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The nature of fluctuating lakes in the southern Amu-dar'ya delta

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ABSTRACT

The delta region of the Amu-dar'ya has a complex history of shifting river channels that has impacted extensively on the Aral Sea and on the areas of the delta that saw human settlement from prehistoric times onwards. This paper explores evidence drawn from archeological, historical and environmental data relating to lakes that formed in the south of the delta on the east bank of the river and their impact on settlement patterns in this area, in particular the potential impact of variable flooding on the major fortified site of Akchakhan-kala. Testing of the area around the sites showed that the site had not been flooded but was founded on riverine or lacustrine clays. Shortly after the initial abandonment of the site, the immediate environment was covered by dune fields.

1. Introduction

The Amu-dar'ya is one of the greatest rivers in Central Asia. Rising in the Pamirs and the Hindu Kush, it runs through northern Afghanistan into Uzbekistan where it crosses the desert to debouch into the Aral Sea (Tolstov and Kes', 1960) (Fig. 1). The delta region and the oasis it has created are geomorphologically complex, reflecting the ever-changing path of the river. The Amu-dar'ya also gave life to the land known over two thousand years ago as Chorasmia, today the Khorezm oasis, the Khorezm region of Uzbekistan and Dashoghuz region of Turkmenistan. The lower reaches of the Amu-dar'ya, surrounded by deserts, experience a harsh dry continental climate with a mean annual rainfall of only c. 80 mm, strong winds, hot summers and deeply cold winters (Andrianov, 1969, 96). The efforts of humans to settle this area have been heavily impacted by the shifting nature of the rivers. The main courses of the Amu-dar'ya, and the more northerly S'ir-dar'ya, changed through time, and some of the major ancient river courses have been identified (Fig. 2). The Akcha-dar'ya ran from the area of modern Urgench/Turtkul' north-east and then north into the Aral Sea, while the Inkar-Dar'ya departed the S'ir-dar'ya at Kz'il-Orda and ran south-west and then north to the Aral Sea, joining the Akcha-dar'ya (Zhan'i-dar'ya) delta. The Dar'yalik and Daudan beds of the Prisar'ikam'ish delta have been traced north-west from the area of Dashoghuz and west to the Sar'ikam'ish depression from which the Uzboy can be traced south and then west to the Caspian Sea. Explorations in these areas have resulted in reconstructions of ancient water courses matched broadly to the various recognized pre-historical and historical periods (Tolstov, 1962; Tolstov and Kes', 1960; Boroffka, 2010).

The delta region was extensively explored in the mid-20th century by a major Soviet era research team, the Khorezmian Archaeological Expedition, led by S.P. Tolstov.[2] This multi-disciplinary group mapped sites, ancient canals and river beds, providing an invaluable background to more recent scientific research. Since 1995 excavations in the Tash-k'irman oasis on the east bank of the Amu-dar'ya have been conducted under the auspices of the University of Sydney Central Asian Programme (USCAP) [3] and the Karakalpak Branch of the Uzbek Academy of Sciences as the Karakalpak-Australian Expedition (KAE) [4] with a particular focus on the major site of Akchakhan-kala (Kazakly-yatkan)[5] (Figs. 3, 4).

This study was initiated to explore the potential impact of ancient lake fluctuations on the site of Akchakhan-kala. Akchakhan-kala is perhaps the largest, and has proved to be certainly among the richest, of the sites known in ancient Khorezm. It was a royal seat of a previously unknown dynasty comprising a massive fortified complex set in a dune field on the east bank of the Amu-dar'ya in the southern part of the modern delta region. The dune field is surrounded today by irrigated

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[4] The Karakalpak-Australian Archaeological Expedition is jointly directed by Professor Vadim N. Yagodin (Research Institute of the Humanities of Karakalpak branch of Academy of Sciences of Uzbekistan) and Professor Alison V.G. Betts (University of Sydney).
[5] Akchakhan-kala was published in early works as Kazakly-yatkan/Kazakl'i-yatkan but the name has been changed in recent publications to reflect its formal listing in the national register of archaeological sites of Uzbekistan (Yagodin et al., 2010; Kidd and Betts, 2010; Betts et al., 2009; Kidd et al., 2008; Betts et al., 2005; Helms et al., 2002; Helms and Yagodin, 1997).

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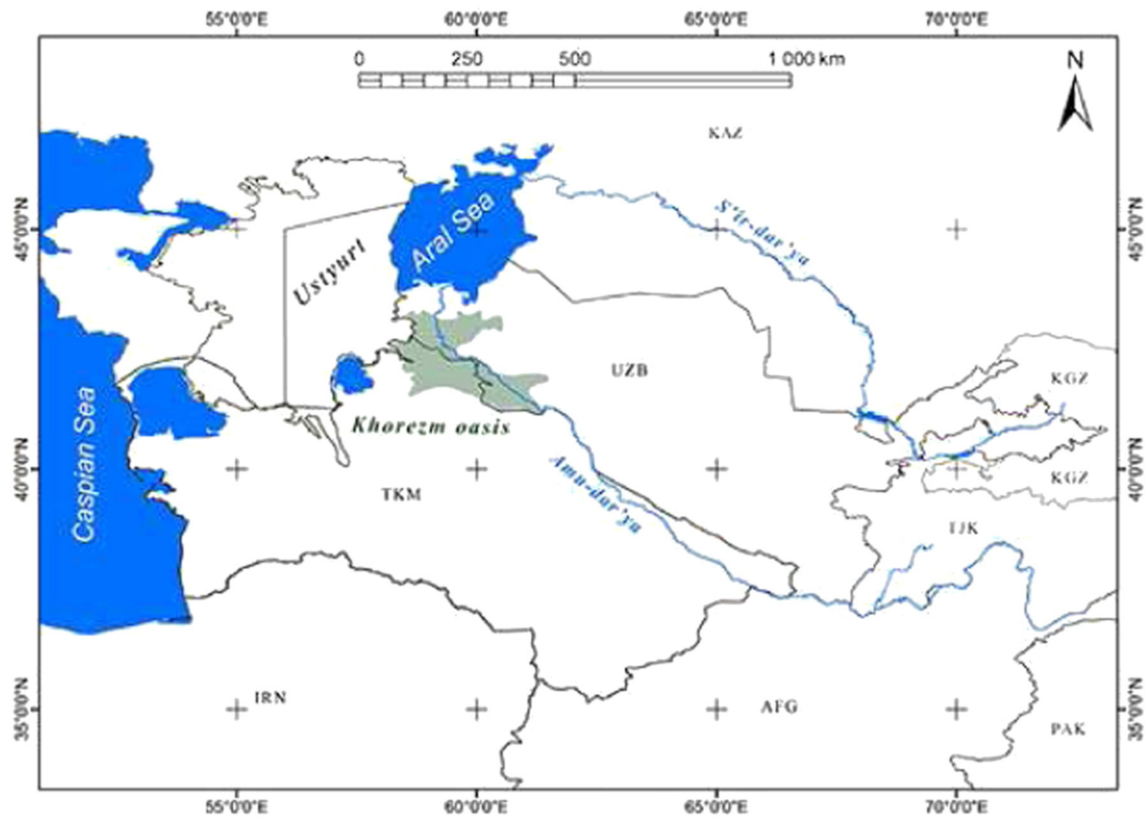

