# Irrigating the desert: water management, agricultural practices, and social complexity in Southern Turkmenistan during the Bronze Age

Arciero, R.

**Citation**

Arciero, R. (2024, December 6). *Irrigating the desert: water management, agricultural practices, and social complexity in Southern Turkmenistan during the Bronze Age*. *Archaeological Studies Leiden University*. Retrieved from https://hdl.handle.net/1887/4171706

# Irrigating the Desert

## Water Management, Agricultural Practices, and Social Complexity in Southern Turkmenistan during the Bronze Age

PROEFSCHRIFT

ter verkrijging van
de graad van doctor aan de Universiteit
Leiden, op gezag van rector magnificus
prof.dr.ir. H. Bijl,volgens besluit van het
college voor promoties te verdedigen op
vrijdag 6 december 2024
klokke 11:30 uur

door

Roberto Arciero

**Supervisor**

Prof.dr. B.S. Düring, Professor of Archaeology of West Asia, Faculty of Archaeology, Leiden University

**Additional Supervisor**

Prof.dr. P.M.M.G. Akkermans, Professor of Near Eastern Archaeology, Faculty of Archaeology, Leiden University

**Doctoral Committee**

Prof.dr. J.C.A. Kolen, Dean of the Faculty of Archaeology and Professor of the History and Heritage of European Cultural Landscapes, Faculty of Archaeology, Leiden University
Prof.dr. R.H.A. Corbey, Professor emeritus Philosophy of Science and Anthropology, Faculty of Archaeology, Leiden University.
Prof. Dr. Mirko Novák, Professor of Near Eastern Archeology, Institute of Archaeological Sciences, Bern University.
Dr.ir. M.W. Ertsen, Associate Professor Water and Society, Department of Water Management, Delft University of Technology.
Dr. J.A. Mol, Assistant Professor in Geoarchaeology, Faculty of Archaeology, Leiden University.

**Institutions that financially supported this project and dissertation:**
National Geographic Society - Early Career Grant (Grant No. EC-219R-18)
LUF - Leiden University Fund (Grant No. W18327-6-EM)
Asian Modernities and Traditions Grant, Leiden University

*To my past, to my future*

# LIST OF CONTENTS

# LIST of FIGURES

# LIST of TABLES

# Chapter 1 – Introduction

## 1. Introduction to the *Bactria-Margiana Archaeological Complex* (BMAC) or *Oxus Civilization*

The last sixty years have witnessed an increase in research on archaeological landscapes, particularly the investigation of irrigated landscapes. Researchers studying Mesopotamia have been at the forefront of this field, demonstrating the complexity of the socio-environmental dynamics and the interdependence of irrigation systems with settlements through time and space (e.g., Adams 1965; 1981; Pournelle 2003; Wilkinson 2003; Hritz and Wilkinson 2006; Hritz 2010; Ur 2002; Ur and Reade 2015; Kühne 2018). In addition to Mesopotamia, early complex societies emerged elsewhere, particularly in regions characterized by river systems and alluvial fans, where local communities devised methods to manage water resources during the 4th and 3rd millennia BCE. Central Asia stands out as one such region, renowned for its remarkable irrigated landscapes (Goudie 2003:190).

Among the biggest irrigated landscapes of the region is the Karakum desert, which hosts the Murghab alluvial fan (Figure 1.1). The Murghab fan has been regarded by various authors as the cradle of the *Bactria-Margiana Archaeological Complex* (BMAC), also known as the *Oxus Civilization*,[1] during the 3rd and 2nd millennium BCE. The Russian archaeologist Viktor I. Sarianidi wrote in 2009 that “thirty-five years ago, hardly anyone could imagine what was hidden under the sandy hills of the Karakum,” and later he adds, “let us imagine what the alert eye of an eagle could have seen some four thousand years ago. Spread out below was the delta of a big river with low sandy banks. Men began to inhabit its branches that richly watered the fertile lands” (Sarianidi 2009:39, 64). In this

---

[1] Both terminologies are widely used, although both are problematic (see Salvatori 2016 for an exhaustive discussion). Recently, Dubova et al. (2018:8) proposed the term “Bactria-Margiana Archaeological Culture” (BMAC) while Biscione and Vahdati (2021) adopted the label “Greater Khorasan Civilization” (GKC). In this dissertation both *Bactria-Margiana Archaeological Complex* (BMAC) and *Oxus Civilization* are used as synonymous.

context, Sarianidi emphasizes the role of the Murghab alluvial fan and its irrigation system in the development of the BMAC between the 3rd and the 2nd millennium BCE.

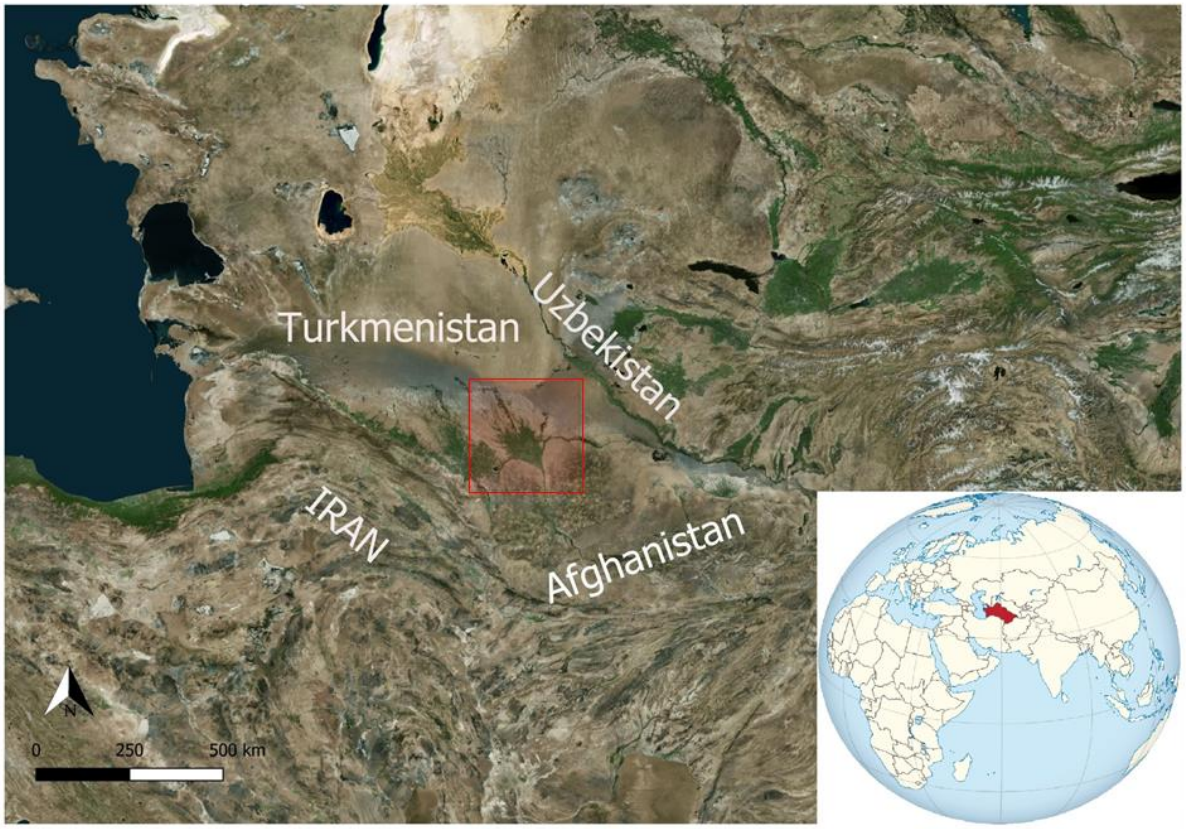


*Figure 1.1 General map of Turkmenistan and adjacent regions. In the red square is the Murghab alluvial fan. The Murghab is the second largest river in the country.*

The term "BMAC" was first coined by Sarianidi, who later excavated the main Bronze Age site of the region, Gonur-tepe.[2] The site of Gonur is the largest of the BMAC centers in the Murghab and has been considered its "capital" by Sarianidi (but see Chapter 3). In its long-lasting excavations, over almost fifty years, Sarianidi – along with other scholars – brought to light an extraordinary cultural complex characterized by exquisite objects, ceramic assemblages, worked semi-precious stones and lapis lazuli beads, distinctive amulets/stamp seals, and anthropomorphic and zoomorphic figurines, as well as unique

---

[2] The word "Tepe" means "hill" or "mound." It is sometimes also presented as "Depe" in some publications (e.g. Gonur-Depe).

architecture (Sarianidi 1990a; 1998a; 2007; Hiebert 1994a; Salvatori 2000; Salvatori et al. 2008; Winkelmann 2014; Frenez 2018; Pittman 2019; Lyonnet and Dubova 2021b).

The study and the analysis of the numerous artifacts, mainly from Gonur graves, revealed relationships between the BMAC and neighboring and more distant regions (Figure 1.2). Artifacts from the BMAC, such as a handled disk, small columns, and precious metal vessels, revealed links with the Kerman and Susa regions in modern-day Iran, for instance (Sarianidi et al. 2012; 2014; Bendezu-Sarmiento and Mustafakulov 2013). Amiet (1977; 1988) argued for substantial interactions with the Elamite world, considering the BMAC as part of the Elamite "*Koine*." In addition, excavations at Tepe Yahya (Hiebert and Lamberg-Karlovsky 1992; Potts 2001; Mutin and Lamberg-Karlovsky 2021) and more recent excavations and surveys in Sistan have provided further evidence for links between BMAC and these regions (Biscione and Vahdati 2011; 2021).

*Figure 1.2 The figure shows the sites and the southern neighboring regions of BMAC interaction.*

Connections with the Indus Valley region are also attested with objects from the BMAC site of Dashly in Bactria, for instance (Sarianidi 1981; 1982). Likewise, many objects such as elephant ivory artifacts, stone statues, small sculptures, and an inscribed Indus seal – all from Gonur – reveal interactions with the Indus world during the late 3rd and early 2nd millennium BCE (Sarianidi 2008a:figs. 108–109; Salvatori 2010; Frenez 2018). Further, some BMAC objects have also been found in Bahrain and the Emirates in the Gulf area (Salvatori 2010; Lombard 2021). These objects led to the hypothesis of an extended "interaction sphere" in West Asia with the expansion of BMAC communities towards other regions, also in the form of possible outposts (Mutin and Lamberg-Karlovsky 2021:577; Vidale 2017:8, 20).

In the core region of the Murghab, archaeologists have mainly focused on interpreting the cultural, political, and economic evolution of the BMAC by focusing on its main large centers. Although the irrigation system has been regarded as crucial by many authors, the focus on main mound areas has nonetheless resulted in the neglect of the wider landscapes and the complex evolution of this region between the 3rd and 2nd millennium BCE.

## 1.1 Chronology of the Region: a Few Notes

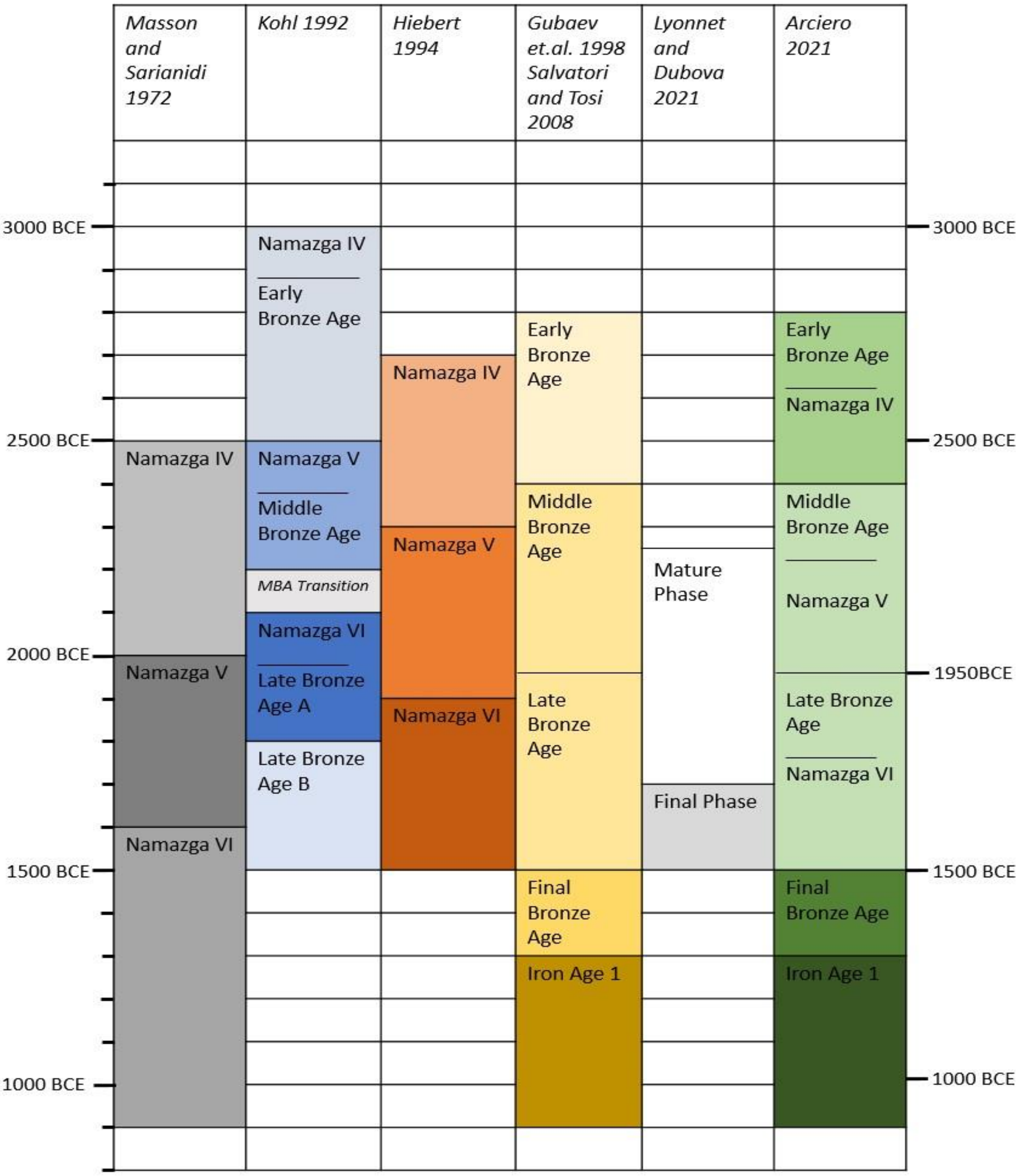
Before presenting a brief summary of the studies in Turkmenistan (with a focus on the Bronze and Iron Ages), it is crucial to introduce, at this early stage of the thesis, the chronology of the region and its issues.

The chronological sequence of the BMAC has been much debated over the last decades and remains problematic. As a result, various scholars have produced different chronologies (e.g., Sarianidi 1990a; Kohl 1984; Hiebert 1994a; Salvatori et al. 2008; Luneau 2010). Although there are numerous radiocarbon dates from various sites (see Lyonnet and Dubova 2021a and Cerasetti et al. 2022 for an updated list of $^{14}$C dates), the stratigraphical sequence in relation to $^{14}$C dates is not always well defined, such as in Gonur. On the basis of the few $^{14}$C dates from the Murghab, some scholars prefer a high (long) chronology, while others prefer a low (short) chronology, roughly 150–200 years later. An additional complication of BMAC chronologies are differences between the Margiana and Bactria. The main BMAC site of Gonur-tepe, which shows evidence for three main periods of occupation, is in part contemporaneous with Tillija Bulak, Gelot, Tugai, Sapallitepa, and Dzharkutan in Bactria, but also Shar-i Sokta IV,[3] and Hissar IIIC in Iran. A recent re-assessment of radiocarbon dates by Lyonnet and Dubova (2021a: Appendix 1) has divided the BMAC into two main periods: period 1 between ca. 2250–1700 BCE, and period 2 between ca. 1700–1500 BCE. However, some radiocarbon dates from Gonur North indicate earlier dates, with seven dates between 2500–2400 BCE and five samples that have dates in the 2300s BCE (Lyonnet and Dubova 2021b:32). Likewise, radiocarbon dates from the earliest levels of occupation of the BMAC centers of Adji Kui 9 and 1 seem to be consistent with an earlier start (Salvatori 2002; Rossi-Osmida 2011:294–295; Lamberg-Karlovsky 2013). While acknowledging the complexity of the chronological problems for the Murghab region, in the current dissertation the chronological scheme used is shown in Table 1.1 and corresponds to the chronology suggested by Gubaev et al. (1998) and Cerasetti (2012).

A further issue that is worth mentioning is the use of different chronological periods. After an initial periodization based on key sites (i.e., Kelleli, Gonur, and Takhirbaj-Togolok phases), it is now common in the Murghab literature to use chronological terms (e.g., Middle Bronze Age), sometimes associated with early Kopet-Dag periods based on Namazga pottery chronology (e.g., Namazga V) from the site of Namazga-Depe. For the present dissertation, I will mainly refer to chronological terms such as Middle Bronze Age, while also adding the Namazga periodization if I am referring to old publications using this system.

---

[3] The chronology of Shar-i Sokhta was recently revised (see Kavosh et al. 2019 for discussion).



|  | Masson and Sarianidi 1972 | Kohl 1992 | Hiebert 1994 | Gubaev et.al. 1998 Salvatori and Tosi 2008 | Lyonnet and Dubova 2021 | Arciero 2021 |  |
|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
| 3000 BCE |  | Namazga IV<br>Early Bronze Age |  |  |  |  | 3000 BCE |
|  |  |  |  |  |  |  |  |
|  |  |  |  | Early Bronze Age |  | Early Bronze Age<br>Namazga IV |  |
|  |  |  | Namazga IV |  |  |  |  |
|  |  |  |  |  |  |  |  |
| 2500 BCE | Namazga IV | Namazga V<br>Middle Bronze Age |  |  |  |  | 2500 BCE |
|  |  |  |  | Middle Bronze Age |  | Middle Bronze Age<br>Namazga V |  |
|  |  |  | Namazga V |  | Mature Phase |  |  |
|  |  | MBA Transition |  |  |  |  |  |
|  |  | Namazga VI<br>Late Bronze Age A |  |  |  |  |  |
| 2000 BCE | Namazga V |  |  | Late Bronze Age |  | Late Bronze Age<br>Namazga VI | 1950BCE |
|  |  |  | Namazga VI |  |  |  |  |
|  |  | Late Bronze Age B |  |  |  |  |  |
|  |  |  |  |  | Final Phase |  |  |
|  | Namazga VI |  |  |  |  |  |  |
| 1500 BCE |  |  |  | Final Bronze Age |  | Final Bronze Age | 1500 BCE |
|  |  |  |  |  |  |  |  |
|  |  |  |  | Iron Age 1 |  | Iron Age 1 |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
| 1000 BCE |  |  |  |  |  |  | 1000 BCE |
|  |  |  |  |  |  |  |  |

*Table 1.1 The table shows the different chronologies for the region according to the different scholars. On the right, the chronology accepted by the present author that follow Gubaev et al. 1998.*

## 1.2 The History of Archaeological Research in Turkmenistan

The first archaeological investigations in southern Turkmenistan began at the end of the 19th century and were carried out by the Russian scholar V.A. Zhukovskij in ancient Merv (close to the modern city of Bairam-Ali) and by General Kamarov at the archaeological site of Anau in 1890, following the Russian conquest of the Turkestan region (Hiebert 1994a; also see Hopkirk 1990). The site of Anau was also excavated in 1904 by the pioneer Western archaeologist in Turkmenistan, Raphael Pumpelly (Pumpelly 1908). For the Bronze Age, the most relevant discoveries and excavations took place at Namazga-Depe and Altyn-Depe along the Kopet-Dag piedmont. The excavations of Namazga-Depe in 1952 were undertaken by the YuTAKE[4] survey project in the 1940s and 1950s, which defined the chronological sequence of the region from the Chalcolithic to Late Bronze Age (Kuftin 1956). Work was initially undertaken by archaeologists from Moscow, including the local Academy of Sciences and Institute of Archaeology. Eventually, local archaeologists, often trained in Russia, became more prominent in the region (Dolukhanov 2010).

The YuTAKE project in Turkmenistan followed earlier work by S.P. Tolstov (1960) in the Khorezm area, which established an important research agenda for the investigation of the region and its irrigated landscapes (see also sections 3.5.1 and 4.2.1). During the 1950s, the excavations at Altyn-Depe along the Kopet-Dag uncovered the first Bronze Age pottery sequence. Between 1954 and 1956, V.M. Masson also established the first chronological sequence for the Iron Age through the investigation of Yaz-Depe (Masson 1959; also see Tosi and Cerasetti 2010).

The chronological sequence from the Kopet-Dag foothills has been used as the primary framework also for the Murghab region (Masson 1988:1; Masson and Sarianidi 1972). The Namazga periods, and in particular Namazga IV, V, and VI (see Table 1.1 for

---

[4] YuTAKE (*Yuzhno-Turkmenistanskaya Arkheologicheskaya Kompleksnaya Ekspeditsiya* – Southern Turkmen Archaeological Expedition).

chronological correspondence), have been used to characterize the Bronze Age periodization in the large, fortified sites of the Murghab (Hiebert 1994a). However, pottery from the region differs in various characteristics from the Namazga assemblages (see Luneau 2014 for further discussion). Nevertheless, based on the similarity in the pottery assemblages, Masson (1959) and Sarianidi (1990a) proposed seeing the Murghab as a variant of the Namazga culture (see Chapter 3 for further discussion).

The YuTAKE project teams also worked in remote desert areas such as the northeastern Murghab, excavating at the Bronze Age sites of Auchin and Takhirbaj 3 (Masson 1959). These excavations resulted in the first chronological framework of the lowland region. The ceramic assemblages were compared to the sequence from the Kopet-Dag area. While Auchin was attributed to Namazga V–VI, Takhirbaj 3 was dated to the Namazga VI period (Hiebert 1994a:15). Yet, despite these early excavations at the Auchin and Takhirbaj 3 sites, it was not until 1972 that the first surveys of the Murghab region began. Led by V.I. Masson and V.I. Sarianidi, the Margiana Archaeological Expedition (MAE)[5] in the 1970s and early 1980s discovered more than 100 Bronze Age sites in the alluvial fan. These included important Bronze Age sites, such as Gonur and Togolok. The sites were documented and often grouped in clusters (e.g., Togolok 1, Togolok 2, Togolok 3, etc.), which appear somewhat arbitrary.

The early interpretation of the Bronze Age Murghab by Soviet scholars was of an arid landscape with distinct “micro-oases” (formed by several main mounds and smaller settlements) interspersed by sand dunes (Hiebert 1994a:39) (but see section 3.4.1 in Chapter 3 for further discussion). All the sites were registered and numbered by the MAE. However, subsequent surveys by Italian teams (i.e., the AMMD team, see below) created confusion as the new project re-numbered some of the sites already identified by the MAE. These surveys, in addition to the initial excavations in the Murghab and the

---

[5] The name “Margiana” is the ancient name of the “Murghab” region. The region was part of the Achaemenid Empire and the name Margiana is attested in the Bisutun inscription in the Kermanshah province of Iran (Schmitt 1990:299–305). The name and description of Margiana are found in Strabo, Ptolemy, Curtius Rufus, and Pliny the Elder (Puschnigg 2020).

region of Bactria, made it clear that both Margiana and Bactria were part of the same cultural horizon (Figure 1.3).

*Figure 1.3 The map shows the "formative" area (white dashed line) and the "core" area (red line) of the BMAC or Oxus Civilization according to Biscione and Vahdati (2021:Fig. 19.2). However, the area of influence of the BMAC extends far beyond.*

This broad cultural horizon was designated by Sarianidi as the "Bactria and Margiana Archaeological Complex" (BMAC). H.-P. Francfort (1984; 2016), instead, proposed the appellation of the "Oxus Civilization" because of its close position to the catchment area of the ancient Oxus River (modern Amu Darya River).

More recently, new investigations in northeastern Iran have led Biscione and Vahdati (2021) to consider using the name "Greater Khorasan Civilization" (GKC) with a core and formative area that corresponds approximately to the Greater Khorasan province in the Sasanian and Early Islamic periods. The excavations in Bactria and in the Margiana, and the discovery and analysis of the first finds, such as the ones from Gonur-tepe, allowed the scholars to better place the BMAC in the broad trans-regional context of cultural interactions.

The dissolution of the Soviet Union in 1991 led to an increase in joint international projects both along the Kopet-Dag and in the Murghab, which boosted archaeological research tremendously in the newly independent state of Turkmenistan.[6] The most significant project for this study has been the “The Archaeological Map of the Murghab Delta” project (AMMD) (Gubaev et al. 1998), which led to a substantial increase in the number of known archaeological sites and of landscape dynamics. The AMMD project aimed to systematically investigate the landscape with a multidisciplinary approach (Bondioli and Tosi 1998). Over two decades (namely the 1990s and 2000s), the project targeted different areas in the northeastern part of the Murghab with a systematic survey that culminated in a clearer understanding of the evolution of settlements from the Bronze Age to the Islamic period and eventually led to a reassessment of the previously dominant “oasis theory” (Cattani and Salvatori 2008; see section 3.4 in Chapter 3 for a more extensive discussion). In addition, the multidisciplinary approach of the AMMD team boosted the understanding of the geomorphology of the Murghab and its paleohydrology on the base of satellite and cartographic maps (Marcolongo and Mozzi 1998; Cremaschi 1998; Cerasetti 2008).

More recently, research on the Bronze Age in the Murghab includes the ongoing excavations at the site of Gonur-tepe by a Russian team[7] and two new projects in the area of Togolok that will be discussed in Chapter 4.

---

[6] Some joint international projects had already started at the end of the 1980s under the auspice of the Turkmen Soviet Socialist Republic and the Academy of Sciences of the Soviet Union (Lamberg-Karlovsky 1994b).

[7] The Russian–Turkmen team is directed by Dr. N. Dubova from the Russian Academy of Sciences – Moscow.

### 1.2.1 Landscape Research in the BMAC

As discussed above, research in the Murghab region increased in the late 1970s with the investigation of the main large centers. The focus was on architecture, resulting in large horizontal exposure of monumental structures, such as at Gonur-tepe (Gonur North and Gonur South) and Togolok 21 (Sarianidi 1986; Sarianidi 1990b), and the investigation of cemeteries such as the ones from Gonur North (e.g., Sarianidi 2007) (Figure 1.4). This provided rich data on the cultural and social organization of BMAC society as well as on their local and long-distance exchange networks. This was particularly true till the end of the 1980s when Soviet archaeologists working in Turkmenistan excavated the main sites, focusing on the social and economic practices of the BMAC. However, although Soviet archaeologists created the first archaeological map of the region and have been pioneers in this respect, little attention was given to investigating the broader Murghab landscape.

The AMMD project and its landscape-targeted investigations included surveys and test trenches across the Murghab, and partially filled the gap. The project provided crucial data for interpreting the developments that characterized the Murghab between the 3rd and 2nd millennium BCE as well as later periods (see section 4.3.2 in Chapter 4 for a detailed discussion of the AMMD project).

Despite this research, however, smaller sites remain poorly investigated. Recent investigations at Gonur revealed the presence of numerous small and rural sites, which were crucial in the agricultural and economic evolution of the site (Dubova 2019). These sites, along with numerous rural sites identified in the Murghab, might clarify many research questions about the complexity and evolution of land exploitation and its economy. As highlighted by Wilkinson et al. (2007) at Tell Beydar (Syria), for instance, the cooperation of small settlements around the main urban center was critical in agricultural production and during periods of environmental stress. Yet, the investigation of these crucial agricultural aspects and small settlement sites has been neglected in research on the ancient Murghab.

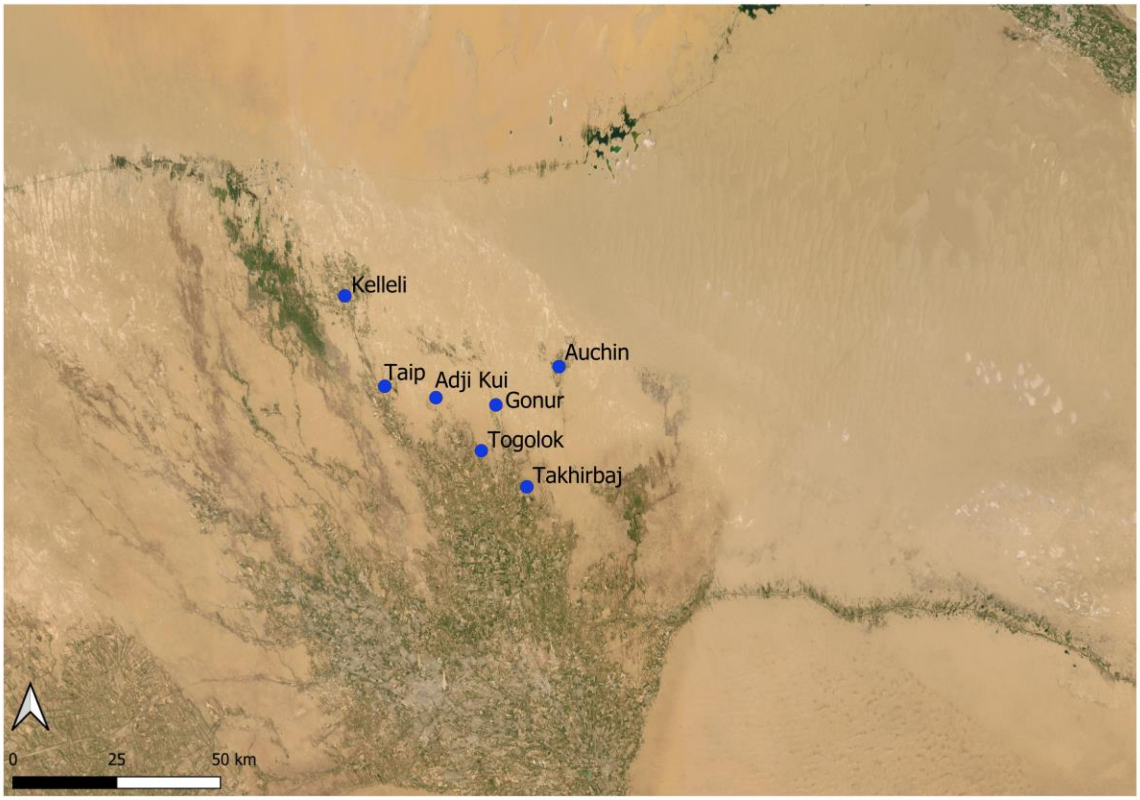


*Figure 1.4 Map showing the primary BMAC sites located in the Murghab alluvial fan.*

Similarly, the presence of pastoralists and farmers in the Murghab and their interaction and coexistence remains poorly understood (see section 3.3 in Chapter 3 for further discussion). The archaeological evidence for small, mobile, or semi-mobile communities has often been neglected during the first decades of research, and their evidence was simply labelled as “steppe presence” in the Murghab (Kuz’mina and Lyapin 1984). However, recent excavations, such as those at the rural sites of Ojakly and Chopantam, provide new data on the social and economic variability of these communities and their relation to BMAC sedentary farmers (Cattani 2008a; Rouse and Cerasetti 2014; 2018). Yet, the role of these pastoral and more rural groups in the farming system and in society remains poorly investigated.

All in all, the paucity of landscape investigations has resulted in limited data bearing on small rural sites and the neglect of local land use and agricultural practices by rural groups.

## 1.3 Reasons for the Present Research

Multidisciplinary research has characterized the investigation of the archaeological landscape in the Murghab over the past two decades, including geomorphological and paleohydrological research. Early investigations by Soviet scholars, such as Suslov (1961), provided a broad understanding of the geomorphological character of the Karakum desert and the Murghab alluvial fan. During the 1990s, the AMMD project strengthened our understanding of the geological history of the southern Karakum (Marcolongo and Mozzi 1998). This resulted in the identification of a shift, during the Holocene, of the entire alluvial fan towards the west (see section 2.2 in Chapter 2 for details). In addition, targeted investigations across the alluvial fan have provided crucial information on the historical development of the Murghab. In this context, an early survey by Cremaschi (1998) in the 1990s (in the Murghab areas of Takhirbaj, Garry Kishman, and between the Gonur and Kelelli sites) provided good data on the changes in the alluvial fan. The analysis of several exposed sections of ancient channels, their pedological profiles, and the analysis of sediments of archaeological sites in the area contributed to the reconstruction of the environmental changes in the Murghab alluvial fan in the Bronze and the Iron Ages.

For the purpose of this research, the identification of the main and most prominent ancient channels by the AMMD in the northeastern region of the Murghab and the dating of these channels is crucial (Cremaschi 1998:20, Table 1). This proposed chronology of the fluvial system was integrated with an already published macro-reconstruction of the main ancient Murghab alluvial fan courses (Figure 1.5) (Cerasetti 2008; 2012).

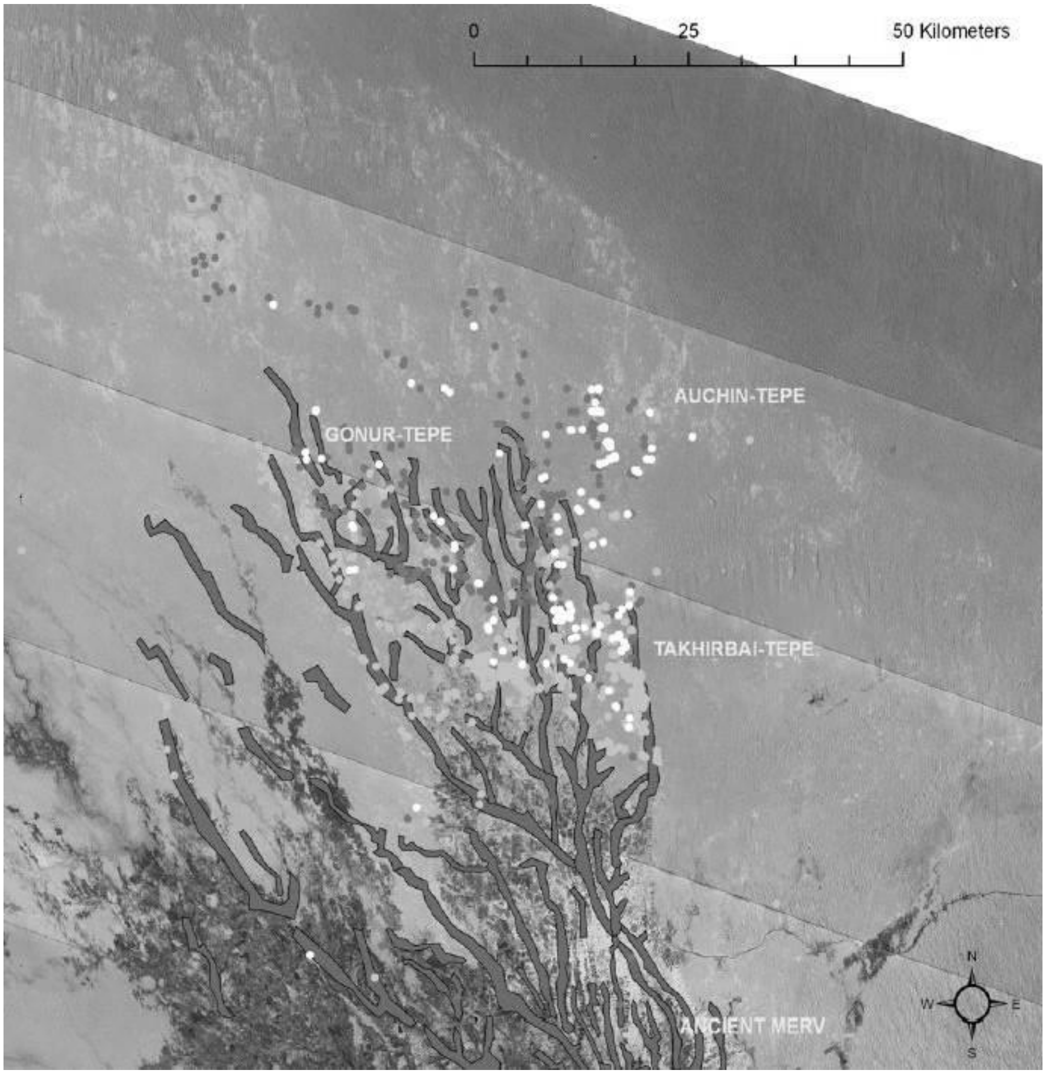


*Figure 1.5 AMMD model of the main paleochannels (dark lines) of the Murghab alluvial fan. The dots show the distribution of Late Bronze Age sites (dark-grey dots), Andronovo sites (white dots), and Iron Age sites (light-grey dots) (Cerasetti 2012:Fig. 2).*

The characteristics of the ancient Murghab were reconstructed on the basis of satellite images, aerial images, and historical maps. The analysis of the past hydrological landscape led to an understanding of the location and the main ancient channels from the Middle Bronze Age to the Achaemenid period (see Cerasetti 2008:31, Fig. 2.3). Likewise, the reconstruction of the main ancient channels shed new light on the evolution of the settlement patterns in the Murghab (Ninfo 2007) (also see section 3.4 in Chapter 3).

Although reconstructions of the alluvial fan provided a broad understanding of the changing fluvial landscape and its relation to settlement systems, we lack good data on micro-regions. Thus, local trajectories remain poorly understood. How local water resources and the agricultural landscape were exploited by local farmers and pastoralists in areas such as Togolok, Adji Kui, or Kelleli remains largely unknown. In addition, it’s equally important to contextualize data obtained from excavations (e.g., botanical data) with local water management and explore their social relevance.

The reconstruction of land management, agricultural production, and water resources is limited by the lack of data on the local hydrological system and surveys that focus on sites along ancient watercourses. A narrowing of analytical scales is therefore required to investigate the local water and land exploitation between the 3rd and 2nd millennium BCE. In this context, this research seeks to apply a local landscape investigation in selected areas that can deepen our understanding through case studies.

### 1.3.1 Aims of the Research

In order to move the analysis of local landscape dynamics forward, it is crucial to investigate the specific areas of the Murghab alluvial fan. The extent of the research areas and the methods are determined by the scope and resources of this thesis. In this context, it was essential to select a) case study areas with robust archaeological data, and b) areas that contain both dense settlement clusters and rural settlement areas. In this context, the two selected landscapes are Ojakly and Togolok (Figure 1.6).

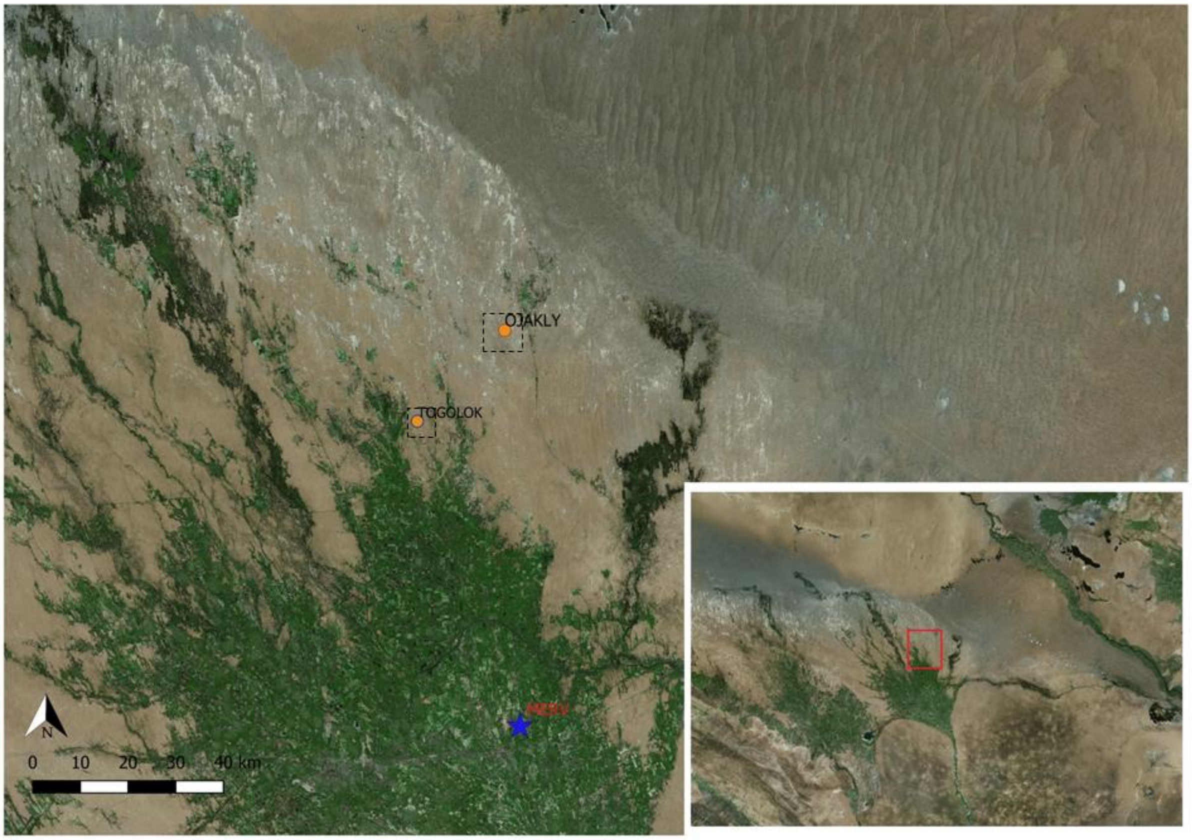


*Figure 1.6 The map shows the location (squares with dotted lines) of Ojakly and Togolok in the northeast of the alluvial fan which have been selected as case study areas for the present research.*

While various fortified settlements such as Gonur or Togolok 21 have been excavated in the Murghab, only two rural sites have been well investigated. In particular, the rural site of Ojakly, excavated in 2010–2011 by the AMMD team (Rouse and Cerasetti 2014), provided crucial data for the chronological sequence, as well as solid zooarchaeological and archaeobotanical evidence. These data supplement the targeted investigation of the network of ancient channels undertaken for this research and are crucial for further interpretation (see Chapter 5). Therefore, at the start of this project the area of Ojakly was selected as a case study area. The second case study area is Togolok, approximately 11 km southwest of Gonur-tepe. This site's cluster area was included in the previous AMMD survey and is one of the most representative Bronze Age centers in the Murghab (Sarianidi 1990a:34–39; Cattani and Salvatori 2008; Cerasetti et al. 2014). The main mound of Togolok 1 is currently under investigation by the TAP team (TAP – Togolok Archaeological Project), which provides a secure chronology of the site and an archaeobotanical and zooarchaeological dataset. Also, the additional mounds of Togolok 1 (second mound) and Togolok 21 (see Chapter 6 for details) excavated by Sarianidi (1990) in the 1980s provide additional data.

The current research thus aims to investigate these two landscapes and to address the following research question:

- How did people in dense settlement clusters and rural settlements of the Murghab exploit water resources and the agricultural landscape during the Bronze Age?

This main question can be further divided into four sub-questions:

i. How can we date these hydrological systems using survey data and absolute dating methods?

ii. How can the distance between the channel and the site be used to infer differences in subsistence economies?

iii. Can targeted investigation of the ancient channels provide a better understanding of past agricultural systems on a micro-scale level?

iv. What evidence do we have for sedentary farmers and pastoralists and differences in water management practices? What are the agricultural differences between dense settlement clusters and rural areas?

These questions will be examined in this thesis through a multidisciplinary approach, including computer-based analysis, survey methods and geoarchaeological analysis (see Chapter 4). This multidisciplinary and micro-level approach will foster our knowledge of ancient water, agriculture, and landscapes and can contribute to our understanding of the Bronze Age Murghab.

## 1.4 Thesis Structure

The present thesis can be broadly divided into three main sections. In short, Chapters 1 to 4 provide the research background and main aims of the present research, along with its methodology. Chapters 5 and 6 present the two case studies and the relevant data obtained in the present research, while the final Chapter 7 presents the discussion and conclusion.

This chapter (Chapter 1) provides an overview of past investigations in the Murghab and the gaps in present research. In addition, it provides the research problems underpinning the current investigation and its main aims.

The second chapter (Chapter 2) discusses the geographical, geomorphological, and hydrological characteristics of southern Turkmenistan and the Murghab region, together with a preliminary overview of the paleoclimate of the region. I introduce a description of *takyr* surface, which are generally associated with ancient watercourses in the Murghab and Central Asia. The local environment of the Murghab is also presented to provide a comprehensive overview of modern environmental dynamics.

The third chapter (Chapter 3) discusses the rise of large, fortified sites in the Murghab region in the 3rd and 2nd millennium BCE. It also presents the theoretical framework of this research.

In the fourth chapter (Chapter 4), I present the methodologies applied in this research and how they can help address the research questions.

The fifth and sixth chapters (Chapters 5 and 6) constitute the core of the thesis. In these chapters, I first present the relevant data from the Ojakly and Togolok excavations. Then, I present the local hydrological systems and data obtained from desk-based and ground truthing surveys of the ancient channels. Similarly, I will present the results from the field-walking survey along the former channels and discuss the chronology of the system through the finds. The absolute dating and the analysis of the stratigraphic channel sequences will be presented subsequently. In Chapter 5 (the Ojakly area), I will also present the results of the agent-based modeling applied to one ancient channel for water management and social dynamics. Equally, water management in areas of the large sites will be discussed in Chapter 6, presenting the results of the carbon isotope analysis from the Middle and Late Bronze Age archaeobotanical samples from the Togolok 1 site.

In the last chapter (Chapter 7), I will discuss and compare the results from the two case studies and integrate these into a broad analysis of the landscape and water dynamics in both regions. I will conclude the chapter by proposing possible alternatives to interpret the complexity of BMAC landscape dynamics at the turn of the 2nd millennium BCE, and I will suggest possible directions for future research in the region.

## 1.5 Limitations and Constraints

Archaeological investigations have to face both funding and unexpected contingency problems, as in field research. In particular, an early career investigation, such as doctoral research, needs to fit within a limited scope and often has limited resources and time. The present research is no exception.

Investigating the ancient Murghab landscape is limited by several factors. There are several processes that can obscure archaeological sites and ancient channels. Alluvial sedimentation in the Murghab fan can mask or cover archaeological deposits. Cremaschi (1998) has argued that the northern fringe of the fan has witnessed limited aggradation of the alluvial sediments, while the central fan (i.e., Merv Oasis) has an alluvial deposit of several meters deep that covers most of the Bronze Age sites (see also Cattani and Salvatori 2008). Some degree of alluvial sedimentation could also have occurred in the central northern fringe of the fan, which could bias the data (but see Chapter 4 for further discussion). For instance, in the area of Togolok, both the previous AMMD surveys and the surveys conducted as part of this project have not detected Middle Bronze Age evidence. However, both the preliminary trench by Sarianidi in the 1980s at Togolok 1 (north mound) and the more recent $^{14}$C dates place the site in the Middle Bronze Age as well (Sarianidi 1990a:34–39; Cerasetti et al. 2022). This may suggest that the Middle Bronze Age presence in the area was greater than the current surface evidence would suggest.

Archaeological deposits and channel traces can also be obscured by dune movement. Sand dunes are prevalent in the northern fringe of the fan. While these are too small to mask large anthropogenic mounds, they can completely cover small rural settlements central to the present analysis. Kohl (1984:144), quoting Sarianidi's estimation, reports that up to 30% of archaeological sites in the Murghab may be covered by dune aggradation. While the area of Ojakly is substantially covered by sand dunes, the area of Togolok is less affected by this problem.

A further problem is the rapid expansion of modern agriculture in the Murghab and the fast digging of new canals in the region that created contingent problems during the survey. In particular, this agricultural expansion has affected the central fan, where several archaeological sites have been partially or completely destroyed by mechanized agriculture. Although the area of the Togolok complex is still partially free from large agricultural fields, illegal excavation of small canals (often 1 x 0.5 m) has brought modern cultivation in the vicinity of the sites and might have partially obscured archaeological evidence.

An additional crucial problem is the dating of the survey sites recorded both by the AMMD and the current research. The periodization of surface ceramics is problematic in many ways (Luneau 2019). Most of the archaeological sites in the Murghab have not been excavated,[8] and – in some cases – excavations have disproven the periodization of sites proposed by surveyors. However, the vast majority of small rural settlements likely represent short-lived occupations and thus correspond to the chronology of the surface material. This is supported by excavation data at the smaller sites (see discussion in section 3.3.1 in Chapter 3). For instance, the $^{14}$C dating from the excavation of the rural site of Ojakly has confirmed the initial date of the surface pottery as being Late Bronze Age (Rouse and Cerasetti 2014). Similarly, further excavation at the rural site of Gonur N., near Gonur-tepe, also confirmed the previous survey dates (Hiebert and Moore 2004). Nevertheless, the problem of the pottery chronology remains and will be further addressed in the case study chapters, as well as in the discussion chapter (Chapter 7).

---

[8] In particular the small and medium rural sites.

## 1.6 Summary

This chapter presented an introduction and overview of the project and the current thesis. As discussed above, the Murghab region has been central to the development of the Bactria-Margiana Archaeological Complex, or Oxus Civilization. In this context, the alluvial fan of the Murghab River certainly played a crucial role in the settlements and social dynamic that characterized the region between the $3^{rd}$ and $2^{nd}$ millennium BCE. Yet, despite this prominent role, research in the region has only marginally investigated the hydrological system. Likewise, the micro-scale approach to the investigation of the paleochannel structures and the agricultural system of the local areas is almost an under-researched topic. However, as discussed in this first chapter, these research areas can provide pivotal data in order to understand the complexity of the settlements and agricultural dynamics in the Murghab during the Bronze Age. These data are crucial to tackle the landscape models put forward in recent decades and to what extent they might be valid today.

Before moving on to the archaeology of the region, however, for the scope of this thesis, it is critical to discuss the climate, geography, and geomorphology of the Murghab landscape in the next chapter.

# Chapter 2 – The Geology and Climate of Southern Turkmenistan

## 2. Overview

In this chapter, I will outline the physical and geological setting of southern Turkmenistan, and in particular, the Murghab alluvial fan, along with its current climate. I will then discuss the paleoclimatic data available for the region that will be later revisited in relation to data from this research in Chapter 7. I will also present data on the present hydrological system of the Murghab and discuss how these data are relevant to this project. I will address the problem of dune movement in the Murghab, and the role of takyr surfaces in the agricultural and ancient hydrological system. Finally, traditional irrigation farming, which provides insight into local water management, will be introduced and discussed.

### 2.1 The Climate of the Murghab Region

Modern Turkmenistan is located between the Aral Sea depression in the north, the Inner Asian mountains in the east, the Iranian Plateau in the south-west, and the Caspian Sea basin in the north-west. Lowland Turkmenistan is characterized by a continental and extremely dry climate (Suslov 1961) due to its significant distance from the ocean, the atmospheric circulation, and the presence of high mountains both to the south-southwest and the southeast (Orlovsky 1994:25). The climate of this region (which includes the Murghab alluvial fan) can be divided into two main seasons: 1) a very dry summer period with stable hot weather, and 2) a relatively humid winter season with extremely unstable weather. Although considerable differences occur in temperature between different regions in Turkmenistan, during the winter season (December to February), average temperatures generally fall below 0°C, while in the spring season (March to May), they increase to 7°–10°C (Table 2.1).

The highest temperatures occur during the summer (June to August) when the weather is generally characterized by monotonous hot temperatures that can reach up to 40°C in the Karakum. During the fall (September to November), the average monthly temperature ranges between 4°C and 21°C. Due to the dry climate, almost all incoming solar radiation is stored in the soil (Orlovsky 1994:26). Although a systematic climatic dataset of the past decades is almost absent in Central Asia, a series of droughts have affected the region of Turkmenistan and Central Asia since 2000. In addition, due to global warming, by 2080, temperatures are expected to increase in Central Asia by 3–4 °C which will have a significant impact on agricultural affordances (Lioubimtseva and Henebry 2009).

Like in other Central Asian countries,[9] most cropland in Turkmenistan is irrigated. The average annual precipitation varies from 110 mm to 398 mm in different parts of the country and occurs predominantly from October to May. However, the mean annual precipitation in the Murghab region is less than 150 mm, and between July and August, only 4% of the annual precipitation occurs.

| **SEASON** | **AVERAGE TEMPERATURE** |
|---|---|
| Winter | From to -9°C to -1°C |
| Spring | From 7°C to 10°C |
| Summer | From 35°C to 40°C |
| Fall | From 4°C to 21°C |

*Table 2.1 Average temperatures in Turkmenistan during the year (data from Orlovsky 1994). However, considerable differences exist between the different regions of Turkmenistan.*

Precipitation hardly occurs in the central Karakum, making agriculture impossible without artificial irrigation (Orlovsky 1994). As such, the future rise in temperatures in the region will potentially increase evapotranspiration, creating severe water stress and increasing agricultural risks, making a tremendous impact on the agricultural economy.

---

[9] The term “Central Asia” is often used to define the five former Soviet republics (Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan, and Turkmenistan) located in the Middle Asian region (Cowan 2007). While acknowledging the complexity of the term, in this thesis I will refer to the same geographical definition when using the term “Central Asia.”

Climatic changes in the region, however, have also been recorded in the past. Climatic variability, including moister periods, as well as periods of drought, likely characterized Central Asia throughout the Holocene and had a serious impact on agricultural and social developments. As such, paleoclimatic data for the region, although limited, are crucial for future discussion in this thesis and will be briefly presented below.

### 2.1.1 The Paleoclimate during the Holocene in Central Asia

The paleoclimate of West Asia has been well-researched over the last few decades, while data from Central Asian regions and, in particular, southwest Central Asia remain patchy (Mayewski et al. 2004; An et al. 2011; Cheng et al. 2015; Sharifi et al. 2015; Shaikh Baikloo Islam et al. 2020). Nevertheless, the paleoclimate of the Middle and Late Holocene in Central Asia has been addressed by various authors.

For the region of Central Asia, and in particular in Uzbekistan and Turkmenistan, the period between 6000 and 3000 BCE (Middle Holocene) is known as the "Ljavljakan pluvial phase." Most authors agree that during this period, the climate was relatively humid, with an annual mean rainfall average as high as 300 mm in the region (Vinogradov and Mamedov 1975; Lioubimtseva et al. 1998; 2014; Varushchenko et al. 1987).

Radiocarbon dates along with palynological analysis have been conducted in the Middle Caspian basin (Leroy et al. 2007; 2014). The data show a desert vegetation with a low presence of trees but with a presence of shrubs such as *Ephedra* and *Calligonum*, which have been radiocarbon dated to 7240-6240 cal. BCE (see full pollen data percentage in Leroy et al. 2014:Fig. 4 and full radiocarbon dates at Tab. 2). After this period, data from the Middle Holocene show a dominance of trees in the coring. In the subsequent period the pollen analysis suggests a steppe-like vegetation from ca. 2160 cal BCE, when there is a change in the botanical assemblage. Leroy et al. (2014) connects this period and the drop in recorded sea level to a broad paleoclimatic change in West Asia, the so-called "4.2 ka BP event".

The 4.2 ka BP dry event has been recorded in various locations in West Asia and other parts of the globe. In the Sistan region of Iran, for instance, the 4.2 ka BP event has been correlated with a dry phase (Hamzeh et al. 2016). This interpretation is reflected in the data of the $\delta^{18}O$ record from a lake (Hamzeh et al. 2016:Fig. 4). In the two cores taken in the lake, the facies C2 (corresponding to the 4.2 ka BP event) is characterized by the absence of any flora and fauna.[10] While the 4.2 ka BP event is largely accepted as a broader event (Bini et al. 2019), its regional impacts remain unclear as, in many cases, paleoclimate records fail to show such evidence. Some scholars argue for a series of dry and wet events with strong regional variation rather than one blanket dry period for the whole region (see Magny et al. 2011; Railsback et al. 2018).

Further paleoclimatic data from the region suggest an increased aridity from the late Middle Holocene. AMS radiocarbon data from Lake Issyk Kul in Kyrgyzstan suggest increased aridity from as early as 4950 cal. BCE. The analysis of the geochemistry of ostracode shells and their stable isotopes show a rapid increase of $\delta^{18}O$ and Sr/Ca values along with a decrease of U/Ca values between 4950 BCE and 2950 cal. BCE (see full data in Ricketts et al. 2001). This has been interpreted by Ricketts et al. (2001) as an evolution from a freshwater and open lake to a saline and closed lake.

In other regions of Central Asia, such as Central Kyrgyzstan, data from Lake Son Kol shows dry interval events between 3000 and 1950 cal. BCE. Data was retrieved from five cores around the lake from which stable isotope, (bio)geochemical and pollen analyses were conducted and AMS radiocarbon dating were derived. Such data show depleted $\delta D_{n\text{-}C29}$ values dated between 4050 and 3000 BCE suggesting a predominantly humid period. From 3000 BCE, however, the data show an increase in the amount of $\delta D_{n\text{-}C29}$ suggesting a pronounced dry episode until 1950 BCE (Lauterbach et al. 2014) (Figure 2.1).

---

[10] In contrast to this interpretation, this absence may be caused by degradation (oxidation) of material present in a later dry period (J. Moll pers. comm.).

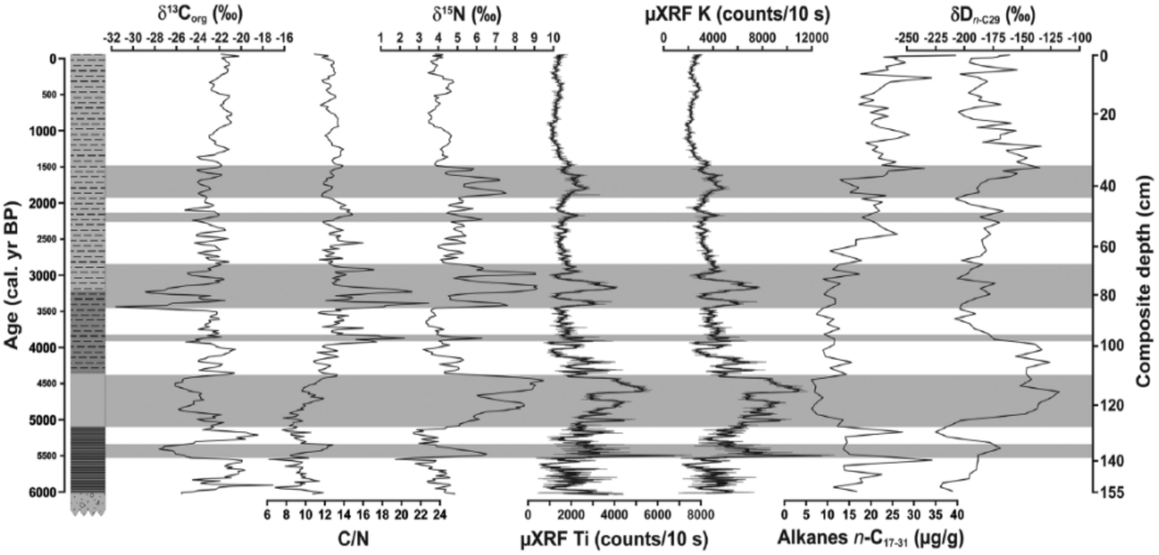


*Figure 2.1 The figure shows the results of (bio)geochemical and stable isotope analyses on the sediments of a composite profile (SONK_11_D1/2) from Son Kol (Kyrgyzstan) (images from Lauterbach et al. 2014:Fig. 5).*

These dry periods in Central Asia seem to occur in the Aral Sea region as well, between 2000 and 500 BCE. During these periods (which correspond to the Bronze and Early Iron Age in the region), the water level only reached 42–43 m a.s.l., which is low compared to previous and subsequent periods (Boroffka et al. 2006:Fig. 4). This interpretation is derived from the analysis of the Ca element in the sediment core that reflects the abundance of gypsum, which is formed during extensive evaporation (Cotellucci et al. 2023). The Ca fluctuation, which is a parameter for climatological lake-level change, is indicative of a lower water level. However, water bodies connected to far away rivers might be impacted by river dynamics that are the result of various factors, including changes that occur where the river originates and this can be far away from the water body, as in the case of the Aral Sea (Boomer et al. 2009). According to Boroffka et al. (2006), however, the river systems of Jana Darya and Akcha Darya were regularly discharging into the Aral Sea during that period, such as before and after.

Similar patterns, with relatively warmer conditions, are also attested in Lake Karakul in Tajikistan from the late 3rd and 2nd millennium BCE. Samples were collected from sediment cores from Lake Karakul and its catchment area and show that in the interval between 2250 and 1550 cal. BCE there are low $\delta^{18}O$ values that have been interpreted by Mischke et al. (2010:Fig. 6) as a result of a relatively high lake level due to high freshwater discharge, probably a meltwater supply as a result of warmer climatic conditions. All in all, although data points across Central Asia have increased in the last decades (summarized in Table 2.2; Figure 2.2), climate change is still a debated topic, and local differences in climate evolution are still insufficiently documented and sometimes contrasting.

Recently, Fouache et al. (2021) outlined a general climatic history for southwestern Central Asia from various proxy data. According to the authors, during the Middle Holocene, 6000–3000 BCE, climatic data suggest a more humid phase characterized by the presence of shrubby vegetation and a subhumid steppe (Maman et al. 2021a). This interpretation is based on data suggesting high water levels in lakes, such as the Aral and Caspian Seas (Fouache et al. 2021). This period is followed by a less humid period compared to the previous one, with a tendency for more arid climatic conditions during the Late Holocene from approximately 3000 BCE. In his study, Fouache et al. (2021) identified three major short-term arid events between 2800–2400 BCE, 1500–900 BCE, and 500–200 BCE.

For the Murghab, there are little paleoclimatic proxy data available. However, data from exposed channels (see below) collected by the AMMD project are indicative of a more dry phase from ca. 2000 BCE (Cremaschi 1998). In the area of Takhirbaj an ancient channel which has a basal deposit characterized by laminated sand overlapped by a colluvial deposit covered by aeolian sand. The colluvial deposit was radiocarbon dated to 1505-1345 cal. BCE, after which the sediment was covered by aeolian sand. Similarly, a channel west of site n.55 in the Murghab has a stratigraphic sequence of thin laminated sand and clayey organic silt. This fluvial sediment was radiocarbon dated by Cremaschi (1998) to 2055-1805 cal. BCE and was sealed by aeolian sand as well (see Cremaschi 1998:Table 1 for radiocarbon data). All in all, these data point towards drier conditions by the mid-2nd millennium BCE in the Murghab. However, data from the present research from Togolok and Ojakly indicate that this dry phase likely started earlier, by the end to the first short-term arid event (2800–2400 BCE) proposed by Fouache et al. (2021) (see Chapter 7 for discussion).

| **Region** | **Period of Dry Phases (cal. BCE)** | **Reference** |
|---|---|---|
| **CENTRAL ASIA** | | |
| **Lake Issyk Kul, Kyrgyztan** | From ca. 4950 BCE | Ricketts et al. (2001) |
| **Lake Son Kol, Kyrgystan** | 3000–1950 BCE | Lauterbach et al. (2014) |
| **Lake Karakul, Tajikistan** | 2250–1550 BCE | Heinecke et al. (2016);<br>Mischke et al. (2010) |
| **Altai mountains, Mongolia** | From 3050 BCE | Rudaya et al. (2008) |
| **Lake Balikum, Xinjiang region, China** | 2350–3850 BCE | An et al. (2011) |
| **Caspian Sea region** | 2050–350 BCE | Rychagov (1997);<br>Kakroodi (2012);<br>Boroffka and Oberhansli (2006) |

*Table 2.2 The table shows the dry periods recorded in the Central Asia region according to different paleoclimatic records.*

Paleoclimate data for the local Murghab region are still scarce, often not easily accessible in the West[11], and inadequate to establish a solid paleoclimatic interpretation. Nevertheless, a change towards a less humid phase and a drier environment by the end of the 3rd to early 2nd millennium BCE, as I will argue later, substantially affected BMAC communities in terms of water and agricultural management, as well as the Murghab's hydrological stability. In particular, the hydrological network and the availability of water resources are likely to have played a role in the settlement pattern of the region between the Middle and Late Bronze Ages. As such, the relevance of this research is the investigation of local-scale dynamics that might relate to paleoclimate and hydrological

---

[11] This is the case with the data from the 'Desert Institute' in Ashgabat

change, as local-scale paleoclimate data are crucial in any research in Central Asia. When considering settlements and social pattern evolution, local climatic variations are pivotal aspects to consider in addition to broader proxy data of the regions that encompass different ecological zones.

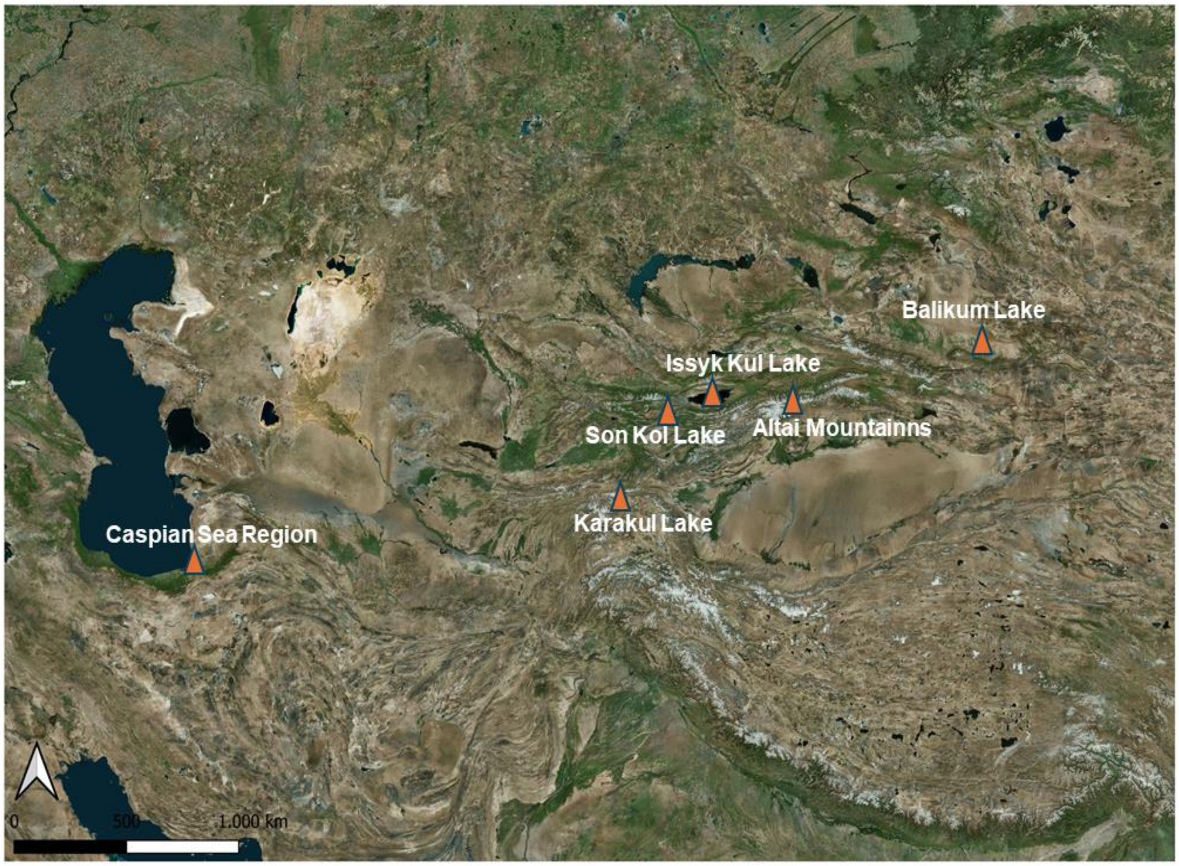


*Figure 2.2 The figure shows the locations of the paleoclimatic records from Table 2.2.*

## 2.2 The Geomorphological Setting of the Murghab Region and its Hydrology

Alluvial fans are characterized by a conical landform that radiates from where the main stream of the river leaves the source area (Bull 1977). This conical landform develops through sediment aggradation. The alluvial fan’s formation is composed by a) a primary process that transports sediment to the catchment area of the fan and b) secondary processes that change sediments previously deposited (Blair and McPherson 2009). According to Blair and McPherson (2009), the condition for the development of an alluvial fan are the topography of the region where an upland catchment drains towards the valley, and enough sediment to construct the fan. A catchment drainage area is characterized by three levels of channels. The first are the main channels, lacking any tributaries, followed by second-level channels downslope, followed by smaller third-level channels. During the accumulation phase of the fan, shifts of the channels may occur across the fan (Bull 1977).

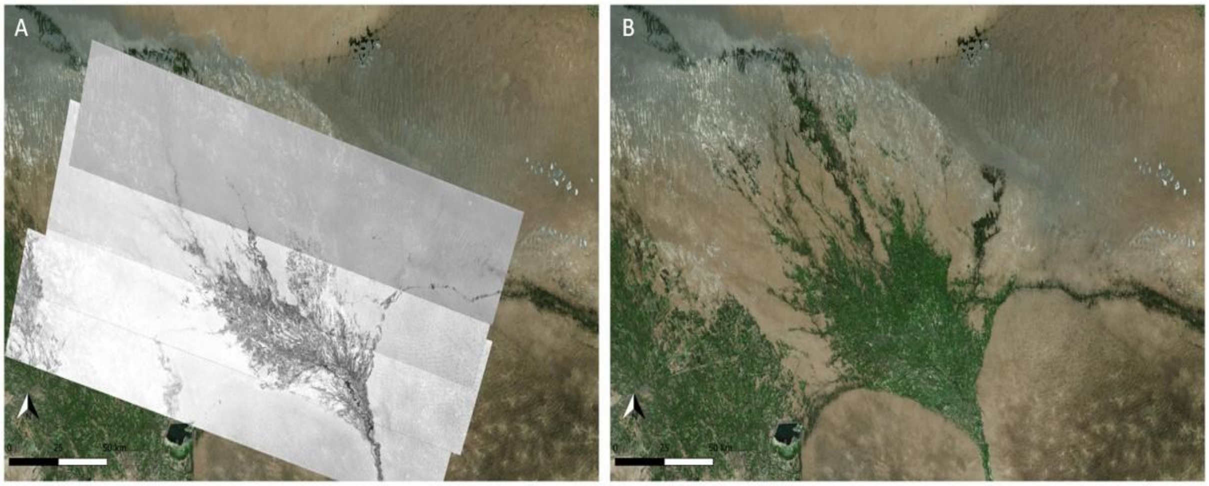


*Figure 2.3 The figure depicts (A) the expansion of the Murghab alluvial fan in the CORONA KH-4A (Sep 18, 1964) image and a (B)contemporary satellite image from Bing Map. Following the final costruction of the Karakum Canal in the late 1980s, the northeastern region has become active again in terms of waterchhannels and agriculture.*

The Murghab fan region is mostly formed by loam, loamy sand, and sandy sediments, generally 1 or 2 m thick (Cremaschi 1998). According to Dolukhanov (1981:361–362), the region has four terraces dating to the Middle and Upper Pleistocene, preserved only in the Kopet-Dag area. The modern Murghab floodplain has an average slope of 1.93‰, with a mean value of 1.16‰, and a standard deviation of 1.57‰, which makes the Murghab an almost flat region (Ninfo 2007).

The present annual mean discharge of the river at Qala-i-Niazkhan station[12] (before the river enters Turkmenistan and without any tributaries) was 46.8 $m^3/s$ (between 1966 and 1976), with a peak in discharge between the months of April and May due to the melting of ice in the mountains (Olson and Williams-Sether 2010:266). However, the annual discharge can vary considerably (Table 2.3). Between 1967 and 1978, the annual mean discharge was between 40 and 50 $m^3/s$, with a high peak in 1969 with a discharge of nearly 90 $m^3/s$ and a lower flow in 1971 of less than 30 $m^3/s$. While the up-stream areas of the fan might have had limited impact of lower discharge, effects might have been especially pronounced on the northern distal fringe of the Murghab.

The modern Murghab alluvial fan has been minimally investigated in terms of its fan and hydrological characteristics. The distal part of the alluvial fan is interspersed with mud plains which are characterized by fluvial silt and clay material (Ghassemi and Garzanti 2019). However, the modern fan is the result of the construction of the Karakum Canal which was completed in 1980s (Zonn 2014). The canal takes water from the Amu Darya River and, in the last forty years, the water has started flowing again in much of the old fan, in particular in the northeast sector. Before the construction of the Karakum Canal, the extent of the alluvial fan was much reduced compared to the modern Murghab (Figure 2.3).

The modern alluvial fan, as mentioned above, ends its journey inland rather than in a lake or sea. Most of the inland fan is located in drylands, such as the Karakum Desert. The river rises in the Paropamisus Mountains (western Afghanistan), while the fan ends in a dry area (Seely et al. 2003) and has specific characteristics. The central part of the fan is characterized by perennial channels with a presence of three levels of channels discussed above in this section. Even before the construction of the Karakum Canal, this central part of the fan was reached by sufficient water. However, the northern or distal area of the fan was characterized by ephemeral channels with intermittent water. Aridity, along with its accompanying fluctuations in rainfall, plays a crucial role in the temporary nature of rivers, as does the exceptionally high rate of evaporation. Flood rivers typically result

---

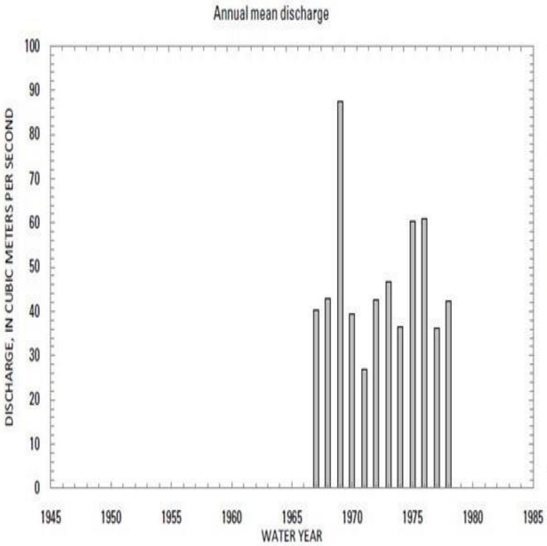
[12] This station is located in northeastern Afghanistan (35º02'N, 64º01'E)

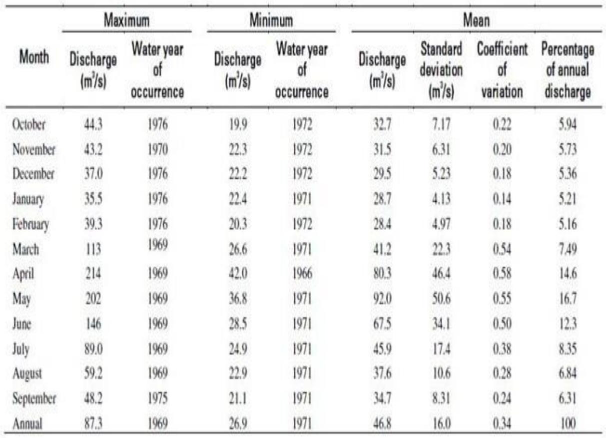
from intense downpours that allow minimal time for water to seep into the soil (Jacobson et al. 1995). In addition, due to restricted water flow, there is a buildup of salt, allowing only salt-tolerant species of vegetation to thrive in the vicinity of these springs and wetlands (Seely et al. 2003).

The resumption of water flow of the Murghab fan, and the expansion of agricultural areas, has led to a significant reduction in the number of ephemeral channels. Nonetheless, in distant regions where arid conditions persist, such as the research sites of Ojakly and Togolok, ephemeral watercourses still exist. During the autumn and winter seasons, flash flood events occur, temporarily activating water channels. However, as indicated by Cremaschi (1998) and Ninfo and Perego (2006), this section of the alluvial fan was marked by the existence of a perennial river system within a humid environment until the 3rd millennium BCE. It is only by the 2nd millennium BCE, and potentially even as early as the late 3rd millennium BCE, as I will argue in this thesis, that the region underwent a process of aridification. During this period, it is probable that some sections of the fan featured permanent channels, while elsewhere ephemeral channels began to increase. The presence of perennial channels during the Late Bronze Age sustained numerous sites, including major tepes. It seems that from the mid-1st millennium BCE the landscape started to resemble the modern one with the presence of large arid areas in the northeast of the fan.

In addition to the occurrence of flash floods in the remote regions of the contemporary fan, the presence of takyr surfaces is also widespread. These features, as I will elaborate on in the following paragraph, hold significant importance in various respects. They serve as drainage basins (comparable to playas in the USA) where water accumulates and have played a crucial role in crop cultivation and animal husbandry. *Takyrs* are situated along dry channels and in interdune areas, and they are prevalent throughout the region (Fleskens et al. 2007) (see section 2.3.1 of this Chapter for discussion).

While the contemporary distal fan exhibits a dry landscape featuring ephemeral streams, the situation during the 3rd and 2nd millennium BCE was different. In this thesis, I will examine the ancient hydrological system and analyze sections of two former channels. Reconstructing the channel system in Togolok and Ojakly is essential to corroborate certain hypotheses regarding the ancient hydrological system, such as whether it was braided or anabranching, and whether they might have resembled the present-day alluvial fan in its active sectors.





| Month | Maximum |  | Minimum |  | Mean |  |  |  |
|---|---|---|---|---|---|---|---|---|
|  | Discharge ($m^3/s$) | Water year of occurrence | Discharge ($m^3/s$) | Water year of occurrence | Discharge ($m^3/s$) | Standard deviation ($m^3/s$) | Coefficient of variation | Percentage of annual discharge |
| October | 44.3 | 1976 | 19.9 | 1972 | 32.7 | 7.17 | 0.22 | 5.94 |
| November | 43.2 | 1970 | 22.3 | 1972 | 31.5 | 6.31 | 0.20 | 5.73 |
| December | 37.0 | 1976 | 22.2 | 1972 | 29.5 | 5.23 | 0.18 | 5.36 |
| January | 35.5 | 1976 | 22.4 | 1971 | 28.7 | 4.13 | 0.14 | 5.21 |
| February | 39.3 | 1976 | 20.3 | 1972 | 28.4 | 4.97 | 0.18 | 5.16 |
| March | 113 | 1969 | 26.6 | 1971 | 41.2 | 22.3 | 0.54 | 7.49 |
| April | 214 | 1969 | 42.0 | 1966 | 80.3 | 46.4 | 0.58 | 14.6 |
| May | 202 | 1969 | 36.8 | 1971 | 92.0 | 50.6 | 0.55 | 16.7 |
| June | 146 | 1969 | 28.5 | 1971 | 67.5 | 34.1 | 0.50 | 12.3 |
| July | 89.0 | 1969 | 24.9 | 1971 | 45.9 | 17.4 | 0.38 | 8.35 |
| August | 59.2 | 1969 | 22.9 | 1971 | 37.6 | 10.6 | 0.28 | 6.84 |
| September | 48.2 | 1975 | 21.1 | 1971 | 34.7 | 8.31 | 0.24 | 6.31 |
| Annual | 87.3 | 1969 | 26.9 | 1971 | 46.8 | 16.0 | 0.34 | 100 |

*Table 2.3 The table shows the annual and monthly mean discharge of the Murghab River between 1966 and 1976 at Qala-i-Niazkhan station (USGS Report 2010, Olson and Williams-Sether 2010:266).*

Availability of water discharge data in Central Asia is often constrained by early Soviet studies (Mitgartz and Shevchenko, 1972) and typically spans no more than 60–70 years. (Table 2.3). Moreover, fluctuations in the size of the Murghab fan can be reconstructed on the basis of historical maps and, more recently, from satellite images. A preliminary study focusing on the period between 1881 and 2001 shows considerable fluctuations in the extent of the alluvial fan with a marked reduction in size at the beginning of the 20th century (Tosi and Cerasetti 2010:Fig. 16). Tosi and Cerasetti reconstructed an expanse of irrigated areas in the Murghab region between 4000 and 6000 km$^2$ during the 20th century. The study shows that in the course of a century, several fluctuations significantly affected the size of the fan and, as a result, the agricultural potential of the region. In ancient times, such fluctuations of discharge might also have impacted the potential for agricultural production and the irrigated lands.

- **Tectonic Movement and Hydrological Change**

Around 70% of modern Turkmenistan is occupied by desert, namely the Karakum (black sand) Desert. This area is the most significant geomorphologic feature in the country and is characterized by deserts of salt, sand, loess, clay, and stone (Ghassemi and Garzanti 2019) (Figure 2.4). Both the Murghab and its adjacent alluvial fan to the west, the Tedjen, are part of the Turan plate and were formed in the second half of the Quaternary Period (Atamuradov 1994:62). However, the Murghab fan has also been shaped by subsequent events. The area is part of a tilted fault block which appears to be colliding with the western side of the Khiva Depression at its eastern limit (Kozolov 1991; Marcolongo and Mozzi 1998:2). Quaternary tectonic movement, as well as reduction in water discharge in this region, has significantly impacted the hydrological system of the Murghab (Rustanov 2014a:14).

An analysis by Marcolongo and Mozzi (1998) presents a tilted fault block, the "Turan Plate," covering much of central and eastern Turkmenistan, which is rising in the east. According to the authors, the late Quaternary geomorphological features appear to be components of a tilted fault block, exhibiting an elevated eastern side and gradually dipping towards the area presumed to be subsiding, situated between the Kopet-Dag and the central Karakum plateau, referred to as the "Turcoman trough" (Marcolongo and Mozzi 1998:1). This tectonic movement led to a westward shift of the entire hydrological fan of the Murghab, likely occurring during the 1st millennium BCE (Marcolongo and Mozzi 1998).

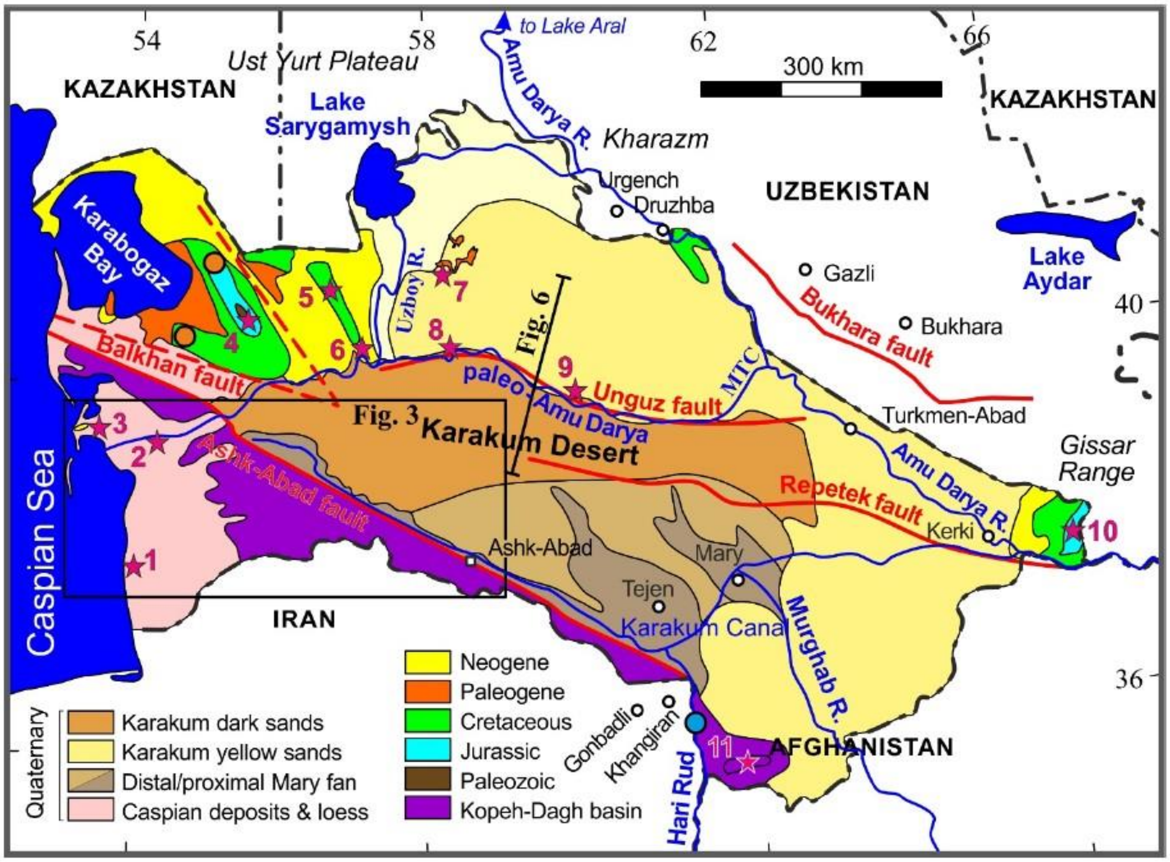


*Figure 2.4 The figure shows the general geological map of Turkmenistan, compiled by Ghassemi and Garzanti (2019:Fig. 2).*

A second process that generated ancient channel systems was the contraction of the water supply of the Murghab. The decrease in water discharge resulted in the many river channels becoming inactive in the northeastern fringe of the fan. The analysis of the high-resolution elevation data (SRTM images)[13] shows the presence of two overlapping fans in the Murghab: the northeastern "Bayram-Ali" Fan and the younger "Mary" Fan to the west.[14] The shift towards the Mary Fan resulted from the tectonic changes discussed above (Figure 2.5). When exactly this shift took place is unclear. Tosi and Cerasetti (2010), considering the presence of the Iron Age main settlement of Yaz-Depe, on the southwest end of the older Bayram-Ali fan, tentatively proposed a shift, particularly a southward shift of the population, not before the end of the Iron Age.

---

[13] Shuttle Radar Topography Mission (SRTM).

[14] Atamuradov (1994:62) citing Fedorovich and Kes (1934) state that "four subsequent deltas, partially overlapping, have been found in the lower reaches of the Murghab."

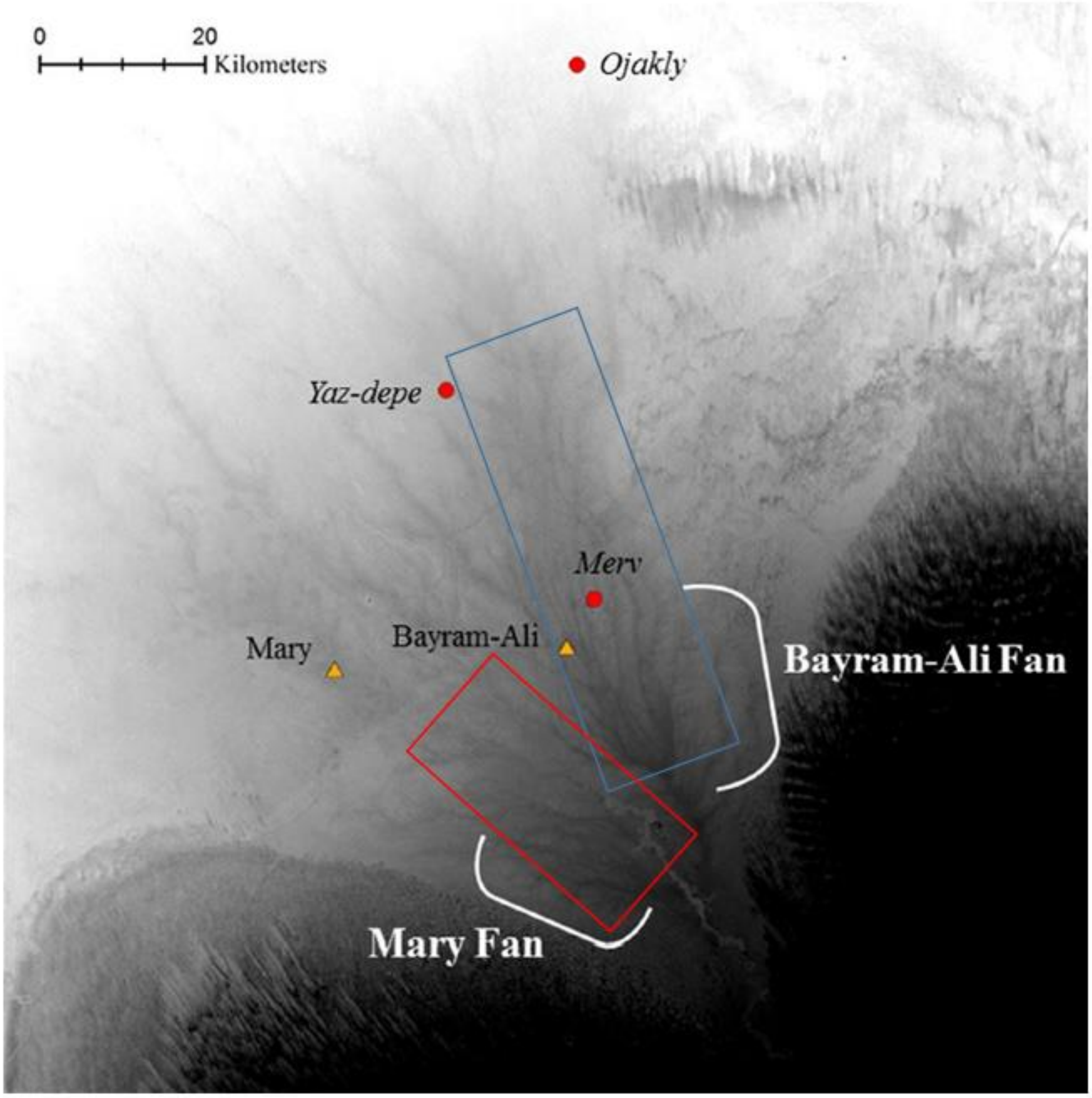


*Figure 2.5 The SRTM image shows the northeastern Bayram-Ali Fan (blue rectangle) and the youngest Mary Fan (red rectangle) (adapted from Rouse 2015:Fig. 3.4).*

As mentioned earlier, an additional problem is a loss in surface water due to evaporation. Evaporation is a key process and the main way rivers lose heat (Maheu et al. 2013). According to Lyapin (1996), in order to overcome water shortages and reduce agricultural production, dams were constructed in the Murghab, probably during the 3rd and 2nd century BCE. Dam construction potentially led to an increase in agricultural production and population growth, especially in the Merv Oasis. However, although small dams could have been in place during the 3rd and 2nd century BCE, there is no convincing evidence for them at present. In fact, it is not until the Arab conquest (8th century CE) that we have clear evidence (from literary sources) for the construction and maintenance of dams along the Murghab River. These sources also provide evidence for state service and the maintenance of large dams (Bader et al. 1996). The vital importance of the Murghab dams for agricultural production in the Merv Oasis is also evident during the Mongol occupation. The Mongols destroyed major cities in the region, such as Merv and Nisa, as well as dams along the Murghab, which led to a decrease in agricultural production and a reduction in settlement numbers and size (Bader et al. 1996).

For the preceding periods there is no archaeological evidence for dams in the Murghab, although the location of Achaemenid "fortresses" in the northeastern region of the Murghab may suggest that the main channels of the alluvial fan were still active in that period (Cerasetti and Mauri 2002:Fig. 7; Lyapin 1996). The northeastern part of the Murghab fan system only fully resumed flowing in the 20th century with the construction of the Karakum Canal, which increased the agricultural potential of the region tremendously (Figure 2.1).

The retreat of the Murghab in the 2nd millennium BCE and its shift later to the west due to tectonic movement created a preserved landscape that can be appreciated through satellite images and aerial photos (Cremaschi 1998; Salvatori 2008a:67). In terms of archaeological research, this landscape offers great potential for investigating past human–water relationships. However, while the investigation of the overall ancient hydrological system of the Murghab has been extensive, targeted investigations of specific channel systems that can foster a thorough understanding of this relationship have not yet been undertaken.

## 2.3 Dune Movement and Soil

The northeastern fringe of the Murghab alluvial fan has been cultivated since the 1960s, and this process accelerated in the 1990s (Zonn 2014) (Figure 2.1). However, up to the 1950s, the central north area of the Murghab was covered mostly by active linear dunes, which are still predominant in the northern part, along with ephemeral run-off water reservoirs forming takyr surface (see below). The desert dunes in the Murghab vary in their form and activity from north to south of the fan. The north of the no longer active fan is characterized by large ridge dunes with an N–S or NNW–SSE direction. They are stable or semi-stable sandy hills or ridges (Maman et al. 2011a). They can measure some kilometers in length, are about 50 m wide, and 10 m high (Cremaschi 1998). In the eastern and southern regions in particular, the dunes take the form of small "barchanoids"[15] with a relatively long shape when occurring in a group (Suslov 1961). In the central south part of the fan, the presence of bush vegetation (mainly *black saxaul*; see section 2.4 of this Chapter) stabilizes dune movement (Cremaschi 1998). These dunes, both in the central and more distant part of the fan, partially cover the ancient landscape, obscuring channels and archaeological sites and have a considerable impact on archaeological and geoarchaeological investigations (Bondioli and Tosi 1998:1).

### 2.3.1 Takyr Surfaces

Takyr surfaces are common in the Murghab region and Central Asia deserts and they are of a crucial economic importance (Dolukhanov 1981). Although sometimes referred to as soil, takyr is not classified as soil by the World Reference Base for Soil Resources. It is a surface with specific and defined properties (Food and Agriculture Organization 1998:7). Takyr generally occur in drainage areas of the former Murghab alluvial fan or in areas that were irrigated and are characterized by a slightly sloping or flat surface with dense clay-loam soils, often with a polygonally cracked surface (Fleskens et al. 2007; see characteristics in Food and Agriculture Organization 1998:73–74) (Figure 2.6). These surfaces occur in various dimensions and are similar to *playa* in the United States, or the *sabkha*/*qaa* in West Asia, although some differences exist (see Briere 2000). According to Bazilevich et al. (1956), the formation of takyr surfaces in the Murghab occurs mainly during the spring flood. They concentrate on slightly sloping surfaces where water can accumulate and can be found along former water channels as well as in interdune areas.

---

[15] Barchanoid derives from name *barchan* which means "crescent dune." They are wavy dune ridges often with asymmetrical geometry and with parallel rows oriented transverse to the direction of the predominant wind. They often move forward from their position during the winter in the Murghab (Tirsch 2014).

Therefore, takyr surfaces can occur in any part of the ancient dried alluvial Murghab fan, and in particular in the central north part.

*Figure 2.6 The picture shows A) a classic takyr surface (red circle) in the northeastern region of the Murghab alluvial fan and B) detail of a takyr surface.*

Lebedeva-Verba and Gerasimova (2010) have described the micromorphology of the formation of takyr and the role of terrestrial and aquatic microorganisms. In short, the accumulated water (waterlogging) on sloping surfaces during the spring and autumn (when there is more rainfall) causes an outbreak of different algae and microorganisms that were previously formed, along with processes of alternating alkalinization and salinization. In the warm and hot seasons, there is a drying out with cracking and shrinking of the surface as well as active deposition of eolian sands and activities of microorganisms, such as zooplankton and blue-green algae, resulting in the formation of a new takyr surface (Lebedeva-Verba and Gerasimova 2010). Takyrs often covers large areas and are often associated with algae and lichens on the surface during the dry season

(Dregne 1976; Orlovsky et al. 2004). For generations, people in the Murghab have used the water accumulating on this surface for various purposes (see below).

It has been estimated that in Central Asia between 130,000 and 318,000 km$^2$ of land comprise of takyr surfaces, of which 31,000 and 40,000 km$^2$ are present in the Karakum Desert (Prasolov 1933; Lezhinsky 1974; Babaev and Vitkovskya 1985; Lavrov et al. 1976). An analysis by Maman et al. (2011b) demonstrates a loss of 20% of these surfaces in the last 40 years, which has considerably reduced their potential as temporary water reservoirs. Of particular interest for the current study are the possible uses in the past of takyr surfaces.

### 2.3.2 The Role of Takyrs in Modern Crop Cultivation and Animal Husbandry

Takyr surfaces have been widely used for crop cultivation and animal husbandry in the Murghab. Fleskens et al. (2007) have grouped the different systems that have been developed for the exploitation of water resources from takyr surfaces. One of the most common systems indicated on historical maps is that of *khaks*, which are one of the most efficient ways of storing water in the Karakum Desert and are widespread in the Murghab. Ethnographic study also indicates how these places, able to collect water for some period, were crucial in the Turkmen economy both for crop cultivation, including opportunistic fields, and animal husbandry (Lalymenko 1989). The *khaks* are dug into the takyr surface to collect water, which can be stored between two and four months. The capacity of *khaks* for storing water can vary from 2 to 100 m$^3$ (Fleskens et al. 2007). These structures are also used for watering livestock, as well as for human consumption (at present, *khaks* have almost disappeared in the northeastern part of the Murghab). It has been estimated that the average total volume of runoff water on takyr surfaces is between 350 and 450 million m$^3$ per year in Turkmenistan (Fleskens et al. 2007). Finally, takyr surfaces facilitate water retention, and many takyrs have been directly ploughed and used in agriculture. While till the 1980s takyrs were used only as watering places for crop cultivation and animal husbandry (Emeljanenko 1994), the use of modern canals excavated with machines in a short time period have drastically reduced their importance. As result, takyrs have been destroyed and ploughed because of the water retention that make these surfaces a good spot for cultivation. This is also evident in satellite images where takyrs are reached by modern canals and are often completely converted into agricultural areas. This destructive practice, as well as the use of heavy vehicles, has resulted in the loss of many takyr surfaces in the Murghab over the last few decades (Fleskens et al. 2007).

In the past, water on takyrs was also crucial for caravan routes. Fleskens et al. (2007:Fig. 2) mention that *kahks* determined the seasonal trekking routes of shepherds north of the city of Ashgabat that extended over 200 km. However, at present, takyrs no longer serve as water storage places and have almost lost their crucial importance. Water can be easily brought to the field by the construction of fast and modern canals.

### 2.3.3 The Role of Takyrs in an Archaeological Context

The importance of takyrs for archaeology has been highlighted by various authors. Cremaschi (1998), while describing takyrs, reported that some takyrs might date to the Bronze Age. According to the author, takyrs can be ancient topographic surfaces which were covered by dunes and were later uncovered again by wind erosion. In fact, in the preliminary AMMD survey of Iron Age sites it is reported that the “Low Lying Depositional Areas” (LLDA), often consist of large takyr surfaces (Genito 1998). Lyapin (1990) claimed that takyr surfaces were often correlated with Bronze Age material. However, no further sedimentological studies have been published that correlates takyr surfaces with a Bronze Age formation, and thus they could have been formed at later stage. In addition, as reported by Markofsky (2010:286) in the Egri Bogaz area, some takyrs that showed Bronze Age materials on the surface failed to show significant evidence of archaeological deposits below such surface level. Thus, Bronze Age materials on takyrs might have been the result of post-depositional processes.

