargar does not fit into an artificial channel, especially with the massive amount of runoff water flowing through these plains and joining the river. Therefore, based on the geoarchaeological evidence, it is safe to assume that the current Gargar could have been an abandoned riverbed of the Paleo-Karun from the early Holocene, which was revived as a channel in the first millennium BCE through direct manipulation of the channel and bifurcation of the then active Karun riverbed at Shushtar (Rashidian 2017; see alternative views in Alizadeh *et al.* 2004 & Moghaddam 2012). This hypothesis can explain the abundant archaeological evidence of the eastern Gargar plains, going back to the Later Village period (fifth to third millennium BCE), as a recent survey testified (Moghaddam & Miri 2007).

Historical sources make it clear that Dez has always joined Karun – or at least the larger branch of Karun (Shoteit / Char-Dangeh) somewhere between south of Shushtar and north of Ahwaz (Le Strange, 1873, p. 239). In the tenth century CE, Istakhri reports that all the watercourses from Khuzestan join at a city named Hisn Mahdi and build a vast delta at the head of the Persian Gulf (Verkinderen 2015, p. 152). He calls this region the land of lakes (Hamun) and mentions the large Shushtar river (Karun) and the Masruqan canal, which is controlled by a great dam at the location of the (Middle Age) city of Askar Mokram and empties a few kilometers south of Ahwaz into a wetland (Afshar 1961 [1340], p. 90).

At the location of the current confluence, outside of the modern village of Band-e Qir, there is a small mound, about 3 meters high and less than two hectares in size. The site was identified recently during a survey and was registered as KS1623 (Moghaddam and Miri 2003). Based on surface pottery, an occupation from the Old Elamite (second millennium BCE) to the Middle Islamic period (Middle Ages) is assumed (Moghaddam and Miri 2003, p. 135).

Based on historical accounts, a comprehensive reconstruction of these rivers has been attempted elsewhere (Verkinderen 2009, Chapter five). However, at least from the tenth century, the smaller branch – Masruqan canal or roughly modern Gargar – has also joined them in this area, whereas in the earlier times, they joined it in Ahwaz or immediately south of the city (Verkinderen 2015, p. 130, see figure 18 for a reconstruction of the Masruqan canal in the tenth century CE).

[1]This hypothesis can be supported by author's recent geoarchaeological survey in that area, where substantial sediment packages of similar nature to the Dez river sediments were identified directly to the northwest and southwest of the Chogha Mish complex. The results are forthcoming in a separate paper.

[2]Ibn-Balkhi (61) reports that the "Mashregan" (e.g., eastern) River was dug by Ardashir Babakan, the founder of the Sasanian Dynasty in the third century CE.

The current confluence of Dez and Karun (see Band-e Qir location in Figure. 1) is first mentioned in the fourteenth century (Verkinderen 2015 pp. 125-126 and p. 135). We know that the confluence of Dez into Shoteit has moved slightly during the last centuries, as it was measured with a 3 km difference between the early and late nineteenth century but was at that proximate location at least in the last six centuries. Before this time, only one mention in the tenth century indicates a junction of Dez into Karun just to the north of Ahwaz (Verkinderen 2009, p. 282-283 & footnote 657). Hence, it is safe to assume that the confluence of Dez and Karun shifted between two or three locations repeatedly during the last millennia.

A detailed look at the archaeological evidence from the region indicates an interesting picture of the evolution of these two rivers prior to their current confluence. The region between the two Karun branches before their confluence to Dez, the Mianab plain, has been surveyed recently (Moghaddam & Miri 2003). At least four sites (see Figure. 2 and Table. 1, site numbers 8, 80, 93, 117) were identified in the region, which date to prehistoric times (Late Middle Susiana, proto-literate, and Late Susa I), and have been occupied throughout the historical times (old-Elamite, Arsacid, and Sasanian) until the Middle Ages (Early and Middle Islamic). In the Elamite and the subsequent Achaemenian periods, the number of sites in the Mianab region increases respectively to twenty-one and twenty-nine (Moghaddam & Miri 2003, p. 102-103, see figure 5 and 6), with three new sites (20, 86, 121) locating directly at the vicinity of the current Gargar flow. In addition, the mentioned site (123) directly at the current confluence of the rivers – near Band-e Qir – also emerged at that time.

Two questions arise in this regard: (1) why are there no settlements prior to the Late Susiana 1 (~ 4400 BCE) in the Mianab plain; and (2) why settlements are appearing at the immediate terraces of the current Gargar river in the Old Elamite period (~ 2400 – 1600 BCE). Additionally, the surveyors raise the question of the probable settlement gap (of about 400 years) between the Late Susiana 1 and the Uruk period, e.g., the period Late Susiana 2 was not present in the surface pottery (Moghaddam & Miri 2003, p. 105).

Intensive land use for industrial and large-scale agriculture has greatly destroyed and disturbed the settlement sequences in this area. Therefore, it is logical to assume that the currently identified settlements are only a portion of the remaining sites from the earliest times (Moghaddam & Miri 2003, p. 100 & Rashidian 2017, p. 250). However, it is highly illogical to assume that only traces of settlements earlier than the mid-fifth millennium could have been affected by this phenomenon; especially if one considers the immediate western plains of current Shoteit, where Adams identified sites with Late Susiana 1 and 2 as well as Uruk period (KS0232). Hence, the answer is to be found elsewhere.