Fig. 1. Map of Central Asia showing the location of the Khorezm oasis.

lands. To the north lies the range of hills known as Sultan-uiz-dagh, a volcanic ridge rich in a variety of minerals. The land is flat and there are several small lakes in the general vicinity of the site. Based on present evidence, Akchakhan-kala was founded around the end of the 3rd century or early 2nd century BCE and was abandoned around the 2nd century CE (Betts et al., 2009). The site saw a partial re-occupation some two centuries later when a *donjon* was built among the standing ruins of the earlier site dated, based on the ceramics, to

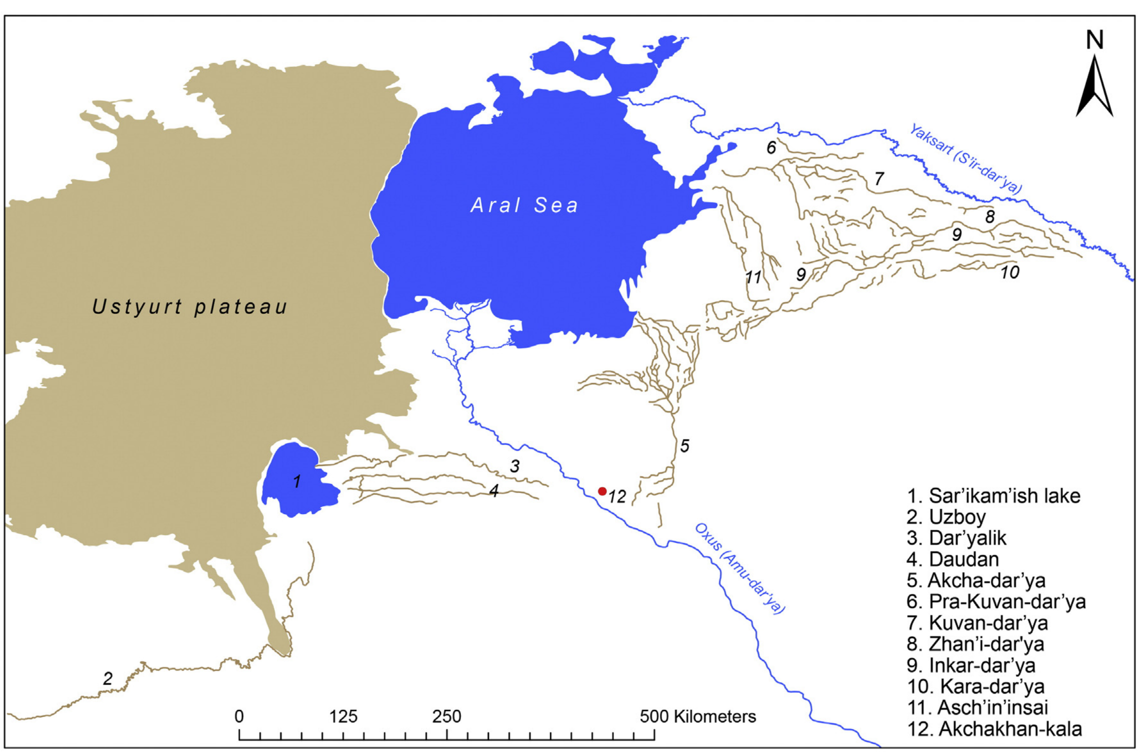

Fig. 2. Map of Amu-dar'ya delta with ancient branches of the river.

Fig. 3. Map of Amu-dar'ya delta showing location of Akchakhan-kala.

the late 4th to 5th centuries CE. To the north of the site are traces of farmsteads, field systems and a canal. The wealth of ancient Khorezm depended on the ability of its people to manage their water supply. They needed water to irrigate their fields. The riverine silts are fertile, but with irrigation, salinity is a constant problem. The river channels provided water for the canals, but their shifting nature must have remained a persistent threat. The lakes provided fish and a cooling microclimate in their vicinity, but would also cause the water table to rise as they spread.

2. Chronology of riverine and settlement shifts

Early traces of human activity across the greater Aral Sea basin can be found going back to the Paleolithic (Bizhanov, 1988; Artyukhova, 2001a,b; Bonora, 2014). By the Neolithic around 5000 BCE, sites of the Kel'teminar culture have been found quite widely spread, on the edges of ancient lakes (Vinogradov, 1981, 24–26). and along the western arms of the delta flowing into the Sar'ikam'ish depression and the Uzboy channel (Levina, 1998; Boroffka et al., 2003–2004). The Kel'teminar people lived mainly by fishing and hunting small animals and birds. The wide spread of Neolithic sites, even out into the now dry Kyzylkum desert, indicates a wetter environment than that of the present day for the period around 6000 to 3000 BCE (Boroffka, 2010). By the Bronze Age, the Uzboy seems to have dried up and the concentration of settlement shifted to the Akcha-dar'ya up to and along its confluence with the Zhan'i-dar'ya and the Inka-dar'ya, ancient southern arms of the S'ir-dar'ya. While sites lingered on there through the Bronze Age, by the time that Akchakhan-kala was occupied, the Kyzylkum was totally abandoned, while settlement was concentrated in the northern and southern deltas of the Akcha-dar'ya, the delta of the S'ir-dar'ya and along ancient channels towards Sar'ikam'ish (Boroffka, 2010, 287, fig. 2).

For the most part, identification of the distribution of archeological sites provides the best evidence for changing patterns of river flow. These have not generally been tested by modern scientific methods, but such attention has been paid to the Aral Sea itself. The recent dramatic fall in water levels in the Aral Sea is not a wholly new event. Throughout human history this body of water has been subject to periodic rise and fall. This is due to a number of factors including human interference in water flow through diversion for irrigation. The other two key factors are the shifting channels of the river beds and environmental and/or climatic change. Various studies have produced differing patterns of change in water levels. The most recent and the most extensive is that of Krivonogov et al. (2010, 2014) who suggest that it is possible to reliably reconstruct events for the last 2 millennia, including 2 transgressive and 2 regressive phases. They document sea level rises in the 6th–12th and the 16th–20th centuries CE and falls in the 13th–14th centuries CE and, in the most recent regression, since the mid-20th century CE. Earlier changes cannot be firmly fixed. Further into the past, they note a lake level below 40 m asl at ~2000 and 4500 cal BP and below 30 m asl at ~7500 and 8000 cal BP.

So far, however, we do not have well-documented proof of the causes of these fluctuations but it is clear from the archeological records that shifting river patterns were a major factor in the environmental history of the Aral Sea region. A recent study suggests that probably all Aral Sea regressions are related to full and part diversion of the

Fig. 4. Akchakhan-kala: old dunes (foreground), active dune field (mid-left), Akchakhan-kala (background).