Critical for the present research, however, is the association of takyr surfaces with possible ancient agricultural fields. Takyr surfaces forms naturally in the Murghab region, and they are often the result of the drainage of water and subsequent formation processes, as mentioned above. However, takyr surfaces may also form as the result of anthropogenic activities (i.e., waterlogging). Considering the takyr formation process outlined earlier, it is conceivable that the formation of takyr surfaces may result from agricultural practices and intentional flooding carried out repeatedly (Fleskens pers. comm.). Intentional flooding is still a common irrigation practice in the Murghab. Thus, takyr surfaces might also be the result of irrigation practices in intense cultivation areas. Lisitsina (1976) explored this hypothesis by investigating the salt content of different takyr or takyr-like surfaces in southern Turkmenistan. The comparison between different takyr surfaces (natural vs. anthropogenic) indicates that takyr deposits in areas identified as ancient fields dated to the 3rd millennium BCE show a lower percentage of salt content compared to naturally accumulated takyr deposits. The analysis by Lisitsina (1976:60) suggests, therefore, that some takyr surfaces in southern Turkmenistan can indeed be linked and formed from ancient farming and irrigation practices.

Additional proxy evidence linking takyr formation and ancient irrigated land, although from a different geomorphological landscapes, is provided by investigations in the Prisarykamysh alluvial–deltaic plain (southern part of the Aral Sea region). Research by Tsvetsinskaya et al. (2002) suggests a direct relationship between the time at which farming irrigation land ceased and the current state of the landscape. Although post-irrigation desertification processes in Central Asia have been much researched (e.g., Minashina 1978), the authors provide local evidence of a direct link in which more ancient irrigated landscapes (from the 4th century BCE) evolved into takyr surfaces.
These data provide an indication of the role as a marker for some takyr surfaces in the northeastern Murghab region and their link to ancient arable and irrigated land. These aspects are further explored in Chapters 5 and 6.

### 2.3.4 Takyrs and Ancient Watercourses

As discussed above, takyr surfaces in the Murghab are generally characterized by sloping flat surfaces or depressions where runoff water can be retained for months and are used for agriculture (Fleskens et al. 2007). Their size can vary from a small takyr (0.5 km$^2$) to a very large one in western Karakum (>100 km$^2$) (Maman et al. 2011b). These shallow depressions usually take an ellipsoidal or circular form. However, takyr surfaces can also take other forms. In Central Asia, elongated and meandering takyr surfaces have been interpreted as evidence for ancient river channels. The "Khorezm Archaeological-Ethnographical Expedition" by Andrianov (1969) in the Aral Sea area, specifically targeted takyr surfaces for reconstructing ancient irrigation (see section 4.2.1 in Chapter 4). The linear traces, visible in the aerial photos, were interpreted as ancient watercourses and had cracked clay surfaces in linear shapes, sand dunes at their edge, and vegetation in the center (Andrianov 2016:89).

In southern Turkmenistan, the irrigation system of the Geoksyur Oasis, located east of the Tedjen River, has been dated to the Chalcolithic period. Also in this case, Lisitsina (1965:30–35) interpreted the elongated form of takyr surfaces as ancient watercourses and artificial canals. The excavation of such features revealed clear cross-section profiles of channels with a sequence of soil layers associated with ancient watercourses underneath a takyr layer of approximately 30 cm (see Lisitsina 1969:Fig. 4).

In the Murghab, a macro reconstruction of the hydrological system of the ancient alluvial plain only began in the 1990s by the AMMD (Cremaschi 1998; Cerasetti 2008). However, the nature of the takyrs and their association with ancient water channels in the Murghab remains elusive. Only limited investigations have been conducted on the takyr as traces of ancient water channels (Cerasetti 2008; Markofsky et al. 2017). Likewise, ancient watercourses in general, such as at Gonur-tepe and Chopantam, were both investigated by chance as part of the archaeological excavations but no systematic studies have been done (Sataev 2008; Cattani 2008a). In this context, the objective of this study is to delve deeper into the connection between takyr surfaces, ancient watercourses, and their location within the Murghab alluvial fan.

## 2.4 The Local Desert Environment

Turkmenistan, and in particular the Murghab alluvial fan, constitutes a unique ecosystem with a large biodiversity (Rustamov 1994). The modern flora and fauna can provide insights into the ancient landscape. The Karakum Desert constitutes the vast majority of modern Turkmenistan, and most of the vegetation in the lowlands consists of small semi-shrubs, shrub psammophyte, or sagebrush-halophyte communities (Orlovsky et al. 2004; Babaev 1994). Among the shrubs and small trees, the most remarkable is the saxaul (Figure 2.7), which includes the white saxaul (*Haloxylon persicum*) and the black saxaul (*Haloxylon aphyllum*).

*Figure 2.7 The black saxaul (Haloxylon aphyllum) in the modern Murghab landscape. Evidence of saxaul has been found at Gonur North and was probably used as a fuel source.*

Interestingly, black saxaul occurs in association with groundwater or surface water such as takyr soils or along water channels (Rustamov 1994: 94). Botanical remains from Gonur-tepe include saxaul (*Haloxylon* sp.) probably used as fuel, along with shrubby thistle (*Salsola* sp.), willow (*Salix* sp.), and tamarisk (*Tamarix* sp.) (Sataeva and Sataev 2014). The latter is still present in Turkmenistan and is particularly salt-tolerant, along with trees like *Populus euphratica* and *Populus pruinosa*. This *tugai*[16] vegetation, and in particular saxaul, was likely more widespread in antiquity and formed a source for fuel or building construction (Sataeva and Sataev 2014). However, the *tugai* coverage has been mostly depleted in the last decades in the wake of new agricultural expansion.

The fauna of Turkmenistan mainly consists of animals endemic to desert or semi-desert landscapes. Among the mammals, the most typical species that can be found in the sandy landscape are foxes (*Vulpes vulpes*), long-eared hedgehogs (*Hemiechinus auritus*), desert hares (*Lepus capensis*), and sand cats (*Felis margarita*). Wild sheep (*Ovis ammon*), gazelle (*Gazella subgutturosa*), and wild boar (*Sus serofa nigripes*) can also be found, including onager (*Equus onager*), although both onager and gazelle have been decimated in recent decades (Rustanov 2014b). Among the various reptiles endemic to the lowlands in Turkmenistan, the steppe tortoise (*Testudo horsfieldi*), also known as the Russian or Afghan tortoise, can be found in the Murghab in areas less disturbed by anthropogenic activities such as the Ojakly area (pers. observation). Interestingly, tortoises, together with gazelle, fox, and hare (*Lepus* cf. *tolai*), were found in the 2018 Togolok 1 faunal assemblage. These animals, endemic to the modern semi-desert Murghab environment, are an indicator of an increasingly dry climate at the end of the 3rd to early 2nd millennium BCE (Cerasetti et al. 2022). Similar finds are reported at the Bronze Age site of Gonur-tepe as well, further supporting this interpretation. The zooarchaeological analysis also reported the presence of wild boar, hare, small rodents, tortoise, and gazelle that were likely hunted at Gonur, although they are a minor component in the assemblage (> 5%) compared to domestic species (Moore et al. 1994; Sataev 2021a).

---

[16] The term *Tugai* refers to forest and riparian vegetation that is present in Central Asia along major rivers.

In addition to animal husbandry, fishing is also part of the modern Turkmen economy, although its economic importance is relatively low. With the ultimate construction of the Karakum Canal, however, new fish species have been introduced in the Murghab and the Tedjen alluvial fan. Fish might have been a minor part of the dietary economy during the Bronze Age as well. Indication of fish are provided by Adji Kui 1 finds, where small fish vertebrae have been identified belonging to the Nemacheilidae family (*Paracobitis* sp.), probably from a small fish variety such as sardine (Spengler et al. 2018). Interestingly, one of the fish bones was partially carbonized, suggesting that they were cooked as part of the diet. In addition to Adji Kui 1, fish bones have also been identified in the Togolok 1 assemblages, suggesting that limited fishing was possibly practiced by BMAC communities (Billing et al. 2022:Fig.10). Likewise, proxy zooarchaeological data from several areas of Eurasia further suggest that fish was part of the diet during the Bronze Age (O’Connell et al. 2003; Gayduchenko 2002).

## 2.5 Traditional Pastoralism and Irrigation Farming in the Murghab

In the 19th and early 20th centuries, most Turkmen were active both in animal husbandry and crop cultivation. These traditional agricultural practices can provide insights into past land and water management in the region.

Over the last two centuries, most of the tribes in the region were semi-sedentary, and only a few were fully nomadic livestock breeders (Ovezberdyev 1962). Before collectivisation of Turkmenistan and the nationalization of lands with the introduction of *sovkhoz* and *kolkhoz farms*, pastures, as well as routes, were divided among tribes (Emeljanenko 1994:42). The division by clans or tribes seems to have also existed for the irrigation system. O’Donovan, who visited the Merv Oasis in 1879–1881, informed us that watercourses were divided among the Turcoman clans (O’Donovan, 1882 II:193). The control of the irrigation system by local tribes, however, was over the main dams and canals only. For instance, O’Donovan reports that all the operations of the dam and main canals at Benti (one of the main dams of Merv Oasis at that time) were under the control of a local *Kethkoda*.[17] The village of Benti consisted of a group of houses along the canal and its inhabitants had to manage and maintain the dam and sluice (O'Donovan 1882 II:189).

Colonel Stewart, who visited Merv and Benti Dam during the same years as O'Donovan, report that, on the eastern side of the Murghab, the Beg and Wakil[18] were the persons who could decide first over the Murghab waters (Stewart 1881:541). In these historical sources, the power among the clans appears to have been horizontally rather than vertically distributed. According to Stewart, policies were discussed among the *Kethkodas*, who also had family rights over water management (Stewart 1881:542).

In Merv, at the time of the visit by Stewart, there were more than 24 *Kethkodas* who would unite and appoint a chief only in case of danger and for a limited time. Likewise, the organization of the irrigation system was not top-down management. It was performed and managed at the family level by local agents. For instance, while describing the everyday life of a Turcoman, O' Donovan (1882 II:189, 350) affirms that the younger members of the families were the ones in charge of digging the irrigation canals and taking care of the fields during the harvest season. The irrigation system of the Merv Oasis was managed by the local clans, while only the major dams were controlled by a regional authority. Similarly, in the neighboring Oasis of Bukhara (Uzbekistan) the control over the irrigation system was also performed by local tribes and only to a minor extent by the governor (*Emir*) (Schuyler 1876:305 in Lamberg-Karlovsky 2016).

O'Donovan also reports that in Merv canal management was not always efficient. While the canals in proximity of the oases were well maintained, irrigation systems in rural areas were not, and small – minor – canals shifted their courses quite often without proper maintenance (O'Donovan 1882 II:194). His report suggested that differences

---

[17] *Kethkoda* is a Persian word for a person who has judicial competence but is not part of state apparatus, and usually operates in a tribal context (Barendese 2009:1756).

[18] These are titles for a chief or representative person.

existed in levels of water management between the oasis core and marginal fields, and that the priority of the maintenance was for the canals in the center of the oases.

How the water was distributed in Merv is also described by earlier travellers. The 10th-century Arab geographer and writer Al-Istakhri described that in Merv, each district and street had artificial canals (called *little rivers* in the text) equipped with wooden sluices to fairly distribute water in the case of both increases and shortages of water (in Kennedy and Moore 1999:123). The distribution was efficient and fair. In charge of the distribution of water was an *Amir* (local officer).

Another Arab geographer, Al-Muqaddasī, who visited Merv during the same century, reports that watercourses far from the main city and in marginal areas were often poorly maintained (in Kennedy and Moore 1999:124). In contrast, recent investigations of the main water canal inside the Islamic city of Sultan Kala in the Merv Oasis confirmed that the canal was well maintained and constantly cleaned over a period of 470 years of activity, as its base had not accumulated any silt layers (Williams 2018). This suggests that control and management over the main dams and canals was probably well regulated in the oasis. In contrast, the maintenance of the peripheral irrigation systems by local agents was probably less systematic.

Several reports from travellers and historians report how famous the Merv Oasis was for its agricultural produce. For instance, the records of Du Huan, a Chinese traveller and officer who visited the Merv Oasis during the Tang dynasty (618–907 CE), inform us about the great varieties of fruits and vegetables that were cultivated at Merv. These include apples, red peaches, and grapes, but also onions, radishes, shallots, gourds, and melons (in Kennedy and Moore 1999:121). Likewise, the Arab geographer al-Istakhri reports that Merv produced the best quality dried fruits and melons. The melons, cut in strips and dried, were exported as far as Iraq. The export of melons, both fresh and dry, is also mentioned by Stewart (1881:532) in the 19th century. Together, these sources describe a well-structured agricultural system where, in addition to staple crops (wheat, barley, and rice), a good variety of garden fruits were also cultivated.

Besides crop cultivation, the second main economic activity in the Murghab was animal husbandry. However, Obzorv, who also visited the Caspian region at the end of the 19th century, reports that most of the Turkmen tribes were not real pastoral nomads, and crop cultivation was also practiced (Obzorv 1897:25–26 in Emeljanenko 1994:41).

Further away from the oases, however, pastures and farming were mainly dictated by the presence of wells. For instance, the Tekyns in the Akhal tribe area lived for most of the year around wells and moved only three times a year. Wells were usually constructed and managed by families who practically owned the wells. However, despite being "private," the use of the wells was free, provided that the users were able to take part in cleaning and repairing of the well on the basis of mutual aid customs (Emeljanenko 1994:43–44).

All in all, reports from medieval and more recent times suggest that traditional farming and pastoralism in the Murghab was part of a complex system in which local communities were involved in various mixtures of agropastoral activities and differences existed between oasis-based and more peripheral irrigation and crop cultivation.

## 2.6 Summary

The chapter presents an overview of modern Turkmenistan's physical and geographical settings, its climate, and the relevant modern fauna, some of which have also been found in the archaeological record and are indicative of a dry region from the 2nd millennium BCE onwards. Likewise, the general paleoclimate data from the Central Asia region discussed above also suggest a drier environment during the Bronze Age. However, the local impacts of climate change on the agricultural and water management system will be discussed in the next chapters. It is likely that changes in the geomorphology of the alluvial plain and climate over the 3rd and 2nd millennium BCE considerably impacted the fluvial regions and water discharge. As I will argue in the case study chapters, this had an effect on BMAC communities and their subsistence economy. In this context, the formation of takyr surfaces, their relation to former channels, and their use for crop cultivation and animal husbandry are of crucial importance in the BMAC context and will be further discussed in Chapters 5 and 6.

Finally, traditional pastoralism and the management of irrigation systems in the region during Islamic and more recent times offer crucial insights into landscape management in the region. Their relevance and implications will be further discussed in the conclusion chapter (Chapter 7). Having presented the problems and the aims of this research and the geographical and geological settings of the region in the first two chapters, in the next one, I will discuss the relevant archaeological context and the theoretical framework of the research.

# Chapter 3 – The Archaeological Context and Theoretical Framework

## 3.1 BMAC Origins and the Broader Context

- **Ancient Designation of the BMAC Region**

The term "Bactria-Margiana Archaeological Complex" was first coined by Sarianidi to identify the area that spans what is now eastern Turkmenistan, northern Afghanistan, and southern Uzbekistan. More recently, as introduced in Chapter 1, Biscione and Vahdati (2021) coined the term "Greater Khorasan Civilization" (GKC), which has recently been used by other authors (Kroll et al. 2002; Cerasetti and Luneau, forthcoming). In addition to the region's modern denomination, its ancient name also remains nebulous. Over the last two decades, different authors have tried to establish an identification in Mesopotamian texts for the BMAC region. Potts (2008) has suggested that the land of Shimashki (*Šimaški*), mentioned in some Mesopotamian texts, might be the BMAC region. By contrast, Francfort and Tremblay (2010) argue that the region of Marhashi (*Marhaši*) corresponds to the BMAC. The region of Marhashi is known to be one of Akkad's main eastern enemies, eventually becoming an economic partner (Guichard 2021:73–75). Other authors identify Marhashi with the *Halil Rud Civilization* in the south-eastern Kerman Province of Iran rather than the Margiana (Steinkeller 2006). More recently, Steinkeller (2016:129) has tentatively tried to link the BMAC region with Tukrish (*Tukriš*), considering that this country was the possible source of lapis lazuli and gold for Mesopotamia. Overall, although direct or indirect *contact* between Mesopotamia and northeastern Iran and southern Turkmenistan is evident from the archaeological record, there is no consensus as to its ancient name in the textual sources (Mutin and Lamberg-Karlovsky 2021; Guichard 2021).

- **The Chalcolithic and Early Bronze Age in the Murghab: Patchy Evidence**

Evidence of earlier occupation prior to the Middle Bronze Age in the Murghab region has been limited to isolated discoveries. Painted surface sherds (of Geoksyur type) dated to the Middle and Late Chalcolithic (Namazga II and III periods – ca. 3500–2800 BCE) have been found north of Kelleli, in sites described by Masimov (1979) as seasonal campsites. In addition, Massimov also reports that in the basal level of Kelleli 1, carinated greyware was found that may suggest an occupation preceding the Middle Bronze Age. At Gonur North, two sherds and three radiocarbon dates fall into the Geoksyur-Chalcolithic period (Lyonnet and Dubova 2021a:20). Additionally, possible evidence of an early occupation is available from the fortified site of Adji Kui 9, northwest of Gonur, where painted ceramics, probably dating to the late 4th to early 3rd millennium BCE have been found (Rossi-Osmida 2007:124). At this site, moreover, Salvatori (2002) dated Unit 17a from the deep sounding to the Middle–Late Chalcolithic period. Similarly, at Gonur North, short-term occupation and narrow walls have been found, suggesting that the site was probably sporadically occupied before the Middle Bronze Age (Sataev 2018).

Further south in the alluvial fan, Lyapin (2014) reports Namazga III pottery at a depth of 4.5–6 m. The amount of alluvial deposition might have therefore obscured archaeological evidence from the Chalcolithic period in the northern fringe (Hiebert 1994a; Salvatori 2008a). However, the deposition of alluvium in the north of the fan is quite reduced compared to that in the south, and very often Bronze Age materials appear after a few centimeters of excavation. Nevertheless, Chalcolithic evidence remains elusive and underrepresented in the Murghab landscape. In contrast, Chalcolithic occupations in the nearby Kopet-Dag region are numerous (Kircho 2021).

A possible explanation for this absence might be the limited occupation of the Murghab region during the late 4th to early-middle 3rd millennium BCE, while it is only in the late 3rd millennium that numerous sites started to appear in the region along with intense urbanization. But what was the origin of this phenomenon?

- **The Origin of the BMAC**

Several authors have considered the BMAC to have derived from the Namazga culture in the Kopet-Dag, postulating a colonization of the Murghab during the Middle Bronze Age (2400–1950 BCE) (Masson 1988:92; Biscione 1977). During this period, the Kopet-Dag communities were in contact with neighboring societies such those in the Indus (Masson 1988: pl. XXII, 2 and 5*)*. Likewise, contact is attested between communities of southern Turkmenistan and societies in northeast Iran to the south, and communities in Uzbekistan and Tajikistan to the east for instance. A metal stamp seal of a type deriving from southern Turkmenistan was found at Tepe Hissar (IIIB levels) in northeastern Iran (Schmidt 1937:Fig. 118, H 2697). Similarly, artifacts that have been found at the site of Altyn-Depe in the Kopet-Dag are comparable to objects from Hissar IIIB (Schmidt 1937:pl. LXI H 2895, LXIV H 2894). Objects deriving from the southeast of Iran are also known. Further, materials found in burials at Altyn-Depe, such as beads, resemble objects from central-east Iran at the Shahdad cemetery (Kircho 2021:133).

Contact is attested with eastern regions as well. Materials found in the lower Zeravshan in Uzbekistan (Guljamov et al. 1966), and in southern Tajikistan, show the presence of Namazga IV and early Namazga V materials (see Table 1.1 for correspondence chronology) (Vinogradova 2021). These interregional contacts with neighboring regions increased during the late 3rd millennium BCE, which marks the floruit of the BMAC (Kircho 2021:134; Mutin and Lamberg-Karlovsky 2021). Thus, during the Early and Middle Bronze Age periods (2800–1950 BCE), communities in the southern Turkmenistan region were interconnected through various networks.

Similarities between Kopet-Dag and the Murghab assemblages can be found in ceramics and iconographic objects, such as the violin-shaped figurine found at Altyn-Depe (Masson 1988:pl. IX; cfr. Rossi-Osmida 2007:183). In this context, as discussed in Chapter 1, it has recently been suggested by Biscione and Vahdati (2021:527) that the Kopet-Dag area, including parts of northeastern Iran, can be considered the “formative” area of the BMAC.

In contrast, Sarianidi has proposed a theory in which the rise of the BMAC occurs as a result of the migration of tribes from the Levant and Mesopotamia (Sarianidi 2009:41–42). According to Sarianidi (2002:78) this is visible in the architecture and specific traditions of monumental buildings. For instance, the throne hall (room 196) of the Gonur palace finds its parallel, according to the author, in the location of the throne in the palace of Mari in Mesopotamia (Sarianidi 2002:79). However, this evidence is meagre and difficult to support.

Similarities between BMAC material culture and that of other regions are at the base of further migration theories. The BMAC has been linked to migration from the Baluchistan region, or Aral Sea region and the Eurasian Steppe (Lamberg-Karlovsky 2003; Alyekshin 1980; Kohl 2002:167-169). This latest hypothesis, however, contrasts with the assemblages from the "steppe" in the Murghab, which are from the first half of the 2nd millennium BCE onwards, thus after the floruit of the BMAC (Cattani 2008b).

Although migration theories alone do not explain the emergence of the BMAC, the movement of the population cannot be ruled out. Recent aDNA analysis indicates the presence of individuals with diverse origins at BMAC sites, while the isotopic analysis from the site of Ulug Depe suggests possible migrations during the Bronze Age (Narasimhan et al. 2019; Kroll et al. 2022). Nevertheless, mass "migration" from distant regions is not supported by archaeological data but, in contrast, movement of individuals or groups likely occurred.

At present, the origin of the BMAC, as well as the absence of early occupation in the region, remains problematic. Although the origins of the BMAC are beyond the present research, I argue that on the basis of the current data the emergence of the BMAC in the Murghab should be understood as an endogenous phenomenon within the wider interregional context of cultural and economic interaction that characterize southern Turkmenistan during the 3rd millennium BCE, and that its roots are more likely in the Namazga culture of southern Central Asia.

## 3.2 Settlement Systems and Architecture in the Murghab Region

The sites of the Murghab region have been grouped by Soviet scholars into nine main clusters (i.e., Egri Bogaz, Kelleli, Taip, Adji Kui, Auchin, Gonur, Adam Basan, Togolok, and Takhirbaj). These sites were located along the main river branches of the Murghab and were initially understood as "oases" separated by sand dunes (Sarianidi 1981:188; Masimov 1981: 218). This was the first model of the settlement landscape of the region. Subsequent research in the Murghab by the AMMD in the 1990s and 2000s led to a reassessment of the model. The intensive survey by the AMMD team suggested a well-watered and continuous agricultural landscape on the basis of a complex system of hundreds of sites, which contrasted with the theory of isolated oases (Gubaev et al. 1998) (but see section 3.4 in this Chapter for further discussion).

The main sites initially identified by the Soviet archaeologists included dense settlement clusters with fortified structures, such as Adji Kui 9 and Adji Kui 1, located only a few hundred meters apart. This settlement system, which developed during the Middle Bronze Age in the Murghab, was associated with an archaeological assemblage that is also found in Uzbekistan and Tajikistan (along the Amu Darya river) and parts of northern Afghanistan during the second half of the 3rd millennium BCE. This area has been defined as the "core" area of the BMAC and was characterized by specific objects, pottery, luxury materials, and architecture (Luneau 2019; Biscione and Vahdati 2021).

### 3.2.1 The Middle Bronze Age

The Middle Bronze Age spans between 2400 and 1950 BCE (see section 1.1 in Chapter 1 for a chronological discussion) and is considered the apex of the BMAC, or the "mature phase." At this time, Murghab societies engaged in substantial trade with societies in neighboring regions (Kohl 2007). It has been suggested that during the Bronze Age with the society had social stratification, imposing architecture, and a possible settlement hierarchy, although lacked a writing system (Salvatori 2008b:93; Lyonnet and Dubova 2021b:24). By contrast, other authors suggest a consolidated state rather than proto-state formations (Hiebert and Lamberg Karlovsky 1992; Hiebert 1994b:176).

### 3.2.1.1 Architecture, Economy, and the Political System

- **Architecture**

One of the most distinctive features of the BMAC is its architecture. Most of the well-known sites of the Murghab are fortified settlements with rectangular towers along the walls and at the corners, which eventually developed into circular towers during the Late Bronze Age (c. 1950–1500 BCE). One of the early examples is Kelleli 3, which shows a monumental rectangular fortress with an exterior double mudbrick wall and a single occupation phase (Hiebert 1994a:17) (Figure 3.1).

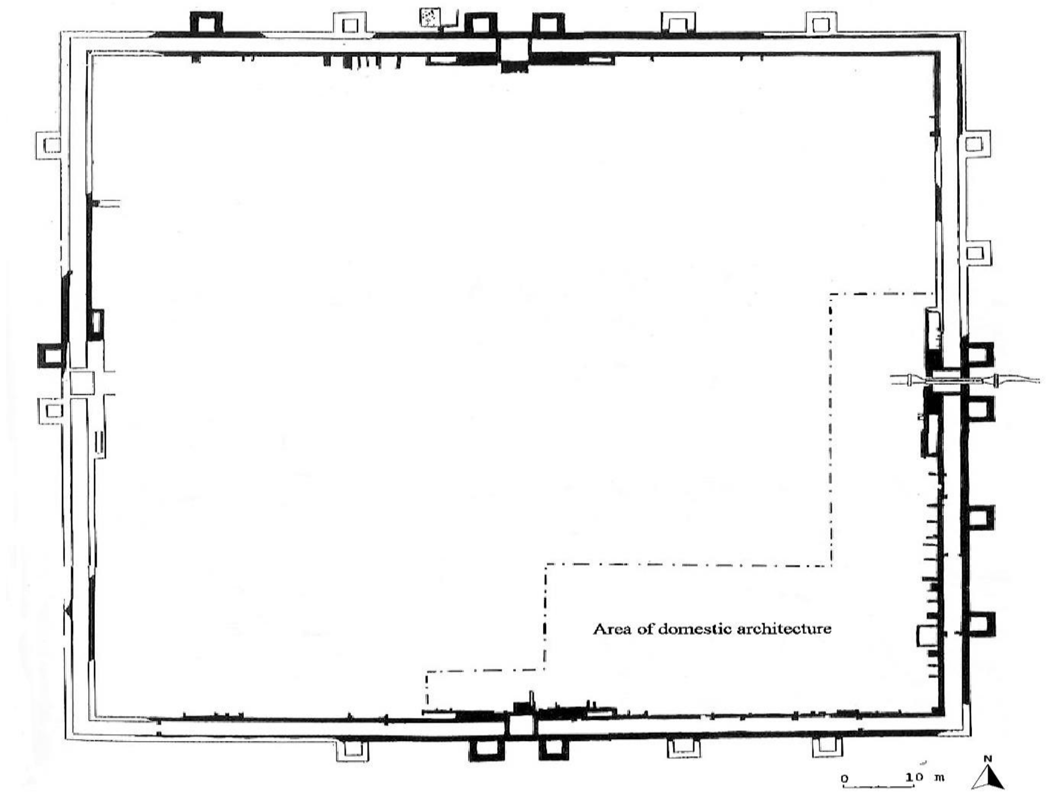


*Figure 3.1 Plan of the fortified site of Kelleli 3 (Hiebert 1994:Fig. 2.5).*

Similar to Kelleli 3, the Gonur North[19] palace has a double wall and a corridor inside with rectangular towers at the corners. The entrances are located in the middle of the walls and are protected by towers. Within the walls there is a fortified palace structure with a complex system of rooms and corridors (Sarianidi 2008a). Interestingly, the area within the outermost oval perimeter wall and the fortified building contains a water system. The excavators of Gonur North identified various water reservoirs in all phases of the complex in front of the gates (Sarianidi and Dubova 2012). According to Sarianidi, these reservoirs were filled with water from the Murghab River as well as rainwater. The largest water reservoir is located in the southern part of the site, within the external wall, while two smaller water reservoirs were located within the second perimeter wall of the citadel. Further, three more reservoirs are located in the north. According to Sarianidi, most of the water pools inside the main building served religious purposes, but evidence supporting this interpretation is scant. It is also possible that it served domestic needs. An in-depth examination of all the drainage systems and the possible direction of water at Gonur North has never been attempted. Possibly, the largest water reservoir located in the south (Figure 3.2) was fed by a canal(s), as the discovery of an artificial ditch in the southwest of the site seems to suggest (Sataev 2008). This canal is one of the few known examples of an artificial watercourse in the Murghab dated to the Middle Bronze Age.

An additional piece of water infrastructure consisted of ceramic pipes. The pipes are cone-shaped, so that one pipe fits into the other (Figure 3.3). The best-preserved pipes in Gonur North were found in the square of the main entrance of the palace. However, ceramic drainage pipes were also discovered in the south mound of Togolok 1 (period 2) and at Togolok 21. Similar to Gonur North, at Togolok 1, these pipes were possibly used for drainage (Hiebert 1994a:58). These drainage pipes show that BMAC communities were able to design sophisticated water systems.

---

[19] Gonur is divided into Gonur North and Gonur South, respectively dated to the Middle and Late Bronze Age.

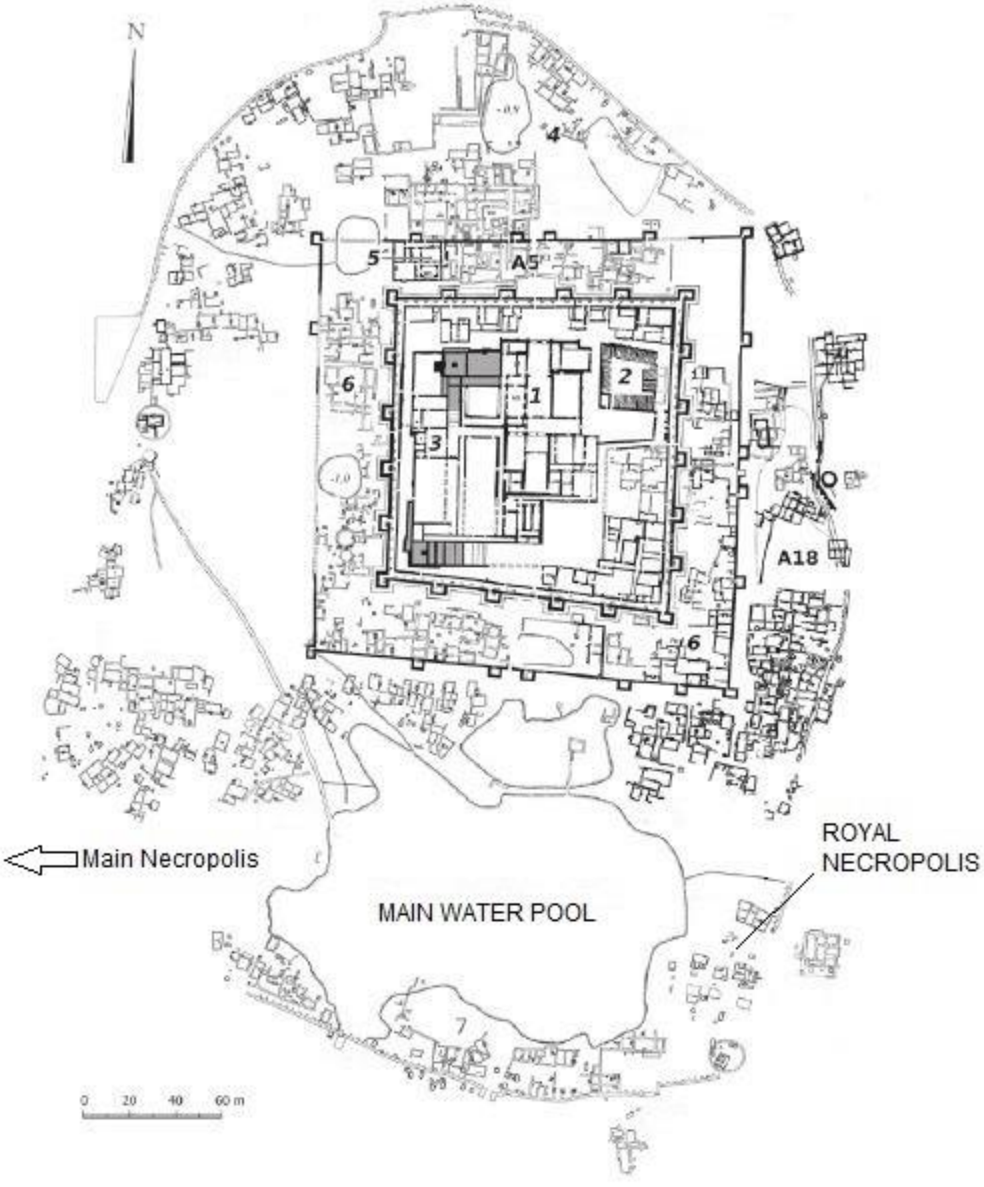


*Figure 3.2 The image displays the multi-phase structure of Gonur North, featuring defensive walls and a central structure referred to as the palace. South of the main complex, there is the primary water pool, while the "Royal Necropolis" is located in the southeastern corner (adapted from Lyonnet and Dubova 2021a:Fig. 10.1A).*

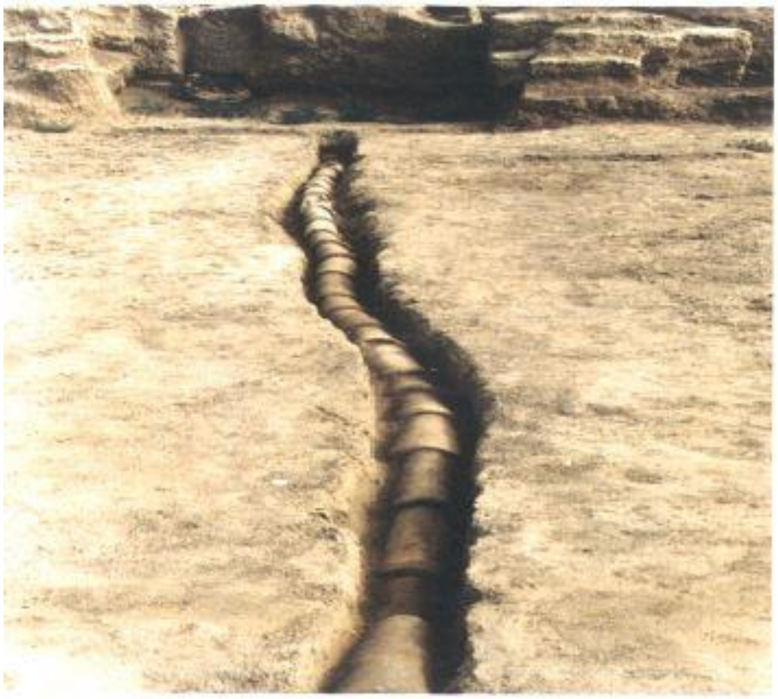


*Figure 3.3 Water pipes found in front of the main entrance at Gonur palace (Rossi-Osmida 2002: 25).*

Although the function of many rooms at Gonur North remains unclear, some were probably used to store materials, such as the parallel, narrow rooms in the northeastern part (Sarianidi 2005:83–87). Similar narrow structures have been identified at other fortified sites, such as Adji Kui 1 and Togolok 21, but also Dzharkutan and Sapallitepa in Uzbekistan, and some have brick-sealed entrances (Muradov 2021:151). Most likely, large sites, such as Gonur North, had granaries to store cereals, such as barley and wheat, cultivated in the nearby fields. These sites, might have had populations of more than 10,000 inhabitants (Markofsky 2010:280; also see chapter 7 for population estimation). However, populations were likely larger if one considers the presence of many satellite sites, like in the Gonur area.

- **Subsistence Economy**

In the absence of texts from the BMAC, its economy has been reconstructed from archaeological evidence. However, as has recently been pointed out by Lyonnet and Dubova (2021b:22), our knowledge about the BMAC economy is patchy, and the stratigraphy from excavated sites is often problematic. Nevertheless, botanical and faunal remains provide evidence for subsistence economies (Hiebert 1994a:130–137; Sataev and Sataeva 2014; Billings et al. 2022).

The evidence from Gonur suggests that a good proportion of the domestic economy was devoted to livestock breeding. The most common animals kept were sheep and goats, followed by cattle. Sheep and goats included mature animals most likely kept for secondary products such as milk or wool (Moore et al. 1994). They were also likely kept for their meat. Wild animals, such as gazelle and wild pigs, have also been found and were likely part of the diet (also see section 2.4 in Chapter 2). However, they constitute a minor component of the faunal remains, comprising less than 5% at Gonur and 7% at Togolok 1 (Sataev 2021a; Cerasetti et al. 2022). Other animals, such as Bactrian camels, horses, and donkeys, were also found, with donkey bones more common than horses (Sataev and Sataeva 2014). These animals do not seem to be part of the diet in Gonur, in contrast to the ovicaprines, as well as cattle, which represent the majority of the meat consumed[20] (Sataev 2021a).

The diet was also comprised of domestic crops, which have been found in abundance. These include barley, wheat, and pulses. Six-row barley (*Hordeum vulgare* subsp. *hexastichum*) is the most common cereal found in the Murghab both in the Middle and Late Bronze Age (Miller 1993). However, the naked form predominates at Gonur (Miller 1999). Among the wheat species, free-threshing wheat (*Triticum aestivum*) is the most common. It has been suggested that the choice of barley can possibly be related to water susceptibility as barley is more drought-resistant than wheat. Naked barley requires more water than the hulled form, but the post-harvesting processing is easier (Spengler 2019a:116). As for wheat, Moore et al. (1994) mention the presence of dwarf or short wheat (*Triticum sphaerococcum*) from the upper levels at Gonur, which is considered a South Asian variety and is more drought-resistant (Costantini 1977). All in all, the

---

[20] In Togolok 1 ovicaprine remains from Late and Middle Bronze Age layers show evidence of butchery marks (N. Amano, Analysis of Faunal Remains from Togolok 1, Adji Kui 1, and Chopantam, Unpublished Report).

adoption of more drought-tolerant crops, such as barley, might be indicative of a less humid environment, possibly already towards the end of the 3rd millennium BCE.

Other cultigens that have been found are chickpea (*Cicer arietinum*), lentil (*Lens culinaris*), and pea (*Pisum* sp.) (Sataev and Sataeva 2014). In addition, evidence of grapes (*Vitis vinifera*) and possibly apples and plums were identified at Gonur, suggesting the presence of orchards in the area (Moore et al. 1994). The presence of these crops seems to be constant throughout the Middle and Late Bronze Age in the Murghab. By contrast, millet (*Panicum miliaceum*) is only attested so far in Late Bronze Age layers (see section 3.3 of this Chapter).

While a significant portion of the botanical and archaeozoological data from the BMAC originate from Gonur, which could potentially bias our understanding, evidence from Togolok 1 appears to show similar patterns (Billings et al. 2022; Cerasetti et al. 2022). As such, the data suggest that the subsistence economy of the larger sites was diverse. Besides meat, the economy was supported by the substantial consumption of cereals that dominated the botanical assemblages. Cereal cultivation (mainly wheat and barley) was accompanied by the presence of various legumes, including garden fruits, such as grapes. These were part of an integrated system in which cereal fields were combined with vegetable and garden areas, likely divided into zones. This suggests an agricultural system in which irrigation served to support different crops at various times of the year (Lamberg-Karlovsky 2013).

Most of the botanical data available in the Murghab, however, are from larger mounds. The survey data from the AMMD show the presence of several sites and hamlets across the landscape that might been involved in other types of crop cultivation (see section 3.4 of this Chapter for discussion). In fact, the data from the two excavated rural sites of Ojakly and Chopantam show less diverse botanical assemblages in comparison to larger sites such as Gonur. Moreover, these rural assemblages have a more common presence of millet which might indicate different agricultural practices. Nonetheless, most scholars have reconstructed agricultural practices during the Bronze Age as homogenous across the Murghab (Salvatori 2008a). The possible diversity of land exploitation is, therefore, of crucial importance for understanding the BMAC. These aspects will be further discussed in Chapter 7.

- **Political System**

The political system of the BMAC has been the subject of various studies (Sarianidi 1990a; Hiebert 1994a; Lamberg-Karlovsky 2003; Salvatori et al. 2008). Interpretations of the Middle and the Late Bronze Age systems have mostly been based on settlement systems (Sarianidi 1990a; Salvatori and Tosi 2008). Likewise, a political system dominated by BMAC elites has been put forward on the basis of graves found at the Gonur North necropolis (Sarianidi 2010a). The richest burials take the form of chamber tombs[21] and cists (Dubova 2021) (which account for only 5% of the 2853 graves in total). The area where these burials were found is referred to as "royal necropolis" of Gonur North, separated from the main necropolis to the west of the settlement (Figure 3.2).

The "royal necropolis" includes several tombs with valuable grave goods. Of exceptional wealth is tomb 3220, which is an underground chamber with supporting walls and a roof (Sarianidi 2006:169). In this tomb, 24 metal vessels were found in gold (2), silver (17), and bronze (5) (Sarianidi 2008a:161; Sarianidi 2008b). In addition, a gold plate and a gold jug with a narrow neck (weighing 1 kg), together with agate beads, were also found, along with large silver vessels with two walking camels in relief (Sarianidi 2005). In some of the chamber tombs, a wooden container (not preserved) decorated with mosaic inlay was also found together with ivory objects (see Dubova 2021:table 10.1, for an exhaustive list).

Interestingly, a four-wheeled wagon was found in tomb 3200 next to the remains of a horse (Sataev 2021b:390). These rich graves, along with fortified citadel within the sites resembling a palace, have been interpreted as evidence of a stratified society with elites[22] (Sarianidi 1990a; Hiebert 1994a; Salvatori et al. 2008; Lamberg-Karlovsky 2003;

---

[21] The chamber tombs are sometimes reported as hypogea in the "royal necropolis" (Dubova 2021).

[22] In contrast to Sarianidi's interpretation, the area of the "royal necropolis" has been interpreted by Lamberg-Karlovsky (2013), as houses with burials underneath the floor.

Francfort 2009). According to Vidale (2017:23–25) the stories of the BMAC elites and their lifestyles are also represented on the BMAC silver objects.

These elites were possibly supported by an embryonic administrative structure. The presence of sealed bullae, geometric tokens, and BMAC-type compartmented stamp seals all suggest the presence of an (early) administrative system, although evidence of an administrative use of these objects has only been documented at Taip 1 and Gonur North (Sarianidi 1998a:23; Sarianidi 1998b; Masimov and Salvatori 2008:106–107).

According to Lamberg-Karlovsky (1994a) the presence of fortified buildings with towers and double walls, such as those at Kelleli 3 or Gonur North, may be compared to later 19th-century *khanates* of Central Asia. The Khanates are understood as an administrative polity ruling over a circumscribed territory from a fortified center that was also the residence of a local *Khan* (Lamberg-Karlovsky 2013). One example of these residences may be Adji Kui 9. The site is located northwest of Gonur and is a typical BMAC doubly fortified settlement with an inner fort. East of Adji Kui 9, at a short distance, the site of Adji Kui 1 was a similar fortified settlement with towers but with individual houses only, with a separated "farmstead" to the south of the site (Figure 3.4). Adji Kui 9 is interpreted by Rossi-Osmida (2007:119) as a possible residence of elites (Lamberg-Karlovsky 2013). Within a system characterized by fortified settlements and elites, the control over the water resources and agricultural areas might have involved tribal rules, according to Lamberg-Karlovsky (2016:42). However, archaeological evidence to support this idea is limited. Crucial aspects of the possible complexities of land exploitation, agricultural production, and water management, and their relationship with the socio-political system remain largely unexplored.

The presence of a "royal necropolis" with rich burials at Gonur North, and its fortification system, which is the largest in the Bronze Age Murghab, could suggest that Gonur possibly played an important political and economic role in the Middle Bronze Age (but see section 3.4 of this Chapter for discussion). Nevertheless, how this translates into control over the landscape and water is unclear. Certainly, the Middle Bronze Age system went through a radical change at the beginning of the 2nd millennium BCE. Both in the Murghab, as well as in the Kopet-Dag, many settlements were abandoned, and there was a visible contraction of settlement clusters (Kohl 1984:135–138; Salvatori 2008a).

This settlement transformation has been interpreted as a "political crisis" that eventually resulted in a de-centralized system in which Gonur was no longer the main site (see the section below and section 3.4 for discussion) (Salvatori 2008a:66; Cerasetti and Luneau, forthcoming). However, Lamberg-Karlovsky (2013:58) is right in asking whether BMAC communities ever had a unified polity or consisted of a series of regional political entities both in the Middle and Late Bronze Age. The investigation of how the local landscape, water, and the agricultural system were managed can contribute to this broader discussion and will be continued in Chapter 7.

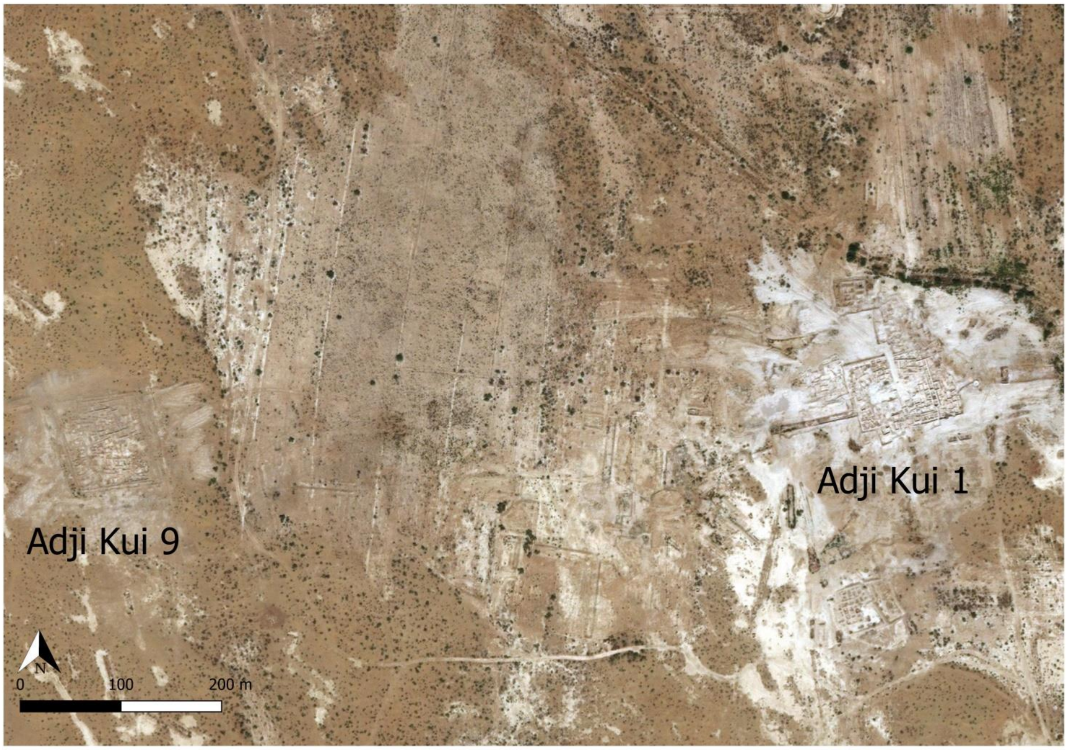


*Figure 3.4 The satellite image (Landsat 8, 2019) depicts the sites of Adji Kui 1 (on the right) and Adji Kui 9 (on the left), situated relatively close to each other. Adji Kui 9 features a fortified fortress. Between the two sites lies a necropolis that was shared by both settlements.*

### - Ceramic Assemblages

In this study, it is important to highlight that pottery chronology remains challenging in the Murghab. Udeumuradov (1993) and P'yankova (1993) offer insightful analyses of Murghab ceramics; however, the Namazga pottery chronology often remains inadequate and lacks regional divisions. Particularly valuable is the pottery analysis conducted by Hiebert (1994a:39–73) at Gonur North, which provides a useful chronological sequence divided into local periods (periods 1, 2, and 3). However, Hiebert's chronological sequence was published in 1994 and since then only new few publications have appeared (but see Udeumuradov 2002; Luneau 2010). The later AMMD publications (Gubaev at al. 1998; Salvatori et al. 2008) provided additional information on the pottery sequence both for the Bronze Age and later periods with useful tables from other excavations, including ICW (Andronovo) pottery (Cerasetti 1998). In the AMMD publications, the late phase of the Bronze Age is divided into the Late and Final Bronze Age (1950–1500 and 1500–1300 BCE). This division is mainly based on the analysis of materials from the Takhirbaj 3 site (i.e., Takhirbaj 3 phase) which is dated to the last phase of the Bronze Age (Cattani and Salvatori 2008). In this study this chronological division between the Late and Final Bronze Age is taken into account.

On the basis of Hiebert's study of Gonur North, during the Middle Bronze Age pottery can be divided into two main periods (Period 1 and 2) characterized by different pottery typologies. These typologies can be divided into four main categories (see Figure 3.5 for the pottery typology of Period 1 and 2). The small vessels are primarily identified by having rim diameters smaller than 15 cm, encompassing items such as bottles, miniature vessels, and small bowls or cups. Large thin vessels, with a general diameter between 15 and 45 cm, represent the main category. This category includes several types, such as thin-shouldered vessels with an upper sherd body thickness ranging from 0.35 to 0.65 cm (Hiebert 1994a:46). Within the additional category of large thick-walled vessels, there are two distinct forms: closed forms primarily intended as storage vessels, and open forms, which may sometimes feature decorations and are less likely to be used for storage purposes. The last main category comprises large storage vessels with very thick walls.

Among this category, the major forms are wheel-made jars with a large base, generally over 70 cm. It is also interesting to note that some of these forms can be taller than 1 m (Hiebert 1994a:56).

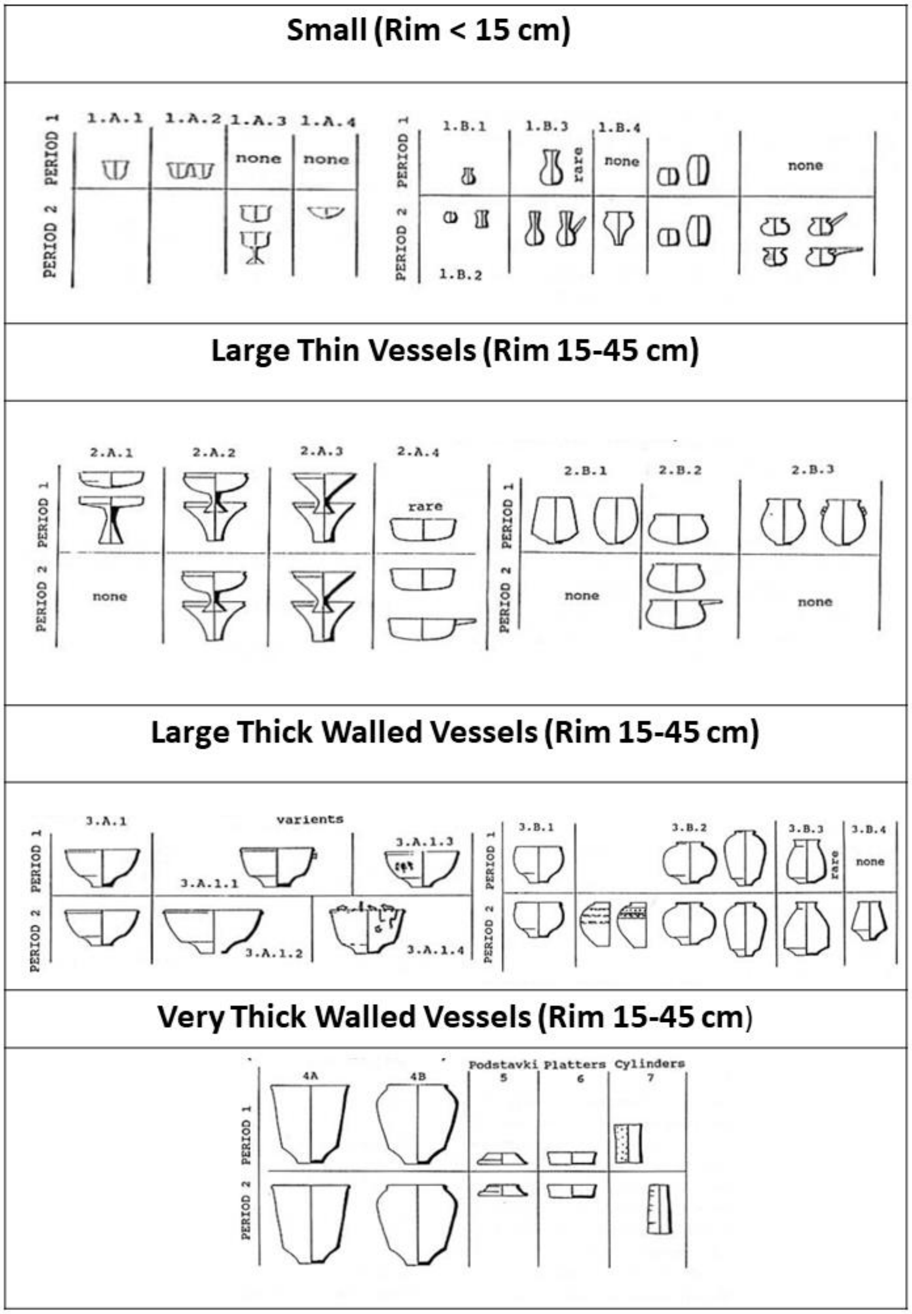


*Figure 3.5 The ceramic typology of Periods 1 and 2, as analyzed by Hiebert from the deep sounding at Gonur North (adapted from Hiebert 1994a:Fig. 4.35).*

Both Periods 1 and 2[23] are characterized by a medium-fine paste with chaff temper. While in Period 2 there is well-sorted fine quartz temper, in Period 1 there is no sand in the temper. The wheel-made pottery ranges from light red to reddish buff (Hiebert 1994a:41). However, Period 1 ceramics seem less red than those of Period 2, while in a domestic context, many pottery pieces have a greenish exterior due to over firing. According to Hiebert (1994a:67) these greenish ceramics have been found in great numbers and were used regardless of having been misfired.

The majority of the ceramics from both periods are undecorated. However, among the decorated ones in Period 1, the most frequent design is horizontal bands around the shoulder and body, while Period 2 vessels that present decoration are generally characterized by reddish-brown paint only. In addition to decoration, potter’s marks are also found in Period 2, although they are not very common. Most of these marks have geometric figures and are found on the side or lower shoulder, base, or bottom part, but also inside the vessels. Likewise, seal impressions – made on vessels prior to firing – with several motifs have been found in a small percentage, although their function is not clear (Hiebert 1994a:59–61).

Of particular interest among the large vessels with thick shoulders are the basins with terracotta rim decoration. These vessels, characterized by a series of small figures, animals and humans on the rims, have been found at different sites in Margiana and Bactria, and in Gonur occur in Period 2. According to Hiebert (1994a:53) the figures on the rims have a particular order, suggesting a possible narrative (Figure 3.6). In addition, according to Sarianidi (1990a), these particular vessels were used during rituals and ceremonies, such as libations.

---

[23] Unfortunately, there are no $^{14}C$ dates for this two periods and division of these periods based on dates are not provided in Hiebert’s publication.

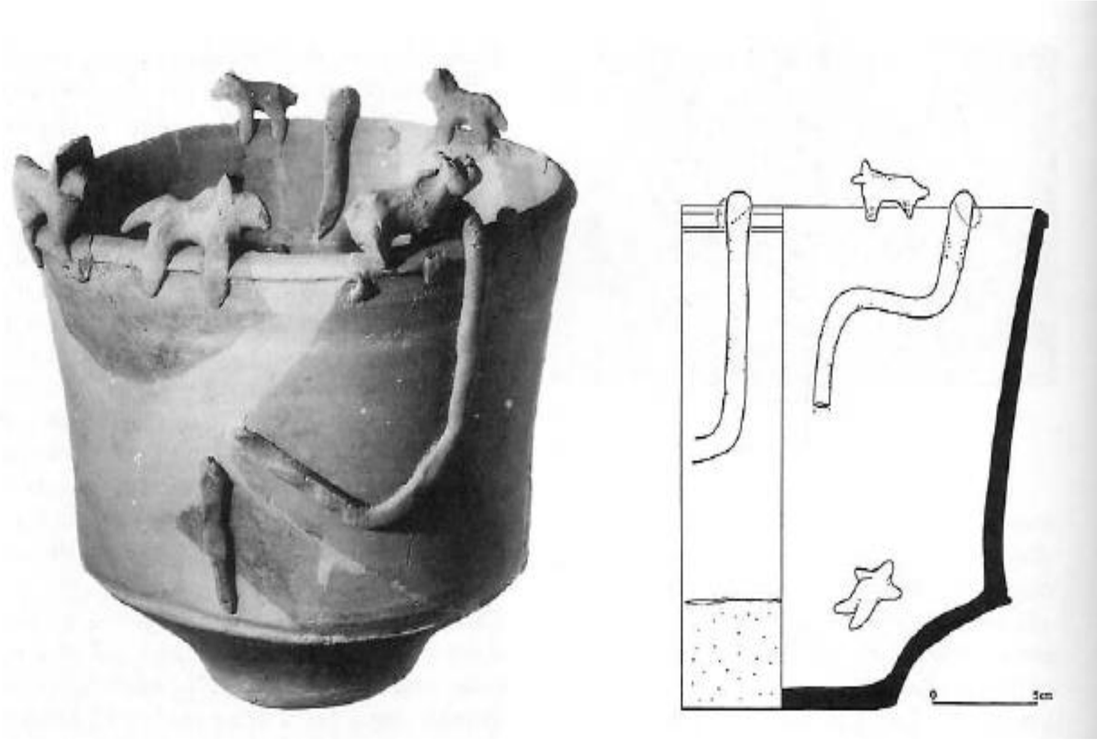


*Figure 3.6 The figure shows a Period 2 vessel with terracotta figurines applied from Togolok 1 (Hiebert 1994:Fig. 4.20).*

### 3.2.1.2 The Late and Final Bronze Age and the “Collapse” of the BMAC

The Late and Final Bronze Age (1950–1500 and1500–1300 BCE) show a considerable decrease in the size of the major settlements and their architecture, as well as an important change in settlement patterns in the Murghab, including the appearance of small settlements (see section 3.4 of this Chapter for discussion on settlement patterns). However, this change does not oppose a shift in the BMAC subsistence economy. Botanical data shows the same cultivated crops as for the previous period, such as barley, wheat, pulses, and garden fruits. Likewise, the recent archaeobotanical analysis from layers radiocarbon dated to the Late Bronze Age from Togolok 1 suggests continuity in crop production (Cerasetti et al. 2019). However, differences in agricultural exploitation existed between dense settlement clusters and rural areas, as I will argue later. In addition, starting from the early 2nd millennium BCE, there is decisive presence of broomcorn millet (Miller at al. 2016:1571). Millet, which is a more drought-tolerant crop than barley and wheat, was recovered from rural areas such as Ojakly and Chopantam, and from impressions on a vessel from the fortified sites of Gonur North and Togolok 21 (Bakels 2003). More recently, evidence of millet has also been found at Togolok 1 from Late Bronze Age layers (Billings et al. 2022). Interestingly, millet is also common at the site of Shortughai in Bactria during this period (Willcox 1989:175–183).

Similar to crop farming, animal husbandry – mainly sheep and goat – did not undergo much change during this period (Salvatori 2008a). It appears that the subsistence economy did not experience radical changes. However, as this thesis will argue, although agricultural management of water resources underwent radical change (see Chapters 5 and 6).

The Late Bronze Age is characterized by the presence of round towers along fortified buildings, such as at Togolok 21. The general architecture plan with very thick exterior walls, such as in Gonur South, and a fortified building at the center is maintained during this period in the Murghab, but we see a marked reduction in the size of large, fortified settlements. This transformation was characteristic not only for the Murghab but also for the Kopet-Dag (refer to section 3.4) (Hiebert 1994a:114–155).

Between ca. 1750 and 1400 BCE, there is also a significant change in the material culture of the BMAC. Prestige goods such as metal ornaments, but also precious and semi-precious stones, became rare, as well as weapons. The terracotta violin-shaped figurines, characteristic of the Middle Bronze Age (Salvatori 2002:107–113; Forni 2017), disappear during this period (Masimov et al. 1998:34). Conversely, there is the appearance of miniature metal objects in graves, such as metal disks or weapons (Luneau 2021a:501, Fig. 18:3). Luneau (2021a) argued that it is a *qualitative* decrease in the objects and imagery that reflects a change in BMAC society. Objects in burials are fewer and of lesser quality compared to those of the Middle Bronze Age (Luneau 2021a: 505). In southern Uzbekistan and Tajikistan, the amount of tombs without bodies seems to increase (Bendezu-Sarmiento and Lhuillier 2019; Dubova 2021). During the Late phase of the Bronze Age, there is also a change in the ceramics. These are now red-burnished wares, with a red slip and sometimes incised decoration (Hiebert 1994a:71; P’yankova 1993). Red-burnished wares are typical of the Namazga VI period. The goblets from this period have a distinctive ridge below the rim, while an inturned rim is observed in the large vessels with the appearance of distinctive cups as well (Hiebert 1994a: 71, Fig. 4.40) (Figure 3.7). Like in the previous Middle Bronze Age, wheel-made ceramics predominate over hand-made pottery. However, Luneau (2021a:501) argues that this distinction in percentage between hand and wheel-made pottery might need to be reevaluated in light of recent excavations; for example, at the site of Saredjar 2 in Tajikistan, most of the assemblage (85%) is hand-made pottery. According to Luneau (2021a), during this period, there is a strong regionalization of pottery. However, the ceramic assemblages and chronologies of the BMAC remains poorly documented. This is also reflected in the lack of further regional subdivisions.

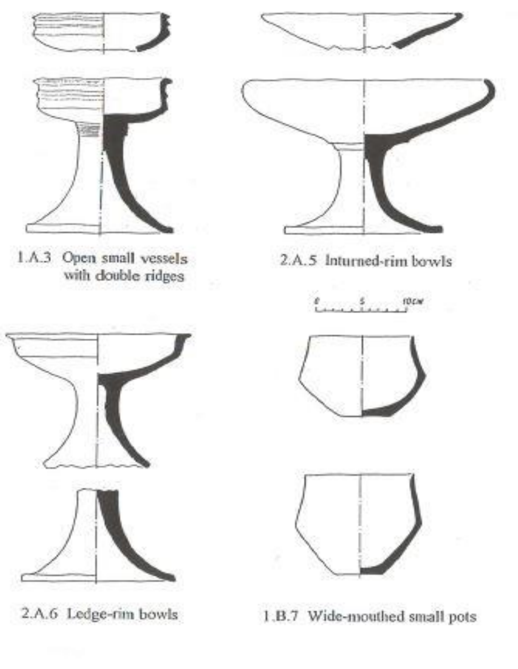


*Figure 3.7 Ceramic forms from Takhirbaj 3 (Hiebert 1994:Fig. 4.40).*

One significant change from the Late Bronze Age in the Murghab is the presence of the "Andronovo" (ICW) ceramic assemblages, which are different from Namazga pottery. These assemblages are further discussed in section below; however, what is important here is that the presence of these assemblages is indicative of a possible intensification in cultural and economic contact with the northern regions, not attested during the preceding period (Kuz'mina and Lyapin 1984).

The architectural shifts, reduction in the size of large, fortified sites, and the notable decline in luxury goods during the Late phase of the Bronze Age have frequently been interpreted by scholars as being indicative of a "collapse" in the economic, social, and political system of the BMAC. However, as argued by Luneau (2019; 2021a), this so-called collapse should be best viewed as a long "transformation" of BMAC society, rather than a social collapse. Certainly, the reduction in luxury goods mark a discontinuity in the local "elites" and suggest a reduction in trade (Cerasetti and Luneau, forthcoming).

While a thorough examination of the origin and evolution of the end of the BMAC lies beyond the scope of this dissertation, it is important to acknowledge that the reasons for these changes are likely complex and diverse. Of particular relevance for the present research is the transformations that took place in its hydrological landscape and their implications for crop cultivation and irrigation practices.

## 3.3 The "Andronovo" Presence in the Murghab Region

These "Andronovo" or Incised Coarse Ware (ICW) assemblages in the Murghab are mainly attested from the Late Bronze Age. These assemblages with affinities to "Andronovo" materials from the northern regions has been linked by various scholars to Andronovo communities, often associated with pastoral groups in Central Asia[24] (Hiebert 1994a; Cattani 2008b; Rouse and Cerasetti 2014). The term "Andronovo" broadly encompasses a diverse range of steppe communities stretching from western Mongolia

---

[24] However, Andronovo sites in Uzbekistan, for instance, are not always linked with pastoral activities.

and the Urals to southern Margiana and northern Afghanistan, including Tajikistan, Uzbekistan. While each group has its own unique characteristics, they share commonalities in funerary practices, material culture, and subsistence economy (Bonora 2021). These Andronovo (ICW) ceramics predominate at rural and ephemeral sites in the Murghab. This evidence has been interpreted as indications of pastoral groups interacting with large BMAC sites (Cattani 2008b; Hiebert and Moore 2004).

The presence of these Andronovo (ICW) assemblages has also been linked with the "collapse" of the BMAC discussed above (Kuz'mina and Lyapin 1984; Vinogradova and Kuz'mina 1996). However, no traces of destruction, intentional burning, or conflicts have been observed in the archaeological record of the Murghab sites, nor in the Kopet-Dag region, where sites also show Andronovo (ICW) assemblages (Biscione 1977). By contrast, these assemblages have been interpreted as evidence for peaceful interaction between BMAC agriculturalists and Andronovo groups in the region (P'yankova 1993; Masson 2002; Salvatori and Tosi 2008).

Further interpretations of the Andronovo (ICW) pottery in the Murghab focus on trading contact. These ceramic assemblages have been interpreted as an intensification of trade with north and northeastern regions during the 2nd millennium BCE (Lyonnet and Dubova 2021a; Luneau 2021b). In neighboring regions, such as the Zeravshan Valley in Uzbekistan, archaeological evidence suggests that several Andronovo sites were directly involved with the exploitation of metal-bearing deposits (Avanesova 2021:667). These sites do not present characteristics of mobile or semi-mobile settlements, but are nevertheless characterized by Andronovo material culture. The region of these sites contains significant ores and minerals, including copper, silver, gold, lead, and especially tin. Metallurgical activities by Andronovo groups are well attested through site excavations (Kuz'mina 1991; 1994:137–146; 2007:85–99; Boroffka et al. 2002; Garner 2021:799). Recent analyses of metal objects from the BMAC found that during the BMAC "mature period" (ca. 2250–1700) copper arsenic alloys were most common. In the Late Bronze Age, however, this was substituted by tin bronzes with a low arsenic content and unalloyed copper (Kraus 2021). According to Lyonnet (2005) this change in the composition of metal objects is indicative of a change in metallurgical production that might link up with a possible intensification of contact with Andronovo groups involved in metal production in the neighboring region. However, in the Murghab, only a few sites associated with Andronovo (ICW) assemblages have been excavated, and none of these show evidence for metallurgical activities or ingot trade. Nevertheless, data from the Central and West Asia region suggest that long-distance metal trade did occur, as the recent analysis on Uluburun shipwreck tin suggests (Powel et al. 2022).

Although Andronovo (ICW) pottery in the Murghab is now well attested, these assemblages were initially considered marginal by Soviet scholars who found little of this material in fortified sites. They initially labeled these ceramics as "steppe" material (Kuz'mina and Lyapin 1984; Sarianidi 1975; 1990a). However, the surveys carried out by the AMMD between the 1990s and 2000s revealed a substantial occurrence with 74 sites characterized by "Incised Coarse Ware" (ICW) ceramics.[25] This pottery is characterized by hand-made grog-tempered pottery often with incised decoration (Figure 3.8).

*Figure 3.8 Typical hand-made "Andronovo" (ICW) pottery from the Chopantam site (previously called site 1211/1219) with fragments of wheel-made pottery (Cattani 2008a:Fig. 9.6).*

---

[25] There are 175 sites that present both Namazga and Andronovo (ICW) ceramics.

It has been argued that this hand-made and incised pottery is similar to the Tazabag'yab (Andronovo) groups in the southern delta of the Akchadar'ya in Khoresmia (Cattani 2008b). Recent XRD/XRF and petrographic analyses conducted on both wheel-made BMAC pottery and hand-made Andronovo (ICW) pottery from Ojakly suggest, however, that these two assemblages were produced from the same clay source (Rouse et al. 2019). As such, Andronovo (ICW) pottery in the Murghab was likely locally made rather than imported from Andronovo regions. However, current archaeological data from the Murghab do not provide evidence for any large pottery production areas, but rather possible small household pottery production, such as at the Ojakly site (Rouse and Cerasetti 2014).

Although the presence of two distinct assemblages in the Murghab from the Late Bronze Age is clear, many research questions remain about the people who used and made these assemblages and to what extent they were distinct groups. Likewise, we need to question the direct relation postulated between Andronovo (ICW) pottery and a specific type of subsistence economy (i.e., pastoralism for Andronovo (ICW) pottery sites and agriculture for BMAC pottery sites) (Hiebert 1994a; Kuz'mina 2007; Salvatori et al. 2008; Lamberg-Karlovsky 2013; Lyonnet and Dubova 2021a; Luneau 2021a). Nevertheless, the presence of these assemblages in the Murghab is of key importance, and the few rural "Andronovo" (ICW) sites excavated in the region deserve a short discussion.

### 3.3.1 Excavated Rural Sites in the Murghab

As briefly discussed in section 3.2, most of the archaeological research conducted in the Murghab has concentrated on larger sites, while excavation of rural, as well as small Andronovo (ICW) sites, has been less central. Yet, archaeological evidence from the last two decades suggests that Andronovo (ICW) sites cannot be regarded as marginal, as almost 74 sites with these assemblages have been recorded by the AMMD. While the discussion on the rural Andronovo (ICW) site of Ojakly will occur in Chapter 5, here I will briefly discuss data from two more excavated rural sites in the Murghab.

- **Gonur-N.**

The site of Gonur-N is located approximately 1 km southwest of the large site of Gonur South in a dune area. The site is dated to ca. 1800–1500 BCE and was characterized on the surface by a predominance of hand-made incised pottery (85% out of 150 sherds collected) (Hiebert and Moore 2004). The rest of the pottery (15%) consisted of wheel-made BMAC-Namazga pottery. The excavation of a test trench of 1 m by 1 m revealed a 90 cm deposit of fine sand overlying layers with in-situ incised hand-made pottery with a few wheel-made BMAC ceramics that matched the pottery found on the surface. The excavation did not show any evidence of possible permanent occupation, such as mudbricks or floors, either on the surface or in the test trench. However, this may also be related to the relatively small size of the excavated trench.

The wheel-made ceramics found at the site are characterized by large tableware shapes, including plates, cups, and tall-footed goblets. According to Hiebert and Moore (2004), the evidence suggests that Gonur North was possibly a seasonally occupied site with no evidence for agriculture. As such, the excavators argued that the Gonur N community was solely engaged in pastoral activities and possibly exchanging products with the nearby site of Gonur.

Interestingly, the site of Gonur-N is situated close to a low ridge interpreted as a paleochannel. The site is located less than 250 m from the current watercourse in an area with a large ceramic scatter (Figure 3.9) (Hiebert and Moore 2004:Fig. 1). According to Wilkinson (2014), these ceramic scatters in the Murghab might be associated with manuring practices. In that case, the site would have been located close to agricultural fields suggesting a possible involvement in agriculture.

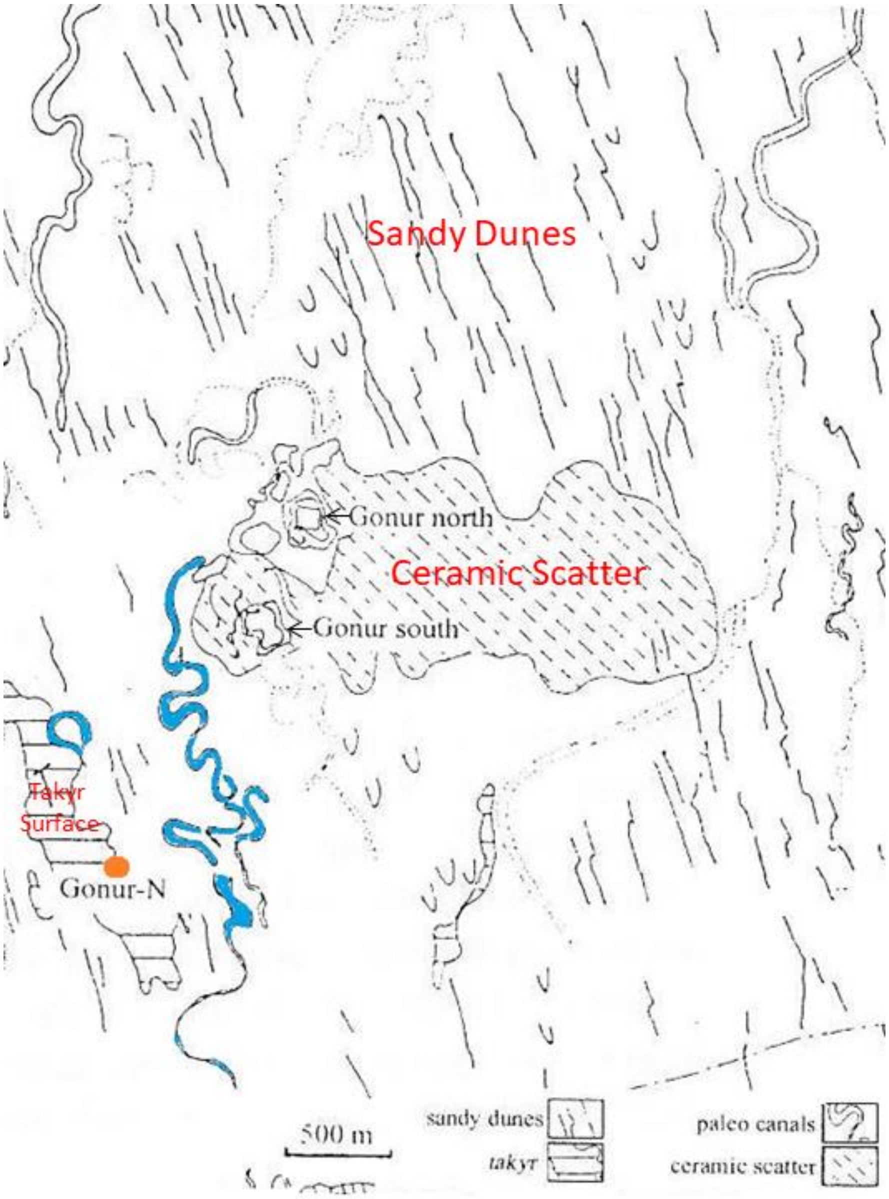


*Figure 3.9 The map shows the location of Gonur N (in orange) and its relationship with agricultural fields and paleochannels (in blue) (adapted from Hiebert and Moore 2004:Fig. 1).*

- **Chopantam**

The site of Chopantam (also published as site 1211/1219) is the southernmost rural site excavated in the Murghab and is located 10 km southeast of the large site complex of Takhirbaj. Unlike the site of Gonur-N, Chopantam is not located in close proximity to any large, fortified centers. The site has various occupation phases and has both

Andronovo (ICW) ceramics and wheel-made Namazga pottery. However, Andronovo (ICW) sites are predominantly characterized by ICW ceramics.. The radiocarbon analyses from Chopantam date the site to ca. 1550–1300 BCE (Cattani 2008a).

In trench 2, the excavators found a sunken dwelling unit at approximately 50 cm depth with vertical walls and an entrance formed by a step (Cattani 2008a:129). Several post-holes were also found, which were probably supporting a roof structure with posts. The dwelling has a circular hearth and a sequence of two ovens.

Findings from Chopantam comprise a grinding stone and several vessels. Three of these vessels contained remnants of charred cereals (*Triticum and Hordeum*) and were found in a pit which was probably there to store them. As such, the area has been interpreted as a cereal storage and processing area that was exposed to fire before it was abandoned. Additional archaeobotanical analysis at Chopantam also showed the presence of other cereals (*Hordeum vulgare, Triticum aestivum/turgidum*), as well as millet (*Panicum miliaceum*) and domestic pulses (*Pisum sativum*, *Lathyrus sativus*, and *Lens culinaris*) (Spengler et al. 2014:Table 2).

At the southern limit of the site, the excavators found an ancient water channel that was not visible on the surface (Cattani 2008b:125). The inactivity of the channel appears to have occurred before or during the life of the site. The presence of pottery and charcoal in the channel has been interpreted by the excavators as an indication of an anthropogenic origin of the watercourse (Ninfo 2007). The stratigraphic sequence of the channel includes a stage of reactivation after a dry period, which might suggest human management of the channel. However, this evidence does not explicitly point to an anthropogenic origin of the channel, as natural channels can also be managed (see Jotheri 2018 for more discussion).

The presence in Chopantam of domestic crops, storage areas, and food processing tools suggest that the inhabitants were involved in farming activities. As such, the people that were living at Chopantam can be best interpreted as “agropastoralists” with strong pastoral component. Likewise, the stratigraphic analysis of the channel, suggesting possible management (Ninfo 2007) and its proximity to the site, may suggest that inhabitants of Chopantam used its water for agricultural activities. However, the presence of a semi-subterranean dwelling and post-holes, as well as the predominant presence of Andronovo (ICW) pottery, has been linked to pastoralism by the excavators (Cattani 2008b).

In conclusion, the evidence from Chopantam suggests that both crop cultivation and pastoral activities were likely practiced at the site. The significant presence of millet may indicate low-investment agriculture within an environment marked by heightened aridification by the latter half of the 2nd millennium BCE (Cremaschi 1998).

### 3.3.2 Urban–Pastoral Interaction and Local Models of Variability

The question of the interaction between the groups associated with sites that show a predominance of Andronovo (ICW) pottery assemblages and sites with BMAC assemblages (Namazga pottery) has been discussed by various scholars (Sarianidi 1990a; Vinogradova and Kuz'mina 1996; Cattani 2008b; Cerasetti 2012; Rouse 2020; Doumani Dupuy et al. 2021). However, the nature of this interaction is still unclear (Cerasetti 2021).

On the basis of the survey and excavations conducted in the region, it appears that, starting from the Late Bronze Age, the Murghab was characterized by the coexistence of two distinct pottery assemblages: the Namazga hand and wheel-made pottery and the incised hand-made "ICW" or "Andronovo" pottery. Andronovo (ICW) ceramics are present at many sites in the Murghab and their occurrence outside of their primary geographical distribution has been interpreted by various scholars as evidence for "steppe-related" pastoralist groups in the Murghab. While this hypothesis is plausible, it oversimplifies the association between ceramic assemblages and human populations. Based on this hypothesis, Andronovo (ICW) sites have typically been linked with pastoralist groups settled near pre-existing concentrated settlements (Sarianidi 1975;

Kramer 1977; Vinogradova and Kuz'mina 1996; P'yankova 1989; 1993; Hiebert 1994a:69; Cattani 2008b). Their location also suggests that interaction with dense settlement areas was common. Nevertheless, the distinction between the two pottery assemblages and the communities using them has been interpreted as representing clear boundaries between lifestyles and economies in the Murghab (Doumani Dupuy et al. 2021). From one side BMAC sites are mainly devoted to agriculture, and on the other Andronovo (ICW) sites are mainly engaged in pastoral activities (Salvatori at al. 2008). However, botanical remains show that rural sites with Andronovo (ICW) pottery were also engaged in different forms of crop cultivation, and their subsistence economy cannot be ascribed as fully pastoral on the basis of pottery assemblages alone. The subsistence economy was influenced by local resources, such as water availability, both for BMAC and Andronovo (ICW) pottery sites in the Murghab as I will argue later in this thesis. As such, diverse agricultural and water exploitation strategies by local communities (both Namazga and Andronovo (ICW) pottery sites) were probably in place in the Murghab and will be discussed in Chapter 7.

Recently, in parallel to Petrie's (2019) paradigm of the Indus Civilization being a cultural "veneer" of urban centers, Rouse (2020) has argued that a similar Oxus veneer existed and probably intensified in a de-urbanized context of the Late Bronze Age (also Luneau 2021a). Similar conclusions about different agricultural strategies have also been recently proposed for the Indus Civilization (Bates and Choi 2023). In this context, delving into the examination of local sites within their broader landscape context becomes imperative in order to unravel the genuine difference in agricultural and water management strategies. Such an approach allows for a more comprehensive understanding of how various factors such as hydrology and land use practices interact to shape agricultural systems and water management techniques within a given region. By considering the wider landscape context, we can discern the nuances in agricultural practices and water resource utilization across different sites, contributing to a more nuanced and accurate interpretation of past human–environment interactions.

### 3.3.3 Millet Cultivation and Agricultural Variability

The spread of millet (*Panicum miliaceum*) cultivation across Central Asia seems to have occurred in the second half of the 1st millennium BCE (Frachetti 2012; Miller et al. 2016). However, Spengler and Willcox (2013) suggested that broomcorn millet may have been introduced into the region at the end of the 3rd to early-2nd millennium BCE, and the Murghab has some of the earliest evidence for millet at the sites of Ojakly, Chopantam, and Adji Kui 1 (Spengler et al. 2014; 2018). Possible evidence of millet is also attested from vessel impressions from Gonur North and Togolok 21, while more recently carbonized millet seeds have been discovered in Togolok 1 as well (Billings et al. 2022; Bakels 2003; contra Meyer-Melikyan and Avetov 1998).

Millet in the Murghab is mostly attested at rural sites and has been suggested that contact with northern steppe groups was possibly instrumental in the introduction of this crop in the region (Spengler et al. 2014). The use of millet for a low-investment agriculture has often been associated with mobile groups in Eurasia (Pashkevich 2003). Perhaps millet was used for opportunistic farming at seasonally occupied sites. In this context, millet requires less labor and land investment and has comparable yields to barley and wheat, a short growing season and, generally, less water demand. The aridification process that seems to have characterized the Murghab in the 2nd millennium BCE, and possibly earlier, may be consistent with the introduction of a more drought-tolerant crop like millet (Spengler et al. 2014). Likewise, the cultivation of this crop could have also been used to mitigate famine risks. However, the differences in crop cultivation between dense settlement clusters and rural areas might be linked to patterns of land exploitation in which large sites, possibly equipped with canals, did not require the cultivation of more drought-tolerant crops. In this context, analysis of land use practices is desired to better understand such differences. This is the aim of the two case studies presented in Chapters 5 and 6.

### 3.3.4 A Comment on the Terminology

The Andronovo (ICW) pottery sites in the Murghab have often been defined as "pastoralists" (Hiebert 1994a; Vinogradova and Kuz'mina 1996; Cattani 2008b). However, evidence from these sites, as discussed above, suggests diverse subsistence strategies. Recently, Rouse and Cerasetti (2018) have classified these sites as belonging to "agropastoralists." Wendrich and Barnard (2008:5) outlined three types of broad mobility (see below). Nevertheless, it's crucial to acknowledge that these classifications generally oversimplify different forms of subsistence economies. Indeed, Bernbeck (2008) is right to suggest that various types of mobility can coexist simultaneously within the same communities.

The first broad category of Wendrich and Barnard (2008) is *pastoral nomadism* which is a broad term that defines mobility centered on the maintenance of flocks (mainly sheep and goats) that are taken from one place to another. Groups move across the landscape to meet human and animal needs. They might occupy the same places several times a year, depending on the routes but they rarely occupy one single place for long time (i.e., seasonal movement).

The second broad category is *semi-mobile pastoralism* that can be defined as a group of people in which the group seasonally occupies specific places. In this case they move two or three times a year. This is the case for examples of modern semi-mobile Kyrgyz pastoralist in the Wakhan-Pamir corridor (Afghanistan) that move two times in a year between summer and winter camps (Callahan 2013:82).

A third broad category is *agropastoralism*, which can be categorized as a combination of pastoral and crop cultivation activities, often viewed as low-investment agriculture (Wendrich and Barnard 2008:7; Buccellati 2008:142).

In the Murghab, archaeological investigations have concentrated on large, fortified sites, and it is likely that the small sites differed in their mobility and agriculture compared to main settlements. Evidence from rural sites suggests forms of agropastoralism, possibly linked to seasonal movement. These sites show evidence of livestock breeding alongside evidence of crop cultivation. For example, both the Chopantam and Ojakly sites (refer to Chapter 5) reveal traces of less permanent structures like post-holes supporting lightweight constructions, along with botanical remains. Further, the site of Chopantam also exhibits evidence of tools for cereal processing. Altogether, this may suggest a seasonal occupation at these sites, possibly associated with low-investment crop cultivation within an agropastoral economy. In contrast, other sites in the Murghab, such as Gonur N., can probably be best interpreted as a small mobile pastoral camp and has not yielded any botanical remains or evidence of permanent structures (Hiebert and Moore 2004).

Therefore, categorizing these small sites across the Murghab simply as "mobile pastoralist" sites, as has often been done in previous decades based on pottery assemblages, is overly simplistic (Cattani 2008b). In this dissertation, I will instead refer to these sites with broad term of "rural sites."[26] I will also employ more specific terms, such as "agropastoralist site" or "mobile site," when these terms, as defined by Wendrich and Barnard (2008), align with the context and characteristics discussed above.

For site clusters with fortified citadels, I will use the broad terms of "dense settlement clusters" or "settlement concentrations." These areas have been considered as oases by Sarianidi (1990). However, while a reconsideration of the oases aspect will be discussed in the last chapter, the use of this term would be misleading in the light of more complex land exploitation by the 2nd millennium BCE. Likewise, it is equally crucial to note that sites like Gonur North, spanning 50 ha and featuring three round walls, can also be classified as an urban area (see Figure 3.2). However, most sites in the Murghab exhibit less complex structures, making the term "urban" inadequate, as exemplified by Kelleli 3, which comprises a small fortified citadel with a simpler internal layout compared to Gonur North. Therefore, while acknowledging the complexity of terminology and the distinctions among urban, proto-urban, and non-urban sites, in this thesis I will

---

[26] In this context, the term "rural" refers to any site that is part of the main fortified centers such as Gonur or Toglok 21. This broader terminology encompasses a variety of sites, which can differ in size and functionality.

collectively refer to these areas as settlement clusters or settlement concentrations, irrespective of their size and potential population.

## 3.4 Models of BMAC Landscape Development

### 3.4.1 The Early Soviet and AMMD Models

The prevalent interpretation and concept of "oases" in the Murghab derives from the excavations and surveys in the 1950s and 1960s (Masson and Sarianidi 1972:137). Soviet scholars saw the Murghab alluvial fan as composed of a series of clustered sites grouped in oases interspersed over the desert. This model was also supported by early paleoclimatic interpretations of the landscape (but see Chapter 2). Both Lisitsina (1978) and Gerasimov (1978), for instance, considered the region primarily as a desert environment over the last ten thousand years. Similarly, Dolukhanov (1981) argued for an almost arid environment. The Murghab was thus interpreted as an arid landscape with an active alluvial fan. In this landscape, areas such as Kelleli, Gonur, or Adji Kui were interpreted as a cluster of sites composing "oases" with agricultural fields around the walled structures (Sarianidi 1986). However, the oasis model did not consider broader exploitations of the agricultural landscape, such as opportunistic agriculture. The areas between these site cluster areas were interpreted as grazing or hunting areas with no crop cultivation (see a representative picture of this model in Hiebert 1994a:Fig.8.2).

The "oasis model," albeit questioned by the AMMD, remains popular (e.g., Kohl 1984; Sarianidi 1990a; Hiebert 1994a). These oases were reconstructed with proxy data from large centers, such as Gonur, in which Moore et al. (1994) envisioned a series of canals with fields and orchards in proximity of the sites with the desert beyond. In this landscape, human occupation was inevitably bound to the artificial oasis environment, while the desert constituted a barrier for a widespread occupation. Therefore, everything in between the oases was an empty landscape.

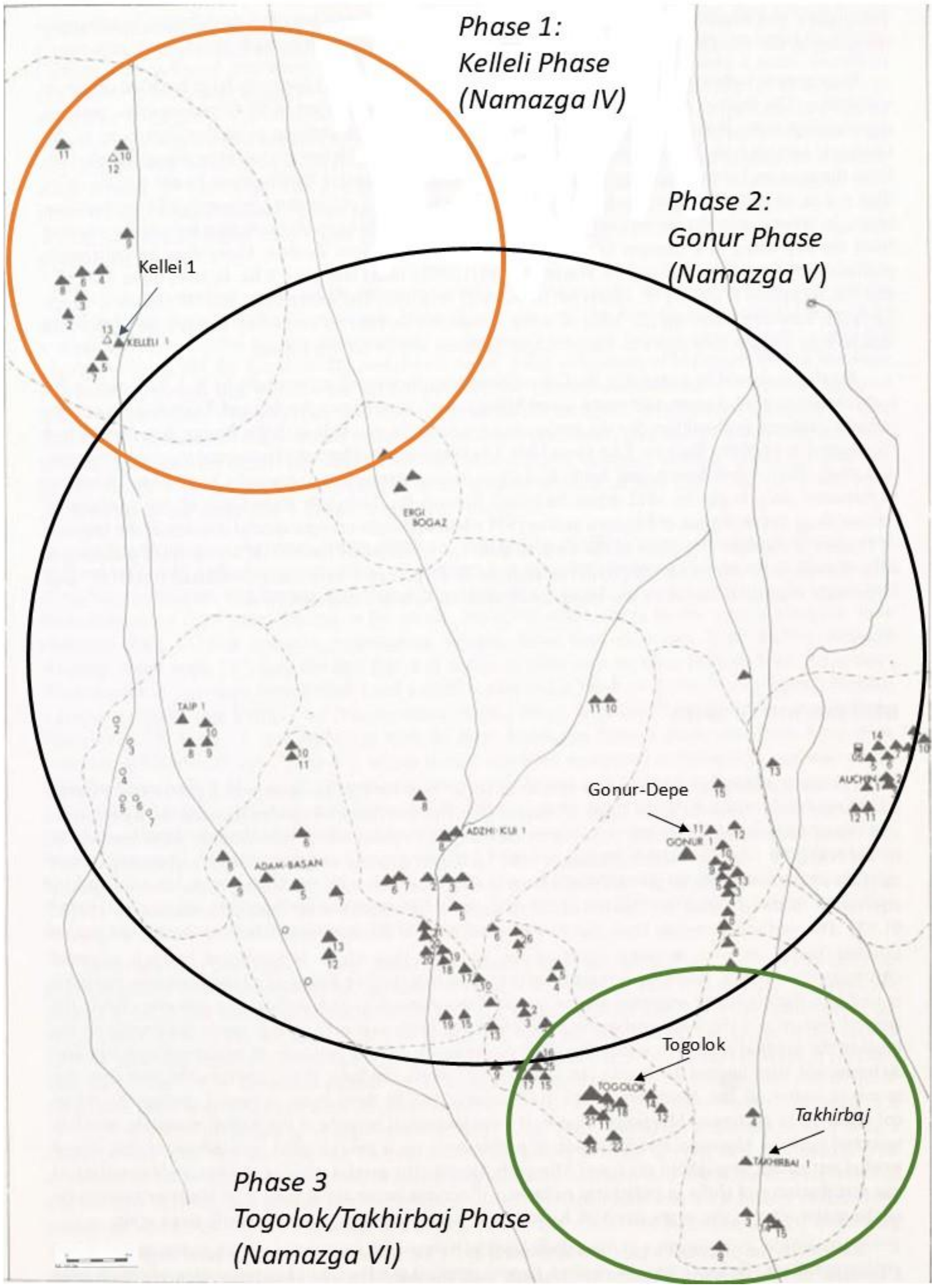


*Figure 3.10 The map illustrates the early "oasis" model, depicting the chronological sequence of the Murghab occupation and the migration of sites towards the south. Phase 1 is characterized by the Kelleli Phase (Namazga IV), followed by Phase 2, known as the Gonur Phase (Namazga V), and Phase 3, identified as the Takhirbaj/Togolok Phase (Namazga VI) according to an early Soviet periodization. (adapted from Kohl 1984: Map 16B).*

The oasis model was also linked to a chronological periodization of the Murghab. Three main chronological periods were associated with the north, central and south occupation sequence of the Murghab during the Middle and Late Bronze Age (Kohl 1984:143–144) (Figure 3.10). In this chronological model, the first phase (*Kelleli Phase*) is associated with the occupation of the north of the alluvial fan and dated to the Namazga V period (ca. 2500–2300 BCE). The second phase (*Gonur Phase*) is associated with the main flourishing of the BMAC in terms of trade and material culture (ca. 2300–1800 BCE). This period characterizes the central area of the northern Murghab, including the main site of Gonur North. The last phase (*Togolok/Takhirbaj Phase*) is associated with a southward shift of sites and the de-urbanization of the Murghab, as well as the appearance of sites with Andronovo (ICW) pottery assemblages (ca. 1800–1500 BCE) (Kohl 1992). In this model, the chronological progression (from Middle to Late) aligns with a progressively southward shift of the sites. This chronological and spatial sequence starts from the assumption that most of the sites had a one-period occupation spanning a few hundred years. However, excavations of sites such as Adji Kui 1 and 9 and possibly Gonur (Lyonnet and Dubova 2021a) have revealed a more extended occupation (Luneau 2019). Likewise, Late Bronze Age assemblages have also been found in the northern area of the Murghab, and layers from Togolok 1 (previously linked to the last phase of the Bronze Age) have been radiocarbon dated to the Middle Bronze Age (Cerasetti et al. 2022). As argued elsewhere (Cremaschi 1998; Salvatori 2008a), the early BMAC phases in the southern area of the Murghab can also be hidden under meters of alluvium, which has potentially masked a widespread occupation of the southern fan since the early periods (i.e., early-Middle Bronze Age).

All in all, it is likely that large areas of the Murghab were occupied during the Middle Bronze Age, but only in the northern area were sites short-lived (i.e., Kelleli 3 and 4) due to lack of water from the river by the late 3rd millennium BCE (Hiebert 1994a:17–20). The absence of occupation in the northern areas during the subsequent Iron Age period further supports the idea of a general southward retraction of the sites, as argued by Salvatori (2008a) (Figure 3.11).

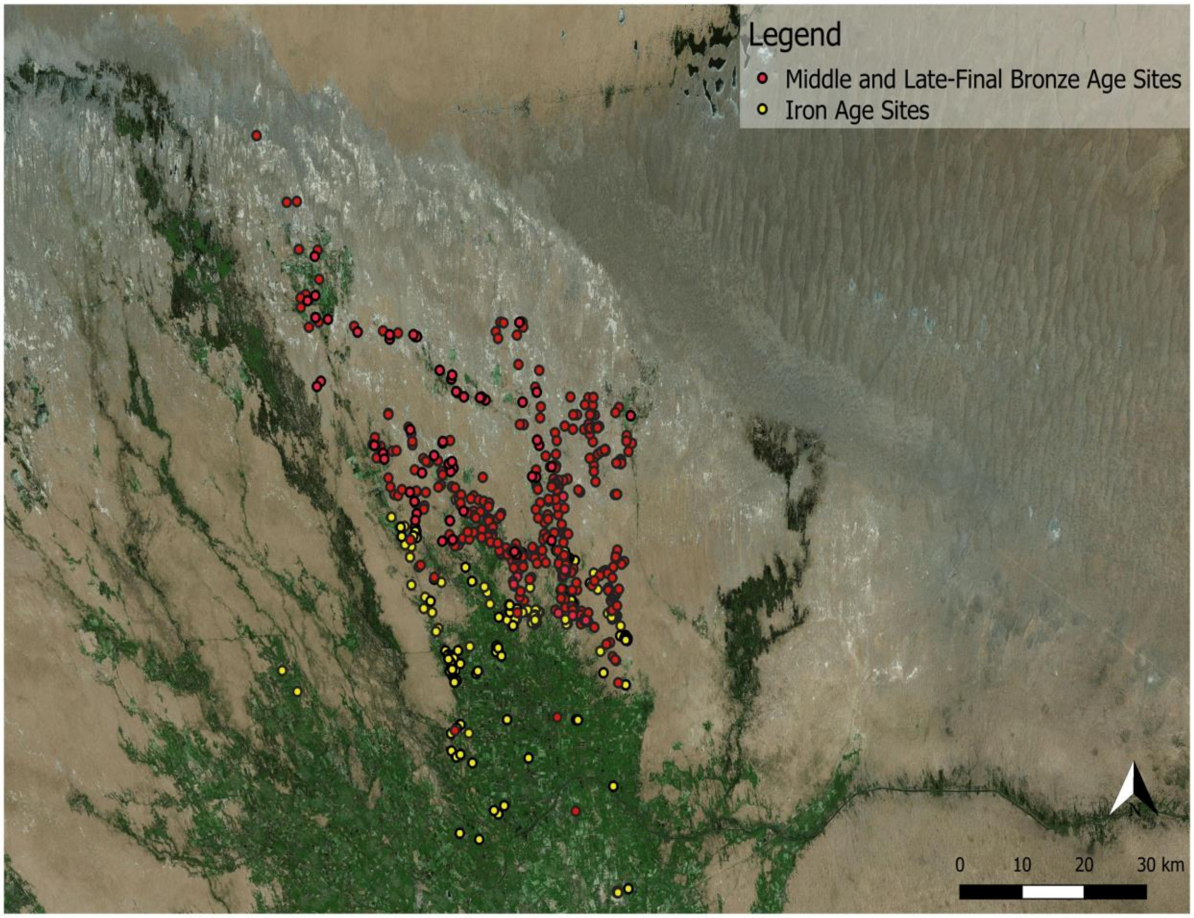


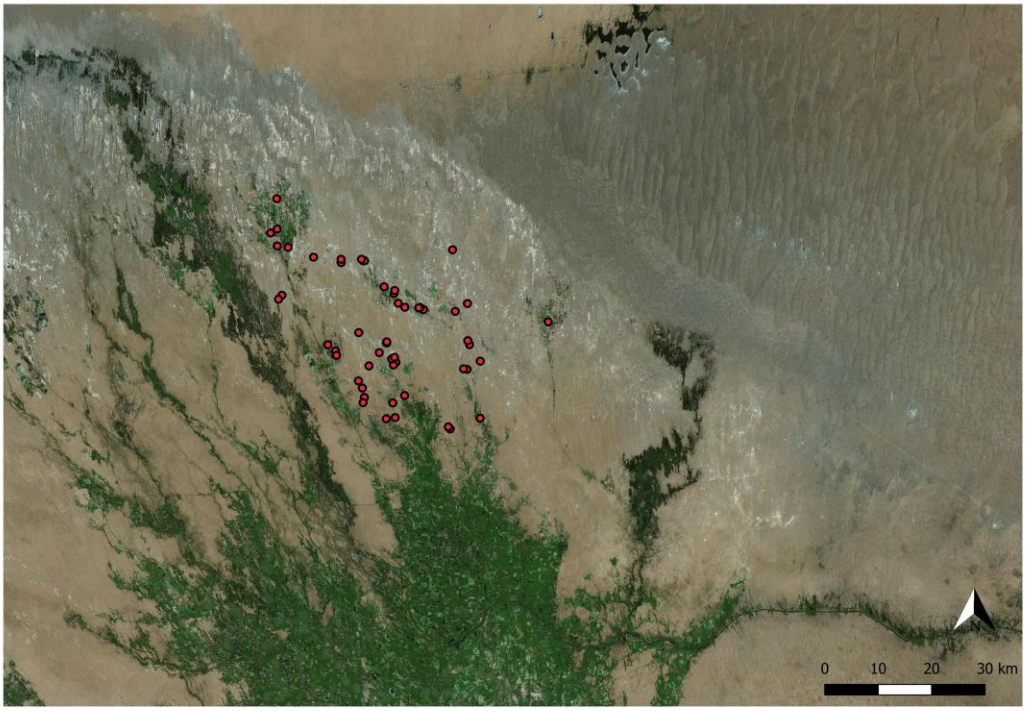
*Figure 3.11 The figure shows the presence of Bronze and Iron Age sites, with the latest mainly located in the southern area (AMMD data/Landsat 8 image).*

The survey by AMMD also suggest a strong reduction of sites in the northern part of the Murghab alluvial fan (Figure 3.11). This shift is likely linked to the retraction of the alluvial fan during the mid-2$^{nd}$ millennium BCE. This hypothesis, as discussed previously in the thesis, is supported by Cremaschi (1998:17–19), who identified several aeolian deposits from exposed ancient channels sections across the Murghab that have been radiocarbon dated to the Late Bronze Age. This would support a model in which from the Late Bronze Age most of the channels in the distal area of the alluvial fan became inactive or started to have a strong decrease in water level. This did not lead to the complete disappearance of Iron Age sites, as some still remain in the northern fringe of the alluvial fan. This suggests that the activity of the channels was not entirely discontinued.