Traces of ancient meanders from the western flow of Karun – current Shoteit – can provide us with an explanation for the absence of the settlements before the mid-fifth millennium BCE in the Mianab plain. These traces are visible on both CORONA and SRTM imagery (proximate location of 31° 49’ N, 48° 53’ E). Furthermore, the earliest identified settlements in the Mianab plain (Moghaddam & Miri 2003, fig. 2,3,4; see settlement numbers 117, 67, 116, and 60) are interestingly alongside these ancient meanders. Therefore, the eastern plains of the paleo-Karun might have gotten only stable enough for establishing settlements after the river migrated westwards with a straighter flow. This event could have given way to a settlement sequence in the plain. The reasons for a change in the meandering character of the paleo-Karun in the mid-fifth millennium BCE shall be found with its neighboring waterway, paleo-Dez.

The area between the current flows of Shoteit and Dez is highly probable to contain traces of last confluences. There are at least two ancient meanders visible in available imagery of the area[1]. One of them locates about 9 km from either channel (approximate location 31° 48’ N, 48° 45’ E). At this very location, Adams has identified three sites (KS227, 228, and 229), dated based on surface pottery to the Late Middle Susiana, Late Susa I, and Sasanian times respectively (Adams 1962). Due to the stretching Haft Tappeh anticline, which has an elevation of about 6 to 9 m above the surface and

[1]Hansman (1970, Figure 1) identifies this trace as a past flow of the eastern Shaur. While this is an appealing idea and puts Shaur at a very central place in the hydraulic regime of the Susiana; yet there is simply no evidence to back this idea. Based on Slope analysis, it is rather probable that this is a continuation of the Dez river. In the end, this does not matter for the current issue, because Shaur can be considered a tributary to Dez upstream and does not play any role in the downstream confluence of Dez and Karun.

separates this part of Shoteit from the plain, this meander can only belong to an earlier Dez flow. This assumption correlates with the hypothesis that Dez migrated westwards between the fifth and second millennium BCE (Hansman 1970; Krikby 1977 & Veenenbos 1958).

New Data; a Geoarchaeological Approach

existing evidence lacks a holistic overview and is not suitable for a comprehensive reconstruction of the Dez-Karun-confluence in the timespan of the cultural evolution of the Greater Susiana. Therefore, new data has been produced, including spatial analysis of the floodplain relief and comparative analysis of the respective sediment packages. Both relative and absolute dating of the fluvial sediments were conducted to provide a timeframe for the sedimentological evolution of the study area. Then, the archaeological evidence was appended to reconstruct the water flows at their junction in the timespan.

Spatial Analysis Based on Remote Sensing Data

Based on the existing evidence, there is at least one traceable confluence of these two rivers in the past. The DEM of the region was studied to achieve two goals: to identify potential alternative areas of interest, as well as to confirm that the relief in the mentioned area is not in conflict with a junction of two rivers. As seen in the map (Figure. 1), the mentioned area consists of the space between Band-e Qir and Ahwaz and to the west bordering the Karkheh River. The past confluences of Dez and Karun are to be found here, based on satellite imagery and DEM analysis.

Parallel to the current straight canal between Band-e Qir and Veys, there are traces of a meandering channel originating from Dez and meeting Karun-e Bozorg directly to the south. There is no doubt that the mentioned canal is artificial, and the mentioned meandering channel is its precedent Waterflow (Verkinderen 2015, p. 130). However, whether this past meandering channel belongs to paleo-Dez, or paleo-Karun remains open. This question can be addressed by comparing the sediment packages of both rivers with the sediments of the meandering area.

The canal between Band-e Qir and Veys is 17 meters above sea level (masl) and flows about 20 km in a north-south direction. Immediately to the east and south of the canal, the average elevation is 24 masl. On the other hand, the Karkheh riverbed is about 18 (from Band-e Qir) to 40 km (from Veys) to the west of the canal and has an average elevation of 36 masl. Therefore, the meandering traces can only belong to a past flow of the Dez River.

As seen in the triangle irregular network (TIN) in Figure. 2, the surface area to the west of the canal is interspersed by a considerable number of triangles, which indicate differences in elevation, based on the neighbor point measurement concept. This outcome means that the past water flow of the rivers in this area was actively meandering between Karkheh and Karun-e Bozorg, resulting in a very heterogeneous relief. Therefore, the past confluences shall be found in this region.

Interestingly, there is a small plain between the Dez-Karun network and the Karkheh river, which indicates a very homogeneous elevation, contrasting the typical relief of the area. Landsat images show that this area is intensively irrigated and consists of an artificially ordered agricultural surface. On CORONA images from 1968, several oxbow lakes and traces of huge meanders are visible at this exact location. Therefore, it is safe to assume that the now leveled area was artificially changed from a former riverbed to its current function. Furthermore, the existence of several aeolian dunes in the vicinity (e.g., 31° 32’ N, 48° 40’ E – 31° 30’ N, 48° 35’ E – 31° 25’ N, 48° 34’ E) supports the hypothesis that the abandoned riverbed was exposed to wind erosion for at least a few centuries, before being integrated into industrial and intensive agriculture in the recent past.