Amu-dar'ya westward into the Sar'ikam'ish lake and through overflow on into the Uzboy (Micklin et al., 2013). The Amu-dar'ya has a heavy sediment load and from time to time this must have built up to such a degree that it caused the river to break out on the left bank into the channels leading to Sar'ikam'ish. Subsequently, perhaps due to heavier flow in the Amu-dar'ya, the sediments damming the northward flow were eroded away and the river once again flowed back into the Aral Sea. Climatic changes that reduced the overall flow in the river would also have played a part, but cannot fully account for the size and rapidity of the most significant regressions in the Aral Sea (Micklin et al., 2013, 27).

There has also been relevant work on regional climate change. The climate of the region is controlled by the intensity of the westerlies and subsidence of dry air masses off the Tibetan Plateau and Tian Shan. These very high mountains form barriers to any significant incursion of moisture from the Asian monsoon systems. Thus large parts of Central Asia are arid but any subtle changes in moisture delivery by the westerlies or by location of river flow are crucial to the well-being of societies and the sustainability of agriculture. Boomer et al. (2009) have identified a low sea level stand that began at some time between ca. CE 0 and CE 400. This is associated with a prolonged period of cold, arid conditions in the Aral Sea region as indicated by the pollen record (Sorrel et al., 2007). At this time the climate in western Central Asia was characterized by cold winter temperatures, relatively cool summers and arid conditions. This changed when between ca. CE 450 and CE 900 there was an increase in temperature and moisture conditions, with annual precipitation almost twice that of the present day (Boomer et al., 2009). Chen et al. (2008) have also reviewed lake level changes across Central Asia and China. They noted that water levels were relatively low between about 300 to 1000 years ago for the Aral Sea, Issyk-Kul and Wulun Lake in Xinjiang and Bayan Nur in Inner Mongolia. These are quite different to the patterns in lakes further south and east where the Asian monsoon systems had increasing influence (see also Li et al., 2011). This indicates that it was the dynamics of the westerlies which controlled the main climates of the Uzbekistan region. Oberhänsli et al. (2007) have also recorded that the period around 2000 years ago was a period of intensification of irrigation around the Aral Sea.

3. River channels and flood events in the southern delta

Tash-k'irman oasis is located in one of the ancient deltas of the Amu-dar'ya, the so-called Southern Akcha-dar'ya delta, formed by a fan-shaped plain bounded on the north by the ridge of the Sultan-uiz-dagh and the sands of the Kyzylkum, on the south-west by the modern Amu-dar'ya, and on the east again by the sands of the Kyzylkum (Fig. 3). The Southern Akcha-dar'ya delta was subject to the same kinds of riverine shifts as that of the Amu-dar'ya at the Aral Sea. At the north-east corner the line of the ancient Akcha-dar'ya river bed passes through a narrow "corridor" that crosses the Kyzylkum over a distance of some 75 km before widening out again into the extensive deltaic fan of the Northern Akcha-dar'ya delta (Tolstov and Kes', 1960, 35–66; Andrianov, 1969, 98–102). The Southern and Northern deltas of the Akcha-dar'ya are the oldest of the three deltas of the Amu-dar'ya river: the Akcha-darya, the Prisar'ikam'ish and the Priaral (Fig. 2). Archaeological studies suggest that the Akcha-dar'ya was in existence by the Chorasmian Neolithic period (5th–3rd millennia BCE) and the Bronze Age (2nd - early 1st millennia BCE). During the Neolithic period only the Southern delta was receiving water, while during the Bronze Age the corridor and the Northern delta were also functioning (Tolstov and Kes', 1960, 35 ff.).

Four internal channels have been identified for the Southern delta: Eastern, Central, Western and Southern. Of these the Central and Eastern channels drained into the main bed of the Akcha-dar'ya and north around the eastern end of the Sultan-uiz-dagh. The Western channel passed through lowlands lying to the south of the Sultan-uiz-dagh ridge where it may from time to time have caused extensive flooding. The Southern channel, on which Akchakhan-kala lies, is located between the ancient Western channel and the modern channel of the Amu-dar'ya. The ancient Southern channel is presently in-filled with an extensive strip of gray, micaceous sand stretching from south-east to north-west for a distance of over 50 km. In some places the sand forms loose mounds up to 8–10 m high, while in others it forms banks of shifting *barchan* (or transverse) dunes up to 4–5 m high. In places where the sand is more stable, there is a thin covering of salt tolerant shrubs. Among the sands are patches of modern fields and there are shallow lakes in the low-lying areas. Traces of ancient fields, ditches

Fig. 5. Map of Istemes in the early 20th century, showing Akchakhan-kala.

Fig. 6. Dune field near Akchakhan-kala: older dunes with active recent dunes encroaching.

and buildings can been seen on the *takyr* surfaces under the sand, marked by scatters of heavily eroded sherds and other artifacts.

The lowlands to the south of the Sultan-uiz-dagh range in the east consist of broad, flat saline surfaces with bands of sand where the ancient river channels once ran. The lowlands in the western part are related to the modern Amu-dar'ya river channel. During the Neolithic period, river channels of the ancient Amu-dar'ya delta were restricted by the Sultan-uiz-dagh range, causing a lake to form along its southern slopes. From the eastern corner of this lake water flowed north past the eastern end of the Sultan-uiz-dagh to the Aral Sea (Tolstov, 1948a, 40).

In the 10th to 11th centuries flood water overflow created a new channel, the Kerder channel (Yagodin, 1986, 79–80). Arab writers in the Middle Ages also describe extensive flooding (Bartold, 1965, 40). In the 19th century all this territory is described as "Istemes" floods or lakes (Yagodin, 2005). The historical existence of these lakes which periodically dried up and then reappeared again is reflected in local Karakalpak folklore where many stories mention the lake Istemes. The same lake is described under the name Akchakul, and in times when the lake dried up, the district carried the name Turangylsay (Alimov n.d). The area was only completely drained after the water levels in the Amu-dar'ya began to fall around the 1960s as a result of extensive irrigation, coinciding with falling water levels in the Aral Sea. Early 20th century Russian mapping of this area shows the general outline of the lake at that time (Fig. 5), indicating that the only modern remnant is the small lake to the south of the town of Eli-kala, still known as Akchakul (Archangelskiy, 1931, 12; Dimo et al., 1913). Indirect proof of the existence of these lakes is shown by the distribution of archeological sites. In the area believed to have been covered by lakes, there are no ancient or medieval sites and very little modern settlement.