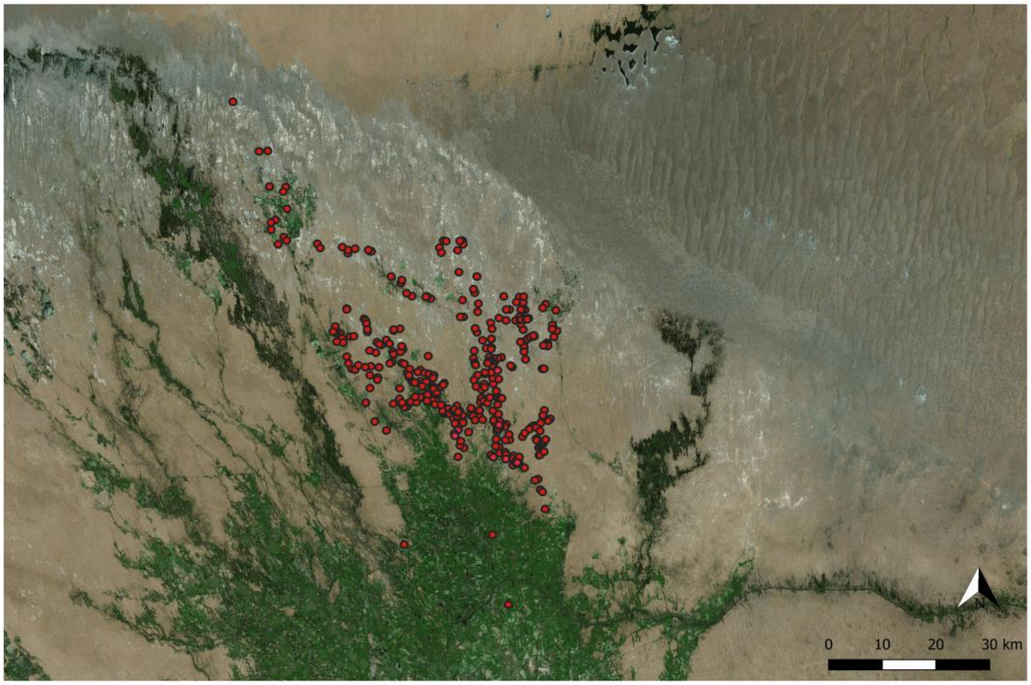
The AMMD survey revealed numerous sites dating to the Middle and Late Bronze Age, as well as the Iron Age (Namazga V and VI). The distribution of these settlements does not fit with the notion that the Murghab was solely characterized by discrete oases as argued by Soviet scholars (Sarianidi 1990a; Cattani and Salvatori 2008). The numerous sites in what was believed to be an almost empty landscape, in addition to an initial reconstruction of paleochannels, led the AMMD to propose a new landscape model. The AMMD team, therefore, argued for an open and well-watered landscape with numerous sites located along the channels during the Middle Bronze Age (Salvatori 2008a:59). This alluvial landscape underwent a process of aridification at the mid-2nd millennium BCE, resulting in a shift towards the south during the Early Iron Age (1300–900 BCE) (Cremaschi 1998). In this model, during the Middle and early Late Bronze Age periods, the Murghab landscape was occupied by a settlement system on a continuous agricultural plain (Salvatori 2008a).

However, the AMMD model did not challenge the centrality of Gonur. Based on Thiessen polygons, Salvatori (2008a:61–62) identified three typologies of sites and Gonur North was the center, below which there were a number of second-rank centers, such as Adji Kui 9. This Middle Bronze Age settlement system changed drastically in the subsequent Late Bronze Age as the main settlements decreased in size (e.g., from Gonur North to the small Gonur South) and we see the appearance of hundreds of small sites across the fan not present during the Middle Bronze Age (Figure 3.12B).

According to Salvatori (2008a:Fig. 5.5), in the Late Bronze Age there was no predominant center but rather a horizontal settlement system. In addition, according to Wright (2008:Fig. 4.2), there was no decrease in the Murghab population, which from large centers was now spread out into smaller settlements (but see discussion in Chapter 7 about this interpretation). While the AMMD model of a continuous agricultural landscape remains pertinent, it is subject to several limitations and challenges, which will be outlined briefly in the following section. In light of the data presented in this thesis, these limitations will be further explored and discussed in Chapter 7.



**A**



**B**

*Figure 3.12 A) Distribution of Middle Bronze Age sites. B) Distribution of Late and Final Bronze Age sites. The Late and Final Bronze Age period shows a considerable increase in the number of settlements along with a decrease in size of the main mounds (AMMD Project data/Landsat 8 image).*

### 3.4.2 Further Models of Landscape Development

The landscape and agricultural models put forth by Soviet and AMMD scholars are characterized by a fundamental dichotomy. On one hand, there exists the oasis-based model, which posits a desert landscape punctuated by settlements clustered within oases. In contrast, the AMMD model portrays a vast, well-watered, and cultivated plain. However, both models fail to consider the intricacies of landscape exploitation, as outlined in section 3.3.3. In this context, I argue that the mosaic of landscapes uses has not been adequately addressed. The resilience and possible varieties of subsistence strategies of local communities, as well as the local paleoclimate, were certainly reflected in different land exploitation and water management practices that will be presented in the two case studies.

The recent investigation and the data collected by Markofsky (2017) in the area of Egri Bogaz in the northern fan suggest a diverse landscapes with various environments where small-scale agriculture was possible. Certainly, this interpretation acknowledges the complexity of agricultural exploitation and land management in the Murghab and has advantages over previous models. However, while Markofsky's investigation addresses local patterns of landscape use (Markofsky et al. 2017), it does not consider the entire spectrum of farming, husbandry and irrigation practices. The extent to which rural communities might have exploited water channels is not investigated by Markofsky. Nevertheless, Markofsky's regional study of settlement dynamics constitutes a significant starting point for the present research and will be further discussed in the final chapter.

Furthermore, in the concluding chapter, both the AMMD and oasis models will be reassessed. While the AMMD model appropriately acknowledges the presence of a landscape featuring paleochannels and numerous settlements, it lacks a comprehensive exploration of local landscape management and the extent of variation among local areas in the Murghab. The examination of both case studies and a holistic approach to the data will prompt a reevaluation of the oasis model.

## 3.5 The Theoretical Context of Hydrological Research

The *Archaeological Landscape of the Ancient Near East* by T. J. Wilkinson (2003) can be regarded as one of the most influential works about landscape archaeology in West Asia. Wilkinson articulates a view of the landscape in which it "must therefore been seen as both actively influencing the lives of the inhabitants as well as being, in turn, heavily influenced by the activities of those inhabitants" (Wilkinson 2003:6). In the monograph he rightly focuses on the complexities of the landscape, and social and historical factors, outlining an integrated approach to investigate the environment. Wilkinson's works are, however, the climax of a long process.

Landscape studies began after World War I with an increased amount of data, such as aerial photos, produced from military campaigns in the Middle East. Pioneering works on the landscape included those by Stein (1938; 1940) or Bowen (1958). These studies clearly pointed to the role played by irrigation. Water resources and irrigation channels were crucial to understanding settlements evolution pattern (Wilkinson 2003: 71). The acknowledgment of the importance of the hydrological landscape resulted in theories linking social complexity and hydrological infrastructures.

The often-cited work by Karl Wittfogel (1957) was influential in many respects and still triggers discussions on the link between water and power (Mori 2020). Wittfogel argued that the development of a massive irrigation network led to an organizational hierarchy and social complexity that were crucial for managing hydrological infrastructure. This theory was subsequently criticized for its deterministic approach (e.g., Andrianov 1969; Hunt 1988). More recently, the investigation of ancient irrigation systems has occurred as part of "human niche construction theory," which contrast with Wittfogel's view.

The construction of irrigation systems, or the management of natural channels, clearly constitutes an alteration of the local environment (Kaptijn 2015). As argued by Wilkinson et al. (2012:157), "human niche construction can be seen to have operated where small-scale communities built upon naturally occurring conditions to divert water to nearby localities with the result that incipient water management then created the conditions for future developments." These future developments included large irrigation systems planned and managed on a state level, such as some examples in Mesopotamia (e.g., Morandi-Bonacossi 2017:134). However, large irrigation systems do not necessarily require a bureaucratic state for their management. Hunt (1988) brilliantly demonstrated that many irrigation systems of considerable size (458,000 ha) can be operated by small-scale communities. The human dimension and the daily practice by local agencies are crucial aspects to consider (Ertsen 2010). Further, it can be argued that "an irrigation system may be initiated under central rule, by a strong state, but daily practices on the smaller scale would still determine success or failure of irrigation considerably" regardless of its state control (Ertsen 2010:167). The success or failure, even in a state planned irrigation system depends on the skill and work of the local agents, for example in the modern Gezira Plain in Sudan (Ertsen 2016:67-69). Similarly, cuneiform tablets from Mesopotamia inform us that workers from local communities were instrumental in maintaining the canals on a daily basis (Tamburrino 2010:45; Vidale 2018). Ethnographic analysis from southern Iraq by Fernea (1970)[27] demonstrated that the management and the control of irrigation networks were organized by local tribes at a local, non-hierarchical level.

More recently, Lamberg-Karlovsky (2016:26), building on Crumley (1995), suggested a "heterarchical model" for managing irrigation systems, which includes cooperation, interaction, and interdependence between communities. The current data from the Murghab, likewise, suggests variability in the management of the agricultural landscape and a pivotal role for local agents. Hence, it is imperative to delve into the management of the water channel system and the potential roles of communities within it. Consequently, the exploration of local ecologies and potential agricultural and irrigation practices emerges as a central focus of this study. Understanding how communities interacted with and managed water resources can provide invaluable insights into the

---

[27] Quoted in Lamberg-Karlovsky 2016.

socio-economic dynamics and environmental adaptations of communities within the Murghab region during the Bronze Age.

- **Investigation of the Water Channel System**

The study of irrigated landscapes is not new. The first attempts to link watercourses with archaeological sites dates back to the 1937 "Diyala Basin Archaeological Project" in Mesopotamia (Jacobsen 1960). Jacobson identified the dates of archaeological sites based on their archaeological materials and, in turn, dated the channel networks on those. This method was later refined by other scholars (see Chapter 4). The groundbreaking work of Adams (1965) marks a turning point in the investigation of irrigated landscapes (Yoffee 1997). The main premise was that settlements exist in proximity of water resources, such as water channels. By surveying, mapping, and collecting archaeological materials, along with the analysis of aerial photos, linear patterns of sites were interpreted as the presence of ancient watercourses (Adams 1957; 1958). Adams undertook the most empirical and extensive investigations of the landscape in Southern Mesopotamia. Later on, Steinkeller (2007), on the basis of the archives from the 3rd millennium BCE, correlated cities and towns initially identified by Adams (Hritz et al. 2020).

These early studies of Jacobsen and Adams created a framework for the investigation of ancient hydrological landscapes. This approach was later augmented with the use of remote sensing analysis, GIS, and geological analyses (e.g., Hritz and Wilkinson 2006; Hritz 2010; Ur and Reade 2015; Jotheri et al. 2018). One of the most remarkable results of Adams' work was his insight that human agents formed and transformed the physical landscape through the construction of dams, artificial canals, and the irrigation of agricultural fields.

The work by Wilkinson (2003; 2014), however, initiated a new stage in the investigation of the "Near Eastern" irrigated landscapes. His initial work concentrated on the systematic off-site survey between tells and the investigation of the farming landscape in dry farming regions (Wilkinson 2003). This led to a great increase in our archaeological perception of these areas and how to understand episodes of urbanization and de-urbanization. The work included ground cores, test pits, and geomorphological and sedimentary analysis, along with absolute dating of irrigation systems. In short, Wilkinson’s investigations demonstrated a crucial importance in our understanding of analyzing farming landscapes, including land use, irrigation, and manuring, using a multidisciplinary approach.

The analysis of the Mesopotamian landscape differs in several aspects from that of the Murghab region. Firstly, Mesopotamia is characterized by the presence of two major rivers, the Tigris and Euphrates. The primary channels in central and southern Mesopotamia often feature elevated levees and overbank deposits, which are frequently identifiable through satellite analysis. Additionally, the presence of elevated levees contributes to the formation of crevasse splays, a defining feature of southern Mesopotamia (Jotheri et al. 2018). Another distinguishing characteristic is the abundance of artificial channels, canals, weirs, and gates, often sponsored by the state, which supplied water to cities and agricultural lands (Morandi Bonacossi 2017). Textual sources describe how these channels and canals were meticulously managed by local communities, as discussed previously. Consequently, agricultural land exploitation in Mesopotamia takes on different forms compared to the Murghab region, where many of these natural and artificial features are absent. In this context, it is crucial to consider the peculiarity of the Murghab landscape without uncritically applying a “Mesopotamian model” of land use to a Central Asian region. However, despite such differences, contextual and multidisciplinary study of archaeological records and the absolute dating of ancient watercourses in Mesopotamia has proved to be the most effective method to analyze the fluvial landscape (Hritz et al. 2020). This methodology will be applied to this research as well. Therefore, the comprehensive model of landscape analysis delineated by Wilkinson and further developed by other scholars (e.g., Jotheri 2016) presents the most robust theoretical and methodological framework for investigating the irrigated landscape and its evolution in the Murghab region.

### 3.5.1 The Early Central Asian Context

Research in the Murghab region did not concentrate on the investigation of the landscape and its broader hydrological system until the 1990s. However, early Soviet research elsewhere in Central Asia, and in particular in the Aral Sea area, focused on irrigated landscapes that are worth mentioning. Multidisciplinary investigation in the 1930s and 1940s by the *Khorezm Expedition* led by S. P. Tolstov located several Neolithic and Bronze Age sites in the region and recorded ancient irrigation networks. According to Dolukhanov (2016), the interest of Soviet archaeologists in the irrigation system derived from the Marxist concept of the “Asian Model” of production that was based, among other aspects, on the irrigation system. This generated interest in investigating ancient hydrological landscapes in some regions of Central Asia.

Andrianov, building on the early investigation of the irrigation system by Tolstov (1948), developed a new and innovative multidisciplinary approach that included the analysis of aerial photos and test pits of the ancient channels in the lower Amu-darya and the Aral Sea area (Adrianov 1969). His groundbreaking study of ancient irrigation, the study of land formation, and the characteristics of local deposits, such as the *takyr*, are of great importance in this research. Further, the identification of Bronze Age canals and the management of ancient agricultural fields provided crucial research and established a methodological landmark for Central Asian landscape studies (Andrianov 2016:137–141).

Andrianov’s approach was also applied in southern Turkmenistan by Lisitsina (1978) at the Geoksyur Oasis in the Tedjen alluvial fan, where aerial photos were processed for the investigation of early paleochannels and agricultural areas. Investigations with test pits revealed the presence of several ancient channels dated to the Chalcolithic period that will be further discussed in Chapter 7.

All in all, the theoretical discussions in Central and West Asia mentioned above serve as the foundation for investigating ancient water systems. This study seeks to advance previous theoretical and methodological approaches by employing remote sensing, surveying, and geoarchaeological analysis to examine the water channel systems of the ancient Murghab, with a focus on specific case study areas (refer to Chapter 4 for the methodology). Through interdisciplinary analysis, the research aims to explore various unknown ancient watercourses and their connection to the local settlement patterns. By studying data from micro-regions, the argument is made that a factual comprehension can elucidate how local communities utilized land and water resources in different ways.

## 3.6 Summary

In this chapter I have introduced the history of archaeology in the Murghab region, focusing on the Bronze Age period. The early investigation of the Murghab by the Soviet scholars concentrated on the main settlement clusters of the region, giving rise to the "oasis model." This model envisioned discrete clusters of sites (i.e., oases) in an almost arid environment. These investigations had the great merit of uncovering a crucial region in Central Asia and brought to light monumental sites such us Gonur North. Subsequently, during the 1990s the survey by the AMMD Project over the northeastern area of the Murghab identified numerous other sites dated to the Bronze and Iron Ages, including sites with Andronovo (ICW) ceramics. The presence of many rural sites across the landscape was interpreted by the AMMD as evidence that during the Middle and Late Bronze Age, the Murghab was an extensive agricultural plain with numerous channels. During the mid-2nd millennium BCE the region probably underwent an aridification process, which had a particular impact on the distal areas of the alluvial fan. The presence during this period of small, rural sites, with Andronovo (ICW) ceramics were interpreted as "exotic" material from northern regions. The existence of these non-BMAC pottery assemblages in the Murghab was associated with pastoral groups by scholars. However, botanical remains from rural sites reveal that agriculture was practiced and a link between pottery assemblages and the subsistence economy should be revised. Although water resources have been regarded as crucial by all scholars working in the region, little research has focused on the Murghab hydrological landscape, and the micro-scale agricultural and irrigation practices.

Hence, this research delves into the hydrological landscape using a multidisciplinary approach primarily pioneered by scholars in West Asia. The specifics of this approach will be elaborated upon in the following chapter.

# Chapter 4 – Methodology

## 4. Overview

Over the last years, a number of archaeological studies have systematically investigated water resources and ancient irrigation systems in the Near East and Central Asia (Adrianov 1969; Ur 2002; Wilkinson 2003; Jotheri and Allen 2020; Orengo and Petrie 20017; Kühne 2018). These studies often combine several techniques of archaeological research. Building upon these earlier approaches, this study investigates the hydrological and agricultural management of the Murghab region using three lines of investigation that will be further discussed in the next paragraphs.

First, the desk-based research consists of a remote study of the ancient channel distribution in the local areas of Togolok and Ojakly through satellite images, aerial photos, and maps using GIS tools and analysis.

Second, the field research aims to ground truth[28] the channel system, integrated with an intensive survey along the ancient river channels. The aim is to verify the channel properties and to gather additional data on the settlements and field systems situated along the watercourses. In addition, the survey aims to provide chronological data of the sites along the channels. Dating these sites provides alternative tools for estimating when these channels were active.

Third, more detailed research includes the investigation of the channel system with core cross-sections, test trenches, and OSL dating, as well as software modelling of selected channels, in order to gain additional information on possible water delivery systems.

---

[28] The ground truthing evaluates the precision of remote sensing analysis with a comparison with on-site physical measurements gathered at ground level.

A further stage of analysis, not previously envisioned at the beginning of the project, emerged during the excavation of the site of Togolok 1 by the TAP team (*Togolok Archaeological Project*) (see Chapter 6). Selected archaeobotanical assemblages from both Middle and Late Bronze Age layers from Togolok 1 were made available by the TAP and selected for carbon isotope analysis ($\delta^{13}C$ and $\delta^{15}N$). This analysis will shed further light on different irrigation and manuring practices at Togolok during the Bronze Age.

Having introduced the general lines of investigation, I will now discuss the methodological approaches in more detail.

## 4.1 GIS Analysis

GIS (Geographic Information System) is now a pivotal instrument designed for the integration and acquisition of diverse spatial datasets, encompassing maps, land morphology, geophysical data, and archaeological plans. Its versatility lies in its capacity to assembling these varied sources, offering archaeologists a comprehensive platform for spatial data analysis.

Among its array of characteristics, GIS facilitates different types of analysis, allowing researchers to delve into intricate patterns and relationships within archaeological landscapes. By overlaying spatial data layers, scholars can unravel qualitative and quantitative data of human activities and environmental dynamics (Conolly and Lake 2006).

Over the last two decades, GIS has solidified its position as an indispensable tool in archaeological fieldwork and analysis. Its application spans from surveying to excavation planning, and post-excavation analysis. Using GIS software, archaeologists can effectively visualize, interpret, and communicate complex spatial information, and enrich our understanding of the collected data. GIS also allows us to visualize spatial data in innovative way that can foster additional research (Conolly and Lake 2006: 13). For instance, it can combine spatial data from different instruments such as satellite platforms, drones, total stations, GPS and D-GPS, which are crucial equipment during any modern archaeological fieldwork. The data obtained using these instruments can later be imported into GIS software, enabling various analyses. GIS software can be purchased (such as ArcGIS) or is available for free (such as QGIS). For this study, I utilized the free QGIS software, enabling a multi-layer analysis of satellite imagery, aerial photographs, and cartographic maps of the Murghab region as well as data from field survey. In the context of this thesis, GIS has been utilized to analyze two distinct aspects.

First, the integration of satellite images and cartographic maps into a GIS entailed importing them as raster data, thereby generating overlapping layers within the GIS system. This strategic layering facilitated the simultaneous visual analysis of the area, leveraging all available data sources. Such an approach streamlined and enabled a concurrent examination of preserved ancient channels, enhancing interpretation accuracy and expediting our knowledge about the past hydrological landscape (Orengo and Petrie 2017).

Second, GIS has been used for integrating all spatial data sources. Notably, all spatial data gathered by the AMMD have been merged into a unified GIS project. Furthermore, the data collected during the surveys conducted in Togolok and Ojakly areas have been seamlessly incorporated into the same GIS project. This strategic integration has paved the way for multifaceted spatial analyses of archaeological sites and preserved ancient channels, which will be extensively discussed in Chapters 5 and 6 of the thesis. Beyond data aggregation, the utilization of GIS has enabled a deeper understanding of the dynamics of human–water interactions during the transition period between the 3rd and 2nd millennium BCE. By analyzing the diverse spatial datasets within a GIS platform, one can gain better insights into the evolving patterns of settlement, environment, and water resources. Such insights have been instrumental in reconstructing and understanding the hydrological landscape and its land use.

## 4.2 Remote Sensing

### 4.2.1 A Short Introduction to Aerial Photo Interpretation and Remote Sensing

The idea of using remote sensing imagery in archaeology is not recent. Aerial photography has been a common technique to study ancient landscapes. One of the first pioneers of Central Asia, Sir Aurel Stein, had already realized the enormous potential of this technique at the beginning of the 20th century and how it can “greatly reduce the obstacles” of archaeological fieldwork (Stein 1921:3).

A boost in aerial photography in archaeology, however, took place during – and immediately after – World War I, among other times, with flights by Theodor Wiegand over Palestine, the aerial photos of Petra by Alexander Kennedy, and exploration of Mesopotamia, Transjordan, and Palestine by Crawford and Beazley (Crawford 1923; Kennedy 1925:15; Beazley 1920). Already in those years the potential of aerial photography for landscape archaeology was appreciated (Collier 1994). Aerial photos taken in 1932 of the floodplain near Tell el-Amarna in Egypt, for instance, revealed crop marks suggesting walls (Parcak 2009:16).

In Central Asia, as discussed in Chapter 3 (section 3.4.3), the Khorezm Archaeological-Ethnographic Expedition (KhAEE) was set up by S. P. Tolstov in 1937 (Tolstov 1952). It was the first archaeological expedition using a multidisciplinary approach in the region. Several specialists worked together, including geomorphologists, geologists, and geographers (Bolelov 2016:7). The use and interpretation of aerial photos proved to be crucial for the investigation of the Aral region and its hydrological system. This methodology was later adopted by Adrianov (2016) to specifically target and map ancient watercourses in the region.

The importance of aerial photography for archaeology was bolstered by the publication of *Ancient Landscapes* by John Bradford (Bradford 1957). However, while aerial photography was at its peak in the 1950s and 1960s, new revolutionary technologies were on the horizon. On the 4th of October 1957, the Soviet Union launched the first satellite, *Sputnik*. The event triggered a “space race” between the Soviet Union and the United States (Cadbury 2006). As remote sensing was evolving, it became evident to archaeologists that many sites correlated with landscape geomorphology. In particular, in the desert and semi-desert areas of Western and Central Asia, many sites were related to the available water resources (Adams 1981; Wilkinson 2003).

In the last decades, several types of satellite images have been used in archaeology, including CORONA, Landsat, SPOT, IKONOS, as well as ASTER[29] images. More recently, LIDAR[30] images have become popular, in particular in densely forested areas due to their ability to penetrate vegetation (e.g., Southern Europe and Central America) (von Schwerin et al. 2016; Masini et al. 2018). In West Asian archaeology, the use of satellite images, including declassified images such as CORONA, turned out to be crucial in many projects (e.g., Ur 2013).

Many survey projects have included satellite images. The availability of those satellite images is generally crucial in the initial stage of landscape projects – along with their costs. Images are often carefully selected based on their potential. For instance, in the Murghab, the relatively flat morphology of channels tracing the northern fringe cannot be well detected in digital elevation models. Despite providing good results for identifying larger ancient channels in the Murghab, ASTER GDEM images turned out to be less suitable for small and shallow paleochannels (Cerasetti and Maiuri 2002).

In addition to the appropriate images, other criteria, such as year and season of acquisition, need to be considered while selecting satellite images. The potential to have several images covering the same area to overcome visibility issues can be crucial (e.g., Orengo and Patrie 2017).

---

[29] ASTER: Advanced Spaceborne Thermal Emission and Reflection Radiometer.

[30] LIDAR: Light Detection and Ranging.

A number of satellites and aerial photos that could be expected to yield good data were selected for this study. In addition, a number of maps that provide data on anthropogenic features in the landscape were also incorporated into the analysis.

### 4.2.2 CORONA Images

The CORONA project started in 1958 with reconnaissance satellites operated by the Central Intelligence Agency. They were used for photographic surveillance of the former Soviet Union, the People’s Republic of China, and other parts of the globe, including West Asia. The aim was to acquire photographs of military interest. The former Soviet Union and West Asia were photographed many times over several years, only a few months apart. The photographs were black and white panchromatic pictures produced as negative film strips in stereo pairs (Hritz 2014). Each CORONA strip covers an area of roughly 20 by 80 km (Figure 4.1). The program operated with different cameras and resolution qualities that often depended on the condition of the landscape and the time they were acquired (Fowler 1996). Despite its use starting in the 1960s, the full archaeological impact of these images only became apparent in the mid-1990s.

*Figure 4.1 Example of a CORONA image strip (Parcak 2009:53).*

In 1995 the U.S. government decided to declassify the CORONA images and make them available for purchase. The images were available at a low cost compared to the multispectral satellite images at that moment. Today, the images can be purchased – among other things – from the USGS website[31] or downloaded for free on CORONA Atlas[32] (but only selected images and regions are available). Apart from their price – cheaper than many other satellite images – the high resolution of CORONA photographs triggered much archaeological research, especially in Western and Central Asian landscape archaeology. New panchromatic landscape images were now available, including the areas in which aerial photographs had not been accessible, difficult to obtain, or simply did not exist (Hritz 2014). Further, many CORONA images were taken before the development of modern settlements and agricultural expansion that have masked or destroyed much archaeological evidence in Western and Central Asia.

Despite good results obtained with CORONA images in West Asian archaeology (Beck at al. 2007a; Challis et al. 2002; Kennedy 1998; Philip at al. 2002; Pournelle 2007; Ur 2003), some limitations need to be taken into account. Analogue CORONA images are scanned and digitized, and they do not possess a spatial referencing system with which they can be uploaded into a Geographical Information System (GIS). This problem can be rectified by using software to georeference the photographs, such as ArcGIS, Qgis, or Global Mapper. However, when using panoramic cameras such as CORONA, distortions are inevitable and sometimes difficult to correct (Altmaier and Kany 2002:228; Sohn et al. 2004:53).

Five CORONA-KH4 (1963) strips acquired by the AMMD project in the late 90s cover almost the entire alluvial fan and were used in this study (Figure 4.2). In addition, one CORONA KH-4A (1964) strip was downloaded from CORONA Atlas (Corona@CAST)[33] that covers the Ojkaly area.

---

[31] earthexplorer.usgs.gov (last accessed April 2024)

[32] corona.cast.uark.edu/ (last accessed April 2024)

[33] More information about the project can be found at the CORONA Atlas website. Images from the CORONA Atlas are automatically georectified once downloaded.

The AMMD team georeferenced the CORONA KH4 images, which do have significant distortions, however. Because of the strip format of CORONA images, coordinates are most precise at the center of the image. In addition, because of the gap in the time period between the CORONA images and the more recent satellite imagery, georeferencing using modern landmarks can be challenging (Altmaier and Kany 2002:27). Fortunately, in the case of Ojakly and Togolok, the areas are not located at the edges of the strips and do not have significant distortions.

A further great advantage of using CORONA images in Turkmenistan is the time they were captured. These images were taken before mechanized agriculture expanded during the 1980s and, as mentioned above, has hidden or destroyed many archaeological sites. This aspect makes the CORONA images of the Murghab especially useful for archaeological investigations of the landscape.

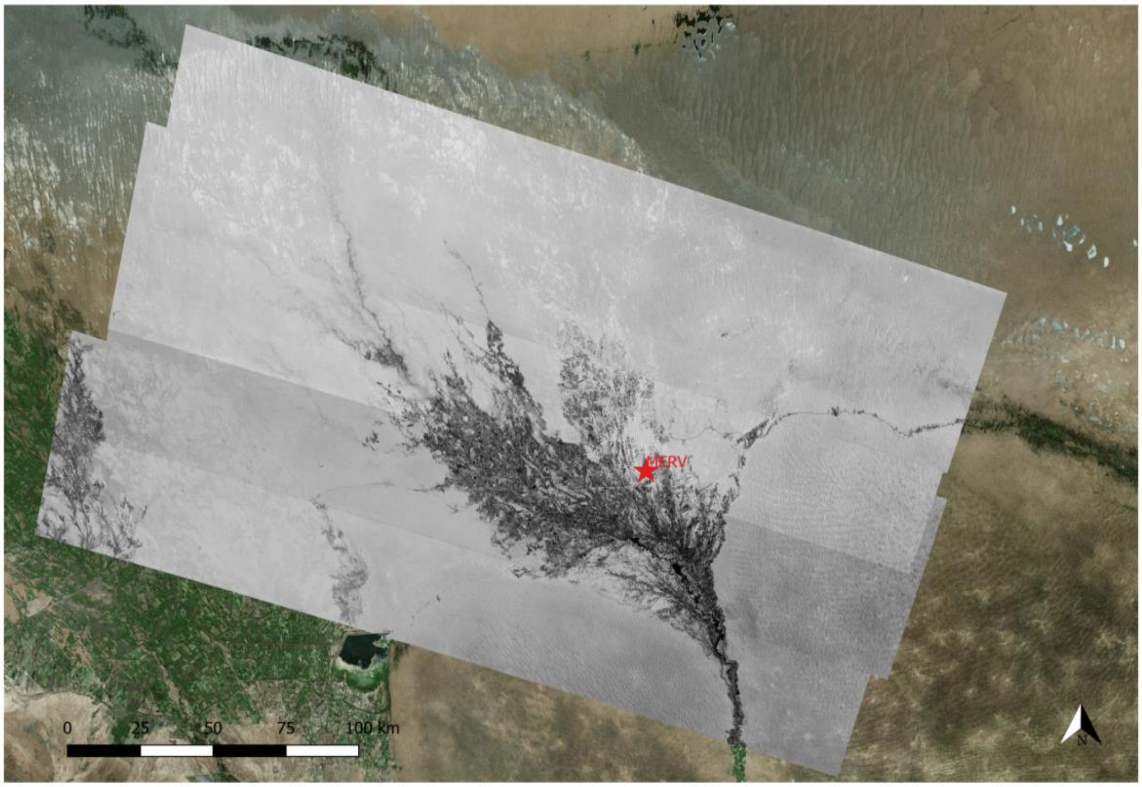


*Figure 4.2 The image displays the four CORONA KH4 (1963) images (black and white panchromatic) covering the Murghab alluvial fan. It is evident that most of the region northeast of the ancient city of Merv was not cultivated during the 1960s and 1970s.*

### 4.2.3 LANDSAT Images

The first NASA/USGS program for earth observation started in 1967, and the first Earth Resources Technology Satellite, better known as “Landsat,” was launched into orbit on the 23rd of July 1972. The program’s main goal was to acquire multispectral information on the Earth’s surface for scientific purposes. The project had a big impact on archaeological landscape research (Giardino 2011). The main advantage of Landsat satellite images was its free acquisition of processed images along with multiple copies of satellite images available for one single area. The Landsat program is still operating with Landsat 8, and the latest Landsat 9 launched on the 27th of September 27th 2021.

For the present project, several Landsat images were downloaded from the USGS website that cover the Murghab alluvial fan with various resolutions. In particular, Landsat 5 (MSS) (1989), Landsat 7 ETM+ (*Enhanced Thematic Mapper Plus*) (2001), and Landsat 8 (2019) have been used for the detection of ancient channels as they cover the entire Murghab fan and turned out to be crucial in the verification process. Although most of the Landsat bands do not provide adequate ground resolution for site identification, they proved to be effective for identifying the main channel traces in both the Togolok and Ojakly areas.

### 4.2.4 Sentinel Images

Sentinel images are part of the Copernicus Programme from the European Union. The program provides high-quality and continuous earth images. The program, which began in 2014 with the first launch, aims to operate over several years and involves the launch of numerous satellites which will cover different aspects of earth monitoring, such as climate change, land use, and vegetation.[34]

---

[34] Details on the earth monitoring services provided by the Sentinel program can be found at copernicus.eu/en (last accessed April 2024)

The Sentinel 2 program was specifically designed for land monitoring, with Sentinel 2A launched on the 23rd of June 2015, and Sentinel 2B launched on the 7th of March 2017. Like with Landsat images, one of the main advantages of using Sentinel images in archaeology is its free availability. Sentinel images are free of charge and can be downloaded from the dedicated ESA website[35] or using QGis; the *Semi-Automatic Plugin Classification* can be used to download Sentinel images (including Landsat and ASTER). Depending on the bands, Sentinel 2 can range between 10 and 60 m resolution on the ground. A further advantage of Sentinel images also derives from its land monitoring program, which combines hundreds of images for the same area. In fact, Sentinel images cover the same region approximately every five days. As a result, by selecting one specific season and region, the user is able to obtain several images (up to six images per month) and up to approximately 72 images for a single year, which forms a considerable database for monitoring and protecting archaeological heritage (Abate and Lasaponara 2019; Khalaf and Insol 2019). In addition, recent projects in Upper Mesopotamia, such as that by Kalayci et al. (2019), have successfully analyzed the spectral signature of ground futures, such as hollow ways, using Sentinel images.

Sentinel 1 and 2 ground resolution for the Murghab region, however, is up to 10 m only for selected bands, making these images less helpful for paleochannel recognition. As a result, Sentinel 2A (2018) images downloaded for this project have only been used for fieldwork preparation and have been useful mainly to select areas not currently under modern cultivation.

### 4.2.5 Aerial Photos

In the late 1990s and early 2000s, the AMMD project acquired aerial photos that cover large parts of the Murghab alluvial fan. The panchromatic aerial photos were captured during the 1950s with an average scale of 1:25,000 and high ground resolution of approximately half a meter (Marcolongo e Mozzi 1998: 8). They provide useful landscape information on remote areas, such as Ojakly, which was partially untouched by

---

[35] See https://dataspace.copernicus.eu/ (last accessed April 2024)

agricultural exploitation at that time. Each photo is part of a series with a specific number (Figure 4.3).

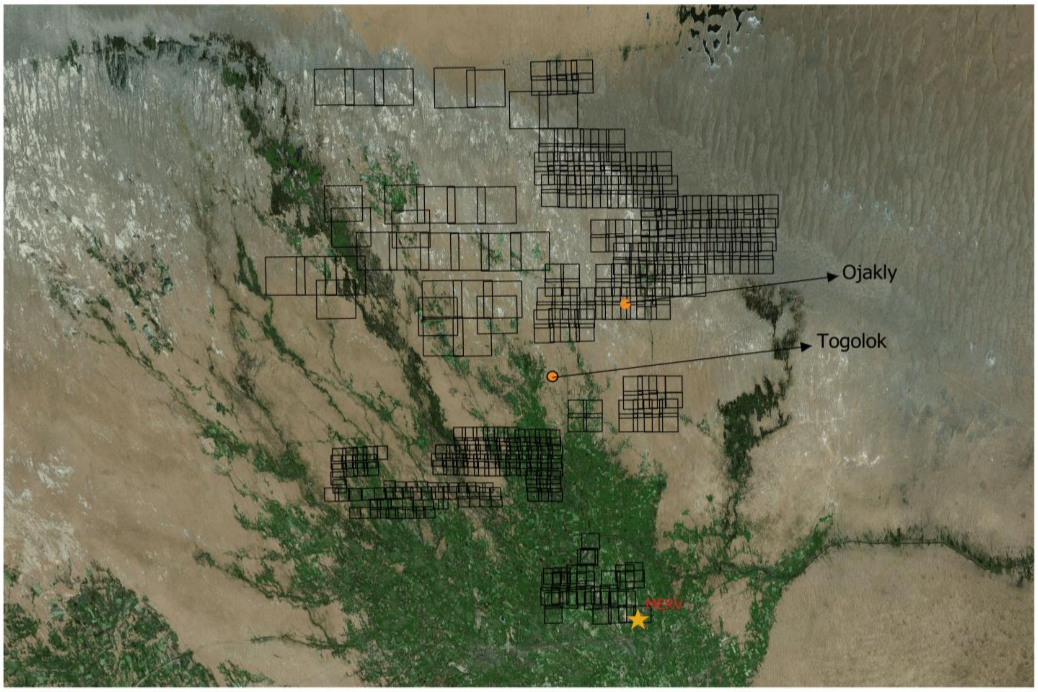


*Figure 4.3 The image shows the distribution of the Aerial photos in the Murghab (black square) acquired by the AMMD team. The site of Togolok is not covered by the aerial photos.*

The progressive numbers of the photos suggest that the Soviet flights had east-to-west and west-to-east directions. Every single aerial photo covers an area of approximately 98 km$^2$ and is labeled with a specific serial number (Figure 4.4). Although the aerial photos by the USSR likely covered the entire Murghab region, not all the serial numbers were acquired by the AMMD project. As a result, the area of Togolok is not covered by the aerial photos, while the area of Ojakly is covered by the B532 series that have been used in this study (Figure 4.3). As with CORONA images, the georeferencing process of aerial photos can be difficult. While the Landsat images are automatically georeferenced when downloaded from the USGS website, the CORONA images are manually georeferenced. Ground control points present in CORONA images are also crucial for georeferencing aerial photos from the Murghab. In fact, in the remote areas of the Murghab alluvial fan, the most reliable ground control points are constituted by the large takyrs that are present in both Aerial and CORONA images. For the present project, several aerial photos were georeferenced by the author using both CORONA and Landsat images.

Despite their great value, aerial photograph have some limitations. Importing old aerial photographs into GIS platforms can be time-consuming and scanning the images can potentially lead to a lower image quality. Acquiring and producing new digital aerial photos over large areas can be expensive as well. However, aerial photographs can be very informative. Many examples in the last two decades can be found in Italy (Campana et al. 2006), the UK (Halkon 2006), and France (Bezori et al. 2002). In West Asia, for instance in Jordan, extensive aerial reconnaissance photography for archaeological purposes has taken place for decades (Kennedy et al. 2011; Bewley and Kennedy 2013).

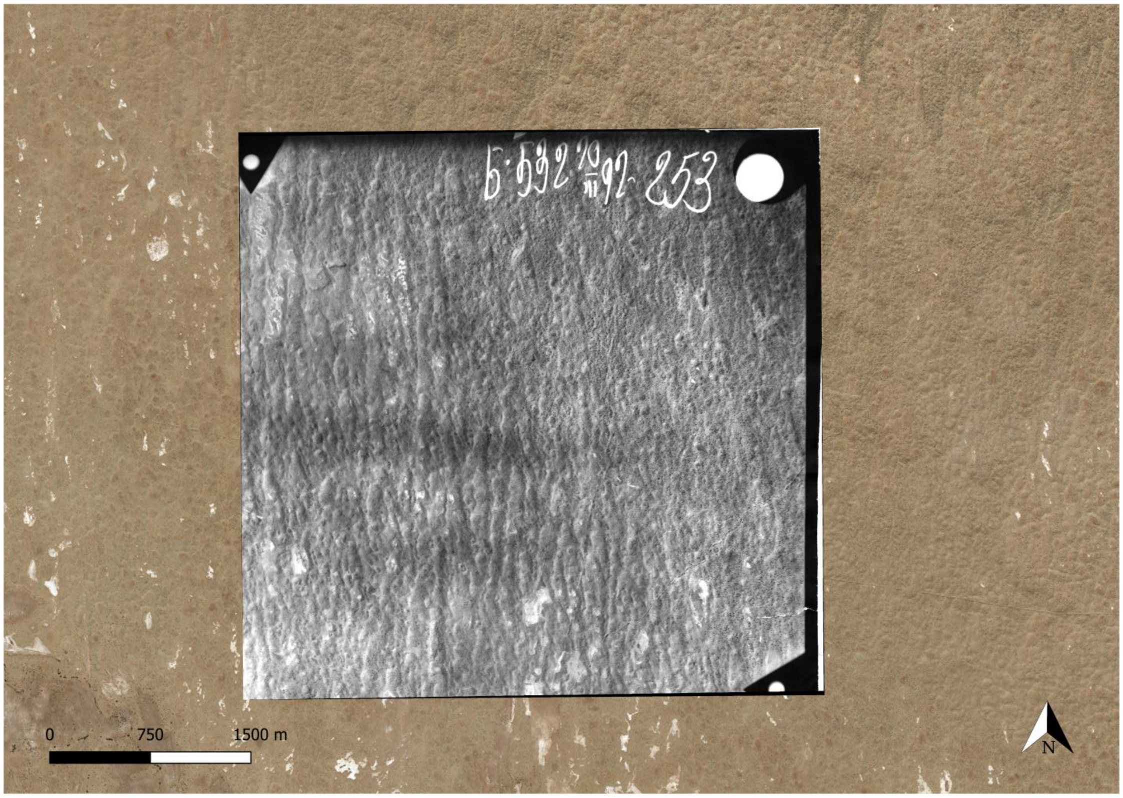


*Figure 4.4 Example of an aerial photo with a size of ca. 98 km2 and a scale of scale of 1:25,000.*

Recently, in the Murghab region, new aerial photos have been produced using a fixed-wing UAV within the "Merv project," which aims to study the Islamic city of Merv and its water system (Williams 2012:2018).

During the 2017 field campaign of the PAM project (*Project for the Ancient Murghab*) aerial photos of the Togolok and Ojakly areas were produced using a MAVIC-pro drone as part of a pilot project in the region (Olson and Rouse 2018). Although these aerial photos have not been used for paleochannel identification in the present study, as they cover a limited area, their detailed scale facilitated the ground truthing of takyr channel surfaces and were used for identifying possible limits of paleochannels.

### 4.2.6 Cartography

Projects aiming to detect archaeological evidence have mainly adopted satellite-based investigations in recent years. However, although not often examined, cartographic maps can provide useful additional information (Hritz 2010). In channel identification, cartographic maps can offer crucial clues for better interpreting the landscape. Thus, integrating maps within a GIS-based approach can lead to a better interpretation of possible archaeological features.

In the case of the Murghab region, modern canals and off-roads, often reported on maps, helps to distinguish ancient features from more modern ones. Until the 1980s, the arid landscape northeast of the ancient city of Merv was characterized by the presence of water reservoirs, locally known as '*khak*' (Figure 4.5). As discussed in Chapter 2 (section 2.3.2), these reservoirs formed key resources for irrigation and animal husbandry in the past and were often connected to artificial canals bringing water to the fields (Fleskens et al. 2007). Yet, most of these recent canals ran dry in the last 25 years and can easily be misinterpreted as ancient canals in satellite analysis.

In the 1990s, the AMMD team acquired numerous soviet maps of Turkmenistan at different scales ranging from 1:10,000 to 1:1,000,000. These maps were georeferenced and have been used in the Togolok and Ojakly areas as additional data for reconstruction and interpretation of the ancient hydrological system.[36]

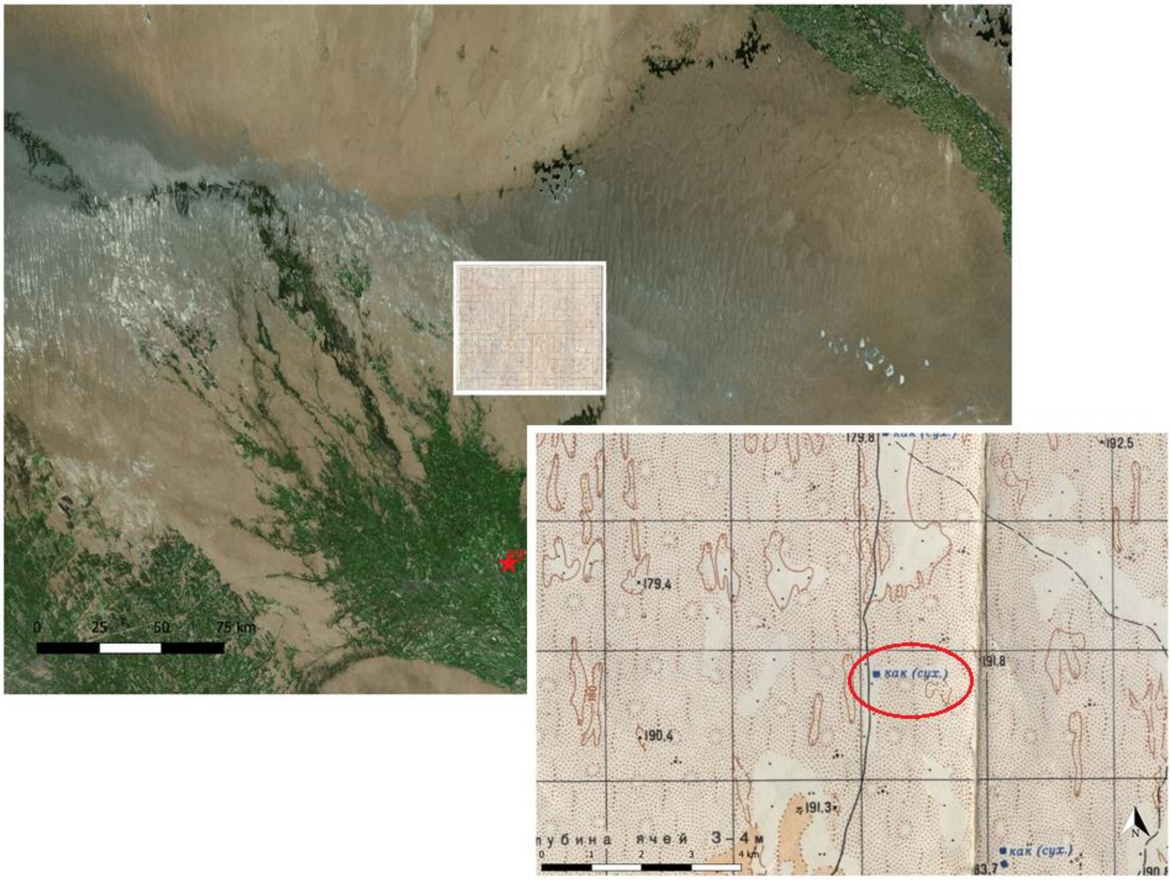


*Figure 4.5 Cartographic map, scale 1:100,000. The red circle indicates the location of a "khak."*

## 4.2.7 Image Analysis and Interpretation

The analysis and the interpretation of channels in the areas of Togolok and Ojakly has been carried out with an integrated approach into the GIS environment combining satellite images, aerial photos, and cartographic maps. Previous reconstructions in West Asia and elsewhere have likewise applied methods such as visual analysis and satellite images to reconstruct and map paleo-rivers (e.g., Ur 2005; Rayne and Donoghue 2018).

---

[36] The interpretation and the reading of the maps and their symbols have been facilitated by using "Soviet Topographic Maps Symbols TM 30-548" from the U.S. Army Department.

However, the selection of specific analysis is always bounded to the characteristics of the research area. Considerable anthropogenic activities or thick vegetation might cover ancient watercourses. The analysis, interpretation, and detection of channel traces (more often a single channel trace) needs to take into account the visibility of the past hydrological systems. For instance, a methodological approach using single multispectral satellite analysis, including LIDAR images, has been applied in environments with consistent anthropogenic activity and vegetation coverage (Salvini et al. 2006; Wang et al. 2012). Likewise, a recent archaeological project carried out in northwest India integrated a multi-temporal and seasonal approach using Landsat 5 images over a period of 28 years, to filter out more recent use of the landscape for agriculture (Orengo and Petrie 2017).

Despite potential problems, arid landscapes can yield good results of preserved ancient hydrological segments. In the last decades, projects using satellite images, including SRTM images, have successfully reconstructed paleochannels in desert or semi-desert areas (e.g., Hritz and Wilkinson 2006; Hritz 2010; Jotheri and Allen 2020; Hu et al. 2017) and distinguished between artificial canals and natural channels (Jotheri 2018).

The analysis and the reconstruction of the ancient channel system in the areas of Togolok and Ojakly has been done through visual interpretation. This is often a crucial step in any analysis involving satellite images or aerial photos; the interpreter has to define specific characteristics that support the identification of an archaeological feature, such as a mound or, in this case, ancient water channels. Single or multiple classes of objects are identified which form the basis of the analysis, including, in some cases, the automated detection of objects. In automated object detection, the targeted objects have specific visual, geometrical, and spectral characteristics, which can be used to generate a series of algorithms (e.g., Beck et al. 2007b; Da Pelo and D’Orazio 2013). Considering that in satellite images objects have diverse properties, the rules that need to be established by the algorithms might vary greatly, and “writing” a successful algorithm can be time-consuming (Orengo and Petrie 2017). Likewise, automated detection needs a training area for testing the algorithms, and in which previous field surveys have already established the position of a large number of archaeological sites. The positive objects generated by the algorithm (understood as archaeological evidence) can be tested against the false positives based on previous field observations. In the case of paleochannels, considering the high irregularity of channel traces, along with their variables tones, shape, orientation, and relative size, visual interpretation was the most effective and the least time-consuming detection method for both the Togolok and the Ojakly areas considering their size.

As discussed previously, the visual interpretation was conducted within a multilayer approach of all available remote data. In this case a GIS-based analysis was crucial in this study. Initially, each identified paleochannel trace was assigned a code in Roman numerals (e.g., Ch_IV).[37] Subsequently, all paleochannel traces were analyzed to ascertain potential connections. When multiple traces were deemed to be part of the same paleochannel, a new code number in Arabic numerals was assigned to these traces (e.g., Paleochannel 2). Consequently, a channel number could comprise more than one channel trace (see Appendices).

- **Interpretation**

The visual analysis of features in satellite images usually involves several characteristics. The features can be classified by their texture, tone or color, pattern, size, and shadows (Joseph 2005; Lillesand et al. 2008; Lasaponara and Masini 2012). Jotheri and Allen (2017) have applied a similar approach for recognizing ancient channels in Mesopotamia using various satellite images, including CORONA. A similar approach has been used for the present research as well.

The modern alluvial fan channel network in the Murghab region presents two major channel categories: the main channels, often more than 10 m in width, and second-level branch channels (often 5 to 8 m in width) connected to the main channel. The

---

[37] Prior to the channel number, a prefix code indicating either Ojakly (OJK) or Togolok 1 (TGK1) was included (e.g., TGK1_ChIV).

northeastern area of the Murghab, now an arid landscape, seems to present a similar channel structure in the past detected by satellite images. However, while traces of the main ancient channels are easy to identify on satellite and aerial photos, as they survive in the form of takyr surfaces (see below), secondary channels or artificial canals of less than 5 m in width have hardly been identified so far.

In the present analyses, several characteristics have been combined for recognizing paleochannels[38], and these form the basis of the analysis in the Togolok and Ojakly areas. These characteristics are:

*Size* – The ancient channels range between 5 to 25 m in width. Similar features – such as off-road paths – which are usually between 2 and 5 m in width in the Murghab, can be interpreted as modern features due to their more narrow widths. However, small channels or artificial canals can sometimes have a width similar to off-road paths which can complicate their reconstruction.

*Direction* – Direction is a crucial element to consider while analyzing the images. The channels identified by the satellite images have a general north/northwest direction. The modern expansion of agriculture has massively affected the Murghab region in the last three decades. The high temperature, and the relatively shallow depth of modern canals that bring water to the fields have resulted in the fast abandonment of many modern channels in the northeast areas of the Murghab. Yet, their becoming inactive and slow dune movement have generated old traces of modern canals that could be misinterpreted as ancient channels during the analysis. However, very often, modern canals in the Murghab have linear directions that do not follow the gradient of the landscape. In contrast, ancient channels follow the natural landscape gradient. In the Murghab, almost all linear features that have an east–west direction can be considered modern features.

*Shape* – Shape is an important parameter in visual interpretation and refers to the form of the channels. A meandering shape suggests the presence of a watercourse of a natural

---

[38] These characteristics have been outlined and successfully applied by Jotheri (2016)

origin. However, an alluvial fan can also include channels with a limited meander. In contrast, extremely straight lines can be associated with man-made channels (or pipelines). Unmanaged artificial canals, however, can also acquire a meandering form within some years, complicating the distinction between natural and artificial watercourses.

*Sediments* – One of the most effective characteristics for identifying channels in the northeastern area of the Murghab alluvial fan are the takyr surfaces discussed in Chapter 3. The takyr is a polygonally cracked surface, often characterized by an irregular shape. In addition, it can be distinguished from its surrounding area as it often has very little vegetation on it (Fleskens et al. 2007). Takyrs can form naturally in the Murghab, and they are usually formed in drainage areas in an ovoid shape similar to playas or salt flats in the United States or sabkha in West Asia (see section 2.3.1 in Chapter 2). However, when they occur in elongated or meandering forms, they often represent a part of old dried channels (Gerasimov 1978).

*Tone* – Takyr surface have a specific tone (or color) in panchromatic images, such as CORONA and aerial photos. The elongated features commonly associated with channel traces have a light or color compared to the darker color elsewhere. Likewise, in panchromatic images, the elongated dunes have a darker color, which is absent on the takyr surfaces. As such, light reflectance and color can point to old watercourses.

An additional parameter often mentioned in the visual interpretations is *association*. This concerns features that occur in proximity or in association with our targeted objects (Lasaponara and Masini 2012). In site detection, several features can be associated with archaeological sites, depending on the landscape, that constitute proximity objects for visual interpretation. In the case of paleochannels, several features can be seen in proximity to watercourses. In the Murghab, green vegetation that occurs along linear or meandering features are a good indicator for ancient channels. Recently inactive channels are still able to retain water along their former banks. These features thus stand out through linear bands of vegetation. Ancient channels can sometimes become active again by modern canals and are subsequently abandoned after a few years. Due to becoming active again, these meandering channels can have green vegetation along both sides of the former watercourse, clearly distinguishable on satellite images. In this case, comparative analysis made on the GIS platform of older and new images, such as CORONA and updated SENTINEL images, is crucial in separating older channels that have started flowing again from more recent ones.

A further element on the basis of remote sensing analysis is the distinction between natural channels and canals. In this thesis I refer to channels for natural watercourses, while canals are meant for artificial features. Jotheri (2018) recently delineated fundamental characteristics useful for distinguishing between natural and artificial watercourses. While part of this analysis relies on geoarchaeological analyses, like test trenching and coring, which were not conducted in our research for all identified paleochannels, other aspects remain relevant for differentiation. As previously discussed, direction and morphology serve as pivotal factors for discerning based on satellite imagery. Canals often exhibit unnatural orientations, such as east to west in the Murghab region, indicative of artificial watercourses. Additionally, they typically display linear configurations and are unlikely to manifest meandering patterns. These attributes offer valuable clues for discriminating between channels and canals at the remote sensing level.

## 4.3 Field Work

### 4.3.1 A Short Introduction to The History of Investigating Ancient Channels

Remote sensing and GIS analysis can provide the first identification of an ancient river system. However, survey of these features and their associated archaeological sites is crucial for a correct reconstruction of ancient farming systems. A survey’s aim is to ground truth paleochannel traces to verify their presence and acquire key characteristics of the landscape. This method has been extensively used in West Asia since the mid-1960s.

The publication of *Heartland of Cities* by Adams (1981) marked a milestone in the research done between the 1960s and 1980s on irrigation and fluvial systems in West Asia. For instance, research by Jacobsen (1960) suggested that the Tigris shifted its course in the 5th and 3rd millennia BCE. Seminal works by Adrianov (1969) and Lisitsina (1969) in Central Asia marked an equally significant turning point in our understanding of the relationship between hydrological systems and settlement patterns. Moreover, the link between the irrigation system and the Bronze Age Tazabagyab settlements in the Aral area, studied by Adrianov, provides crucial proxy data for understanding the possible management of water resources by Andronovo (ICW) pottery sites in the Murghab, that will be further discussed in Chapter 7.

In Mesopotamia, the works by Adams truly influenced the investigation of the landscape by Wilkinson (2003: XIII). Wilkinson's work focused on the "development of the cultural landscape and its features in light of the physical, cultural, and historical context" (Wilkinson 2003:11). The landscape was investigated as a component formed by several elements, the study of which would disclose the social and economic layout of ancient societies. The analysis of Mesopotamian landscapes, their irrigation, and agricultural systems were examined with a multidisciplinary approach that included the site survey, off-site archaeology, and satellite and aerial image investigation, along with geomorphological investigation of channels. This growth of new research projects in Mesopotamia led Wilkinson to found the *Center for Ancient Middle Eastern Landscapes* (CAMEL) at the Oriental Institute in Chicago in the 1990s (Gibson 2020:3). The new center gave a boost to the discipline with new landscape-scale research projects with innovative approaches and served as a training center for a new generation of scholars.

In addition to archaeological research, investigation into textual sources from Mesopotamia led to a better understanding of the management of water resources (Rost 2015; 2017). In the early 2000s, works such as that by Steinkeller (2001) have effectively described the functions and location of irrigation networks based on the Ur III period texts from Umma. More recently, archaeological investigations by various authors have boosted research of irrigation systems in the Mesopotamian landscape. Investigations from Ur (2003; 2005) and Hritz (2014), for instance, integrated past survey data with newly identified sites and paleochannel systems with the use of declassified satellite images (e.g., CORONA) and digital elevation models (DEM). Likewise, more recent geoarchaeological investigations, such as by Yacoub (2011) and Jotheri et al. (2018), effectively use a multidisciplinary approach in the study of past hydrological systems in Mesopotamia. Those studies have effectively built a well-defined methodology that will be later discussed in the present chapter.

### 4.3.2 Previous and Current Survey Projects of the Murghab Region

The archaeological and topographical exploration of the ancient city of Merv in the Murghab region began in 1946 with the establishment of the YuTAKE (*South Turkmenistan Archaeological Complex Expedition*). From 1950 onwards, the YuTAKE team led by V. M. Masson concentrated their studies on the settlements along the Kopet-Dag Mountains (southern Turkmenistan) (Tosi and Cerasetti 2010). The exploration of the Murghab region intensified throughout the 1960s and 1970s, while the most important discovery occurred in 1972 with the identification of Gonur-tepe (Sarianidi 1981). The surveys in the Murghab region by Soviet scholars comprised an area of more than 5,000 km$^2$ until the 1980s and was mainly devoted to the identification and investigation of mounds sites, such as Kelleli, Togolok 1, and Togolok 21 (Hiebert 1994).

In the 1980s, the Institute of Archaeology of the USSR Academy of Science began to investigate more areas of the central and northern–eastern sector of the Murghab alluvial fan (Gubaev et al. 1998:201–267). However, one of the most crucial limitations of these surveys was the research method and the relatively limited interest in a multidisciplinary investigation (see Chapter 3). Towards the end of the 1980s, and with the collapse of the Soviet Union, Western teams started their collaborative investigations in the region.

In 1989, the first scientific protocol between the Institute of Archaeology of the USSR Academy of Sciences and the Italian team from IsMEO (*Istituto Italiano per il Medio ed Estremo Oriente*) was signed. This protocol eventually led to the establishment of the AMMD project (*Archaeological Map of Murghab Delta Project*) between Italian and Turkmen colleagues. The AMMD project started a multidisciplinary investigation of the northeastern part of the Murghab alluvial fan with intensive surveys and geomorphological investigation. The flat region was divided into two sectors and explored mainly by a walking transect survey and by helicopter for aerial photos (Tosi and Cerasetti 2010). The first preliminary archaeological map of the region was completed in the mid-1990s (Gubaev et al. 1998) and integrated with new investigations and archaeological excavations in the mid-2000s (Salvatori at al. 2008). The survey in the 1990s and 2000s led to the identification of hundreds of new sites dated from the Bronze Age to the Sasanian and Islamic periods. The sites were mainly dated based on the pottery assemblages and their types were categorized based on three aspects that will be further discussed in section 4.3.4. The AMMD project also fostered investigation into the early hydrological and water channel system of the Murghab, providing the first radiocarbon dating of ancient channels (Cremaschi 1998), along with the first macro-scale reconstruction of the main ancient watercourses of the alluvial fan (Cerasetti 2008). The AMMD project ended in 2013 while in 2014, the new joint project (TAP - *Togolok Archaeological Project*)[39] started to excavate the large mound of Togolok 1 (Cerasetti et al. 2019; 2022). Meanwhile, other teams from Switzerland started a collaborative project at Gonur,[40] while a new Russian team continued the excavation at same site.[41]

Building upon the previous survey projects, the recent PAM project (*Project for the Ancient Murghab*) started in 2016[42] and aims to investigate the intra-sites relationship in specific micro-regions of the Murghab, including that of Togolok. The project wants to integrate past survey data with additional data from further surveys, using drone

---

[39] The TAP (*Togolok Archaeological Project*) is directed by Dr. B. Cerasetti from ISMEO (*Associazione Internazionale di Studi sul Mediterraneo e l'Oriente*) and FU-Berlin.

[40] The Swiss project, directed by Prof. M. Novák, started a new excavation project at Gonur.

[41] The Russian team is directed by Prof. N. Dubova from the Russian Academy of Science-Moscow.

[42] The PAM project (*Project for the Ancient Murghab*) is directed by Dr. L. M. Rouse from Washington University in Saint Louis and the German Archaeological Institute.

platforms and pedestrian surveys to better define the under-researched relationship between sites and intra-sites (Olson and Rouse 2018). Likewise, the project wants to integrate a detailed investigation of the geomorphology of selected areas of the Murghab, along with several targeted investigations, such as palynological analysis, that can contribute to disentangling the human–environmental relationship in the Murghab during the Bronze and Iron Ages.

### 4.3.3 Pottery Clusters: What Do They Represent?

The identification of archaeological sites across the Murghab landscape and their relative chronology was established from the surface spreads of archaeological material and mound formation. The majority of the sites in the region (c. 70–80%) have shallow deposits less than 1 m deep (Cattani et al. 2008:41) with materials from a single period on the surface. However, the interpretation of surface concentrations can be problematic.

How to interpret surface concentrations remains difficult, and sparks the question of to what extent surface scatters represent settlements or the result of post-depositional processes (Bintliff and Snodgrass 1988; Taylor 1973; Taylor 2000). For instance, the distribution over several kilometers of low-density abraded pottery in Mesopotamia has been interpreted by Wilkinson (1982) as the result of manuring practices. There, settlement-derived debris was spread as manure around settlements in agricultural fields to increase crop productivity (Wilkinson et al. 2004). In one of his recent papers, Wilkinson attempts to differentiate between pottery concentrations that signify the remnants of houses or local farmsteads, and small abraded pieces of pottery within extensive scatters areas that might support the general interpretation of manuring practice (Wilkinson 2014). In this context, Wilkinson attempted to distinguish between "site" and "manuring" assemblages in the Murghab on the basis of comparative data from the Balikh Valley. In this case, he distinguishes between raised areas and lower areas. The "raised areas (with high scatter densities) above lower ground (with sparse scatters) are likely to indicate in situ habitation." In contrast, "where lower areas are associated with moderate to high scatter densities [and] are adjacent to raised areas with low-density scatters, these probably relate to manuring" (Wilkinson 2014). Certainly, the vast quantity of sherds that Wilkinson found around sites such as Sohar in Oman and Tell Sweyhat in Syria, that gradually decrease in density away from the sites, can be potentially attributed to manuring (Wilkinson 1982). A similar picture has been described by Cleziou (et al. 1998) for the site of Togolok 1 that will be discussed in Chapter 6. Besides manuring, several natural as well as anthropogenic factors might affect distributions in the region, including research strategies and post-depositional processes (Wilkinson and Tucker 1995:17; Banning 2002:72; Ur 2002). The first factor that might obscure the visibility of the archaeological materials is shifting sands. Aeolian deposits might completely cover surface assemblages or channel traces.

However, in the Murghab it is unlikely that mounds would be completely covered. A second factor in a former fan environment is alluvial deposition. The accumulation of alluvial sediments contributed to masking archaeological evidence (Cremaschi 1998; Salvatori and Tosi 2008). According to Tosi and Cerasetti (2010), alluvial and aeolian deposits in the northern area of the Murghab might cover more than 60% of the landscape. In addition, the alluvial deposits in the south of the alluvial fan might explain the scarcity of Middle Bronze Age sites which are possibly buried under 4 to 6 m of deposits (Bondioli and Tosi 1998). Although Togolok and Ojakly are located in the central and distal areas of the fan, and were less affected by alluvial deposits, part of the archaeological evidence and channel traces might have been obscured as well.

Natural elements, however, are not the only factors that influence pottery visibility. A third factor is agriculture. The recent agricultural expansion in the Murghab, as in other areas of West Asia, strongly hampers site detection and preservation (Rouse and Cerasetti 2018:Fig.3). Although quantitative and risk assessment analysis of site destruction has never been attempted for the Murghab region (e.g., Zaina 2019), the fast expansion of mechanical excavators in the Murghab is evident from satellite images from the last decades. Although mechanized agriculture did not significantly affect the large mounds, such as Togolok 1, ploughing has led to the destruction of many flat sites and features in the region.

In addition to site visibility and site destruction, additional elements might bias our understanding of the past landscape. Archaeological materials present on the surface, such as pottery, are subject to erosion and aeolian deflation. As such, transport, transformation, and in some cases destruction of the deposit, can alter and create *false* patterns (Foley 1981: 162–63; Sabori et al. 2018). In parts of the southern Levant, for instance, sediments from hilltops were eroded, resulting in the concentration of sediment downslopes covering archaeological material or in the exposure of architectural remains on top of the mounds (Banning 2002:72). In the Murghab, aeolian deflation – particularly in the winter periods – may be responsible for the redeposition of archaeological materials or *mixing* of materials from different periods of occupation. Moreover, analysis by Markofsky and Bevan (2012) on directional influences and spatial autocorrelation of pottery material in the Egri Bogaz area, suggests that watercourses may have influenced the distribution of surface pottery assemblages.

### 4.3.4 The Definition and Categorization of “Site”

As mentioned in the previous section, the definition of a *site* is problematic, and it is often not clear how to define a site on the ground. Certainly, the identification and definition of a *site* in the Murghab (and in Western and Central Asia) is straightforward when applied to large mounds that represent stratified deposits (e.g., Togolok 1). However, the definition and identification of a site has become less straightforward when dealing with artifact clusters (mainly small or larger concentrations of pottery). The definition of a *site* in these cases can be context-dependent and ambiguous. In this project, a considerable surface scatter of materials (at least 25m$^2$) is defined as a *site* and “is regarded as a locus of concentrated human activity” (Wilkison et al. 2004). As such, smaller surface clusters or isolated finds have not been considered nor registered during the survey (see below for methodology).

The categorization of sites for the present project follows that adopted by the AMMD project between 1990 and 2008 (see below) (Bondioli and Tosi 1998; Cattani et al. 2008).

Likewise, site numbering follows the AMMD sequence, as a new register of sites would have created confusion. The data generated by this study have also been integrated with the site data from the previous AMMD survey (Gubaev et al. 1998; Salvatori et al. 2008) along with the sites recorded in Soviet surveys in the areas of Togolok and Ojakly. A publication by Sarianidi (1990a) shows an overview of sites recorded by YuTAKE team in the Murghab, although these data are often fragmentary and not well published, and they lack raw data. Between 1994 and 2005, the AMMD surveyed large areas of the Murghab alluvial fan (Clezious et al. 1998:26–34; Cattani and Salvatori 2008:1–27) (Figure 4.6). The first surveys in the 1990s concentrated in the southern part of the alluvial fan in the area of Togolok.

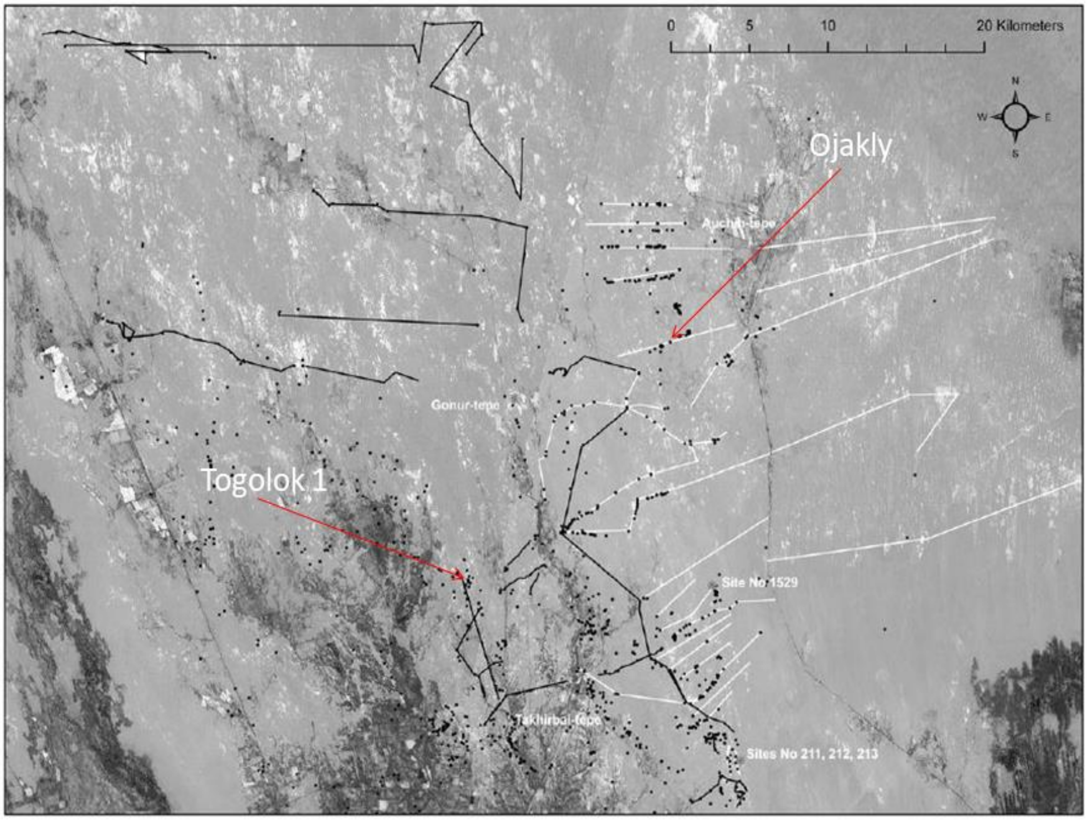


*Figure 4.6 The figure shows the AMMD walking transects conducted in the northeastern region of the Murghab alluvial fan. The black lines represent surveys conducted from 1994 to 2005, while the white lines show surveys conducted from 2006 to 2009. These transects were planned to navigate around natural obstacles, such as canals, and anthropogenic features, such as agricultural fields, within the alluvial fan (adapted from Cerasetti 2012).*

In the following years, the transects were expanded to the areas between Taip and Gonur North, and between Kelleli and Egri Bogaz. During the early 2000s, the survey extended further east, covering areas east and west of Auchin and west of Gonur North, and Takhirbaj. These latest surveys led to the discovery of numerous Andronovo (ICW) pottery sites, which eventually culminated in the investigation of Chopantam and Ojakly, excavated in 2006 and 2009–2010, respectively (Cattani 2008a; Rouse and Cerasetti 2014). Sites were categorized by the AMMD according to the extent of the pottery distribution and mounds, and were grouped into four main site categories.

The *tepe* (or *depe*) is the most prominent site category (as they represent solid anthropogenic mounds) and are highly visible across the landscape (up to 5–7 m in elevation and ca. 5 to 10 ha in extent). They generally have a high density of pottery, such as at Togolok 1 (Cleziou 1998). They often represent multi-period sites with mudbrick fortified structures that have been associated with administrative or religious use, such as at Adji Kui 9 or Togolok 21 (Sarianidi 1990b; Bondioli and Tosi 1998: IX; Rossi Osmida 2007). In this research, no new mounds (tepe) were recorded as their presence was already known.

In addition to the mounds, three more site categories were recorded by AMMD: the a) *Elevated Depositional Area* (EDA), b) *Low-Lying Depositional Area* (LLDA), and c) *Scatters* (Bondioli and Tosi 1998: IX–XIX).

*EDA* sites are characterized by a slightly elevated surface (<1 m) and have a large densities of surface materials. They are considered single-period sites associated with mudbricks strictures and possibly kiln structures. They can range between 1 or 2 ha. Several of these sites in the AMMD database have pottery from the Middle and Late Bronze Age and Iron Age.

*LLDA* sites are flat area and have artifacts covering <1 hectare. Defining the border of LLDA sites was often difficult and subject to the interpretation of the surveyors. This depends on the boundaries which are not always straightforward to interpret in the field (Plog et al. 1978; Banning 2002:200).

*Scatter sites* or artifact clusters are the most ubiquitous categories in the Murghab. They are small areas of artifacts (between 0.1 and 0.5 ha) with a moderate or low density of materials on a flat area, sometimes associated with takyr surfaces but also present in sandy areas. They are often associated with pastoral or seasonal use, such as at Gonur N., as most of these sites lack evidence for mudbrick structures (Hiebert and Moore 2004). The vast majority of these sites remain unexcavated and little is known about them. A further category in the AMMD dataset, not representing sites, is *potsherd* which represents isolated finds. This category was not considered in this research.

For the present project, sites were recorded adopting a similar categorization of the AMMD dataset. Their category names, however, have been changed to facilitate their recording and analysis (Table 4.1).

| New Site Category | Description | Former AMMD category |
|---|---|---|
| **Tepe** | Artificial mound (up to 7 m) with a high density of pottery dispersal (>5 ha) | Tepe |
| **Low Mound** | Slightly elevated surface (<1 m) with the presence of a large density of surface materials (1–2 ha) | Elevated Depositional Area (EDA) |
| **Large Cluster** | Flat areas with a high distribution of artifacts (<1 ha) | Low-Lying Depositional Area (LLDA) |
| **Small Cluster** | Flat area with distribution of artifacts (<0.5 ha) | Scatters |

*Table 4.1 The table shows the four-site categorization of the present project and how they correspond to the previous AMMD categories (Gubaev et al. 1998; Tosi et al. 2008).*

The dataset from the AMMD survey has been integrated into this research and provided crucial information for settlement distribution analysis in relation to water resources (see Chapters 5 and 6). However, detailed description of sites in the AMMD database are usually reserved for larger sites, such as low mounds (i.e., EDA) or large cluster sites (i.e., LLDA). As a result, small cluster sites often lack additional information. Likewise, many sites from the early 1990s survey also lack descriptions in the database.

In addition to AMMD data, past Soviet surveys have also been integrated into the project database and uploaded into the GIS platform (Sarianidi 1990a). The main problem with the Soviet data is the overall categorization of any settlement under the broad definition of *site*, without any further data or sub-division into site categories. This creates a *false* homogeneity of the data collected. However, when a description of these sites is provided elsewhere, the sites have been tentatively categorized under the site categories of the thesis (Table 4.1). Small and large clusters of sites are often not represented in Soviet survey data as the main focus of the early survey was on the main archaeological sites (i.e., tepe and low mounds).

### 4.3.5 Field Survey

The field survey aimed to ground truth the channel traces identified in the remote sensing stage. The main objective was to acquire dating evidence for the use of water channels and more data on their characteristics. In addition, it aimed to identify settlements that may inform us about irrigation and agricultural practices in the Bronze and Iron Ages.

The fieldwork surveys were conducted in two field season for a total of seven weeks under the umbrella of the PAM project (*Project for the Ancient Murghab*). The TAP project (*Togolok Archaeological Project*), which excavated the Togolok 1 site during the 2014, 2015, and 2018 field seasons, was also instrumental both for the preparation and logistics of the fieldwork. In addition, TAP provided archaeobotanical samples for carbon isotope analysis from Middle and Late Bronze Age layers (see section 4.5 of this Chapter). The fieldwork was the second stage of analysis of the fluvial system and was divided into two parts.

The first part of the fieldwork was composed by the reconnaissance of the paleochannels analyzed via remote sensing, while the second part was characterized by a transect-based field survey to record additional sites along the former channels.

As discussed above, the introduction of mechanized agriculture has led to drastic changes in the central Murghab, which have recently started to affect the distal areas of the fan as well. This situation and the construction of small canals to irrigate new fields is an ongoing process that generates an unpredictable landscape. As a result, it produces natural and artificial barriers to fieldwork surveys that need to be taken into account during fieldwork preparation.

#### 4.3.5.1 Ancient Channel Scouting and Recording

The first transect-based channel reconnaissance was conducted east of Ojakly. The transect comprised about 4 km up to the Auchin canal. The walking team was composed of five members,[43] located 100 m apart. After having completed this first transect, where we detected several traces of old channels, the team obtained a better understanding of the landscape and its channel structure.

During the field walking, the locations of paleochannels were recorded, and the GPS data were imported into the GIS.[44] Because of the limited size of the screen of the GPS, we printed maps of the paleochannels as well, facilitating their reconnaissance. For each channel we documented its characteristics and took photographs.

After the first pedestrian reconnaissance, it was clear that channel traces – often between 5 to 10 m in width, and with the specific takyr surface and almost no vegetation – were visible from a car as well. Therefore, it was decided that we would proceed with the scouting of channels by car. The method turned out to be faster and more efficient and allowed the team to verify and record the same channel at various locations in the

---

[43] The fieldwork team was composed of four members from the PAM project and two expert desert drivers with a 4x4 UAZ car who were hired thanks to cooperation with archaeologists from the Merv Archaeological Park near the modern city of Bayram-Ali. One of the drivers, who also collaborated in past excavations with the AMMD as an experienced worker, was the fifth member of the walking team.

[44] The team was equipped with two GPS Garmin GPSMAP 64s to record the exact location of the observed paleochannels. The use of GPS allowed the uploading of raster and vector data. As such, satellite images and the desk-based reconstruction of paleochannels network were uploaded onto the two devices.

Togolok and Ojakly areas. Several east–west and vice versa transects were made by car both in the Ojakly and Togolok areas.

Moreover, the information we could obtain from the driver and local shepherds about the current situation of desert roads and passages across modern canals was crucial at this stage. This is because the fast development of agricultural expansion with the creation of new field systems (particularly in the Togolok area) and the construction of small and large modern canals (Figure 4.7) impeded access to parts of the landscape the team planned to survey. Therefore, designing survey routes in collaboration with local drivers was vital.

*Figure 4.7 The rapid expansion of field systems in the northern regions of the Murghab, along with the modern machine excavation of canals, frequently obstructed passage during the survey. Furthermore, cultivated fields and canals often result in the destruction of archaeological evidence. The image depicts a canal excavated in the vicinity of Togolok.*

#### 4.3.5.2 Pedestrian Survey

The pedestrian field season had two main objectives: a) survey along the former channels in both the Togolok and Ojakly areas for site identification and dating, b) the coring and excavation of the channel test trenches to investigate their stratigraphic sequence and to obtain absolute dates with OSL analysis. Building upon the experience of the first field season and the difficulties of accessing some areas, a preliminary verification in the Netherlands of the field walking areas turned out to be pivotal. Considering the time, the budget, and the people involved, it was crucial to set up efficient planning. Preliminary desk-based assessment of the Togolok and Ojakly areas was conducted by analyzing three up to date Sentinel 2 images. As a result, green areas representing current field systems or areas with major modern canals were deselected as potential target for survey.

As Adams (1981) argued, the chronology of sites situated along the canals in Mesopotamia can provide general dates of the irrigation system and when it was in use. The “dating by association” method remains the most efficient one for archaeologists to suggest a chronological period for paleochannels in the absence of any additional analysis (Wilkinson 2003:83). In this case, the dates of the sites located along the channels suggest when the watercourses were at least active. This provides an indirect relative chronology of the paleochannels, suggesting possible periods of activity. In this context, the aim of the survey was to detect and date sites aligned along the paleochannels that could suggest periods of activity. The extensive transect-based survey previously conducted by AMMD, while revealing the presence of numerous settlements possibly aligned along channels, did not target any channels. Most of the ancient channels recorded in AMMD transects were accidental discoveries (Cattani et al. 2008; Ninfo and Perego 2006), and no further research has been undertaken.

Prior to the fieldwork, several survey areas were selected on the basis of Sentinel 2 images discussed above. Transects were created both for Togolok and Ojakly regions. At Togolok, a total of six survey areas were created, while at Ojakly, a total of eleven survey areas were drafted on a GIS platform. Each area extends for ca. 500 m to the left and right of the former watercourses and followed the natural meandering forms of the channels (Figure 4.8). In this context, 500 m can be considered an adequate distance to detect sites located in proximity to the water channels. The distance between sites and water channels will be further assessed later in this study (see Chapters 5 and 6 for the analysis).

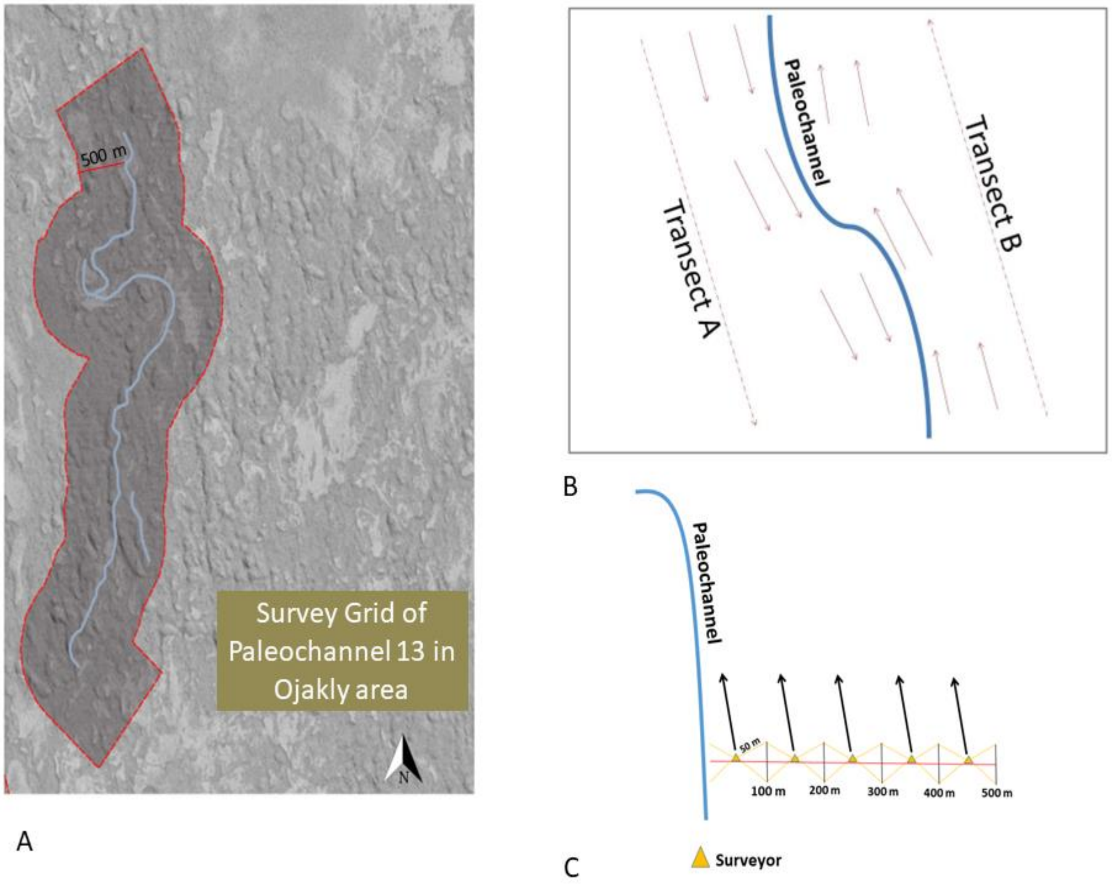


*Figure 4.8 The figure shows A) the survey area from Paleochannel 13 in Ojakly, B) a schematic representation of walking transects A and B along a former channel, and C) the walking survey method. The paleochannel was surveyed on both the left and right of the the paleo-bank.*

The field-walkers were spaced 100 meters apart from each other.[45] The ancient channels were surveyed both on the left and the right (transect A and B). Prior to the survey, the

---

[45] The walking team was composed of three team members from the PAM project and two team members from the TAP project, in addition to the drivers and a few other workers that had worked extensively with the AMMD team in the past.

walking transects were uploaded on a GPS in the form of raster polylines, including the channels. Admittedly, when compared with other survey methodologies and resolutions, particularly in the Mediterranean region (Cherry 1983), the walking transects are spaced far apart. However, a similar methodology has been applied in arid regions of West Asia with good results. It was determined that a similar distance was suitable for achieving the desired results (Wilkinson et al. 2004:196). Also, during the autumn season, there is minimal green vegetation, and visibility is excellent.

During the field walking survey, each walker carried bags for pottery collection. As the general strategy of the field survey was to obtain a relative chronology of sites near the channels, single finds were not recorded as they do not make assessments on activities. In contrast, concentrations of archaeological materials on the basis of site typologies described in Table 4.1 was recorded.

When a site was encountered, the team halted for the recording.[46] Given the high number of pottery fragments and considering that archaeological materials were collected to date the sites, only a selection of diagnostic pottery was collected.[47] Rims, bases, decorated pottery, and handles, as well as small finds, were collected. These items were later entered into the databases, photographed, and drawn at the basecamp.

The analysis of the pottery and its chronology is limited by uncertainties concerning the Murghab ceramic sequence. The chronology of the Bronze and Iron Age is still under discussion and various chronological sequences have been proposed. There are significant problems in the study of Bronze Age pottery in Turkmenistan that have not been overcome (see Hiebert 1994a:39–73; Cattani and Genito 1998:75–87; Luneau 2010 for further discussion). In this study, the diagnostic pottery has been assessed as dating to the chronological periods of the Murghab (i.e., Middle Bronze Age, Late Bronze Age,

---

[46] The paper recording form included 1) date, 2) name of the survey area, 3) number of the survey area, 4) paleochannel trace number, 5) new site number, 6) uniquely raw photo number, 7) GPS point number, 8) brief description of the site, 9) registration of the bag number of the collected pottery associated with the site, 9) extra notes or any other relevant details.

[47] On each bag there was the number of the new site associated with the pottery and the GPS point with UTM coordinates.

etc.).[48] Pottery data were entered into the pottery database and saved on two backup hard disks in addition to the project laptop. In addition, all the data produced for this study will be stored with DANS (*Data Archiving and Network Services*)[49] in collaboration with Leiden University and will be available open access.[50]

Lastly, to avoid any possible confusion the number of newly recorded sites in the field follows the AMMD sequence. In the past, the surveys by the Soviets and that of the AMMD team created two different identification systems. Considering that the vast majority of sites in the Murghab have been numbered by the AMMD team in the last two decades of research, it was logical to adhere to the AMMD site sequence.

### 4.3.6 Paleochannel Investigations

In order to further explore the hydrological system of the Ojakly and Togolok areas, two channel traces were chosen for coring and test trench investigation. The objective was to analyze both a small and a large channel to examine their hydrological characteristics and determine the absolute dates of the channels using OSL analysis. Prior to the fieldwork, a preliminary survey by car was conducted to assess various channels identified through ground truthing. Eventually, after evaluating several options, Paleochannel TGK1_Ch_IX in Togolok and OJK_Ch_V in Ojakly were identified as the most suitable candidates for coring and test trench investigations.

#### 4.3.6.1 Hydrological System and Geoarchaeological Approach

In Chapter 2 (section 2.2) I discussed the characteristics of the Murghab alluvial fan. In short, the Murghab fan concludes its journey inland, and its modern shape is determined to a large degree by the construction of the Karakum Canal. The remote regions of the fan are marked by temporary streams that become active during the autumn and winter

---

[48] The pottery assemblages were mainly analyzed by Dr. E. Luneau from the German Archaeological Institute (DAI) and members of the PAM and TAP teams.

[49] https://dans.knaw.nl/en/data-stations/archaeology/ (last accessed April 2024)

[50] DANS use an open access license CC-BY-4.0.

seasons. Conversely, the central portion of the fan, such as the Merv area, features permanent channels. However, prior to the construction of the Karakum Canal in the 1980s, much of the northeastern section of the fan had dried out, with only temporary channels subject to flash flooding events.

During the Bronze Age the northeastern sector of the fan witnessed significant development, with sites like Gonur North, and Adji Kui 9. These sites were situated along the primary branches of the former fan (Sarianidi 1990a; Salvatori et al. 2008), which had a hydrological system characterized by a network of main channels and small streams. This particular scenario makes the northern areas of the Murghab fan highly suitable for geoarchaeological investigation.

In section 4.3.1, I explored a multidisciplinary approach to studying landscapes in West and Central Asia, incorporating archaeology, remote sensing, and geoarchaeology. In recent decades, geoarchaeological analysis has emerged as indispensable for investigating and dating past hydrological systems (e.g., Wilkinson 2003; Fouache et al. 2012; Malatesta et al. 2012; Jotheri et al. 2018; Rashidian 2021). In arid landscapes in particular, geoarchaeological investigations play a central role in reconstructing relationships (Wilkinson et al. 2010). As such, ancient fluvial systems hold significant relevance in West and Central Asia, often featuring archaeological evidence along their courses. Studying such systems can shed light on the relationship between local communities and water resources. In addition, analyzing various aspects of the fluvial system can help clarify why sites are situated in specific locations and the extent of their access to water resources. For example, in Mesopotamia, scholars like Jotheri et al. (2018; 2022) have focused their research on riverine sub-environments such as crevasse splays, marshes, and irrigated soils, which are essential for comprehending past human–environmental interactions in Mesopotamia. A similar geoarchaeological approach can also illuminate the water dynamics in the Murghab region.

Among the most prevalent fluvial landscapes are floodplains characterized by flat beds with stream channels (Goldberg and Macphail 2006:91). As outlined in Chapter 2, floodplains are found across various regions worldwide, including arid areas. Essential for understanding human–environment interactions is the study of floodplain evolution, which involves analyzing different sedimentary processes, deposits, and facies that undergo changes over time (Brown 1997). This holds particular significance in regions where civilizations originated along river branches, as seen in the cases of Mesopotamia, the Indus Valley, and the Murghab.

In this context, the investigation of stream deposits and channel patterns can provide valuable insights into the development of a hydrological system. Analyzing channels can help us understand the history of watercourses (Costanzo et al. 2023). Coring and test trenches of channels are optimal methods for investigating ancient watercourses (Jotheri 2016). Employing hand augers for coring channels at various points, as I will discuss in the following paragraph, is a crucial method to examine channel cross-sections. Trench excavations can offer insight into the stratigraphic sequence of channels and their evolution. Through this method, the different stages and stream velocity of channels can be inferred from the materials transported, technically defined as *sediment load* (Goldberg and Macphail 2006).

The reconstruction of the former paleochannel system in Togolok and Ojakly, understood as traces of its system, can shed light on the possible forms of the past hydrological system. As we know from modern fluvial system, the morphology of channels can vary depending on the sediment transported and flow conditions. Leopold and Wolman (1957) classified fluvial channels as straight, meandering, and braided patterns. Despite undergoing scrutiny in recent decades, these channel typologies remain relevant. While remote sensing analysis in this study is limited to channel traces, it nonetheless can provide some insights into the typology of the channel system.

Channel types depend on hydraulic and sedimentary factors (Knighton 1998:208) (Figure 4.9). The first channel category is composed by straight singular channel. This type is rare and generally takes this form because little erosion occurs along the banks (Goldberg and Macphail 2006:89).

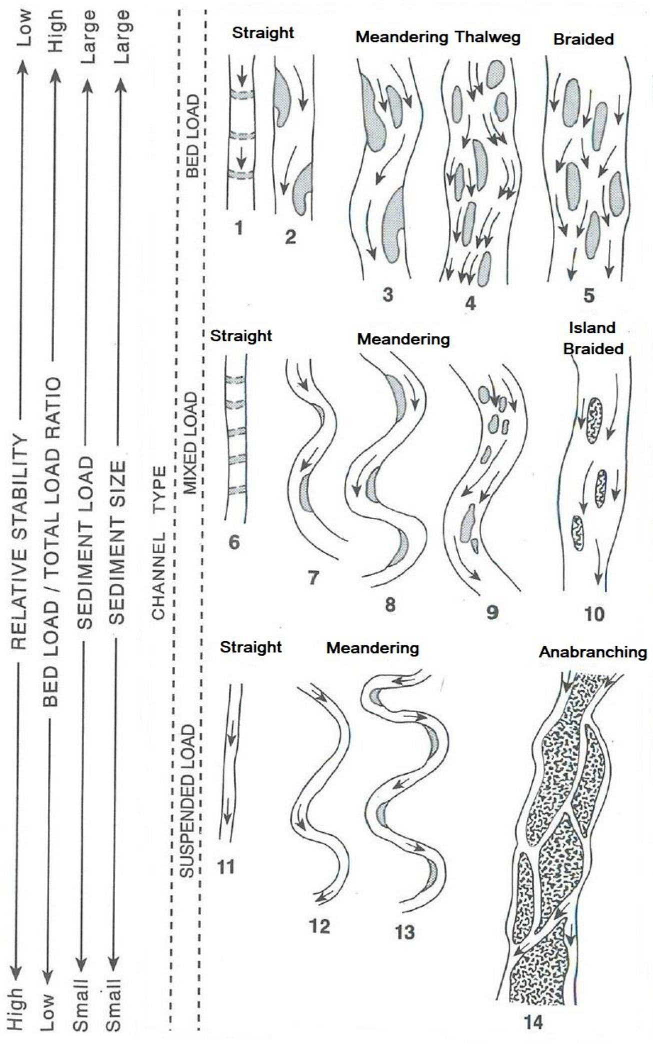


*Figure 4.9 The figure shows the main classification of channel patterns (adapted from Knighton 1998:Fig. 5.16).*

The second category is the meandering channel. Meandering watercourses, according to Kellerhals et al. (1976) can have a series of meanders with a different deviation angle. Asymmetry of the meanders can be regarded as inherent characteristics (Carson and Lapointe 1983, Knighton 1998:213).

The third category of multichannel rivers regularly form floodplains. According to Knighton (1998) multichannel rivers can be grouped into two main categories of a) braided rivers and b) anabranching rivers. The anabranching rivers are composed by subgroups of which the most common is the anastomosing, characterized by low-energy flood plains[51] (Nanson 2013) (see below for definition).

Braided rivers are characterized by repeated convergence, divergence, and joining of the channels (Bristow 1987). Braided channels occur in alluvial fans in a semi-arid or arid environment, in particular where rapid change of water discharge can occur with easily eroded stream banks (Boggs 2001). In a braided system, channels are separated by islands or bars. Bars do not have vegetation and are unstable, while islands are usually stable and vegetation occurs (Knighton 1998:230). In anabranching rivers, islands are quite large, vegetated, and stable compared to the braided ones that are considered as in-channel features (Makaske 2001).

Within anabranching systems, single channels are often independent of one another, while their specific characteristics vary. In fact, single channels can form straight, meandering, or braided channels (Schumm 1968; Brice 1984). The sinuosity of the anabranching channels can vary, but they are generally characterized by a low gradient and low width–depth ratio (Knighton 1998:Table 5.10).

One of the characteristics of channels in flood plain is their capacity to shift. It is usually regarded as a slow process, mostly due to avulsion (Smith and Smith 1980; Makaske 1998:70–76). Avulsion occurs when a channel breaks the banks, often during a period of high discharge, and forms a new channel while abandoning its former channel. Similarly, erosion of the outer banks of a meander can lead to the formation of an oxbow lake that is a result of a meander being cut off (Goldberg and Macphail 2006:91). In the context of the formation of a new channel, anabranching rivers are characterized by the presence of three categories of channels (i.e., primary, secondary and tertiary). As discussed in Chapter 2, the modern Murghab alluvial fan presents these three categories with low levees, and this is evident in the modern fluvial system. Similarly, even though only sections of former channels may be discernible through satellite imagery in the Murghab,

---

[51] It is important to stress that some authors (i.e. Brice et al. 1978, in Schumm 1985) consider anabranching and anastomosing as synonyms. However, there is often no consensus on terminology as it is difficult to incorporate a definition based on channel pattern only (Makaske 2001).

one would expect a comparable pattern from the Bronze Age period as well (see discussion in Chapters 5 and 6).