Fluvial sand indicates past water flows, which can be detected in soil profiles using particle size analysis. Therefore, available data on sand content of the area[1] from the surface and 2 m depth were refined for the area, in which older confluences of Dez and Karun were estimated. In addition, data on the occurrence of a certain soil class named fluvent (an indication of regular flooding) has also been considered to include the areas, which could be older flood plains to paleo water flows.

Another factor is the area’s slope or watershed, which depends on the relief and provides us with the possible direction of the water flow within the

[1]such as ISRIC (International Soil Reference and Information Centre), and GSI (Geographical Survey of Iran)

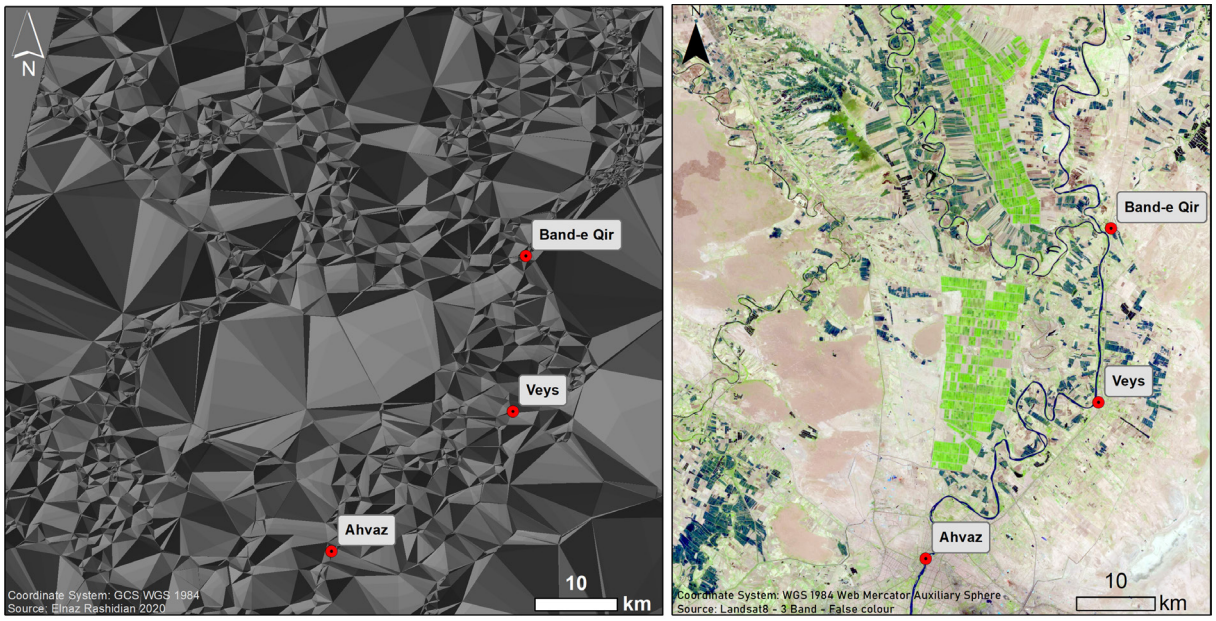


Figure. 2: *LANDSAT Image of the mentioned area in false color (right), and the produced TIN of the area based on DTM (illustrated by the author)*

area, based on the neighboring relief and overall elevation. These raster datasets were then compared using spatial tools of the ArcGIS software. The spatial comparison allows to detect areas with three different combinations: (1) areas with approximately the same amount of sand content from the surface to the depth of 2 m; (2) areas with a gradual increase of the sand content with increasing depth; (3) areas with a gradual decrease of sand content with increasing depth.

The results (shown in Figure. 3) can be interpreted as follows: the quantity of sedimented fluvial sand is dependent on the duration of water flow at any given location. Therefore, any variation in this quantity in varying depths can indicate the water flow distribution at that location.

Based on the physical rules of geomorphology, the deeper sand packages shall be older than the packages near the surface. Therefore, it can be stated that older confluences of the two rivers shall lay within the areas with an increase of sand content with increasing depth. On the other hand, the areas with the approximately same amount of sedimented sand shall be identified as the perennial water flows during the whole timespan.

Finally, the recent confluence of the two rivers shall be located within the areas with a decreasing amount of sand content in depth. Since the current water flow of Dez and Karun lies within area 2, and the recent confluence – discussed below – lies within area 3, the estimations of this spatial analysis can be confirmed via experimental data.

Correlating data from the mentioned analysis and visible traces on CORONA imagery have led to identifying possible past flows and their junctions. These lines are shown on the map (Figure. 4). These suggested water flows shall provide others with a framework for further investigation, primarily archaeological surveys.

Stratified Sampling Survey and OSL-Dating

During a geoarchaeological investigation on the riverine landscape of the Greater Susiana, a stratified sampling survey was carried out by the author in two field campaigns during the spring and autumn of 2014. Amongst them, three cores – B1, B2, B3 – are relevant for the present paper (see Figure. 5 and Table. 2).