This study was initiated to explore what impact this pattern of flood events might have had on the site of Akchakhan-kala. The Russian map of Istemes in the early 20th century (Fig. 5) shows that Akchakhan-kala lies close to the shoreline, while an inlet seems to penetrate the dune-field just to the south of the site. While there is no historical mention of Akchakhan-kala, the ancient name of which is not known, in later periods, medieval historians and geographers mention Khorezmian cities that were lost to the river, either because the river undercut its banks and washed away the town or because the canals were breached and caused damaging floods. The Islamic scholar Al Biruni, a Khorezmian native, claimed that the early capital of Khorezm was moved to the city of Kyat after the previous capital, Dardzhash, was inundated by floods (MITT I, 1939, 138; Al-Biruni, 1879).

4. Environmental study

In 2013 studies were carried out around the site to determine the environmental history before, during and after the site was abandoned.

Akchakhan-kala is located in a sea of sand dunes on an otherwise generally flat plain, 10–15 km north east of the present bed of the Amu-dar'ya. The dunes have a number of features which seem to put them in two broad age categories. There is an older sequence of gray-yellow sands with some soil development, with active and non-active termite mounds, a light scatter of *Lycium*, *Kochia*, *Salsola* and other Chenopodiaceae species. This sequence generally overlies clays; it is relatively stable but is being mobilized in places where disturbance of the vegetation is evident. A younger dune sequence of mostly mobile dunes up to several meters high occurs above the surrounding plain. These generally overlie the older dune sequence, or sometimes the clays directly. They are yellowish orange in color, have no termite mounds present, and are largely un-vegetated, although occasional grasses, Chenopodiaceae and *Ephedra* species are present in swales (Fig. 6). Both dune types cover the Akchakhan-kala citadel walls in places, indicating that the main construction of the walls is older or at best near contemporaneous with the dunes.

Here we describe a selection of sediment sequences and use radiocarbon where possible to reconstruct the past and contemporaneous environmental setting of Akchakhan-kala. Radiocarbon samples of shell, bone, charcoal and plant fragments were collected in the field and prepared in the laboratories at ANSTO in Sydney. These were measured on the STAR Accelerator except for two especially small samples which were measured on the ANTARES Accelerator which has the capability of measuring samples as small as a few micrograms of graphite target. Samples, date numbers and general notes on the preparation method to graphite are given in Table 1.

Table 1
Radiocarbon samples.

Sample site	Material	ANSTO code	δ^{13}c (‰)	Age (BP)	Calibrate age (2σ)
Inside Wall	Shell	OZQ776	-4.0 ± 0.1	1345 ± 35	636–722 CE
Inside Wall	Shell	OZQ777	-8.5 ± 0.1	5500 ± 35	4448–4293 BCE
Inside Wall	Bone	OZQ775	-17.5 ± 0.1	2080 ± 30	87 BCE–214 CE
Amu-Dar'ya	Shell	OZQ780	-11.5 ± 0.1	Modern	Modern
Ancient lake	Organics in gypsum	OZQ781	-25.0 ± 0.1	$16{,}260 \pm 160$	19,799–19,091 BCE
Site 4 (Area B)	Charcoal	OZQ774U1	-25.0 ± 0.1	3770 ± 70	2457–1984 BCE
Site 4 (Area B)	Plant matter	OZQ774U2	-21.7 ± 0.1	4230 ± 45	2917–2669 BCE
Site 6 (Area C)	Charcoal	OZQ771	-25.0 ± 0.1	8670 ± 110	8196–7528 BCE
Site 6 (Area C)	Plant matter	OZQ772	-22.9 ± 0.1	$10{,}050 \pm 80$	10,008–9310 BCE
Site 8 (Area D)	Charcoal	OZQ773	-25.1 ± 0.1	2460 ± 100	903–613 BCE
Site 10 (Area E)	Plant matter	OZQ778	-23.5 ± 0.1	Modern	Modern
Site 11 (Area E)	Plant matter	OZQ779	-24.2 ± 0.1	Modern	Modern

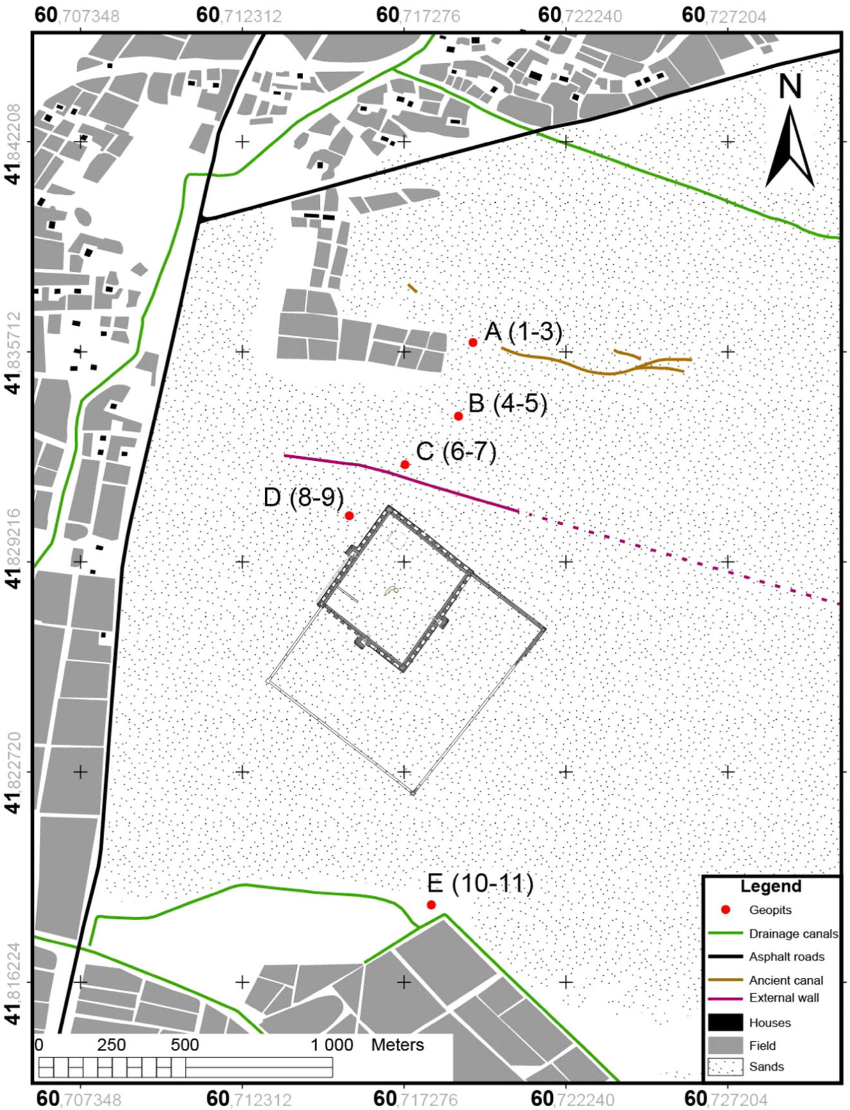

Fig. 7. Map of the area around Akchakhan-kala showing the location of the test pits.