Although rivers can be categorized as meandering, braided, or anabranching systems, as discussed above, very large and long rivers, such as the Tigris and Euphrates in Mesopotamia, can exhibit diverse patterns. Jotheri (2016) argues that the Euphrates shows an anastomosing pattern from Shinifiyah to the marshland area, while the sections from Dhuluiya to Kut, or from Kut to Qurnah show a meandering pattern, for instance. Determining the typology of the ancient hydrological system can offer profound insights into various aspects of the settlement pattern during the Bronze Age. Also, understanding the configuration of the channel system provides valuable clues about the location of archaeological sites and key areas of human activity and economic strategies.

The presence of archaeological sites along abandoned meandering, braided, and anabranching stream deposits underscores the importance of geoarchaeological investigation. Identifying the timing and causes of river evolution and its relationship to settlement patterns is crucial. Similarly, comprehending how human activities interacted with a specific river morphology is essential for any further inquiry (Rashidian 2021). In Mesopotamia, for example, geoarchaeological studies revealed the timing of levee aggradation in channels, leading to the interpretation of favorable conditions for irrigated agriculture (Jotheri 2016).

Therefore, conducting geoarchaeological investigations, which involve employing cores and test trenches to examine the ancient channel system within the research areas, is essential for comprehending the relationship between channels and local communities, as well as their potential attributes. These investigations will allow researchers to analyze sedimentary deposits, stratigraphic layers, and other geological features associated with ancient channels, providing valuable insights into past land use, water management practices, and human interactions with the environment. Likewise, such investigations can shed light on why particular channels were selected, the reasons for their abandonment, their water capacity, and their overall evolution (Mantellini et al. 2008).

#### 4.3.6.2 Channel Cores

Before initiating the excavation of the test trenches in Togolok and Ojakly some preliminary analyses were conducted in the field. The surface elevations of the paleochannel cross-sections were obtained with a total station.[52] To investigate the stratigraphic sequence of the channels, several cores along the cross-sections of the channels were taken with the use of a hand auger. The aim of the cores were a) to have a preliminary idea of the stratigraphic sequence of the identified channels before excavating the test trench and b) with a series of transect cores perpendicular to the paleoflow of the channels, obtain its cross-section. The data obtained were crucial to a preliminary understanding of the channel sequence.

In total, nine cores were taken at both channels in Ojakly and Togolok. Two different hand augers from Leiden University suitable for mud to more compact soils were used. An extra hand auger head was acquired in the Netherlands. While it was crucial to have a hand auger that could assure a minimum of friction during penetration into the soil, it was equally important that the head could hold potential sand or sandy deposits common in this region. Therefore, it was pivotal to evaluate the different deposit types the team could have encountered during the drilling and decide the selection of hand augers based on these potential parameters. As such, a new hand auger with a 7 cm head suited for sand deposits was acquired.[53] The head had extra wings on the sides that keep the soil in and prevent coarse or fine sand from falling out during the extraction of the hand auger from the core.

Before starting coring on the basis of the line perpendicular to the paleoflow created on the GIS platform and with the aid of a GPS, several points were selected for cores along the cross-section of the paleochannels. While coring with the hand auger, a sample bag with sediments was taken when a change in the sediment was observed, such as texture, color, or any other characteristics (e.g., pottery, shell, etc.). The sediments for each core

---

[52] The measurements were obtained using a total station TOPCON GTS 250W

[53] Specifically, an Edelman auger, sand type was acquired.

were described in the field based on their texture, grain size, and color. On the basis of field observations, a drawing of the cores was produced in the field and later upgraded at Leiden University. The draws of the cores were later integrated into the channel cross-section obtained with the total station lining up the different stratigraphic sequences of the channel.

#### 4.3.6.3 Channel Trenches

After having obtained a preliminary cross-section of the channels with cores, test trenches were excavated at the center of the former channels. The trenches both in Togolok and at Ojakly measured 2 by 3 m and approximately 2 m in depth (Figure 4.10). They were excavated without any mechanical excavator.[54] During the fieldwork, two profiles (west and south) for each trench were described, analyzed, and drawn in the field. The stratigraphic layers of the profiles were analyzed on the basis of their macroscopic properties, such as their composition, texture, color, and macrofossils. In order to obtain an absolute chronological sequence of the channels, and its fluvial evolution, samples for Optically Stimulated Luminescence (OSL) analysis were taken at different points from the profile sections of two ancient channels (see Chapters 5 and 6 for sampling details). OSL analysis proved to be an effective methodology to date ancient watercourses in other fluvial contexts (e.g., Berking et al. 2017; Fouache et al. 2012; Toonen at al. 2020).

In total, seven OSL samples were retrieved from both trenches. The sediment layers were sampled with a metal tube (20 cm long with 5 cm diameter). Likewise, dosimetry samples were collected for each retrieved sediment tube for the dosimetry analysis. In the OSL laboratory, an approximately 5 cm slice of sediment from both edges of the tubes was withdrawn. This is because, during the sampling, particles from both ends of the tubes might have been exposed to daylight, which would zero the luminescence signal.

---

[54] Although the use of a mechanical excavator would have sped up the fieldwork, there was no excavator available at that time in the field. In addition, both areas are far from the nearest farming villages (namely the former "Sovkhoz" of Bayram-Ali), and the cost of bringing an excavator and a specialized worker into the desert for at least a week was prohibitive with the current budget.

Indeed, the OSL dates the time since particles (quarts or polyminerals – mainly feldspar) were deposited and received no further sun light. Both the OSL sampling in the field and the subsequent analysis in the laboratory were conducted by Dr. Daniela Müller at the Institute of Earth and Environmental Sciences – Geology, Albert-Ludwigs-Universität Freiburg (Germany). The OSL analysis from both Ojakly and Togolok samples follow Lamothe et al. (2003) and Preusser et al. (2014) for laboratory methodology and correction procedures.

The OSL dates are presented in Chapters 5 and 6 in BCE with corresponding date in BP[55]. However, BCE dates are integrated into the text to better correlate the ages with the BMAC context.

*Figure 4.10 The figure shows the early stage of excavation of the Togolok test trench on Paleochannel 7.*

## 4.4 Modeling of a Water Channel

The importance of water resources for the BMAC civilization has triggered numerous discussions in the last decade (Lamberg-Karlowsky 2013; Salvatori 2008a; Sarianidi 2009). In Chapter 3, I have discussed the importance of hydrological systems in a theoretical context. The relevance of the organization of an irrigation system and its

---

[55] The OSL were retrived in 2018.

development and maintenance have been long discussed in Near Eastern archaeology (see Mori 2020 for an updated discussion). In addition, although many irrigation systems were envisioned, constructed, and organized by central authorities, other systems – even of large scales – were not (Wilkinson and Rayne 2010; Berking 2018; Morandi Bonacossi 2017; cf. Hunt 1988; Wilkinson et al. 2012; 2015).

In the last decade, to analyze the management of ancient irrigation systems, scholars have applied modeling software that imitates such systems (Ji et al. 2003; Ertsen 2010; Tianduowa et al. 2018). These models allow for the design and analysis of the different degrees of management by calculating scenarios of management of a water channel system. By running possible scenarios of water management, this allows us to estimate the complexity and coordination of a water channel system.

### 4.4.1 SOBEK Software Analysis

In order to estimate different degrees of water management, one ancient channel trace identified in the Ojakly area was modeled using SOBEK-Rural software (1D).[56] The software is a modeling suite that creates one or two-dimensional grids (1D-2D) and simulates different flows and water processes in several irrigation and channel systems. The software has been used for archaeological and non-archaeological analysis to simulate floods and create scenarios within water systems with good results (Laserna 2003; Ertsen 2010; Prinsen and Becker 2011; Musa et al. 2015; Tianduowa et al. 2018). Among other things, the software can create different forms of canal cross-sections, including closed and open-air canals (similar to natural channels). It can model different inflows of water (Q) into a given channel. The water inflow can vary over time (i.e., from a few hours to days), simulating different scenarios in which there are different levels of water intake. Of crucial interest for this study is that the water level and water discharge passing through the canals can be calculated by the software at specific points and times throughout the canals. Likewise, the program can calculate the different water levels and

---

[56] The software was developed by the Deltares - *Dutch Research Institute*. The full version of the software was made available through collaboration with TU-Delft, thanks to Dr. M. Ertsen.

discharge trend of a given canal over a determined time period (e.g., showing the different water levels reached by a canal over 24 hours).

In addition, the SOBEK software allows us to study a wide range of characteristics of an irrigation system, including the modeling of weirs, gates, pumps, or culverts – although most of these tools have not been used for the present channel model. Notably, the software can calculate the management of an irrigation system, such as opening/closing of the gates and weirs at a given time, including coordination between gates within a specific time frame that simulates the management of human agents (see Chapter 5).[57]

Among the numerous channel traces, both in Togolok and Ojakly, one channel trace (Paleochannel 10) in the Ojakly area was modeled using SOBEK software. The channel represents one of the longest known channel traces identified in the area (>4 km). The selected section was likely part of the Murghab alluvial channels system (see Chapter 5). Yet, linking the different channel traces identified in Ojakly with reconstructed channels on an arbitrary level using the software would have produced unreliable results and scenarios. Therefore, only one channel trace was modeled with SOBEK.

The model aims to test various scenarios of management. While the results from these scenarios pertain to a single channel, they give rise to several broad aspects of discussion regarding the potential degrees of cooperation among BMAC communities. These aspects are further elaborated upon in Chapters 5 and 7, where the implications of the different scenarios are examined and discussed.

## 4.5 Isotope Analysis

Over the last two decades, stable carbon isotope analysis has been used in archaeology as an effective tool to analyze the relationship between crops, ancient irrigation practices, and water use (Araus et al. 1999; Flohr et al. 2011; Riehl 2008; Riehl et al. 2008; Stokes et al. 2011; Wallace et al. 2013). The analysis of $\delta^{13}$ C is derived from the stress that

---

[57] For more details visit https://www.deltares.nl/en/software/module/sobek-1dflow-rural/ (last accessed April 2024).

occurs in the plants when they do not receive sufficient water in the form of either rainfall or irrigation (Stokes et al. 2011).

The utilization of stable carbon isotope discrimination ($\delta^{13}$C) from archaeobotanical remains has become a standard method since the 1990s (Araus et al. 2007; Fiorentino et al. 2008). By integrating isotope results with paleoclimate data from the relevant time period, one can infer water management practices by interpreting level of $\delta^{13}$C. For instance, if the $\delta^{13}$C of the crop indicates that the plant received sufficient water in an arid environment, this strongly suggests that the crops likely received water from other sources, like irrigation (Flohr et al. 2019).

Although comparative modern data from the Murghab region are not available, Wallace et al. (2013) have recently assessed the reliability of stable carbon isotopes by investigating present-day crops (wheat, barley, and lentils) in multiple locations in Southwest Asia and the Mediterranean, with a particular focus on marginal and arid environments. These experiments provided reliable modern references, in terms of $\delta^{13}$C levels, from arid environments and from crops that are grown under known hydrological and climatic conditions. As such, as an interpretative framework to comprehend crop $\delta^{13}$C values Wallace et al. (2013) introduced a model consisting of bands representing broad levels of crops in relation to water (i.e., poorly-watered, moderately-watered, well-watered). Likewise, an additional experiment by Flohr et al. (2019) also confirmed the validity of the $\delta^{13}$C bands values proposed by Wallace et al. (2013). Those data are crucial for a correct assessment and interpretation of the isotope results in this thesis. However, while it is theoretically possible to interpret the data by comparing plant isotope results with the estimated amount of naturally available water for a specific crop, this operation is far from straightforward. Different factors can affect plant $\delta^{13}$C values, including climate fluctuations and the agriculture cycle which might result in an unreliable interpretation, which has raised concern (Stokes et al. 2011; Flohr et al. 2019).

Nevertheless, by comparing available paleoclimate data, modern regional data from the same crops, and other non-irrigated or wild plant data from the same site, it is possible to infer various irrigation practices and plant management to some degree (Ferrio et al. 2005). Likewise, irrigation practices and water management can be inferred by looking at variations between isotope results from various sites from the same region, and from different chronological layers from the same site, as in the case of Togolok 1 (see Chapter 6).

Agricultural management in arid lands, however, is not limited to irrigation. As pointed out in this chapter, the extensive distribution of pottery in the Murghab around the major sites has been interpreted by Wilkinson (2014) as possible evidence for manuring. In plants, manuring has an effect on the value of N in isotope composition ($\delta^{15}N$) that can be analyzed in the laboratory on archaeobotanical samples. In short, by analyzing the $\delta^{15}N$ results from the archaeobotanical assemblages and comparing these results with proxy data from arid regions, some general conclusions can be drawn about possible manuring practices (Kanstrup et al. 2011).

### 4.5.1 Togolok Botanical Samples

In September 2014, the TAP (*Togolok Archaeological Project*) started the excavation of the northern mound of Togolok 1 (Cerasetti et al. 2019; see Chapter 6). Although the excavation is still in its early stages, the trench excavated in the central northern area of the mound reached the Middle Bronze Age layers of the settlements (Cerasetti et al. 2022; see Chapter 6). During the excavation, several sediment samples for archaeobotanical analysis were collected from the Middle and Late Bronze Age layers (see Chapter 5 for $^{14}C$ dates and botanical contexts). Among these, 22 seeds have been selected for carbon isotope analyses from several botanical assemblages of different stratigraphic units. The analysis on the $\delta^{13}C$ and $\delta^{15}N$ samples was conducted at the Max Planck Institute of Geoanthropology in Jena (Germany).[58] The methodology applied to the analysis of the samples follows Wallace et al. (2013).

---

[58] The analyses were conducted by Ayushi Nayak from the Max Planck Institute of Geoanthropology (Jena, Germany). This is a preliminary analysis based on limited samples. A more comprehensive study, incorporating additional samples from both the Middle and Late Bronze Age layers, as well as samples from other sites in the Murghab region, will soon be published by the team led by Dr. R. Spengler.

The analysis of isotope results derived from botanical samples representing various crop categories offers valuable insights into the practices of manuring and water management prevalent during the Middle and Late Bronze Age. By examining the isotopic signatures present in these samples, one can discern patterns indicative of agricultural strategies, including the use of manure as fertilizer and the different water inputs between the Middle and Late Bronze Age. Understanding the nuances of water management practices is crucial for reconstructing the agricultural systems of the BMAC and understanding their socio-economic dynamics. These possible degrees of variability in water channel systems will be further discussed in Chapters 5 and 7.

## 4.6 Summary

This chapter presented the theoretical framework and the methodology applied by this research. The methodological and analytical approach is composed of several steps outlined in Figure 4.11.

In the first step, a remote sensing analysis is used to map and reconstruct the ancient hydrological system on both case study areas of Togolok and Ojakly. Subsequently, the field investigation included the reconnaissance of the remotely identified ancient channels, while a transect-based survey served to identify sites located along ancient watercourses. By dating these sites through their surface material, it is possible to estimate by association the possible periods of activity of the channels. This provides a relative chronology of when these watercourses were active.

The analysis of the ancient channels and their evolution was also investigated by means of channel cores with a hand auger and test trenches. This aim of the cores and test trenches is to further analyze the stratigraphic sequence of the channels and their fluvial evolution. In addition, OSL samples were retrieved from both trenches to obtain absolute dates of two channels.

The last two steps in the analysis of the ancient agriculture and channel system are the use of an agent-based model (SOBEK software) and stable carbon isotope analysis from Togolok 1 botanical samples. This analysis aims to further investigate the different degrees of water management based on possible agent-based modeling scenarios and different levels of water stress in plants between the Middle and Late Bronze Age.

All in all, the methodology of the current study includes a holistic approach that combines different data both from remote sensing and survey methods, with the addition of a geoarchaeological analysis. As discussed in this chapter, this multidisciplinary analysis has been successfully applied elsewhere in West Asia and has the potential to shed new light on and disentangle the complexity of the land and hydrological exploitation in the Murghab during the Bronze Age.

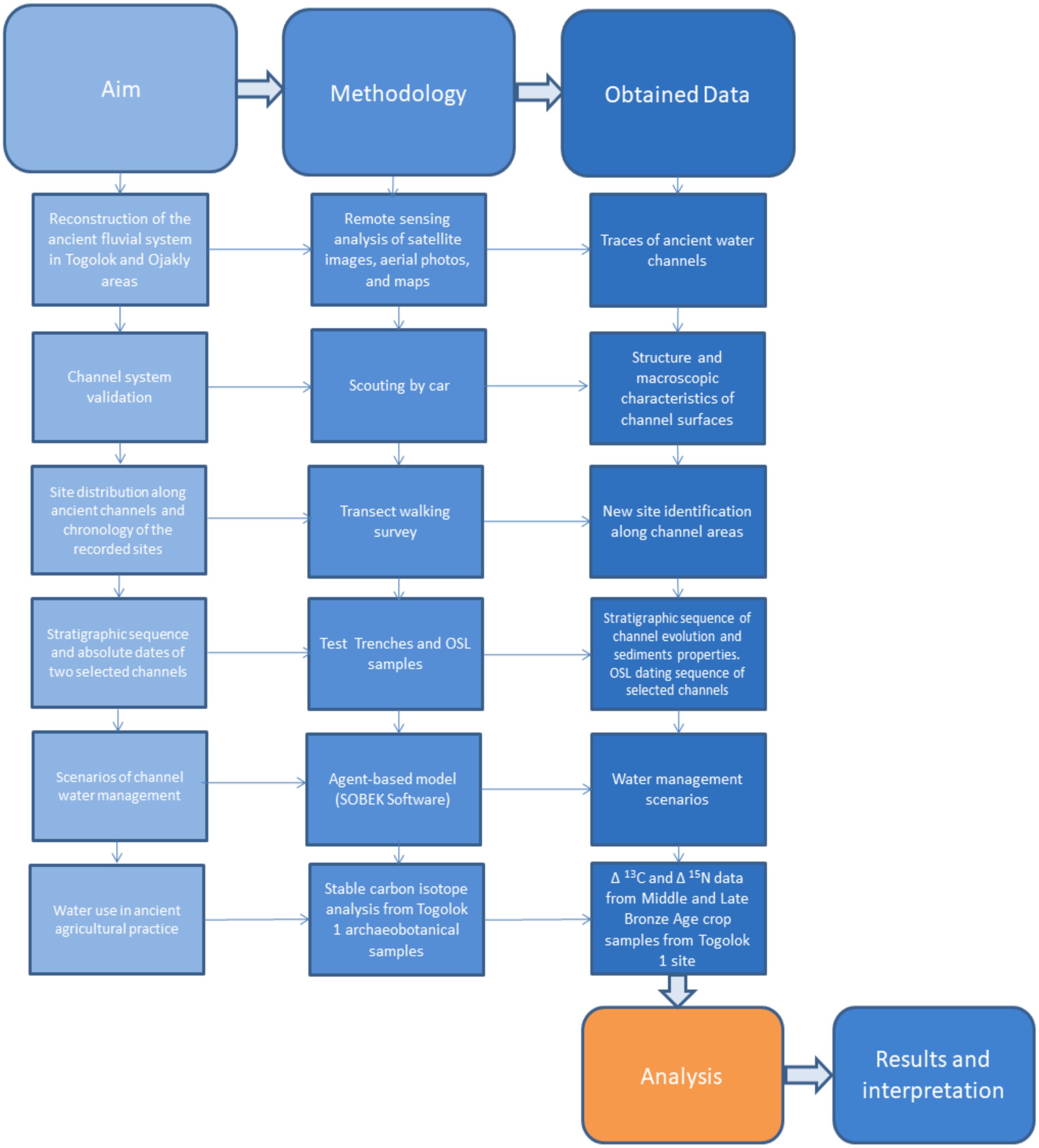


*Figure 4.11 Schematic chart displaying the methodology and data obtained from the present project.*

# Chapter 5 – Results from the Ojakly Area

## 5. Results: The Ojakly Area

### 5.1 Overview

In the preceding chapter, I have outlined the methodology and limitations of this research. In this chapter, I will present the multidisciplinary analysis conducted in the Ojakly area. Before presenting the data, I will briefly discuss the Ojakly site and its archaeobotanical and zooarchaeological data. These data provide the starting point for the interpretation of the ancient agricultural and irrigation practices in the area. Subsequently, I will present the result of the remote sensing analysis of the channel system and the field-walking survey. The analytical lens will focus then on the geomorphological analysis of the stratigraphic test trench made in the paleochannel at Ojakly, as well as the absolute dating of the channel. I will then discuss the results of the analysis of the takyr at Ojakly using an agent-based model (SOBEK software), and discuss three possible scenarios of water management in the Murghab.

### 5.2 The Peripheries and the ICW (Andronovo) Presence in the Ojakly Area

"Andronovo" assemblages in the Murghab region occur in the form of pottery, namely Incised Courseware (ICW), which dominates the ceramics at some sites (Cattani 2008a). The presence of this hand-made and incised courseware has been interpreted by several authors as evidence for the presence of nomadic pastoralist groups from northern regions (e.g., Kuz'mina and Lyapin 1984; Cattani 2008a; Cerasetti 1998; Rouse and Cerasetti 2014. see discussion in Chapter 3, section 3.3). In the last decades, the relation between pastoralists and farmers in the Murghab was often perceived as a dichotomy between the sown versus steppe (Di Cosmo 2002; Rouse 2020). In this theory, mobile pastoralists settle in marginal areas that are not inhabited by BMAC communities. Their diet is improved by the exchange of cereals and other agricultural foodstuffs with agricultural communities. In this perspective, pastoralists in Eurasia are considered a singular element within the broader "pastoralist-agriculturalist economy." (Khazanov 2005). However, in contrast to this dichotomy, it has been suggested that pastoralists in Central Asia conducted forms of agriculture, or low-investment agriculture with the use of fast-growing cereals such as millet, within a mixed "agropastoral" economy (Chang et al. 2002; Spengler et al. 2016). This latest interpretation has also recently been put forward for the Murghab (Rouse and Cerasetti 2018), although there is still much debate on the topic (see a recent debate in Spengler et al. 2021).

Although much research has focused on the Murghab, little attention has been devoted to the investigation of peripheral areas (see Chapter 3, section 3.2). Up until the collapse of the USSR, the Central Asian region was mainly investigated by Soviet archaeologists (Lamberg-Karlovsky 1994b). These archaeologists focused on the excavation of mounds in the region, such as Gonur or Togolok 21 (Masson and Sarianidi 1972; Sarianidi 1981). The focus was on large, horizontal settlement excavations, and the aim was to uncover temples, possible royal and elite residences, production areas, and their associated necropoleis. The idea was to investigate the social, economic, and ideological structures of the BMAC through the excavation of key sites, and little attention was devoted to smaller sites in the wider landscape (Hiebert 1994a). As a result, interpretations of the agricultural exploitation of the landscape in the Murghab are hampered. A landscape-oriented investigation, with pedestrian surveys of the Murghab, only started in the 1990s by the AMMD team (see section 3.4.1 in Chapter 3). The AMMD team conducted surveys in various sub-regions of the Murghab, encompassing the region west and southwest of the mound site of Auchin 1. This area has become partially integrated into the research area of this study (Gubaev et al. 1998; Salvatori et al. 2008) (Fig. 5.1).

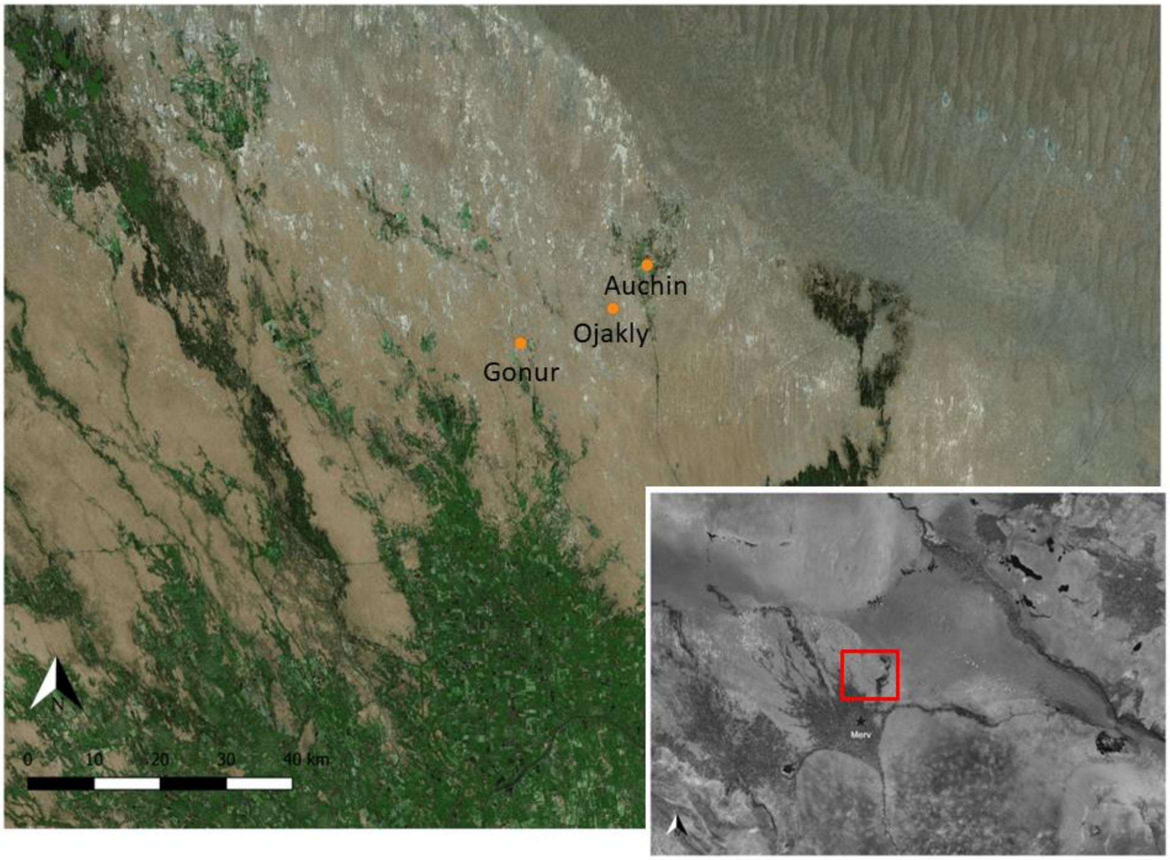


*Figure 5.1 The map shows the location of Ojakly and its distance from the sites of Auchin and Gonur.*

The AMMD survey led to the identification of almost 78 sites within an area of approximately 140 km$^2$. In addition, the AMMD also identified 33 sites with incised coarseware (ICW) or “Andronovo” pottery that were labeled as ICW sites by the Italian team. In the survey, the ICW site n.1744 stood out for its remarkable density of material over a large area. The site, later called Ojakly, was then excavated by Rouse and Cerasetti between the 2009 and 2010 field campaigns. Along with Chopantam, it represents the only excavated ICW (Andronovo) site in the Murghab (Rouse and Cerasetti 2014). Considering its significance as the main site of this marginal area, it is essential to introduce some Ojakly data before delving into the discussion of the results regarding the paleochannel system of the research area.

## 5.3 The Ojakly Site

### 5.3.1 Excavations and Interpretations

The site of Ojakly is located 11.5 km northeast of Gonur-tepe, and it has provided crucial information about possible land exploitation and the domestic economy of peripheral areas. The site is approximately 3 ha based on the pottery distribution. Within the site, the researchers excavated three areas. According to the radiocarbon dates from Ojakly, the occupation of the settlement dates between 1742 and 1440 BCE (i.e., the Late and Final Bronze Age, ca. 1950–1300 BCE).[59]

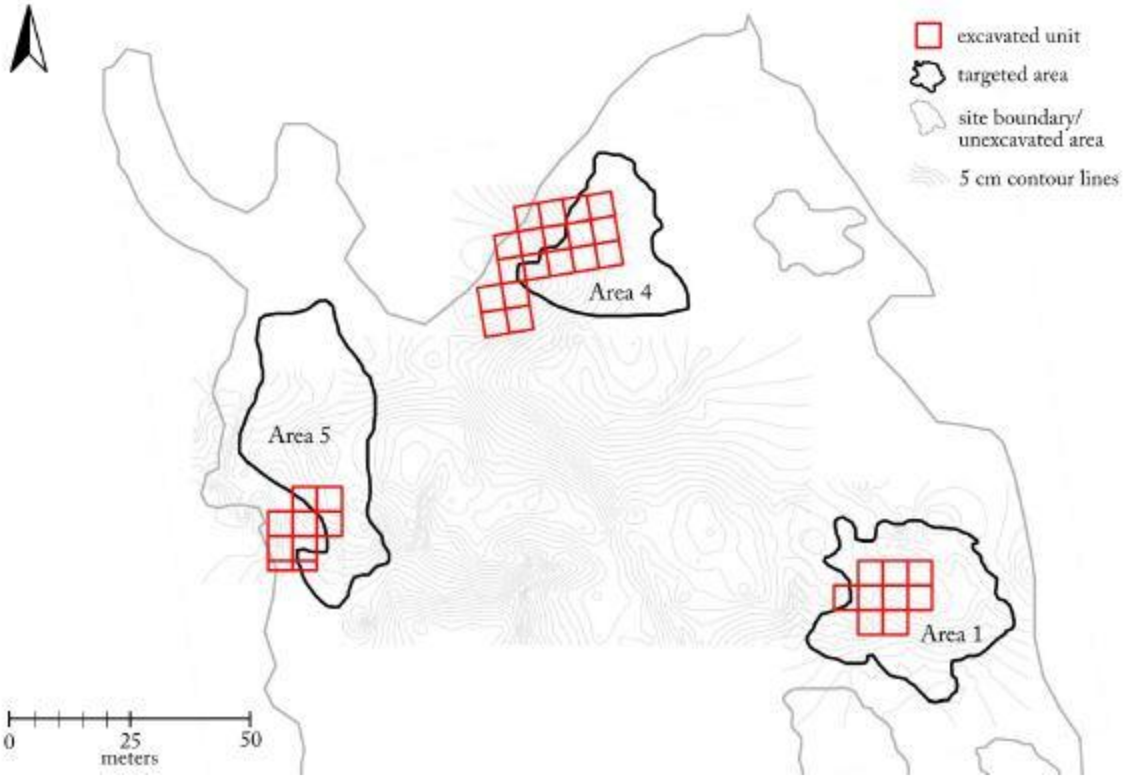


*Figure 5.2 The plan shows the Ojakly site with excavated areas (red squares), Area 1, Area 4, and Area 5. (Rouse 2015:Fig. 4:5).*

---

[59] See Rouse (2015:120) for uncalibrated radiocarbon dates.

According to Rouse and Cerasetti (2014), Area 1 and Area 4 (Figure 5.2) can be interpreted as domestic areas. In both areas, various phases of occupation were identified with post-holes, storage pits, fireplaces, and oven-like structures. However, despite the identification of a great number of post-holes – approximately 100 – no clear structures were identified. The evidence of daub, along with the impression of reeds associated with post-holes in Area 1 was interpreted by Rose and Cerasetti (2014) as evidence for temporary structures for repeated or seasonal occupations. Interestingly, Area 4 presented a concentration of cooking wares around fireplaces with the presence of burnt or partially burnt animal bones, which led Rouse and Cerasetti (2014) to interpret this part of the site as a cooking area, in contrast to Area 1 interpreted as a residential area.

Area 5 has been interpreted as a production area with the presence of baked clay features and possible firing events on the surface layers (Rouse 2015:119). In this area, the most significant archaeological evidence consists of a subterranean pottery kiln. The kiln was a vertical double-chamber construction that was 2 m long. The interior surfaces, walls, air conduits, and floors were carefully plastered, and fingermarks were still visible over the entire surface. Interestingly, the fill of the kiln included various fragments of unfired hand-made pottery and animal bone remains suggesting later deposition (Rouse and Cerasetti 2014). Furthermore, several plant remains were also identified in the kiln, which constitute the bulk of the botanical remains (wild and domestic crops) found in Ojakly (see section 5.3.2 below).

More than 90% of the pottery found in Ojakly is hand-made courseware, while only 10% belongs to the wheel-made ceramics from the local Namazga-BMAC ceramic tradition (Rouse 2015:158–9; Hiebert 1994a). The wheel-made pottery has a variety of open and closed forms and hardly any decoration. In contrast, almost all the ICW ceramics from Ojakly are part of the “Andronovo” cultural horizon (Rouse 2015). These pots were locally produced as the laboratory analysis suggests a local clay source (Rouse et al. 2019). The Andronovo (ICW) pottery differs significantly from the “kitchen ware” found at mounded sites in the Murghab, which usually imitates the Namazga wheel-made forms and has a well-levigated paste. These “kitchen wares” from BMAC sites usually have textile impressions and are wheel-finished as opposed to the hand-made pottery found at Ojakly. It is unclear, however, what the Andronovo (ICW) vessels from Ojakly were used for, and what they might have contained.

## 5.3.2 Subsistence Economy

Archaeobotanical and faunal samples were collected from all three areas at Ojakly, and they can provide insights into agriculture and land exploitation around Ojakly.

- **Botanical Remains**

There are seven archaeobotanical soil samples recovered from Ojakly with identifiable macrobotanical material. However, most of the recognized seeds come from the kiln deposit. The majority of seeds in Ojakly were categorized as belonging to weeds (88%). Likely, wild herbaceous material found its way into the kiln during the burning process, along with dung used as fuel. Nevertheless, a considerable amount of seeds were also categorized as agricultural[60] (Figure 5.3) (Rouse and Cerasetti 2014).

Among the domestic cereals recovered in Ojakly, barley (*Hordeum vulgare*) was the most prevalent, and both naked and hulled six-rowed forms were found. Naked barley is easier to harvest and process, but more difficult to store without losses (e.g., insects and parasites), and it can be more water-demanding (Spengler et al. 2014). In contrast, hulled forms of barley can have higher yields, but it is less easy to process (Byung-Kee and Ullrich 2008). Nevertheless, by the second millennium BCE, the naked form became predominant in Central Asia (also at Gonur), replacing the hulled form, while some sites, such as Chopantam, were using a mix of naked and hulled forms (Spengler 2015:227). Interestingly, in the first millennium BCE, there was a second switch towards hulled varieties (Lister and Jones 2013).

---

[60] Regarding the sampling and analysis methods of faunal and botanical remains from Ojakly, see Rouse 2015:130.

Also interestingly, within the kiln deposit, barley (*Hordeum vulgare var. vulgare*) seeds are prevalent, whereas outside the kiln context, millet (*Panicum miliaceum*) predominates (figure 5.3). A good quantity of charcoal and 130 six-rowed barley rachises were also found inside the kiln deposit, of which 10.8% were infected by a fungal disease (*Ustilago hordei*). As noted by Rouse (2015:148), on the basis of Cappers (2006) interpretation of Egypt during the Roman period, this particular form of the fungal disease can be associated with intensive cropping (Cappers et al. 2012).

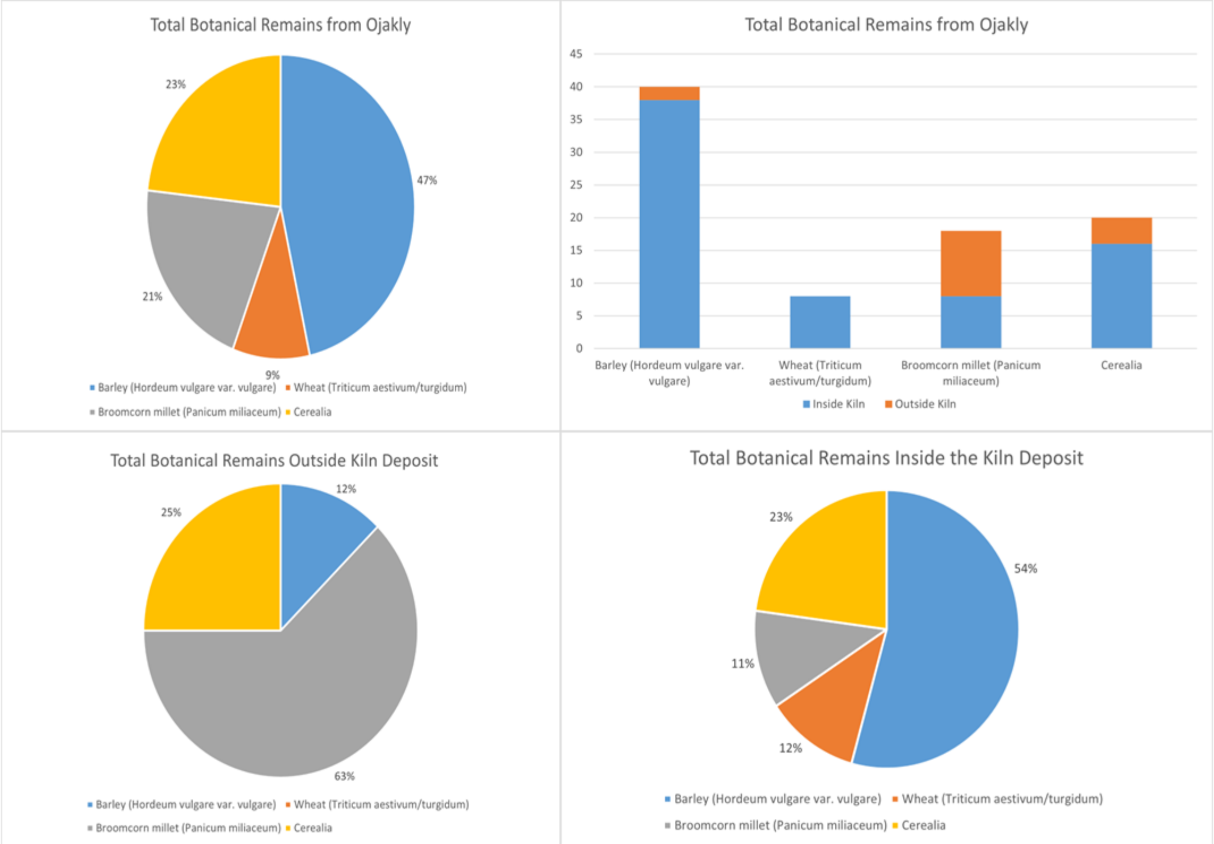


*Figure 5.3 Botanical remains from Ojakly. The first graphs (upper-left) show the total amount of botanical remains from Ojakly, where barley and wheat predominate (rachises are not present). The second graph (bottom-left) shows the total amount of botanical remains outside the kiln deposit (Area 5 and 1) where millet predominates. The third graph (bottom-right) shows the total amount of botanical remains inside the kiln deposit where barley predominates. The fourth graph (upper-right) shows the difference in botanical remains inside the kiln deposit and in the remaining contexts. Wild plants are not considered (data from Rouse 2015:145).*

A substantial amount of charcoal was also found inside the kiln, likely the result of fuel burning. Although the charcoal from Ojakly remains unidentified (Rouse 2015:148), microscopic analysis of wood remains from Gonur showed that saxaul (*Saxaul* sp.) was by far the most abundant wood type used as fuel (Sataeva and Sataev 2014). Other trees, such as tamarisk (*Tamarix* sp.), were also present in the botanical remains at Gonur to a lesser extent.

In addition to domesticated plants, weeds constitute the majority of the specimens in the archaeobotanical assemblages from Ojakly (387 seeds: 88 %), and most of these could only be categorized to the family and genus and not to species. In the Murghab, the analysis and interpretation of wild plants remain poorly developed. However, they can provide significant information about the local climate and human activities. As such, various wild plants identified at Ojakly can be identified as occurring in grasslands and arid areas, and some relate to species that are still present in the Karakum and the adjacent area of Kopet-Dag. For instance, the genus *Stipa* found in Ojakly occurs in savanna habitats and grasslands. According to Atamuradov (1994:63), steppe grasses, such as *Stipa* had already become dominant during the Pliocene–Pleistocene. Furthermore, Kamakhina (1994:145) suggests that such steppe flora disappeared in many areas of the Central Kopet-Dag due to extreme overgrazing of the area. One cannot rule out a similar hypothesis for the Murghab, where this wild plant is attested in the archaeological evidence.

The family of *Amaranthaceae*, also recovered at Ojakly (i.e., *Chenopodium* spp.) is widespread in the desert area of western Central Asia, and it is still present in the Kopet-Dag region today although it also occurs in less arid environments in northern Central Asia (Grubov 1966). Interestingly, chenopod seed usually dominate the archaeobotanical assemblages of wild plants in Central Asia (Anthony et al. 2005; Rühl et al. 2015). However, it is not clear whether the high presence of chenopods represents human consumption or is part of animal foraging practices. This plant has often been seen in Central Asia as an indicator of the presence of pastoral camps in the vicinity of the sites (Spengler et al. 2013). Recently, Spengler (2019b) – on the basis of experiments by

Wallace and Charles (2013) – suggested that the high presence of chenopods in Central Asia might reflect the ability of the plant to survive the digestive process and the subsequent burning of animal dung (Miller and Smart 1984). Notably, the majority of *Chenopodium* spp. in Ojakly was found in the kiln deposit, possibly as part of dung fuel. Among other wild plants identified in the kiln, there is *Galium* sp. This plant is widely present in steppe, desert, and semi-desert areas, including the Kopet-Dag mountains today (Fet 1994:155). The species of Galium aparine and the yellow bedstraw of the species *Galium verum* were commonly used to curdle milk to make cheese among pastoralists (Vickery 1995:437; Defelice 2002), but no evidence of milk processing was found in Ojakly. Similar to *Galium*, the species *Xanthium* sp. was also found in the kiln deposit. Although is a rare species (it is found in less than 10% of Turkmenistan), it occurs as *Xanthium spinosum* L. in the southwest Kopet-Dag, and it is generally considered as a weed of pastures and grasslands found some time in association with waterways (Fet 1994:162). Two more plants from the family of *Cyperaceae* and the genus *Alhagi* sp. (camel thorn) were also found in the kiln and are nowadays still present in the Karakum (Kharin 1994:72). The family Cyperaceae provides excellent grazing in spring and is a good sand-fixing plant in the region (Gintzburger at al. 2003:177). Camel thorn (*Alhagi* sp.) is common in arid areas, and it is considered to grow readily in cultivated fields, while it does well near a source of water (Kharin 1994:72–3). Furthermore, it is inedible to humans and it is eaten by goats in the region (Rouse 2015:148).

The analysis of the wild plants primarily discovered in the kiln deposit suggest a local environment characterized by both semi-arid and more humid areas.

- **Faunal Remains**

The faunal assemblages in Ojakly were predominately recovered in fireplaces and refuse deposits. According to Rouse (2015:135), only one-quarter of the total amount of the assemblage was identifiable to genus, size, class, or finer taxonomic level. The dominant species identified in Ojakly are cattle (*Bos taurus* or *Bos indicus*), sheep (*Ovis aries*), and goat (*Capra hircus*) (Rouse et al. 2022a) (Figure 5.4). However, one fragmentary equid toe bone was also found in the kiln, along with nine pig teeth (*Sus* sp.). As for the pig teeth, it was not possible to distinguish between wild boar and domestic pig. However, most of the *Sus scrofa* remains identified in the Murghab are labeled as wild boar (Moore et al. 1994). As suggested by Rouse et al. (2022a), the equid bone can most likely be associated with a donkey (*E. asinus*), wild kulan, or onager (*E. hemionus kulan* or *onager*). Interestingly, the Turkmen kulan is still popular today among the agropastoralists in the Murghab as a means of transport during grazing (personal observation).

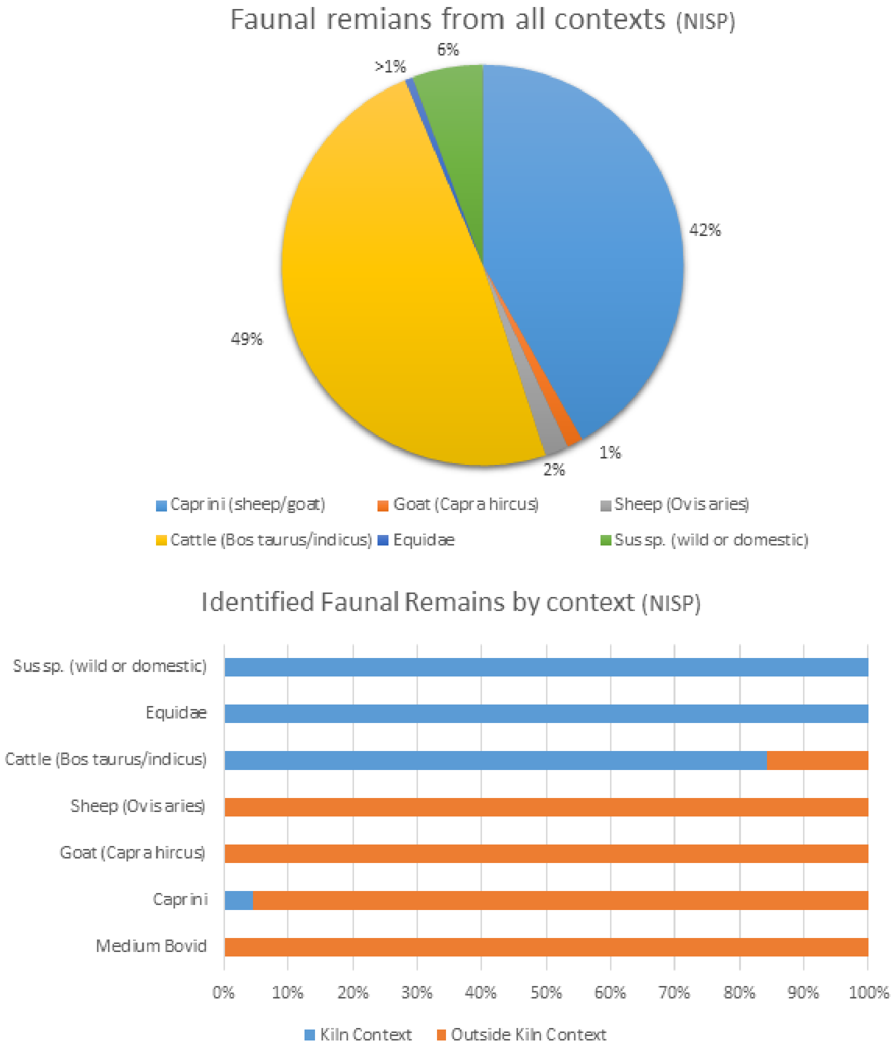


*Figure 5.4 Faunal remains from Ojakly. The upper graph shows the total amount of faunal remains recovered in Ojakly. The bottom graph shows the difference between the faunal remains from the kiln deposit and the faunal remains from all other contexts (data from Rouse 2015:137).*

Regarding the Bovidae remains, they were classified as “large bovids” and “medium bovids” (Rouse et al. 2022a). It should be noted that the term medium bovid was assigned to bones from which the distinction between sheep, goat, and gazelle was not possible. However, according to Rouse (2015:135), medium-size bones are best attributable to domestic sheep and goat rather than local gazelle (*Gazella subgutturosa*).

Among all the assemblages, there is a substantial difference between the overall faunal remains recovered and those from the kiln. While goat and sheep remains (NISP) predominate across the site, their numbers are significantly lower in the kiln deposit, where cattle bones predominate (Figure 5.4). According to the excavators (Rouse and Cerasetti 2014), the bones found inside the kiln constitute an intentional deposit rather than a casual event.

Most of the bones are highly fragmented and have evidence of processing, such as cut marks, splitting, and hacking, with possible extraction of marrow (Rouse 2015:134). In the assemblages, cattle remains are dominated by cranial specimens (in particular in the kiln), while sheep and goat occur as post-cranial specimens. The cattle bones show processing for food preparation and derive mainly from adult animals (Rouse 2015:138). The age of the sheep and goat (NISP) falls between young and adult, with a small percentage of juveniles (< 1 year old). This might suggest that the animals were kept primarily for wool and secondary products such as milk, but also used for meat (Rouse et al. 2022a). However, these age profiles are based on small numbers, and should be treated with caution. Rouse et al. (2022a) suggest that cattle were possibly acquired from elsewhere, while sheep and goats were kept at the site. However, there is little evidence regarding whether cattle, sheep, and goats were kept at the site or at a distance from it, as well as what grazing strategies were implemented.

- **Ojakly Subsistence Economy**

Given the absence of permanent structures, and the high percentage of Andronovo (ICW) pottery, Rouse and Cerasetti (2014) interpreted Ojakly as a pastoralist site. However, based on the data from rural sites such as Chopantam, as well as Ojakly, I argue that the broad definition of “agropastoral” might be more suited (Rouse 2020; also see Rouse et al. 2022b; Spengler et al. 2021). In Chapter 3, I discussed the different forms of *mobility*. The evidence in Ojakly suggests that agriculture was practiced. An extensive analysis by Spengler et al. (2021), spanning various regions in Central Asia, indicates that some populations typically categorized as mobile pastoralists were, in fact, sedentary in the region. In addition, pastoral communities played a significant role in the dispersal of millet to the West, and cultivation and caprine management became increasingly intertwined, such as at the site of Begash in Kazakhstan (Hermes et al. 2019).

Agriculture, including low-investment agriculture, implies that communities need to stay in one place for some months to manage fields during the growing season. The site of Ojakly was possibly occupied on a seasonal basis. Indeed, as argued by Rouse and Cerasetti (2014) its occupation phases suggest a repeated use of the place. Although Ojakly has evidence of cattle, which are often perceived as sedentary animals, they might also have been used in seasonal mobility (Rouse et al. 2022a). Petroglyphs in the Mongolian Altai are indicative that the yak (*Bos grunniens*) were the primary transport animal in the Bronze Age. These animals were able to carry dwellings or lightweight structures, along with all the furnishings (Jacobson-Tepfer et al. 2007: II, Plate 530; Jacobson-Tepfer 2008). Furthermore, among the Kyrgyz modern semi-nomads in the Wakhan-Pamir corridor (Afghanistan), yaks are still regularly used to transport yurts, beds, stoves and all items between summer and winter camps (Callahan 2013:82). More recently, isotopic analysis of cattle has suggested that during the Middle and Late Bronze Age in Europe these animals covered long distances, thus able to move from one place to another on a seasonal basis (Brusgaard et al. 2019).

Although few in number, and only from the kiln deposit, one can argue that cattle present in Ojakly could have also been used to transport loads from one place to another. No evidence of food processing tools have been discovered at Ojakly, unlike at Chopantam, where stone tools and jars with botanical remains provided further evidence of agricultural practices (Cattani 2008b). However, stones do not occur in the Murghab, and grinding stones should be considered as valuable material to be taken along when moving on a seasonal basis. Therefore, their absence cannot be considered as evidence for the absence of crop cultivation and food processing in Ojakly (but see Rose 2015). Further, Spengler et al. (2021) recently suggested that agricultural tools could have also been made of wood, as in the case of some modern regions of Central Asia, and thus rarely preserved in the Murghab.

Although the presence of cereals in Ojakly is limited compared to that of dense settlement cluster areas, the large number of weeds recovered in the kiln deposit suggests the possible burning of animal dung. It has been suggested that naked cereals, lacking protective hulls, survived poorly in the digestive process and are, therefore, less common than weeds (Wallace and Charles 2013: Spengler 2019b). Seeds that do not undergo a carbonization process rarely survive in archaeological deposits. Thus, free-threshing grains in Ojakly could possibly be under-represented, considering that the majority of botanical remains were found in the kiln deposit as a result of the burning of animal dung and little evidence had survived outside the kiln.

All in all, although the array of crops is extremely reduced in Ojakly compared to dense settlement cluster contexts, their presence should not be understood as marginal in the Ojakly subsistence economy. While I acknowledge that some of the crops, perhaps the more water and labor-demanding ones, might be the result of an exchange with local agricultural communities (Spengler et al. 2014), cereals, such as millet, were likely the result of local crop cultivation. Botanical remains have been discovered throughout the site at varying degrees, suggesting localized and limited cultivation practices.

## 5.4 Results: Remote Sensing Analysis of the Paleochannel Network

Evidence from Ojakly suggest some form of crop cultivation. However, where the fields were located and possibly irrigated has not been investigated.

Analyzing satellite images and aerial photos typically serves as the initial step in investigating ancient hydrological systems and agricultural areas (e.g., Wilkinson and Rayne 2010; Rayne 2015). In the last decades, satellite images have been crucial for detecting paleochannels, artificial canals, herringbone structures, or crevasse splays, for instance, offering many clues for the reconstruction of the ancient irrigation system. The Murghab region, with its flat desert landscape, provides perfect conditions to reconstruct ancient channel systems. Detailed irrigation networks at Ojakly were mapped using satellite images, aerial photos, and old maps. This resulted in the mapping of linear and curved features that were interpreted as ancient channels. The aim of this first step of the analysis was to understand the possible locations of the channels and how they relate to sites. In order to identify ancient channels, different satellite images were used. These satellite images have been discussed more extensively in Chapter 4.

For the Ojakly area, the first images analyzed were from CORONA. CORONA images, particularly KH4 and KH-4A,[61] were used to analyze the irrigation system in the Ojakly region. KH-4A, with its superior spatial resolution of 2.75 m (9 feet), proved most important for identifying paleochannels. The northern–eastern area of Ojakly has been affected by agricultural expansion over the last few decades which has almost completely destroyed channel features. CORONA images have been crucial for studying these lost landscapes.

Aerial photos from the AMMD were also used to identify ancient irrigation features in the Ojakly area.[62] These photos were compared with CORONA images from the 1960s and 1970s. The aerial photos offer high spatial resolution, albeit with darker edges likely due to negative film strips.

Analysis of the aerial photos revealed valuable data on ancient channel systems, with paleochannels appearing lighter and meandering forms discernible. Takyr surfaces, appearing as light areas with high reflectance, and dune ridges with darker shadows, are distinguishable, aiding in landscape interpretation (Figure 5.5). Attempts to identify possible sites along the channels yielded few distinct visual signatures, with individual tepes like Auchin 1 showing a specific signal (Figure 5.6). Distinguishing between dunes

---

[61] Specifically images ds009038001AF011 and ds1010-1055df126.

[62] Specifically photos B532-115, B532-111, B532-113, B532-170, and B532-172, dating back to the late 1980s.

and anthropogenic mounds can be challenging, as they share similar visual characteristics.

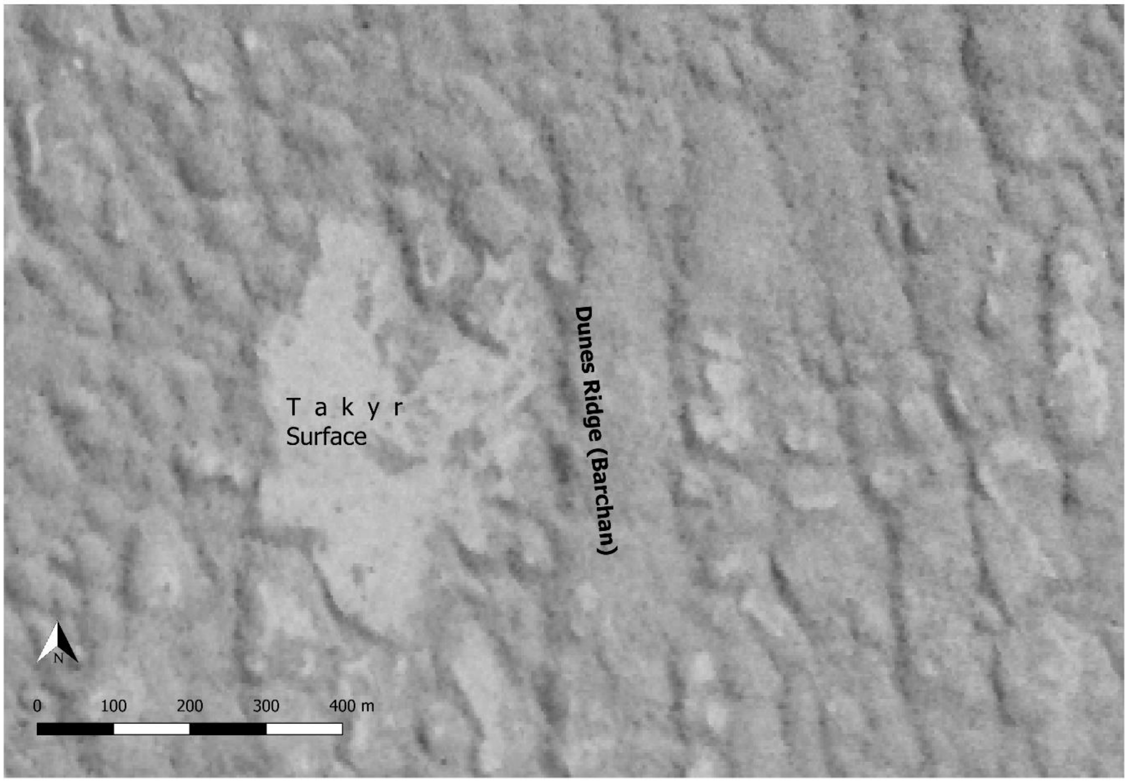


*Figure 5.5 The figure shows the difference between a takyr surface northeast of Auchin 1 and the barchan dunes in a CORONA image (1964).*

Maps of various scales[63] of Ojakly also provided validation data for reconstructing paleochannels. They were pivotal in identifying areas of sand dune accumulation and large takyrs. Indeed, maps highlight significant takyrs like the Auchin takyr in the north, and aid in understanding their spectral signals. Additionally, these maps delineate man-made water reservoirs known as *khaks*, as well as dwelling areas. Interestingly, on the basis of image correlation with cartographic maps and CORONA KH-4A images, a dwelling structure was identified. This was later confirmed by ground truthing and will be discussed later (section 5.4.2).

---

[63] Specifically, maps at the 1:100,000 scale (# U-30-50) and 1:200,000 scale (# J-41 NW-4).

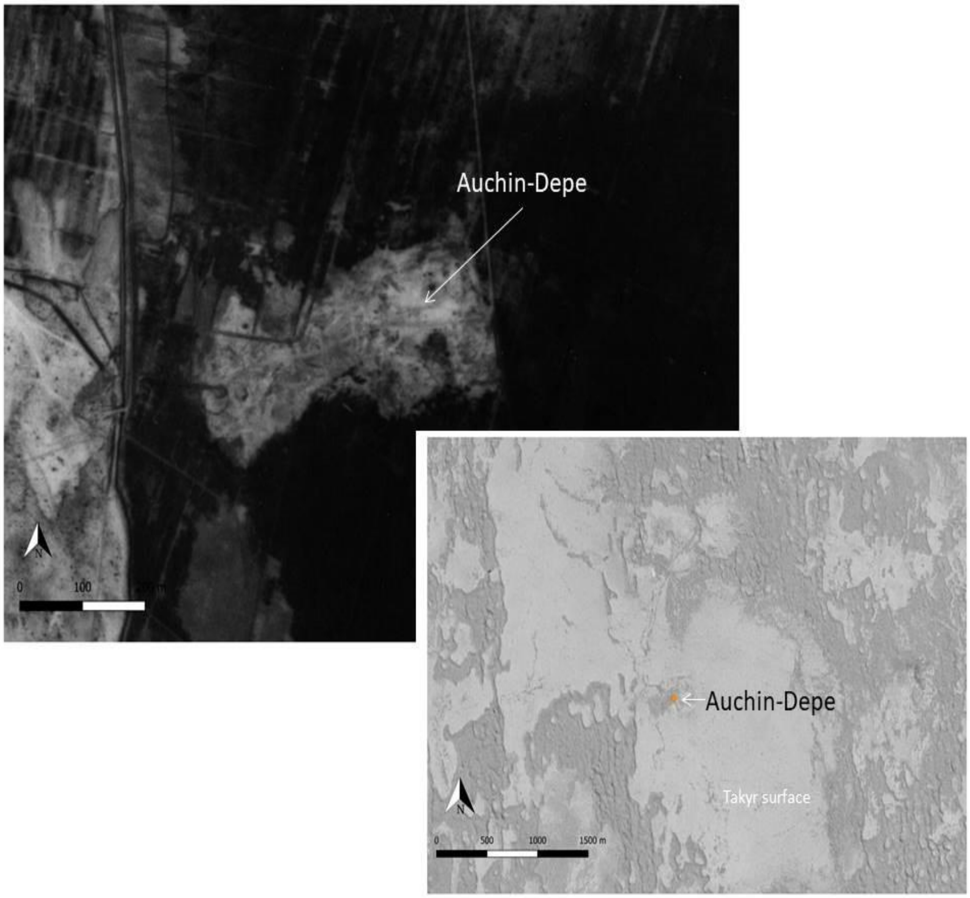


*Figure 5.6  In the aerial photo (from the 1980s) (upper left), the spectral signal of Auchin 1 can be recognized across the landscape also thanks to the different signals of cultivated takyrs. The tepe is almost invisible in the CORONA image (1964). However, despite the possible tepes (or depes) in aerial photos, and its geometry which are different from takyr surfaces, sites are hardly visible in terms of different spectral signals both in aerial photos and CORONA images.*

Of special value were SRTM imagery and ASTER GDEM that have proven effective for detecting fluvial branches, as demonstrated in the Middle Zeravshan Valley in Uzbekistan (Mantellini et al. 2008). However, in the distal fan area where Ojakly is situated, ancient natural channel banks are of limited height, making them less suitable targets for SRTM imagery. Only modern canals associated with *khaks*, directing water to nearby fields, can be confidently identified in SRTM images in these distal areas.

## 5.4.1 The Ojakly Paleochannel System

The investigation of the Ojakly landscape was done through a visual analysis of the paleochannels. The paleochannel system was reconstructed through an integrated approach of all available satellite images and aerial photos, including Soviet cartographic maps, within a GIS-based environment (see Chapter 4 for methodology).

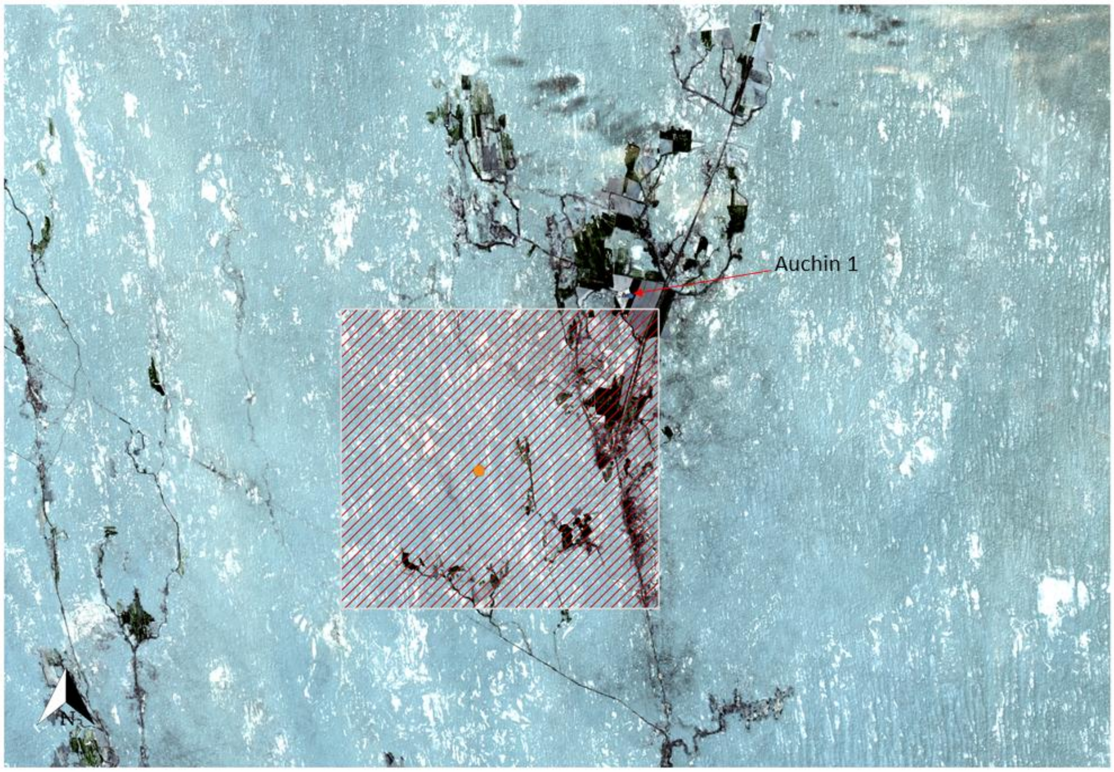


*Figure 5.7 The square with the oblique red lines shows the research area, which is approximately 123 km2. The orange point displays the position of Ojakly (Landsat 8 pansharpening image).*

In the GIS platform, a research area of *ca.* 123 km$^2$ was selected, centered on the site of Ojakly (Figure 5.7). The area is located in the northeastern part of the Murghab and comprises part of the Auchin Oasis. The Auchin area was initially surveyed by Soviet archaeologists and later by the AMMD.

Auchin 1 represents the main site of the Auchin Oasis, which is composed of seventeen sites identified by the Soviets, dispersed over an area of approximately 175 km$^2$

(Sarianidi 1990a:11–13). However, the relation between these settlements in the Auchin Oasis remains unclear. For example, the site of Auchin 1 and Auchin 15 are more than 12 km apart – roughly a 3 h walk – without any site cluster in between, but still part of the same "oases" (Sarianidi 1990a:11).

The site of Auchin 1 was first excavated by Masson in the 1950s, and later by Sarianidi in 1972 (Masson 1959:12–28; Sarianidi 1990a:10–11; Kohl 1984:147; Hiebert 1994a:15–16). The site, dated to the Middle and Late Bronze Age and with a size of approximately 3 ha, is located approximately 8 km northeast of Ojakly (Figures 5.6 and 5.7). Excavations by Soviet teams revealed the presence of large, fortified buildings with mudbrick walls (3 m thick) and round towers. According to Sarianidi (1990a:10–11), the building has two main building phases, while a small necropolis is located at the southwestern edge of the settlement, outside the fortified building. Materials from the graves includes rich objects, such as bronze bracelets, but also other objects made from ceramic, turquoise, and lapis lazuli beads and biconical chlorite beads that presented a dot-in-circle design. Also, alabaster bottles were recovered at site, along with seal amulets made from stone (Kohl 1984:148). Interestingly, within the pottery assemblage discovered at Auchin 1, certain sherds exhibited characteristics of the ICW (Andronovo) type (Sarianidi 1990a:11). The subsequent survey by the AMMD to the west of Auchin 1 revealed the presence of several additional sites with ICW pottery (Cerasetti 2012).

It is likely that agricultural areas were located within a few kilometers from the main mounded sites in Auchin. The large takyr area surrounding the site of Auchin, for instance, was possibly cultivated, and the agricultural zone could have been irrigated by canals. The analysis conducted by this study in the northeastern part of the research area suggests the presence of canals south of Auchin 1 and to the east of Auchin 12 (see section 5.5 of this Chapter). Although archaeobotanical analysis from Auchin 1 is lacking, data from mound sites from the Middle and Late Bronze Age, such as Gonur and Togolok 1, suggest that the cultivation comprised domesticated cereals, legumes, and garden fruits such as apples (Sataev and Sataeva 2012; Sataeva and Sataev 2014; Cerasetti et al. 2022; see Chapter 3). However, the number of small sites across the present research area of 123 km$^2$ (62% of the total) represent rural entities with a less intense agricultural agenda.

- **Modern Artificial Canals**

The research area is defined by three contemporary canals. The primary canal, known as the Auchin canal, is situated roughly 5 km east of Ojakly (Figure 5.8, Canal A). Another canal traverses the terrain northwestward, drawing water from the Auchin Canal (Figure 5.8, Canal B). The third canal, about 7 km to the west, draws water from a secondary canal to the south (Figure 5.8, Canal C). Based on satellite interpretation, this last modern canal is likely an old channel that has become active again. The CORONA image dated to 1964, in fact, shows the presence of several traces of channels well before it became active again, which probably happened in the early 1990s, as the Landsat TM dated to 1987 does not show any active channel. In addition, although the channel was artificially started again with water from the southern canal, its meandering form is likely the result of the natural gradient as well as unmanaged maintenance.

Modern canals are also present in the south/southeast and east of the research area and irrigate three main modern agricultural areas (Area 1, 2 and 3 in Figure 5.8). In the south, an artificial canal takes water from the southern longitudinal canal (Canal B) to irrigate an extensive takyr located approximately 1500 m north of it in Area 1 (Figure 5.8). Interestingly, while the analyses of the CORONA image show the presence of paleochannels north of this Area 1 (see next paragraph), the satellite image does not show any presence of paleochannels in Area 1, suggesting that modern canals in this area are unlikely the result of old channels becoming active again.

The second largest agricultural area (Area 2) is located in the southeast of the research area. The agricultural zone is irrigated thanks to the artificial canal taking water from the main Auchin canal. This canal is not an old channel becoming active again, but the area shows the presence of a large takyr in the CORONA images, as well as in the cartographic map (U-30-50) prior to its cultivation. The large takyr seems to be located in the vicinity of Paleochannel 13 for which OSL analysis suggests that it became inactive at the beginning of the 2nd millennium BCE (see below section 5.6).

The largest of the modern agricultural areas in Ojakly (Area 3) is located in the east/northeast of the research area and is the result of the construction of the Auchin canal (approximately 14 m wide based on satellite images). The canal ends its course approximately 10 km north of the site of Auchin 1 and delivers water to the large agricultural areas located on the right and left banks of the canal. The agricultural fields are located right in a large takyr (visible on CORONA images) that once covered the area until the early 1990s, including the site of Auchin 1 (Figure 5.6). The mound of Auchin 1 only seems to be partially preserved (on the basis of recent satellite images), and the area around the site (approximately 42 km$^2$) is heavily cultivated. Therefore, it is likely that sites such as Auchin 11 (n. 1167), Auchin 12 (n. 1166), and Auchin 3 (n. 1469) have been partially or completely destroyed.

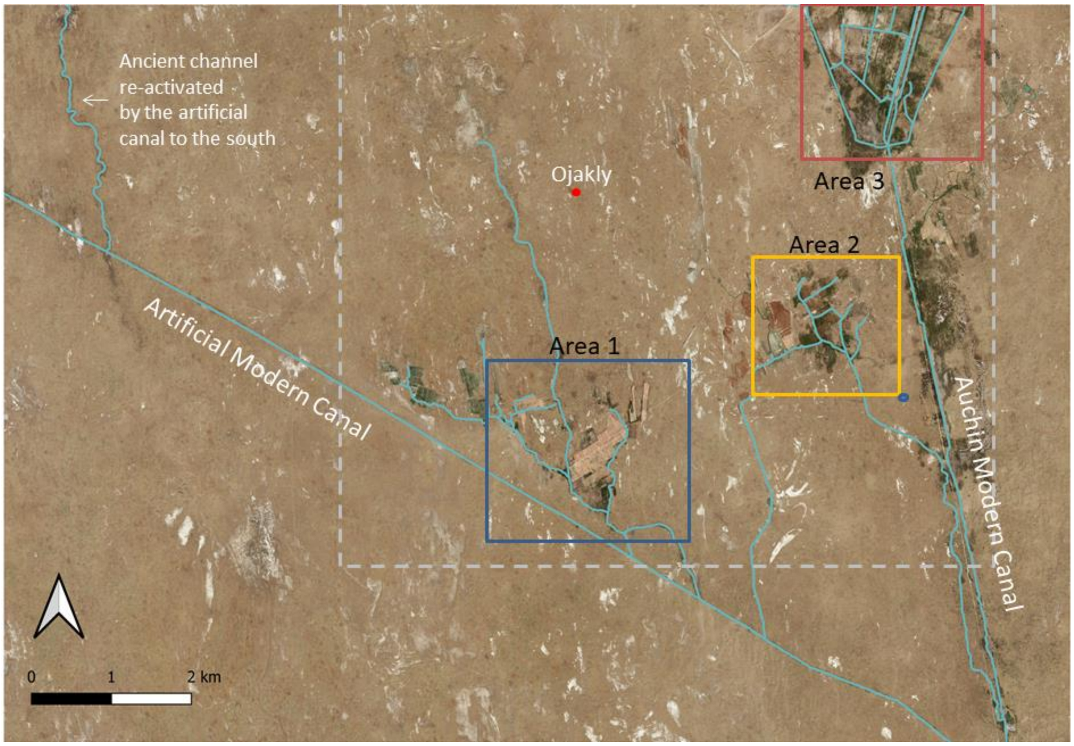


*Figure 5.8 The areas in the colored squares are the modern agricultural fields present in the research area (grey dashed line). The areas are characterized by large takyr surfaces in CORONA images and were recently converted into agricultural fields. It is possible that old channels have become active again because of modern canals, like the channel on the left side of the image (and outside the research area).*

- **Ancient Channels**

The identification and interpretation of ancient riverbeds in the area of Ojakly is made particularly difficult by the presence and the movement of dunes. Sand dunes can influence paleochannel detection, and they are also crucial in the overall investigation of archaeological sites (see Chapter 4; Cremaschi 1998). The sand and the formation of elongated barchans (Figure 5.9), often of large size, can partially or completely cover ancient water channels. As a result, the visibility of paleochannel traces is frequently less than a few kilometers or even a few hundred meters. In some cases, only small traces or channels could be distinguished in satellite images and aerial photos, as in the case of Paleochannel 3, for instance, while in some other cases, such as Paleochannel 15, a trace up to 5 km can be distinguished in the CORONA image (Figure 5.10).

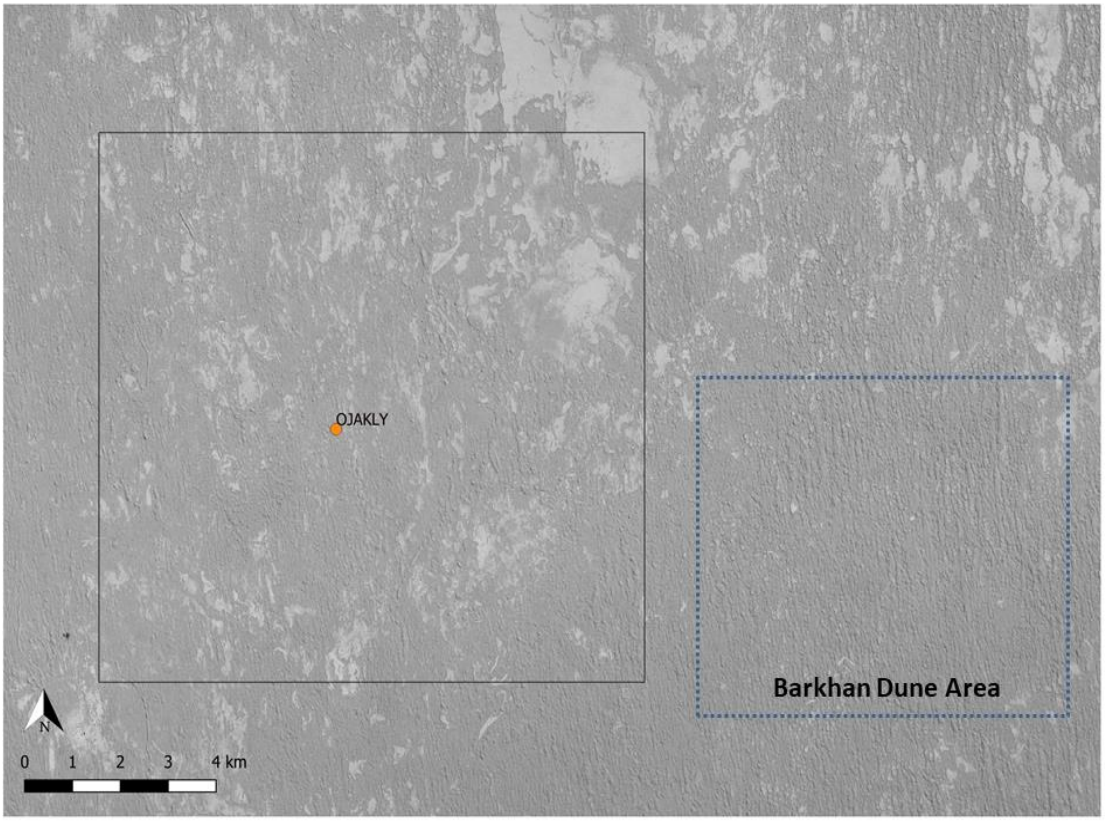


*Figure 5.9 The CORONA image shows the eastern region (outside of the research area) that has massive elongate barchans that cover sites and can partially or completely impede the detection of ancient water channels.*

The paleochannel analysis of the Ojakly area revealed the presence of 41 paleochannel traces (Figure 5.10). However, this number does not necessarily correspond to 41 different watercourses. In fact, when different paleochannel traces show approximately the same width and are aligned on the same flow direction, one can expect that they were likely part of the same channel. Likewise, in the case that two or more paleochannel traces are connected branches, I have considered them as part of the same channel, such as Paleochannel 1 in Figure 5.11 which is characterized by two branches (namely OJK_Ch_IXa and OJK_Ch_IXb) considered as one channel.

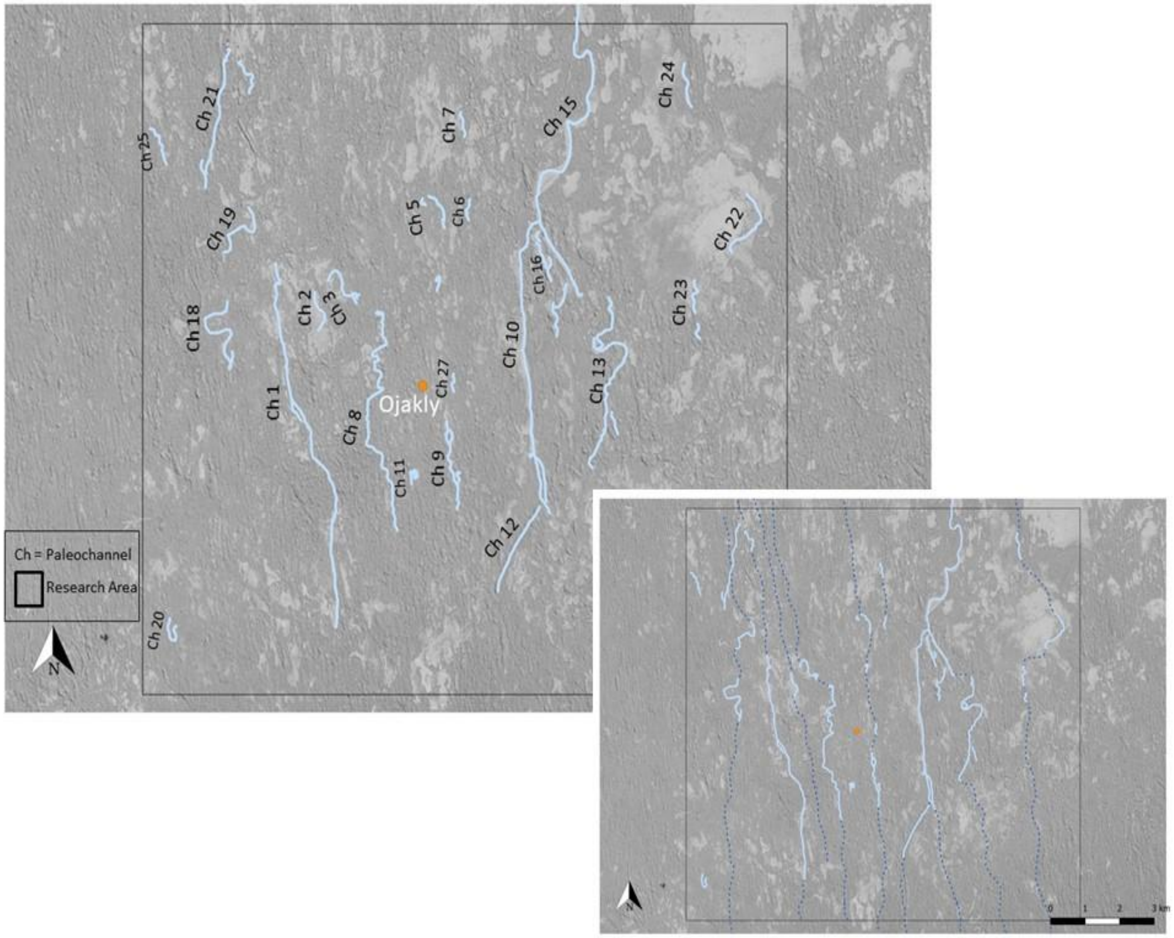


*Figure 5.10 The upper-left figure displays the trace of paleochannels identified in the Ojakly area. Only the main paleochannels have been numbered in the picture (CORONA image 1964). On the bottom, the dashed lines intend to show the possible flow direction of the paleochannels.*

Table 1.1 (in the Appendix 1) describes the paleochannel traces identified in the Ojakly area, some of which are grouped as a single paleochannel. As a result, within a total of 41 traces identified in the Ojakly area, 28 have been interpreted as part of the same water channel composed of one or multiple segments.

It is worth noting, however, that although several traces have been considered as separate paleochannels in Table 1.1 (in the Appendix 1), their flow direction and linearity within the landscape gradient can possibly be interpreted as one channel (see Figure 5.12). When the possible connection between ancient channel traces was too weak to suggest that they were part of the same paleochannel, the traces have been documented as separate paleochannels with distinct numbers.

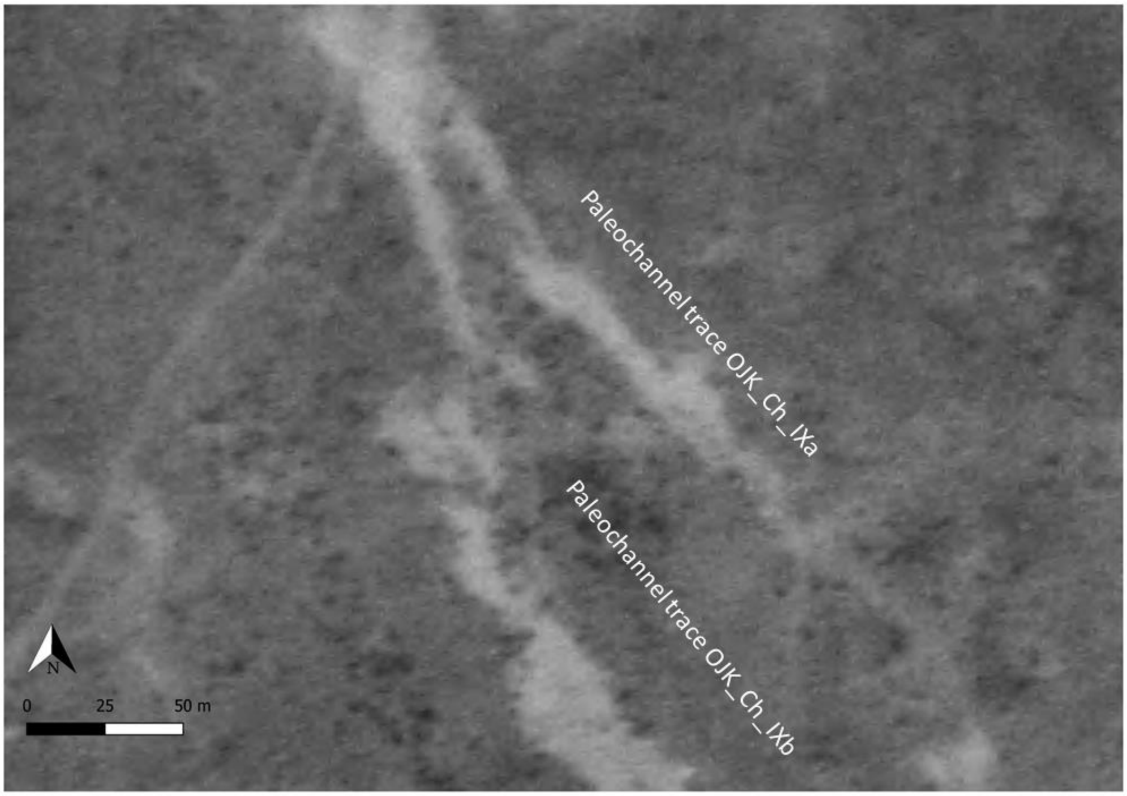


*Figure 5.11 The aerial photos shows the traces of paleochannel OJK_Ch_IXa and OJK_Ch_IXb. Considering the traces and their proximity, they have been interpreted as part of the same paleochannel. Trace OJK_Ch_IXb can possibly be the result of an up-stream avulsion episode rather than a tributary channel.*

In Chapter 4, I discussed the method used for detecting the paleochannels. The overlay of various satellites and aerial photos taken in different decades, as well as maps, led to detection by visual interpretation of the Ojakly paleochannels landscape. In the images, several curves (possibly meanders) can be distinguished based on their texture, gradient, and their spectral signal, such as the curves of Paleochannel 13 (OJK_Vb) which was later examined through a test trench (see section 5.8.3 of this Chapter). Their forms are often quite clear in the visual analysis, and their occurrence in linear-like features, among other aspects, confirms that we are dealing with ancient water channels (see section 5.4.3 of this Chapter).

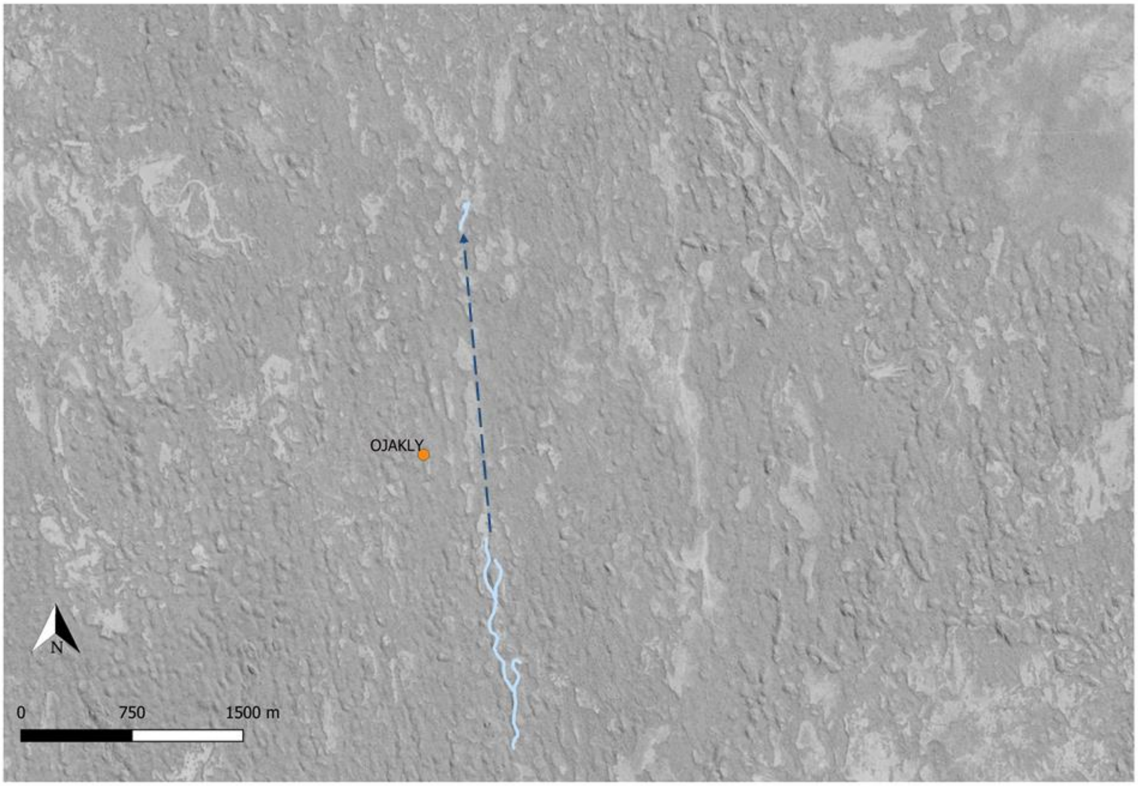


*Figure 5.12 The figure shows Paleochannel 9 (OJK_Ch_IIa, OJK_Ch_IIb, OJK_Ch_IIc) and Paleochannel 28 (OJK_Ch_XIIa, OJK_Ch_XIIb), which have been interpreted as separate paleochannels. However, their flow direction and linear characteristics might indicate that they were originally part of the same channel, with their traces potentially obscured by sand dunes.*

Interestingly, river processes such as possible channel avulsion can also be observed (Figure 5.13). Avulsion can be classified as an erosional process of the riverbanks which, as a result, can produce channel diversions with the formation of new, multiple channels on the floodplain or reoccupation of older channels (Knighton 1998:234). For instance, in the CORONA image (Figure 5.13), the positions of three paleochannel traces (OJK_Ch_XIa, Ch_XIb, and Ch_XIc) suggest an avulsion process, as the segments appear to stem from the same channel. Consequently, they have been regarded as a single channel (referred to as Paleochannel 3).

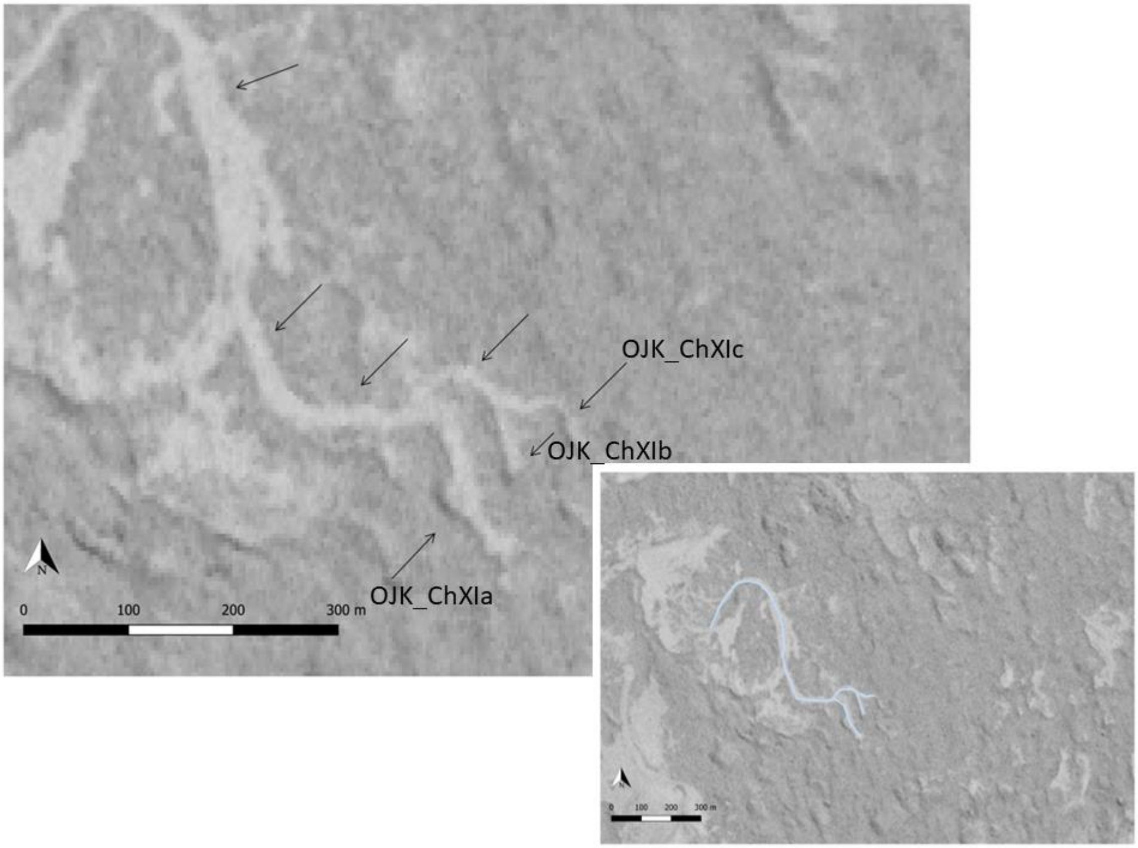


*Figure 5.13 Paleochannel 3. The black arrows (upper-left) indicate the paleochannel takyr surfaces. Although only a segment of the entire channel can be recognized, these multiple paleochannel traces probably are the result of several channel avulsions.*

In addition to channel traces, it is worth noting here that no crevasse splays have been detected on the satellite images. A crevasse splay is formed when the levee of a river channel is broken, and the water flows directly onto the floodplain, forming a crevasse channel as a result of point failures (see Figure 5.14). This is often the result of a natural event and can depend on repetitive flooding and obstruction (Bristow et al. 1999). Common causes are obstruction blocking the discharge[64] of the channel, creating an

---

[64] See Glossary for definition.

avulsion process forcing the water to flow, and create a crevasse splay with new watercourses (MacIntosh 1983; Jacobberger 1988; in Makaske 2001).

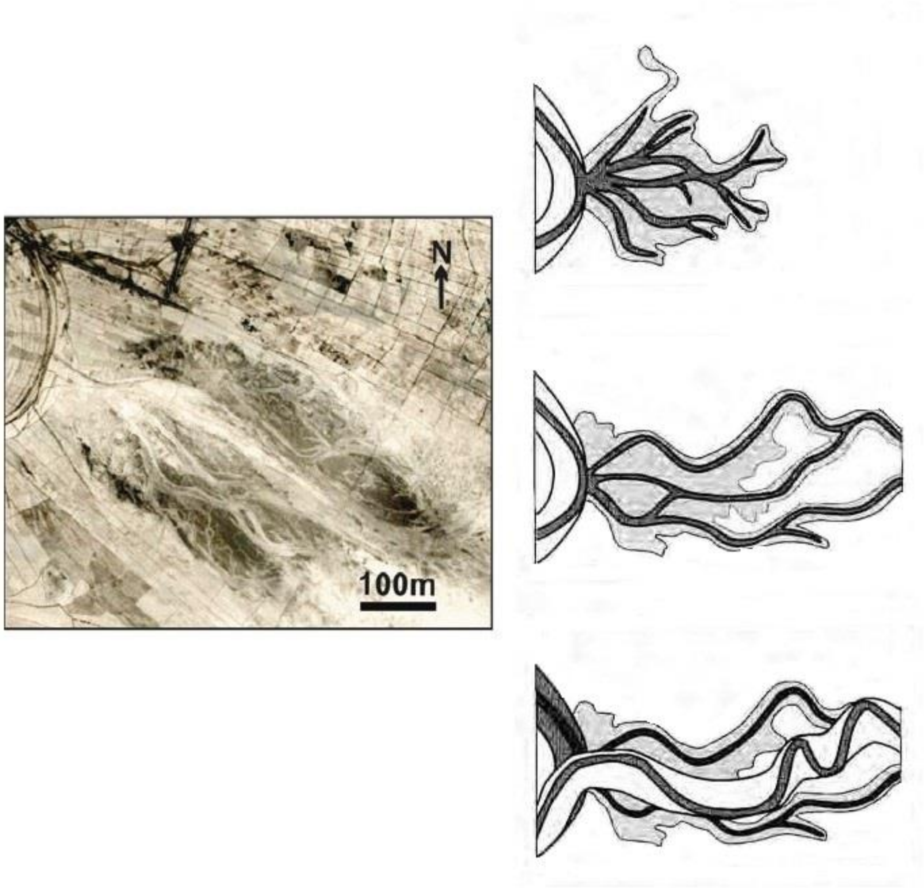


*Figure 5.14 Example of crevasse splays from the southern Mesopotamian floodplain. Crevasse splays can be detected from satellite images. Right: evolution of channel pattern from a crevasse splay (adapted from Jotheri 2018:Fig.6.6; Wilkinson 2003:Fig.5.9).*

According to Wilkinson (2003:88–9), crevasse splays were the preferred location to control water and dig artificial canals to irrigate agricultural fields. This is because the new fan has coarse river sediment, and channels have lower and less steep levee slopes, which are easier to manipulate for water control. In this situation, damming a smaller tributary channel was the easiest way to irrigate fields (Wilkinson 2003:88). Evidence of this practice is attested in the 3rd millennium BCE texts from Mesopotamia where there is mention of filling channels with dirt to create small rudimentary dams able to divert water (Steinkeller 2001:notes 17, 80, in Wilkinson 2003:88).

The absence of crevasse splays in the Ojakly area can relate to two factors. The first is the dunes, that can easily mask the smaller channels that are less easy to detect in satellite images. Thus, only the main channels, with a well-defined spectral signal, are more likely to be identified in the Murghab. A second factor explaining the absence of crevasse splays is the hydrological structure of the ancient alluvial fan with possible low aggradation of the ancient channels at the northern fringe, in contrast to the elevated levees that were present in Mesopotamia that would impeded the formation of crevasse splays (Jotheri 2018). Thus, although no crevasse splays have been detected, shallow levees in the Murghab may have been utilized as primary sources of irrigation, as they exhibit characteristics similar to channels found in crevasse splays.

Another characteristic of the hydrological system in the Ojakly area is the frequent curvature observed in the paleochannels, which could potentially be interpreted as meanders. There is no agreement on why and how many channels develop into a meandering shape (Callander 1978). The possible meandering shapes or curves observed in the paleochannels identified in Ojakly could result from the potential instability of the system[65] (Blodeaux and Seminara 1985; Seminara and Tubino 1989). This would suggest that the hydrological system in Ojakly underwent repeated changes in the courses of its rivers. In such cases, new channels were naturally formed while others were abandoned over time. Considering the structure of the paleochannel traces identified in Ojakly (see section 5.4.3 of this Chapter), and the presence of several curvatures interpreted as meandering features, we can suggest that erosion, instability, and channel deformation were likely factors at play in Ojakly area.

- **Artificial Channels (Canals)**

Features identified with high confidence as artificial channels, which were subsequently ground truthed, have not been discovered in the Ojakly area. Nonetheless, certain features identified solely through remote sensing could indicate the possible presence of canals.

---

[65] However, meanders may also develop due to the river’s tendency to establish a minimum ratio between sinuosity (or meandering) and slope adjustment (Chang 1988). Nelson and Smith (1989) suggest that these characteristics and the formation of meandering forms are typical in wide and shallow channels.