B1 (Figure. 6) lies a few meters to the west slope of the site KS1623. A few centimeters under the surface begins a sediment package of cultural material, including charcoal and pottery fragments. A diagnostic fragment of pottery (Figure. 7) was recovered from the borehole, which can be dated relatively to the mid-first millennium BCE, based on comparable pottery (see Alizadeh 1985, p. 190: fig.1, W (register no. 5-22); Alizadeh 2008, p. 254: figure 21, C). The cultural debris is poorly sorted and seems to be secondarily sedimented in this area, probably as runoff from the site throughout the last

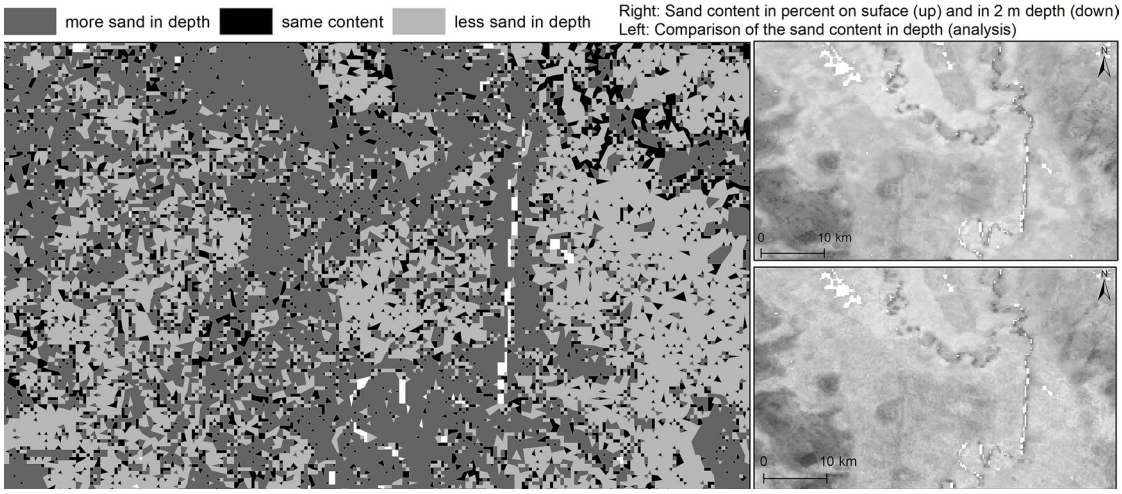


Figure. 3: *Sand content on surface and in 2 m depth, as well as a model based on their comparison (illustrated by the author)*

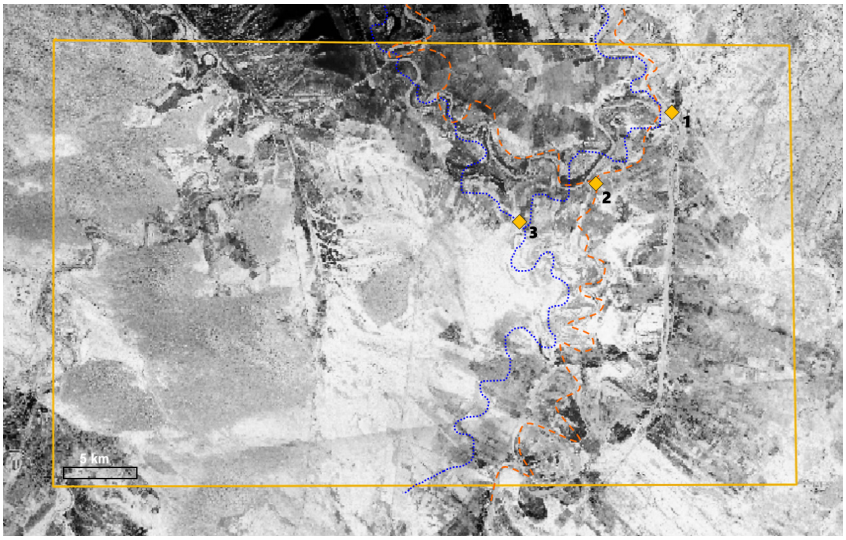


Figure. 4: *Hypothetical past confluences of Dez and Karun based on remote sensing analysis (illustrated by the author)*

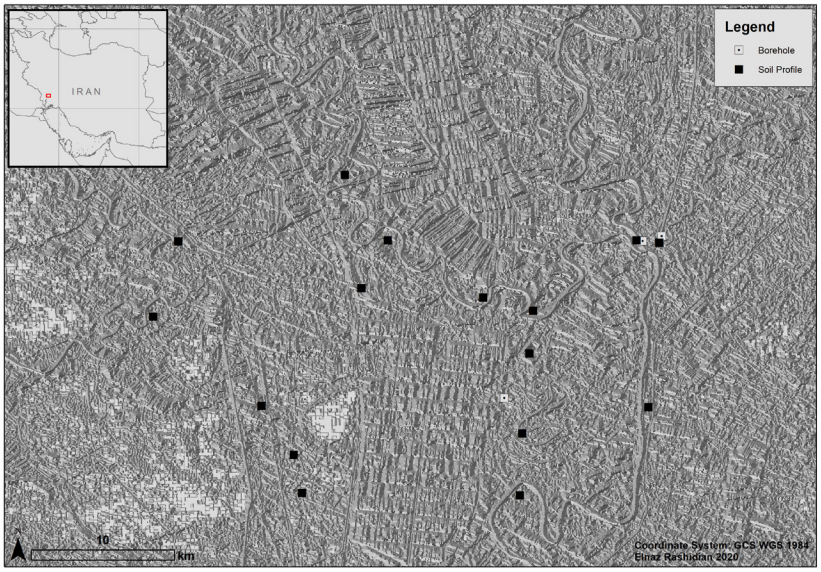


Figure. 5: *Study area on aspect showing the location of boreholes and soil profiles (illustrated by the author)*