The test pits examined in this study (Fig. 7) will be described in a sequence from north to south. A schematic version of each sediment section, and radiocarbon dates where applicable, are shown in Fig. 8. The locations of the pits consist of house sites, sediments close to but not in the citadel, and some clay pans south of the citadel. In addition two surface samples inside the citadel were dated and an age estimate was made of an apparently ancient lake bed from a gypsum crystal. Three surface samples were collected near the southern corner inside the citadel; two consisted of shell and one of bone. Two shell samples were dated and returned ages of 636 and 4293 BCE (Table 1). The older sample has an age aligned with the clay while the younger age post-dates the abandonment of Akchakhan-kala. The younger sample may have been carried to the site by human agency. The bone sample was located with the younger shell sample and is assumed to have had a similar origin but it could have been from a grazing animal which entered the site. The bone had a good collagen yield (0.9% by weight) and returned an age of 87 BCE to 214 CE (2σ range) and this is consistent with the age of the citadel. The younger shell sample (636–722 CE) probably postdates use of the citadel.

Two regional samples were collected for dating. A clearly abandoned channel of the Amu- dar'ya is located 5.1 km NNW from Akchakhan-kala and pottery scatters in the surrounding dunes attest to occupation of the area. The occupation phase is not directly dated but a shell sample from the channel returned an age of Modern, suggesting the channel was recently abandoned by the river, although some earth works suggest that this part of the old channel may have recently been used for local water storage. The Khorezmian Archaeological Expedition noted that in the 1950s to 1960s, prior to the beginning of mass development of irrigation in the south of the Republic of Karakalpakstan, the Western channel, while no longer a flowing river, still existed as a series of elongated depressions partially filled by water.[6]

The second sample was collected in a region north of Akchakhan-kala, along the foothills of the Sultan-uiz-dagh close to the site of Svent-tepe, where there is evidence of ancient and abandoned shorelines (Fig. 9). Gypsum crystals are common in the area (e.g., Fig. 10) and suggest that the dying phase of a lake contained shallow and probably warm water which led to the deposition of the gypsum. A large crystal with inclusions was selected for radiocarbon dating. The inclusions were concentrated by dissolving the gypsum and these returned a sample of about 10 μg. The age, and presumably the dying lake in which it was formed, was over 19,000 BCE.

[6] Andrianov, 1969.

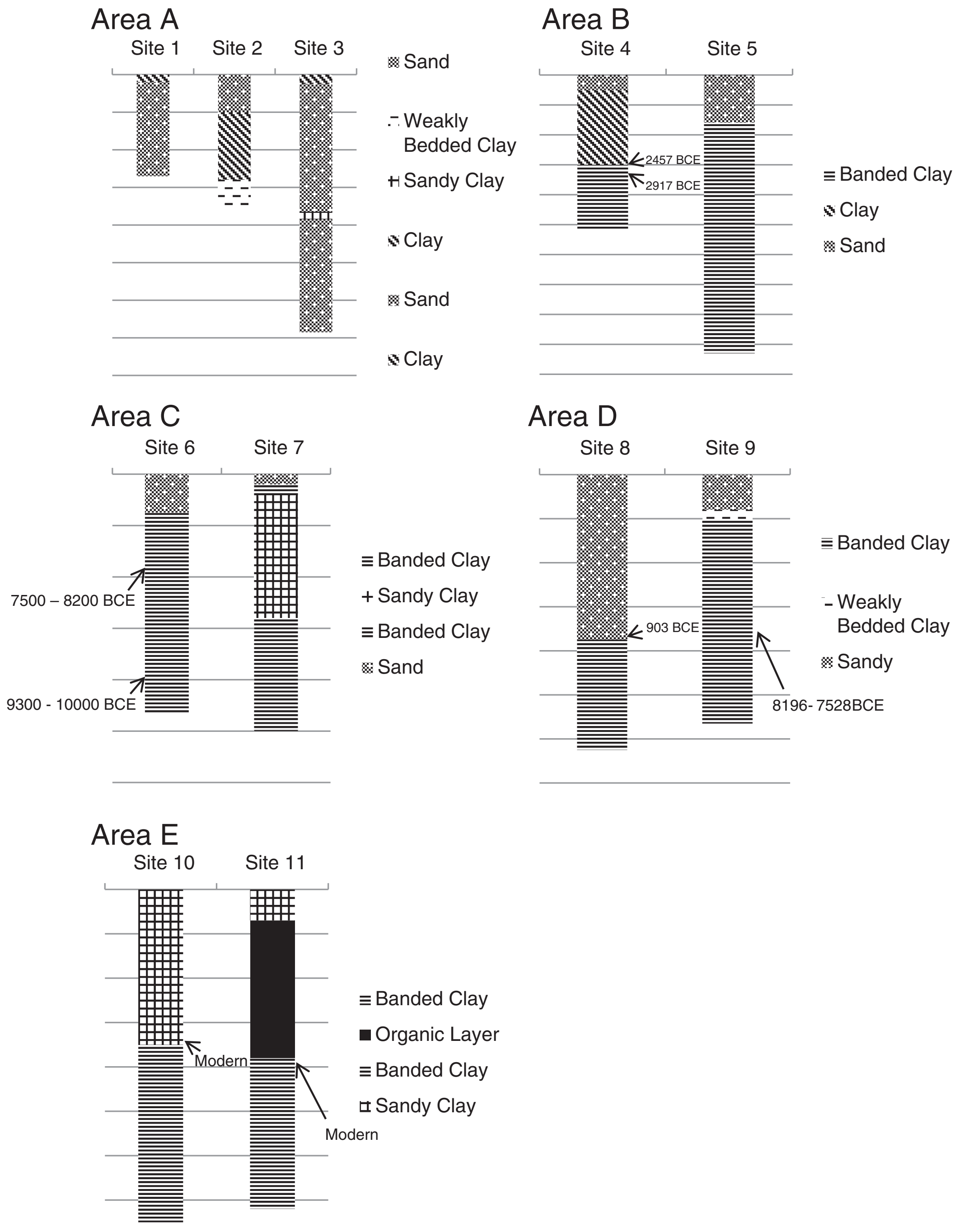

Fig. 8. Schematic diagrams showing stratigraphy of the study sections.

The sediment sequences are described from north (Area A) to south (Area E). Digging at each site was abandoned when the water table was reached. Fig. 8 gives a diagrammatic representation of all the stratigraphies described below.

At Area A (Fig. 11) a number of house sites have been identified. They are revealed by their relatively flat surface and building footings, and traces of compacted walls and pathways. They are also located near traces of the Tash-k'irman main canal which indicates that an irrigation system was in place, most likely contemporaneously with the house sites, and that agriculture was practiced. Three pits were dug in this area across about 10 m^2. Site 1 had a clayey surface overlying the modern dune sand. The surface clay suggests the presence of a local depression formed by deflation, and ponding has accumulated salt and fine clayey material. No flecks of pottery or charcoal were observed in this or the other pits at Area A sites. Site 2 had 18 cm of sand overlying clay. The lower clay had weak bedding and was thus deposited in water. The section between 18 and 58 cm depth had interruptions to the bedding by weak ped formation. This suggests the upper layer had weak soil formation sometime before deposition of the dune sand. Site 3 had a reduced clay overlain by an oxidized clay then sandy clay grading into sand, then clay then 53 cm of overlying sand. None of these pits had readily identifiable material for radiocarbon to establish a chronology for these sequences.