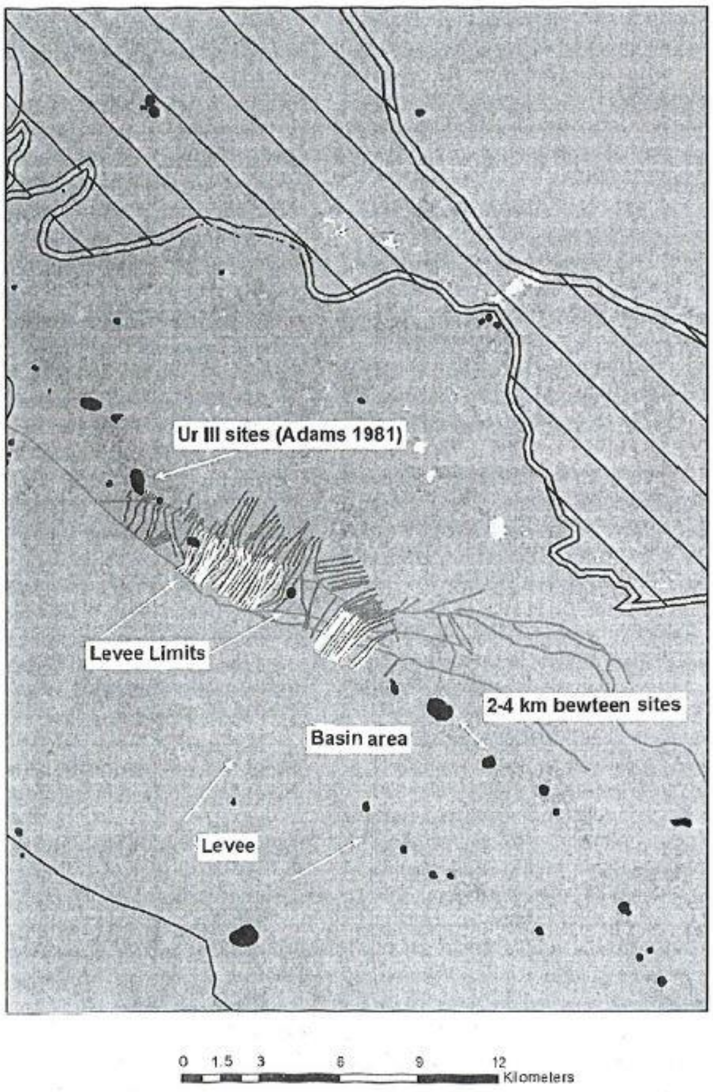


*Figure 5.15 The figure shows a typical schematic of narrow lines of canal structures of the field in the region of Nippur (from Wilkinson et al. 2013a:Fig. 4.16).*

In southern Mesopotamia these features have been widely recognized (Widdel et al. 2013:Fig 4.7; Wilkinson et al. 2015:Fig. 4). In that region canals form irrigation systems in the form of "herringbone" structures which were already present in the 4th millennium BCE. With this system, secondary canals, derived from the main channel, delineate narrow lines (canals) for "furrow irrigation" (Figure 5.15). With furrow irrigation, and the implementation of herringbone canals, surplus water was gathered into drainage canals positioned at the end of each canal line. Areas such as Nippur (Adams 1981:Figs. 30–31;

Widdel et al. 2013:Fig. 4.16) show evidence for these irrigation systems, which are considered long-lasting structures that were easy to manage (Wilkinson et al. 2015). According to Widdel et al. (2013: 68), in Mesopotamia, the secondary canals of the system were between 1.3 to 2 km in length and 150–300 m distant from each other, with tertiary cross canals at 60–100 m intervals, covering several hectares. By contrast, smaller irrigation systems with classic “herringbone structures” were no more than 2–3 ha large.

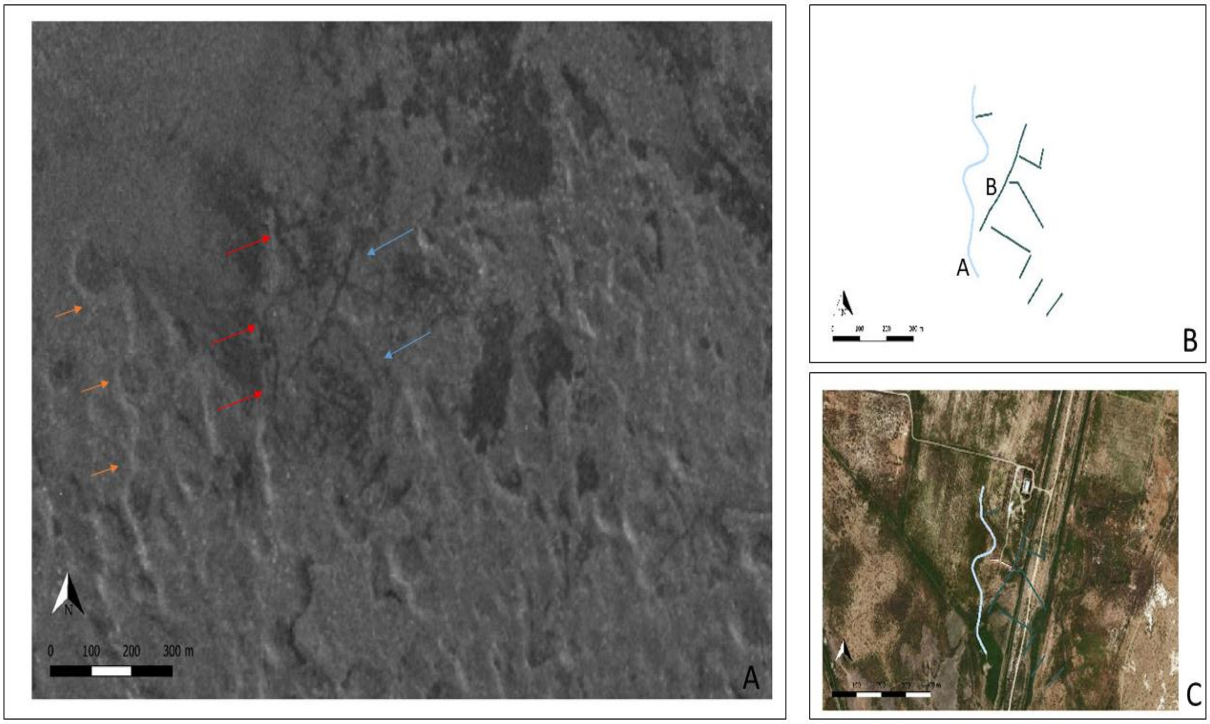


*Figure 5.16 A) The image shows the traces of Paleochannel 23 (OIK_Ch22a), highlighted by red arrows, and the canals highlighted by blue arrows. The orange arrows show a meandering form which is a dune formation (image: CORONA KH4 Band 1 Gray – white to black) B) reconstruction of Paleochannel 23 (blue line marked with A) and canal system (green lines marked with B), C) The satellite image (Landsat 8 – natural color) shows the modern landscape with the presence of modern fields that probably have destroyed or partially destroyed the channels and canals.*

Similar canal structures have be recognized in the Ojakly area based on satellite analysis (Figure 5.16). The area located on the east of Paleochannel 23 (OJK_Ch_XXIIa), which shows channels with possible meandering structure, presents small and straight traces of linear features (canals?) with a distinct spectral signature associated with takyr surfaces. These potential canals have been identified at the northeast edge of the research area, near the main site of Auchin 1. It is thus possible that these canals were part of the agricultural surroundings of the mound settlement, serving water to the local fields. In total, nine straight features can be identified in the satellite images, of which more lines (lines B in Figure 5.16 B) seem to depart from the main Paleochannel 23 and can be associated with artificial canals. These linear features can only be distinguished on a CORONA image (1964) since the area has been cultivated from the 1980s onwards (Figure 5.16 C). Interestingly, these linear features may suggest a structure with secondary canals at 80–130 m distance and a tertiary canal at 50–60 m distance apart. However, due to the presence of large cultivated fields, ground truthing was not possible in the area, and test pit or hand-auger analysis has not been attempted to verify the presence of these possible canals. Nevertheless, the structure of the features on satellite highly suggests the presence of an artificial system to irrigate fields.

Similar structures were discovered by S. P. Tolstov during the survey in the Aral Sea area and were dated to the Bronze Age. In this region, the southern alluvial delta of the Akchadarya, several Bronze Age sites were associated with the presence of paleochannels. Interestingly, a lateral canal connected to the main Akchadarya channel was discovered. The canal was clearly visible on the ground, and it was much longer (up to 20 km) compared to the small possible canals in Ojakly (Adrianov 2016).

However, the vast majority of the irrigation system dated to the Bronze Age in the Aral Sea area were smaller and located along the banks of the river or next to small takyrs with the presence of small narrow canals (Tolstov and Kes 1960:42–45 in Adrianov 2016:145). Examples are from sites such as Kokcha 16, belonging to the Tazabagyab Bronze Age culture, in which canals are next to the main channel. In addition, according to Adrianov (2016:148), there were diversion ditches (from 0.5 to 1.5 m. wide) as well as several canals with structures similar to the canals identified at Ojakly (Figure 5.17). This canal pattern suggests the presence of shallow levees with artificial dikes to divert water from the main channels to artificial canals for furrow irrigation. Fields were usually located along the channels, and possible small gates or sluices might have regulated the flow of water.

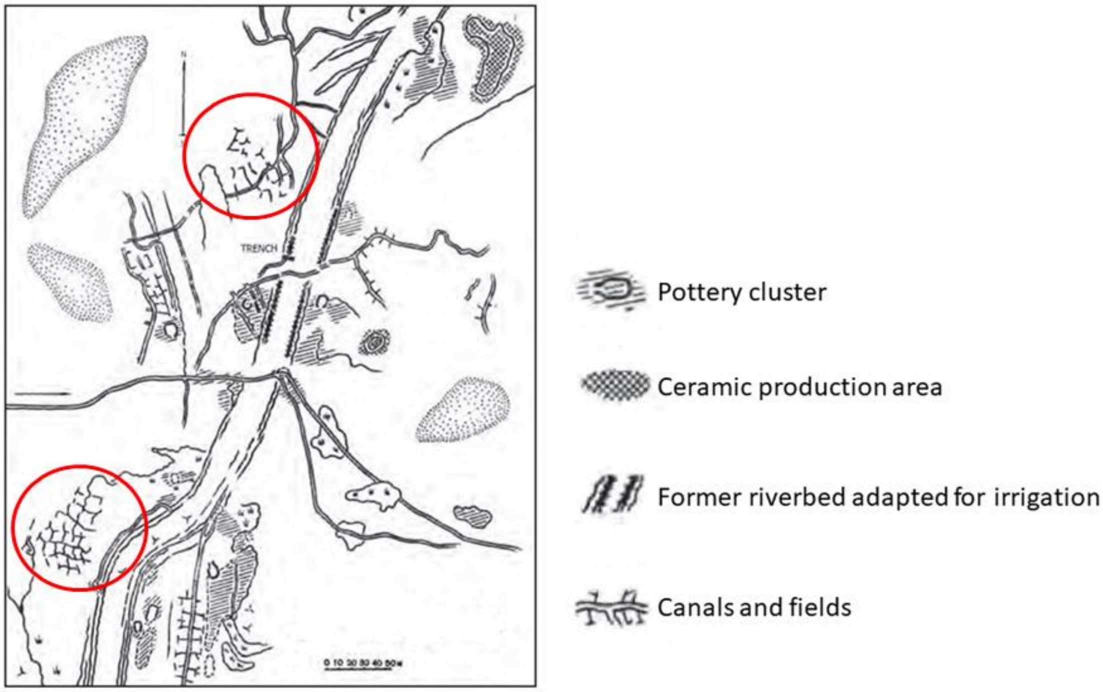


*Figure 5.17 Settlement plan with the presence of artificial canals dated to the Bronze Age in the Aral Sea area (Adrianov 2016:Fig. 30). In the red circle, possible canals whose structures are similar to Ojakly canals from Figure 5.16.*

.

Interestingly, geoarchaeological research by Masson (1967:334) in the Tedjen River in southern Turkmenistan also revealed the presence of an ancient artificial dike close to the settlements of Khapuz-Depe dated to the Bronze Age (3rd millennium BCE). These features are similar to the structures Adrianov described in the Aral Sea area. Considering the strong cultural affinities of the Murghab area with the southern Turkmen region along the Kopet-Dag area (see Chapter 3), it is likely that a sharing of technological know-how could have been in place. The presence of possible canals identified in the northeast of the Ojakly area, as well as the occurrence of canals at Gonur North (Sataev 2008; Hübner 2019), supports the existence of water management which included small dams and weirs to regulate water flow. However, their evidence in the Murghab on the basis of the survey and remote sensing analysis remains elusive. In contrast, the identification on the ground of the main channels is well-supported and will now be discussed.

### 5.4.2 Paleochannel Ground Truthing

Remote sensing provides a first indication of a former hydrological landscape (Wilkinson 2003). However, the data acquired through desk-based analyses are hypothetical. Several factors can affect the analysis and provide false positives (Lasaponara and Masini 2012). For example, modern or natural ground features can be misinterpreted as ancient structures solely on the basis of remote sensing analysis. Therefore, ground truthing is a crucial stage to validate remotely acquired data.

During two fieldwork seasons the project team (see section 4.3.5 in Chapter 4) surveyed the Ojakly area to: a) validate the paleochannels detected by remote sensing and b) conduct archaeological surveys in selected areas. Paleochannels can be considered as former river channels that have become inactive (Vervoort and Annen 2006). However, sometimes they remain sources of subsurface water and thus are good places for cultivation (Mohammed-Aslam and Balasubramanian 2010; Jotheri 2018:Fig.6.12; also see below section 5.8).

A first walking survey transect was conducted east of Ojakly for about 5 km. The walking survey was meant to verify ancient channel riverbeds and their characteristics and possibly find archaeological evidence of settlements associated with these paleochannels. By contrast, the western part of Ojakly was surveyed by car (see section 4.3.5 in Chapter 4 for details) at selected places to verify paleochannel structures and check anomalies that could be associated with old channels that emerged during remote analysis.

The first walking survey (Area 11, see Figure 5.27 for survey areas) east of Ojakly crossed the following paleochannels remotely identified from satellites and aerial photos:

- **Paleochannel 10** (OJK_Ch_IVa) is approximately 15 m wide at the visit point, although the left bank of the former river was not easy to identify due to vegetation (Figure 5.18). The right bank had an elevation of about 2.5 m, while the left was around 1 m high. Both sides of the river were characterized by sparse, low vegetation. The riverbed was cultivated at the time of the visit (May), and it was not possible to identify the ground surface. As discussed in Chapter 2, the often porous properties of paleochannel surfaces can retain moisture and, thus, can be used for agriculture (Chen et al. 1996).

*Figure 5.18 Paleochannel 10 (OJK_Ch_IVa). The photo shows the former paleochannel bed currently under cultivation (white dashed lines) at the time of the visit. In the background, the elevation of the former bank can be seen. The human figure shows the scale.*

- **Paleochannel 13** (OJK_Ch_Va) is approximately 18 m wide at the visit point and is located in the center of the research area and has a flat surface and slightly elevated levees of 0.5 m, while less elevated levees were observed at the second visit point approximately 600 m to the north. While the more modest banks made this channel less visible on the ground, the paucity of the vegetation on the channel bed was a crucial marker. The surface of the paleochannel was formed by a flat compact takyr surface, and it was possible to observe the meandering form of the old channel (Figure 5.19).

*Figure 5.19 Paleochannel 13 (OJK_Ch_Va). The figure shows the former channel bed (white dashed lines). It is possible to observe the meandering form of the old channel. The human figure shows the scale.*

- **Paleochannel 17** (OJK_Ch_VIIIa-b) (Figure 5.20) has a flat takyr surface, approximately 4 m wide and is thus smaller than the ones detected on CORONA, with very limited elevations on both banks (ca. <0.5 m) but with marked vegetation of the right and left banks and an absence of vegetation on the bed. It is likely that this is the remnant of an old channel.

*Figure 5.20 Paleochannel 17 (OJK_Ch_VIIIa). The figure shows the former channel bed (white dashed lines) characterized by takyr surface. The human figure on the left shows the scale.*

- **Paleochannel 9** (OJK_Ch_IIa) (Figure 5.21) was covered by an elongated dune and could not be characterized with good confidence at the point of the visit. However, its meandering structure was clearly visible from satellite analysis. Moreover, low vegetation bordering the dune was similar to plants observed on other riverbeds usually associated with takyr surfaces (Rustanov 1994a:87). It appears that the takyr surface visible from CORONA images was later covered by sand at the time of the visit.

*Figure 5.21 Paleochannel 9 was covered by an elongated dune and could not be well investigated.*

- **Paleochannel 8** (OJK_Ch_I) (Figure 5.22) is located relatively close to Ojakly, approximately 700 m west of the site. The paleochannel was approximately 10 m wide and similar to other channels. The former bed has a flat takyr surface dominated by green vegetation on both banks. The banks were of a limited elevation making the identification of the ancient channel difficult. However, the absence of vegetation and the takyr surface, as well as an elongated form, indicate an ancient watercourse.

*Figure 5.22 Paleochannel 8 (OJK_Ch_I). The figure shows the former channel bed (white dashed lines) characterized by a takyr surface and small vegetation on it.*

- **Paleochannel 1** (OJK_Ch_IXa) (Figure 5.23) is one of the longest in the Ojakly area. It is approximately 10 m wide at the visit point and has a takyr surface with almost no vegetation. The curved form of the paleochannel has slightly elevated banks (approximately 0.5 m on the right, and between 0.5 and 1 m on the left bank). The watercourse was easily distinguished on the ground. It is likely that the current elevation of the former banks is also the result of dune movement. However, small and medium channels in the distal area of the Murghab alluvial fan generally have shallow banks.

Figure 5.23 Paleochannel 1 (OJK_Ch_IXa). The figure shows the former channel bed (white dashed lines) characterized by a takyr surface and meandering form.

In addition to the paleochannel survey, other features were also checked in the survey. In particular, an elongated feature with a southeast–northwest direction that was detected both on CORONA and Landsat images. The feature has a different color than the channels which is normally typical for the elongated dunes (barchans) in the area. Initially, this linear feature was interpreted as a canal on the basis of satellite analysis (Figure 5.24A). However, the survey later confirmed that this was a modern canal with steep levees (Figure 5.25). Likewise, a modern farmstead was also checked. This settlement was also present on the map in addition to CORONA images, where the farmstead had a distinctive black spectral signature with a geometric-like form (Figure 5.24B and C). Other small canals, not identified both on CORONA and Landsat, were recorded during the survey in its vicinity. It is likely that these canals were in use during the Soviet period (probably until the 1980s) to irrigate fields taking water from a local *khak* nearby where water was stored.

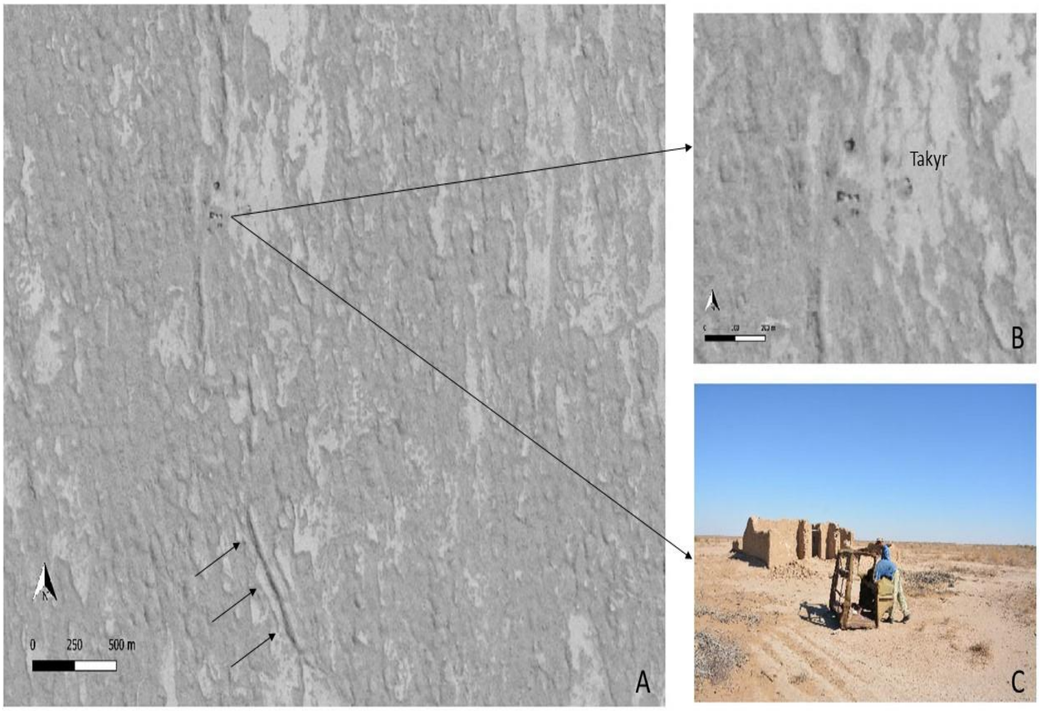


*Figure 5.24 A) CORONA KH-4A image showing the modern artificial canal (black arrows on the bottom of image) and the spectral signature of farmsteads. B) A zoomed-in image of the farmstead area on the CORONA image, and C) a photo of the abandoned farmstead visited in September 2018.*

*Figure 5.25 The photo shows one of the artificial canals surrounding the modern farmsteads in the northwest of the research area in Ojakly.*

### 5.4.3 Paleochannel Characteristics

- **Paleochannel Validation in the Ojakly Area**

The remote sensing analysis in the research area could not fully reconstruct the fluvial system and only some of the channels could be detected. Parts of the channels are covered by sand dunes (Figure 5.21) or have not been preserved. The validation survey of the paleochannels aimed to increase the quality and the understanding of the system.

Interestingly, almost all the paleochannels that have been checked have similar characteristics, such as flat takyr surfaces with scarce vegetation consisting of small shrubs (e.g., *Anabasis salsa*) or greenish algae (Vinogradov 1962). In the Ojakly area, the former rivers usually have shallow banks with an average height between 0.5 and 1 m. The channels have an elongated form, while some also have curves that are possibly meanders. The presence of takyr surfaces of elongated forms is a crucial indicator of the presence of ancient channels (Adrianov 2016:78, 89).

- **The Structure of the Ancient Fluvial System in the Ojakly Area**

A fluvial system, as described by Knighton (1998:261–262), develops over time. Rivers demonstrate an ability to adapt and react to alterations, which may stem from various factors including climate and tectonic activities. In Chapter 2, I outlined the major ecological changes of the Murghab fluvial system that have been postulated (Marcolongo and Mozzi 1998). However, human intervention in the fluvial environment can also constitute a major factor that can alter a river system (Knighton 1998:263).

During the Ur III period in Mesopotamia, several measures were in place to prevent a major flood (Civil 1994:100). Texts report the presence of more than one flood dike, probably located along the Tigris. In addition, there are records of workers performing flood-watch duties (Rost 2015:171–2). In the Murghab, discerning the extent of human interventions and their influence on the fluvial landscape proves challenging. Classifying the fluvial system in the Ojakly area is also problematic due to incomplete data (Rust 1978; see contra Makaske 2001). Nonetheless, some observations can be made.

The Ojakly region has paleochannels with some meanders exemplified by paleochannel 18 (OJK_Ch_XVIII). Conversely, other channels have straight configurations (Makaske 2001). On CORONA images the paleochannels in the Ojakly area have an average of ca. 15 m in width. Further, some darker spectral signatures in the center of former channels, such as Paleochannel 15 (OJK_Ch_VI), can be interpreted as a possible channel bar (Figure 5.26). The extent and the presence of channel bars separating the branches can indicate braided channels.

While the Ojakly area exhibits a range of channel patterns including possible meanders and braided forms, these characteristics align with the broader classification of the Murghab system in the past as an anabranching fluvial system (Schumm 1968; 1985). A similar system has been proposed for the ancient Meana and Chacha fans in southern Turkmenistan (Marcolongo and Mozzi 1998). However, distinguishing between braided and anabranching patterns in the Murghab may require further sedimentological analyses (Xu et al. 2019).

A further consideration is the nature of the watercourse (natural or artificial). It is difficult, however, to determine whether the paleochannels in Ojakly were part of an artificial system (also see Chapter 4 on methodology). Recently, Jotheri (2018) has outlined some key differences that can help us to discriminate between natural channels and artificial canals. Artificial canals rarely form meanders, while steep levees are meant to prevent any flooding or channel avulsion. In contrast, the excavation of channel banks can reveal the presence of gentle and layered banks, which can be the result of the natural accumulation of coarse material along the channel sides, while straight and steep sides are cross-sections characteristic of artificial canals.

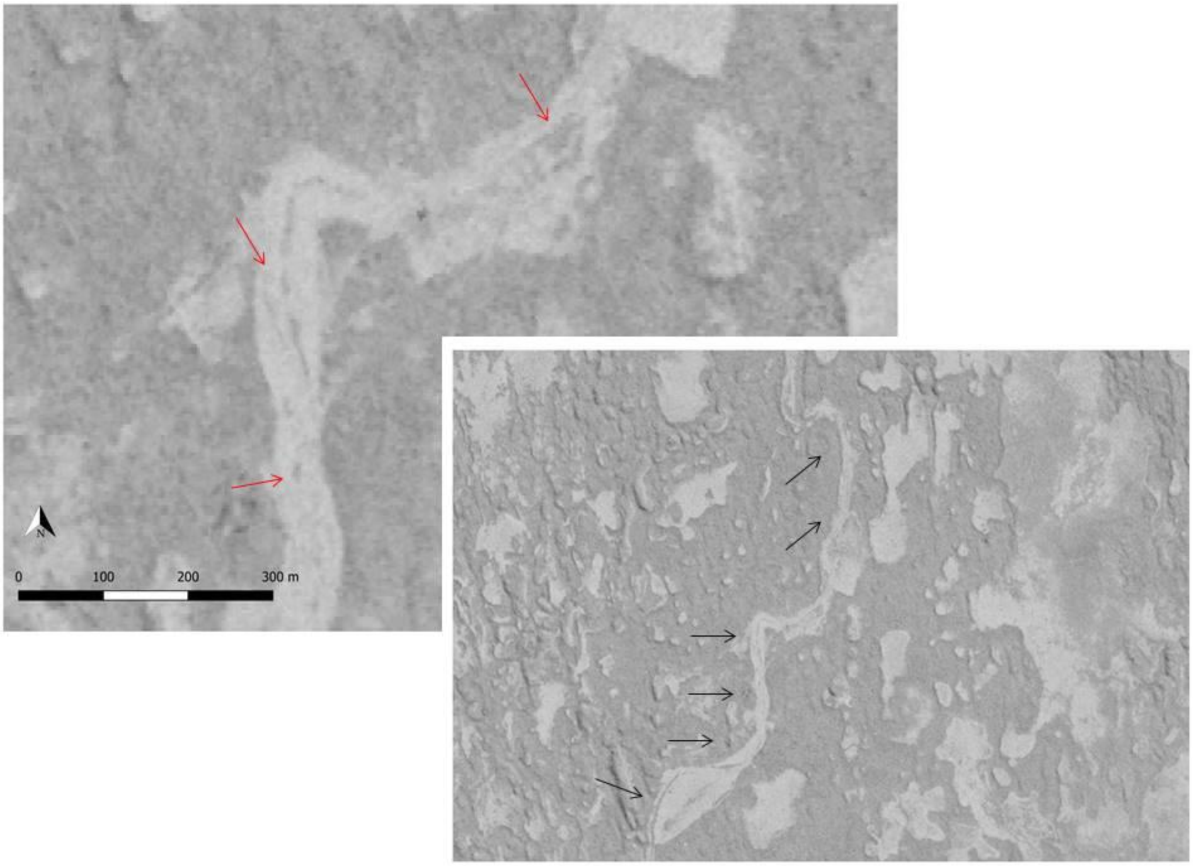


*Figure 5.26 Paleochannel 15 appears to be larger than other channels, with the presence of darker areas (red arrows) in the middle of the channel, with a different spectral signature from the light takyr surface. These areas can be interpreted as possible channel bars with the presence of multiple channels separated by small islands. Black arrows (bottom right) indicate the general trace of paleochannel.*

Stream direction can also help us differentiate between channels and canals. Natural rivers generally follow the slopes of the landscape, while artificial canals do not necessarily adhere to the gradient (Wilkinson 2003). For instance, modern canals in the Murghab, while taking advantage of the natural slopes of the landscape, follow an unnatural east-to-west direction. In contrast, paleochannel traces identified in Ojakly generally follow a south–north/north–east gradient. The channels, albeit almost straight in some sections, often show meanders suggesting a natural genesis.

The excavation of the cross-section of Paleochannel 13 (OJK_Ch_Vb) (see section 5.8.2 of this Chapter) revealed a gentle slope typical for a natural channel (Jotheri 2018). In addition, on the basis of the hand auger cross-section, the channel was much larger than the artificial canal excavated near Gonur which was characterized by a straight course and width of only 3 m (Sataev 2008). Taken together, the channels recognized in the Ojakly area suggest that these paleochannels can be classified as natural formations. Their gradients and natural configurations, characterized by curves and gentle slopes, align with typical features of natural watercourses. However, this acknowledgment doesn’t dismiss the potential for local community involvement in watercourse management, including bank manipulation, as highlighted by Rashidian (2021). Therefore, it is likely that channels utilized as primary water sources underwent some level of management.

## 5.5 Results of the Field Survey in the Ojakly Area

The survey of the Ojakly area aimed to assess the presence of sites along the channels and their distribution in relation to the watercourses. As discussed in Chapters 3 and 4, the area of Ojakly was previously surveyed both by Soviet and the AMMD teams. These data will be integrated with the analysis and further discussed in section 5.5.1. In Chapter 4, I outlined how the pedestrian survey was conducted (section 4.3.5). The first survey transect (Area 11) was perpendicular to the flow direction of the paleochannels. Prior to the survey, ten areas along paleochannels were selected (Table 5.1). The survey was conducted parallel to the paleochannels covering 500 m on each side. Due time constraints and resources, some paleochannels could not be surveyed, but we aimed to cover representative survey areas (see Figure 5.27). Likewise, in the northeast of the research area, Paleochannel 15 and Paleochannel 24 were not surveyed due to the presence of modern canals and agricultural areas.  As discussed above, a general problem in the distal Murghab fan is the sand cover that masks many archaeological features (Kohl 1984; Gubaev et al. 1998). Vegetation is an additional factor that can mask sites. However, the site survey took place during the autumn, when the vegetation constituted by shrubs was less extensive. According to Markofsky (2010:162), in the fan, the vegetation cover is 20% in spring, and only 5% during autumn. Thus, vegetation has a small impact on site visibility.

| SURVEY AREA | SIZE | PALEOCHANNEL |
|---|---|---|
| **AREA 1** | 1.91 km$^2$ | **Paleochannel 21**<br>(OJK_Ch_XXa, OJK_Ch_XXb, OJK_Ch_XXc) |
| **AREA 2** | 2.07 km$^2$ | **Paleochannel 1**<br>(OJK_Ch_IXa, OJK_Ch_IXb) |
| **AREA 3** | 1.23 km$^2$ | **Paleochannel 1**<br>(OJK_Ch_IXa) |
| **AREA 4** | 1.77 km$^2$ | **Paleochannel 8**<br>(OJK_Ch_I) |
| **AREA 5** | 0.81 km$^2$ | **Paleochannel 11**<br>(OJK_Ch_IIII) |
| **AREA 6** | 1.22 km$^2$ | **Paleochannel 4**<br>**Paleochannel 5**<br>**Paleochannel 28**<br>(OJK_Ch_XIIa, OJK_Ch_XIIb, OJKCH13a, OJK_Ch_XIIIb) |
| **AREA 7** | 1.31 km$^2$ | **Paleochannel 9**<br>(OJK_Ch_IIa, OJK_Ch_IIb, OJK_Ch_IIc) |
| **AREA 8** | 1.39 km$^2$ | **Paleochannel 10**<br>**Paleochannel 12**<br>(OJK_Ch_IVa, OJK_Ch_IVb, OJK_Ch_IVc) |
| **AREA 9** | 1.82 km$^2$ | **Paleochannel 10**<br>**Paleochannel 16**<br>(OJK_Ch_IVa, OJKCh7b, OJK_Ch_VIIc) |
| **AREA 10** | 2.64 km$^2$ | **Paleochannel 13**<br>**Paleochannel 14**<br>(OJK_Ch_Va, OJK_Ch_Vb, OJK_Ch_Vc) |
| **AREA 11** | 2.53 km$^2$ | **Paleochnnel 10**<br>**Paleochannel 27**<br>**Paleochannel 13**<br>(OJK_Ch_IVa, OJK_Ch_XXVII, OJK_Ch_Va, OJK_Ch_Vb) |

*Table 5.1 Walking survey areas in Ojakly and associated paleochannels.*

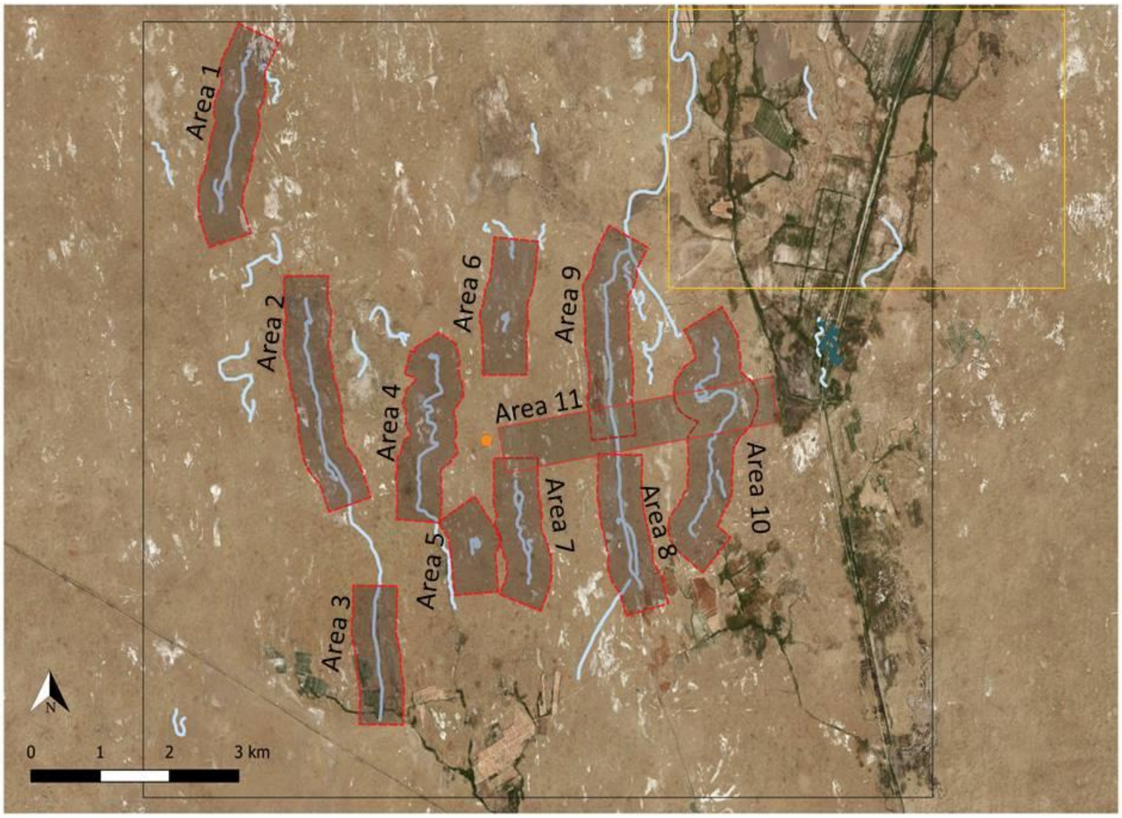


*Figure 5.27 The figure shows the survey areas. The orange square marks the cultivated area that was not possible to survey.*

### 5.5.1 Recorded Sites

During the course of two field campaigns, a total of eleven areas were surveyed at Ojakly along the paleochannels detected by remote sensing (Figure 5.27). Only the first area of the survey (Area 11) is perpendicular to paleochannel traces and was a continuation of the previous transect by the AMMD. The perpendicular survey also aimed to verify the paleochannel traces and structure. During the survey, 12 new sites were identified in the research area in addition to the sites identified by past survey (Figure 5.28) (see Table 1.2. in the Appendix 1 for site catalogue).

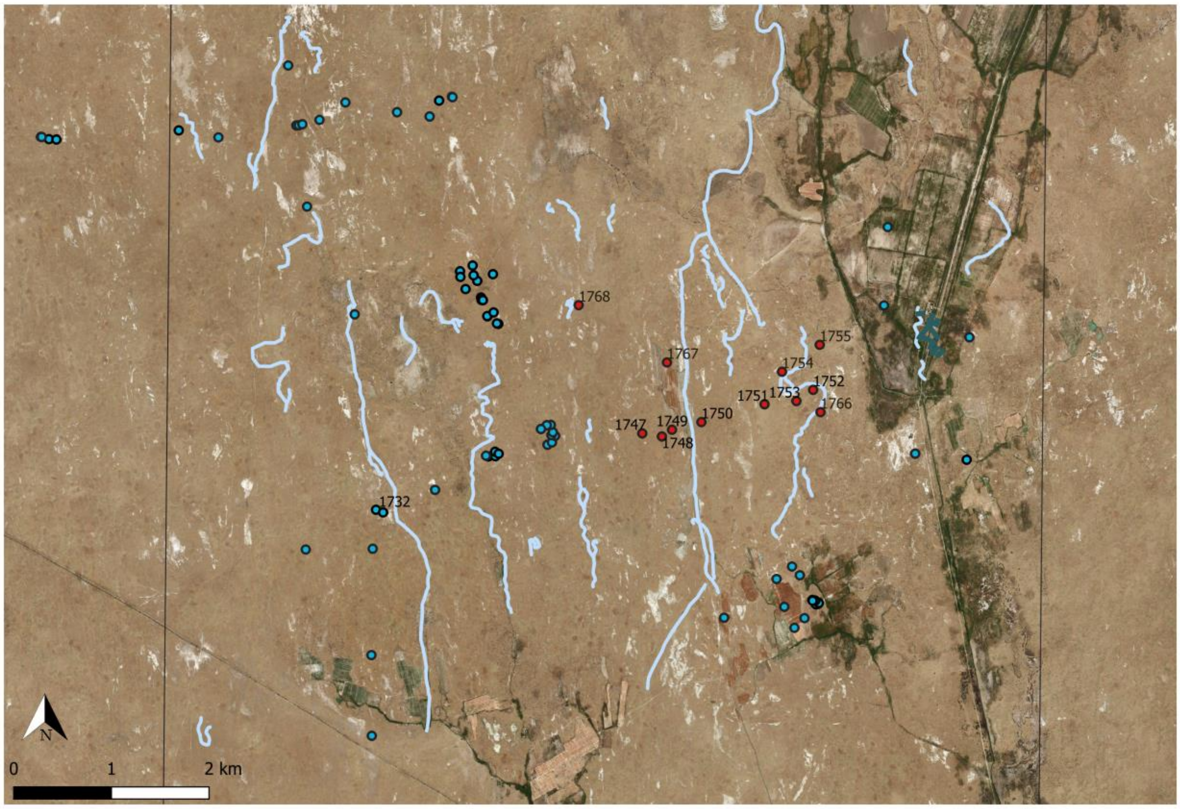


*Figure 5.28 The image displays the distribution of newly identified sites from the current survey, marked in red. Sites previously identified by AMMD and Soviet surveys are depicted in light blue. Paleochannels are shown in blue, while the green lines represent possible artificial canals. It is likely that these traces of ancient channels were interconnected.*

During site identification, only some artifacts were collected (i.e., diagnostic pottery), mainly for dating purposes. As discussed in Chapter 4, the sites were photographed, and their coordinates were recorded (see Table 5.2; see Chapter 4 for detailed methodology). Subsequently, the collected pottery was photographed and drawn at the base camp in Merv (see section 5.5.2 of this Chapter for chronology).

The recorded sites have artifacts spread over flat or slightly elevated surfaces. The main finds consist of pottery, while some sites also have evidence of kiln fragments. Most of the sites fall under the categories of small and large clusters.[66]

---

[66] For site categories see Table 4.1 in Chapter 4. For site descriptions see Table 1.2 in the Appendix 1.

*Figure 5.29 Evidence of kiln fragments at site n.1748.*

In survey Area 11, four new sites were recorded. The first group of sites located west of Paleochannel 10 (Area 10) consist of sites n.1747, n.1748, and n.1749. Site n.1747 is a large cluster site and is characterized by a slightly elevated area. Site n.1748 is a large cluster site and includes ICW (Andronovo) pottery along with BMAC pottery. Also, several kiln wasters were recorded at this site that may indicate pottery production (Figure 5.29). At the northeast of this site, at a distance of ca. 150 m, the team also identified site n.1749. The site is a small cluster located on a takyr surface. To the east of Paleochannel 10 the team identified site n.1750, also a large cluster site.

On the cross-section between survey areas 10 and 11, the team identified four new sites. Site n.1751 that has both ICW (Andronovo) pottery and BMAC pottery and was classified as a small cluster. At a few meters distance from this site along Paleochannel 13, site n.1753 is the largest site recorded during the survey and it was classified as a low mound. The site has large quantity of pottery but no kiln fragments were recorded. Its size and characteristics suggest that it was more permanently occupied. In contrast, site n.1752 located at a short distance away is categorized as small cluster. Along the same Paleochannel 13, the team also identified site n.1766. The site is characterized by a large pottery spread and it has several kiln wasters (Figure 5.30). These fragments are similar to the overfired kiln fragments excavated in Gonur North and it is likely that the site had a pottery workshop area.

*Figure 5.30 The figure shows site n.1766 with the presence of fragments of kiln wasters.*

In Area 10 two more sites were identified. These sites are located east and west of Paleochannel 13. Sites, n.1754 and n.1755 were characterized by the presence of a small assemblages of pottery (small clusters) and might represent temporary occupations along the channel.

In the survey Area 9 site n.1767 was also identified. The site is at the edge of an agricultural area, and it is likely that part of the site might have been destroyed. The site is a small cluster and has both ICW (Andronovo) and BMAC assemblages. This is perhaps not surprising as the presence of BMAC alongside with ICW (Andronovo) pottery was recorded in 11 more sites in the Ojakly area, including Auchin 7, 11, 12, and 16 for instance (Sarianidi 1975:22–4; 1990:12).

In survey Area 6 in the proximity of Paleochannel 28 site n.1768 was identified. It is a relatively small cluster site with pottery on a takyr surface.

During the survey of the eastern areas, namely survey Areas 1, 2, 3, and 4 (Figure 5.27), the team did not encounter any new sites. This is consistent with the results of the AMMD survey (Figure 4.6) which also did not find any sites east of Ojakly. It is interesting to note that many sites surveyed by the Soviet and AMMD teams are along paleochannels identified in this study (see section 5.5.1 of this Chapter) although not necessarily close to them. This aspect will be further discussed in section 5.6.

### 5.5.2 Chronology of the Recorded Sites

As already discussed in Chapter 1, despite decades of excavations in the Murghab, the Bronze Age pottery chronology remains unclear. Only some radiocarbon dates are available in comparison to all the sites excavated. Further, the Namazga V and VI pottery assemblages from the BMAC have been poorly researched (Luneau 2010; 2021a). In this context, it is difficult to have a more accurate chronology of the sites based on surface pottery.

Apart from the ceramic assemblages, other finds might help to date a site. For instance, flat violin-shaped female figures can help as they are generally dated to the Middle Bronze Age (Masson 1988:92). Likewise, quadrangular amulet/stamp seals with a hole drilled through the longitudinal axis, for instance (e.g., Sarianidi 1998a: 301, Fig. 1646.2), are dated to the Late Bronze Age (Forni and Arciero 2022). However, during the present survey, none of such objects were identified, and sites are dated with only pottery material.[67]

On the basis of the pottery, the majority of sites in the survey can be dated to the Late Bronze Age (Namazga VI period) (Table 5.2). The dating of the sites is consistent with the previous survey conducted by the AMMD (Cerasetti 2012). However, there are two sites (n.1750 and n.1753) that have pottery from the Middle Bronze Age as well.

Site n.1753, identified in the survey of Area 11, present several fine ware rims with a beige inner and outer surface with wheel marks that are known from Gonur North (Hiebert 1994a:55, Fig.4.22; Sarianidi 1990a:215, tabl.X, 17), together with some fine ware bases with orange surfaces and a red engobe and horizontal polishing on the outer surface (Sarianidi 1990a:212, tabl.VII, 15).

Site n.1750 shows two different types of pottery. Fine ware rims with a beige outer surface and a buff inner surface, and coarse ware rims with sand or grog temper and brown – light to dark – outer surface along with a light brown inner surface which has parallels at the site of Gonur 20. The latter was radiocarbon dated to the (late) Middle and Late Bronze Age (Fontugne at al. 2021:877). However, some fine wares seem to have persisted across the Middle and Late Bronze Ages (Luneau, in Cerasetti et al. forthcoming). As such, identifying a single period for this pottery can be problematic.

In addition to BMAC pottery, sites n.1751, n.1748, and n.1767 also have coarse wares, which have parallels in ICW (Andronovo) pottery. Site n.1748 has coarse ware rims with sand and grog temper and pottery with a grey-brownish outer surface along with a beige inner surface (refer to parallels in Cerasetti 1998: 71, Fig.I, 2). Site n.1751 also has Andronovo (ICW) pottery, whose paste is similar to Ojakly (Cerasetti 1998: 73, Fig.III, 20). A recent analysis made on pottery fragments from Ojakly, Chopantam, and other ICW (Andronovo) sites in the Murghab show that the fabrics are similar. In addition, the

---

[67] The analysis of the pottery assemblages was conducted by Dr. E. Luneau from the German Archaeological Institute (DAI).

clay sources for this ICW (Andronovo) pottery appear to be of local origin (Rouse et al. 2019).

It is noteworthy to mention that Namazga (BMAC) pottery discovered at these recorded sites also features coarse ware, categorized as “kitchen” ware (P’yankova 1994). This pottery, however, has different fabrics, production techniques, and vessel forms than the ICW (Andronovo) coarse ware. It is similar to wheel-shaped forms but with a hand-made technique (sometimes completed on a wheel) (Cattani 2008a:143).

| **Site #** | **Chronology** | **Site Category** | **Namazga pottery (NMZ) or ICW (Andronovo) pottery (ICW)** | **Survey Area** | **Survey Year** | **Coordinates (UTM 41 N)** |
|---|---|---|---|---|---|---|
| 1768 | LBA | Small Cluster | NMZ | Area 6 | 2018 | 427084 E<br>4235181 N |
| 1767 | LBA | Small Cluster | NMZ-ICW | Area 9 | 2018 | 427986 E<br>4234595 N |
| 1766 | LBA | Large Cluster | NMZ | Area 10 and 11 | 2018 | 429559 E<br>4234086 N |
| 1755 | LBA | Small Cluster | NMZ | Area 10 | 2018 | 429551 E<br>4234775N |
| 1754 | LBA | Small Cluster | NMZ | Area 10 | 2018 | 429165 E<br>4234499 N |
| 1753 | MBA-LBA | Low Mound | NMZ | Area 10 and 11 | 2017 | 429312 E<br>4234199N |
| 1752 | LBA | Small Cluster | NMZ | Area 10 and 11 | 2017 | 429483. E<br>4234314 N |
| 1751 | LBA | Small Cluster | NMZ-ICW | Area 10 ad 11 | 2017 | 428986 E<br>4234166 N |
| 1750 | MBA-LBA | Large Cluster | NMZ | Area 9 and 11 | 2017 | 428340 E<br>4233984 N |
| 1749 | LBA | Small Cluster | NMZ | Area 9 and 11 | 2017 | 428039 E<br>4233906 N |
| 1748 | LBA | Large Cluster | NMZ-ICW | Area 11 | 2017 | 427935 E<br>4233837 N |
| 1747 | LBA | Large Cluster | NMZ | Area 11 | 2017 | 427734 E<br>4233869 N |

*Table 5.2 The new sites recorded by the present project during the survey in the Ojakly area.*

## 5.5.3 The AMMD and Soviet Survey Data

The research area in Ojakly was previously surveyed by Soviet scholars between the 1950s and 1970s and later by the AMMD team in the 1990s–2000s. However, none of the preceding surveys specifically targeted the paleochannels. Earlier surveys followed an east–west direction, largely neglecting areas adjacent to the channels and identified numerous sites. The proximity of settlements to water channels underscores the importance of these sites. An examination of selected settlements deemed pertinent to the current research is essential (Figure 5.31). These settlements will also be discussed in the discussion chapter (Chapter 7).

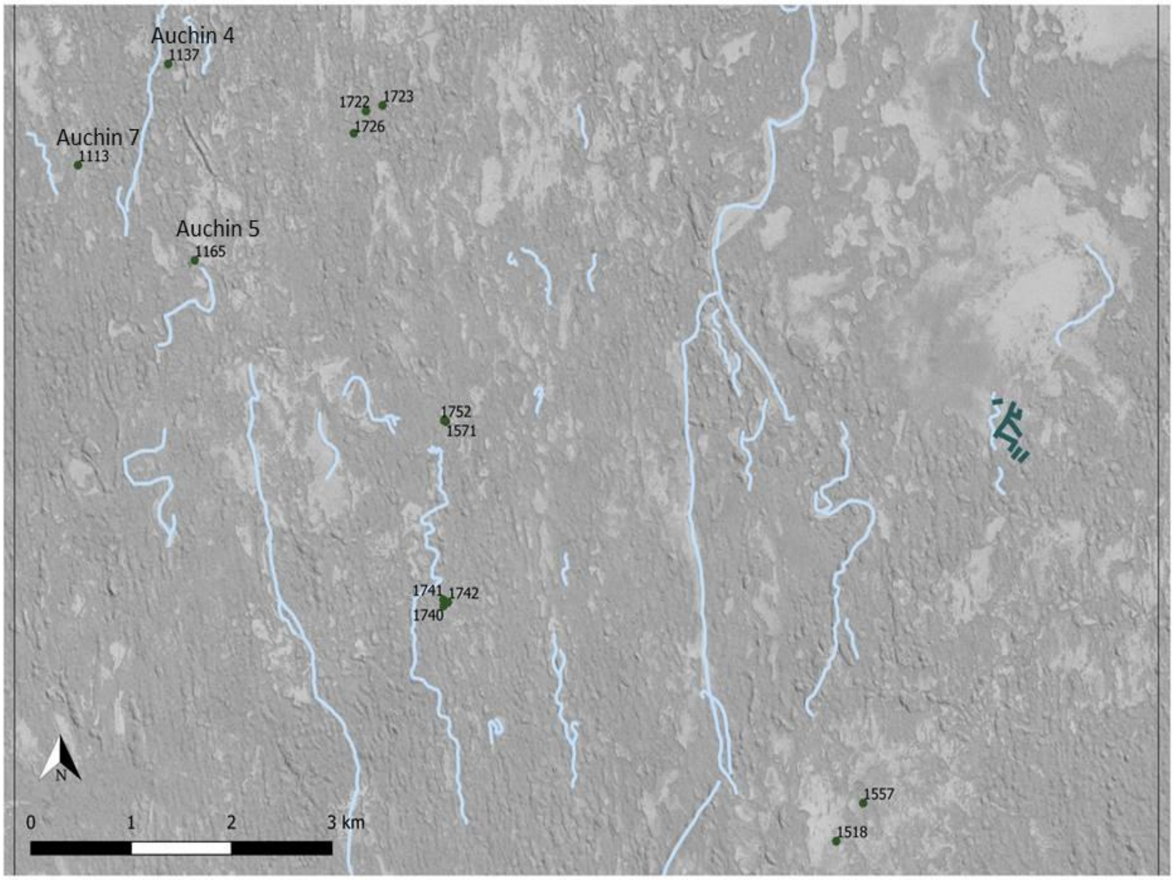


*Figure 5.31 The figure displays the primary sites identified by the Soviet and AMMD surveys in the Ojakly area. Black lines delineate the east and west sides of the research area. Paleochannels are depicted in blue, while green lines represent potential artificial canals.*

Among the sites recorded in the past, Site n.1518, recorded in 2006 by the AMMD team as a large cluster (*Low-Lying Depositional Area – LLDA*) is located in the southeast of the research area and is spread over a large area on a takyr and has Namazga (BMAC) pottery and kiln fragments in the northeast of the site. The site is at a distance of less than 500 m from site n.1557 which is characterized by a predominance of ICW (Andronovo) pottery. Considering the flow direction of the paleochannels detected in Ojakly, sites n.1557 and n.1518 may have been in the proximity of Paleochannel 10.

In the northeast of the research area, site n.1726 has both Namazga (BMAC) and ICW (Andronovo) pottery. It was classified by the AMMD as a large cluster (LLDA) and is located on a takyr. The AMMD team identified a built-up area in the south of the site. Along with the site, further small cluster sites (e.g., sites n.1722, n.1723, n.1719) were identified no more than 200 m apart, forming one of the most important clusters of sites. No traces of paleochannels could be identified, but it is unlikely that such a cluster of sites could have existed without a nearby watercourse.

Alongside Paleochannel 8, two more clusters of sites are worth mentioning. Sites n.1571 and n.1572 were classified by the AMMD as large clusters (LLDA) and had many fragments of ICW (Andronovo) pottery. The sites are located within survey Area 4 of the present project. While site n.1571 is located on a dune area, site n.1572 – which is only 25 m away – is located on a takyr surface. Site n.1572 showed mainly ICW (Andronovo) pottery and was classified as a large cluster site. According to the AMMD team, both sites may be part of a single site forming one of the larger ICW sites in the area.

Located further to the south and at about 8 meters southwest of Ojakly, sites n.1740, n.1741, and n.1742 form a large cluster (Figure 5.28). The sites are located 30–40 m apart and have a large proportion of ICW (Andronovo) pottery. Although registered separately, they might be one site.

Other significant sites identified in the area include the mound sites documented by the Soviet archaeologists. According to Sariandi (1990a:12) Auchin 4, located within survey

Area 1, had a large spread of pottery over 200 m on an elevated area. The site can be classified as a low mound located 120 m from Paleochannel 21 (Sariandi 1990a:12). A similar low mound site is Auchin 7 (Figure 5.28), located between Paleochannel 21 and Paleochannel 25, which has an length of about 120 m with evidence of circular structures on the surface. Auchin 5, also classified as a low mound, is located southwest of survey Area 1 at 100 m distance from Paleochannel 19 and shows evidence for a pottery kiln.

The previous surveys conducted by Soviet archaeologists and the AMMD team indicates that the research area contained many sites. However, it is worth noting that parts of the research area were devoid of settlements, whether temporary or permanent, which contrasts with the notion of oases, as discussed in Chapter 3. This issue will be explored further in Chapter 7. However, a crucial aspect requiring discussion in the next paragraph is how communities situated themselves in relation to water resources and the potential implications for their economy and water management.

## 5.6 Settlements and Channels in the Ojakly Area

Site distance from water channels is a crucial factor to investigate. In Chapter 2, I briefly discussed the paleoclimate in the Murghab. Numerous studies focusing on the Murghab indicate that the local paleoclimate became increasingly arid from the 2nd millennium BCE onwards (Cremaschi 1998; Ninfo 2007; Markofsky et al. 2017). Access to water was indispensable for crop cultivation and animal husbandry practices. Consequently, the distance to water sources can offer valuable insights into potential subsistence strategies (Rouse and Cerasetti 2017). The aim here is to analyze the location of site type (i.e., tepe, low mound, large cluster, and small cluster) and pottery assemblages (i.e., Namazga or ICW-Andronovo) in relation to water access.

Recently, Rose and Cerasetti (2017:Fig.4) assessed water–site distances for the Murghab, focusing on the northeastern part of the region. Their analysis suggests that few major differences existed between site types and distance to water channels in the Late and

Final Bronze Age. Likewise, there appears to be little difference between sites that have only Namazga (BMAC) pottery or ICW (Andronovo) pottery, and sites that have a mix of both assemblages. In contrast, in the Iron Age period, tepe and low mound sites are located at a greater distance from the waterways compared to small and large clusters. This change towards an increased distance from channels has been interpreted by Rouse and Cerasetti (2017) as a modification in the agricultural systems and the possible use of more advanced hydraulic technologies able to bring water over larger distances. This broad analysis of the Murghab, however, does not consider local trajectories. For instance, it overlooks differences in economic patterns, settlement distribution, and access to water between dense clusters sites and rural areas.

The ongoing investigations in the Gonur area suggests that the sites around the fortified center of Gonur North were socially and economically connected to the main site. These sites have mud-brick buildings and workshop areas, and access to water reservoirs and possibly artificial channels (Sarianidi and Dubova 2012:39-43; Hübner et al. 2019). These features suggest sophisticated irrigation technologies. However, the picture emerging from the analysis in the Ojakly area suggest a distinct scenario.

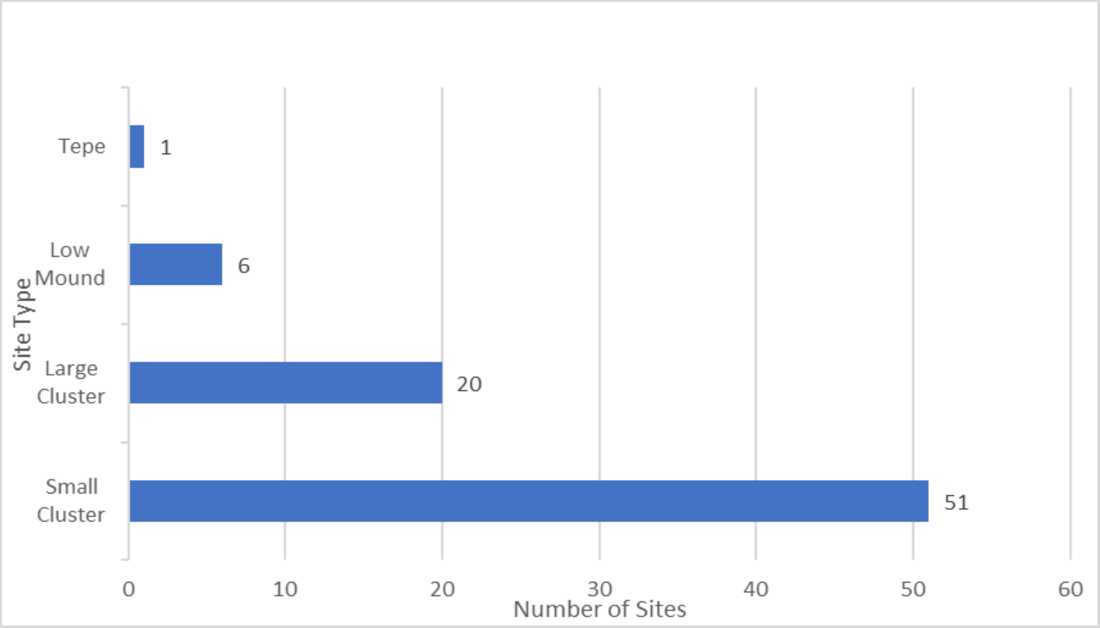
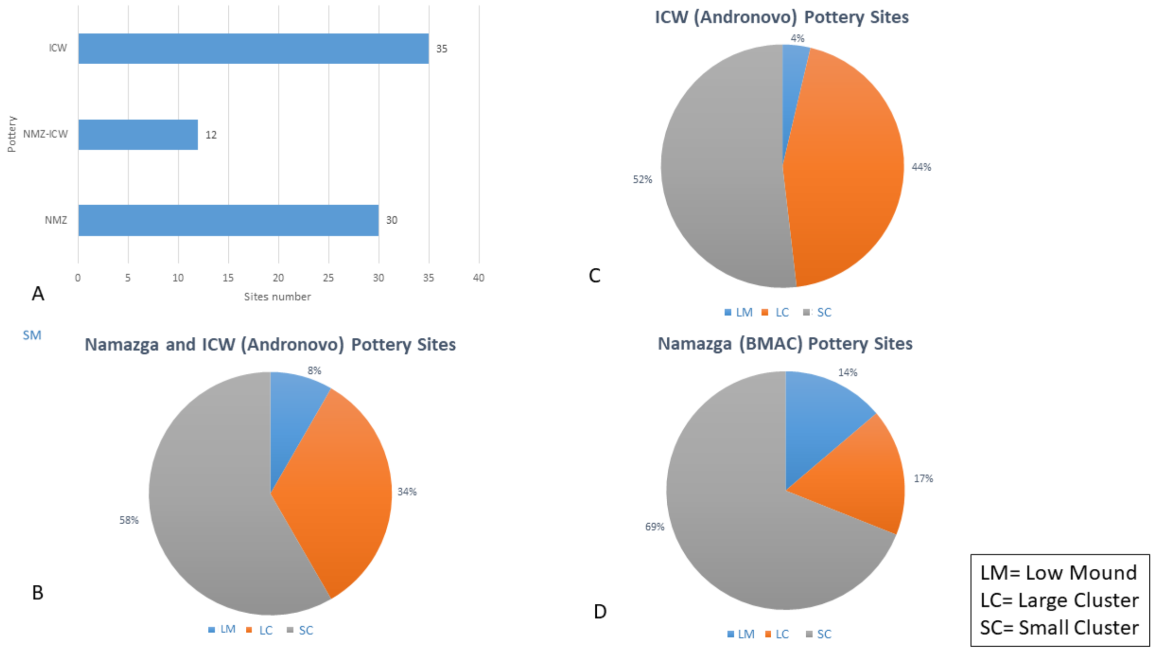


*Figure 5.32 The graph shows the total number of sites in the Ojakly area (n=78) and their number according to site typology as recorded by the present project and AMMD survey. The only tepe is Ojakly.*



ICW (Andronovo) Pottery Sites

Namazga and ICW (Andronovo) Pottery Sites

Namazga (BMAC) Pottery Sites

*Figure 5.33 A: the graph shows the number of sites classified for pottery type in Ojakly area with Namazga pottery sites (NMZ), ICW (Andronovo) pottery sites (ICW), and a mix of Namazga and ICW (Andronovo) pottery sites (NMZ-ICW). B: the graphs show the percentages of Namazga and ICW (Andronovo) pottery sites according to their classification as LM (Low Mound), LC (Large Cluster), or SM (Small Cluster). C: the graphs show the percentages of ICW (Andronovo) pottery sites according to their classification as LM (Low Mound), LC (Large Cluster), or SM (Small Cluster). D: the graphs show the percentages of Namazga pottery sites according to their classification as LM (Low Mound), LC (Large Cluster), or SM (Small Cluster).*

In the Ojakly area of a total of 78 sites, 51 are small clusters (65 %) and 20 sites (26%) are large clusters, while only 6 sites are low mounds (8%) (Figure 5.32). Only one site (i.e., Ojakly) was recorded by the AMMD as a tepe. A further classification can be made by pottery assemblages (Figure 5.33). Among the sites recorded in the research area, there are those that have either Namazga (BMAC) pottery or ICW (Andronovo) pottery (30 and 35 sites respectively), while some sites have mixed assemblages (12 sites). Small cluster sites predominate over these three sites categories (Figure 5.33). However, some differences can be observed. While small cluster sites account for 69% of sites with Namazga (BMAC) Pottery (Figure 5.33D), this percentage decreases to 58% for sites exhibiting a mixed pottery assemblage (Figure 5.33B), and to 52% for sites with ICW (Andronovo) pottery only (Figure 5.33C).

Sites featuring only ICW (Andronovo) pottery include the biggest percentage of large cluster sites (44%) (Figure 5.33C), whereas the percentage of low mound sites is drastically reduced (4%). In contrast, the percentage of low mound sites increases in the mixed pottery sites (8%; Figure 5.33B), with almost 14% of the total in Namazga (BMAC) pottery sites (Figure 5.33D).

As discussed in Chapter 3, the different ceramic assemblages in the Murghab have often been interpreted as proxies for social groups (Kuz'mina and Lyapin 1984; Kuz'mina 1994; P'yankova 1994; Salvatori at al. 2008) in which ICW (Andronovo) pottery sites were interpreted as pastoral sites (Cattani 2008b). However, while ICW (Andronovo) pottery is undoubtedly associated with the broader Andronovo horizon, the type of agriculture practiced at these sites cannot be directly linked to pottery assemblages (Cerasetti 2021). In this context, analyzing the distance to water channels may aid in assessing economic activities and water management practices according to their pottery assemblages.

To assess differences between sites and their distance to water resources, I have examined the average distance from the nearest paleochannel in the Ojakly area according to site typology, as shown in Figure 5.34.[68] In Chapter 4 (section 4.2.5) I discussed the 500 m distance that was used during the survey as a rough estimate of a walkable distance from a water resource. However, this limit of 500 m to discriminate between sites located close and far from water channels is an arbitrary one. What is far or near may differ based on economic activities. While the survey data collected by this project was limited by the 500 m distance, the incorporation of AMMD data, which did not take into account distance to paleochannels, provide a control dataset of sites for the Ojakly area. In this context, a histogram that shows the distribution of sites within a graphical representation was adopted to identify patterns in the distance of sites to channels. In Figure 5.34, the histogram's horizontal axis, which displays discrete intervals in water distance (50 m), reveals two primary aggregated sets of sites between 136 and 336 m, and between 386

---

[68] The distance is calculated based on the detected ancient channel traces. Although somewhat biased due to the potential presence of other traces buried under sand dunes, it nonetheless provides crucial insight into water–site distance.

and 586 m respectively. After 736 m, there is a decline in sites. As such, the water–site distance of all sites in Ojakly suggest the existence of two main groups of aggregate sites along the watercourses. The first group of sites is located within 336 m, while the second group is further away, from 386 m onwards. This could indicate sites located closer to the channels and those situated further away.

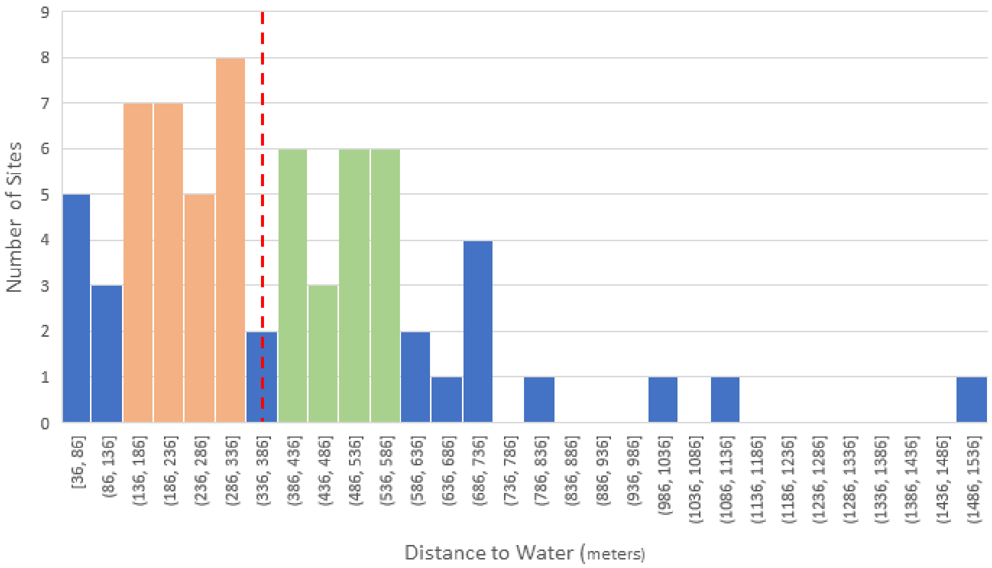


*Figure 5.34 The figure shows discrete intervals every 50 m in water distance from the nearest paleochannels. The orange and green colors highlight the two different clusters of sites. The red dashed line highlights a remarkable drop-off of sites between the two groups.*

The analysis of the distance to channels for site types shows remarkable differences (Figure 5.35). There is a shorter distance from paleochannels for low mounds, with an average of 309 m, in contrast to small cluster sites, that have an average of 406 m from paleochannels, while large cluster sites have an average of 389 m. According to Rouse and Cerasetti (2017:Fig. 10), low mounds during the subsequent Iron Age were further away from water sources, with a range between 1.5 and 2 km from the nearest paleochannel. What is worth nothing, however, is that the average distance of all three site categories in Ojakly are greater than those at Togolok (see 6.4.4 in Chapter 6), suggesting that peripheral settlements are further away from water resources. This aspect will be further discussed in Chapter 7.

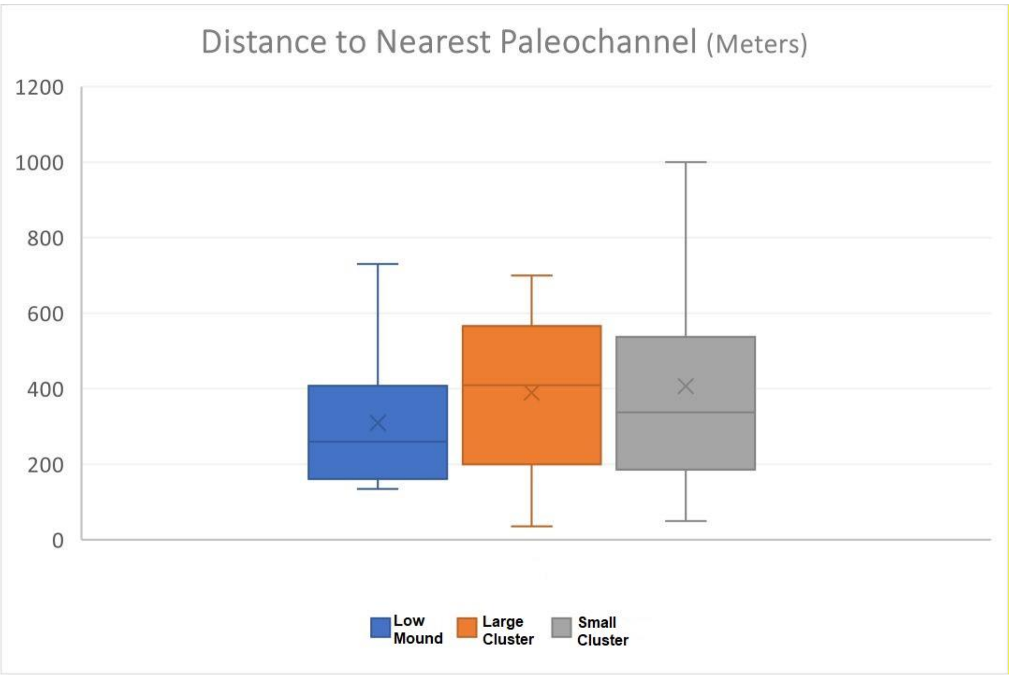


*Figure 5.35 The boxplot shows the distance to the nearest paleochannel in the Ojakly area according to site type. Low mound sites (n=6) mean=309 m, large cluster sites (n=21) mean=389 m, small cluster sites (n=51) mean=406 m. The mean is indicated by × in the boxplot, while the median is indicated by a solid line.*

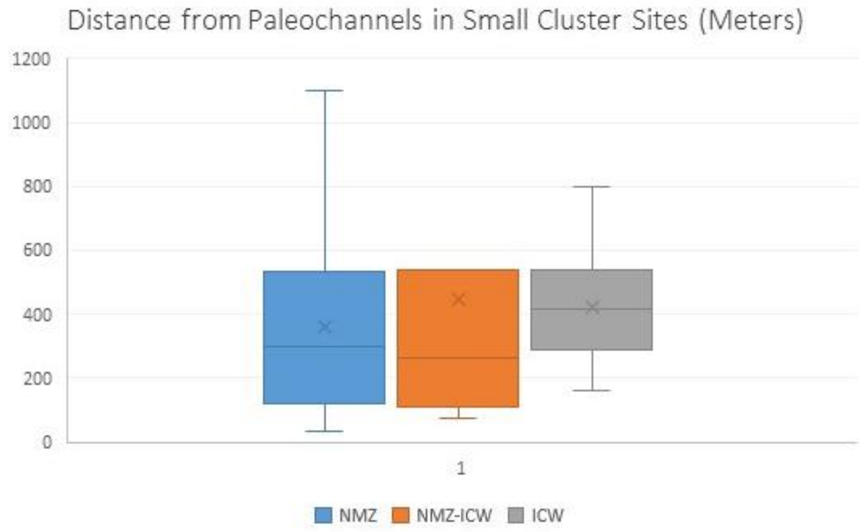


*Figure 5.36 The boxplot shows the distance to the nearest paleochannel in the Ojakly area of small cluster sites according to pottery assemblages. Namazga pottery sites mean=362 m, Namazga and ICW (Andronovo) pottery mean=449 m, and ICW (Andronovo) pottery mean=421 m. The mean is indicated by × in the boxplot, while the median is indicated by a solid line.*

For small clusters (Figure 5.36) the data show a remarkable difference between Namazga (BMAC) sites and ICW (Andronovo) and mixed pottery sites. While Namazga (BMAC) pottery sites are located at an average of 362 m, the other two site categories ICW (Andronovo) pottery and mixed pottery sites) have a significant increase in distance of 421 and 449 m respectively.

Similar differences in water distance can be observed for large clusters where Namazga pottery sites are generally located at closer distance compared to ICW (Andronovo) sites and mixed pottery sites (Figure 5.37). However, for the large cluster sites, the difference between Namazga pottery sites and ICW (Andronovo) sites is marginal (379 and 378 m respectively). This indicates that linking subsistence economy with only pottery assemblages is problematic.

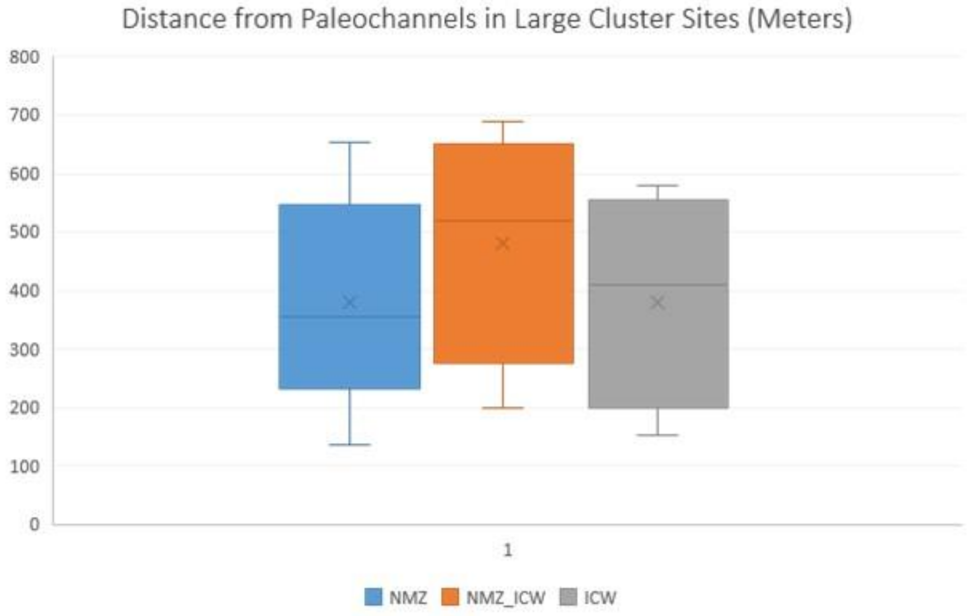


*Figure 5.37 The boxplot shows the distance to the nearest paleochannel in the Ojakly area of scattered sites according to pottery assemblages. Namazga Pottery sites mean=379 m, Namazga and ICW (Andronovo) pottery mean=482 m, and ICW (Andronovo) pottery mean=378 m. The mean is indicated by × in the boxplot, while the median is indicated by a solid line.*

In Ojakly the average distance to water channels is significantly shorter than for the Murghab as a whole (Rouse and Cerasetti 2017:Fig.6). This suggest that we need to investigate land use practices in specific regions.

Although ICW (Andronovo) sites have often been associated with pastoral economies in the Murghab (Cattani 2008a:143), the data presented here also suggest other economic practices. It is likely that some ICW (Andronovo) large cluster sites that were located in proximity to channels may have taken advantage of their position to carry out forms of (low-investment) agriculture. In contrast, Namazga (BMAC) pottery sites, often associated with agricultural economies that are located further away from channels might suggest activities not necessarily based only on crop cultivation. For instance, in large cluster sites, half of the Namazga (BMAC) sites are located further away from water channels (Figure 5.38), possibly suggesting subsistence activities other than crop cultivation.

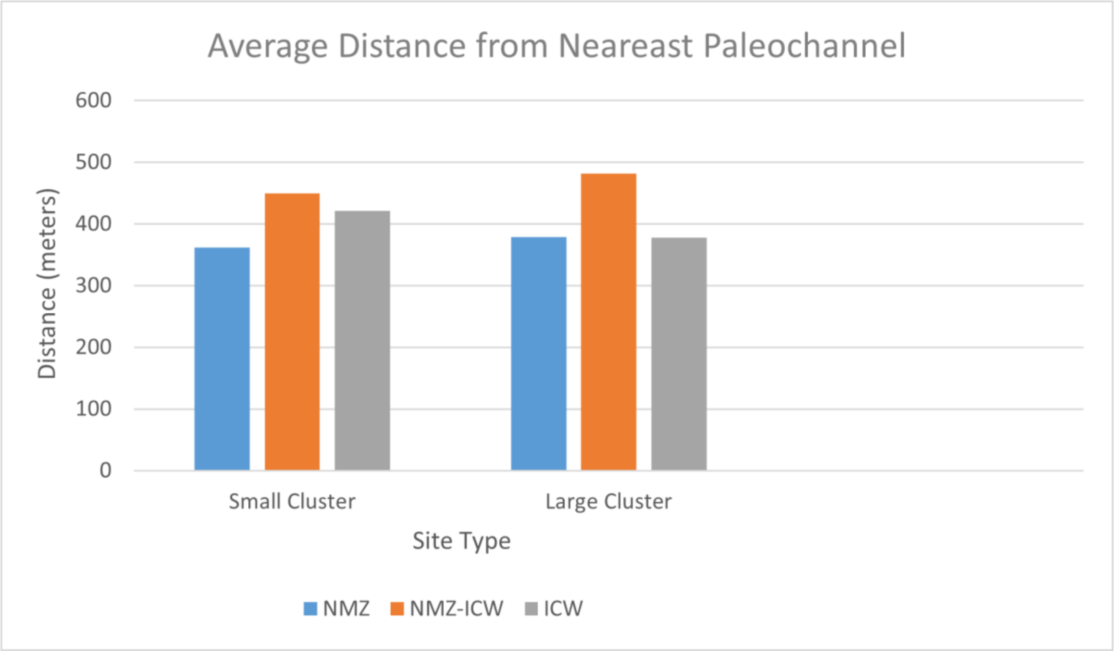


*Figure 5.38 The graph shows the average distance calculated from Figures 5.36 and 5.37 based on site type and pottery assemblages. Low mound sites are not shown due to their limited data available for the Ojakly area.*

Undoubtedly, regardless of the distance of sites from channels, wells might have played a significant role. Until the 19th century, caravan routes passing through the Karakum Desert were structured based on the location of wells, which were essential for guiding their paths. Emeljanenko (1994:43) informs us that these wells were constructed by specialized individuals, primarily Kurds and Iranians assisted by Turkmen, because they had depths of more than a dozen meters. It is probable that during the Bronze and Iron Ages, groundwater levels were shallower than they are today, potentially leading to a more widespread distribution of wells. However, evidence of possible structures related to wells has not been documented in the Murghab for the Bronze Age. Nevertheless, it is likely that wells were present in the Murghab, and that either crop cultivation or animal husbandry could have been practiced with the use of groundwater. Certainly, small-scale fields could have been irrigated using such water sources. Similarly, small sites situated farther from water channels could have utilized wells for small-scale agriculture. However, larger communities and extensive field systems would have required greater water demands, which could have been more easily met by water from natural channels and settlements located in close proximity to them.

All in all, the Ojakly data suggest that both Namazga and (ICW) Andronovo pottery sites can be equated with either pastoral or crop cultivation activities. It is likely that people living in the Ojakly area during the Late Bronze Age relied on mixed farming in which small clusters close to paleochannels were possibly involved in crop cultivation and irrigation, while others practiced pastoralism or a small limited form of cultivation with use of wells, with no correlation with pottery assemblages. These aspects will be further discussed in Chapter 7.

### - Kiln Sites and Water Resources

Further investigation into the distances between water sources and sites center on those with evidence for pottery kilns. As discussed in section 5.5.1 of this chapter, certain sites display fragments of kilns on their surfaces, indicating pottery production activities. For example, sites n.1748 and n.1766 exhibit scatters of kiln wasters. Unlike Togolok, where pottery production was distributed along a series of sites located along the same channel (see 6.4.4 in Chapter 6), in the Ojakly area, these sites stand as isolated entities with kilns.

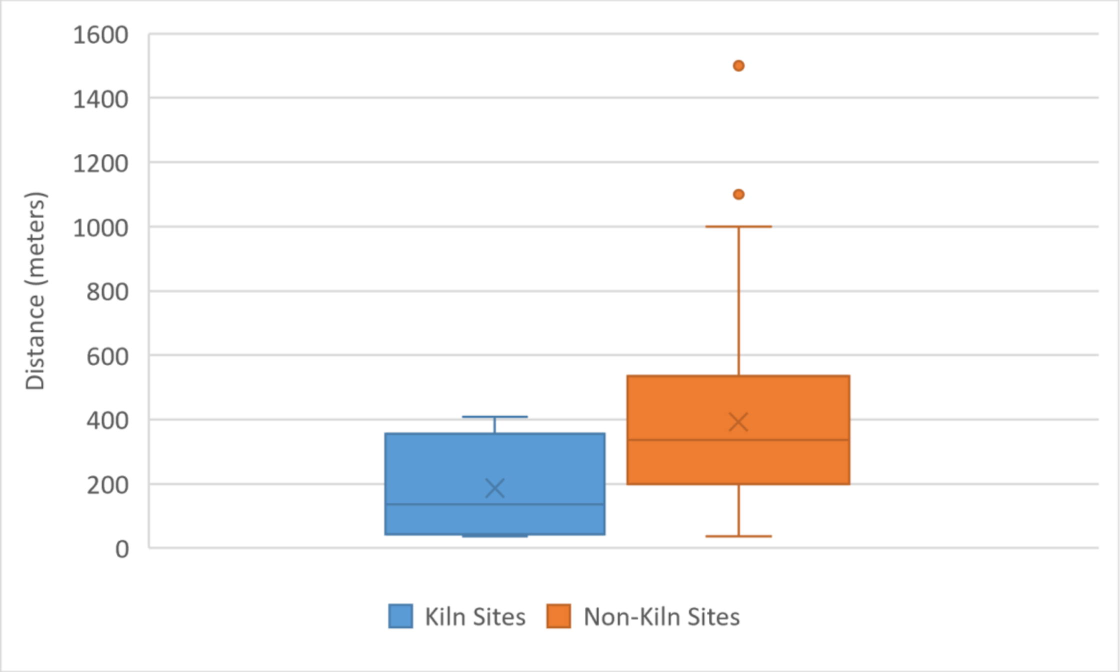


*Figure 5.39 The boxplots show the average distance from water sources (paleochannels) for sites that show kiln evidence (mean=186 m) and sites without any kiln evidence (mean=392 m). The mean is indicated by × in the boxplot, while the median is indicated by a solid line.*

However, despite the absence of large pottery workshop clusters in Ojakly, it is reasonable to assume that the pottery production sites required adequate water resources. The distance of sites with evidence for pottery production is generally closer to channels, demonstrating evidence of pottery production, which suggests that they are generally located near water channels (Figure 5.39). The data reveal an average distance of 186 m for sites with kiln evidence on the surface, and 382 m for sites lacking kiln evidence. This significant decrease in sites–water distance underscores the importance of water accessibility. Such data illuminate the close relationship between water and economic activities in the Ojakly region.

## 5.7 Paleochannel Chronology

In Chapter 4, I discussed how canals are frequently dated through associated settlements. While dating channels directly without additional absolute dating methods is challenging, the presence of settlements along the channels or canals has often been considered as a *terminus* for the use of the channels. Such ‘‘dating by association” has been used to date watercourses when lacking absolute dates (e.g., Wilkinson and Rayne 2010). However, these methods only suggest the time the channel was used by local communities.

Therefore, the presence of an “aggregating line” of settlements along an ancient watercourse strongly suggests that the channel was active during the period when these sites were occupied (Wilkinson 2003:83). It is unlikely, indeed, that these settlements would have been positioned along a river branch which was no longer active. However, ‘‘dating by association” does not provide any evidence that the channels were active (or inactive) before the settling or after the abandonment of the settlements. It rather suggests a chronological indication of when the watercourses were active. In Turkmenistan, local communities of pastoralists often made use of active channels for their local subsistence economy. Until the last century, before the Sovietization of the country forced mobile pastoralists to settle, local pastoralist communities were accustomed to settling along active river branches of water channels in the Murghab fan for animal husbandry (see example in Figure 40) (Edgar 2004).

On the basis of ‘‘dating by association,” we can suggest that the paleochannels in the Ojakly area were mainly active during the Late Bronze Age (Figure 5.41). The problems with pottery chronology in the Murghab, discussed in Chapter 3 (section 3.2.3), does not allow for any further chronological distinction. The majority of the sites along the former channels are small clusters and probably temporary occupations that were likely short lived. The AMMD data show that most ICW (Andronovo) sites in the research area are located along Paleochannel 8. In addition, the aggregated line of sites n.1671, n.1570, n.1561, and n.1564 suggest that these sites were also located along Paleochannel 8.

Similarly, other groups of ICW (Andronovo) such as sites n.1518, n.1515, and n.1557 may have been located along Paleochannel 13.

*Figure 5.40 Yurts along a canal in Bairam-ali (Merv Oasis), Murghab region (Turkmenistan), 1905–1915 (photo by S.M. Prokudin-Gorskiĭ, Library of Congress Prints and Photographs Division Washington D.C., USA, CC BY).*

Ojakly, which is dated to the Late Bronze Age, is located between Paleochannel 9 and 27 and Paleochannel 8 (Rouse and Cerasetti 2014). These paleochannels are located between 400 and 700 m respectively from Ojakly. The botanical assemblages from Ojakly discussed in section 5.3.2 suggest that some form of agriculture was practiced, and that the vicinity of the channels may be indicative of their possible use as irrigation channels. One cannot rule out the existence of further smaller canals that were not detected by remote sensing. It is reasonable to assume, therefore, that these paleochannels linked with the Ojakly site were at least active during the Late Bronze Age. However, some other channels may have been active before this time.

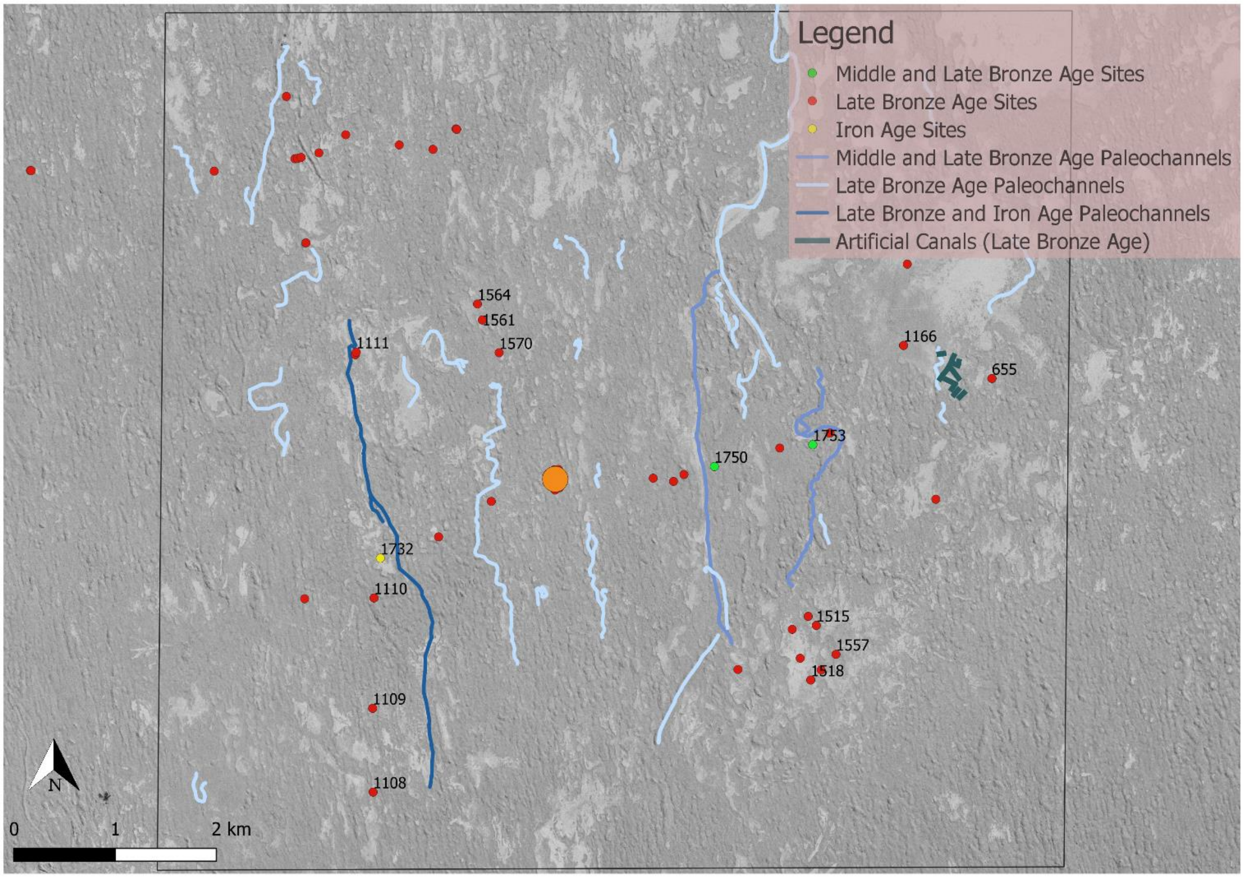


*Figure 5.41 The figure indicates the probable periods of channel activity based on the associated sites surveyed by the current project, the AMMD, and Soviet surveys in the Ojakly area.*

The Middle and Late Bronze Age chronology of sites n.1753 and n.1750 suggests that Paleochannel 10 and Paleochannel 13 were active during the late 3rd and early 2nd millennium BCE. This chronology is consistent with OLS dating from Paleochannel 13, which shows that the channel was active as early as the second half of the 3rd millennium BCE (see section 5.8.3 of this Chapter). In addition, site n.1753 along Paleochannel 13, which was classified as a low mound, has a large spread of pottery. This site might have functioned as a more permanent settlement during that period, which would have necessitated access to water from the channel.

To the northeast of the research area, the possible lateral canals of Paleochannel 23 (Figure 5.16) can be dated to Late Bronze Age as Auchin 12 (n. 1166) in its proximity has evidence of both Namazga (BMAC) and ICW (Andronovo) pottery dated to this period (Sarianidi 1990a:23). Site n.655 also has similar material culture and both sites are located along Paleochannel 23.

According to the Soviet survey data, along Paleochannel 1 there are many sites dating to the Late Bronze Age with sites such as Auchin 13 (n.1110), Auchin 15 (n.1108), Auchin 14 (n.1109), and Auchin 16 (n.1111). Nevertheless, the AMMD survey also identified site n.1732, dated to the Achaemenid period (Iron Age 3), along the same channel. This would suggest that at least this branch of the river system was also active in later periods. Although the association between channels and sites in the Ojakly area suggest that they were active mainly in the Late Bronze Age, it is likely that some channels were still active during the Iron Age and possibly later. Notably, during the Yaz III period (550–340 BCE) a series of “defensive fortress” lines were situated approximately 28 km southwest of Ojakly. These settlements likely relied on water from active channels (Cattani and Salvatori 2008: Fig. 1.8). However, later evidence of occupation during the Sasanian and Islamic periods was also discovered throughout the Murghab, including in distant areas such as Egri Bogaz. This suggests that reduced water activity was likely present in the northeast area of the Murghab long after the Bronze Age (Bonora and Vidale 2008; Markofsky 2010:169).

All in all, we can suggest that the Ojakly paleochannels were active during the Late Bronze Age. However, it’s important to note that these channels a) might not have been continuously active and b) they could have been active before and during later periods. Nevertheless, the reduced Iron Age presence in the area suggests that the system became less active towards the end of the 2nd and early 1st millennium BCE, forcing communities to move southwards.

## 5.8 Results of Paleochannel Investigations

### 5.8.1 Fieldwork Preparation

The test trench excavation started as desk-based analysis of satellite images of the paleochannels looking for possible candidates. The main obstacle to the survey and test trenches was the location of new agricultural areas. In addition, the construction of modern canals, usually dug in a few hours or days, can create substantial obstacles to fieldwork. To overcome this problem, a recent satellite Sentinel 2 image was inspected looking for any potentially obstacles. In the GIS platform, a number of transects were drawn to make sure that the coring and test trench were perpendicular to the paleochannels. On satellite images, the flow direction of the paleochannels is self-evident; however, the vegetation can complicate channel identification on the ground and thus pre-assessments of the channel cores and trenches is crucial.

For the coring of the paleochannel cross-section, it was crucial to evaluate the difference in soils that we could encounter during the drilling. Two types of hand augers suitable for diverse soils were selected (see section 4.3.6.2 in Chapter 4 for details).

During the first day of fieldwork, various paleochannel locations were inspected. The criteria for the selection of the paleochannel were a) to be within a few kilometers from Ojakly and not at the edges of the research area, b) to have a well-defined and recognizable channel structure both on satellites and on the ground, and c) lacking substantial vegetation along the paleochannel (or agricultural areas) that could impede coring. After this preliminary assessment, Paleochannel 13 (OJK_Ch_Vb) was selected for further investigation. In particular, a specific curve of Paleochannel 13 was chosen for coring and the test trench. The curve was well defined both on satellite and aerial photos images as well as on the ground. Paleochannel 13 is located approximately 3 km east of Ojakly (Figure 5.42) and is near to sites n.1751, n.1753, n.1752, and n.1754 (Figure 5.28). According to the pottery assemblages of these sites, Paleochannel 13 was possibly active during the Middle and Late Bronze Ages.

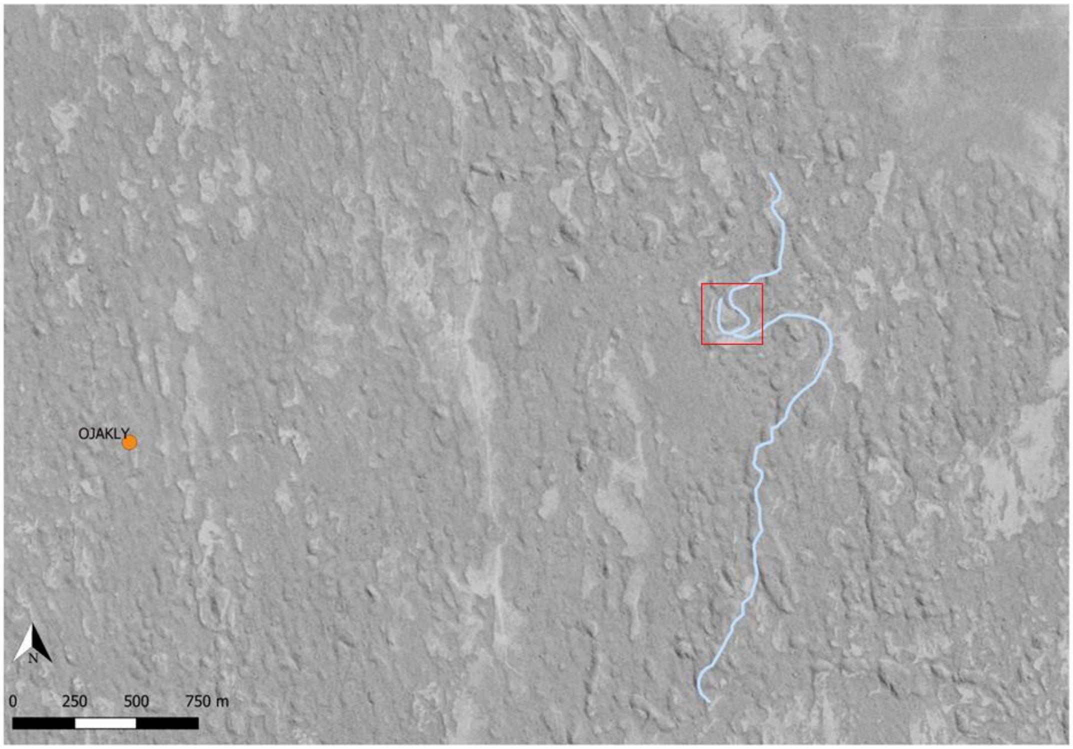


*Figure 5.42 The figure shows Paleochannel 13. In the red square, the channel section identified for the test trench. Paleochannel 13 is located approximately 3 km east from the Ojakly site (Image CORONA KH-4A).*

## 5.8.2 Cross-Section Coring

The paleochannel coring was conducted to verify their cross-section stratigraphic sequence. By extracting core samples from various points along the channel, we aimed to gain insights into the layers of sediment that compose its structure. Moreover, the stratigraphic analysis allows us to understand channel development.

Considering the small width of the meander, only three cores were necessary (Figure 5.43). The first core (Core #1) was drilled in the middle of the paleochannel to test the stratigraphy of the channel. An additional two cores (OJK_Cr_2; OJK_Cr_3) were drilled on the east and west of the channel in areas considered as former banks of 14 m (Core #3) and 19 m (Core #2), respectively, from the first central core (figure 5.44).

*Figure 5.43 The image shows the paleochannel (blue arrows) and the coring points (#) along the cross-section. The middle point indicates the test trench position and core n. 4 at the bottom of the trench.*

The hand auger has a length of up to 5 m. However, depending on the core and the properties of the sediments encountered, it was not always feasible to drill the entire 5 m. During the coring, field observations were made when a change in the soil, texture, color, or other characteristics (i.e., pottery, shell, etc.) was observed, according to depth. However, the drawings only show the main sediments (Figure 5.44). Core #2, located on top of a sand dune, reached almost 5 m. The profile reveals an almost complete sequence of very fine sand (as depicted in Figure 5.44), which could potentially be aeolian in nature. This observation implies that the core was likely conducted either outside the former bank of the river or in an area where the former bank was shallow and subsequently covered by aeolian sand deposits. Coring #3, located west of the paleomeander, reveals an initial sequence of fine sand and silty sand spanning up to 1 m. Beneath are alternating strata of silty sand, silt, and silty clay. Below these final meters the sediment consisted predominantly of sand, with a minor silt component emerging after the 4-m mark. The sediments encountered in the two cores have distinct characteristics.