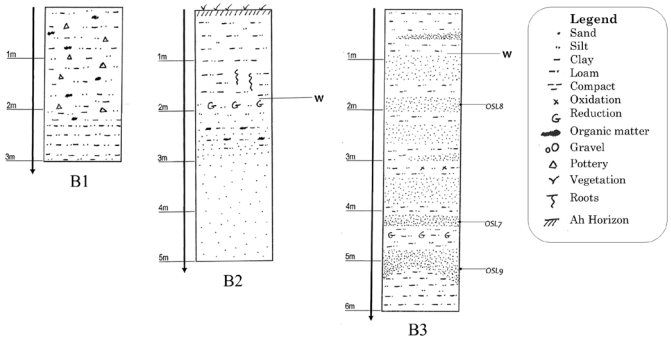


Figure. 6: *Schematic view of boreholes, including the location of the OSL samples; W shows the water table at coring time*

Table. 2: *key data on mentioned boreholes*

Core	Coordinates	Elevation (masl)	Depth (m)
B1	31°39'25" N and 48°53'17" E	21.6	3
B2	31°39'14" N and 48°52'34" E	16	5
B3	31°33'19" N and 48°47'20" E	4.4	6

millennia. The package has high salinity and low mineral content.

At about 2.5 m depth, the sediment changes into a very homogenous brown loamy soil with finer particles and a rather good sorting, the percentage of clay particles changes from 27 to 40. Due to the highly compact nature of this sediment, further drilling was impossible. Therefore, this horizon seems to be the virgin soil of the site. In summary, B1 shows a natural soil package with immediate cultural debris in secondary sedimentation, without any indications of fluvial sediments in the immediate environs of the site.

B2 (Figure. 6) is located about 2.5 km to the west of the site on the immediate eastern terrace of the current Shoteit river. Under a recent soil with high bioturbation and vegetation on the surface lies a sediment package of silty loam and clay with gleyic patterns, indicating a high groundwater level and saturated soil for a long time every year. This package ends abruptly at about 2 m depth, changing to a very silty sand (87% sand content) with very bad sorting for at least 3 m. Due to wholly water

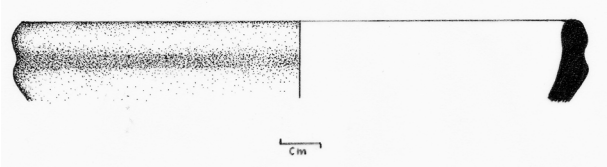


Figure. 7: *Diagnostic pottery fragment from B1 (illustrated by the author)*

saturation of the sediment, sampling into the depth below 6 m was not possible at the time.

There are indications of both reduction (black carbon) and oxidation (orange concentration) in the sediment. The sediment package has a comparable low salinity and remarkably high calcium content. It stretches over several meters into the depth. Based on the Karun fluvial regime from the upstream at Shushtar, there is strong evidence for a flow of Karun at the riverbed of current Shoteit at this location for at least a millennium, unrelated to the confluence of Shoteit and Dez.

B3 (Figure. 6) is about 15 km to the site's southwest at one of the visible traces of past confluences. The landscape is very flat at this location, and the surface is covered with a few centimeters of water with high salinization due to evaporation. Immediately under the eroded surface, a sediment package of very reduced grey-green silty loam stretches about 1 m, with lenses of sand at every dozen centimeter. This sediment is interrupted by a sand layer with high salinity and stretches over 1 m, where another interruption of a very compact clay loam appears. Then, there are another 1 m of the similar sand layer with much higher salinity.

At 3 m depth, the sand layer changes from reduced grey to oxidized brown with ferric concentrations, indicating a change in the hydraulic regime. Finally, at 5.30 m depth, the layer changes into a very homogenous brown clay loam, stretching into the 6 m and hindering deeper drilling. Therefore, it is safe to assume that a gravel bed to the paleo-river is well below 7 m depth.

Interesting characteristics of B3 consist of the micro slope of the layers (see Figure. 8), as well as an absence of any coarse material, and the regular change from brawn clay loam to brown or grey sand. These indicate a highly turbulent water flow and at least two changes in the hydraulic regime of the flow.

Three samples for OSL-dating were obtained from the fluvial sand sediments of B3 at different depths (see Table. 3). At the sampling time, the water level was at 110 cm depth; all samples were taken in wet condition. The dating was conducted on quartz using the central age model.