Two pits were cut in Area B, which lies to the north of the site. Site 4 (Fig. 8) shows sand overlying clay, probably formed on a deflation surface overlying 19 cm of a reddish clay with weak bedding and ped

Fig. 9. Old shoreline north of Akchakhan-kala.

formation (see example in Fig. 12). The base of this section has an age of about 2457 BCE and this overlies a banded reddish clay. Plant remains at 37 cm depth have an age of 2917 BCE.

Area C lies to the north-west of the site, with two pits, one on either side of the outer boundary wall. Site 6 had 15 cm of sand overlying a bedded reddish clay. No pottery fragments were seen in the deposit. A radiocarbon date on charcoal at 39 cm depth gave an age of 8670 BCE, while a date on plant remains at 79 cm depth had an age of ca. 10,050 BCE. Site 7 was originally excavated by Professor Vadim Yagodin in the 1990s (Yagodin et al., 1996, 104–5) (Area 4). It has about 8 cm of sand overlying a 7 cm layer of clay containing pottery fragments. Pottery fragments are also present at 35 cm depth in a sandy clay. This is underlain by 90 cm of a massive reddish clay-devoid of pottery fragments.

Two sites (8 and 9) were examined about 20 m to the west of Akchakhan-Kala NW wall (Area D) (Fig. 5). Site 8 had a sand with salt layer overlying 65 cm of sand. Pottery flecks were present between 40 cm and 60 cm. The upper levels of sand were from modern dunes while the pottery was in darker colored sand which was presumably from the older dune series. Small flecks of charcoal and bone were present at 75 cm depth and these were dated at 903 BCE. No pottery fragments were observed below this level. The lower 50 cm of reddish clay was massive in form with peds present throughout.

Fig. 10. Gypsum crystals on old lake sediments. Inclusions from the crystal on the left returned a radiocarbon age of ca 19,799–19,091 BCE.

Site 9 had 15 cm of modern dune sand overlying a weakly banded clay with peds. A 2 cm layer of clay overlying a dark organic band had several pottery flecks present. This was underlain by 29 cm of yellowish gray clay and then 36 cm of reddish gray clay. At 71 cm depth some plant organic matter was seen and this was dated at 8196–7528 BCE.

About 1.05 km SE of Akchakhan-kala is a series of pans and both old and young dunes are present (Area E). This area coincides roughly with the 'inlet' on the Russian map of Istemes (Fig. 5). There is a clear sequence where the younger dunes are encroaching on an older dune field from the north and west (Fig. 13). Two sections located about 100 m apart were studied.

Site 10 had 9 cm of sand and salt crust overlying sandy clay then a dark organic layer. A sandy reddish clay then occurred until 39 cm depth. Pottery fragments were in low abundance but occurred above this depth. A reddish clay was found between 39 and 82 cm depth and a yellowish gray clay with bedding was found below this to 105 cm depth where the water table was intersected.

Site 11 had a 5 cm thick sandy salt crust underlain by 6 cm of sandy clay then from 11 to 40 cm was a sand layer containing pottery flecks. Below this was a bedded organic layer (radiocarbon dated as Modern) then 25 cm of weakly bedded reddish clay. A date on organic matter from Site 10 also came out as Modern. Local people remark that extensive flooding and shallow water existed in this region in the 1930s. It appears that the two Modern ages confirm this.

5. Discussion

In general, pottery fragments are assumed to be related to the presence of Akchakhan-kala, and are largely confined to the old dune sand phase except in clay immediately underlying sand (e.g. Fig. 5 Area B). The age bracket of the site, and thus this material, is between the late 3rd century BCE and the early 2nd century CE.[7] The young dune phase has some surface pottery flecks but these are most likely wind-blown and reworked as this dune phase probably post-dates occupation at Akchakhan-kala. The clays which are bedded, sometimes weakly bedded, appear to consistently predate evidence of pottery flecks. The clays were deposited in water, probably from over bank flow flooding, and the upper age of these around Akchakhan-kala is about 2450 BCE. This date predates the known construction of the site.

[7] Betts et al., 2009.

Fig. 11. Site of ancient settlement and Area A pits, with traces of Tash-k'irman Canal in the foreground.

Since some clay with pottery at Site 8 (Fig. 5, Area D) was observed near Akchakhan-kala, there is a suggestion that the citadel may have been built in a wet phase but soon after this the landscape dried out. This could have been due to climate change, receding lake levels, or a shift southward by the Amu-dar'ya. This can be tested by further research on the dynamics and migration history of the main channels.

Evidence provided by this study shows that the last lake episode or flood event in the immediate vicinity of Akchakhan-kala occurred around or just prior to the time of the establishment of the site, and that by the time of its abandonment there was a period of drying. While the environmental history of the Southern Delta is not well documented, the key indicator for shifts in water levels, the presence or absence of archeological sites, suggests that water levels in the shallow Istemes basin fluctuated constantly throughout the history of human occupation there and before. Many fossil shore lines (e.g., Fig. 9) are present and there is an abundance of gypsum, some of which was probably deposited in the last throes of desiccation of a warm shallow lake, although the one age we have is a much earlier date, greater than 19,000 BCE. If the early 20th century Istemes is taken to represent a medium to high transgression, the area in the western part of the Southern Delta that would have been flooded has no ancient or medieval sites and very little modern settlement. We can suggest that the Istemes lake was a constant, if irregular, presence in this area. We might then postulate that while Akchakhan-kala may have been established at a period of transgression, possibly close to the lake shore at the time, the lake itself may have receded and certainly never again flooded back over the site. However, the close proximity of the lake shore from time to time would have offered a potential threat to the site. While there is no evidence that the site was ever flooded, rising water tables would have had the potential to impact on the agricultural potential of the immediately adjacent farmland. Today, extensive irrigation in the southern delta has caused major problems with salinization, rendering many of the fields unusable.

Fig. 12. Area C Site 7 sediments showing banding in water borne sediments and a weak overprint of ped formation.