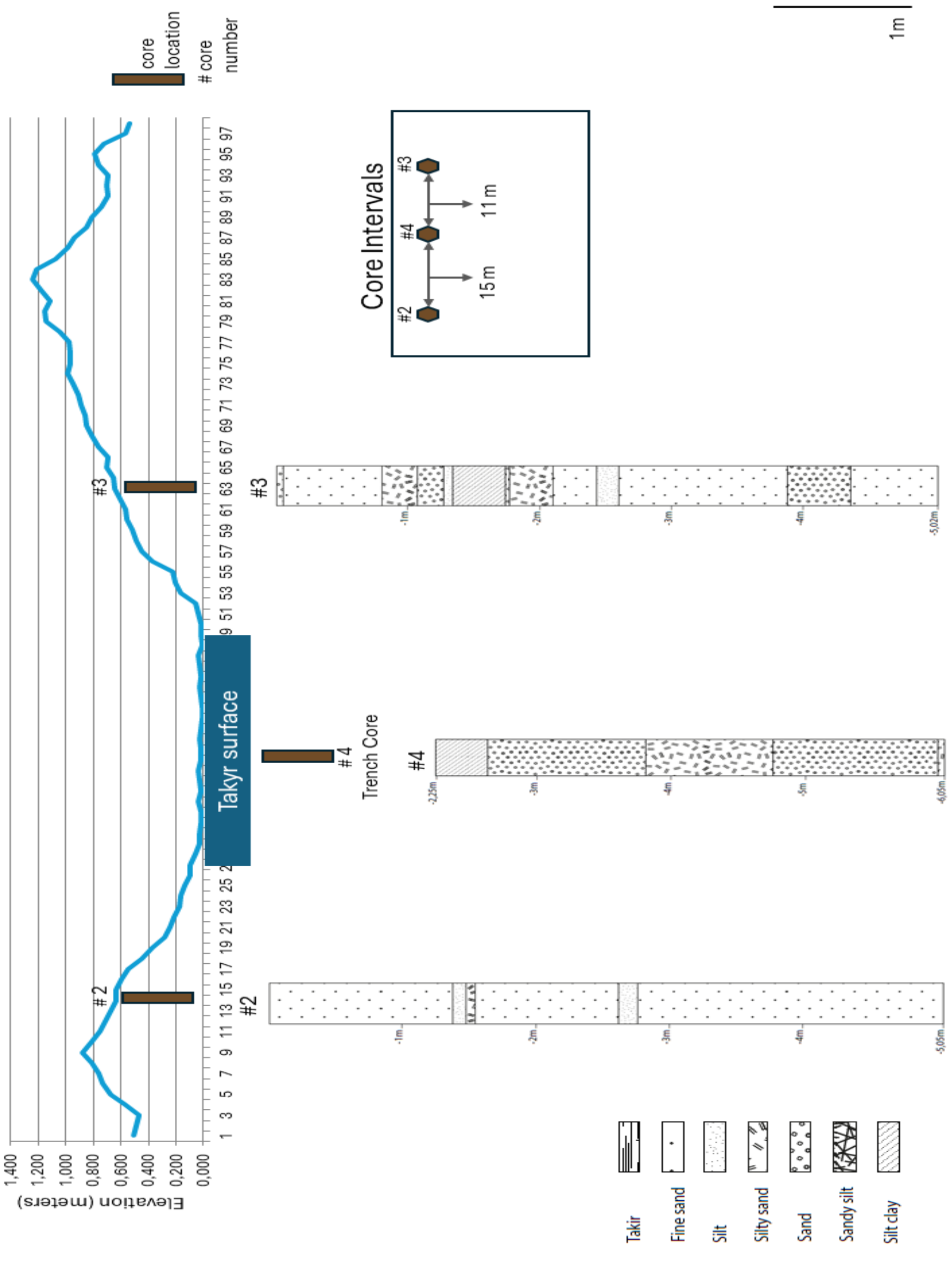


*Figure 5.44 The figure shows the cross-section of Paleochannel 13. The left core is core n.2, and the right core is n.3. The central is the core made at the bottom of the test trench.*

In the test trench, a stratigraphic sequence of descending layers (Figures 5.45 and 5.46) suggests that the former channel might have had larger dimensions than currently visible, whether observed on the ground or via satellite imagery. Despite the trench being excavated in the center of the visible channel bed, the structure of the layers of the southern profile indicate that the channel's center could potentially lie several meters to the west. Consequently, the initial sediment layers, extending up to 2 m identified in core #3, may represent remnants of the channel itself or the aftermath of overflowing events from it. These findings underscore dynamic processes of sediment deposition and channel evolution over time, findings that have also been subsequently observed in the test trench.

### 5.8.3 The Test Trench

The midpoint of channel bed was selected for the trench excavation. The aim of the trench was to a) (partially) expose the profile of the paleochannel and analyze the stratigraphy and the fluvial facies and b) obtain OSL dates of the channel.  The test trench was located 15 m south of the first core in the middle of the paleobed (UTM 41N, N 38.25476 E 62.19005). The trench is 3×2 meters with a depth of 2.28 m, excavated without any mechanical excavator. After the excavation, drawings of the west and south profiles of the trench were made. Subsequently, sediment samples from each layer identified were collected from the south profile. In the west profile, three OSL samples were taken at 76 cm, 123 cm, and 202 cm of depth, while a fourth sample was retrieved from the core at the bottom of the trench at 255 cm from a sandy layer (Table 5.3) (see next paragraph for layer description). To further analyze the stratigraphic sequence of the channel, a fourth hand-auger core was drilled at the bottom of the test trench for a total depth of 3.80 m, reaching a total of 6.08 m for the test trench (Figures 5.45, 5.46 and 5.47). All sedimentary layers for OSL analysis were sampled with metal tubes and dosimetry samples were collected for each sediment (see Chapter 4 for details on OSL sampling procedures) (Fattahi 2015).

In the OSL analysis, the quartz turned out to be not adequate for luminescence dating, and therefore feldspar (F) and polymineral (PM) fractions were used, applying correction for fading. The corrected OSL ages from the Ojakly samples[69] follow Lamothe et al. (2003) and Preusser et al. (2014).

| **Sample code** | **Trench profiles** | **Depth (cm)** | **Mineral** |
|---|---|---|---|
| OJK18-1 | Western | 76 | Feldspar |
| OJK18-2 | Western | 123 | Polymineral (Feldspar) |
| OJK18-3 | Western | 202 | Polymineral (Feldspar) |
| OJK18-4 | Core/Bottom Trench | 255 | Feldspar |

*Table 5.3 The table shows the OSL samples from the western section of the Ojakly test trench in Paleochannel 13 (OJK_Ch_Vb).*

## 5.8.4 Section Description and Discussion

- **Section Description**

In the fieldwork campaign, out of the four sections of the trench, the western and the southern section were documented (Table 1.3 in the Appendix 1). Each sediment unit was numbered. The south profile (Figures 5.45 and 5.46)[70] of the trench has a surface sloping towards the west.[71] The trench has a takyr surface (unit #1) on top with well-sorted silty sand layer (unit #2) covering small layers of silt and silty sand (units #3, #4, and #5) with a final darker small layer of silt (unit #6) of ca. 3cm. These small layers cover a fine sand layer (unit #7) sloping towards the center. Subsequent large unit layers are characterized by silt sediment (unit #8), a small unit of clay (unit #9) and a light silty sand and silt (units #10, #11) covering a compact silty clay unit (unit #12) that might extend to -2.67 cm according to the core at the bottom of the trench (Figure 5.47).

---

[69] The OSL ages were derived by Dr. Daniela Mueller at Freiburg Luminescence Laboratories (Freiburg University - Germany).

[70] See a detailed description of both profiles in the Appendix 1.

[71] The sloping surface of this section is similar to section 6b of the artificial (?) canal found at Chopantam (Cattani 2008b:Fig. 9.7).

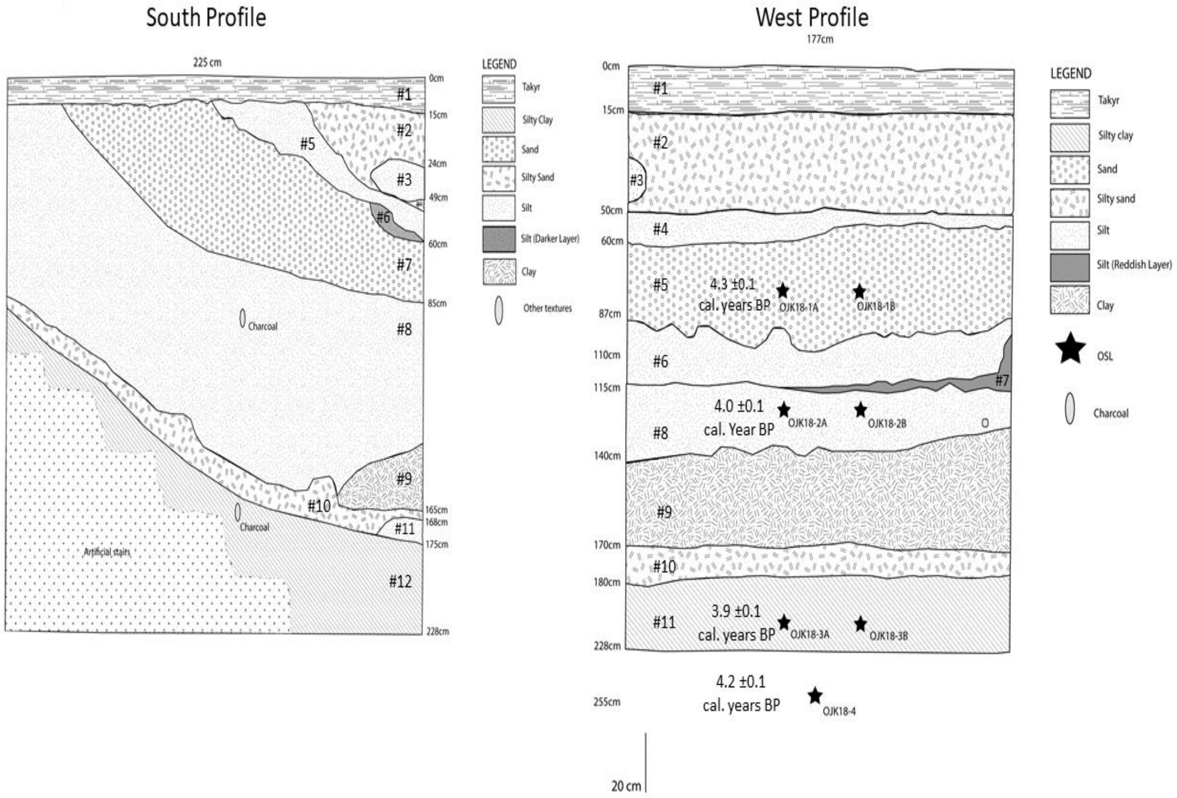


*Figure 5.45 The figure displays the South and West profile drawings of the Ojakly Trench along with OSL dates. The OSL sample OJK18-4, although indicated in the West profile here, was retrieved at the bottom of the trench, at -255 cm.*

The western profile (Figures 5.45 and 5.46) presents a first takyr layer (unit #1) followed by a unit of silty-sand (unit #2), and small units of silt (units #3 and #4). Similar to the southern profile, there is a unit layer of sand (unit #5) from which one OSL sample (OJK18_1A and 1B) was retrieved. This unit covers two sediment layers of silt (units #6, #8) interspersed by a small a reddish sediment unit of silt (unit # 7). From the silt unit (unit #8) one OSL sample (OJK18_2A and 2B) was retrieved. This unit was covering a compact clay unit (unit #9) covering a layer of silty-sand (unit #10) and a compact layer of silty-clay (unit #11), where a fourth OSL sample (OJK18_3A and 3B) was retrieved.

*Figure 5.46 Photos of the South and West profiles of Ojakly Trench.*

The four sedimentary layers sampled for OSL age were collected on the western profile only, with the only exception of one final OSL sample retrieved from the bottom of the trench from a silt-clay layer at -255 cm. The four OSL results are presented in Table 5.4. It is important to note that OSL dates may sometimes lack precision in their stratigraphic sequence, as observed for instance in Fouache et al. (2012:Fig.4). However, all four results cluster around the end of the 3rd and the beginning of the 2nd millennium BCE which is indicative of a precise period of activity of the channel. Specifically, while the date at the top (OJK18-1) indicates a calibrated age of 2382–2182 BCE (4.3 ±0.1 cal. years BP), the lower samples (OJK18-2A-B and OJK18-3A-B) both fall within the same range of ages: 2082–1882 BCE and 1982–1782 BCE (4.0 ±0.1 and 3.9 ±0.1 cal. years BP), respectively. The last sample has a corrected age of 2282–2082 BCE (4.2 ±0.1 cal. years BP).

| **Sample code** | **Grain size (µm)** | **Age$_{corrected}$ IR$_{50}$ (ka)*** | **Age BCE** |
|---|---|---|---|
| OJK18-1 | 63–100 | 4.3 ±0.1 | 2382–2182 BCE |
| OJK18-2 | 4–11 | 4.0 ±0.1 | 2082–1882 BCE |
| OJK18-3 | 4–11 | 3.9 ±0.1 | 1982–1782 BCE |
| OJK18-4 | 100–150 | 4.2 ±0.1 | 2282–2082 BCE |

*Table 5.4 The table presents the corrected OSL ages (IR50) from Ojakly test trench. The corrected OSL ages from Ojakly samples follow Lamothe et al. (2003) and Preusser et al. (2014). Complete OSL data results are available in the Appendix 2 (Table 2).*

It's important to highlight that OSL ages can be obtained through two different methods: IR50 and pIRIR150, from which corrected ages are derived (refer to Lamothe et al. (2003) and Preusser et al. (2014) (see Table 2 in the Appendix 2 for IR50 and pIRIR150 ages). Both age methods have the potential to be correct, but they must be considered alongside other evidence. In the case of Ojakly, the corrected age IR50 results cluster around the Middle and Final Bronze Age periods (2400–1500 BCE). In contrast, the corrected ages pIRIR150 are much older (6th and 5th millennia BCE). These older ages (pIRIR150) are not consistent with any archaeological evidence found in the area, and with profile interpretation (see below). Based on these older ages, it appears that sites n.1751, n.1753, n.1752, n.1754, and n.1766, identified during the survey, were situated along a dried watercourse in this instance as OSL dated layers of fluvial activity (see below). However, while these sites could be interpreted as small and temporary occupations that may not necessarily have required a nearby watercourse, site n.1766 likely served as a more permanent settlement. This site, categorized as a large cluster, exhibits evidence of several kiln wasters similar to those found at Gonur North, indicating the presence of a pottery workshop.

In this context, it is improbable that site n.1766, as well as the other sites along the same channel, would have been situated along a no longer active watercourse. Therefore, the strong presence of several sites aligned along the same channel supports the hypothesis that the IR50 age, which suggests channel activity between the end of the 3rd and the early 2nd millennium BCE, is the correct one. This IR50 age will also be used for the Togolok area as well.

- **Section Interpretation and Discussion**

The shape and size characteristics of the sediments are determined by the flow history of a river and the average grain size changes from up-stream to down-stream parts of a river Knighton (1998:136). In the Knik River in Alaska, for instance, the average grain size decreases from 300 mm to 44 mm along the course of the river (Bradley et al. 1972). Indeed, the ability to transport sediments tends to decrease with distance from the main channel (Walling et al. 1992). Likewise, during flood events, there is a suspension of sediments from the upper channel to the floodplain consisting of silts and clays and fine fraction materials that are deposited (Knighton 1998:145). In this context, channel stratigraphy can inform us about changes in past flow intensities. This analysis can be carried out on a naturally exposed section of a river, or in the case of Ojakly, through trench excavations.

In the Ojakly trench, the upper units in both profiles are characterized by an alternation of silt and fine-waved silty-sand deposits until a depth of about -85 and -110 cm. This rapid alternation can be interpreted in anabranching river system as evidence for sequence of repeated changes in river flow (Widera et al. 2019; Nanson and Gibling 1978). The geometry and the structure of layer stratification provide crucial information about the intensity of the deposition beds[72] (Jopling and Walker 1968).

---

[72] A sand layer between -60 and -85/-87 cm depth on both profiles has cross-stratified sands with few possible ripple cross-bedding. Miall (1977) has identified different lithofacies for braided and anastomosing rivers and refers to laminated sand-silt as characteristic of low water accretion. Ripples from cross-lamination can be a record of tractional transport of fine and well-sorted sand produced by unidirectional current in the lower flow regime (Bridge 2003). In anastomosing rivers, they are generally indicative of a steady flow regime with a constant low-flow velocity (Widera et al. 2019).

Although in a former riverbed with well-sorted sand-rich layers, cross-lamination and ripples[73] are not always easily visible in the deposit, due to good sorting of the sand layers. In the upper unit layers beneath the takyr surface (unites from #3 to #5 in the west profile) these are visible, and they may indicate a repeated change in the flow regime. This may have been determined by an irregular and variable hydraulic regime in the distal areas of the Murghab alluvial fan.

These upper unit layers suggesting a changing flow regime are preceded by a more stable flow condition. The lower units of the trench[74] show consistent deposits of silt, clay, and silt-clay on both the western and southern sections with an alternation of darker and light colors.[75] These layers imply different stages of water flow. However, the presence of significant silt-clay and clay deposits at the bottom suggests deposition stages primarily marked by suspended sediment during low-flow periods (Widera et al. 2019). It is likely that during a good part of the channel's development, water flow was constant in a low energy regime with few flow variations. Moreover, according to the hand-auger analysis from the bottom of the trench, the silty-clay deposit reaches -239 cm depth (Figure 5.47).[76] Below this layer, coring with the hand auger intercepted a sand layer. This sand layer below the silty-clay layer might represent the bottom of the channel, although this was not the coarsest fraction detected, suggesting that the channel was probably deeper.

Taken together, the alluvial activity of Paleochannel 13 appears to feature relative stability during the late 3rd millennium BCE but was marked by various water flow stages. However, the alternation of silt, sand, and silty-sand in the upper layers, particularly evident in the southern profile, indicates that between the end of the 3rd millennium and the beginning of the 2nd millennium BCE, the channel experienced rapid

---

[73] See Glossary for the definition of cross-lamination and ripples.

[74] Below 115 cm depth.

[75] In the western profile, the presence of ripple and wave cross-lamination were present between -115 and 140 cm depth. From between -140 and the bottom of the trench at -228 cm depth, the texture of the layers shows a form of polyhedral clay and clayey-silt with a small (10cm) line of silt-clay deposit.

[76] A similar clayey layer was observed at the bottom of the water channel excavated in Chopantam (Cattani 2008b: fig 9.7, SU 115).

fluctuations in water flow intensity, resulting in alternating stages of low and high-water intensity.

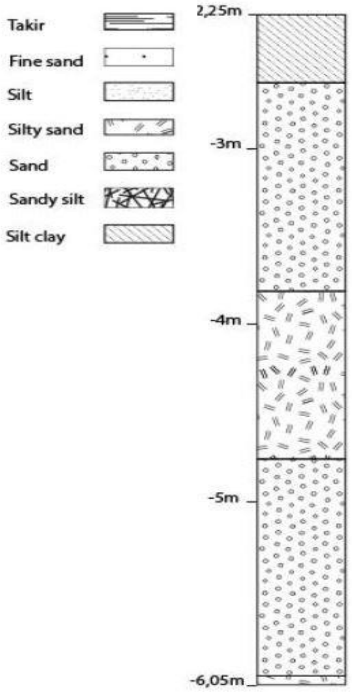


*Figure 5.47 The figure shows the core (n.4) at the bottom of the trench. The core started at -2.25 m and reached -6.05 m. It is likely that the silt clay deposit in the upper layer represents the bottom of the paleochannel.*

Interestingly, in the distal fan area of Egri Bogaz (located a few kilometers from Ojakly) Markofsky (et al. 2017) observed a similar pattern of possibly erratic flow events in a paleochannel section. The clayey layers of Markofsky's AU1-01 trench located have a strong peak in the Mn/Fe ratio.[77] These measurements are indicative of a redoximorphic aspect[78] that suggests variable flow conditions.[79] In addition, the decline in the Ca/Sr ratio[80] may be indicative of an increase in biogenic calcites that may have accumulated

---

[77] This can be observed in trench AU1-01between -75 and -85 cm depth.

[78] Redoximorphic conditions consist of soil color which is formed by translocation, reduction, and oxidation of manganese and iron. This happens after episodes of water saturation and desaturation. These features are visible in the filed sample as well as under the microscope (Vepraskas et al. 2018).

[79] Trench AU1-01 was dated by OSL to the end of the 3rd and beginning of the 2nd millennium BCE (4010±320 cal. yr BP) (Markofsky et al. 2017; Fig.13)

[80] This can be observed above 40 cm in trench AU1-01

during less active depositional stages of the paleochannel (Markofsky et al. 2017:9). These variations of the river flow in the distal areas suggest instabilities in the hydrological system towards the end of the 3rd millennium BCE.

This fluvial instability, along with an increasingly arid environment is also suggested by the sandy layers in other former channels of the Murghab dated by $^{14}$C to the first half of the 2nd millennium BCE (Cremaschi 1998).[81] Further OSL data by Markofsky et al. (2017) from an additional test trench in the Egri Bogaz area confirm this trend of increasing aridity, in the following 1st millennium. This reconstruction is consistent with the little archaeological evidence dated to the Iron Age (Yaz period) in the distal area of the fan (Salvatori el al. 2008). Indeed, in the Ojakly area, the majority of the sites are dated to the Middle and Late Bronze Ages only, and there is little evidence of Iron Age occupations in comparison to previous periods. However, as discussed in section 5.5.5, it is likely that although the majority of channels became inactive at the end of the Bronze Age, a period characterized by instability and shifting of watercourses, a few channels remained active during the Iron Age and later periods.

- **Natural Channels or Artificial Canals**

The test trench in the Ojakly Paleochannel 13 and the satellite analysis do not provide evidence we are dealing with a man-made canal. The trench from Paleochannel 13 confirmed that it was a natural watercourse. As suggested by Jotheri (2018), some characteristics can be taken into account to distinguish between man-made and natural channels. In the case of Ojakly, the channel follows the general slope direction of the Murghab floodplain with a north/northwest direction and has a curved form suggesting a natural origin. Likewise, the southern section of the test trench confirmed that the paleochannel has a wide bed and gentle slope rather than a narrower bed and steep slope, which are usually associated with an artificial canal. In contrast, the possible evidence for canals discussed in section 5.4.1, found at the northeast edge of the research area, exhibits an unusual east–west direction with straight courses aligned in a specific pattern. Taken

---

[81] See section 2.1.1 in Chapter 2 for discussion about Cremaschi's data.

together, this evidence suggests that Paleochannel 13 is a natural channel rather than an artificial watercourse.

## 5.9 The Takyr Areas in Ojakly

Over the last few decades, many takyrs in the Murghab region have been destroyed. During the intensive agricultural expansion between the 1970s and 1980s, takyrs were particularly affected by development. In the southern area of the Murghab many takyrs, usually situated within large oases, such as Merv, were ploughed and used for agriculture as their soils often retain water.

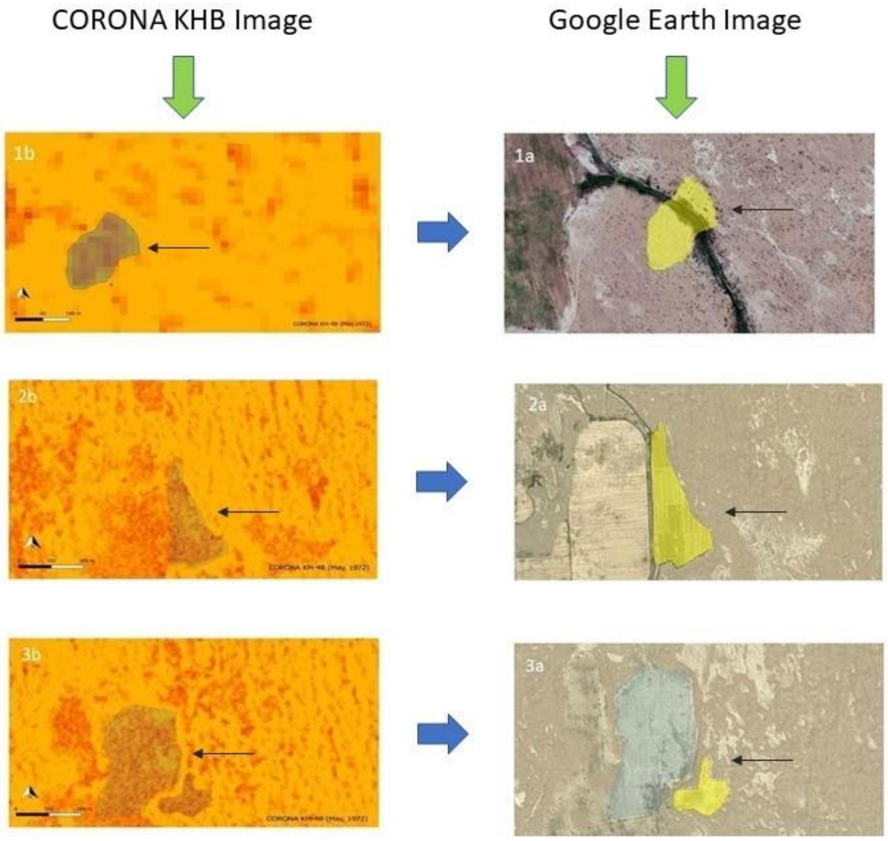


*Figure 5.48 The figure shows how former takyr surfaces in the CORONA images (left) dated to the 1970s (dark color indicated with black arrow) are now cultivated in recent Google Earth images (2018) (right) (indicated with black arrow). The agricultural areas exactly follow the takyr's perimeter of the CORONA images. Due to modern irrigation, many takyr surfaces have been destroyed.*

Takyr surfaces have traditionally also been used as water catchment areas (e.g., *khaks*) (see Chapter 3). In recent years, however, many takyrs have been covered by aeolian deposits when not ploughed by vehicles (Fleskens et al. 2007). For instance, Figure 5.48 shows some takyr surfaces in the Murghab, identified in a CORONA-KH4 image dated to 1972, that have recently been ploughed. The modern agricultural fields are situated on the former takyr surfaces.

Although large takyr surfaces can be the result of modern processes (Lebedeva-Verba and Gerasimova 2010), Cremaschi (1998:16) argues that small takyr surfaces in the distal fan may date to the Bronze Age. Evidence for this is the common occurrence of Bronze Age pottery on takyrs (Cleziou et al. 1998; but see Markofsky 2010). On the basis of these characteristics, however, one cannot rule out that takyr soils were also used during the Bronze Age as places for agricultural production.

The formation (*pedogenesis*) and micromorphology of takyr surfaces is a complex process described by Lebedeva-Verbaa and Gerasimova (2010). According to the authors, the formation of takyrs is primarily influenced by the interaction between alluvial clay soil and the action of aeolian sand. Takyr surfaces, like playas in other regions, develop in combination with various factors, with flooding episodes as a main component along with other factors, including aeolian sand. Without this combined action, takyr surfaces cannot form (Lebedeva-Verbaa and Gerasimova 2010). Therefore, the aridification process by the 2$^{nd}$ millennium BCE and the presence of aeolian sand, may have already facilitated the formation of takyr surfaces over alluvial deposits in distal areas. Although takyr formations naturally occur in desert areas in Central Asia (Gerasimov 1978), one cannot rule out that it can also build up as a result of anthropogenic activities, notably intentional flooding for agriculture (Fleskens pers. comm.). Repeated irrigation of land along channels may have caused takyr formations after many years and, thus, may be indicative of former farming lands. However, distinguishing between ancient anthropogenic formation of takyrs from natural ones is difficult and would require additional analysis that goes beyond the present research. Nevertheless, remote sensing data on where takyrs are located may suggest the location of ancient agricultural fields. In this context, I specifically examined takyr areas closely connected to paleochannels, as they would naturally form due to potential intentional flooding. As discussed in the previous paragraph, the distribution of paleochannels and settlements suggests that agricultural fields were situated along natural courses or at a small distance from them. Similarly, the possible artificial canals found in the northeast of the research area is situated near a watercourse. Takyr areas located along and connected to channels are more likely to be of anthropogenic relevance than large takyr areas further away from paleochannels, which would have required long canals to be irrigated (Figure 5.49). In the Ojakly area, on the basis of CORONA, Landsat, and aerial images, several takyr surfaces were classified and will be now examined.

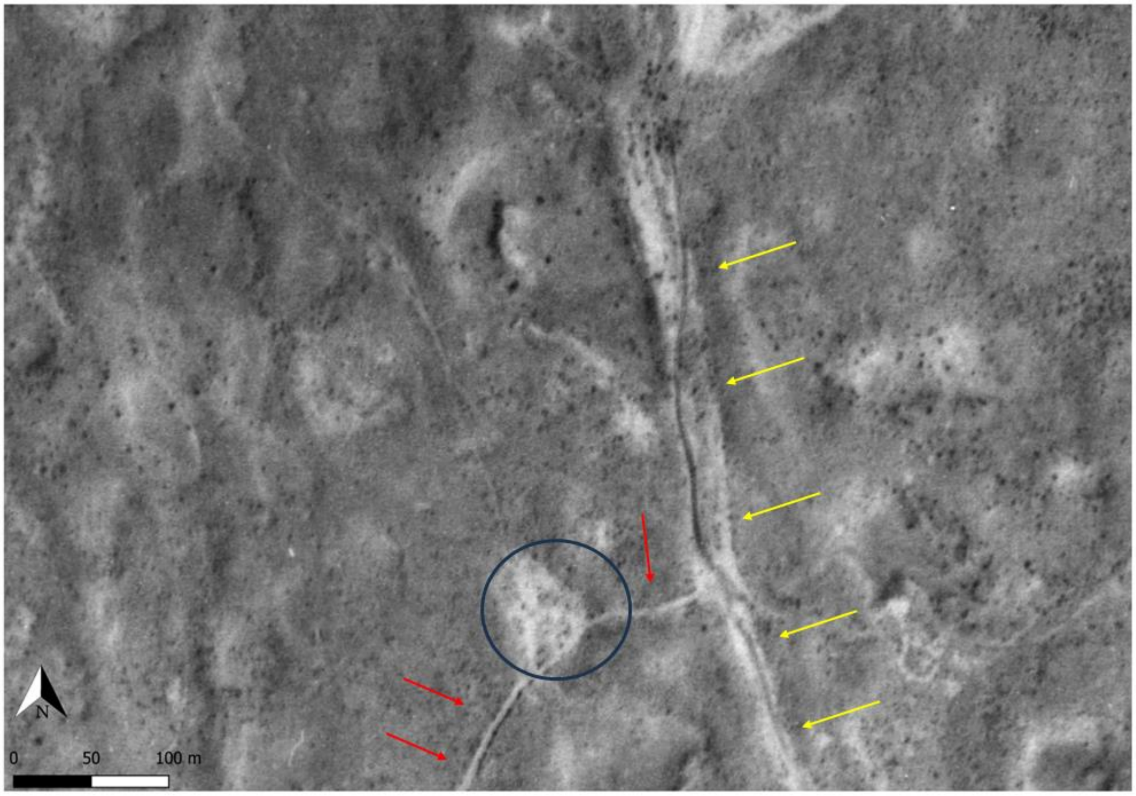


*Figure 5.49 The blue circle highlights the takyr area along Paleochannel 10 in the central-eastern area of Ojakly. For the takyr analysis, only those located along paleochannels, such as this one, have been considered. The red arrows represents Paleochannel 10 (OJK_Ch_IVa), while the yellow arrows indicates Paleochannel 15 (OJK_Ch_VI).*

### 5.9.1 Results of the Takyr Analysis

The visual analysis of the satellite images and aerial photos for Ojakly shows the presence of 60 takyr areas connected to paleochannels (Figure 5.50). The majority of the paleochannels have small takyr areas along their courses. Interestingly, Paleochannel 1 (OJK_Ch_IXa) has the largest concentration of takyr areas along its course. In contrast, Paleochannel 8, the closest channel to Ojakly has relevant takyr areas on the up-stream part only. However, other channels show a distribution of takyr surfaces along the entire course, such as Paleochannel 10.

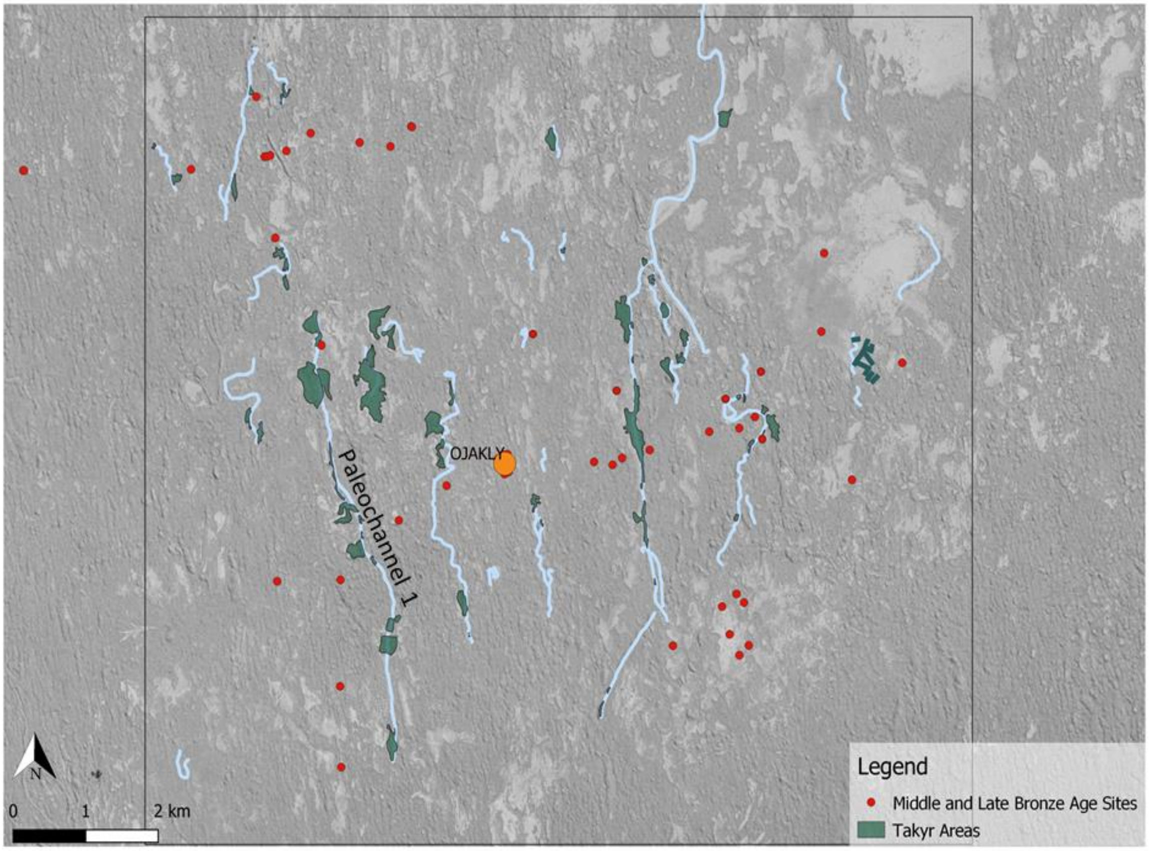


*Figure 5.50 The figure shows the takyr areas connected to former channels. Takyr areas not connected to channels have not been considered in the present analysis.*

The takyr areas have an average size of 2.23 ha (Figure 5.51). However, as shown in Figure 5.51, the vast majority of takyr surfaces are characterized by a size of less than 2 ha, and only a few measure between 2 and 5 ha with a steady drop-off in takyr areas as hectares increase. This analysis is indicative that the possible land use in the Ojakly area was characterized by small agricultural fields (<2 ha) along channels.

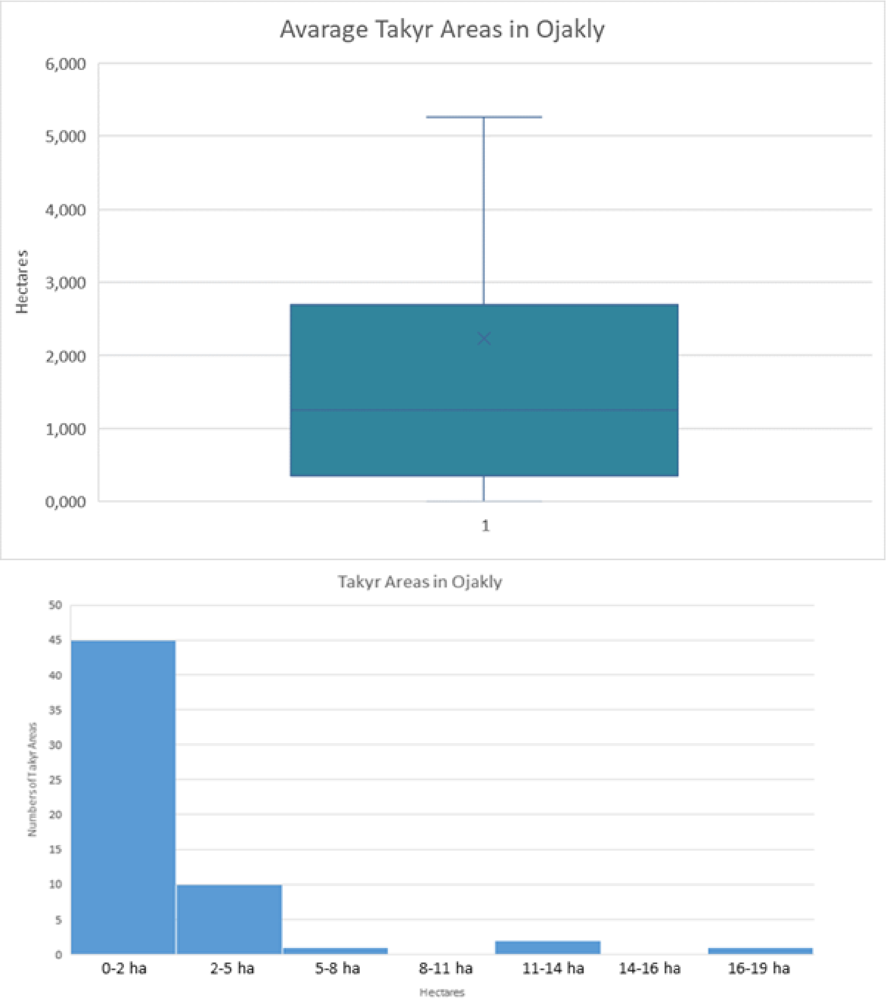


*Figure 5.51 The upper boxplot presents the average of takyr areas present in Ojakly. The "×" is the mean (2.23 hectares), while the solid line is the median. The bottom histogram displays the frequency of occurring takyr areas within determined values. The vast majority of takyr areas in Ojakly fall within 0 to 2 ha.*

This distribution suggests that possible agricultural activities in the Ojakly area occurred on small fields and only along channels. The presence of small settlements clustered along the channels, probably representing one or two dwellings, may be indicative of small-scale and opportunistic crop cultivation. While certain sites might indicate small, temporary occupations, it’s possible that agricultural areas were periodically reoccupied for farming activities over time. However, the analysis suggests that large agricultural fields may not have been present in the Ojakly area, including large areas irrigated by wells. This aspect will be further discussed in Chapter 7.

## 5.10 Results: Modelling the Irrigation System

As evidence from Gonur North suggests, small canals, as well as small dikes, were probably in place in the Bronze Age in the Murghab (Sataev 2008; Hübner et al. 2019). Within irrigation systems, the timing of water at a specific moment in the year is crucial for crops. For instance, although modern wheat requires at least 510 mm of water to be productive according to Leonard and Martin (1963:285), it also requires at least 50–80 mm of water directly before the harvest. Water seasonality, therefore, is as crucial as the total amount of water for a successful crop cultivation. As argued by Ertsen and Kaptijn (2015), who investigated the Zerqa Triangle in the Jordan Valley, the success of an irrigated agricultural field is determined by irrigation during specific time periods. Likewise, investigation in the region of Nippur and Uruk in Mesopotamia suggests that different forms of irrigation management can lead to a diverse degree of salinization, and this has been regarded as a major problem for crop productivity (Jacobsen and Adams 1958; but also see Powell 1985). Thus, seasonality is crucial in irrigation agriculture.

While access to channels could potentially be guaranteed to local actors in the Murghab, the natural hydraulic flow regimes of a channels can create mismatch in the timing of water delivery between up-stream and down-stream. As such, Lamberg-Karlovsky (2013) argues that access to water in the Bronze Age Murghab could have led to conflicts. According to him, there was a strict control over water resources such as channels, canals, weirs, and reservoirs under an authority. This control and coordination was supposedly centered in fortified settlements much like historical khanates that ruled over land and water in Central Asia (Lamberg-Karlovsky 1994a). This argument, however, has its problems. We possess limited knowledge about the potential political regime of the

BMAC, leading to a lack of information regarding control over water resources. Similarly, there is little or no evidence of conflicts among the fortified settlements, such as Gonur, in the Murghab region, that would support such a hypothesis. On the contrary, the absence of conflicts may lend support to a coordination policy. Access to water and the timing of its delivery could have been effectively managed by local agents without necessarily necessitating imposing authority over horizontal coordination. In this context, the use of an agent-based model can potentially disclose crucial aspects related to water access and delivery time in irrigation systems. This may lead to hypotheses about the management level of the BMAC irrigation system.

The aim of using SOBEK software (see also Chapter 4) is to evaluate, based on an ancient paleochannel in the Ojakly area, to what extent different management practices (referred to as scenarios) might have required increased coordination among local actors. Although the current analysis of a single channel cannot disentangle the complexity of irrigation systems across the Murghab, it can nonetheless propose scenarios and levels of coordination, or lack thereof, among BMAC communities.

To test possible management dynamics, Paleochannel 10 (OJK_Ch_IVa), which is the longest documented paleochannel (4km) in the Ojakly area, was modeled with SOBEK software. In Chapter 4, I explained the use of the software and how to apply different scenarios. While it wasn’t feasible to verify the exact depth of the channel, this parameter was computed based on the depths of similar channels in Soviet cartographic maps, which offered an average value. In addition, the gradient of the paleochannel was calculated with ASTER GDEM with a resulting average slope of 1%. The width of the paleochannel was calculated at various points along the channel when a major change in channel width was observed based on satellite images.

### 5.10.1 Modelling Paleochannel 10

Paleochannel 10 was modeled for three different scenarios. The channel represents one of the longest paleochannels and thus has well-distributed takyr surfaces along its course. Evidence from the site area of Gonur and possibly the Ojakly area (see section 5.4 of this Chapter) suggests that water was diverted from natural channels. The presence of sites in its vicinity, such as n.1748, n.1749, and n.1767, all dated to the Late Bronze Age (LBA) and thus possibly contemporaneous, suggests that local communities might have been engaged in agricultural irrigation and the management of its course, including possible lateral streams. Similarly, the takyr analysis indicates the presence of six takyr areas along its course, which may represent contemporaneous farming areas.

Assuming the presence of small lateral streams with rudimentary dams and weirs, as evidence at Gonur suggests (Sataev 2008), these have been tentatively reconstructed leading to takyr surfaces identified by remote sensing (Figure 5.50). Although the presence and the length of these lateral canals is hypothetical, the aim here is to evaluate the differences in water amount that could be effectively delivered to agricultural areas within a specific timeframe (24 hours). Indeed, different water levels at lateral canals might suggest different management scenarios, such as water scarcity between up-stream and down-stream canals. This analysis has also the potential to estimate possible coordination among actors operating along the same water system. Water levels calculated by the software in the lateral canals can serve as a proxy for possible water management and help estimate whether different management practices can result in an increase or shortage of water resources. In the Murghab region, lateral canals frequently function as reservoirs for water utilized in furrow irrigation, a practice that remains prevalent today. Consequently, changes in canal water levels directly impact irrigation methods and water distribution.

In the model, water is diverted from the main Paleochannel 10 to lateral canals by small dams, while the water flowing into later canals is regulated by weirs. A weir at the end of any lateral canal works as the valve of the canal. Although the model has seven different lateral canals in correspondence to seven takyr areas, (Figure 5.52), while the water level is calculated as 24 hours long by the software. This model enabled the exploration of three distinct scenarios, each representing varying degrees of potential cooperation among local groups employing dams and weirs to regulate water levels flowing into lateral canals.

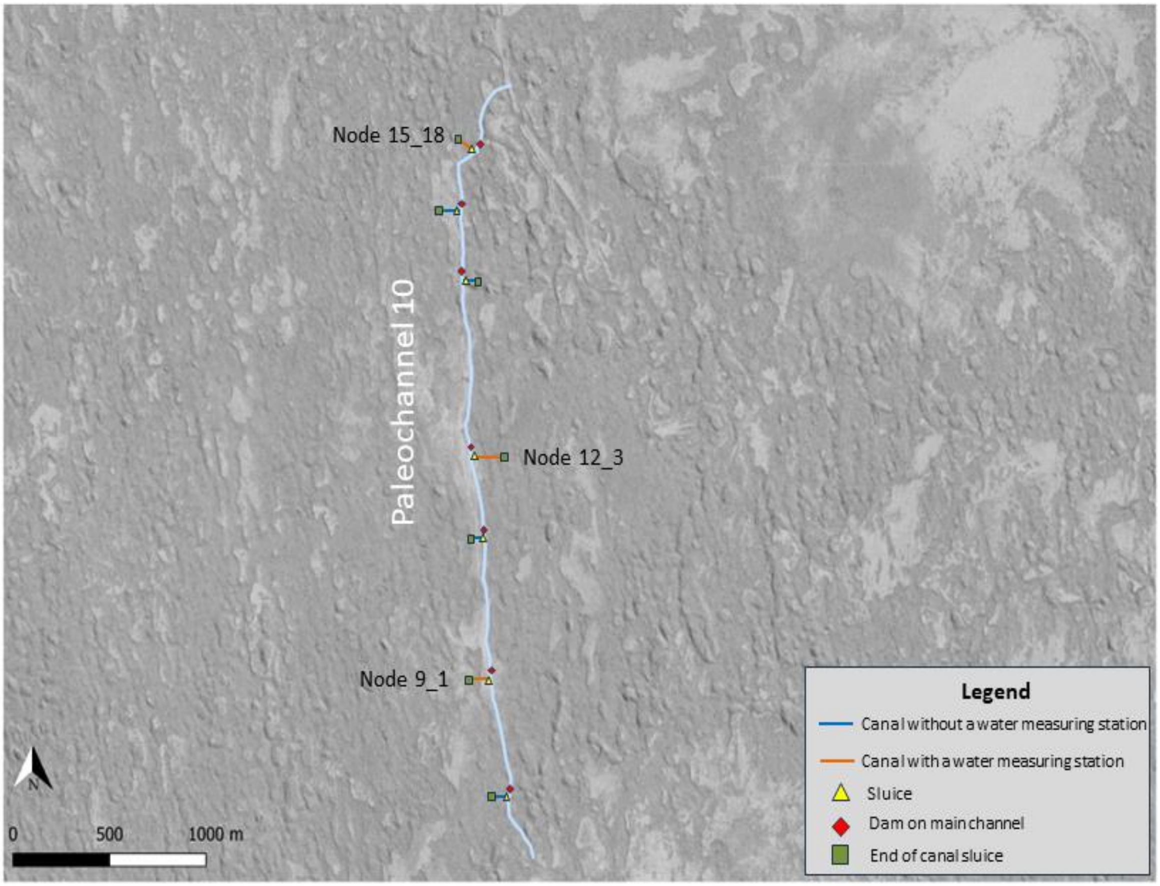


*Figure 5.52 The figure illustrates Paleochannel 10 as reproduced in SOBEK software with addinational lateral canals. The bottom of the image corresponds to the up-stream end of the channel.*

In total there are seven canals that collect and store water, but water level is calculated (water stations) only in three lateral canals (up-stream, middle-stream, down-stream).[82] **Scenario 1** is a free system in which no dams are present along the main channel, and the lateral canals receive as much water as possible in 24 hours without any gates regulating the water.

---

[82] The water stations are node 9_1 Up-stream, node 12_3 Middle-stream, and node 15_18 Down-stream.

**Scenario 2** presents a series of dams along the main channel after the lateral canals and weirs at the beginning of each stream regulating the water. However, there is no coordination of the open/closing time of the dams and weirs and all of them open and close at the same time. **Scenario 3** is more complex compared to Scenario 2. Like Scenario 2, it involves gates and weirs at each lateral canal. However, in Scenario 3, the dams and weirs between up-stream and down-stream canals operate in coordination regarding their opening and closing[83]. The water inflow is calculated at the base of the first cross-section and maintains a permanent water inflow (Q) level of 1.5 m above the datum.

#### 5.10.1.1 Scenario Results

Based on the current scenario results, I aim to examine: a) the amount of water collected in each lateral canal under varying degrees of coordination, and b) whether there are significant differences in water levels between up-stream and down-stream lateral canals.

In Scenario 1, data from the three water level stations show a significant difference in water level. The water station at the first later canal (up-stream) shows a water level that, after a period of 2 hours, is at 118 cm above the datum (Table 5.5). The second water station (middle-stream) shows a water level after the first 2 hours of 112 cm. The last water station (down-stream), shows a static water level, after the first 2 hours, of 90 cm. The final result shows a considerable decrease in the water level between the up and down-streams canals, with a total reduction of 23% of water between the two water stations (Table 5.5).

In Scenario 2, after the closure of the weirs, the first lateral canal (up-stream) exhibits a water level of 117 cm. The second lateral canal (middle-stream) displays a water level of 100 cm, while the down-stream canal water station (down-stream) has a final water level of 81 cm after 24 hours. Comparatively, in Scenario 2, except for the first lateral canal,

---

[83] For instance, when the upstream dams are open, the downstream dams are closed, and vice versa.

there is a decrease in the water level of the middle and down-stream lateral canals (Table 5.5).

In Scenario 3, Despite the effects resulting from the opening and closing of various dams and gates at different times, it is evident that the water level remains constant at 100 cm for all three lateral canals at 24 hours (Table 5.5). The primary distinction in scenario 3 lies in the timing. Specifically, while the up-stream canal reaches a water level of 100 cm in the lateral canal as early as 10 hours, the down-stream lateral canals experience a shortage in water level until 16 hours due to the operation of the up-stream dams. However, they eventually reach the same water level by 19 hours. Consequently, by the end of the day, all the lateral canals receive an equal amount of water.

#### 5.10.1.2 Water Management Scenario

The main aim of the models was to test to what extent different water management of the irrigation system could lead to an increase or shortage of water availability in the fields. Indeed, different water availability would have had an impact on the groups of people operating on the same water system. As discussed in Chapter 3, the use of dams and weirs in the management of the irrigation system is attested in Mesopotamia both from archaeological evidence and written sources (Tamburrino 2010). In Central Asia, Adrianov (2016) argues for coordination in the canal system as far back as the Bronze Age in the Aral Sea area.

In the first scenario, there is no management on lateral streams or dams, with a decrease of 23% in water availability between the first up-stream lateral canal and the last down-stream lateral canal (Table 5.5). This percentage increases up to 30% in the second scenario. Notably, in these two first scenarios, local agents operating up-stream along the same paleochannel would have a clear advantage for the water resource as they would get more water able to irrigate their fields. Only in the third scenario every lateral canal receives the same amount of water at the end of the day. As a result, the three different scenarios suggest that similar water levels could only be achieved through possible coordination, and this would have necessitated possible agreements between local agents. This analysis, however, presents analytical limitations that must be taken into account. Data from one single channel must also be treated with caution. However, the result can be indicative that when several agents operate on one single channel without any forms of coordination, there is a clear decrease in water level in lateral canals, if the water is taken simultaneously. Moreover, the analysis of settlement distribution in relation to the water channel suggest that groups of sites are often clustered along the same channels. A third limitation concerns the seasonality of the water required for crop cultivation (e.g., Sataev and Sataeva 2012; Sataeva and Sataev 2014; Cattani 2008b). The different scenarios analyzed only display a decrease in the amount of water.

However, quantifying the impact of reduced water supply for down-stream canals on crops, and its potential consequences such as plant stress or decreased crop yields, is challenging, particularly given the difficulty in assessing the water requirements of ancient crops (R. Cappers pers. comm.). For instance, modern millet requires almost half as much water as wheat for productive growth (Peterson 1982: 22).

| **Scenarios** | Water Level – *First Water Level Station (Node 9_1 – Up- Stream)* | Water Level – *Second Water Level Station (node 12_3 – Middle-Stream)* | Water Level – *Third Water Level Station (Node 15_18 – Down-Stream)* | Water Reduction – *First vs Third Water Level Stations after 24 hours* |
|---|---|---|---|---|
| **Scenario 1** | 118 cm | 112 cm | 90 cm | **23% of water reduction** |
| **Scenario 2** | 117 cm***** | 100 cm | 81 cm | **30% of water reduction** |
| **Scenario 3** | 100 cm | 100 cm | 100 cm | **0% of water reduction** |
| ***** 117 cm is the water level after 24 hours. However, the water level of this node reaches 150 cm after 10 hours. | | | | |

*Table 5.5 The table presents the different water levels reached by the lateral canals in the different scenarios at the end of the day (24 hours). The right column shows the percentage difference in water level between up-stream and down-stream.*

Altogether, the agent-based model of Paleochannel 10 suggests that dense settlement cluster areas, such as Gonur or Togolok 1, with a varieties of crops cultivation, would have required coordination in terms of amount and timing of water delivery. In contrast, peripheries and more marginal areas, where opportunistic agriculture was practiced at the household level, would not have necessarily required a high a degree of coordination. However, the analysis of Paleochannel 10 also suggests that the presence of a several areas of crop fields along the same channel might necessitate coordination, including more peripheral areas as well. Ethnographic studies are indicative that water management and maintenance of the canals in Merv Oasis in the 19th century was greater in the urban area and decreased towards the peripheries. Thus far, the current result is nevertheless indicative that in the Murghab a diverse irrigation system, with distinct water management and coordination among the local agents, was likely in place during the Bronze Age. This aspect will be further discussed in Chapter 7.

## 5.11 Synthesis

The data presented in this chapter suggests that the Ojakly area had a system of natural irrigation channels during the Bronze and Iron Ages. Data from the test trench indicates that part of this system underwent an initial stage of development characterized by a possible low-energy flow. This stage was then followed by a more variable flow regime between the end of the 3rd and the beginning of the 2nd millennium BCE that likely had an impact on the stability of the water supply and agricultural practices. During the 2nd millennium BCE, most of the channels possibly underwent a process of inactivation.

In addition to geoarchaeological investigations, the survey conducted in the research area suggests that the many settlements were located along the ancient watercourses. These distances are not correlated with site types or pottery assemblages. While ICW (Andronovo) sites exhibit an increased difference in distance compared to other sites, this distance aligns closely with Namazga (BMAC) pottery sites when considering large cluster sites. This data suggests that practices related to crop cultivation and pastoralism may have been similar among sites exhibiting different pottery assemblages in rural areas. Consequently, it challenges the notion that subsistence economy can be inferred solely from pottery assemblages, as suggested by other scholars. As such, regardless of their pottery assemblages, settlements may have been involved in irrigation agriculture and pastoralism. The available data, however, provides little evidence about possible water management and coordination, but use of the agent-based models can provide crucial hypotheses in this regard.

Data from SOBEK software, indeed, suggests that communities along the same channel may have likely cooperated in order to receive equitable amounts of water. This might be particularly evident in dense settlement cluster areas where we find a diversity of crop cultivation. In contrast, more patchy settlements along the channel would not necessarily have necessitated cooperation in water management. All in all, the data from the Ojakly area suggest a more heterogeneous water and agricultural management that differs from the model of land exploitation previously proposed. These aspects will be further discussed in Chapter 7. But, before moving to a broader discussion, the next chapter will assess similar data from the Togolok region.

# Chapter 6 – Results from the Togolok Area

## 6. Results: The Togolok Area

### 6.1 Overview

This chapter presents the result of the analysis conducted in the Togolok area, which is one of the main cluster site areas of the Bronze Age Murghab. Before presenting the results of the analysis, I will briefly discuss the main excavated sites of Togolok that provide the context for interpreting the hydrological and agricultural systems. Similar to Chapter 5, the results of the analysis of the irrigation system and the survey, including the chronology of the settlements, will be presented in two separate sections. The following analysis of the test trench and OSL samples provide further data on the evolution of the paleochannel system in Togolok. In the final section, I will discuss the results of the carbon isotope analysis of the Togolok botanical samples and their possible implications for water management in the Middle and Late Bronze Age.

### 6.2 The Cluster Site Area of Togolok

The Togolok area, located 14 km southwest of the main site of Gonur, was surveyed by the YuTAKE project in the 1970s, and in the 1990s by the AMMD project. The initial survey by a Soviet team (which includes a larger area compared the one examined in this research) led to the identification of 31 sites, of which the main one is Togolok 1 (Figure 6.1). In the Togolok area Sarianidi (1990a:34) identified a “cluster” of sites that he later defined as “oases.” However, as I will discuss in Chapter 7, this term remain problematic as site relations remain poorly understood in the Murghab. These sites are located over various distances, and their dimensions might suggest a settlement system with administrative or religious centers, along with rural settlements.

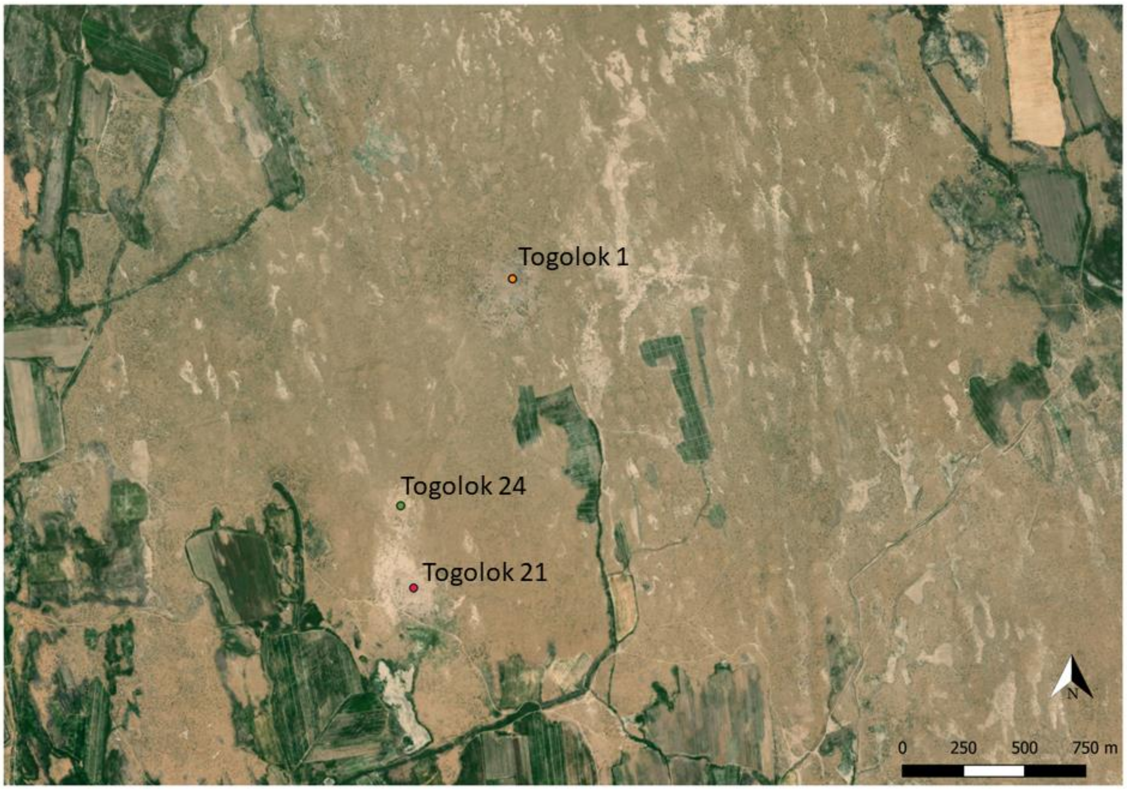


*Figure 6.1 The figure shows the Togolok area with the identification of the excavated sites within the research area.*

As discussed in Chapter 3, investigations have predominantly concentrated on the large fortified settlements while neglecting their hinterlands. Although two of the major sites have been excavated in Togolok,[84] questions persist about the nature of the possible administrative control over the landscape and water management. Surveys by the AMMD revealed the presence of many additional small settlements in the hinterland, whose roles and relationships with main centers remain unclear. Often perceived as supporting satellites to the primary large settlements, these sites may have also maintained independent relationships with each other, not necessarily tethered to the main settlement. (cf. Schawartz and Falconer 1994). Investigations of the wider landscape, focusing on the channel systems can, therefore, help us to understand the role of main and small rural settlements and their distribution across the landscape.

---

[84] Namly Togolok 21 and Togolok 1 (south mound).

Before exploring the Togolok hydrological landscape, however, it is necessary to briefly review the excavated sites that have provided crucial data for interpreting the landscape management.

### 6.2.1 Togolok 21

Togolok 21, which is the most prominent excavated site of the Togolok area, was built at the top of a small natural hill and was extensively investigated by V. Sarianidi in the 1980s. It includes a monumental complex with a rectangular shape with perimeter walls and semi-circular towers. Like at Adji Kui 9, inside the defensive walls there is a "fortress." The construction, which is entirely in mud brick, shows regular planning with walls in the main east–west or north–south orientation (Figure 6.2).

The main entrances of Togolok 21 are located in the north with a second entrance possibly located in the southern wall. According to Sarianidi, the main building inside the defensive walls is divided into a northern sector and a southern sector with a chain of narrow corridor-like rooms (rooms 48, 32, 30, 44) dividing the two parts. The northern part has a central courtyard (room 23) with long rectangular rooms around (rooms 14, 20, 39 and 24).

Of interest in this research are the cylindrical ceramic pipes that may have been used as drainage structures (Sarianidi 1991). Pipes of this kind in Margiana are rare and have been discovered in only a few locations, including Gonur and Togolok 1. Their presence suggests a deliberate investment in water drainage infrastructure. It implies that the water either had to be directed to these pipelines or, if they served as a drainage system, it was channeled to specific areas for collection or dispersal.
Within the inner fortress, in the south-west corner of the building, there are a small number of narrow cells (rooms 49, 47, 57, 59, 60, and 62–5) separated from each other by a passage with a central corridor in the middle. The function of these spaces is unclear, but the shape, along with similar narrow rooms outside, may suggests storage purposes.

Room 34 inside the fortress had a special brick stand with large pythos vessels. Organic remains inside these vessels were identified and interpreted as ephedra and poppy pollen (Meyer-Melikyan and Avetov 1998). Further, impressed organic remains on pottery vessels were initially interpreted as *Cannabis sativa*. However, subsequent analysis by Bakels (2003) identified the impressed organic materials as broomcorn millet (*Panicum miliaceum*). Millet has also been found in Togolok 1, in support of Bakels' interpretation.

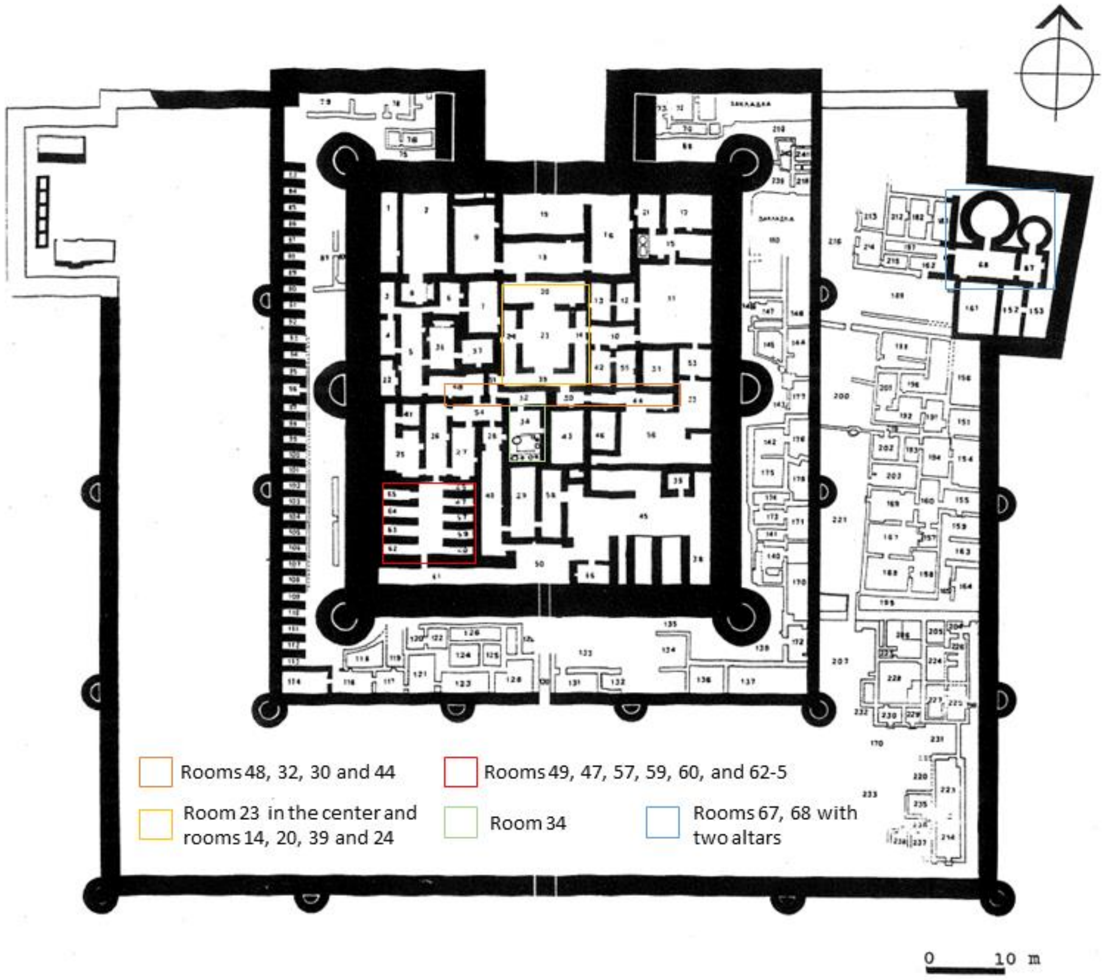


*Figure 6.2 The general plan of Togolok 21 (Hiebert 1994a:Fig.2.7, adapted from Sarianidi 1990b:Fig. 25).*

The site of Togolok 21 was interpreted by Sarianidi as a "temple" rather than a fortress for administrative purposes. The fortress structure is similar to Gonur South, and the presence of stamp seals strongly suggests a function that goes beyond that of a temple. It is likely that Togolok 21 had multiple functions, including water management, at least for its immediate surroundings. The chronology of the materials and the $^{14}$C dating from several rooms date Togolok 21 to the Late Bronze Age (c. 1900–1500 BCE) (Fontugne et al. 2021).

### 6.2.2 Togolok 24

Togolok 24 is located northwest of Togolok 21 and has a size of ca. 180 × 100 m with an elevation of almost half a meter (Sarianidi 1990a:52). The site dates to the Late Bronze Age on the basis of pottery as well as copper seals. In the northeast area of the site, Sarianidi identified a small cemetery with a series of tombs constructed with mud bricks (Hiebert 1994a:23). Togolok 24 appears to be a satellite site connected to the larger sites of Togolok 21 and Togolok 1 located nearby.

### 6.2.3 Togolok 1

The complex of Togolok 1 is located ca. 15 km southwest of Gonur. The site is composed of two mounds, a large northern mound (Tepe 1) and a small, lower mound (Tepe 2) to the south (Figure 6.3). Tepe 1 (or Depe 1) has a size of ca. 9 ha with an elevation of 4 m, while the second mound reaches about 2.30 ha in size with an elevation of 2 m. On the southern mound, a fortified building was excavated by Sarianidi in 1987–1988 (Sarianidi 1986). During the same years, Sarianidi (1990a:33) also made a stratigraphic sounding on the northern mound. On this same mound, Salvatori also opened a small test trench in 2005[85] to investigate the upper part of the mound. Subsequently, the TAP (*Togolok Archaeological Project*) started excavating the northern mound in 2014. The excavations and investigation of the two mounds (Tepe 1 and Tepe 2) provided crucial data to define and explore the area of Togolok and will now be briefly discussed.

---

[85] Unpublished report.

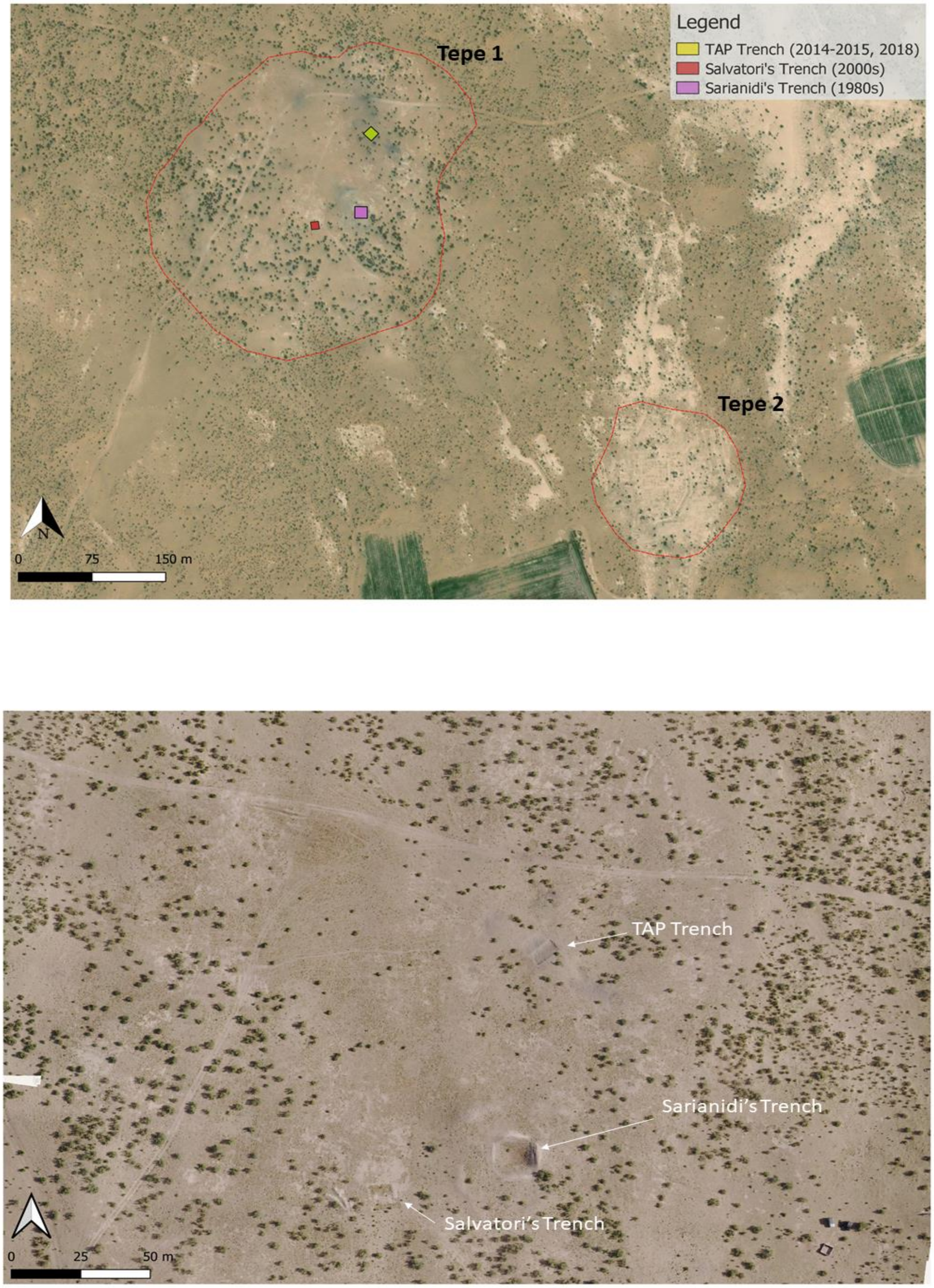


*Figure 6.3 Top: The figure shows the two main mounds of Togolok 1 (Tepe 1 and 2) with excavated trenches on Tepe 1; Bottom: the figure is an orthophoto showing the trenches Sarianidi excavated in the 1980s, Salvatori's trench excavated in the 2000s, and what TAP (Togolok Archaeological Project) excavated in 2014, 2015 and 2018 (Drone photo by K. Olson).*

#### 6.2.3.1 Togolok 1: Southern Mound (Tepe 2)

The excavation of the southern mound by Sarianidi brought to light a fortified square (ca. 29 × 30 m) with circular towers on three sides (Figure 6.4). Analogous to Togolok 21, Sarianidi observed two construction phases for Togolok 1. The entrance to the building is located in the north between two round towers. According to Sarianidi (1994) the fortified structure can be divided into northern (public) and southern (private) areas. The northern area of the fortified building has rooms with white gypsum plaster on the walls and floors (Sarianidi 1994). Outside of the fortified center, on the eastern side, a richly furnished burial was found (Hiebert 1994a:Fig. 2.11). Among the special finds from Togolok 1 (south mound) there are miniature stone columns, soft stone vessel fragments, and stamp seals were found. The ceramic assemblages found within the fortified building are typologically similar to those at Togolok 21, and date the site to the Late Bronze Age (P'yankova 1989).

The southern mound of Togolok 1 was interpreted by Sarianidi (1994) as a small "rural shrine" because of the presence of rooms with white gypsum plaster similar to Togolok 21, and the alleged recovery of hallucinogenic plants. However, the functions of the square and rectangular rooms inside and outside the inner fortress, as well as the general function of the site, remain unclear.

Of particular interest at Togolok 1 is the presence of ceramic water pipes similar to those recovered at Togolok 21 (Figure 6.5). The existence of these features at both Togolok 21 and Togolok 1 provides compelling evidence that the inhabitants of the Togolok area possessed specialized expertise in water pipe systems. This suggests also that the community in the Togolok area recognized the importance of effective water distribution and drainage systems for sustaining their settlements.

*Figure 6.4 Plan of Togolok 1 (Tepe 2) with its fortified inner structure with a square plan (Sarianidi 1991:Fig. 37).*

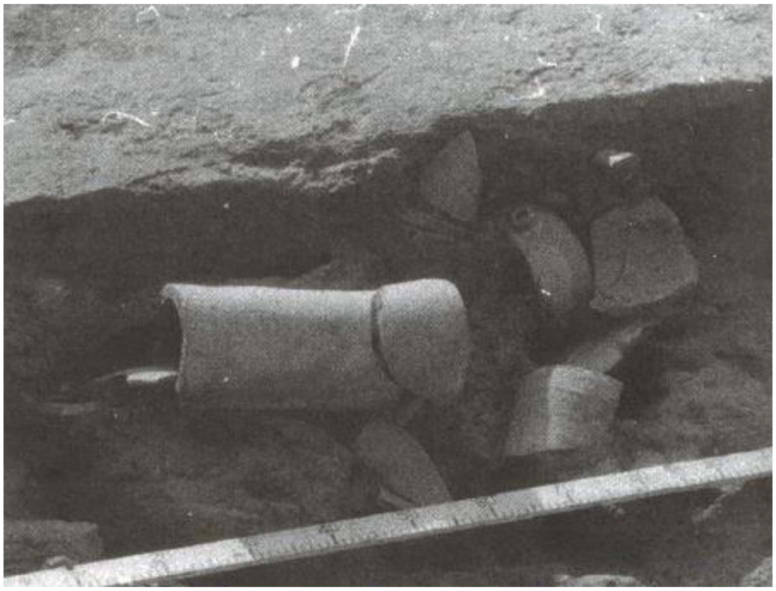


*Figure 6.5 Ceramic pipes in situ at Togolok 1 (Tepe 2) (Hiebert 1994a:Fig. 4.29).*

### 6.2.3.2 Togolok 1: Northern Mound (Tepe 1)

The northern mound of Togolok 1 (i.e., Tepe 1) is the main mound of the Togolok cluster. The site is ca. 9 ha in size and has an elevation of ca. 4 m. The first test trench was excavated by Sarianidi on the central southwestern part of the mound (Figure 6.7). According to Sarianidi (1986:8–9), the initial test trench on top of the mound revealed four different phases. The first and oldest level is represented by brick walls that were part of a small room compartment. The multi-roomed house also existed in the second phase with pottery from the Late Bronze Age. The third level was mainly characterized by a refuse deposit and the fourth level dated to the Iron Age (1500–1300).

- **Recent Excavation Campaigns (2014–2018)**

In 2014, excavation of the main mound started again by the TAP team, and it provided crucial data for interpreting the domestic economy and agriculture in the Togolok landscape. I will briefly discuss these excavation results and present the botanical and zooarchaeological data.

The excavation area was divided into two trenches. Trench 1A revealed evidence of two distinct phases of occupation. The first phase featured an artificial platform and yielded a significant quantity of seeds, coprolites, and sheep and goat bones. In the second phase, a compact artificial platform was identified, alongside circular fireplaces containing ash and organic material (for details, see Cerasetti et al. forthcoming). Pottery recovered from this context was dated to the Late Bronze Age (1950–1500 BCE). Among the finds, a rectangular-shaped chlorite amulet/stamp-seal was found in this trench with a common iconographic motif widely documented in Margiana (Forni and Arciero 2022: Fig. 4).

*Figure 6.6 The figure shows the north trench (1A) with a detail of the excavated organic (TAP project photo).*

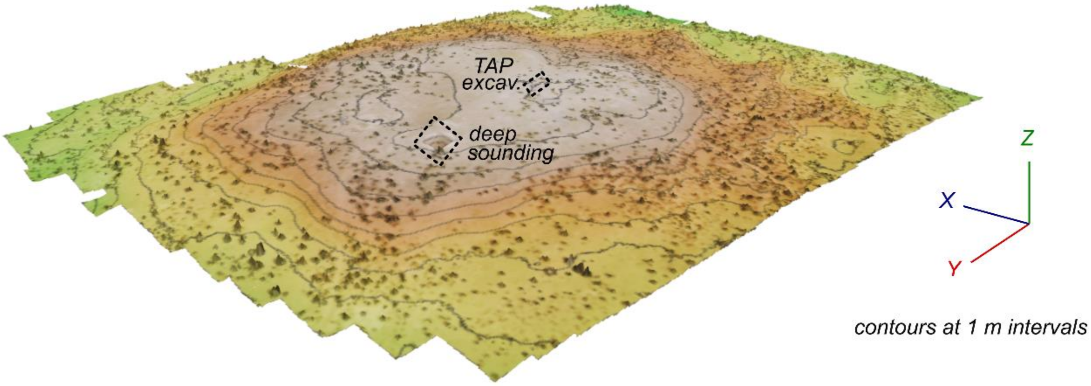


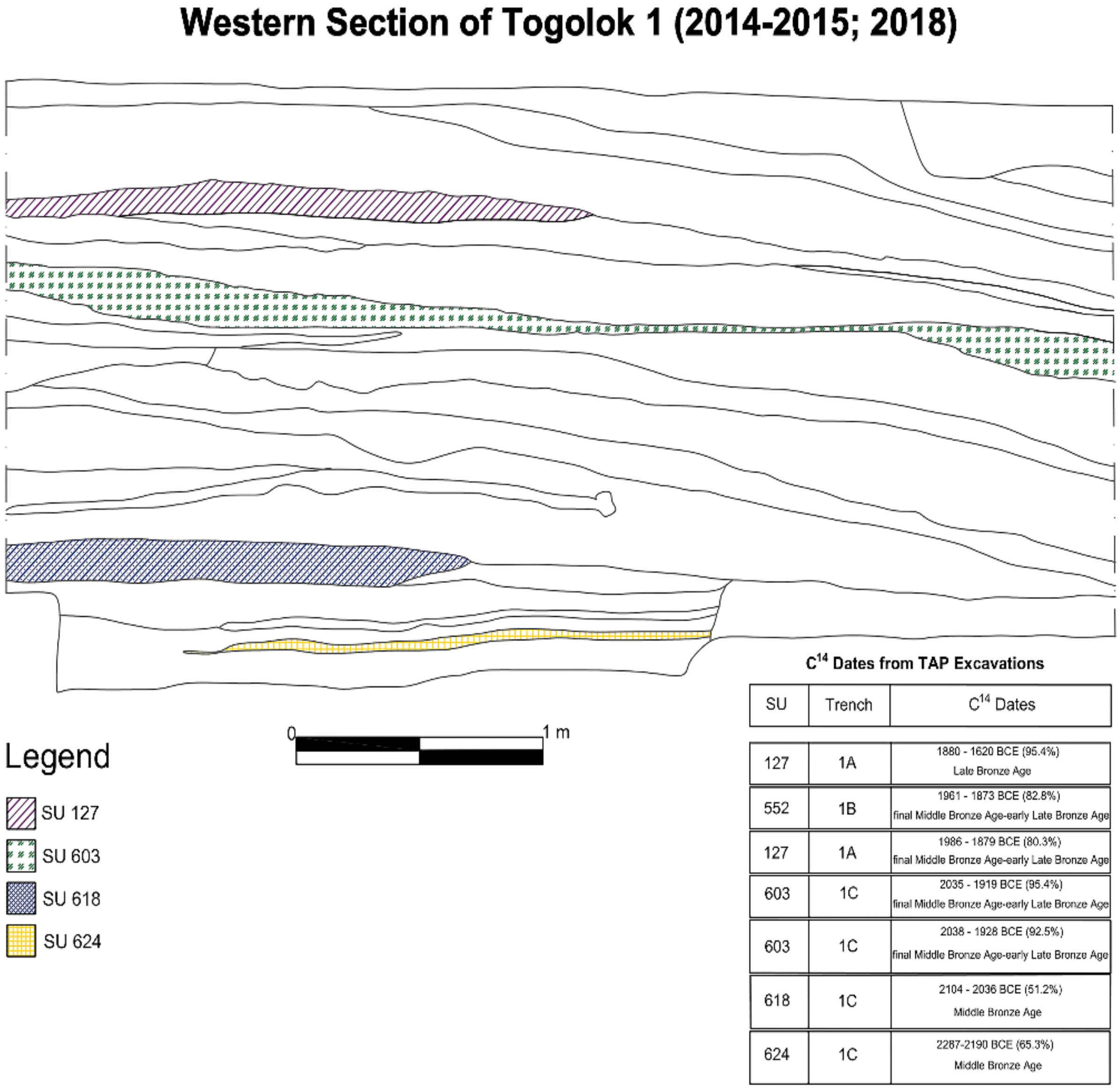
*Figure 6.7 3D model of Togolok 1 (Tepe 1) based on digital elevation overlays and draped with 1 m contour lines (adapted from Cerasetti et al. 2022: Fig. 6). The deep sounding was made by Sarianidi in the 1980s.*

In Trench 1B, three distinct occupation phases were documented. The first and most recent phase revealed three fireplaces situated at the center of the trench, rich in animal bones and hand-made pottery. Additionally, an occupation level characterized by an artificial platform was identified. The second phase of occupation featured an additional artificial platform and a large fireplace located on the southwest side of the trench. Finally, a third and final phase of occupation was marked by a compact artificial platform, accompanied by the presence of five semi-aligned post-holes in the eastern area of the trench (Figure 6.8) (Cerasetti et al. forthcoming). Notably, a significant finding in this trench is a female violin-shaped terracotta figurine, prevalent in the Murghab region until the Middle Bronze Age (Masimov et al. 1998:35).

*Figure 6.8 Semi-aligned post-holes from the third phase of occupation of the south Trench (1B).*

In 2018 a small trench sector of 2 × 6 m of Trench 1A was dug almost 2 m in depth (later called Trench 1C). The excavation of this sector revealed the presence of four subsequent artificial platforms (Cerasetti et al. 2022). The lower layers, beside the artificial platforms, revealed mudbrick fragments possibly part of a structure. Within this unit an additional flat violin-shaped female terracotta figurine was found (Cerasetti et al. 2022:Fig.11).

The $^{14}$C dates of the trenches place the last occupation phases of Togolok 1 to the last phases of the Middle Bronze Age to the early Late Bronze Age (ca. 2100–1800 BCE), while the deepest layers of Trench 1C are dated to the Middle Bronze Age (Figure 6.9).



**$C^{14}$ Dates from TAP Excavations**

| SU | Trench | $C^{14}$ Dates |
|---|---|---|
| 127 | 1A | 1880 - 1620 BCE (95.4%)<br>Late Bronze Age |
| 552 | 1B | 1961 - 1873 BCE (82.8%)<br>final Middle Bronze Age-early Late Bronze Age |
| 127 | 1A | 1986 - 1879 BCE (80.3%)<br>final Middle Bronze Age-early Late Bronze Age |
| 603 | 1C | 2035 - 1919 BCE (95.4%)<br>final Middle Bronze Age-early Late Bronze Age |
| 603 | 1C | 2038 - 1928 BCE (92.5%)<br>final Middle Bronze Age-early Late Bronze Age |
| 618 | 1C | 2104 - 2036 BCE (51.2%)<br>Middle Bronze Age |
| 624 | 1C | 2287-2190 BCE (65.3%)<br>Middle Bronze Age |

*Figure 6.9 Western section of Trench (1C) (2014–2015 and 2018 excavations), with the table of the radiocarbon dates (2014–2015 and 2018 excavations) (Cerasetti et al. 2022:Fig. 8).*

The initial excavation of both trenches led the excavators to interpret the area as seasonally occupied, given the lack of permanent structures and evidence such as post-holes suitable for makeshift structures. Particularly, the area of Trench 1A, distinguished by thick organic layers, was interpreted as a potential animal pen deposit (Cerasetti et al. 2022).

- **Botanical Assemblages from Togolok 1**

The preliminary analysis of botanical samples from Togolok 1 concerns the layers excavated in 2014. However, analysis from 2015 samples suggest similar results (Billings and Spengler pers. comm.). The results are from layers dated to the end of the Middle Bronze Age and Late Bronze Age. The sample collection follows the methods described in Pearsall (2015).[86]

The botanical samples collected revealed the presence of wild and domesticated plants, while 22,208 carbonized botanical remains were identified in total (Billings et al. 2022). Among the domestic crops, there is a prominence of naked and hulled barley (*Hordeum vulgare* var. *nudum* and *H. vulgare* var. *vulgare*), but also free-threshing hexaploid bread wheat (*Triticum aesitivum*) is present in good quantities (Figure 6.10). Both were probably used for making bread, as the presence of grinding stone pieces from the Middle Bronze Age layer suggest, although grinding stones can be used for various purposes (Cerasetti et al. forthcoming). According to Billings et al. (2022), the Murghab wheat and barley may have been planted in early fall with a late spring harvest. Considering a decrease in the water flow of the Murghab during the fall and winter months, these crops would have likely required irrigation.

A remarkable cereal that was found in Togolok 1 is millet (*Panicum miliaceum*). The crop has been found in samples from the latest layers of occupation and supports the earlier identification by Bakels (2003). This discovery dates the presence and possible cultivation of millet in Togolok being already in place at the end of the Middle Bronze

---

[86] The analysis of botanical samples was conducted by M. L. Carra from the University of Bologna and T. Billings and R. Spengler from the Max Planck Institute at Jena (Germany).

Age[87] and is consistent with the presence of millet found at the nearby site of Adji Kui 1 (Cerasetti et al. 2018). The seeds found at Togolok 1 are quite large compared to wild millet, and, according to Billings et al. (2022), they might be domestic.

Among other crops in the assemblage, legumes were detected, including peas (*Pisum sativum*), grass peas (*Lathyrus sativus*), and lentils (*Lens culinaris*). In lower numbers, chickpeas (*Cicer arietinum*), bitter vetch (*Vicia ervilia*), and fava beans (*Vicia faba*) were also present (Fig. 6.11) (Billings et al. 2022). Compared to cereals, these crops are generally more water-demanding and certainly required a degree of irrigation (Cerasetti et al. forthcoming; Murphy-Bokern and Watson 2017). However, among the legumes, both lentils and grass peas are often grown in a semi-arid region and are considered drought tolerant. Legumes can also be planted together with winter-sown wheat but also in the summer in a heavily irrigated system (Zohary 1969). This diet was integrated with tree crops. The analysis identified a small number of grape pips (*Vitis vinifera*) in the assemblage as well as plums – possibly *Prunus insititia* (cf. Malus/Pyrus).

Among the wild plants, which are crucial to better understanding the local climate, we find that *Galium* sp. (60%) and *Alhagi* sp. (21%) predominate (for a complete list of the assemblages see Billings et al. 2022:Tab.1). Other wild species include species common in arid regions, such as *Convolvulus* and *Alhagi* sp. (*Camel thorn*), along with *Trifolium* and *Galium*, *Silene*, *Centaurea*, *Orlaya* (Harris et al. 1993). In contrast, some further plants identified are typical of wet environments and occur in landscapes with natural or artificial channels, such as *Carex*, and *Galega*. However, wild plants of the family of *Cyperaceae*, which are often common markers of wetlands or irrigation areas, were not identified (Miller and Marston 2012).

The preliminary analysis of the botanical assemblage, which did not take into account the Middle Bronze Age samples recovered in 2018, suggests an agricultural economy with many types of domesticated crops, with an animal husbandry component. The presence

---

[87] The results from a radiocarbon date on millet obtained from Togolok 1 indicate a calibrated range of 2197–1983 cal. yr BCE, with a 95.4% probability using OxCal 4.4 IntCal 20 (Billing et al. 2022:Fig. 3).

of different legumes in the assemblages suggests a diverse diet. The inhabitants of Togolok 1 also consumed arboreal fruits that might have been cultivated locally or traded from the nearby piedmont region. However, cereals and legumes seem to be part of local cultivation. As suggested by Traci and Spengler (in Cerasetti et al. 2022), the evidence of rachis in the assemblages suggest that cereals were cultivated locally. In addition, the presence of cereals seeds embedded in dung, produced by grazing animals, further suggests the presence of local fields near Togolok 1.

*Figure 6.10 Botanical remains from Togolok 1. A): a) hulled barley (Hordeum vulgare var. vulgare); b) naked barley (Hordeum vulgare var. nudum; c) free t hreshing hexaploid wheat (Triticum aesitivum); B): a) common peas (Pisum sativum), b) lentils (Lens culinaris), and c) grass peas (Lathyrus sativus); C): a grape pip (Vitis vinifera), showing ventral and dorsal sides (Cerasetti et al. 2022:Fig. 14).*

All in all, the botanical evidence suggests a diet in which the main processed foods were composed of cereals (wheat and barley) with the addition of millet, legumes, and garden fruits. This botanical spectrum is consistent with data from other sites such as Gonur (Miller 1993; 1999; Moore et al. 1994; Sataev and Sataeva 2014). The diet, however, was integrated with animal husbandry, which was complementary at Togolok 1.

### - Zooarchaeological Assemblages from Togolok 1

The zooarchaeological remains from the latest phase of occupation at Togolok 1 comes mainly from fireplaces and are generally highly fragmented.[88] Due to this fragmentation, only 21.6% of the total amount (n=270) from the 2014/2015 field campaigns could be identified. Among the remains, the majority are sheep and goat (*Ovis* vel. *Capra*) (67%) with a total of 36 fragments and 6 being the minimum number of individuals (MNI) (Cerasetti et al. forthcoming).

Among the domesticated species (which compose 91.6% of the determinable samples), cattle (*Bos indicus*) and pig (*sus domesticus*) have also been identified (respectively 10% and 12%). In addition, a single dog metapodial bone (*Canis familiaris*) was also identified.

Wild species identified from the 2014–2015 excavations only represent 8% of the total assemblage. Yet, they are informative of the Togolok environment. The preliminary analysis identified foxes (*Vulpes* sp.), wild gazelles (*Gazella* sp.), turtles (*Testudo horsfieldii*), and hares (*Lepus* sp.),[89] which suggest an open environment, not extremely humid with low vegetation around (Cerasetti et al. forthcoming).

---

[88] The preliminary analysis of zooarchaeological remains from Togolok 1 (2014–2018 field seasons) was conducted by A. Curci (University of Bologna) and J. De Grossi Mazzorin and A. Potenza (University of Salento-Lecce).

[89] According to De Grossi Mazzorin (unpublished report) the single fragments of adult hare may be *Lepus* cf. *tolai*, which is endemic to the semi-desert areas of Turkmenistan. The presence of this animal would suggest a less humid environment by the end of the 3rd millennium BCE.

The remains from the 2018 excavation layers dated to the Middle Bronze Age were also highly fragmented, and only 12.3% of the total could be identified. Among the species, a large part is domestic and belongs to sheep and goats (*Ovis Capra*) mainly (71%). The other domesticated species (22%) are cattle (*Bos taurus*), followed by a small percentage of pig (*Sus domesticus*) and four bones of a dog (*Canis familiaris*). Interestingly, two equid bones (*Equus* sp.) were also identified, which were not present in the Late Bronze Age layers (Cerasetti et al. 2022). Among the wild species, a small percentage is formed by gazelle (*Gazella* sp.), rodents (*Rodenzia* sp.), and a bird skull (*Aves ind.*) (Cerasetti et al. 2022).

The preliminary analysis of the sheep and goat suggests the presence of adults and sub-adults (Cerasetti et al. 2022). These animals were probably used as food but also for secondary products such as milk and, possibly, wool. Milk and wool are produced today by modern shepherds in the Murghab for household use (Arciero and Forni 2018). Further analysis and more extensive excavations will help to address more questions, such as the age of death and sex assessments, which can clarify more aspects of animal husbandry and exploitation in the Togolok area.

Overall, preliminary data from Togolok 1 are consistent with general a exploitation of mainly ovicaprids, along with other domesticated animals such as cows and pigs.[90] The very low percentage of non-domestic animals is indicative that they were marginal for subsistence in Togolok 1. In addition, small vertebrae of fish were also found in archaeobotanical samples (Figure 6.11). The fish is possibly *Nemacheilidae Paracobitis* sp. which is endemic to the West and Central Asian rivers today and was also identified in Adji Kui 1 (Billings et al. 2022; Spengler et al. 2018).

---

[90] Detailed data on zooarchaeological analysis and minimum number of individuals (MNI) both from 2014/2015 and 2018 excavation can be found in Cerasetti et al. forthcoming and Cerasetti et al. 2022.

*Figure 6.11 Fish vertebrae recovered from Togolok 1 archaeobotanical samples (SU 109) (Billings et al. 2022:Fig. 10).*

### 6.2.4 The Domestic Economy of the Togolok Area

The data from the first three seasons of excavations suggest an integrated economy with crop cultivation and animal husbandry that characterize Togolok 1 and its surroundings. The botanical remains include cereals, wheat, and barley and some millet. Legumes, such as lentils and grass peas were complementary food sources, along with garden fruits. Interestingly, millet has mainly been found at smaller sites, such as Ojakly and Chopantam, and has been argued to be a suitable crop for low-investment agriculture (Miller 2008; Spengler et al. 2018). The spread of millet from East to Central Asia has sometimes been associated with the movement of mobile pastoralists and is dated as early as the $3^{rd}$ millennium BCE (Endo et al. 2023; Motuzaite Matuzeviciute et al. 2022, Miller et al. 2016, Frachetti et al. 2010, Pashkevich 2003). Millet is a fast-growing, warm-season crop, and it is less water-demanding than wheat and barley. For small, semi-mobile communities, such a low-risk crop could have been especially suitable. However, at Togolok 1, millet appears to be marginal compared to barley and wheat, like at other larger sites such as Gonur and Adji Kui 1 (Table 6.1) (Sataev and Sataeva 2014; Spengler et al. 2018). The documented agricultural system, incorporating various cereals and legumes with different growing seasons and water requirements, would have likely necessitated a dependable irrigation system. Moreover, the short distance between

Togolok 1 and Togolok 21 (1.5 km) suggests that agricultural fields and irrigation systems may have served both sites.

| **Plant species** | **Murghab Region, Turkmenistan** | | |
|---|---|---|---|
| | **Togolok 1** | **Gonur Tepe** | **Adji Kui 1** |
| **_Hordeum vulgare_ var. _vulgare_ (hulled barley)** | x | x | x |
| **_Hordeum vulgare_ var. _nudum_ (naked barley)** | x | x | x |
| **_Triticum aesitivum/turigidum_** | x | x | x |
| **_Triticum_ cf. _sphaeroccum_ (highly compact wheat)** | x | x | |
| **_Triticum_ cf. _dicoccum_** | | x | |
| **_Triticum monococcum_** | | x | |
| **_Panicum_** | x | x | x |
| **_Cicer arietinum_** | x | x | x |
| **_Lens_** | x | x | x |
| **_Pisum_** | x | x | x |
| **_Lathyrus sativus_** | x | x | x |
| **_Vicia faba_** | x | | x |
| **_Vicia ervilia_** | x | | x |
| **_Vitis_** | x | x | |
| **cf. _Malus_** | x | x | |
| **cf. _Prunus_** | x | x | x |
| **_Crataegus_** | x | | x |
| **_Pistacia vera_** | | | |
| **_Lallemantia_ (oil crop)** | | | x |
| **_Linum_ (cf. flax seed)** | | | |

*Table 6.1 The table presents the most important botanical species (presence/absence) recovered from fortified sites (adapted from Billing et al. 2022:Table 2).*

Regarding the faunal remains, the main type of husbandry in Togolok 1 revolved around the keeping of sheep and goats, with a small percentage of cows and pigs. The analysis of seeds embedded in the dung may be indicative of grazing regimes. Certainly, the presence of both domestic and wild seeds in the dung surviving the digestive process may indicate the existence of two potential grazing locations (Spengler 2019b): cultivated fields post-harvest and the steppe. Nevertheless, domestic seeds embedded in the dung could also imply that sheep and goats were fed with straw or crop chaff (Billings et al. 2022).

Altogether, the preliminary analysis from Togolok 1 trenches suggests an agropastoral system integrating cereals, legumes, and fruits. Sheep and goat husbandry was also essential for broadening the spectrum of economic activities that included pastoralism.

This agricultural system would likely have necessitated some form of management, such as crop rotation throughout the year. In such a scenario, the coordination of the irrigation system, whether from canals or natural channels, along with the distribution of settlements, played a crucial role in ensuring the efficiency and success of the system.

## 6.3 Results: Remote Sensing Analysis of the Paleochannel Network

The botanical data from Togolok 1 suggests that the Togolok area was likely dependent on irrigation farming during the 3rd and 2nd millennium BCE. As discussed in Chapter 3, during the first decades of investigations by Soviet archaeologists, little attention was given to farming landscapes. The presence of channels and possibly canals in a dense settlement cluster areas have often been postulated, but no systematic research has been undertaken on the water management system. Likewise, how hamlets and small sites that characterize the surroundings of large sites fortified sites in Margiana were located with respect to water resources has not been investigated.

The first stage in the investigation of the Togolok hydrological landscape is the analysis of satellite images and maps. Unlike the Ojakly area, Togolok 1 is located today in a less arid area with some vegetation. Bushes and saksaul trees can mask paleochannel traces. Moreover, due to its location closer to modern villages, the Togolok area is being farmed extensively at present. As a result, sites and paleochannel evidence have been partially destroyed. In this context, satellite images and maps taken before the expansion of farming have been crucial to identifying ancient channel traces.

The first satellite images that were examined are from CORONA.[91] The CORONA images captured in the 1960s and 1970s (see Chapter 4), before the agricultural expansion, proved to be crucial for identifying ancient channels.

Landsat images also provided good data on the landscape despite their low resolution. However, in Landsat images[92] modern vegetation cover is quite visible. The multispectral images are particularly crucial for validating ancient and modern channels.