Based on the presented OSL analysis, the whole sediment package of B3 dates to the tenth to eleventh century CE. Hence, this sediment provides substantial evidence of a past confluence on Dez and Karun prior to their current confluence near Band-e Qir. Furthermore, because of the nature of these sediment packages and their similarities with the Dez fluvial packages from other soil profiles, and based on the visual traces on the surface, it is most probable that Karun – or their tributaries – flowed to this location and joined the Dez river.

Once one considers all the information from the current and new data presented here, one can see the indications of an anthropogenic impact on the confluence of these two rivers. The current confluence has been active since at least the fourteenth century. The here presented confluence at B3 has been active in the eleventh century. There is evidence for a gradual shift of the Dez downstream starting from this confluence and ending at the current location in Band-e Qir, which probably explains the gap from the eleventh to the fourteenth century.

Historical accounts back the assumed location of the Masruqan (Shadarwan?)[1] canal between the two current tributaries of Karun, at least from the first millennium BCE until the tenth century CE. Unfortunately, the specific event of the confluence migration of not mentioned anywhere[2] . However, the confluence migration, along with the destruction of the presumed Band-e Qir dam, has led to the revival

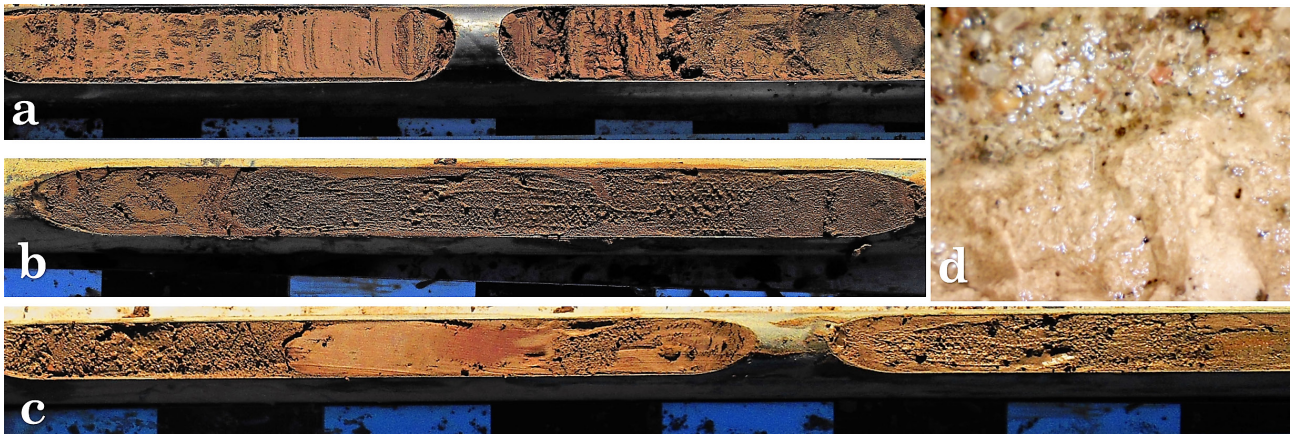


Figure. 8: *B3 in depths 1 m (a), 3.5 m (b), 6 m (c), and the slope layered sediments at 5.3 m depth (d) 50 times enlarged (photographed and illustrated by the author)*

Table. 3: *Data on OSL-samples from B3*

Sample	Depth from surface (cm)	Age (ka)
OSL7	470	1.1 ± 0.2
OSL8	190	1.0 ± 0.1
OSL9	520	1.0 ± 0.1

[1]Loftus (1857, p. 300) suggests that the Karun riverbed between the two dams – Band-e Mizan and Band-e Qaisar – is "paved with stone" and called Shadarwan. Verkinderen (2015, p. 119) believes that Shadarwan was a technical term referring to lakes emerging after a dam, and do not refer to the name of the canal, as some suggested.

[2]Moghaddam (2012, p. 41) suggests that the collapse of the Band-e Mahibazan – located about 3 km south of Shushtar – has been the trigger for the Gargar canal's avulsion and the eventual emergence of the Gargar river

of a paleo-riverbed of Karun between Shushtar and Band-e Qir, creating the current Gargar river, whereas the river has occupied parts of the straight Masruqan canal between Band-e Qir and Veys. This fact explains the archaeological evidence of the Mianab survey, where a shift of settlements to north and west and a decrease in settlements have been reported (Moghaddam and Miri 2003, 104: compare fig. 9 and 10). The current case study is a further example of the implications of an anthropogenic manipulation of waterways.

Discussion of the New Data

Considering the presented data, the following confluences can be identified so far: (a) current confluence, (b) the junction from Late Antiquity to the Medieval Age, (c) the ancient confluence(s) of paleo-Dez and Paleo-Karun from the Prehistory to the Antiquity, and (d) the original confluence of Paleo-Dez and Paleo-Karun prior to the emergence of the Persian Gulf.

The Current Confluence

The Masruqan canal plays a pivotal role in the location of the current confluence of Dez and Karun. Others have reconstructed this canal (Moghaddam 2012 & Verkinderen 2015) and placed it geographically between the two current Karun branches in the Mianab plain. The current confluence has undoubtedly emerged after the Masruqan canal was abandoned, sometime in the second half of the second millennium CE. The current Gargar river has taken its current shape then, probably due to an avulsion.