In addition to addressing the question of the potential impact of lake fluctuations on Akchakhan-kala, the study provides some valuable information on the general environmental history of the Southern Akcha-dar'ya delta. The dates on gypsum from the ancient shoreline along the southern foothills of the Sultan-uiz-dagh show that lakes have been forming in the area covered by the early 20th century Istemes since at least some 20,000 years ago. It seems likely that rising and falling lakes were a constant phenomenon in this area right up until the canalization of the river in the mid-20th century. This is also relevant to the dates obtained from the test pits. Most of the dates were on plant matter but the three on charcoal bear comment. The earliest (8196–7528 BCE: Area C, Site 6) may be related to a prehistoric presence in the area, one that would not be entirely out of place. The Neolithic in the delta region is the Kel'teminar Culture, dated predominantly in the 4th to 3rd millennia BCE but with a developmental period going back to the 6th millennium BCE, on the Mesolithic/Neolithic boundary (Tolstov, 1958, 39 ff.; Vinogradov, 1960, 1968, 1981). The presence of large lakes supporting Neolithic settlements, even in the K'iz'il-kum, provides evidence for a humid climate in the Neolithic (Boroffka, 2010). Neolithic sites have been found mainly in the Southern Akcha-dar'ya, which at that time ended in a series of lakes and deltaic fans up to the line of the Sultan-uiz-dagh (Vinogradov, 1968). This date may capture a rare Mesolithic presence in the same region.

The date from Area B, Site 4 (2457–1984 BCE) dates to the Bronze Age. Once again, the Southern Delta is known to have been occupied in the Bronze Age but this date, falling in the late 3rd millennium, is a little unusual and, interestingly, may relate to the ephemeral Early to Middle Bronze Age of the wider region. The Early Bronze Age in Khorezm is a 'dark age' as it is in much of the steppe regions of Central Asia and Kazakhstan (Betts et al., 2013). In Khorezm there appears to be a cultural break in the early 2nd millennium BCE between the Neolithic Kel'teminar of the late 3rd millennium BCE and the Late Bronze Age of the later 2nd millennium BCE, the Tazabag'yab. It has been suggested that this 'gap' perhaps reflects lack of discovery rather than lack of

Fig. 13. Site of old lake beds with vegetated old dune in foreground.

presence of sites (Itina, 1977, 40), and this fleck of charcoal might be relevant in this regard.

The date from Area D, Site 8 (903–613 BCE) may relate to Early Iron Age or Archaic Period occupation pre-dating the establishment of the main site of Akchakhan-kala. At this time small communities practicing simple irrigation agriculture lived in the Southern Akcha-dar'ya delta (Tolstov, 1948a, 69–70; Itina, 1977, 15–16, 147), while the Saka pastoral nomads of the Eurasian steppes were also using the lands bordering on the oasis, particularly on the west bank of the Amu-dar-ya. A trench laid out across the canal to the north-west of Akchakhan-kala (Fig. 7) revealed a complex stratigraphy with a sequence of at least seven canals of different widths and depths. Overall, the older canals were wider at up to 11 m (Canal 1) while one of the most recent (Canal 7) was only 3 m wide. Andrianov's major study of the ancient Khorezmian canals enabled him to show that for the Archaic period (7th–5th centuries BCE) wide shallow canals were characteristic (Andrianov, 1969, 116–124). This is connected with the practice of using ancient river beds as the basis for canals. Through time, as they were more formally constructed, the canals became narrower and deeper.

While we do not have absolute dates for the canal system at Akchakhan-kala, a sherd recovered from Canal 3 has been dated according to the Khorezmian typology to the 4th–3rd BCE (KAE, 2005). It is possible that the earliest cut may date back to the Archaic period, or even slightly earlier, and it is certainly likely that the canal system pre-dates the main site. The date from Area D, Site 8 most probably relates either to a farmstead supported by the early canal system or a camp site of local herders or hunters coming to the area (lake shore?) for a short term visit.

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References

Al-Biruni (transl.) 1879. The chronology of ancient nations (transl. E. C. Sachau). London.

Andrianov, B.V., 1969. Drevniye orositelnyye sistemy Priaralya (V svyazi s istoriey vozniknoveniya i razvitiya oroshaemogo zemledeliya) (Moscow).

Archangelskiy, A.D., 1931. Geologicheskie issledovaniya v Nizov'yakh Amu-Dar'i. Trudi Glavnogo Geologo-Razvednogo Upravleniya B. C. H. X. C. C. C. P. 12. Geologicheskoe Izdatel'stvo, Moscow, Leningrad.

Artyukhova, O.A., 2001a. Paleoliticheskie mestonakhozhdenija na territori Kyzylordinskoy oblasti. Trudy Mezhdunarodnikh Margulanovskikh Chteniy, posvjashennikh 10-letiju nezavizimosti Respubliki Kazakhstan na temu "Dostizhenija I perspektivy arkheologicheskoy nauki nezavizimogo Kazakhstana", Kyzylordapp. 58–60.

Artyukhova, O.A., 2001b. O Paleolite Priaral'ja. Khabarlary - Izvestija Serija Obschestvennykh Nauk 1 (230), 32–38.

Bartold, V.V., 1965. K istorii orosheniya Turkestana. Sochineniya [Collected Works in 9 Volumes] vol. 3: Moscow.

Betts, A., Yagodin, V.N., Khozhaniyazov, G., 2005. Arkheologicheskie izyskaniya 2004 goda vv drevnem tashkyrmanskom oazise. Vestnik (Karakalpakskogo Otdeleniya Akademii Nauk Respubliki Uzbekistan) 5 (201), 84–88.

Betts, A., Yagodin, V.N., Helms, S.W., Khozhaniyazov, G., Amirov, S., Negus-Cleary, M., 2009. Karakalpak-Australian excavations in ancient Chorasmia, 2001–2005: interim report on the fortifications of Kazakl'i-yatkan and regional survey. Iran XLVII, 33–35.

Betts, A., Jia, P.W., Dodson, J., 2013. The origins of wheat in China: potential pathways for its introduction. Quat. Int. 1–11 http://dx.doi.org/10.1016/j.quaint.2013.07.044.

Bizhanov, E., 1988. Paleolit Usturta. Vestnik Karakalpakskogo filiala AN Uzbekskoi SSR 1 pp. 68–71.

Bonora, G.L. 2014. Updating report on the prehistorical human settlement in the Syrdarya Alluvial Plain, in C.C. Lamberg-Karlovsky and B. Genito (eds. in chief) B. Cerasetti (Ed.) My life is like the summer rose. Maurizio Tosi e l'Archeologia come modo di vivere. Papers in honour of Maurizio Tosi for his 70th birthday. Oxford, BAR, pp. 31–47.

Boomer, I., Wünnemann, B., Mackay, A.W., Austin, P., Sorreld, P., Reinhardt, C., Keyser, D., Guichard, F., Fontugne, M., 2009. Advances in understanding the late Holocene history of the Aral Sea region. 2009. Quat. Int. 194 (1–2), 79–90 (1 February).

Boroffka, N.G.O., 2010. Archaeology and its relevance to climate and water level changes: a review. In: Kostianoy, A.G., Kosarev, A.N. (Eds.), The Aral Sea Environment283 Hdb Env Chem (2010) 7. Springer-Verlag, Berlin Heidelberg, pp. 283–303. http://dx.doi.org/10.1007/698_2009_1 (2009, Published online: 11 June 2009).