Sentinel images, in particular Sentinal-2, were used to identify paleochannels in the Togolok area. However, as discussed previously (see Chapter 4 on methodology), their ground resolution for the Murghab is low. Therefore, they have only been used to differentiate between paleochannels and modern canals.

*Figure 6.12 The figure shows the drone operation during the drone survey in the Togolok area.*

Unmanned Aerial Vectors (UAV), commonly known as “drones,” have not been specifically adopted for paleochannel reconstruction in the Togolok area. However,

---

[91] The Togolok area is covered by the same strips that cover the Ojakly area.

[92] For the area of Togolok, Landsat 5 TM and Landsat 8 (provided in Bingmap via QGis) were used for reconstructing and interpreting paleochannel features.

during the first fieldwork season,[93] a small part of the research area was mapped (Figure 6.12). The photo-mosaic produced was incorporated for validating part of the paleochannels identified by satellite images. The good resolution of the aerial photos facilitated a broad understanding of the paleochannels in the Togolok area, including their takyr surfaces.

Maps, alongside satellite images, played a pivotal role in interpreting the paleochannel system in the Togolok area. Moreover, like in the Ojakly area, maps were especially valuable for distinguishing modern roads from channels and identifying artificial structures such as *khaks* and modern canals.

### 6.3.1 The Togolok Paleochannel System

The Togolok area comprises 31 sites, of which the main mound is Togolok 1. The area was initially surveyed by Soviet archaeologists who identified substantial pottery scatters around the main sites (Sarianidi 1990a:43). In the 1990s, the area was re-surveyed by the AMMD, which identified several additional settlements. The AMMD conducted a specific survey in Togolok based on rectilinear, uni-directional route methodologies (Bintliff and Snodgrass 1985) in order to investigate the pottery scatters around the mounded sites. These surveys served to highlight the spread around Togolok 1 and to investigate land use as well as workshop areas as already done elsewhere (Wilkinson 1982; 1989). The survey conducted by Cleziou et al. (1998) documented a dense spread of pottery around Togolok 1.[94] Although this spread might relate to erosion processes or manuring (see Wilkinson 2014 on this topic), beyond 1 km from the site of Togolok 1 there is a rapid fall-off of surface pottery that can be best interpreted as different land uses rather than relating to erosion or manuring (Figure 6.13). As such, the extent of this dense spread of pottery materials around Togolok has been interpreted by Cleziou as a possible farming area at the main site of Togolok 1.

---

[93] The drone survey was conducted under the umbrella of the *Project for the Ancient Murghab* (PAM) whose objective was a pilot mesoscale survey of the Togolok 1 site and a few adjacent areas; the drones produced more than five thousand aerial photos (Olson and Rouse 2018).

[94] They documented over 2000 pottery pieces per sampling point.

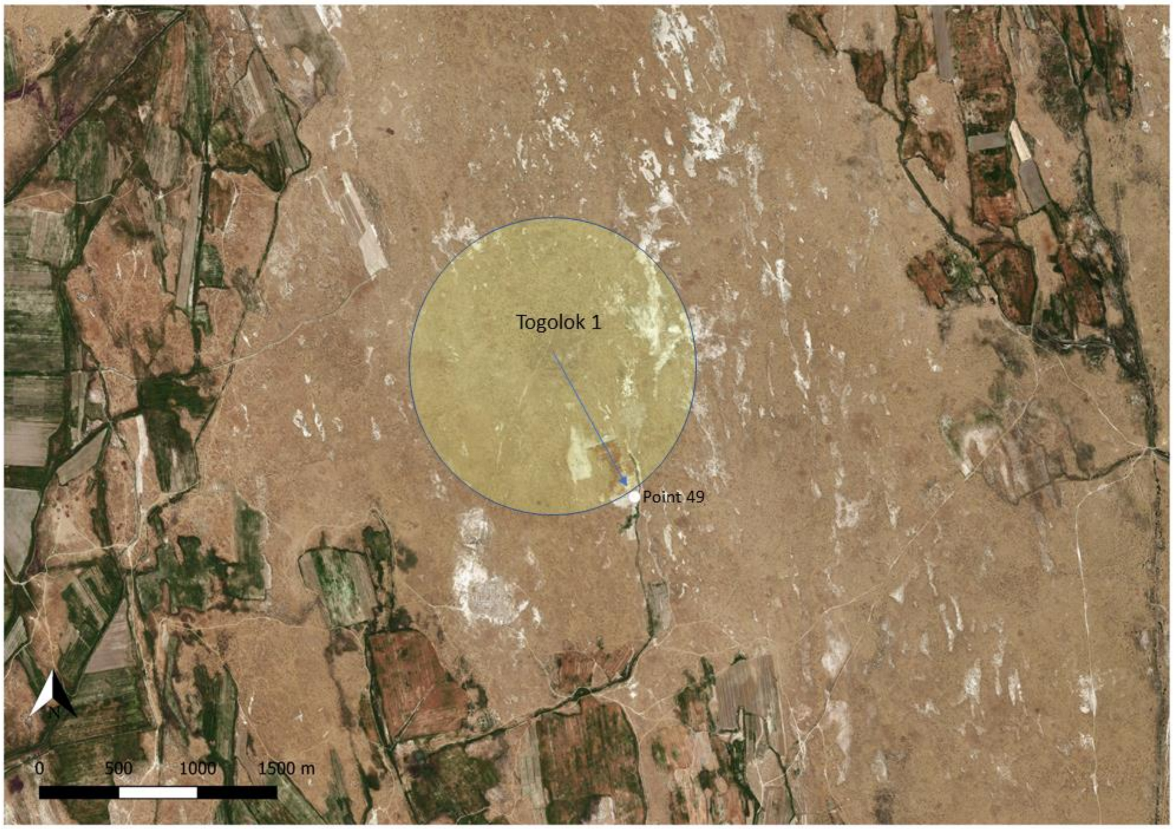


*Figure 6.13 The figure presents the area where the greatest concentration of ceramics was recorded by Cleziou et al. (1998) and Cattani and Salvatori (2008). Point 49 on the map marks the location after which, walking from the center of Togolok 1, there is an abrupt decline in pottery distribution.*

In 2009, an additional survey was conducted by the AMMD in the area. Four strips of ca. 9 ha extending to the northwest and southeast of Togolok 1 were surveyed (Cerasetti et al. 2014:Figure 12). The survey strips were located in the vicinity of Togolok 1 in an area that previously Cleziou et al. (1998) had found concentrations of pottery. However, employing a distinct and more detailed survey methodology featuring a 20 × 20 m grid, the team uncovered the existence of four significant clusters of pottery, situated both to the northwest and southeast of Togolok 1. These clusters may suggest the presence of small settlements near Togolok 1 or indicate different land uses (Cerasetti et al. 2014:Fig.15) The results of the surveys, both by the AMMD and Soviet, suggest the presence of many small sites in the Togolok area possibly playing a role in water and land management. To investigate ancient watercourses, a research area of approximately 28 km$^2$ was selected on a GIS platform with the center at Togolok 1 (Figure 6.14).

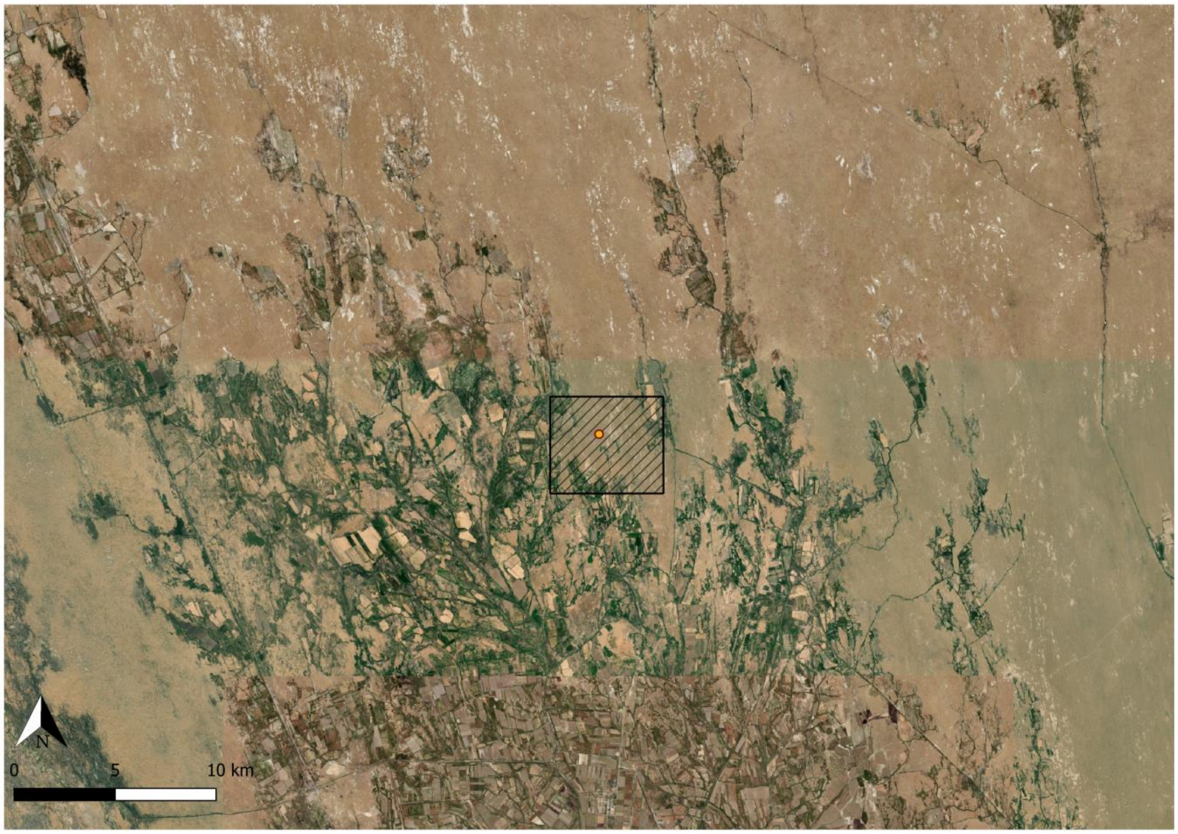


*Figure 6.14 The square with oblique black lines shows the research area. The orange point is Togolok 1 (north mound) which is the main site of the Togolok area.*

- **Modern Canals**

Over the last decades, there has been substantial agricultural expansion in the Togolok area, despite the fact that both Togolok 21 and Togolok 1 are within a heritage-protected area. At the present, the Togolok area is bounded by three major agricultural zones, which have limited the possibility of ground truthing of the ancient paleochannels, and have partially or completely destroyed these features (Figure 6.15). As a result, the research area in Togolok is smaller than that in Ojakly, which was much less affected by modern agriculture.

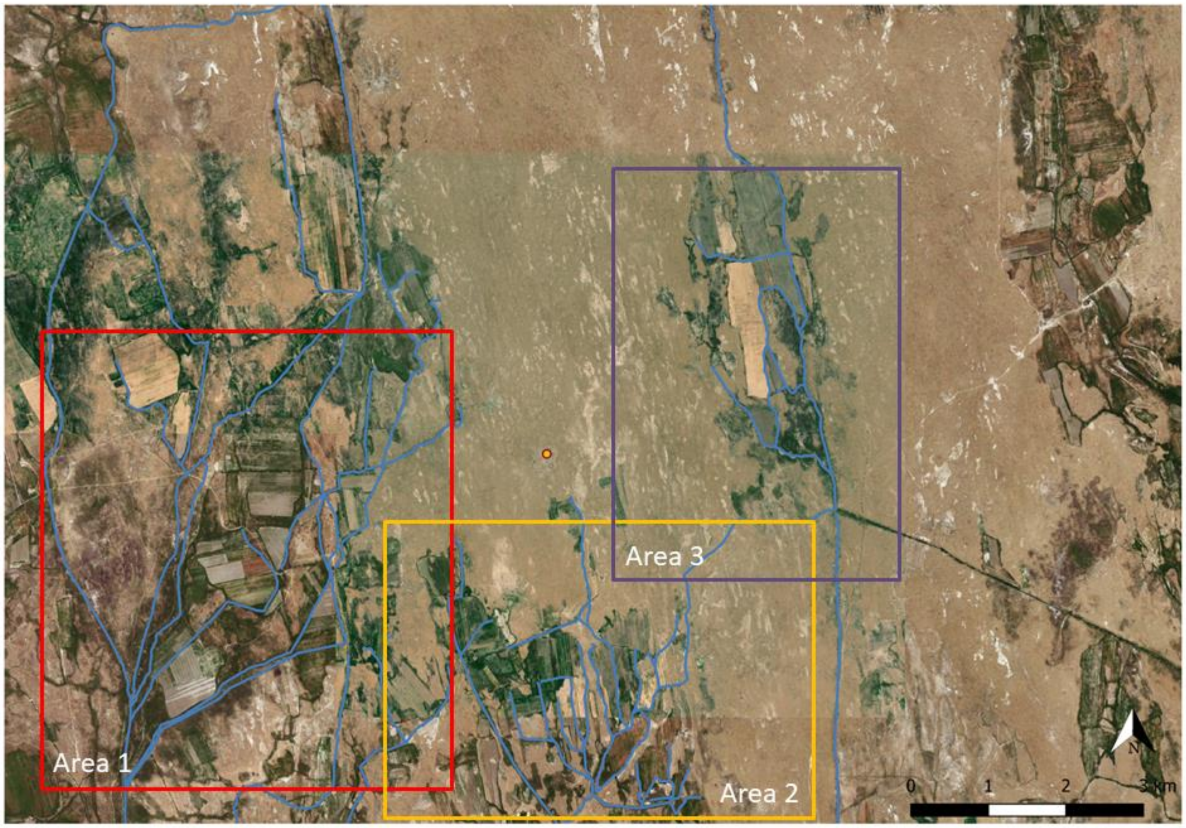


*Figure 6.15 The figure displays the three modern agricultural zones surrounding the Togolok area. It is evident that certain modern channels have become active again because of old channels, while the majority of small canals have been excavated using machinery. The orange point marks Togolok 1.*

The western area (Area 1, Figure 6.15) is approximately 4 km from Togolok 1. The area shows the presence of four major canals and several smaller canals delivering water to the fields. It is likely that the area started to be cultivated during the 1980s, as the satellite images show. Indeed, in the CORONA image dated to the 1970s the area is free of canals and fields. In addition, it also shows that most of this agricultural area was very large and it is unlikely that the present modern canals are the result of the old channels becoming active again. Their modern flow direction is north/northeast while almost all the ancient channels detected near Togolok have a north/northwest direction. However, one cannot rule out that some of the modern canals partially overlap with older channels, but this is difficult to investigate. The CORONA images also highlighted a black anomaly in the southeast of Area 1 similar to the one detected in Ojakly (Chapter 5, Figure 5.24). The

Landsat images show the presence of possible water storage areas in the same location, along with evidence of an abandoned farmstead (Figure 6.16). These anomalies should be best understood as a recent farmstead and water storage facilities.

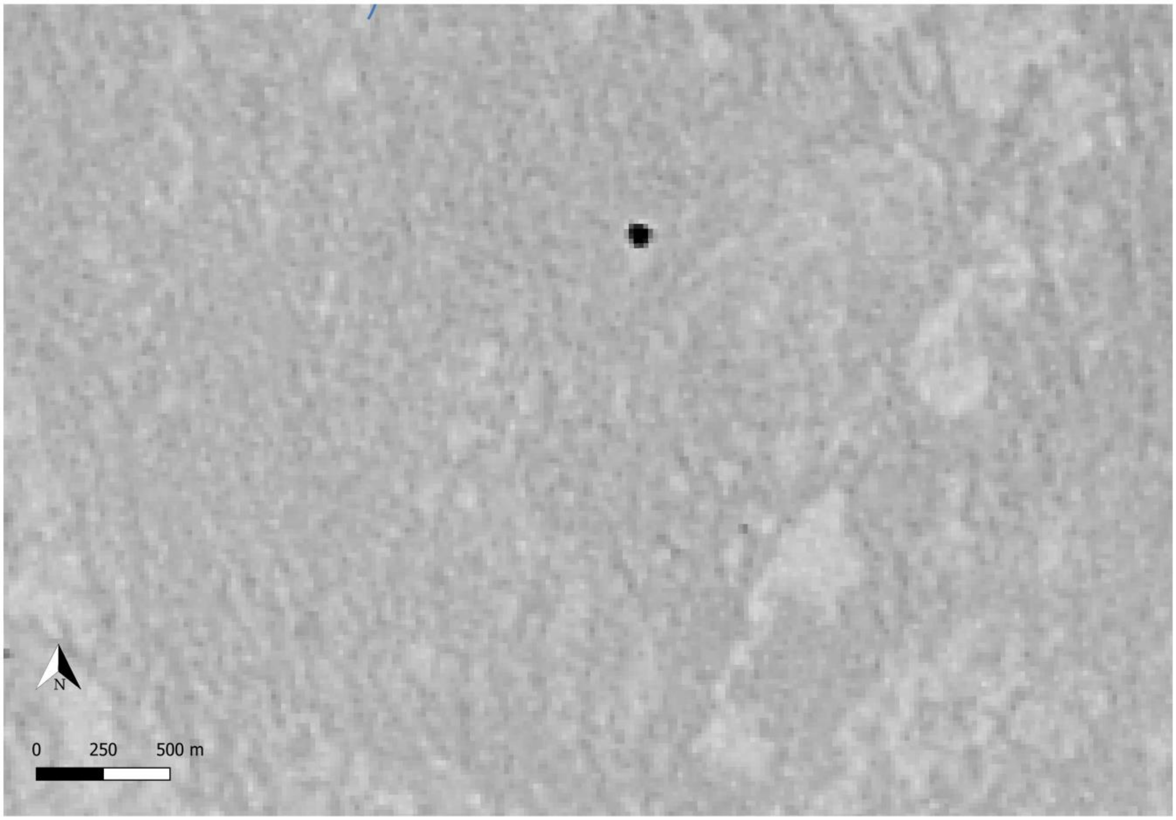


*Figure 6.16 The figure shows the presence of possible water storage areas, or an abandoned farmstead structure (black anomaly) located in Area 1 from Figure 6.15.*

The second largest agricultural area (Area 2, Figure 6.15) is located ca. 3.5 km south of Togolok 1. Like Area 1, it started to be cultivated in the 1980s, as satellite images suggest. The CORONA image shows the area has a large takyr and, from the north, there has been an artificial canal dug in recent years which reaches Togolok 1 to ca. 400 m. The canal brings water to a small irrigation area that impeded the complete paleochannel survey of Area 4 (see section 6.4 of this Chapter for survey areas). Unlike in Area 1, the modern canals that bring water to the fields have a north/northwest direction. It is possible that some of these modern canals are older channels that have become active again. Notably, the flow directions of modern canals are consistent with those of the ancient channels. Further, the CORONA images show the presence of elongated lines in the southwest of the agricultural area (Area 2, Figure 6.16) with spectral characteristics similar to those of old channels. However, in the absence of any ground truthing, these possible ancient channels must be interpreted with caution.

The third largest agricultural area is located approximately 3 km northeast of Togolok 1 (Area 3, Figure 6.15). Like Areas 1 and 2, the CORONA image shows that it was characterized by large takyr surfaces that were later taken into cultivation. Landsat images are indicative that the area was first irrigated in the 1980s, while in the 1990s new canals with an east–west direction were dug. Unlike in Area 2, the CORONA image does not show any elongated features with characteristics of old channels. However, the possible flow direction of old channels such as Paleochannel 10 (TGK1_Ch_XII) (see next paragraph) may also be indicative of the presence of old channels in this area that are not visible in the CORONA images.

- **Ancient Channels**

The identification of ancient channels in the Togolok area was conducted by visual analysis and by comparing satellite images and cartographic maps. The combination of the different images and maps on a GIS platform led to the interpretation of ancient channel traces. The visual detection was based on spectral signals along with elongated or meandering shapes and the directionality of former watercourses.

The interpretation of paleochannels in the Togolok area was hampered by the presence of dunes and agricultural fields. Ancient channels spotted in CORONA images could often not be validated in Landsat images for these reasons. The north part of Paleochannel 1 (TGK1_Ch_XIV), for instance, is now covered by an extensive field system (Figure 6.17). Therefore, the ground truthing of the paleochannels in the first field season was crucial to correctly interpret these paleochannels.

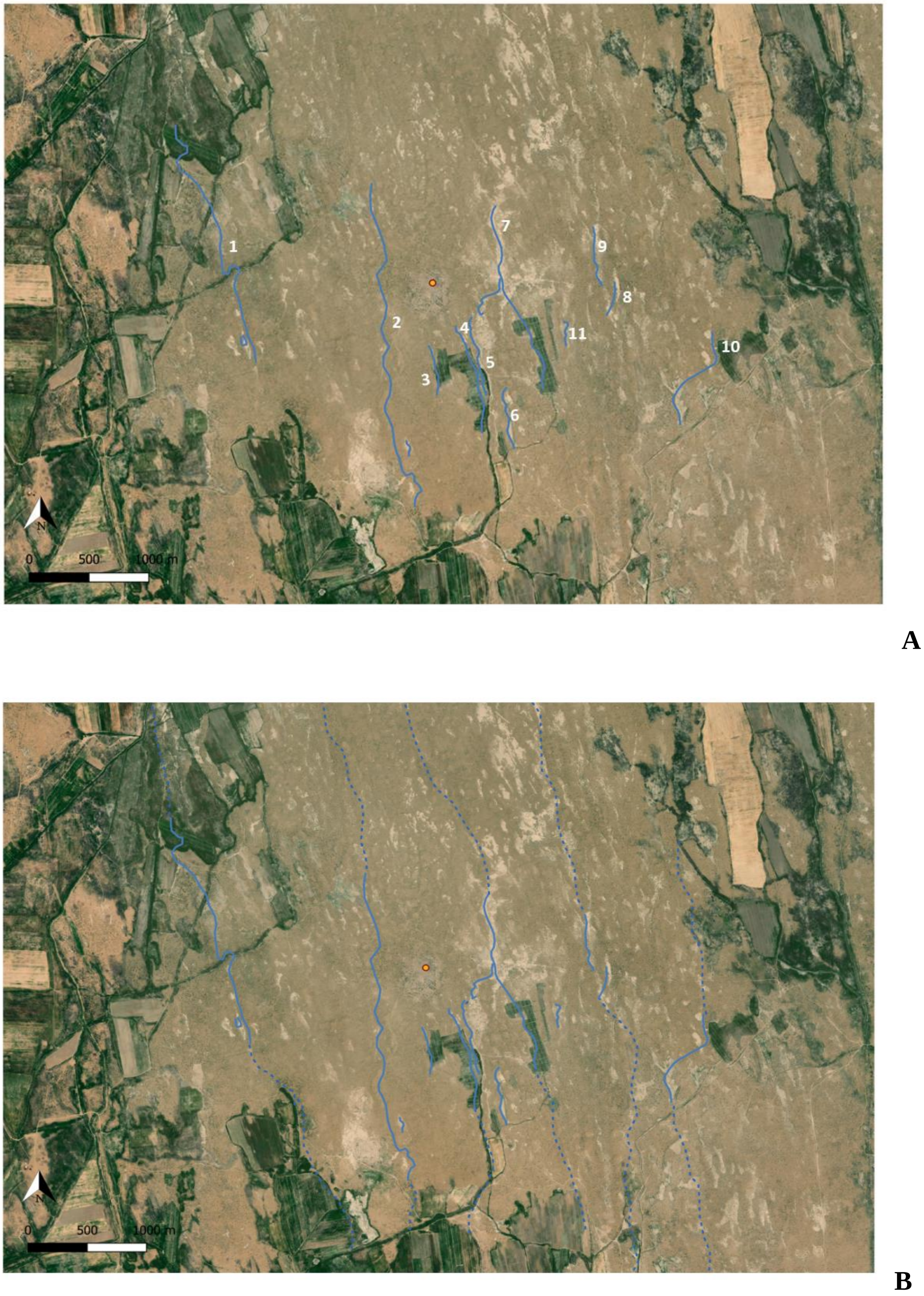


*Figure 6.17 A) The image displays the paleochannel identified in the Togolok area. B) The dashed lines in the image indicate the possible flow direction of the paleochannel traces, suggesting a north/northwest direction.*

In the Togolok area, a total of 14 paleochannel segments were identified and grouped in 11 paleochannels (Table 3.1 in the Appendix 3) (Figure 6.17). Similar to the previous case study of Ojakly, when the position of the paleochannel segments most likely represented fragments of the same channel, they have been grouped as a single watercourse. Compared to the Ojakly area, where there are many short channels, in the Togolok area, most of the paleochannel traces detected are longer than 1 km. In addition, the paleochannels identified at Togolok show little evidence for avulsion compared to Ojakly.

The flow direction of the paleochannels detected in the Togolok area is north/northwest with the presence of very small curves suggesting possible meanders. The area has four main channels. Three of them, Paleochannel 2, 4, and 5, are located west and east respectively, of the main mound of Togolok 1 at a distance of between 300 and 500 m. Likewise, Paleochannel 2 runs at approximately 300 m from Togolok 21, possibly acting as a main water resource for both sites. Although Paleochannel 5 could only be detected over a few kilometers, it passed adjacent to the southern mound of Togolok 1. Further to the north, Paleochannel 7 runs along the kiln areas discovered by Sarianidi (1990a:35, 251–252) and, along with Paleochannel 2, it forms the primary channel system of Togolok 1.

The paleochannel traces identified at Togolok, similar to those at Ojakly, have shallow levees compared to those in Mesopotamia. Such lightly elevated channels would have been favorable places for building dams and diverting water, as water from shallow canals is actually easier to manage and control (Wilkinson 2003:89).

In the research area, the majority of settlements are located along channels (see section 6.4.4 of this Chapter). The distance between paleochannels, in particular in the area between Paleochannels 2 and 5, is only 300 to 500 m. By contrast, in the Ojakly area, there is an average distance between paleochannels of about 1 km. The smaller distance between channels in Togolok, along with the shallow levees, would have been advantageous for cultivation with intra-channels crop fields. Small canals and dams might have been in place between channels, feeding an extended agricultural area. Indeed, as discussed above (section 6.2.4 of this Chapter), botanical analysis from Togolok 1 suggests a multi-crop agricultural system with grains, pulses, and fruits (Billings et al. 2022).

- **Artificial Channels (Canals)**

Although Togolok 1 and Togolok 21 are large, fortified sites, no artificial canals have been identified on satellite images or in a pedestrian survey. So far, the only excavated canal in the Murghab is located south of Gonur North. The canal has a transversal axis and was probably taking water from the main channel west of Gonur. Additional possible canals have recently been detected by geomagnetic survey east of Gonur North and between Gonur North and Gonur South (Dubova 2019; Hübner et al. 2019). The size of the archaeological sites at Togolok might suggest that similar canal features existed in the Togolok area as well. However, these features are difficult to identify on satellite imagery. Sataev (2008:Fig. 90) informs us that the canal excavated at Gonur North had a width of approximately 2.5 m and a depth of approximately 1 m. Such small features would be very difficult to identify in remote sensing and would retain less moisture than large natural channels. In addition, in Gonur, the canal was a short-lived structure later re-filled with ash and settlement debris (Hübner et al. 2019). As such, it is likely that these canals might be better visible in geophysical investigations. For instance, the geomagnetic investigation around the Late Bronze Age site of Takhirbaj, southwest of Togolok, revealed the possible presence of a ditch near the main citadel (Becker 2007). Evidence of early management of these canals is attested at the site of Sarazm in the Middle Valley of Zeravshan (Tajikistan), where a canal has been dated by OSL to the Early Bronze Age (3rd millennium BCE). Evidence suggests that the bottom of the canal was artificially prepared and traces of the clearing of the canal have been observed that suggest maintenance (Cez 2019).

Altoghter, the analysis conducted in this study indicates the existence of a natural channel system in the Togolok area, with several settlements situated along them. In addition, the short distance between these channels may have been augmented with small canals, which would have boosted the development of a larger agricultural area. However, the presence of such canals cannot be proven at present.

## 6.3.2 Ground Truthing the Paleochannels

During the field season the paleochannels remotely identified in the Togolok area were ground trothed (Figure 6.18). As discussed for the Ojakly area, remote sensing analysis only represents the first step in the evaluation of an ancient paleochannel.

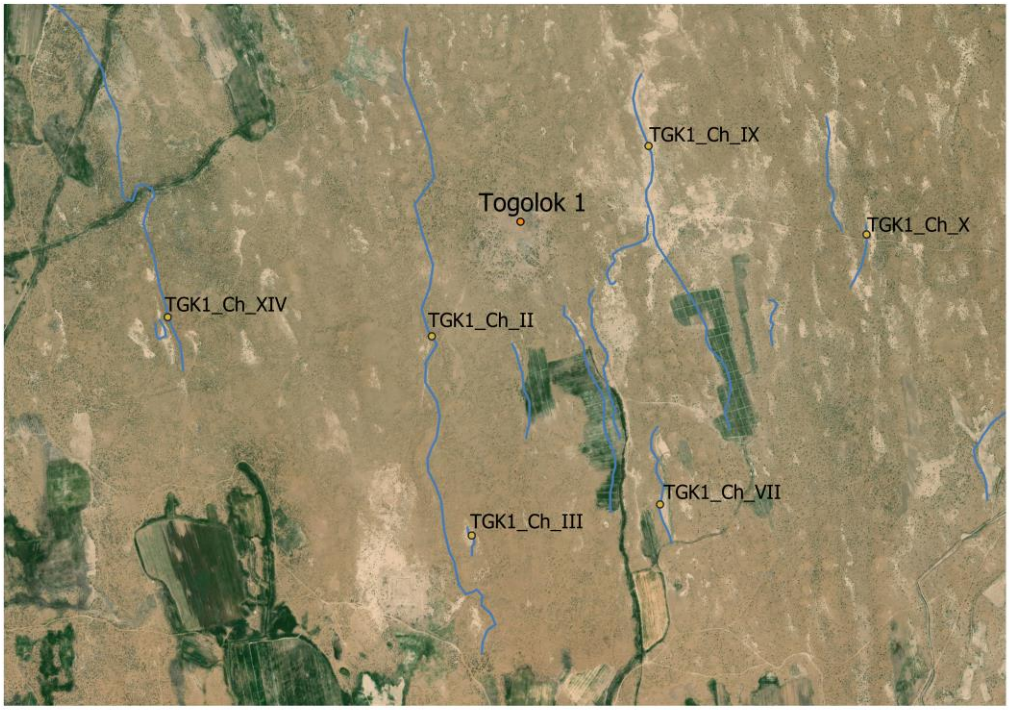


*Figure 6.18 The figure shows the control locations of the paleochannels identified by remote sensing analysis.*

Although the color, direction, the size, and the shape are good indications of the presence of a former riverbed, only ground truthing can confirm their existence (Jotheri and Allen 2020). Moreover, a paleochannel survey is crucial to understand the characteristics of the local ancient fluvial system and to find out to what extent different areas in the Murghab, such as Toglok and Ojakly, were similar.

As discussed in the methodology chapter (Chapter 4), the first paleochannel survey was conducted by car, targeting specific points identified on satellite images.[95] These points were selected as the best location to verify the presence of the ancient watercourses and to allow the identification of channel characteristics and possible archaeological evidence. The survey by car allowed the verification of the following paleochannels:

- **Paleochannel 1** (TGK1_Ch_XIVa and TGK1_Ch_XIVb) was approximately 30 m wide at the point of the visit. The segment TGK1_Ch_XIVb suggest the presence of a possible middle channel bar of approximately 20 m wide with former banks (Figure 6.19). The riverbed consists of a takyr surface that could be followed on the ground for more than 200 m, with almost no vegetation on it. The left former bank was characterized by small bushes with a slight elevation form of about ca. 1 m while the right bank was less then ca. 0.5 m in elevation.

*Figure 6.19 The figure presents Paleochannel 1 (TGK1_Ch_XIVb) with its takyr surface marked with dotted line.*

---

[95] The survey was conducted jointly with the "Project for the Ancient Murghab" (PAM), directed by L. Rouse (German Archaeological Institute – DAI / Washington University in St. Louis).

- **Paleochannel 2** (TGK1_Ch_II and TGK1_Ch_III) was detected from CORONA images. Although its elongated form and its spectral signal, as well as its flow direction, were evident on the satellite images, sand dunes had completely covered these features. However, the former riverbank could be determined as the west and east bank were slightly elevated to ca. 1 m. In addition, similar to what was observed in Ojakly at Paleochannel 8, the former riverbed was characterized by reduced vegetation compared to the bush vegetation on the sides. By contrast, at the smaller paleochannel traces at TGK1_Ch_III, part of the same channel was visible with a takyr surface that had some minor bush vegetation on it (Figure 6.20).

*Figure 6.20 The figure presents the  the takyr surface of Paleochannel 2 (TGK1_Ch_III) marked with a dotted line.*

- **Paleochannel 6** ( TGK1_Ch_VII) was characterized by a takyr surface with sand dune accumulation on the right and left paleobanks. The former channel could be observed on the basis of the scarce vegetation on it (Figure 6.21). Notably, a small modern anomaly was visible in the middle of the paleochannel that was likely formed by a recent flash flood from rain. Indeed, few days before our visit, the Murghab had experienced some days of heavy rain. It is common in flood plains that ancient riverbeds can occasionally be re-activated. Some of them are still used as a source of water for cultivation (Chen et al. 1996).

*Figure 6.21 The picture presents the takyr surface of Paleochannel 6 (TGK1_Ch_VII) marked with a dotted line.*

- **Paleochannel 7** (TGK1_Ch_IX) was characterized by a large takyr surface with almost no vegetation on it (Figure 6.22). The former riverbanks were slightly elevated (≤ 20 cm). However, the presence of the former watercourse was evident from the very scarce vegetation on the bed and the bush vegetation along its former banks. Interestingly, a small pottery assemblage was found on the bed of the channel. It is probably the result of post-depositional processes, notably flash flood events, which can move artifacts (Markofsky and Bevan 2012). This pottery was dated to the Middle and Late Bronze Age. During fieldwork we noticed that the south part of the present paleochannel was cultivated, and the area was occupied by field systems. Indeed, ancient channels are a good place for cultivation as they can retain moisture.

*Figure 6.22 The figure shows the takyr surface of Paleochannel 7 (TGK1_Ch_IX) with the presence of small assemblages of pottery next to the meter stick.*

**- Paleochannel 8** (TGK1_Ch_X), at the point of the visit, was characterized by a takyr surface with almost no vegetation on it (figure 6.23). Similar to Paleochannel 7, the former channel banks were slightly elevated to *ca.* ≤ 20 cm and showed sand dune accumulation with bush vegetation on it. The modern road that led to the Togolok 1 site cut the paleochannel through the middle (Figure 6.24). During the fieldwork, the area was surveyed with a drone that resulted in a detailed recording of the channel features that confirmed the elongated takyr structure of almost 300 m (Figure 6.24).

*Figure 6.23 The figure shows the takyr surface of Paleochannel 8 (TGK1_Ch_X) characterized by almost no vegetation.*

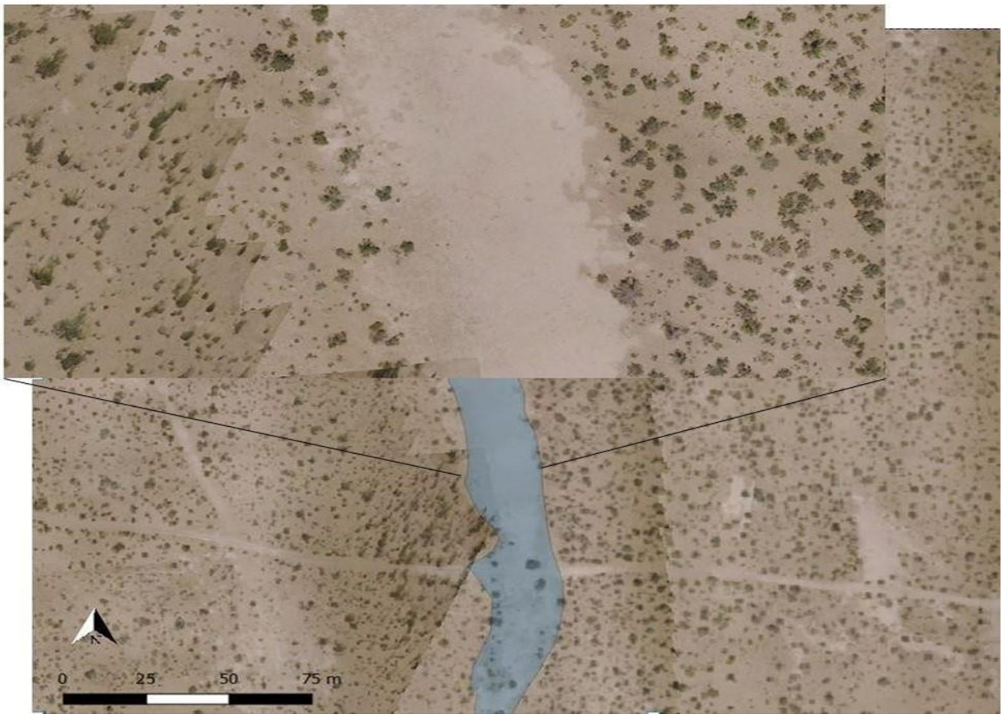


*Figure 6.24 Image of Paleochannel 8 obtained with a DJM Mavic Pro drone. The takyr surface and the elongated form of the former channel with shallow former riverbanks are evident. The riverbed has almost no vegetation.*

- The trace of **Paleochannel 10** (TGK1_Ch_XII) was identified in the CORONA images. At the time of the visit, the possible evidence of an ancient riverbed was covered by sand dunes (Figure 6.25). No elevations could be seen of the possible riverbanks. However, despite the absence of any evidence, its curved form (a possible former meander) and the same spectral signal on CORONA images are a strong indication for the presence of an ancient channel.

*Figure 6.25 The sand dune accumulation prevented the identification of Paleochannel 10 (TGK1_Ch_XII) in Togolok.*

## 6.3.3 Paleochannel Characteristics

- **Validation of Paleochannels in the Togolok area**

The survey by car permitted me to validate the paleochannel structure of Togolok area. Similar to Ojakly, the majority of the channels have shallow beds with limited bank elevations of between 0.5 and 1 m. The channel beds had flat cracked takyr surfaces in most cases with almost no vegetation (mainly small algae). The shallow former banks were usually covered by sand dunes and were overgrown by small bushes. These characteristics are similar to those observed in the Ojakly area. Similar characteristics were also described by Markofsky (2010:180–181) and by Cattani (2008b:140), who identified similar features in the region of Takhirbaj 3.

When sand covers the paleochannel, other characteristics can aid their identification. Slightly elevated levees that bound the former riverbanks alongside the former river can provide key information. In the area of Egri Bogaz, for instance, Markofsky (2010:Fig. 71) identified a possible channel with two elevated sand deposits with an elongated flat surface in the middle covered by sand.

### - The Structure of the Ancient Fluvial System in the Togolok Area

Classifying the ancient fluvial system in the Togolok area is made difficult by the reconstruction of the paleochannel system. Like at Ojakly, most of the ancient waterways could only be partially reconstructed. The presence of modern agricultural systems has masked the presence of paleochannels, such as south of Togolok 24.

The paleochannels identified in the Togolok area have a mostly linear form with the presence of curves that can be interpreted as a small meander. In section 5.4.3, I discussed that river channels can be conventionally classified as straight, meandering, and braided (Leopold and Wolman 1957). The channel patterns depend on hydraulic flow and on sedimentary aspects (Schumm 1963). As discussed for the Ojakly paleochannels, braided channels can occur in a variety of environments, including landscapes with a semi-arid climate (Knighton 1998).

One of the characteristics of braided channels is the presence of channel bars.[96] The central channel bar of a river as described by Leopold and Wolman (1957) requires the deposition of coarser material, usually not deposited by stream courses. Once the deposit grows, and is more consistent with successive additions, the bar becomes more defined in

---

[96] See Glossary for definition.

its shape with the creation of flanking channels that can also cause bank erosion (Knighton 1998:233). The presence of channel bars in the Togolok area can be suggested on Paleochannel 1 (TGK1_Ch_XIVb). The channel has an elevated area in the center that can be interpreted as a possible channel bar. It is covered by a sand dune, and from a satellite image (Figure 6.26) two small flanking takyr channel beds can be observed on both sides, of which the western one is wider. The ground truthing conducted confirmed the presence of a small area covered by a sand dune and increased vegetation in the middle of the paleochannel. The area was slightly elevated compared to the takyr surface on the riverbed.

*Figure 6.26 The image shows one paleochannel trace (TGK1_Ch_XIVb) with a takyr surface and a possible channel bar covered by aeolian sand in the middle.*

In addition to one channel bar, braided channels can also have multiple bars, which usually occur in wider channels. In this situation, the water flow becomes concentrated into several smaller streams, which then cut through a sandbar that was built earlier and this can create multiple bars (Knighton 1998: 234). In the down-stream section of Paleochannel 7 (TGK1_Ch_IX), the channel appears wider compared to the other channels.

In the center of the channel, the spectral signal of multiple features is different from the normal takyr surface (Figure 6.27). It is darker, and most likely has an aeolian sand deposit. These features appear to be similar in terms of color and shape to the one observed in Paleochannel 1, verified by ground truthing. It is likely that the presence of these features in a much larger channel may represent evidence of possible multiple channel bars. However, such a hypothesis is preliminary, as no ground truthing was performed but it nevertheless provides an indication of the possible channel system.

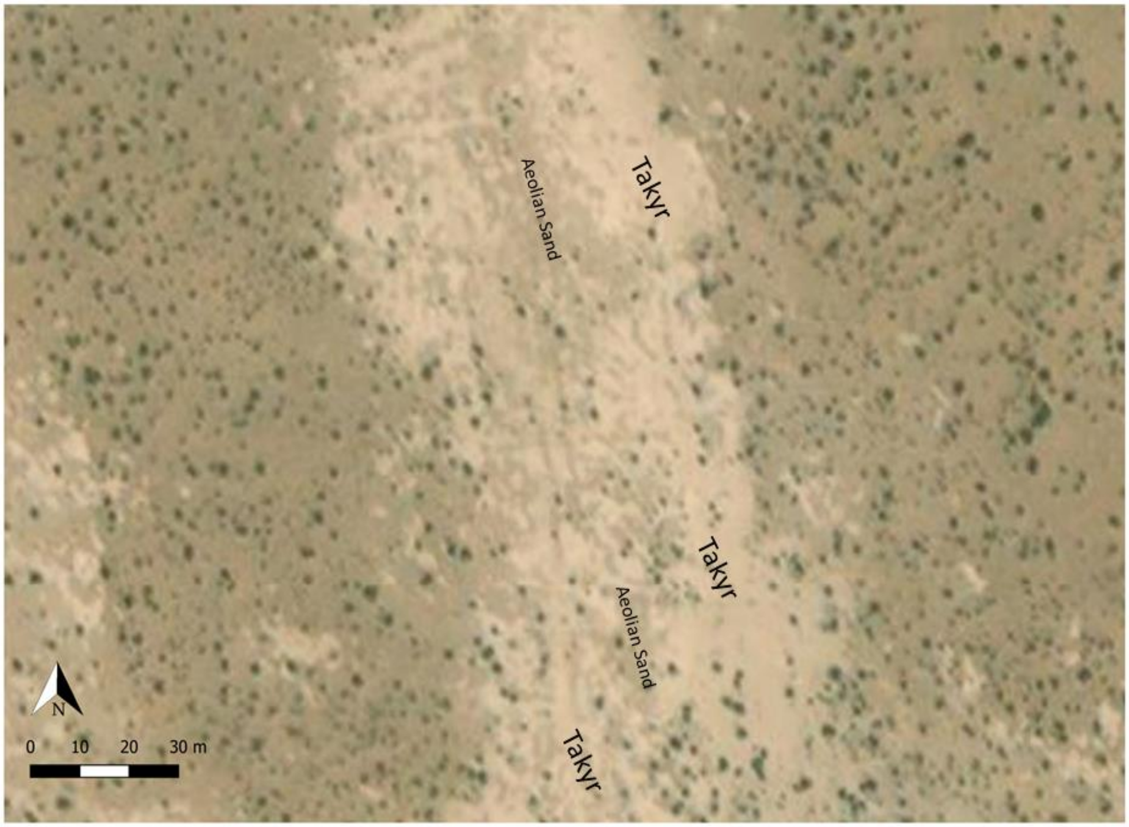


*Figure 6.27 The image shows one paleochannel trace (TGK1_Ch_IX) with takyr surfaces and possible multiple channel bars slightly elevated and covered by aeolian sand.*

The presence of several straight to curve channels at a relatively short distance, as well as the presence of possible braided channels with possible middle and multiple bars, suggests we are possibly dealing with an anabranching river system. As discussed in Chapter 5, Makaske (2001) classified this rivers as a composite form of a multi-channel system.[97] This system can be composed of either individual channel belts that may be straight, but also meandering, and braided. However, while anabranching rivers can potentially have all the three different categories of channels outlined above, some categories occur more often, such as straight and meandering forms (see section 4.3.6.1 in Chapter 4 for river system characteristics).

It is unlikely that the channels identified in the Togolok area were part of a system of artificial canals. In section 5.4.3 in Chapter 5 I discussed the characteristics outlined by Jotheri (2018) to distinguish between artificial canals and natural channels. The channels identified in Togolok, such as Paleochannel 2, have curves that are most plausibly meanders, which are characteristic for natural channels, while canals are usually characterized by a linear course. In addition, the possible presence of middle channel bars in some of the identified channels further suggest a natural processes rather than an artificial formation. However, the substantial amount of sites along specific channels in Togolok might be indicative of possible maintenance of the natural channels.

The characteristics from the channels identified in Togolok with curves (possible meanders), sinuosity, and a natural gradient of flow, all suggest they are natural channels located at a short distance from each other. The botanical assemblages including well-preserved barley and wheat rachises, alongside seeds embedded in animal dung (see section 6.2.4 of this Chapter; Billings et al. 2022) further suggest that agricultural fields were located along and between these channels and that water from the channels was used for irrigation.

---

[97] However, definition and characteristics of this river system based on channel pattern only is debated (Rust 1978; Smith and Smith 1980; Schumm 1985; Yonechi and Maung 1986; Knighton and Nanson 1993).

## 6.4 Results: the Field Survey in the Togolok Area

The remote sensing analysis and the field survey conducted in the Togolok area documented various channels that provided water to settlements. The Soviet and AMMD surveys identified more than 30 small settlements in the area. However, these past investigations did not target any paleochannel traces; within the scope of the current project, six areas were selected along the identified paleochannels (Table 6.2) to better understand the relationship between settlements and water resources, also in terms of channels periods of activity (see sections 6.4.4 and 6.4.5 below).

| **SURVEY AREA** | **SIZE** | **PALEOCHANNEL** |
|---|---|---|
| **AREA 1** | 1.47 km$^2$ | **Paleochannel 1**<br>(TGK1_Ch_XIVa, TGK1_Ch_XIVb) |
| **AREA 2** | 2.19 km$^2$ | **Paleochannel 2**<br>(TGK1_Ch_II, TGK1_Ch_III) |
| **AREA 3** | 0.98 km$^2$ | **Paleochannel 4**<br>**Paleochannel 5**<br>(TGK1_Ch_V, TGK1_Ch_VI) |
| **AREA 4** | 1.44 km$^2$ | **Paleochannel 7**<br>(TGK1_Ch_IX) |
| **AREA 5** | 0.91 km$^2$ | **Paleochannel 8**<br>**Paleochannel 9**<br>(TGK1_Ch_X, TGK1_C11) |
| **AREA 6** | 1.02 km$^2$ | **Paleochannel 10**<br>(TGK1_Ch_XII) |

*Table 6.2 Togolok walking survey areas with relative size and paleochannels presence.*

The survey methodology for Togolok was the same as for Ojakly (see Chapter 4 for the survey methodology). The survey areas covered almost all the paleochannels detected by remote sensing analysis, with the exception of Paleochannel 3.

As discussed in section 5.5 in Chapter 5, vegetation and sand dune accumulation are the main factors that affect archaeological visibility. However, the Togolok area is generally less impacted by sand accumulation compared to the distal areas, such as Ojakly or Adam Basan. In addition, the second field survey season, which targeted the paleochannels, was conducted during the fall when there is less lush vegetation compared to the spring. As a result, areas with accumulated archaeological materials (mainly pottery) were quite visible on the surface during the survey.

*Figure 6.28 The figure shows the six survey areas in Togolok (orange boxes).*

### 6.4.1 Recorded Sites

Although the AMMD survey of the last two decades in the Togolok area recorded many sites (see section 6.4.3 below), during the field campaign a total of ten new sites were found (Figure 6.29; Table 3.2 in the Appendix 3). When a new site was discovered, it was recorded with a GPS point and photographed on the ground. As for Ojakly, only a sample of archaeological diagnostic material was collected (e.g., diagnostic pottery).

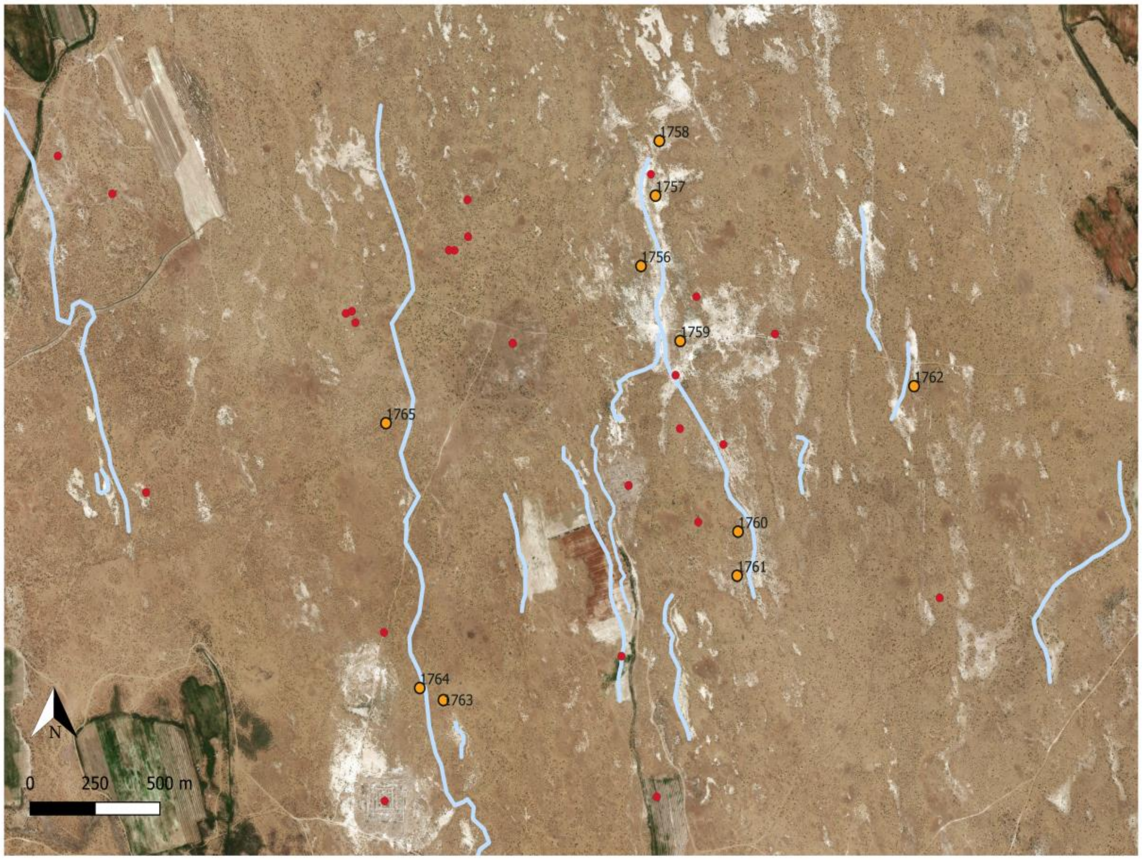


*Figure 6.29 The image shows the distribution of the new sites identified by the present project in Orange. In Red, the sites previously identified by AMMD and Soviet surveys dated to the Bronze and Iron Age.*

Most of the sites recorded by the present project are located in Area 4, while Areas 2 and 5 also present sites along their former channels.

In Area 2, Paleochannel 2 is the longest channel in the Togolok area and it is located east of Togolok 21. Along the channel three new sites were recorded. Site n.1765 was recorded on the west of Paleochannel 2 and was characterized by an aggregation of pottery on a flat surface over an area of less than 1 ha and recorded as large cluster. Towards the south, sites n.1764 and n.1763 are located 100 m apart from each other on the left and right sides of Paleochannel 2. Site n.1763 is on a flat surface in the vicinity of a takyr with a pottery cluster and was recorded as small cluster. Similarly, on a flat surface next to a small takyr, site n.1764 has a small pottery concentration as well. None of these sites show evidence for structures on the surface or kiln fragments.

In the survey of Area 4, six new sites were recorded along Paleochannel 7 which currently hosts the highest concentration of archaeological sites along its former course. Site n.1758 and n.1757 are located approximately 200 m from each other. While site n.1758 was characterized by a small concentration of pottery on a flat surface (small cluster), site n.1757 is on an elevated surface with a substantial scatter of pottery and was recorded as a low mound. Interestingly, several kiln fragments were found on this site. It is likely that sites such as n.1757 were part of the pottery production cluster nearby discovered by Sarianidi (1990a) along Paleochannel 7 (see below, section 6.4.3, for discussion). Towards the center of the former channel, site n.1756 has a pottery cluster on a slightly flat area and was recorded as large cluster. Approximately 300 m to the south, site n.1759 is on a similar surface area with a considerable amount of pottery and kiln wasters and recorded as large cluster. On the left bank of Paleochannel 7, two more sites were identified: n.1760 and n.1761. Site n.1760 has an area of dispersed pottery recorded as a large cluster. Similarly, site n.1761, located approximately 150 m to the south, is on a slightly elevated area and has a substantial cluster of pottery and was recorded as a large cluster.

In Area 5, which includes the traces of Paleochannel 8 and 9, only one site was recorded. Site n.1762 was recorded on a small flat area with a small amount of pottery, and was categorized a small cluster.

The AMMD survey documented the existence of sites dating back to the Late Bronze Age in Area 1 during the survey (refer to section 6.4.3). Similarly, no additional sites were recorded in Areas 6 and 3.

The recorded sites from this research generally have a flat or slightly elevated surface with a good amount of pottery and were recorded as large cluster sites. They are mainly single-period sites on the basis of their pottery chronology. Although the survey by the AMMD in the Togolok area did not take into consideration paleochannel location, it is interesting to note that sites recorded by the AMMD and the present project are mostly located along paleochannels (see below, section 6.4.3). Therefore, understanding the distribution of settlements in this area also requires consideration of their economic activities, including land use and irrigation practice.

### 6.4.2 Chronology of the Recorded Sites

As discussed in this thesis, the pottery chronology for the Murghab alluvial fan remains poorly known (Luneau 2010; 2021b). Similar to Ojakly, in the present survey the chronological assessment of pottery was conducted in the field and only samples of diagnostic pottery were collected and photographed, and a broad chronological period was assigned.

Most of the pottery collected at the sites in the Togolok area are wheel-made, although some hand-made pottery was also found that belongs to BMAC (Namazga) pottery (Hiebert 1994a: 41). The sites recorded are mainly dated to the Late Bronze Age (see Table 6.3), with the only exception of sites n.1760 and n.1761 that have pottery dated to the Iron Age 1. The Bronze Age pottery recovered from Togolok is primarily characterized by undecorated vessels. No rims or basins of large bowls were recorded at the sites, nor were terracotta figurines that are usually applied on the rim of these containers (Hiebert 1994a:53). The pottery fabrics of the Bronze Age ranged from rose or reddish color to more beige-buff. Also, darker red wares were recovered, which Hiebert (1994a:40) suggests were more common in the Late to the Final Bronze Age.

The diagnostic pottery dated to the Iron Age 1 (Yaz 1 period) include rims and a base of an unpainted grey ware, as described in Bonora and Vidale (2008). Only sites n.1760 and n.1761 have a good amount of these assemblages, while sites such as n.1759, n.1762, n.1763, and n.1765 contain only a few diagnostic sherds dated to this period.

The sites recorded in the Togolok area are consistent with the data recorded by the AMMD survey that date the sites in the research area mainly to the Late Bronze Age. It is interesting to note that neither the AMMD nor the present survey recorded sites dated to the Middle Bronze Age. However, the excavations of Togolok 1 by Sarianidi and, more recently by the TAP project (Sarianidi 1990a; Cerasetti et al. 2022) contain assemblages dating to this period. It is now commonly accepted that the main tepes are often characterized by a long chronological sequence of multi-temporal occupation. In contrast, the excavation of small Bronze Age sites such as Gonur N., Ojakly, and Chopantam, including the small Iron Age site n.999, suggest one-period occupations (Hiebert and Moore 2004; Cattani 2008b; Rouse and Cerasetti 2014; Bonora and Vidale 2008). Therefore, it is reasonable to suggest that the vast majority of small sites recorded in Togolok can be dated to a single period, which is indicated by the surface material. Consequently, although the primary site of Togolok 1 had been inhabited since the Middle Bronze Age, it was during the late 3rd to early 2nd millennium BCE that the surrounding landscape underwent a significant process of occupation.

| **Site #** | **Chronology** (secondary periods in brackets) | **Site Category** | **Namazga pottery (NMZ), Iron Age Pottery (YAZ)** | **Survey Area** | **Survey Year** | **Coordinates (UTM 41 N)** |
|---|---|---|---|---|---|---|
| 1756 | LBA | Large Cluster | NMZ VI | Area 4 | 2018 | 324917 E<br>4220716 N |
| 1757 | LBA | Low Mound | NMZ VI | Area 4 | 2018 | 324965 E<br>4220911 N |
| 1758 | LBA | Small Cluster | NMZ VI | Area 4 | 2018 | 324980 E<br>4221064 N |
| 1759 | LBA (IA 1) | Large Cluster | NMZ VI (YAZ I) | Area 4 | 2018 | 325031 E<br>4220504 N |
| 1760 | IA1 | Large Cluster | YAZ I | Area 4 | 2018 | 325195 E<br>4219968 N |
| 1761 | IA1 | Large Cluster | YAZ I | Area 4 | 2018 | 325190 E<br>4219845 N |
| 1762 | LBA (IA 1) | Small Cluster | NMZ VI (YAZ I) | Area 5 | 2018 | 325738 E<br>4220363 N |
| 1763 | LBA (IA 1) | Large Cluster | NMZ (YAZ I) | Area 2 | 2018 | 411969 E<br>4218096 N |
| 1764 | LBA | Small Cluster | NMZ | Area 2 | 2018 | 411897 E<br>4218131 N |
| 1765 | LBA (IA 1) | Large luster | NMZ (YAZ) | Area 2 | 2018 | 411803 E<br>4218871N |

*Table 6.3 The new sites recorded by this survey project in the Togolok area.*

It’s important to note that neither the present survey nor the previous AMMD survey in the Togolok area recovered any specific ICW (Andronovo) pottery sites. However, ICW (Andronovo) pottery was found during the excavation of Togolok 1 (south mound) in rooms 14 and 20 (Hiebert 1994a:69). Similarly, the TAP team from the north mound of Togolok 1 also recorded hand-made pottery, which resembles the forms from Ojakly (E. Luneau pers. comm.). Nevertheless, the survey indicated an absence of ICW (Andronovo) pottery in the research area, suggesting that if it existed, it was marginal to the main BMAC settlements.

### 6.4.3 The AMMD and Soviet Survey Data

In line with the Ojakly area, the current research incorporates sites identified from previous landscape investigations conducted by both Soviet and AMMD surveys. These sites hold significant value in unraveling the dynamics of settlements concerning water resources. By integrating data from these historical surveys, a comprehensive understanding of the interplay between Togolok communities and water availability can be attained.

The past surveys identified more than 40 sites, ranging from small clusters to large clusters and low mounds, and tepes. Of these sites, it is worth mentioning a few of them that stand out and are relevant for the general understanding of the settlement distribution in the Togolok area (Figure 6.30).

The survey conducted by Soviet archaeologists identified several sites, of which the main ones, Togolok 1 and Togolok 21, have been discussed in section 6.2. The majority of the other recorded sites in Togolok are low mounds. Among the sites identified as “Togolok” by Sarianidi (1990) are Togolok 11, Togolok 18, Togolok 22, and Togolok 23, which are located within the investigation area of this project. These sites are small mounds with scatters of archaeological materials over 50 to 400 m. The sites within the Togolok area, characterized by their significant size and the substantial material recorded on their surfaces, represent enduring occupations.

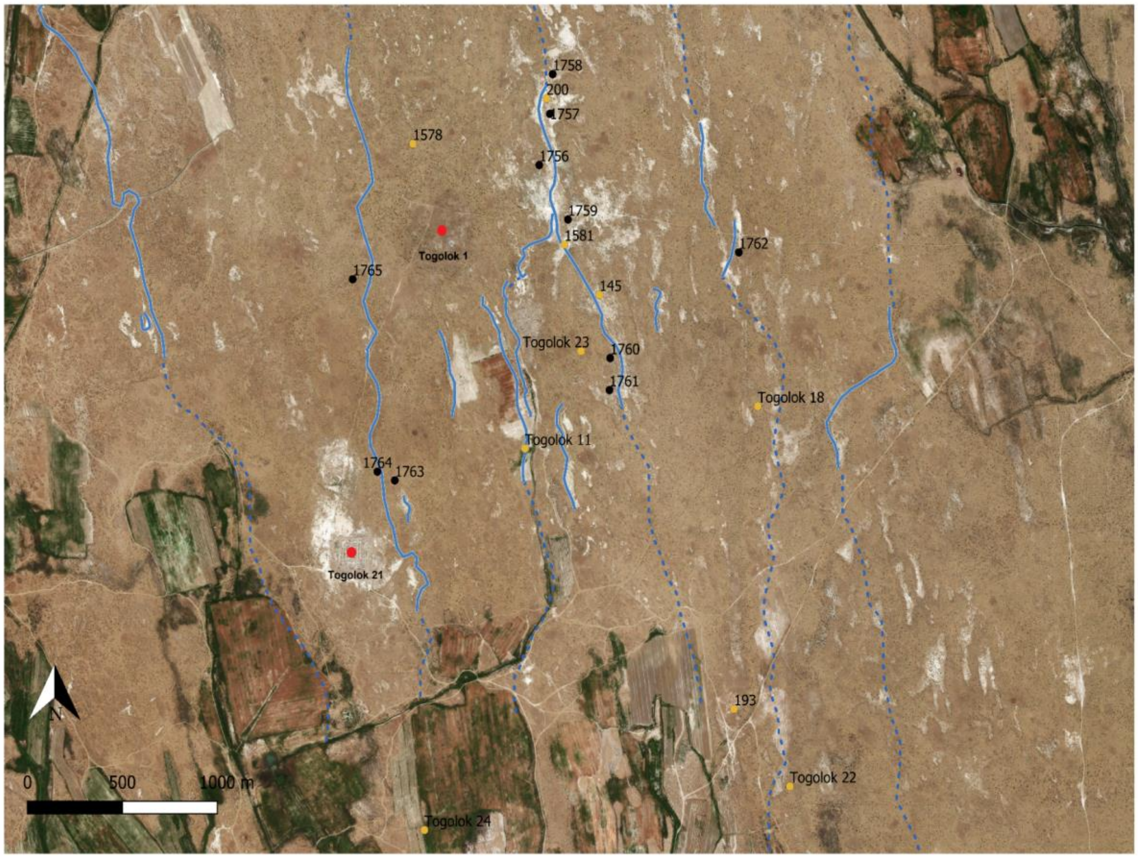


*Figure 6.30 The figure shows the main sites identified by the Soviet and AMMD surveys in the Togolok area (orange dots) and the sites identified by the present survey (black dots).*

Notably, sites like Togolok 23 and Togolok 11 are situated along former watercourses, indicating their strategic placement in relation to water resources.

Relatively large scatters of archaeological material that may also indicate more permanent occupations have also been recorded by the AMMD (Figure. 6.31). Sites such as n.1578, located to the north of Togolok 1 and probably connected to the main mound, were characterized on the ground by a large scatter of pottery over an elevated area. Similarly, site n.1581 to the east of Paleochannel 7 has a large scatter of material, as well as site n.145, located south of n.1581 along the same paleochannel. Of the same category are sites n.193 and n.376, with an abundance of pottery, in comparison to small cluster sites recorded in their vicinity. Drawing on parallels with the nearby site of Gonur North, this large discontinuous concentration of materials identified in Togolok may represent households/farmsteads that are located along channels.

Sarianidi also excavated two “quarters” to the northeast of the main Togolok 1 mound where he uncovered eleven two-chambered pottery kilns (Sarianidi 1990a: 37–40). These pottery kilns are located near Paleochannel 7. Further pottery production areas have also been identified by the AMMD along the same channel. Sites n.200 and n.199 along the northern part of Paleochannel 7 have kiln fragments on the surface, suggesting the presence of additional kilns. Robust evidence was also found at site n.199, where in a large area abundant kiln evidence, including kiln wasters, were recovered. Additional evidence has been found at sites n.1757 and n.1759, where concentrations of kiln fragments were also found. Site n.1757 is located approximately 100 m from n.200 and might be part of the same site.

All this evidence suggests that Paleochannel 7 served as a vital water source for pottery production. Its close proximity would have offered abundant clay for potters’ needs and ample water for clay processing. A comparable scenario, with pottery kilns situated near a channel, is observed at site n.999 from the Iron Age and in the Egri Bogaz region from the Bronze Age (Bonora and Vidale 2008; Markofsky 2010:177). Although a complete understanding of the economics of Togolok 1 and Togolok 21 and adjacent sites is beyond the scope of this current research, the investigation of the water resources for the first time offers a step in the right direction.

### 6.4.4 Settlements and Channels in the Togolok Area

The distance between sites and the nearest water resources, in the form of channels, were crucial for the ancient subsistence economy. Therefore, as argued in Chapter 5, the analysis of their proximity is considered crucial. (Wilkinson 2003; Rost 2017; Rouse and Cerasetti 2017).

Of the total of 53 sites recorded in the Togolok area by the present project and past surveys, the majority of the sites are classified as large clusters (Figure 6.31), compared to Ojakly, which shows a majority of small clusters in the area (see Figure 5.32 in Chapter 5).

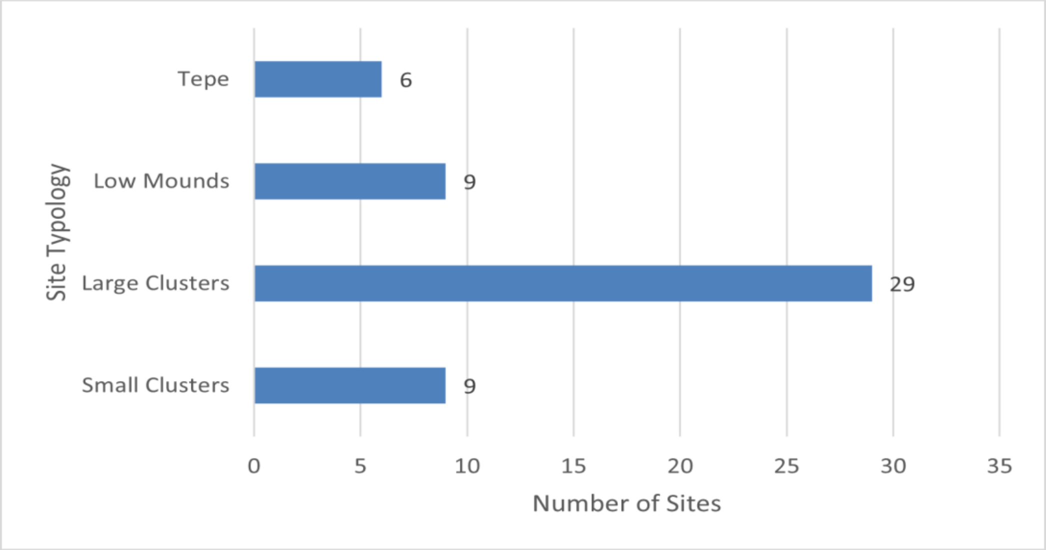


*Figure 6.31 The graph shows the total number of sites in the Togolok area (n=53) and their number according to site typology as recorded by the present project and the AMMD project.*

The large number of large cluster sites is not surprising in the Togolok area. These sites can be indicative of more permanent structures that one would expect to find in settlement clusters with the presence of three large settlements (Togolok 1 (both mounds) and Togolok 21). Notably, as discussed before, sites with ICW (Andronovo) pottery exclusively have not been recorded in Togolok (Figure 6.32A). Indeed, the vast majority of sites recorded have only Namazga pottery (NMZ) and are dated to the Bronze Age Some other sites continue into the Iron Age as well, as indicated by the occurrence of Yaz pottery. Sites mainly dated to this period, however, are few compared to Bronze Age sites, suggesting that the area underwent a process of depopulation at the end of the 2nd millennium BCE.

Of the total amount of sites in Togolok area, large clusters and low mounds make the majority (up to 73%) of all the Namazga sites that likely represent forms of permanent occupations linked to agriculture and/or workshops (Figure 6.32 B). Similarly, sites that have Yaz pottery (Figure 6.32 C) include a considerable number of low mounds and large clusters (up to 84%) indicative of permanent occupations.

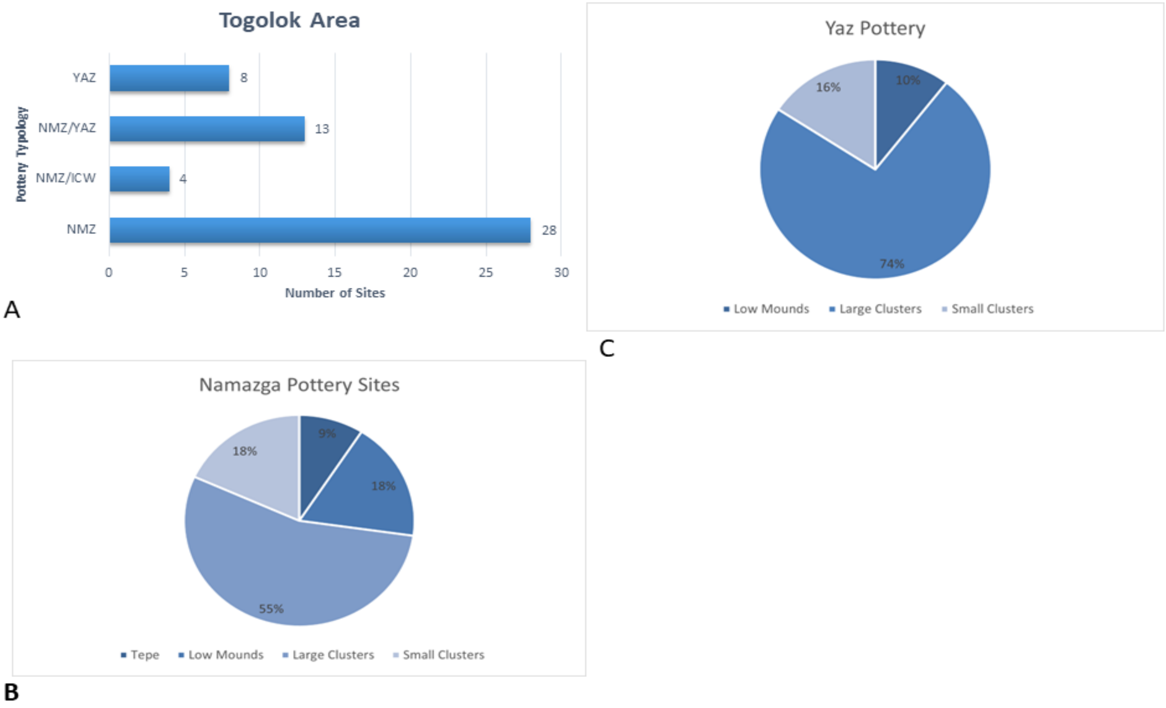


*Figure 6.32 A: The graph shows the number of sites classified by pottery type in the Togolok area with Namazga pottery (NMZ), ICW (Andronovo) pottery, a mix of Namazga and Yaz pottery (NIAZ), and Yaz pottery (Yaz). B: The graphs show the percentages of sites with Namazga pottery according to their classification as Tepe, Low Mounds, Large Clusters, and Small Clusters. C: the graphs show the percentages of sites with Yaz pottery according to their classification as Low Mounds, Large Clusters, and Small Clusters.*

When considering the distance to water channels in the Togolok area, the average distance from the nearest paleochannel is 162 m for sites with Namazga pottery (Bronze Age), while for Yaz pottery sites (Iron Age) it is 364 m (Figure 6.33). Therefore, there is a 55% increase in the distance to water during the Iron Age period. This aligns with a broader trend of increased distance noted throughout the northeast of the Murghab during the Iron Age (Rouse and Cerasetti 2017). In addition, there is also a tendency for tepe sites during this period to be further away compared to mow mounds or large clusters (Rouse and Cerasetti 2017:Fig.10). The greater distance of all sites during the Iron Age has been interpreted by Rouse and Cerasetti (2017) as an indication for the adoption of more advanced irrigation technologies (see also Masson 1959; Kohl 1984; Lyapin 1996).

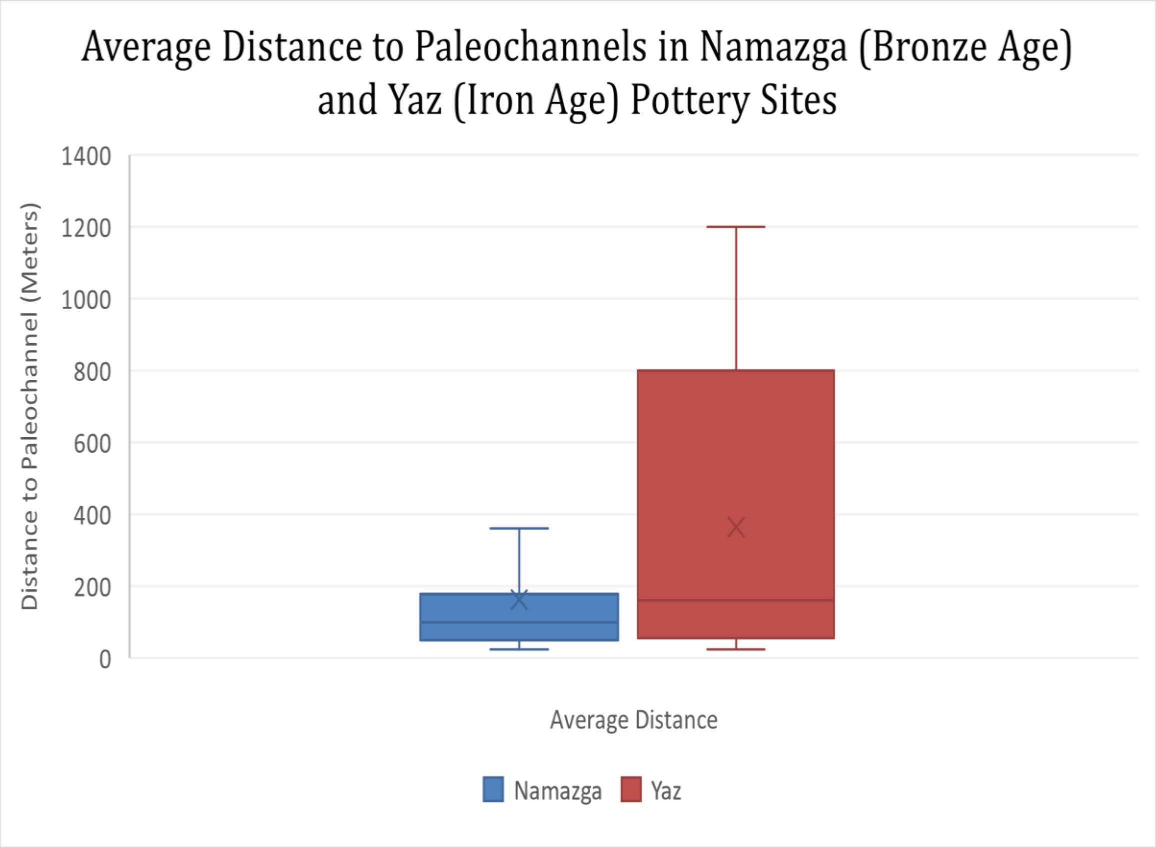


*Figure 6.33 The boxplot shows the distances to the nearest paleochannel for sites that present Namazga pottery (Bronze Age) (mean=162 m) and Yaz pottery (Iron Age) (mean=364 m). The means are indicated by an ×. All sites categories are included.*

As discussed in Chapter 5, an analysis of the distance from sites to water channels in the Ojakly area unveils a significant gap of sites at a certain distance. This suggests the presence of two distinct groups of settlements along the channels, where one group is situated closer to the water resource (see Figure 5.34 of Chapter 5). By applying the same water distance method, the histogram in figure 6.34 shows a drastic drop-off of sites after the interval of 324–374 meters with only a few small groups after this point. It is unlikely that this drop-off of sites after this point is the result of sampling bias; while the current survey focuses on paleochannels in the Togolok area, previous surveys did not prioritize this aspect and all the recorded sites have been included in the analysis.

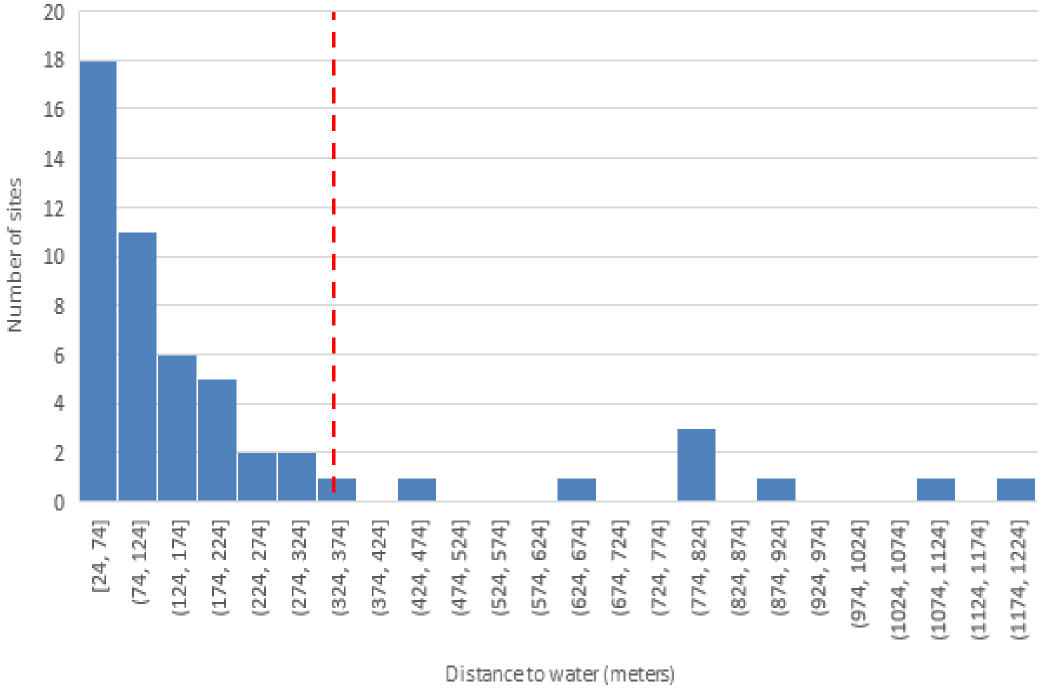
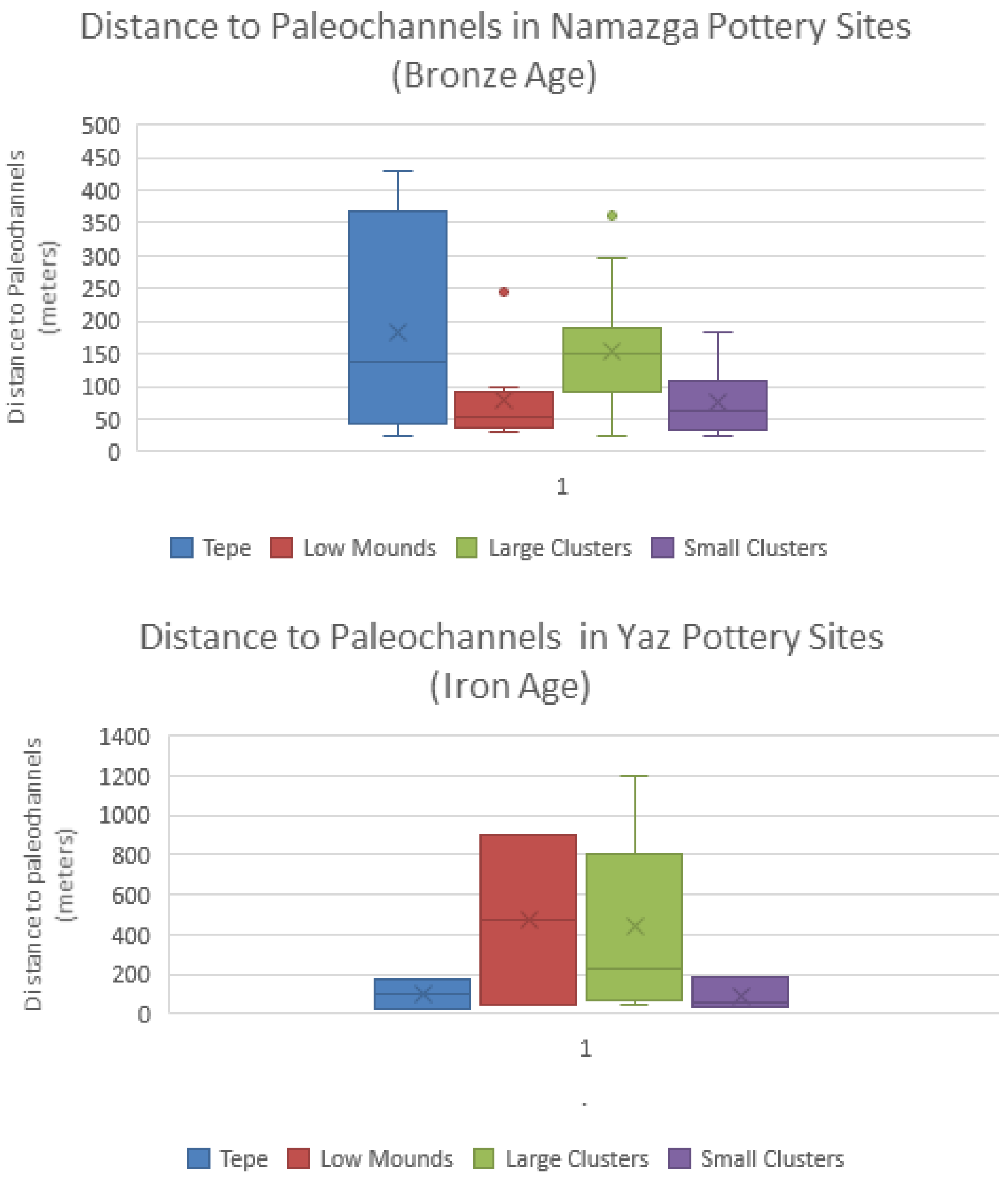


*Figure 6.34 The figure shows discrete intervals every 50 m in distance from the nearest paleochannel. The red dashed line highlights a remarkable drop-off of sites in the Togolok area and marks a discriminating point.*

Interestingly, even in this initial histogram analysis, the clustering of sites close to the channels is prominent in the Togolok area. Unlike the Ojakly area, where we observe a notable divergence with two distinct groups of sites clustering based on water proximity, the pattern in Togolok displays a gradual decline of sites as distance from the channels increases. This suggests a more proximal relationship between settlements and channels in the Togolok area, highlighting a different use of the landscape.


Distance to Paleochannels in Namazga Pottery Sites (Bronze Age)

Distance to Paleochannels in Yaz Pottery Sites (Iron Age)

*Figure 6.35 Top: The boxplots show the average distance to paleochannels for Namazga pottery sites divided by Tepe (mean=183 m), Low Mounds (mean=80 m), Large Clusters (mean=153 m), and Small Clusters (mean=75 m). Bottom: The boxplots show the average distance to paleochannels for Yaz pottery sites divided by Tepe (mean=101 m), Low Mounds (mean=473 m), Large Clusters (mean=475 m), and Small Clusters (mean=91 m). The means are indicated by an ×.*

Beyond the general site–channel distance analysis, a closer examination of the Namazga and Yaz pottery sites reveals discernible patterns. The distance to paleochannels for small clusters between the Bronze and Iron Age remains rather unchanged (Figure 6.35). These sites are generally located within 100 m from the nearest paleochannels in both periods. This may suggest that small temporary occupations along the channels were engaged in similar activities in both periods. However, change can be observed for low mounds and large cluster sites (Figure 6.35). These two site categories are located further from the water in the Iron Age. The average distance during the Iron Age for large cluster and low mound sites is considerably higher compared to Bronze Age (Figure 6.35). This might be related to better technologies for transporting water over greater distances, as suggested by Rouse and Cerasetti (2017), or a different use of the landscape.

### - Kiln Sites and Water Resources

Compared to the Ojakly area, where only a few sites have evidence for kilns, the Togolok region boasts a substantial cluster of sites that indicate pottery production. As previously discussed, most sites with evidence for kilns are situated along Paleochannel 7. In close proximity to this paleochannel, Sarianidi (1990a) excavated eleven pottery kilns, confirming the presence of pottery workshops. The presence of the fortified sites of Togolok 1, comprising both mounds, and Togolok 21 likely required a substantial production of pottery.

In the preceding section, I explored how sites dating back to the Bronze Age are relatively close to water channels compared to those dated to the Iron Age (Figure 6.33). Within this context, when considering sites with evidence of kilns or pottery kilns, this distance is even smaller. While in general Bronze Age sites exhibit an average distance of 176 m from the nearest paleochannels, this distance is only 89 m for sites with kilns, with a reduction of nearly 49% in distance (Figure 6.36). This trend aligns with data from Ojakly, where sites with evidence for kilns are also situated closer to water resources. Undoubtedly, the close proximity to water channels was crucial for pottery production. Additionally, the proximity to a clay source was likely indispensable for efficient and rapid pottery manufacturing.

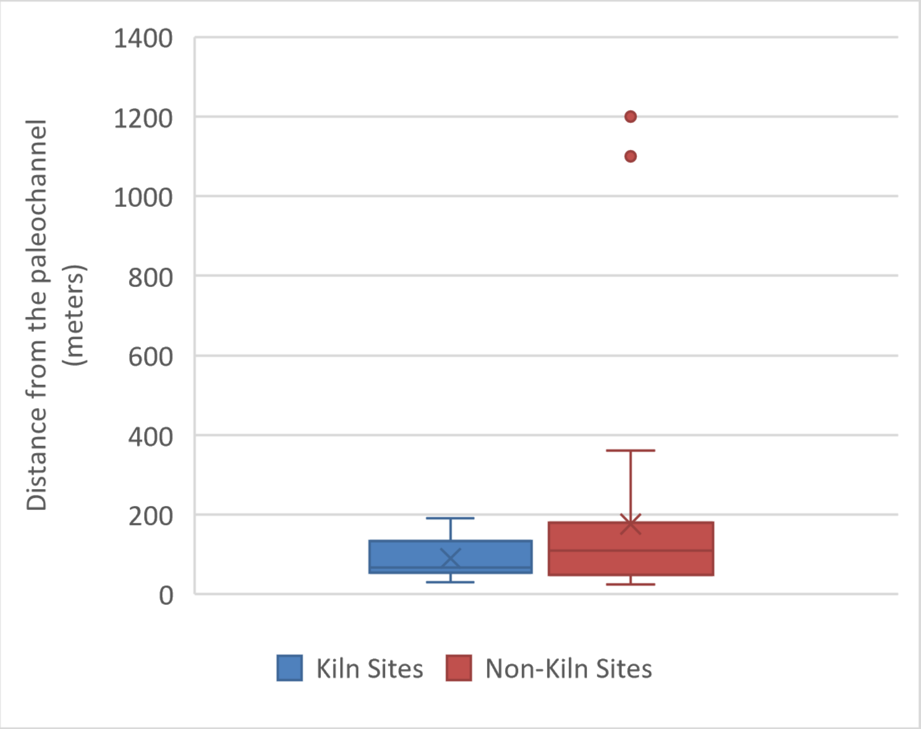


*Figure 6.36 The boxplots show the average distance from water sources (paleochannels) for sites that show evidence for kilns (mean=89 m) and sites without any evidence for kilns (mean=176 m). The means are indicated by an ×.*

### 6.4.5 Paleochannel Chronology

In Chapter 5, I conducted an analysis, utilizing the dating by association method (Wilkinson and Rayanne 2010), to determine the potential periods of activity of the channels in the Ojakly area. Applying a similar methodology, I propose here to suggest when the paleochannels identified in the Togolok area might have been active.

On the basis of settlement occupations along the channels in Togolok, it is likely that the Togolok channel systems were active during the Bronze and Iron Age periods (Figure 6.37). The western paleochannels were probably active during the Late Bronze Age, as the numerous sites located along these channels would suggest. Notably, the pottery assemblage and the radiocarbon dates from Togolok 21 suggest that Paleochannel 2 was active in the 2$^{nd}$ millennium BCE (Fontugne et al. 2021). However, due to its proximity to Togolok 1 it is likely that this channel was in use in the Middle and Late Bronze Age as well, thus by the end of the 3rd and the 2nd millennium BCE. Similarly, nearby Paleochannels 3, 4, and 5 were also active during the Middle and Late Bronze Ages.

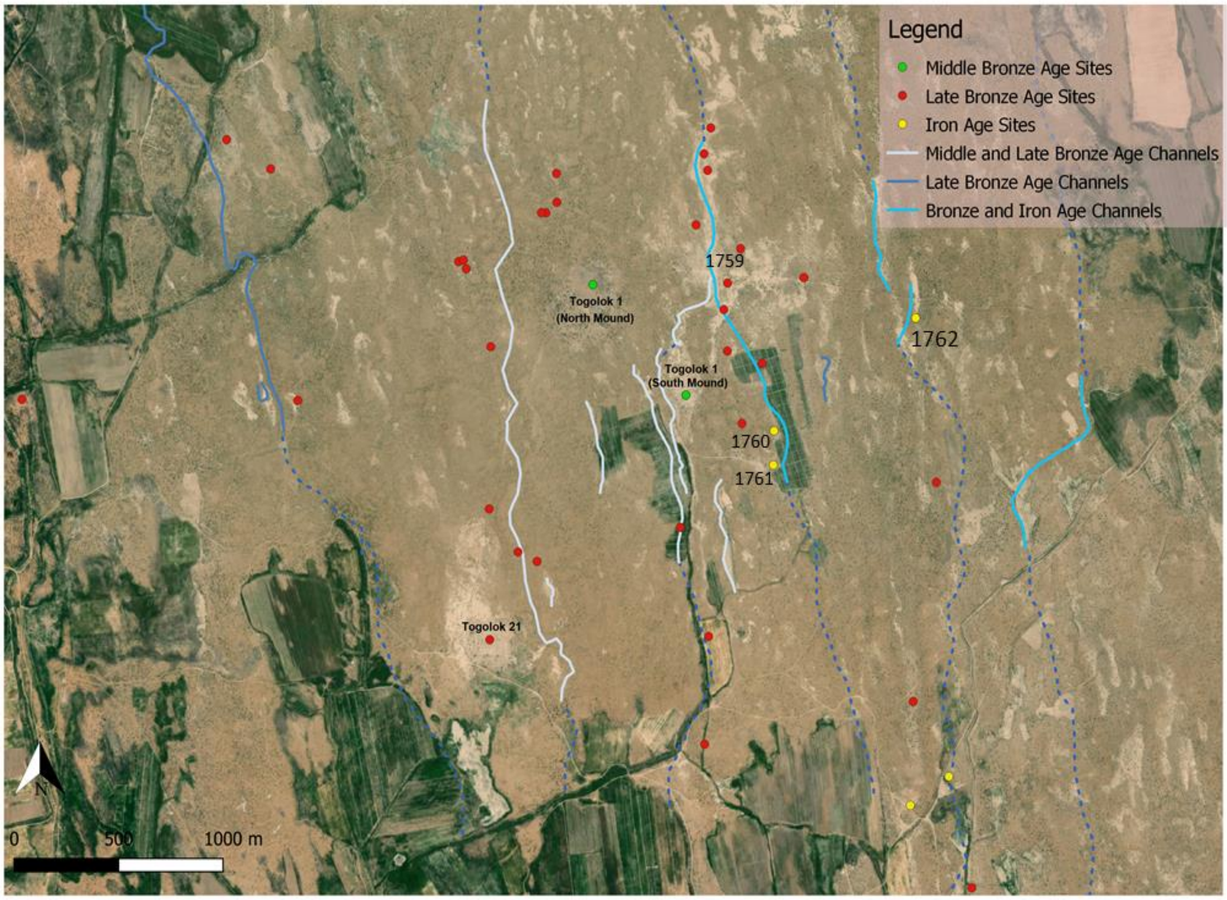


*Figure 6.37 The figure indicates the periods of channel activity based on the associated sites surveyed by the current project, the AMMD, and Soviet surveys in Togolok area.*

The sites recorded along Paleochannel 7 are dated to the Late Bronze Age and the Iron Age. For instance, sites n.1760 and n.1761 can be dated by surface material to the Iron Age 1, while site n.1759 has pottery of both the Late Bronze Age and the Iron Age 1. The vicinity of this paleochannel to Togolok 1, and the presence of several pottery kilns likely necessitating water and clay, suggest that the channel was active during the Middle and Late Bronze Age. However, sites dated to the Iron Age only are indicative that the channel was possibly still active during the subsequent period. Site surveys suggest that during the Iron Age the area of Togolok was almost depopulated, as the reduced evidence of Iron Age finds compared to the Bronze Age suggests.

Similarly, sites located in the east present a mix of Bronze and Iron Age occupations. Sites such as n.1762 – recorded by the present project – or n.1016 and n.156 (these latest are not shown in figure 6.37) suggest that the eastern channels were still in use during the Iron Age. In addition, in the south-east (outside of the research area) along the possible flow direction of Paleochannel 10, there is a cluster of low mound sites dated to the Iron Age, further suggesting that there might have been active channels during this period.

In conclusion, evidence from Togolok indicates that the paleochannel system was active during the Bronze Age, with some channels remaining active in subsequent periods as well. Moreover, the activity of certain channels during the Iron Age suggests a shift in settlements from the west to the east of the research area by the end of the 2nd millennium BCE. This shift may indicate that channels near the primary sites of Togolok 1 and Togolok 21 ceased to provide adequate water, potentially leading to partial abandonment.

## 6.5 Results: Paleochannel Test Trench

### 6.5.1 Fieldwork Preparation

Like in the Ojakly region, satellite images were analyzed to identify potential locations for paleochannel test trenches. The proliferation of agricultural fields surrounding Togolok posed challenges for both surveys and test trench placements. Moreover, elongated takyrs frequently attracted farmers for sporadic crop cultivation, as discussed in Chapter 4 (Fleskens et al. 2007; Kalutskov and Glukhov 2014). Similarly, farmers’ rapid construction of canals often hindered passage through the survey areas. Therefore, a recent analysis of a Sentinel 2 image covering the Togolok area was conducted to pinpoint potential paleochannels suitable for test trenches and coring.

During the first day of the survey the paleochannel locations were inspected by the team for cross-section coring and the test trench. Among them, Paleochannel 7 was selected for its vicinity to Togolok 1 and for its well-defined river structure on the ground. The channel trace is located 600 m east of Togolok 1 (Tepe 1), and it is one of the main channels in the area with two pottery workshops along its former course.

The central northern part of Paleochannel 7 (TGK1_Ch_IX) was selected for the test trench. This part of the paleochannel was easy to identify on the ground, with an elongated takyr surface with sparse vegetation in its center and a well-developed bank on its eastern side.

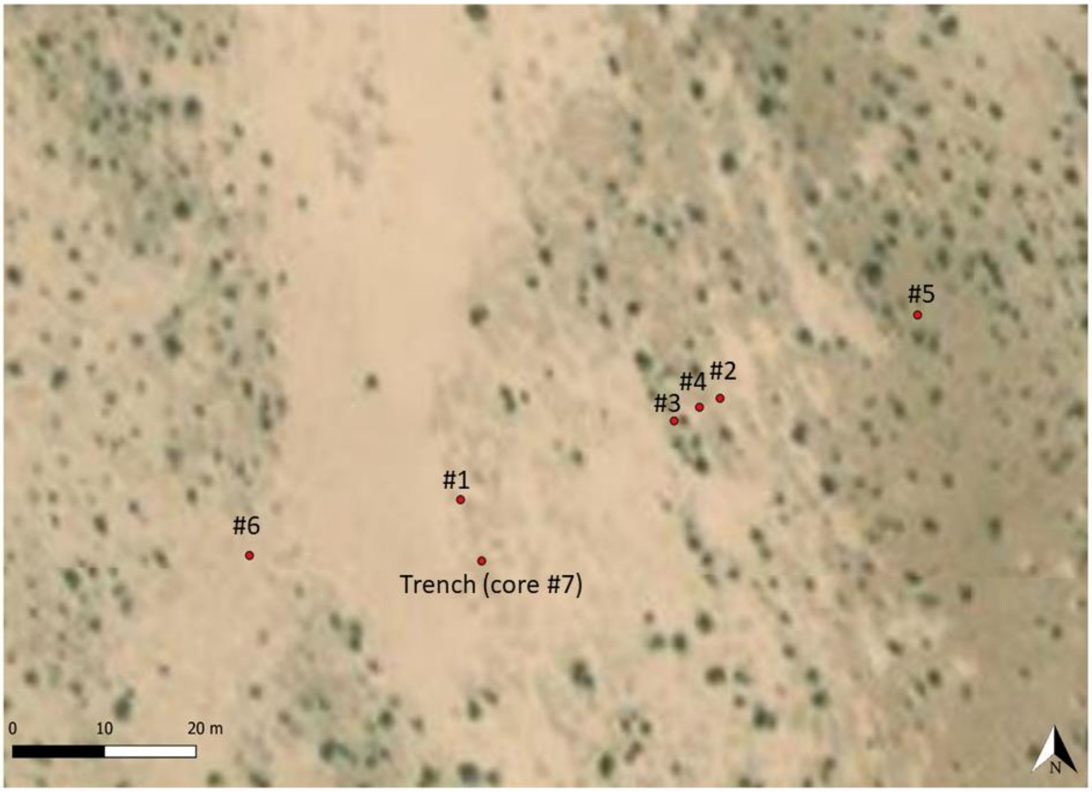


*Figure 6.38 The figure shows the trench point (Trench) in Paleochannel 7 and the hand-auger cores by numbers. Core n.7 was drilled at the bottom of the trench.*

### 6.5.2 Cross-Section Coring

Like in the Ojakly area, prior to excavating the test trench, we performed paleochannel coring along the cross-section of the former channel. As mentioned in the preceding chapter, these cores serve to analyze the structure of the channel and its stratigraphic sequence. The Togolok channel was large, necessitating several cores.