Several reasons are to be considered as a trigger for this event: (1) a very wet winter after a few dry summers could have brought a massive volume of runoff from the eastern part of the Karun plains into the hydraulic system just south of Shushtar, resulting in reactivation of an old and dry riverbed of paleo Karun, now being considered Gargar. This sequence has been documented in a neighboring region in the eastern corridor (Rashidian 2017). Global climate data corresponds with a warmer period at about 1100 to 1300 CE, and a wet and cold timespan – the so-called little Ice-Age – from 1300 to 1600 CE (alternatively from 1400 to 1850 CE), which fits into this scenario; (2) the waterworks at Shushtar were subject to manipulation at least from the Sasanian times and were damaged sometime after the Middle Islamic time (Moghaddam 2012, pp. 44-47). This event could have triggered the avulsion of the Masruqan canal and the emergence of Gargar (Verkinderen 2015, p. 132, see his arguments against the hypothesis of both Moghaddam 2012; Alizadeh *et al.* 2004).

In summary, the current confluence of Dez and Karun is a direct result of an avulsion of the Masruqan canal and reactivation of the Gargar river in its current form, sometime before the fourteenth century CE.

Dez-Karun-Confluence from the Antiquity to Medieval Times

The new OSL dating provides an absolute timeframe for this past junction, whose traces are still visible (31° 36’ N, 48° 48’ E) at about 9 kilometers southwest of the current confluence. The sedimentation dated to the eleventh century is heavy, e.g., 3 m thick. The well-sorted fine-sand particles confirm a continuous water flow. These sediments are strikingly similar in texture and mineral content to those obtained from the active Dez river about 20 km upstream of the river (Figure. 5).

Therefore, this confluence is the original junction of Dez and Karun prior to the Shushtar waterworks from at least the second millennium BCE (sites with Sukkalmah and Arsacid pottery, Moghaddam and Miri 2003) to the tenth century CE. Based on historical accounts, this confluence might have gradually shifted slightly to the north (Verkinderen 2015, p. 126, based on Yaqubi).

After the migration of the confluence to the current location, the remaining flow of Dez gave up very gradually, making huge scrollbars and oxbow lakes, which are still visible today, especially on CORONA imagery.

Ancient Confluence(s) of Dez and Karun before the Antiquity

The identified paleo-flows based on sand content and satellite imagery are of importance. As seen here (Figure. 3), there are at least two possible past confluences in the area west of the current Karun. The eastward migration of the Dez-Karun-confluence in the last millennia before the current confluence can be assumed as well. This assumption correlates with the general assumption that the rivers Dez and Karun (and Karkheh) have migrated westwards between the fifth and second

millennium BCE (Kouchoukos 1999; Krikby 1977 & Veenenbos 1958). In contrast to the absence of archaeological sites from Prehistory in the environs of Ahwaz, a well-connected settlement system was established since the first millennium CE.

It has been suggested that the Susiana plains were aggrading from the ninth to the second millennium BCE (Krikby 1977, p. 280 & Lambeck 1996). In this timespan, the plains of lower Susiana could have been a low-energy tidal marsh, as suggested by a recent geoarchaeological study (Heyvaert & Baeteman 2007; Heyvaert *et al.* 2010). Afterward, a gradual incision of the riverbeds has been observed in the sedimentary record (Krikby 1977 & Heyvaert & Baeteman 2007), which correlates with archaeological finds from the eastern plains of Gargar (Alizadeh *et al.* 2004, p. 72). For lower Susiana plains, this incision has been dated to about 1250 BCE (Heyvaert & Baeteman 2007).

From the location of the current Ahwaz city, leaving the Ahwaz ridges, Karun has a turbulent hydraulic history. Traces of the earliest known paleochannel of Karun (K1) have been detected at about 70 km southwest of Ahwaz, as a braided riverbed with at least two distinct channels flowing towards the Shadegan marshes and the Persian Gulf, which is considered active from the eighth millennium BCE. After a period of abandonment, this channel was revived in the Late Medieval times, being the current Karun-e Kur (Blind Karun) (Heyvaert *et al.* 2010, p. 122).

Another paleochannel (K2) can be traced directly west of Ahwaz, meandering to the west, and reaching the great wetland (Hur Al-Azim) at the current Iran-Iraq border (Heyvaert *et al.* 2010, p. 120). This channel was probably active from the third millennium BCE (Heyvaert & Baeteman 2007, p. 102 - figure 11). Both channels seem to have given way to the third and current Karun channel in Late Antiquity (Heyvaert *et al.* 2010, p. 125, table 11.2.). Interestingly, a paleochannel of Karkheh (the neighboring river to the west of Dez) correlates with this paleochannel of Karun, suggesting a possible confluence of Karun and Karkheh at a time between the fourth century BCE to the seventh century CE (Heyvaert *et al.* 2010, p. 126). This possible confluence could have been responsible for further distributing fluvial sediments in the floodplains between Karun and Karkheh south of Shushtar and north of Ahwaz, which later became a flourishing urban area with at least three major cities in the Early and Middle Islamic times.