Boroffka, N.G.O., Bajpakov, K.M., Achatov, G.A., Erzhanova, A., Lobas, D.A., Savel'eva, T.V., 2003–2004. Prospektionen am nördlichen Aral-See, Kazachstan. Archäologische Mitt. Iran Turan 35–36 (2005), 1–81.

Chen, F., Yu, Z., yang, M., Ito, E., Wang, S., Madsen, D., Huang, X., Zhao, Y., Sato, T., Birks, J., Boomer, I., Chen, J., An, C., Wünnemann, B., 2008. Holocene moisture evolution in arid Central Asia and its out-of-phase relationship with Asian monsoon history. Quat. Sci. Rev. 27 (2008), 351–364.

Dimo, N.A., Nikitin, V.V., Nozhin, L.L., 1913. Почвенные исследования в бассейне р. Аму-Дарьи. Краткий отчет о работах осенью 1912 г. Москва, 1913.

Helms, S.W., Yagodin, V.N., 1997. Excavations at Kazakl'i-yatkan in the Tash-k'irman oasis of ancient Chorasmia: a preliminary report. Iran 35, 43–65.

Helms, S., Yagodin, V.N., Betts, A.V.G., Khozhaniyazov, G., Negus, M., 2002. The Karakalpak-Australian excavations in ancient Chorasmia: the northern frontier of the "civilised" ancient world. Anc. Near East. Stud. 39, 3–44.

Itina, M.A., 1977. Istoriya stepnykh plemen Yuzhnogo Priaral'ya (II - nachalo I tȳsyacheletiya do n.e.). Trudi Khoresmskoy arkheologo-ethograficheskoy ekspeditsii. X, Moscow.

KAE 2005. Археология древнего и средневекового Хорезма от раннежелезного до позднежелезного века (vii–vi до н.э.–xiii в. н.э.). Unpublished annual report of the Karakalpak-Australian Expedition, Nukus, 2005.

Kidd, F.J., Betts, A.V.G., 2010. Entre la fleuve et la steppe : les nouvelles perspectives sur le Khorezm ancien. Comptes Rendus, Académie des Inscriptions et Belles-Lettres (CRAI) 2010 IIpp. 637–686.

Kidd, F., Negus-Cleary, M., Yagodin, V., Betts, A., Baker-Brite, E., 2008. Ancient Chorasmian mural art. Bull. Asia Inst. 18, 69–95.
Krivonogov, S.K., Kuzmin, Y.V., Burr, G.S., Gusskov, S.A., Khazin, L.B., Zhakov, E.Y., Nurgizarinov, A.N., Kurmanbaev, R.Kh., Kenshinbay, T.I., 2010. Environmental changes of the Aral Sea (Central Asia) in the Holocene: major trends. In: Jull, A.J.T. (Ed.), Proceedings of the 20th International Radiocarbon Conference. RADIOCARBON vol 52, Nr 2–3, pp. 555–568.
Krivonogov, S.K., Burr, G.S., Kuzmin, Y.V., Gusskov, S.A., Kurmanbaev, R.K., Kenshinbay, T.I., Voyakin, D.A., 2014. The fluctuating Aral Sea: a multidisciplinary-based history of the last two thousand years. Gondwana Res. 26, 284–300.
Levina, L.M., 1998. K istorii i issledovanii Khorezmskoj arkheologo-etnograficheskoj ekspeditsii v Vostochnom Priaral'e. In: Nerazik, E.E. (Ed.), Priaral'e v drevnosti i srednevekov'eK 60-letiiu Khorezmskoj arkheologo-etnograficheskoj ekspeditsii. Vostochnaja Literatura, Moscow, pp. 42–59.
Micklin, P., Aladin, N., Plotnikov, I., 2013. The Aral Sea: The Devastation and Partial Rehabilitation of a Great Lake (Google eBook), Springer Science & Business Media (22 Nov 2013).
MITT I, 1939. Materiali po istorii Turkmen i Turkmenii I (Moscow-Leningrad).
Oberhänsli, Hedi, Boroffka, Nikolaus, Sorrel, Philippe, Krivonogov, Sergey, 2007. Climate variability during the past 2,000 years and past economic and irrigation activities in the Aral Sea basin. Irrig. Drain. Syst. 21, 167–183.
Sorrel, P., Popescu, S.M., Klotz, S., Suc, J.P., Oberhänsli, H., 2007. Climate variability in the Aral Sea Basin (Central Asia) during the late Holocene. Quat. Res. 67, 357–370.
Tolstov, S.P., 1948a. Drevniy Khorezm. Akademia Nauk, Moscow.
Tolstov, S.P., 1948b. Po sledam drevnekhorezmiyskoy tsivilizatsii (Moscow-Leningrad).
Tolstov, S.P., 1958. Raboty Khorezmskoy arkheologo-ethograficheskoy ekspeditsii AN SSSR v 1949–1953 gg. Trudi Khoresmskoy arkheologo-ethograficheskoy ekspeditsii T. II. Moscow.
Tolstov, S.P., 1962. Po drevnim deltam Oksa i Yaksarta. Nauk, Moscow.
Tolstov, S.P., Kes', A.S., 1960. Nizov'ya Amu-dar'i Sarykamysh Uzboy. Istoriya formirovaniya i zaseleniya. Material'i Khorezmskoi Èkspeditsii III. Moscow.
Vinogradov, A.V., 1960. Novȳe neoliticheskie nakhodki Khorezmskoĭ ékspeditsii AN SSSR 1957 g. Material'i Khorezmskoi Èkspeditsii IVpp. 63–81.
Vinogradov, A.V., 1968. Neoliticheskie pamyatniki Khorezma. Material'i Khorezmskoi Èkspeditsii VIII, Moscow.
Vinogradov, A.V., 1981. Drevnie okhotniki i rybolovy sredneaziatskogo mezhdurech'ja. Trudi Khoresmskoy arkheologo-ethograficheskoy ekspeditsii X111. Moscow.
Yagodin, V.N., 1986. Nekotorye voprosy istoricheskoy geografii Priaral'skoy del'ty Amudar'i v VII–XIV vv. AP III. Tashkent.
Yagodin, V.N., 2005. The medieval Aral Sea crisis. Archäologische Mitt. Iran Turan 37 (2006), 307–322.
Yagodin, V.N., Helms, S.W., Khozhaniyazov, G.Kh., 1996. O rabotah Tashkyrmanskoy mezhdunarodnoi arkheologicheskoi ekspeditsii 1995 g. Vestnik (Karakalpakskogo Otdeleniya Akademii Nauk Respubliki Uzbekistan) 3 (145), 101–107.
Yagodin, V.N., Betts, A.V.G., Kidd, F., Baker Brite, E., Khozhaniyazov, G., Amirov, Sh., Yagodin, V.V., Fray, G., 2010. Karakalpak-Australian excavations in ancient Chorasmia. An interim report on the Kazakly-yatkan wall paintings: the portrait gallery. J. Asian Art Archaeol. 4, 7–42.