On the other hand, there are no indications that Dez ever flew to the south of Ahwaz, meaning that Dez and Karun never joined south of Ahwaz. Therefore, all the three mentioned Karun channels are indeed channels for the Karun-e Bozorg River after the confluence of Dez and Karun. Hence, we are left with the mentioned area of interest, north of Ahwaz, to trace past confluences of these two rivers.

Karun and Dez have always joined somewhere between south of Shushtar and north of Ahwaz. However, the area between their current flow from Band-e Qir to Veys and from the past confluence to Ahwaz was probably not stable due to hydraulic shifts of the confluences during the ninth to the second millennium BCE. Hence, no settlement system was established here at this time.

Confluence(s) of Paleo-Dez and Paleo-Karun Prior to the Persian Gulf

The location of the paleo-confluence is directly dependent upon the identification of paleo-flows of Dez and Karun. However, it is impossible to identify their confluence before the fifth millennium BCE due to their unknown flow. Additionally, the extent and location of the northern paleo-coastlines of the Persian Gulf are yet to be reconstructed with substantial evidence[1].

A confluence was probable in Ahwaz, based on a combined elevation model from the contours of the lowland Susiana and the head of the Persian Gulf prior to its filling with water. The west basin of the Persian Gulf has filled gradually, starting in the Early Holocene (~12KYA) in at least three steps with stillstands in between (Lambeck 1996), which is crucial for tracing the paleo-confluence of these rivers. Because, in the absence of a well-developed river delta on the Biaban shelf and the generally small volumes of river sediments in the Persian Gulf, one assumes that the rivers may have deposited their sediments long before reaching the sea (Lambeck 1996, p. 54), meaning either a slow and shallow water flow or minor sedimentation freight. Either way, this indicates a probable confluence around current Ahwaz and not further to the south.

[1]There are a dozen reconstructions for the head of the Persian Gulf from Early to Mid-Holocene. None of them are convincing and most of them contradict each other.

The paleo-Dez and paleo-Karun must have been joined by paleo-Karkheh in this timespan, creating the paleo-confluence because of the young age of the currently known Karkheh riverbeds. It is also possible that there were only two paleo-rivers on the Susiana plains prior to the Persian Gulf's emergence (Gasche 2005). Another possible scenario is that paleo-Karkheh had joined the Paleo-Euphrates far more to the north than the current Great swamp (Hur Al-Azim) at the current Iran-Iraq border (Lambeck 1996, p. 53). The situation regarding the other crucial confluence is relatively comprehensive. Ground penetration radar (GPR) analysis has shown the paleo-Arwand river's trace on the bottom of the west basin (Purser 1973). Therefore, it is safe to assume that paleo-rivers from the Mesopotamian plains joined the paleo-river from the Susiana plains at the current head of the Persian Gulf, currently dominated by sabkha. Paleo-Dez and Paleo-Karun must have flown more to the west of the plain due to the tectonic dynamics and the current anticlines in the Susiana plains.

Was there a time at which the two rivers did not join? This is possible in the period before the Holocene. However, the question of such confluences remains open, for the current methods of geoarchaeology in the intensively populated and immensely manipulated riverine landscapes are not sufficient. This question shall be investigated by employing large-scale paleoenvironmental studies, not limited to one country's borders, but rather as a joint project among the concerning states, Iran and Iraq.

There is a need for more extensive data, especially regarding the earlier times to fully reconstruct the flow of these two rivers and their respective confluence at any given time of their life. The here presented assumption shall summarize state of the art and pose focused questions for the future investigation of this dynamic landscape in the framework of the Anthropocene.

Concluding Remarks: Geoarchaeology of Confluence

The confluence of two rivers affects their whole regime and changes the degree of their interaction with their environment. Therefore, it must be studied prior to interpreting archaeological data, especially regarding the settlement patterns.

Putting all the available data together proves that there are still more gaps than facts to the biography of the crucial elements of the ancient landscape in the Near East. There must be continuous effort to fill these gaps and comprehensively connect the dots, correlating geodata with archaeological evidence. Revisiting older assumptions and readdressing past discussed issues is of utmost importance in moving forward the discourse of the human-environment-interaction.

The following points can be made regarding the presented case study: First, the massive anthropogenic impact during the first millennium BCE to the first millennium CE has been crucial to shape the two rivers and shift their confluence subsequently. There are several indications for a massive change in the hydraulic regime of the Greater Susiana in this timespan. Second, the dynamic nature of lower Susiana and the head of the Persian Gulf has made it almost impossible to trace sedimentations prior to the second millennium BCE (Gasche 2005). Any hypothesis in this regard can only be tested via hydraulic modeling and will remain mere speculation until new methods of data production are developed and used here.

This paper has aimed to summarize the available data on this question and present new and relevant data to fill the gaps. It shall also emphasize the impact of the combined nature of humans and the environment on the riverine landscapes and the immediate or delayed response of the river system to these forces.

These successive changes must be studied embedded in their geomorphologic and hydraulic setting. I hope to have shown the hybrid nature of the confluence of these two decisive rivers as an example of human-environment interaction. After all, such interactions have led to the new geological era we now live in: the Anthropocene.

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