The first core (TGK_Cr_1 / #1) was drilled in the center of the ancient river to assess the stratigraphy of the paleochannel (Figure 6.39). The team decided to investigate the eastern cross-section with more cores as it has an elevated former bank compared to its western section. Four cores were drilled along the eastern bank of the channel (Figure 6.38). One additional core (TGK_Cr_6 / #6) was drilled on the western bank of the paleochannel, outside of the takyr surface. Finally, an extra core (TGK_Cr_7) was conducted on the base of the test trench to further analyze the paleochannel stratigraphy.

*Figure 6.39 The figure shows the coring of the first hand auger core (TGK_Cr_1) at the center of Paleochannel 7 in the Togolok area. The paleochannel is located approximately 600 m from the main mound of Togolok 1.*

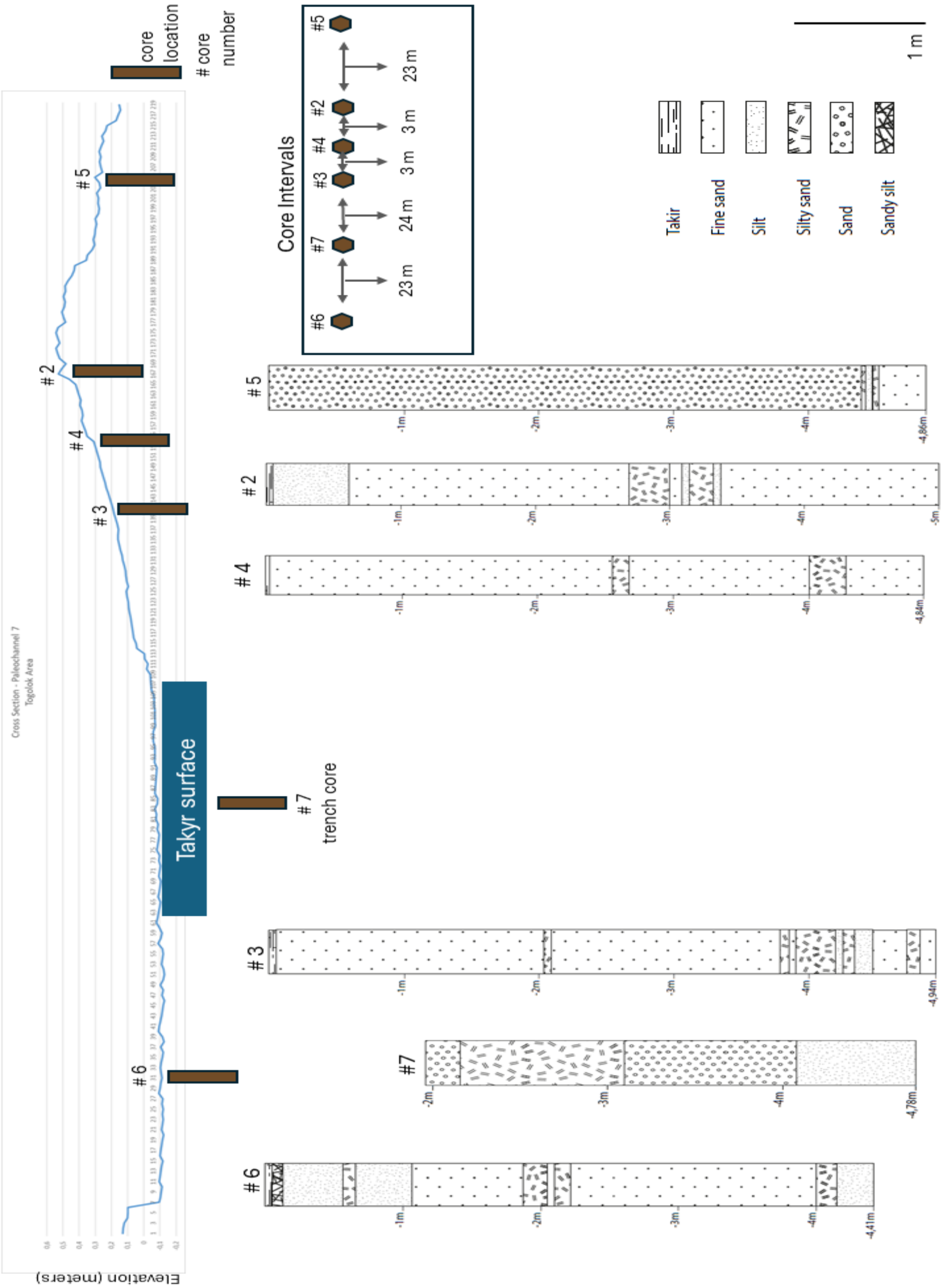


*Figure 6.40 Elevation of the cross-section of Paleochannel 7 (Togolok area) with corresponding stratigraphy of the seven cores. Core n.7 was drilled at the bottom of the trench.*

The hand auger used by the team in Togolok was the same used for the Ojakly area and could take a sample up to 5 m. However, for some cores, such as core 6 (TGK_Cr_6 / #6), it was not possible to reach the full depth of 5 m. As discussed in Chapter 4, field observations were made when a change in the sediments was observed such as soils, textures, color, or any other characteristics. Drawings of the cores have subsequently been made.

Figure 6.40 shows the sequence of four cores made on the east of Paleochannel 7 over the paleobank of the channel. Cores #3, #4, and #2 (Figure 6.40) exhibit a similar sediment sequence. Initially, there is a layer dominated by sand extending nearly 2 m from the surface, followed by intermittent layers of silt and silty sand. The subsequent layer, approximately 1 m thick, is again predominantly sandy, while the lowermost layers consist primarily of silt and silty sand. The easternmost core has a different stratigraphic sequence. Indeed, Core #5 shows a complete sequence of sand until up 4.60 m with no takyr surface on the top. This sequence of sands for more than 4 m suggests that the core was drilled on top of a sand dune outside the paleochannel. In contrast, the westernmost core exhibits a stratigraphic sequence distinct from those to the east of the paleochannel. Core #6 reveals a takyr surface unit atop a sequence of sandy silt, silt, and sand layers. This sequence closely resembles what has been observed in the test trench excavated at the channel’s center. The layers from this last core suggest that the channel’s boundaries might extend to the location of this core.

### 6.5.3 The Test Trench

The test trench was located in the middle of the paleobed (UTM 41N, N 38.11623, E 62.00347), approximately 7 m south of the first core. The test trench of 3 × 2 m was excavated by hand and reached a depth of 1.94 m. Upon completion of the trench excavation, drawings of the west and south profiles of the trench were produced.

From the west profile we took two OSL samples at 72 and 184 cm depth, while a third OSL sample was taken from the south profile at 142 cm depth (Table 6.4). The sedimentary layers were sampled with same methodology described in Chapter 4. Like at Ojkaly, the quartz contained in the samples turned out to be unsuitable for luminescence dating, and feldspar (F) and polymineral (PM) (feldspar fraction) had to be used. The analysis follows the process described in Lamothe et al. (2003) and Preusser et al. (2014).

| **Sample Code** | **Trench Profile** | **Depth (cm)** | **Mineral** |
|---|---|---|---|
| TGK18-1 | Western | 72 | Feldspar |
| TGK18-2 | Southern | 142 | Polymineral (Feldspar) |
| TGK18-3 | Western | 184 | Feldspar |

*Table 6.4 OSL samples retrieved from west profile and south profile of Togolok trench (TGK_Ch9 paleochannel).*

## 6.5.4 Section Description and Discussion

- **Section Description**

The west and south profiles (Figures 6.42 and 6.43) of the trench are characterized by an alternation of mainly sand, silt, and clay (see Table 3.3 in the Appendix 3 for a description).

The first layer on both profiles is characterized by a takyr surface (#1) of a compact layer of clay-silt loam. The subsequent units, also on both profiles, are characterized by a silty-sand compacted deposit (#2 on both profiles), of which in the west profile has small shells in it. The subsequent layers of the profiles are composed by sand[98] (#3 on both profiles) covering small alternating layers of sand, and silty clay (on the west profiles #4–6 and on the south profile #4–7). These small layers were covering a macro-layer of cohesive clay (#7 on the west profile and #8 on the south profile). This mass of clay was

---

[98] This layer was characterized by few cross-laminations visible on both profiles.

covering on both profile another macro-layer of sand (#8 on the west profile and #9 on the south profile).

The core with the hand auger made in the middle of the bottom of the trench (Figure 6.41) suggests that this last layer of sand that characterized both profiles continued reaching a depth of 214 cm. The subsequent layers comprised silty sand, sand, and silt. It appears that the channel's depth exceeded that of the excavated test trench, as evidenced by the core's stratigraphy, which did not encounter a distinct layer confidently interpreted as the channel bottom.

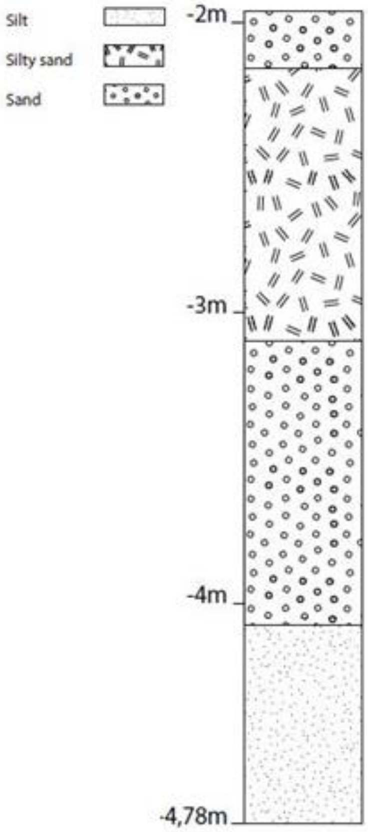


*Figure 6.41 Drawing of trench Core n.7 at the bottom of the test trench (TGK_Cr_7).*

As discussed in Chapter 5, it's important to note that OSL dates may occasionally lack precision in their stratigraphic sequence. Indeed, the first OSL sample (TGK18-1) shows a corrected age of 3682–3482 BCE (5.6 ±0.1 cal. yr BP) while second sample (TGK182) shows a corrected age of 3282-2882 BCE (5.1 ±0.2 cal. yr BP) retrieved at 72 cm depth (table 6.5). The bottom samples retrieved at 184 cm depth shows an older corrected age of 4082–3882 BCE (6.0 ±01 cal. yr BP). Drawing from the data presented in section 5.6.4 of Chapter 5, where OSL dates are compared with archaeological evidence, both corrected systems have been examined (i.e., IR50 and PIRIR1150). Specifically, as for Ojakly, we have considered the corrected age of IR50, as detailed in Table 6.5, with comprehensive data provided in the Appendix 2.

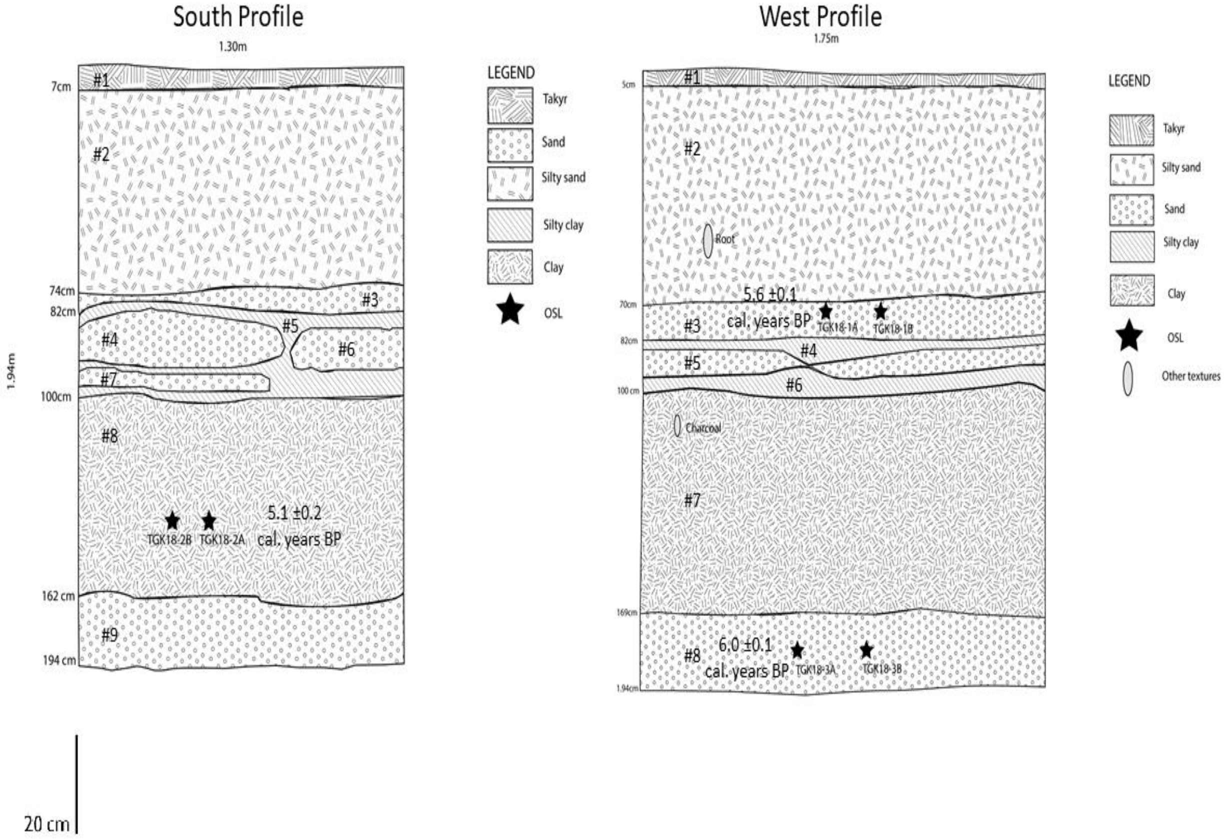


*Figure 6.42 The figure displays the South and West profile drawings of the Togolok Trench along with OSL dates on both profiles.*

*Figure 6.43 Photos of the South and West profiles of Togolok Trench.*

| **Sample Code** | **Grain size (μm)** | **Age $IR_{50}$** (ka)* | **Age BCE** |
|---|---|---|---|
| TGK18-1 | 63–100 | 5.6 ±0.1 | 3682–3482 BCE |
| TGK18-2 | 4–11 | 5.1 ±0.2 | 3282–2882 BCE |
| TGK18-3 | 150–250 | 6.0 ±0.1 | 4082–3882 BCE |

*Table 6.5 The table presents the corrected OSL ages (IR50) from Togolok Paleochannel 7 (TGK1_Ch_IX). Correction following Lamothe et al. 2003. De values are calculated using the Central Age Model (Galbraith 1999). Full OSL data available in the Appendix 2.*

- **Section Interpretation and Discussion**

In Chapter 2, I discussed how material that is transported in river channels can form various sediments. The bed material can be characterized by sediment structures. Alluvial fan deposits in braided and anabranching rivers are generally dominated by sand, silt, and clay deposits (often mixed) (Church 2006).[99]

The deposition of the material in alluvial environments occurs when the flow velocity is considerably below the settling velocity of a given particle. The material which is transported can be divided into three main categories: the dissolved load with material transported in solution, the wash load with small and fine particles moving readily in suspension, and third one which comprises material that can be found on the river bed (Knighton 1998:118).[100]

In the test trench, the bottom layers both in the west and south profiles present a sand layer covered by a massive layer of clay deposits on both profiles.[101] This latest deposit may suggest, in anabranching rivers, a disposition from suspension during low or very-low-energy water stages (Makaske 2001).

The layers in the middle of the trench are characterized by an alternating strata of sand, silty clay, and sandy silt deposits. These layers, that also present visible cross-laminations[102] can be interpreted as deposition from traction and suspension in a changing water flow regime that was deposited during different events (Widera et al. 2017).[103]

---

[99] These sediments can be characterized by a more or less large-scale cross-stratification material or massive unit layers, generally cohesive (see Glossary for definitions).

[100] The wash load transports the finest-grained fraction in suspension because the settling velocity is too low and thus is transported at the same speed as the flow and is deposited only when the velocity of the flow is reduced. According to Knighton (1998:123), the rate in the wash load transport is mainly determined by the amount of finer-grade sediments from the drainage basin. This material is mostly supplied by the erosion of riverbanks and from surface erosion.

[101] The sand layer did not present any cross-stratification. See Appendix 3 for a complete description.

[102] See Glossary for broad definition.

[103] Cross-stratification of a sediment in a riverbed is manifested as laminations of strata. The laminations are often quite visible in alluvial deposits, and are generally formed by the movement of the bedforms, namely the erosion and deposition. After the deposition of a stratum, there is a formation of new

The upper layers of both trench profiles exhibit a thin layer of sand with cross-lamination, overlain by a thick layer of silty sand containing shells.[104] Therefore, these upper layers may be understood as deposition layers formed during medium to lower flow regimes across various periods but under relatively stable flow conditions without significant fluctuations (Bridge 2003; Widera et al. 2019).

Paleochannel 7 stands out as one of the primary channels in the Togolok area, situated in close proximity to both mounds of Togolok 1. Analysis of the paleochannel’s stratigraphy within the trench, along with OSL dating, indicates fluvial activity between the late 5th and mid-4th millennia BCE (pre and Early Chalcolithic periods[105]), characterized by a relatively low flow regime. OSL dating of the middle-upper layers suggests a transition during the 4th and early 3rd millennia BCE (Middle and Late Chalcolithic periods), wherein the channel shifted from a low-flow regime to a phase marked by more substantial flow, yet remaining relatively stable, as indicated by the upper layers.

In contrast to the test trench in the Ojakly paleochannel, the Togolok trench suggests a broader channel spanning several meters. It’s plausible that the upper layers, which were not sampled for OSL dating, beneath the takyr surface, correspond to the Bronze and Iron Age periods. This hypothesis gains support from the presence of numerous sites along Paleochannel 7, dating back to the Bronze and Iron Ages, indicating that the channel remained active during these periods. A constant water flow of Paleochannel 7 played a pivotal role in supporting agricultural practices, including the cultivation of various crops (see section 6.2.4 of this Chapter for botanical remains), as well as facilitating pottery production and ensuring a steady supply of clay. Conversely, an intermittent or nearly inactive channel would have been inadequate in providing the necessary water for agricultural and other economic activities.

---

laminae layers during the deposition. The cross-stratification is a process that is often not the result of a single event but of two or several deposition events (Allen 1963).

[104] Mollusc shells are widely recognized as common animal remains in flood sediments (Alexandrowicz 2021).

[105] For the pre-Chalcolithic and Chalcolithic chronology of this thesis I refer to Bonora and Vidale 2013: Table 9.1.

- **Natural Channel or Artificial Canal**

The extent and presence of settlements with defensive walls and towers in Togolok support the notion that agricultural fields were likely sustained by artificial channels. However, while it’s conceivable that the inhabitants of Togolok constructed canals, evidence from the trench and cores suggests that Paleochannel 7 is natural. As discussed in Chapter 5, Jotheri (2018) proposes that the nearly straight form and steep levees are indicative of an artificial channel. However, the curved shape and width of Paleochannel 7 do not fit the characteristics described by Jotheri, as well as those of canals discovered elsewhere, such as at Gonur (Sataev 2008). Nonetheless, it cannot be discounted that significant channels like Paleochannel 7 were regularly maintained, given their proximity to the main settlement of Togolok 1.

Altogether, the result from the test trench provides evidence for a hydrological system in the northeast Murghab area that was already active during the 5th millennium BCE. In Chapter 3, I discussed the sporadic presence of Chalcolithic evidence in the Murghab. In the Kelleli region, for instance, Kohl (1984:146) notes the presence of surface pottery that dates to the Chalcolithic period of Geoksyur-type (Namazga II or III). Also, Massimov informs us of the presence of grey wares possibly associated with the Late Chalcolithic (Namazga III period) in the basal levels of Kelleli 1 (Kohl 1984; Masimov 1979). A few Geoksyur styles painted sherds (Namazga III period) have also been found at Adji Kui 9 and Gonur (Rossi Osmida 2007:125). The discovery of isolated Chalcolithic artifacts in the Murghab region has led to interpretations suggesting a near absence of occupation during this period (Lyonnet and Dubova 2021b:20). This observation has ignited considerable debate among scholars (Khol 1984; Sarianidi 1990a; Salvatori et al. 2008). However, this seemingly sparse archaeological record stands in stark contrast to the evidence of hydrological activity in the Murghab region, which could have potentially facilitated human occupation along its river channels. This contradiction between archaeological finds and the apparent hydrological potential of the region shed new light on this matter and will be further discussed in Chapter 7.

## 6.6 The Takyr Areas in Togolok

Previously in this thesis I discussed the takyr surfaces, their characteristics, and their use in the Murghab region.[106] Takyr surfaces have been the preferred areas for agriculture in the Murghab due to their capacity to retain water (Kalutskov and Glukhov 2014; Markofsky 2010:32). The degradation process that many takyrs have undergone in the last decades in the Murghab led to a loss of about 8000 km$^2$ (Maman et al. 2011). Many of the destroyed takyrs are located in the southern-central Murghab region, including the Togolok area. The Togolok area, which was free from agricultural fields in CORONA images dating to the 1970s, it is now almost entirely surrounded by them. Although there is no recent data about takyr destruction rates from the last 10 years, takyr surfaces continue to be destroyed and cultivated.

Takyrs can be generated both by natural and artificial processes as argued in Chapter 5 (Lebedeva-Verbena and Gerasimova 2010). Notably, these places would have been also crucial for storing water. Such water would have been crucial both for herding and/or opportunistic farming. While the formation of a takyr is a natural process, anthropogenic activities, such as repeated intentional flooding, can also potentially generate the formation (Gerasimov 1978).

As previously analyzed in the Ojakly aArea, in Togolok a visual analysis of takyr surfaces located in close proximity to the identified paleochannel, was conducted using CORONA and Landsat images. The relatively small distance between the vast majority of settlements in the Togolok aArea and watercourses is indicative of agricultural activities located in the proximity of waterways. As argued before, it is likely that crop cultivation was supported by the presence of small canals near water courses.

The visual analysis shows the presence of several takyr surfaces in the Togolok area. Interestingly, many of these takyr surfaces are located along the paleochannels, and are not far from Togolok 1 (both mounds) and Togolok 21 (Figure 6.44). Out of all the takyr

---

[106] In Chapters 3 and 5.

areas, 24 surfaces are situated within 500 m of the paleochannels. Several takyrs are situated alongside the primary Paleochannel 7, some with a size of more than 8 ha. Within these areas lie a succession of sites, such as site n.200 or site n.1757, identified through the ongoing project survey, revealing evidence of kiln fragments. Nevertheless, these sites are positioned on the outskirts of the takyrs, potentially adjoining agricultural zones. Additionally, numerous other smaller sites were discovered beyond these agricultural boundaries.

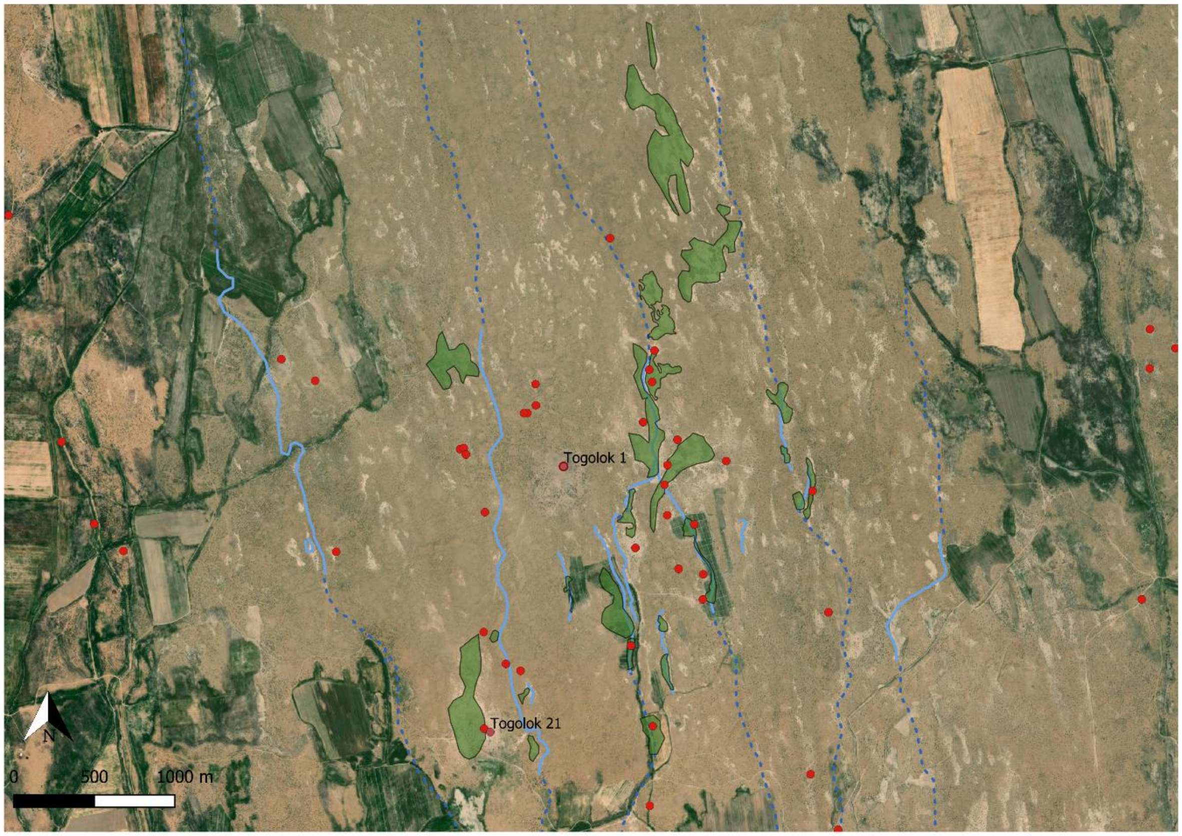


*Figure 6.44 The figure shows the takyr areas in proximity to former channels. Takyr areas not in proximity to channels have not been considered in the present analysis.*

In addition to Paleochannel 7, other channels present takyr surfaces of a considerable size. To the west of Togolok 21, Paleochannel 2 shows the presence of only five takyr areas, of which two large areas are 10 and 6 ha, respectively. Notably, the biggest one is located east of Togolok 21. Two more large takyr areas of approximately 13 and 9 ha respectively, are located northeast of Togolok 1. Paleochannels 4, 5, and 6 primarily exhibit smaller takyr regions positioned along their watercourses.

In the eastern sector, towards Paleochannel 9, there is an absence of large takyr areas. This observation aligns with previous discussions indicating a shift in settlement patterns towards the east during the Iron Age period in Togolok. Consequently, the lack of substantial takyr areas in this sector supports the hypothesis suggesting a significant decrease in population in the Togolok area during the Iron Age and thus also a decline in agricultural areas. This demographic decline likely contributed to the eventual abandonment of the primary settlements of Togolok 1 and Togolok 21.

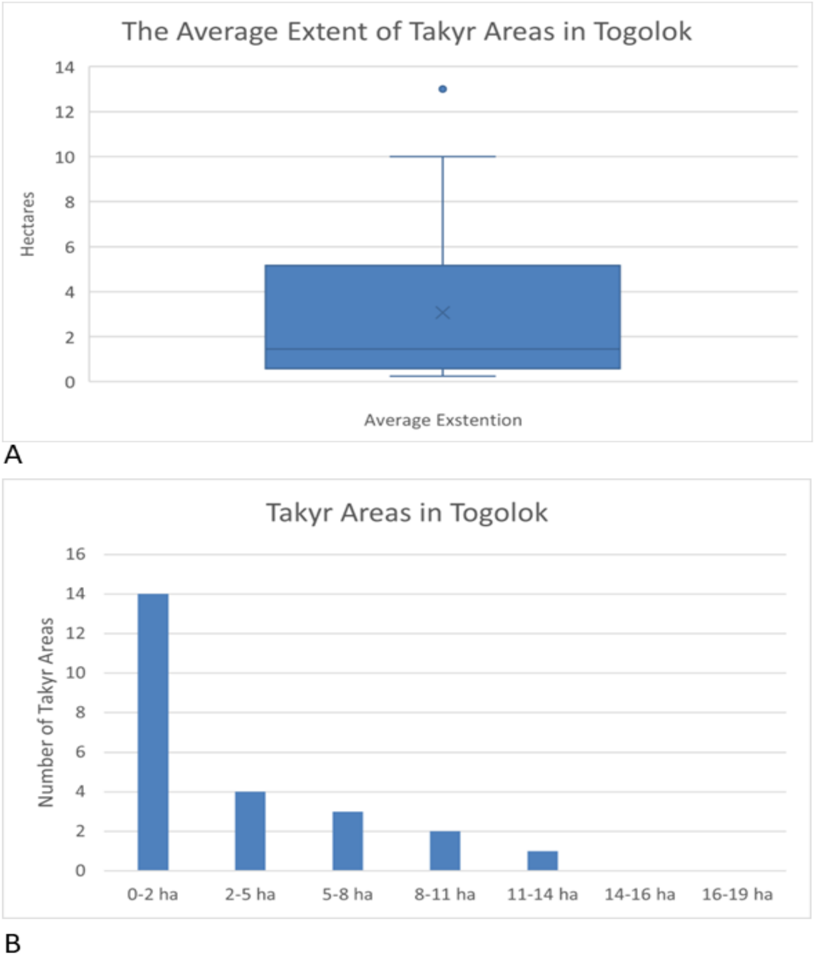


*Figure 6.45 A) The boxplot shows the average extent of takyr areas in Togolok. The "×" is the means (3.07 ha). B) The histogram shows the frequency of takyr areas according to determined intervals in ha.*

Unlike the Ojakly area, the Togolok area displays a substantial extent of takyrs, averaging 3.07 ha each (Figure 6.45a). While the entire area predominantly comprises a large percentage of small takyrs ranging between 0 and 2 ha (Figure 6.45b), there are numerous areas exceeding 2 ha. In contrast to Ojakly, where areas above 5 ha are exceedingly rare, in Togolok, regions ranging between 5 and 14 ha are present in substantial numbers (45% of the total takyr areas) (Figure 6.45b). This data suggests that the Togolok region likely depended on a significant number of larger agricultural areas along the channels to support a larger population. However, it is probable that agricultural areas were not concentrated solely around the main sites but were distributed widely along the channels. Consequently, various crop production would have necessitated irrigation management throughout the year, as well as a consistent water supply. How this irrigation management possibly changed between the Bronze and Iron Ages, however, is further discussed in the next section.

## 6.7 Isotope Analysis from Botanical Samples

Information on irrigation practices has traditionally been derived from different sources, including the ecology of species and processing by-products of plants, but also irrigation infrastructure such as dams or artificial canals (Jones et al. 1995; Farrington 1980; Charles et al. 2003; Wilkinson 2003; Kirchner 2009; Wilkinson and Rayne 2010). Over the last decade, studies on phytoliths and stable carbon isotope analysis have additional indications of possible irrigation and manuring practices (e.g., Madella et al. 2009; Piperno 2006; Ferrio et al. 2005; Heaton et al. 2009; Fiorentino et al. 2012).

In Chapter 4, I discussed how stable carbon isotope analysis of plants may serve as an indicator for crop irrigation. This analysis enables us to gauge the degree of stress experienced by plants when they lack adequate water supply. As such, the percentage of $\delta^{13}C$ in the plants can vary according to the water received, and this indicates whether a crop was well-watered (or not). However, different plants have different levels of $\delta^{13}C$, and thus, models for interpreting the level of water vary between plants, such as barley, wheat, or legumes, but can also vary according to geographical areas (Araus et al. 2007).

Moreover, $\delta^{13}C$ levels in the plants can be determined by additional factors, including groundwater, and evapotranspiration which, as a result, can determine water loss. In addition, soil properties as well as intensity of light and temperature during the growing season can influence $\delta^{13}C$ levels in plants (Tieszen 1991; Broadmeadow and Griffiths 1993; Heaton 2009; Hidy et al. 2009).

Nevertheless, even with various factors affecting water stress, in arid regions, the primary factor influencing $\delta^{13}C$ remains the availability of water (Ferrio et al. 2005).

Contemporary crop cultivation data serves as a crucial baseline for interpreting older sample data. (Araus et al. 1997; 1999; 2003; Fiorentino et al. 2012). Although there is a lack of data from the Murghab, experiments conducted by Wallace et al. (2013) in similar arid regions offer proxy evidence to evaluate $\delta^{13}C$ from the botanical remains in Togolok. In the framework proposed by Wallace et al. (2013: Figure 5), different levels of $\delta^{13}C$ can be indicative of *poorly-watered*, *moderately-watered*, and *well-watered* crops. According to this framework, in poorly-watered crops $\delta^{13}C$ values are usually below 16‰ for wheat. When moderately-watered, for which water is not a limiting factor for crops growing, $\delta^{13}C$ values can reach up to 17‰ for wheat. When $\delta^{13}C$ values are above 17‰ the crops can be considered well-watered (also see Araus et al. 1999: 206). The thresholds for wheat are considered to be the same as for the lentils and peas (i.e., 16‰), while values for barley are 1–2‰ higher compared to wheat. Single crop samples, however, can exhibit higher or lower $\delta^{13}C$ values due to the local condition of the crops, and thus a single data point should be considered with caution (Figure 6.46).

The data generated from the analysis are indicative of the possible irrigation in the Togolok in the Middle and Late Bronze Ages. However, they have specific limitations that need to be briefly mentioned. The $\delta^{13}C$ values provide only an approximation of the water status (low–medium–high). Further, $\delta^{13}C$ values do not necessarily indicate water added during the growing season, but the general water received by the plants either naturally or by irrigation (Wallace et al. 2013). Therefore, additional paleo-environmental data and archaeological contexts are crucial for interpreting isotopic value results.

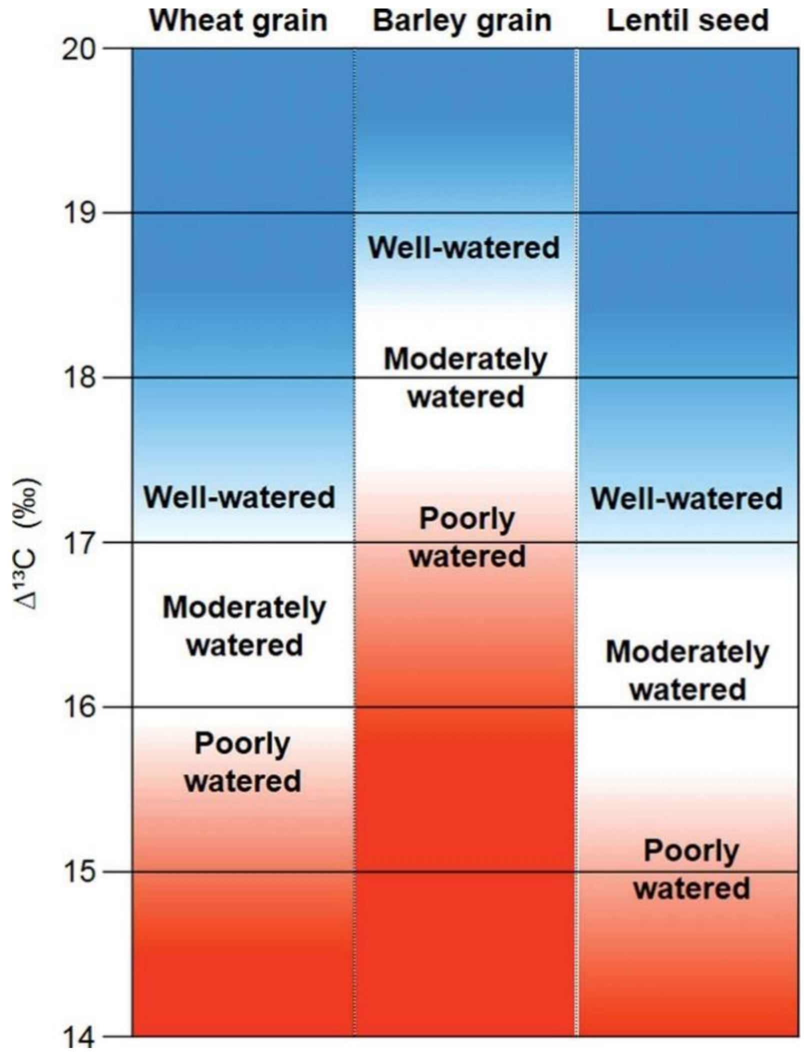


*Figure 6.46 The image shows the interpretation of $\Delta^{13}C$ in wheat, barley, and lentils in terms of water stress (Wallace et al. 2013:Fig.5).*

During the excavations between 2014 and 2018 by the TAP team at Togolok 1 (Cerasetti et al. 2019; 2022), several archaeobotanical samples were collected from the Middle and Late Bronze Age layers. Among all botanical assemblages analyzed, 25 samples were selected for carbon isotope analysis. The samples selected correspond to wheat (*Triticum aesitivum*), barley (*Hordeum vulgare*), pea (*Pisum sativum*), and lentil (*Lens culinaris*), taken from different stratigraphic units (Table 6.6). The analysis was conducted at the

Max Planck Institute in Jena (Germany), and the methodology applied to the analysis of the samples follows Wallace et al. (2013).[107]

| Site | SU | Year | Seed | Seed numbers | Chronology |
|---|---|---|---|---|---|
| **Togolok 1** | 108 | 2015 | Barley | 5 | LBA |
| **Togolok 1** | 108 | 2015 | Wheat | 3 | LBA |
| **Togolok 1** | 108 | 2015 | Pea | 1 | LBA |
| **Togolok 1** | 109 | 2015 | Wheat | 4 | LBA |
| **Togolok 1** | 109 | 2015 | Barley | 6 | LBA |
| **Togolok 1** | 109 | 2015 | Pea | 1 | LBA |
| **Togolok 1** | 109 | 2015 | Lentil | 1 | LBA |
| **Togolok 1** | 624 | 2018 | Barley | 2 | MBA |
| **Togolok 1** | 618 | 2018 | Wheat | 1 | MBA |
| **Togolok 1** | 618 | 2018 | Lentil | 1 | MBA |

*Table 6.6 The table presents the botanical samples selected for isotopes analysis from the Togolok 1 trench. The samples are from different stratigraphical units that were radiocarbon dated to the Middle and Late Bronze Ages.*

## 6.7.1 Results of the Isotope Analysis from Togolok 1

From the excavation of two trenches in Togolok 1 by the TAP team, wheat, barley, peas, and lentils from Late Bronze Age layers were selected along with a small sample of wheat, barley, and lentils from Middle Bronze Age layers from Trench 1A.

The carbon isotope from both layers shows interesting results. As per the experimental data from Wallace et al. (2013), the $\Delta^{13}C$ values[108] for wheat samples from Late Bronze Age layers are largely above the 17‰ threshold, which suggests that these crops were

---

[107] More specifically, the isotope analysis was conducted by Ayushi Nayak from the same institute. This is a preliminary analysis; a more comprehensive analysis with an expanded sample size will be published at a later stage.

[108] Following Wallace et al. (2013), the $\delta^{13}$ C result were converted into big delta ($\Delta^{13}C$).

well-watered (Figure 6.47). A few samples from the assemblages are between 16‰ and 17‰, which indicates a moderate water input. Samples from barley are generally above the 18‰ threshold, which suggests moderately to well-watered values. Among the cereals, wheat appears to have been better watered compared to barley. Lentils and peas also appear to be well-watered, although one single pea sample appears to be moderately watered.

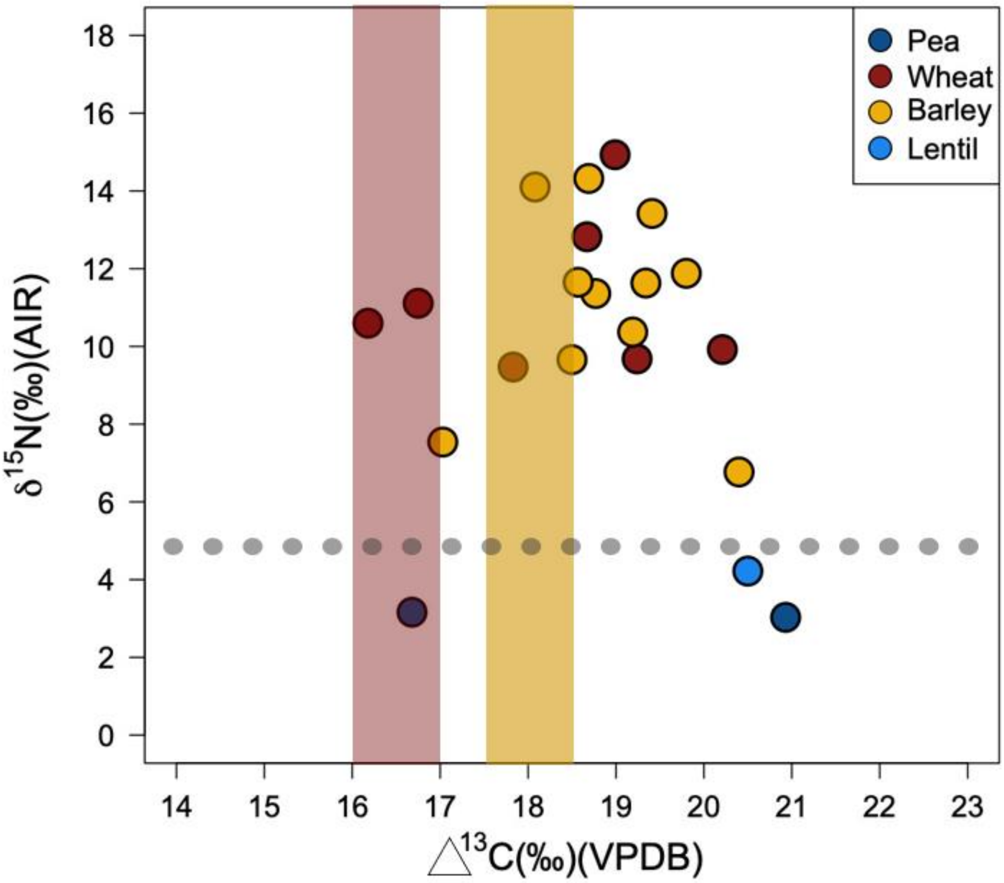


*Figure 6.47 The figure shows the isotope result for Late Bronze Age botanical samples of wheat, barley, pea, and lentil from Togolok 1. In the plot, the red (for wheat) and yellow (for barley) bands correspond to the levels separating low and well-watered samples (Wallace et al. 2013). The dash line displays medium- and well-manured crops (above the line) from the experimental d15N data (Bogaard et al. 2013).*

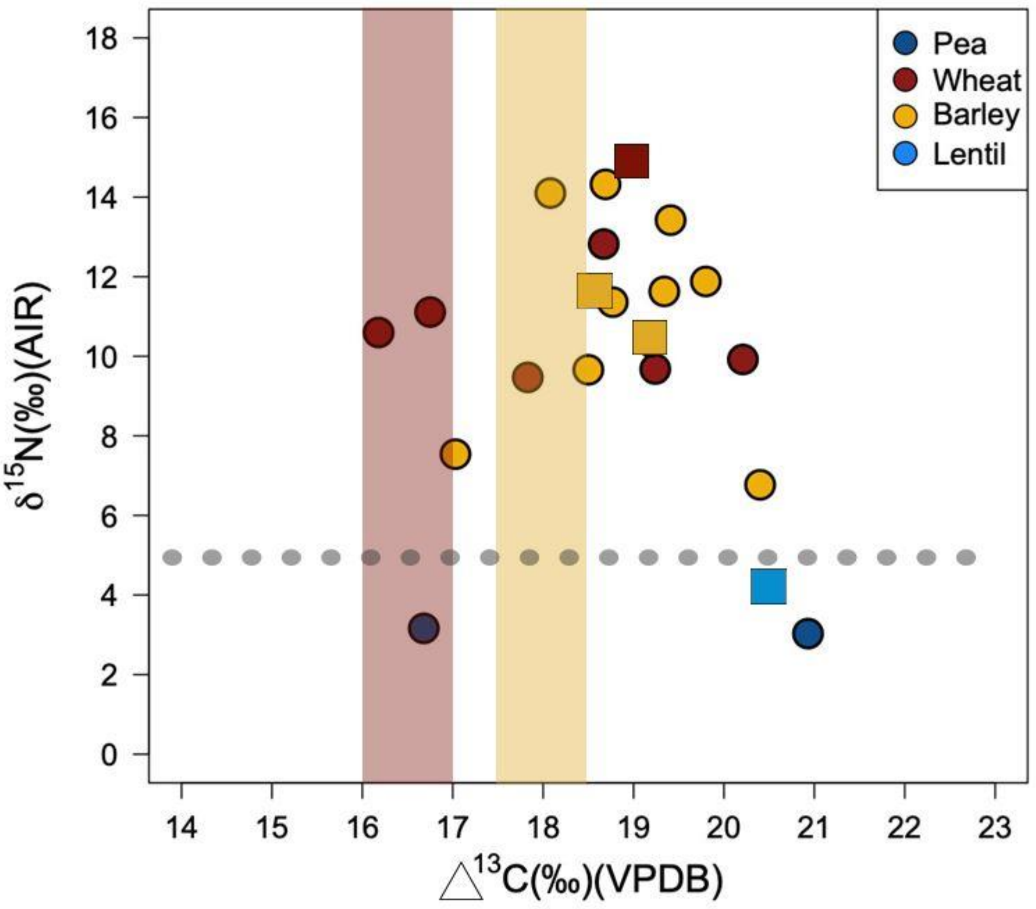


*Figure 6.48 The figure shows the isotope result for Middle Bronze Age botanical samples of wheat, barley and lentil (square) which are displayed against Late Bronze Age samples (circle) from Togolok 1. In the plot, the red (for wheat) and yellow (for barley) bands correspond to the levels separating low and well-watered samples (Wallace et al. 2013). The dashed line displays the medium- and well-manured crops (above the line) from the experimental d15N data (Bogaard et al. 2013).*

The samples from the Middle Bronze Age layers are lower in number but are also indicative of well-watered crops (Figure 6.48). Both wheat and barley from the Middle Bronze Age samples are above the minimum threshold and appear to be well-watered. Similarly, lentils appear to have been cultivated in well-watered conditions. Although limited in number, the Middle Bronze Age samples seem to indicate comparatively higher levels of water compared to the Late Bronze Age samples.

In addition to $\Delta^{13}C$, the level of $\delta^{15}N$ can be indicative of possible crop manuring (Kanstrup et al. 2011). In plants, $\delta^{15}N$ largely reflects the N in soil, which is affected by manure, aridity, and salination. As in the case of Togolok, both the Middle and Late Bronze Age samples of wheat and barley appear well-manured. The level of $\delta^{15}N$ for both wheat and barley are above the minimum thresholds according to experimental $\delta^{15}N$ data in Bogaard et al. (2013), while peas and lentils are below the assigned value. Nevertheless, non-manured legumes usually fall below 2–3 per mill. Therefore, it can be inferred that both legumes likely received adequate manuring, indicating a significant level of agricultural management for these crops.[109] Recently, manuring practices have been suggested by Wilkinson (2014) on the basis of pottery scatters around Togolok 1 (see Chapter 3), and this suggests that local farmers in the vicinity of Togolok 1 likely practiced manuring during both the Middle and Late Bronze Ages.

Altogether, isotopic data suggest that crops in Togolok received a medium to well-watered supply, both for cereals and legumes. It's interesting to note that despite indications of increased aridification and hydrological instability in the distal fan area during the 2nd millennium BCE, crops during the Late Bronze Age still received sufficient water with minimal water stress. Additionally, although the Middle Bronze Age samples are limited in number, they suggest less water stress compared to the Late Bronze Age samples. It's probable that during the Late Bronze Age local communities had to intensify irrigation to maintain levels of adequate watering to prevent crop failure. However, comparative data indicate that crops in both periods were moderately to well-watered, reflecting effective water and land management practices by local farmers despite any possible increasing aridification.

## 6.8 Synthesis

The data presented above suggest that the Togolok area included several active channels during the Bronze Age and Iron Age that were able to sustain agricultural activities. The botanical analysis is indicative of an agricultural system characterized by various crops, including grains, legumes, and garden fruits. Part of these crops were likely cultivated in the immediate surroundings of the sites, as

---

[109] It is important to note that $\delta^{15}N$ levels can also be influenced by aridity and caution must be used.

suggested by seeds embedded in animal dung. Further, agricultural fields were likely located along the channels. Although the majority of the takyr areas are small in terms of size, there are also larger takyr areas between 5 and 14 ha, suggesting larger agricultural fields to sustain larger populations compared to the Ojakly area. Stable channels able to provide sufficient water were also favorite locations during the Bronze Age for agricultural as well as other economic activities such as pottery production.

In contrast to the Bronze Age, during the Iron Age there is an increase in the distance to water channels which may suggest a change in water technology. The presence of Iron Age sites along channels located to the east of the research area also suggests an eastern shift in the fluvial landscape during this period. Indeed, radiocarbon data from Togolok 1 suggests that the site was abandoned by the end of the Bronze Age period (Cerasetti et al. 2022). This is further supported by the limited presence of Iron Age sites, found both near watercourses and further away.

The OSL dating and analysis of the stratigraphic profiles of the test trench in Paleochannel 7 suggest the presence of active rivers as early as the Chalcolithic period (5th and 4th millennia BCE). This raises questions about the potential early occupation of the Murghab during the Chalcolithic and early Bronze Age, which will be explored further in the next chapter. The analysis of the two trench profiles, however, also suggests a relatively low flow regime during the Chalcolithic and a more substantial flow during the subsequent period. It is likely that the regular water intake from the channels facilitated agricultural activities along the channels. The isotope analyses on botanical samples from Togolok suggest that crops, cereals and legumes were moderately to well-watered during the Bronze Age, with very little indication of possible episodes of water stress during the Late Bronze Age. They also present a good level of possible manuring.

This agricultural and water system of the Togolok area exhibits similarities with the rural area of Ojakly, yet there are also significant differences that will be discussed in detail in the following chapter.

# Chapter 7 – Discussion and Conclusion

## 7. Discussion

### 7.1 Overview

In the first three chapters of this thesis, I discussed the geography and archaeology of the Murghab in the 3rd and 2nd millennia BCE and the research problems connected to archaeological landscape investigation and the study of past hydrological systems. In addition, I discussed the "steppe" or "Andronovo" question in the Murghab, as well as the two main models of settlement systems that have been proposed in the last decades. In the case study chapters (Chapters 5 and 6), I investigated the paleochannel systems and settlement pattern of two micro-scale regions and to what extent these areas might be representative of different forms of agricultural and water management practices during the Bronze and early Iron Age.

In this chapter, I will build on the data of these separate case studies and present a general discussion that re-evaluates the settlement dynamics in the Murghab and what role the hydrological and agricultural system played in shaping these dynamics. I will begin by discussing how data from the two micro-areas in the Murghab may inform us about the local paleoclimate as well as the resilience of BMAC communities. Finally, I will present the conclusions drawn from this analysis and propose avenues for future research in the Murghab region.

### 7.2 Climate Change and Local Dynamics

The last decades have seen a boost in the amount of paleoclimatic data in West and Central Asia. This new data has often been used to explain changes in settlement patterns and the "collapse" of ancient civilizations (Dalfes et al. 1997). For instance, paleoclimate change has been used to explain the collapse of the Akkadian Empire in Mesopotamia (Cullen et al. 2000; Weiss 2016) or the de-urbanization of the Indus Civilization

(Staubwasser et al. 2003; Lawler 2007; Berkelhammer et al. 2012). The correlation of these events has often been central to the reconstruction of cultural and settlement histories. However, such relations between past climate and socio-cultural changes have also been criticized. Therefore, how climate change impacted past societies needs to be demonstrated rather than assumed by simple correlations.

In this context, models of cultural change that leave out the complexity of local human adaptation and rely only on broad climate events are too simplistic (Coombes and Barber 2005:303). As Wossink (2009:5) pointed out, many studies link climate change data with archaeological evidence indicative of socio-cultural transformations. However, although there is no doubt that climate-induced changes existed in the past, there is often insufficient attention to what actually happened in specific societies. For instance, social structures can play a crucial role in determining the effects of environmental changes on society (Wossink 2009:42). Communities under similar resource and climate stress might have different responses and show diverse degrees of resilience. This is the case for modern communities in Egypt for instance. Despite being under the same climate stress during prolonged droughts, the adaptive response of the Ma'aza tribe in the Egyptian Eastern Desert has differed from their urban counterparts (Hobbs 1990). For instance, Bedouin from the tribe protect drought-tolerant trees, such as acacia, from over-exploitation and also during periods of minor drought in order to safeguard these trees. This practice of confronting drought periods contrasts with the responses of their urban counterparts, suggesting different approaches to addressing the same problem. This example highlights the significance of cultural responses to climate change. This issue will now be explored in greater detail.

### 7.2.1 Micro-Climatic Changes and Social Response

Climate-induced changes in past societies are often understood as monolithic changes that occur over large regions (Weiss 2016). In contrast, I argue that the responses to such changes are better understood as the cumulative outcome of action undertaken by people, often at the household level (McIntosh et al. 2000 :4; Wossink 2009:5). As argued by

Winterhalder (1980:147), the response to climate variability by households and individuals is also based on cultural knowledge and practices. Such knowledge is often crucial to climate change responses that may differ from one society to next (McIntosh et al. 2000:24). At the Tell Sabi Abyad site in Syria, the local response to the “8.2 ka climate event” triggered an accelerated and particular development of ceramic bulk storage containers, for instance (Akkermans et al. 2015).

Paleoclimatic data often record general climate events that span centuries. By contrast, shorter climatic changes that might affect a community over, for example, ten years, are much harder to track down in the records. These short-term climate events may strongly impact local societies. In today’s context, we observe that the current climate crisis is characterized by rapid events unfolding within a few years, leading to severe problems, necessitating diverse adjustments across various sectors (Boazar et al. 2019; du Plessis 2019; EU Communication 2021).

Changing environments can generate different adaptation strategies (Winterhalder 1980: 147; Halstead and O'Shea 1989: 1; Wossink 2009:34). For instance, a rapid change in precipitation can lead to several adaptation mechanisms based on the economic and social situations (Halstead and O’Shea 1989; Minnis 1996:67). Practical examples of how local communities may react differently to climate changes comes from ethnographic research (Maddison 2006; Morton 2007; Kurukulasuriya and Mendelson 2006). For example, a comprehensive survey conducted among African farmers across eleven countries indicates that small-scale farms engaged in animal husbandry exhibited greater resilience compared to large-scale farmers (Seo and Mendelsohn 2006). Specifically, within the same geographical area, small farms were able to adapt by transitioning their livestock to more heat-tolerant breeds. Conversely, large farms faced greater susceptibility to the impacts of climatic variability, as they lacked the flexibility to swiftly transition a significant number of animals. In essence, the findings highlight how smaller, more agile farming operations are better equipped to respond to and mitigate the effects of climate change compared to larger-scale agricultural enterprises.

As argued by Sala (2014), under rapid climate change, agropastoralist groups can also increase labor investments or switch between stock-breeding and crop cultivation. Wossink (2009:37) had also argued that the response to environmental stress might differ from one household to the next, further highlighting that climate crisis may lead to different responses within the same community. Therefore, when considering vast regions, like Central Asia, it is evident that climate change exerts a varied impact across the diverse ecological ecozones within the region. For instance, Dixit et al. (2014) asserted that when assessing the impact of climate change on settlement patterns in the Indus Valley, it is essential to consider the broader diversity present within the region. As such, a more detailed evaluation of the relationship between climate and settlements is crucial when dealing with regions with diverse ecological areas.

Climate change has also been linked to the end of the BMAC (see Chapter 3). However, this “collapse” has been challenged by Luneau (2019), who stressed the importance of social and economic factors in these changes. According to that author, there was a substantial change in the ideology and in funerary practices at the end of the Bronze Age (Luneau 2021a). Therefore, the changes that occurred in the transition from the Bronze to the Iron Age should be understood as a complex socio-cultural reconfiguration of BMAC society (Luneau 2016; 2019). However, in light of the climate change that undoubtedly occurred in the Murghab between the end of the 3rd and the 2nd millennium BCE, it is crucial now to discuss and compare the results of the Togolok and Ojakly areas and to evaluate local adaptive differences between communities. It is also equally crucial to integrate such data into a broader discourse of agricultural exploitation models.

## 7.3 Re-evaluating the Local Dynamics during the 3rd and 2nd Millennium BCE

In Chapter 3, I discussed the two main environmental and settlement models that have been put forward in the last decades for the Murghab during the Bronze Age. Although paleoclimatic data are indicative of an aridification process from the late 3rd and early 2nd millennia BCE as discussed in this thesis, the “oases model” proposed by Soviet scholars has various problems (Sarianidi 1990a; Udeumuradov 1993). This model proposed a landscape characterized by settlement clusters grouped in oases in otherwise empty landscapes. In Sarianidi’s interpretation (Sariandi 1990a), these oases were fertile areas with vegetation, water channels, and large agricultural fields able to sustain large communities, in stark contrast to the surrounding dry landscape characterized by empty areas, with large dune areas and no crop cultivation, channels and settlements (Figure 7.1a created by Hiebert exemplifies this model). In the arid landscape in between the “oases,” pastoralism was supposedly the sole viable economic activity, sustained by localized underground springs.

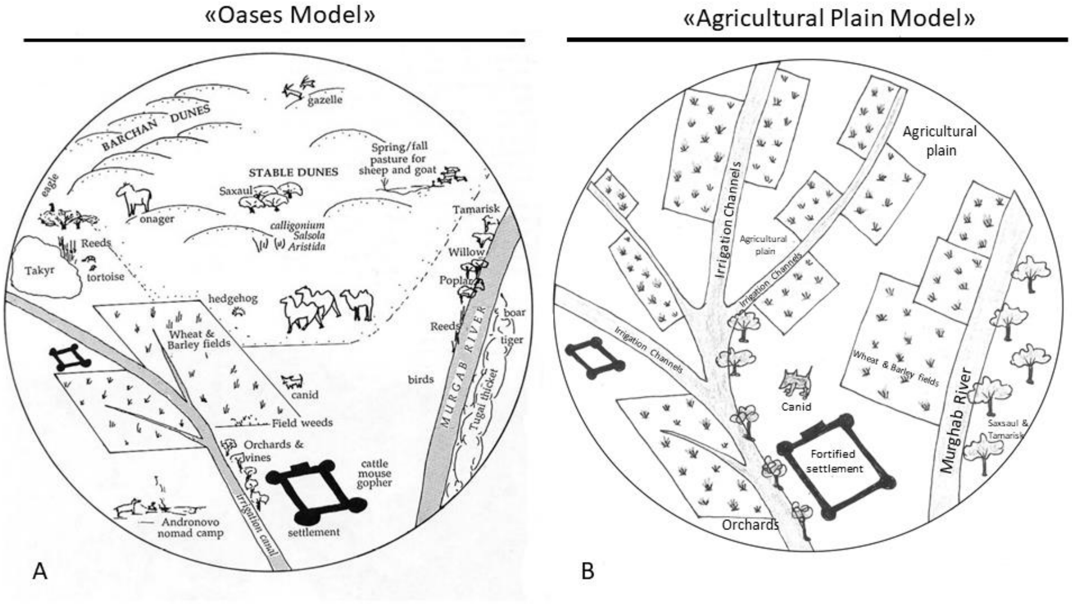


*Figure 7.1 The figure represents the two settlement models put forward by Sarianidi in the “oasis model” (Figure A) and by the AMMD in the “agricultural plain model” (Figure B). (Figure A adapted from Hiebert 1994: Fig.8.2.; Figure B illustration by S. Leonardi.).*

In sharp contrast to this model, as argued in Chapter 3, the survey undertaken by the AMMD revealed numerous sites well beyond the clustered oases posited by Sarianidi. Additionally, the AMMD uncovered the existence of multiple ancient channels capable of supporting such an extensive array of settlements (Gubaev et al. 1998). Building upon these evidence, the AMMD team proposed a new model wherein a continuous agricultural plain stretched across the Murghab, contrasting with these discrete “oases” (Figure 7.1b, exemplifies the AMMD model based on Hiebert’s drawing).

The examination of the Murghab landscape through two distinct case studies of Ojakly and Togolok in this study, however, presents contrasting perspectives, each posing unique questions and challenges to the two existing landscape models proposed so far. The investigation of these local areas sheds light on the complex interplay of social, economic, and environmental factors influencing settlement distribution and agricultural management in the Murghab region between the 3rd and 2nd millennia BCE. These dynamics defy the simplistic categorizations put forwards by these two models and call for a reconsideration and reevaluation of landscape uses and dynamics.

In the following discussion, I will examine both the hydrological and settlement distribution from both study regions. By discussing the local settlements and hydrological patterns from Togolok and Ojakly, it will be possible to better reassess the settlement models proposed for the Murghab as a whole.

### 7.3.1 “Dots” along the Channels

The survey conducted in the Togolok and Ojakly areas revealed the presence of several sites close to paleochannels that were previously unknown. Before discussing settlement patterns in relation to the general settlement model of the Murghab, it is worth discussing the post-depositional processes affecting these regions and what the sites identified represent.

Archaeological materials can be transported, especially by strong winter winds, and redeposited elsewhere. It has been argued (Markofsky 2010) that sand accretion caused by winds is especially prominent between takyrs and dune ridges. Therefore, archaeological materials are more likely to be discovered between dunes and over takyr areas due to the redeposition caused by wind (Vitkovskaya 1990; Orlovsky et al. 1994).

However, the second and most prominent factor, already introduced in Chapter 3, is sand movement. Sand and dunes in the Murghab can mask large portions of landscape, including archaeological material such as pottery, that can also be moved and redeposited by such phenomena. This can substantially bias our landscape understanding. While precise estimations based on experimental data have yet to be conducted, it is likely that a significant number of sites in the remote regions of the Murghab are buried beneath sand dunes. While tepe sites are less likely to be entirely covered by dunes, both large and small clusters of sites can be obscured by this process.

A third factor that has an impact on archaeological redeposition is run-off water by former channels. This correlation led Markofsky and Bevan (2012) to argue that the analysis of the directional component of the pottery – clustered along former watercourses in the Murghab – may be indicative of such depositional processes. An additional factor of post-deposition of material is the human or animal movement that can cause the dispersal of archaeological materials. In the Murghab, local shepherds move extensive flocks around the region between the winter and summer seasons. This movement can contribute, to a lesser extent, to the dispersal of archaeological materials (Bintliff and Snodgrass 1988:508–509).

A further problem is site visibility. Surveys conducted in Togolok and Ojakly during late fall, when vegetation is less abundant compared to spring or early summer, increase the likelihood of detecting major pottery clusters (both small and large). Further, as previously mentioned, sand accumulation along the Murghab River poses a significant challenge by masking sites. This problem is particularly pronounced in the Ojakly area, where sand encroachment is more prevalent.

While acknowledging any post-depositional processes, I argue that the aggregation of pottery in both the Togolok and Ojakly areas for the most part represents evidence of anthropogenic activities (i.e., temporary or permanent occupations). The aggregation of pottery identified in the present survey and that of the AMMD survey show a pattern distribution along specific channels in the Togolok area (see section 7.7 of this Chapter) that suggests that local communities specifically selected some watercourses over others. However, also the manuring hypothesis deserve attention.

### 7.3.2 Reconsidering the Manuring Hypothesis in the Togolok and Ojakly Areas

Artifact scatters in the landscape might have multiple origins. Recently, as briefly discussed in Chapter 3, Wilkinson (2014) suggested that these scatters across the Murghab might represent manuring activities. This interpretation is based on parallels in West Asia, where low-density scatters of pottery have been interpreted as resulting from manuring practices (Wilkinson 1982; Ur 2002; Newson et al. 2007; Kaptijn 2009). This interpretation is not surprising as the application of manure to fertilize the fields is also a well-known practice in antiquity in the Mediterranean region (Bintliff and Snodgrass 1988).

Based on previous research, Wilkinson (2014) outlines specific criteria to discriminate between occupation-related pottery finds and pottery scatters resulting from agricultural manuring. He distinguishes between raised areas with dense pottery assemblages that likely indicate *in situ* habitation on the one hand, and flat areas associated with moderate to high material density that can be related to manuring on the other hand. Small raised areas with a high density of materials likely represent settlements. In his approach, Wilkinson takes into account the percentage of pottery sherds per $m^2$ and their continuous distribution. For instance, at Tell Sweyhat (Syria), Wilkinson (1982) estimates several thousand sherds within an area of 177 $km^2$ around the settlement with subsurface and surface densities between 24 and 26 sherds per $m^2$. Further, Wilkinson notes a radial distribution of pottery (Wilkinson 1982:Fig. 6) with an overall decrease away from Tell Sweyhat (Wilkinson 1982:Fig. 5). Similarly, at Sohar (Oman), the sherd counts are in the order of 2.5–10 sherds per $m^2$ with a maximum density of 37.5 sherds per $m^2$. Based on Wilkinson's observation, it is crucial to shed light on the nature of the pottery scatters identified along former watercourses in the Togolok and Ojakly areas and their interpretation as sites in some cases.

The continuous distribution of material observed by Wilkinson in Syria and Oman finds possible parallel only in selected areas of the Murghab. At Togolok 1 there is indeed a radius around the main mound, where Cleziou had detected a high amount of pottery that might be related to manuring, following Wilkinson's observation (Cleziou et al. 1998). The pottery extends across a potential arable area around Togolok 1 and towards Paleochannels 2, 4, and 7. These areas surrounding the primary mound, where pottery density is notably high, may suggest regions where manuring activities were concentrated (but see Cerasetti et al. 2014). However, although the surveyed areas along the channels shows promise as fertile arable land, it appears unlikely that it was intensively fertilized. Throughout the survey in the Togolok and Ojakly areas, pottery was not extensively distributed along the channels. Instead, pottery presence was observed mainly in the form of scattered sherds of low to medium density, collected at specific points. Notably, there was no widespread distribution of pottery between these collection points, which represent either permanent or seasonal occupation sites.

Although the sampling survey strategies for the present project did not carry out a systematic count with grids, allowing density analysis (see Chapter 4 for methodology), sherd densities along the channels were significantly lower than the scatters described by Wilkinson and the one observed around Togolok 1. The pottery along the channels in Togolok and Ojakly observed during the survey did not present continuous carpets over large areas. In contrast, in the two case study areas, the pottery sherds were distributed in discrete locations (collection points) along former water channels. These pottery assemblages are often less than 1 ha in size, and sometimes located in slightly elevated areas (see Appendix 1 and 3). Out of the total number of sites discovered by the current projects in both areas, the majority (75%) do not exhibit any signs of significant takyr surfaces indicating the presence of sherds on potential arable land. In addition, in the Togolok area, only 12% of the sites identified by the present project and the AMMD are situated within major takyr surfaces, with the majority positioned outside or on the periphery of these surfaces. Conversely, in Ojakly, all sites are located outside major takyr areas. This evidence further suggests that these concentrations of pottery represent remnants of past occupation rather than scattered pottery intended for manuring the land.

While the hypothesis of manuring along the channels cannot be entirely dismissed for the Murghab, considering that other regions might adopt different practices, one would expect a more extensive, consistent, and continuous distribution of materials in favorable locations along the channels if this were the case. In contrast, certain channels exhibit a consistent pattern of pottery at specific intervals while others, potentially used for manuring and good arable lands, lack any pottery evidence. In addition, some pottery assemblages contain kiln fragments, such as along Paleochannel 7 in the Togolok area, which strongly contrasts such manuring hypotheses.

Altogether, the continuity and density of sherds, as emphasized by Wilkinson (1982), are crucial indicators unlikely to be present along the surveyed channels in this research. As such, the discrete concentration of pottery (found in small, large, and low mound areas) likely indicate distributed settlements along the watercourses.

### 7.3.3 Economy and Settlement Pattern in the Murghab

The settlement distribution of the Murghab in the Bronze Age was generally comprised of fortified citadels, such as Togolok 21 or Adji Kui 9, and small hamlets that might represent temporary structures or small farmsteads. Near Gonur, small settlements are attested in the vicinity of the main citadel through surveys and excavations (Fribus 2020). As discussed in Chapter 3, during the 2nd millennium BCE, there was a decisive increase of small settlements and a shift away from the main mounds in the Murghab, as well as in the piedmont area of the Kopet-Dag (Biscione and Tosi 1979; Salvatori 2008a). The presence and increase of these small settlements, in Ojakly and Togolok areas as well, can be viewed as a shift towards a more rural economy.

This increase in rural sites is probably also related to a change in agricultural practices within a changing environment that occurred in the 2nd millennium BCE. As argued above, many sites along the channels probably represent temporary or more permanent occupations, likely farmsteads. However, small cluster sites in the Murghab have often been interpreted as pastoralist campsites (Cattani et al. 2008: 44). This interpretation mainly relies on ethnographic parallels from the region. Up to the 19th century, it was common for local pastoralists to move their livestock from one grazing area to another on a seasonal basis (Niyazklychev 1973). The Russification and the later Sovietisation of Turkmenistan during the 20th century strongly impacted pastoralist practices leading to the sedentarization of many pastoral communities (Edgar 2004). However, opportunistic campsites with kilns for domestic uses, and small animal enclosures for sheep and goats are still common in the Murghab (Arciero and Forni 2018). These campsites are occupied periodically by shepherds who bring their livestock to various pasture areas. Undoubtedly, for the Bronze Age, the zooarchaeological data from the Murghab suggests that livestock breeding was of crucial importance both for central and rural sites. In Gonur North, for instance, sheep and goat dominated the assemblage (70%), while cattle bones constituted a small percentage (25.4%), including wild species (Sataev and Sataeva 2014). Similarly, the analysis of the archaeozoological remains from the 2014 and 2015 excavations in Togolok 1 shows a majority of sheep and goat (60%) (Cerasetti et al. 2022). These percentage numbers are even higher for the rural site of Ojakly, for instance (see Chapter 5).

This substantial presence of sheep and goats in many archaeological contexts suggests that livestock breeding was ubiquitous in the Murghab, and that was not a prerogative of rural and more distant sites (Moore et al. 1994; Rouse and Cerasetti 2018: Rouse 2020). From the mound settlements, different types of livestock breeding might have taken place, including exploitation of the surrounding landscape, as well as more distant type of pastoralism. According to Moore et al. (1994), the presence of wild seeds, such camel-thorn in sheep dung in Gonur, probably indicates that sheep were not only grazing around the site. This finds parallels at Togolok 1, where deposits with a large amount of sheep and goat dung with both wild and domestic seeds have been found, suggesting different grazing strategies (Billings et al. 2022: Fig.9).

The current evidence suggests that the interplay between crop cultivation and pastoralism was thus common in the Murghab in the 3rd and 2nd millennium BCE at different levels according to the site. This interplay is also present in the rural sites, including the non-BMAC ones. Both in Ojakly and Chopantam, archaeobotanical data suggest the presence of a reduced but consistent assemblage of crops, including cereals, that were likely cultivated in the immediate vicinity (Spengler et al. 2014).

The data suggest that an initial paradigm in which main settlement concentrations were located along the main branches of the Murghab and devoted to crop cultivation, while rural settlements, particularly ICW (Andronovo) sites, were far from water resources and devoted to pastoralism, needs to be reconsidered (Salvatori 2008a:59–67). In the Ojakly area, for instance, large cluster sites with either Namazga and ICW (Andronovo) assemblages had similar average distances to paleochannels and even less compared to mixed Namazga-ICW pottery. This contradicts the perspective that ICW (Andronovo) sites are typically found in areas far from water channels compared to the Namazga sites. Additionally, it is noteworthy that more than one-third of ICW (Andronovo) sites are situated near watercourses.

Although a clear-cut distinction solely on the basis of water distance should be treated with caution, this analysis nonetheless shows that linking economic activities directly to ceramic assemblages is problematic. Economic subsistence practices in the Murghab were characterized by a wide spectrum of farming types rather than a dichotomy of crop cultivation or to pastoralism. In this context, the varaities of channel to site distance, particularly in the Ojakly area, is also a reflection of this wide economic spectrum. However, the differences in water distance between Togolok and Ojakly can be also understood as different types of land use. This aspect, as well as the increased number of settlements during the Late Bronze Age, will be discussed in the next paragraphs.

## 7.4 Center–Periphery Dynamics in the Murghab

The settlement system with dense settlement cluster areas and small rural site areas was most dense during the Late Bronze Age in the Murghab (Hiebert 1994a; Salvatori 1998). However, the relationship between the small rural settlements and the fortified centers such as Gonur is not well understood. Past investigations of small sites has been limited, and most attention has been devoted to the main mounds. In addition, the increase of small sites during the Late Bronze Age has been associated with a modification of the political structure of the BMAC, and little attention has been devoted to changes in landscape management (Salvatori 2008a; see Petrie et al. 2017).

A good example of how rural settlements could be central to the economy of central sites in West Asia can be found at Tell Beydar (northern Syria) dating to the mid to late 3rd millennium BCE. It was argued that Beydar would have needed 214 ha to feed its population (Ur and Wilkinson 2008:313). However, the site hinterlands did not include such an extended agricultural area. Only with the seven subsidiary settlements, located in the proximity of the main site, could Beydar have supported its population. At Beydar, satellite sites were crucial for feeding the large population of the town and in the whole economy of the area (Sallaberger and Ur 2004:66; Widell et al. 2013:59–60). The importance of cooperation between central settlements and hamlets is also evident in the agent-based modeling for Beydar. The analysis simulated a span of 100 years, incorporating natural factors like weather, hydrology, crop growth, and soil evolution, alongside social processes such as crop farming, herding, trade, and daily interactions among households. In the model, several scenarios of environmental stress were tested, such as prolonged droughts and chronic crop blights (Wilkinson et al. 2007). The results showed that resilience could only be obtained via cooperation, and this was strictly related to the network capacities of the small settlements around the main site. While this agent-based model focuses on a single settlement system at Tell Beydar, it nonetheless exemplifies how rural communities can play a vital role in managing environmental crises.

The climate towards the end of the 3rd and the beginning of the 2nd millennium BCE in the Murghab is characterized by increased aridity. The stratigraphic analysis from the Ojakly test trench discussed in Chapter 5 (section 5.6.3) shows a variable flow regime of the channel during this period. This suggests that the river flow was unstable by the end of the 3rd and the beginning of the 2nd millennium BCE. This is consistent with data from the distant fan area of Egri Bogaz in the Murghab that show a similar variable flow regimes by the 2nd millennium BCE. It is likely that the erratic water supply of the distant Murghab fan contributed to a higher mobility in the region. The survey by the AMMD recorded more than a thousand small sites with Late and Final Bronze Age assemblages. This increased number of small sites within a changed settlement distribution, implying a new type of agricultural and land management. It may also suggest an agricultural response to overcome water stress in the plants by the 2nd millennium BCE. For instance, carbon isotope analysis of botanical samples from Togolok 1 does not indicate significant water stress in plants. While some Late Bronze Age samples exhibit lower water levels compared to those from the Middle Bronze Age, the data nonetheless also suggest moderate to well-watered crops for the Late Bronze Age samples. This is indicative that despite potential increases in aridity, the local community at Togolok 1 managed to maintain effective irrigation of their fields. It is likely that the increased distribution of small sites, including fortified sites such as Togolok 1 or Togolok 21, played a crucial role in this respect.

As discussed in Chapter 3, the early analyses of the ancient distant Murghab fan focused on the reconstruction of the main channels only (Cremaschi 1998; Cerasetti 2008:Fig 2.3). However, the Togolok and Ojakly area analysis in this study demonstrates that the reconstruction of smaller channels is central to understanding settlement complexity during the Middle and Late Bronze Ages. As such, agricultural and irrigation management has been shaped by this complexity and is now worth considering.

### 7.4.1 Settlement Systems and the Problem of Single-Period Occupation.

As discussed in the previous paragraphs, there was a major increase in small sites, often in rural areas, during the Late Bronze Age. These small sites have not been investigated much, and almost all of these sites have only been dated by surface pottery. However, the archaeological materials collected on the surface are indicative of the last phase of occupation. In the last decade, the single-period chronology of the larger Murghab sites has undergone considerable revision and critique (Luneau 2019). While the main mounds in the Murghab were predominantly dated to a single period by the soviet chronology, it is evident that many of them have larger occupations. In contrast, the smaller sites typical of the Late Bronze Age may represent single-period occupations. The excavations conducted at Ojakly, Chopantam, and Gonur N. have substantiated the single-period occupation implied by surface assemblages (Rouse and Cerasetti 2014; Cattani 2008a; Hiebert and Moore 2004).

In this context, concerning small settlements, surface pottery can indeed serve as a reliable indicator of the site's chronological occupation. However, as discussed in this thesis, pottery periodization in the Murghab region poses several challenges that could potentially skew our comprehension of settlement patterns and their chronology.

Over the last decades, little investigation has been devoted to dividing chronological pottery periods (e.g., Middle or Late Bronze Age) into sub-phases with a robust $^{14}$C data sequence. The Murghab settlement system models have often ignored the problem of site phases and possible repeated occupations of the same settlement (Salvatori 2008a). This issue is not new and has been addressed by scholars in other regions who used various models to overcome such problems, such as in the Indus Valley region where it has been demonstrated that the contemporaneity of the sites is a crucial factor to consider in assessing settlement dynamics (Schacht 1984; Sumner 1994; Dewar 1991;1994; Petrie and Lynam 2020). For the Murghab, Wright (2008) might be correct in pointing out that dispersed nature of the sites during the Late Bronze Age and the contemporary reduction in size of the main settlements did not equate to a decrease in population. However, the issue of the contemporaneity of sites in the Murghab has been little considered by scholars, despite the fact it can have crucial implications for our understanding and interpretation of the Murghab settlement systems and demographic reconstructions.

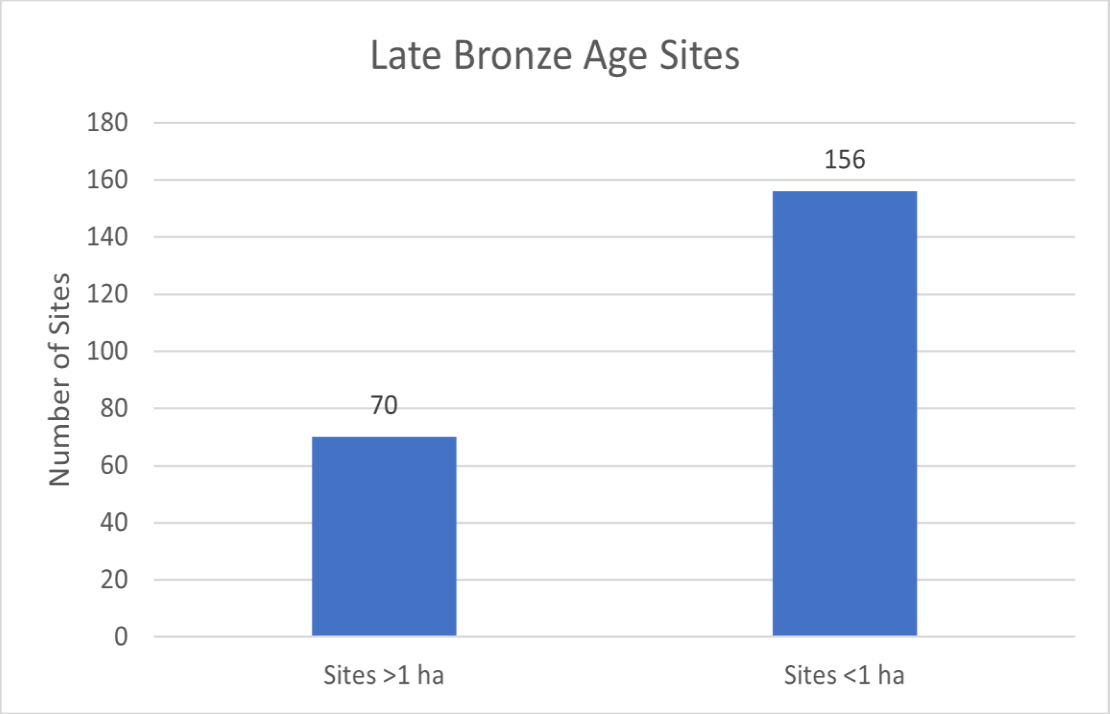


*Figure 7.2 The column chart shows the number of sites dated to the Late Bronze Age divided by sites that exceed 1 ha (left) (n=70) and those that do not exceed it (right) (n=157).*

Although breaking down chronological periods into sub-periods is outside of the scope of the present thesis, it is worth acknowledging the problem in light of the settlement and paleochannel systems. The instability of the hydrological system during the long period of the Late Bronze Age (1950–1500 BCE) coincides with a fragmentation of sites into smaller settlements dispersed more widely across the landscape. However, the lack of additional data and excavation of small sites has often led to considering all these small sites as contemporary. This contemporaneity of occupation can lead to an overestimation of the actual land occupation and population. In contrast, small sites in the Murghab during the Late Bronze Age may have experienced occupation and reoccupation at various times due to an increased mobility. This mobility served as a strategy to cope with an unstable hydrological system, requiring movement across active channels. As such, small sites might have shifted more often due to deactivation and a different level of water flow of small river channels, as documented for Ojakly paleochannels. If one considers that the Late Bronze Age period spans over 450 years, and the majority of LBA sites (69%) are small rural sites of less than 1 ha, it is likely that these very small sites may represent short term occupation sites by local groups that are not contemporaneous with each other (Figure 7.2).

Further, the total number of rural sites exhibiting Late Bronze Age chronology is 469. Assuming a conservative estimate of a 40-year occupation span for each individual site, it could suggest that only approximately 42 sites were occupied at the same time in the Murghab region. While the primary focus of this paragraph is not to extensively delve into this aspect, which would require more investigation, this basic calculation serves as an indicator of the critical importance of considering this factor when analyzing the occupation of the Murghab region. Underestimating this issue, as mentioned above, can lead to an overestimation of sites and population during this period. This aspect is crucial when assessing water management practices during this period and the potential challenges related to possible depopulation and transformation of the BMAC.

## 7.5 Pastoralism and Agricultural Practices: Same Landscape, Different Strategies.

Although the idea of a dichotomy between settled agriculturalists and mobile pastoralists strongly influenced the interpretation of the Bronze Age subsistence economies of the Murghab, data from rural sites suggest, in contrast, the use of mixed agropastoral strategies rather than exclusive pastoralism (Cattani 2008b; Spengler et al. 2014; Rouse and Cerasetti 2018). As discussed in previous paragraphs (section 7.3), various sites may have depended on similar subsistence activities irrespective of their pottery assemblages and group levels. However, to what extent these areas might have had different degrees of pastoral and crop cultivation activities is a matter of discussion in this chapter.

Undoubtably, botanical remains can provide a crucial indication of agricultural variety (see next paragraph). Nevertheless, the distance from water resources can also provide indications for agricultural differences between dense settlement clusters and rural site areas. As such, data from both Togolok and Ojakly may support different types of agricultural and irrigation management.

An early investigation by the AMMD suggested forms of agricultural activities along the channels for the later Iron Age period. In the southern area of the distal fan Cattani and Salvatori (2008:9–10) documented two lines of settlements with fireplaces, walls, and mud brick structures along a paleochannel. Beyond these sites, interpreted as farmhouses, was a low-density distribution of Yaz III pottery (550–340 BCE, Iron Age 3), possibly as a result of manuring activities (Cattani and Salvatori 2008:Fig. 1.7). Cattani and Salvatori (2008) interpreted this evidence as a sequence of sites behind which there were cultivated fields.  A similar hypothesis can be expected for both the Togolok and Ojakly areas where settlements are located along channels with agricultural fields next to them. However, the percentages of settlements and their distribution change substantially between the two areas. Figure 7.3b illustrates the number of sites and their relative distances in discrete sections of 50 m in both the Togolok and Ojakly areas. In the Togolok area, it is evident that the majority of sites (56% of the total) are situated within approximately 100 m from the water channels, with a sharp decrease in sites beyond about 300 m. In contrast, the distribution in the Ojakly area differs. In Figure 7.3a, two clusters of sites (in orange and green) constitute the majority of sites in the research area (70% of the total). These clusters are located farther away from water sources than those in the Togolok area. Even the first cluster of sites, which is closer, is located between 100 and 300 m from the nearest paleochannel. Only a small percentage of sites (22% of the total) are situated within approximately 100 m from the nearest channel, in sharp contrast with 56% from the Togolok area. This data indicates a strong tendency for sites in Togolok to be positioned very close to watercourses. Additionally, the data suggest that the distance from water sources between Togolok and Ojakly is distinct, implying that in rural areas, water management and its relation to agriculture and land management may vary significantly.

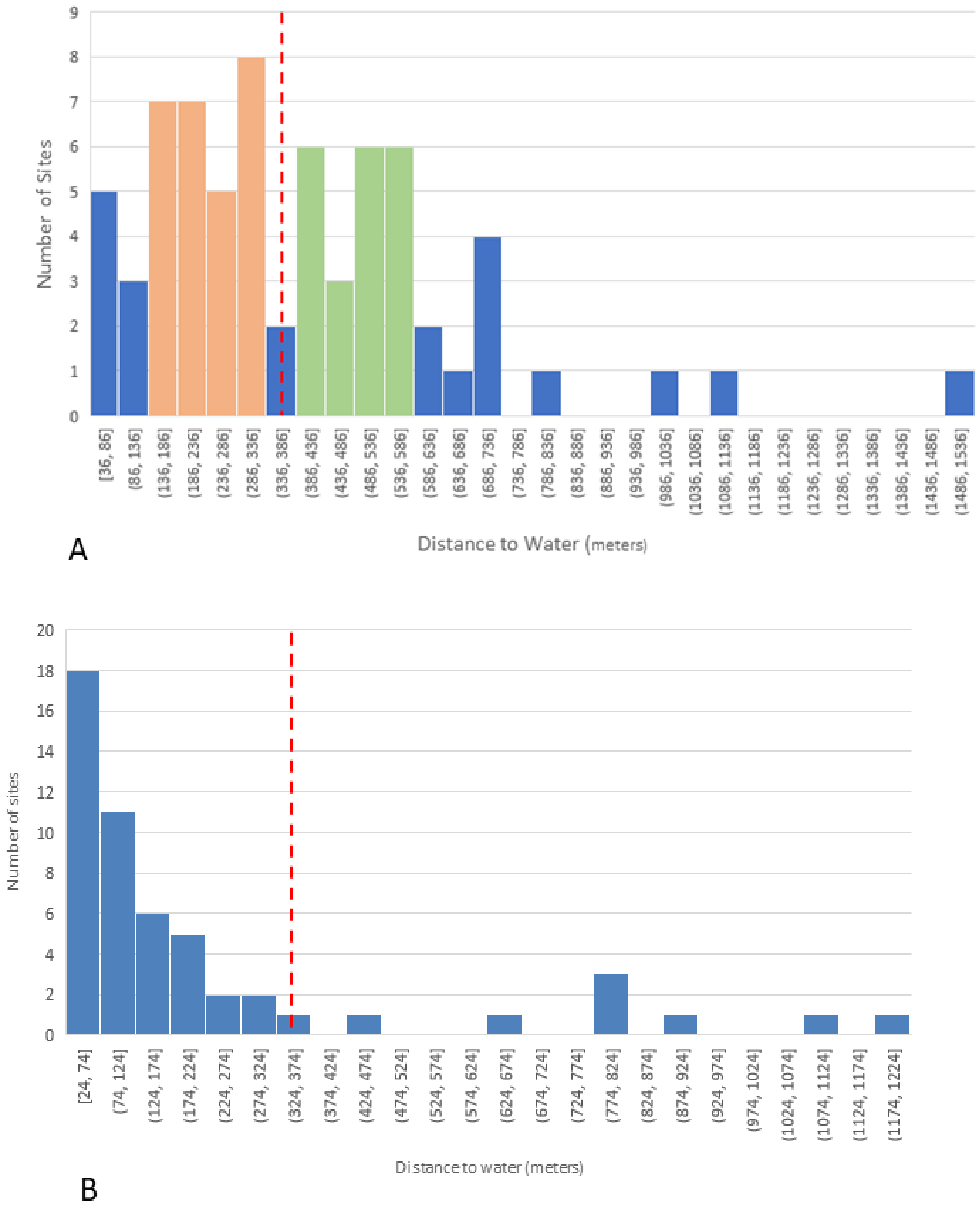


*Figure 7.3 A) The histogram shows discrete intervals every 50 m in water distance from the nearest paleochannels in the Ojakly area. The orange and green color highlight the two different cluster of sites. The red dashed line highlights a clear drop-off of sites between the two groups. B) The histogram shows discrete intervals every 50 m in water distance from the nearest paleochannels in the Togolok area. The red dashed line highlights a point of a clear drop-off of sites.*

To further test the water–site distances between Togolok and Ojakly, I conducted a Mann-Whitney U test on both water–site groups of the Togolok and Ojakly areas. The Mann-Whitney U test is a non-parametric test that is used when the data of the groups are non-normally distributed, in contrast to the T-test (Emerson 2023). The non-parametric test ranks all the combined data together, regardless of their group belonging, and calculates, for each group, the sum of the ranks. The rank of all the values are combined together from lowest to highest. Subsequently, the test calculates the statistic for each group (i.e., U1 Togolok and U2 Ojakly).

$$U1=n1n_2+n1(n1+1)/2–R1$$[110]

$$U2=n1n_2+n2(n2+1)/2–R2$$

The U test is meant to confirm or reject the null hypothesis (i.e., statistical or no statistical differences between the two groups) (for details about the U test, see MacFarland and Yates:103–132; Hollander et al. 2015). In the test, the last value to be determined is the p-value.[111] If the p-value is less than the significance level (usually set to a value of 0.05; see Hollander et al. (2015), the difference between the two groups is statistically significant. In the case of the two groups of Togolok and Ojakly paleochannel–site distance, the p-value that results from the non-parametric test is:

p-value : 1.88877 x 10^(-7)[112]

Considering that the p-value is significantly lower than the value of 0.05, the distance between paleochannels and sites between Togolok and Ojakly areas is statistically different. Although with caution, this test is indicative that the channel–site distance, and thus agricultural practices that derived from it were different between rural areas and dense settlement clusters.

---

[110] In the formula: U1 is the U statistic for group 1; U2 is the U statistic for group 2; R1 is the sum of ranks for group 1; R2 is the sum of ranks for group 2; n1 is the sample size of group 1; n2 is the sample size of group 2.

[111] The Mann-Whitney U test was conducted using Excel, from which the p-value was determined.

[112] Another way to represent the number is 0.000000188877.

In the Murghab, evidence of artificial channels able to transport water is rare. As discussed in Chapter 3, only a few canals were found in the Gonur area (Sarianidi and Dubova 2012; Hübner et al. 2019). However, these canals in Gonur North cover short distances between natural channels and the potential fields. Therefore, as proposed by Cattani and Salvatori (2008), it is likely that at the end of the 3rd and in the 2nd millennium BCE, agricultural fields in the northeast of the alluvial fan were located near natural water sources able to support irrigation without the use of long artificial canals. Notably, as discussed above, the Togolok area, which has a rich array of cultivated crops, also shows a high percentage of sites close to paleochannels, in contrast to Ojakly (Figure 7.3).

Considering the increasing aridity between the end of the 3rd and the 2nd millennium BCE, communities located far from the channels, in particular in the Ojakly area, are unlikely to represent a groups whose primary subsistence economy was based on crop cultivation. In contrast, these sites might have practiced pastoralism along with small forms of opportunistic farming, including the use of wells. Equally, not all sites located along channels represent crop cultivation communities, as pastoral groups may also prefer areas along channels for their livestock. However, despite these observations, the data concerning the relationship between water and sites discussed in this paragraph suggest that rural areas and dense settlement cluster areas may have responded differently to increasing aridity by employing distinct strategies. To delve deeper into this crucial question and its implications for our understanding of settlement patterns in the Murghab, it is essential to explore additional data that could provide further insights into the matter.

## 7.6 Agriculture and Subsistence Economies in Rural Areas

In the Togolok and Ojakly areas, as argued above, the lack of evidence for artificial canal and dam networks suggests that agricultural fields were located along the channels that could provide sufficient water to irrigate the fields. The satellite analysis did not detect any canals, apart from small features in Ojakly that could not be verified on the ground. If an extensive network of larger canals (exceeding 5 m in width), as often postulated (Lamberg-Karlovsky 2013), had existed in locations like Togolok, it is likely that this would have been partially detected in CORONA or ASTER images. Therefore, data from both rural areas and large fortified sites, such as Togolok, suggest that irrigation in the 3rd and late 2nd millennium BCE was centered on natural channels with the possible addition of small dams and minor canals that escaped remote detection.

While both the Togolok and Ojakly areas may share similarities in terms of the absence of a significant canal system, they nonetheless exhibit distinct characteristics. The area of Ojakly during the 2nd millennium BCE likely relied on mixed farming in which rural sites distant from water channels were engaged in herding, while small-scale agriculture was practiced by small communities living near natural channels. The analysis of the takyr areas is crucial in this respect. Compared to Togolok, the Ojakly area is generally characterized by small to very small takyr areas next to channels. This system is indicative of small plots spread widely across the landscape. In contrast, in the Togolok region, large takyr areas are present that are indicative of more large-scale farming. If one considers the water to site distance for Togolok and Ojakly discussed above, the data shows a higher percentage of sites in Ojakly located further away from water resources.

In addition, these sites are also distributed along channels that have limited takyr areas. As such, it is likely that in rural regions crop fields were marked by small plots situated near channels, rather than expansive agricultural zones. This distinct land use strategy, in contrast to that at settlement clusters, aimed to optimize labor investment and mitigate the risk of water scarcity associated with extensive agricultural fields. The preference for this agricultural practice in rural settings may have been influenced also by the hydrological variability of the distal channels of the fan, necessitating a different approach compared to dense settlement cluster areas. This hypothesis gains further support from botanical remains indicating a scaled-down farming system.

Compared to the dense settlement clusters, like Togolok, the crops from rural sites are less varied (Table 7.1). Agriculture focused on specific crops able to sustain small populations and which required less water and labor investment (Spengler 2019a:164). As for legumes and garden crops, only selected ones were cultivated, while there is evidence for the majority of them in larger fortified sites such as Gonur (Sataev and Sataeva 2014). Further, crops such as millet (*Panicum*) predominate the assemblages in rural sites.[113] In contrast, cereals and garden crops predominate in settlement clusters, such as Togolok 1 and Gonur (Sataev and Sataeva 2014; Billings et al. 2022). The increased percentage of millet at rural sites can indicate low-investment agriculture as well as forms of opportunistic farming along active channels (Miller et al. 2016). Indeed, millet requires less water and less time to grow, and it is also less labor-demanding.

| **Plant species** | Murghab Region, Turkmenistan | | | | |
|---|---|---|---|---|---|
| | **Togolok 1** | **Gonur** | **Adji Kui 1** | **Ojakly** | **Chopantam (Sites 1211–1219)** |
| *Hordeum vulgare* var. *vulgare* (hulled barley) | x | x | x | x | x |
| *Hordeum vulgare* var. *nudum* (naked barley) | x | x | x | x | x |
| *Triticum aesitivum/turigidum* | x | x | x | x | x |
| *Triticum* cf. *sphaeroccum* (highly compact wheat) | x | x | | x | x |
| *Triticum* cf. *dicoccum* | | x | | | |
| *Triticum monococcum* | | x | | | |
| *Panicum* | x | x | x | x | x |
| *Cicer arietinum* | x | x | x | | |
| *Lens* | x | x | x | | x |
| *Pisum* | x | x | x | | x |
| *Lathyrus sativus* | x | x | x | | x |
| *Vicia faba* | x | | x | | |
| *Vicia ervilia* | x | | x | | |
| *Vitis* | x | x | | | |
| cf. *Malus* | x | x | | | |
| cf. *Prunus* | x | x | x | | |
| *Crataegus* | x | | x | | |
| *Pistacia vera* | | | | | |
| *Lallemantia* (oil crop) | | | x | | |
| *Linum* (cf. flax seed) | | | | | x |

*Table 7.1 The table shows the presence/absence of recorded crops in the main fortified sites of Togolok 1, Gonur, Adji Kui 1, and the rural sites of Ojakly and Chopantam in the Murghab (table adapted from Billings et al. 2022:Table 2).*

Taken as a whole, the reduced set of crops, the spread of small takyrs, as well as the distribution of sites across different channels, is indicative that forms of small-scale land

---

[113] In Ojakly, millet is the predominating crop over site layers, with the exclusion of the kiln deposit. For the other crops, barley is the predominating one, and is also a drought tolerant crop (Rouse and Cerasetti 2014).

and irrigation management characterized rural sites with a mixed economy. In contrast, in settlement clusters, such as Togolok, large takyrs along with vast array of crops suggest a variegated agricultural system able to sustain large numbers of inhabitants. At Gonur, for instance, a population between 2,100 and 2,265 was estimated by Markofsky (2010:280). However, considering the extent of Gonur North (>50 hectares) and its hamlet sites, this might be a very low estimate. If one considers its entire extent, Gonur North might have encompassed a population of more than 12,000 (see section 7.8 of this Chapter for a population estimate at Gonur North).

All in all, these data suggest that different forms of land management were in place during the end of the 3rd and 2nd millennium BCE. Dense settlement cluster areas necessitated a different water intake for an extended set of crops able to provide a specific and more reliable amount of water for mixed crop production. In contrast, this agricultural production was more limited in rural areas due to different land management and water availability.

As discussed in Chapter 2, the landscape management system in site clusters areas was highly developed, while rural areas featured a decentralized system. This dichotomy finds parallels in the descriptions of the Merv oases by Arab geographers. These geographers, who visited Merv in the 10th century, reported that watercourses far from the main city and in marginal areas were often poorly maintained (Kennedy and Moore 1999: 124). This observation is corroborated by the excavation of the canal system within the Islamic city of Sultan Kala in Merv, which shows evidence of good maintenance (Williams 2018). In rural areas, communities often rely on small-scale agriculture and animal herding. In modern Turkmenistan, this subsistence economy is still partially practiced. Although modern cultivation includes crops like watermelon and cotton, small-scale farming persists in the northeast Murghab region, including the Togolok area. Preliminary ethnographic studies, including interviews with local shepherds, indicate that the roles of shepherd and agriculturalist often overlap in the Murghab (Arciero and Forni, 2018). Throughout the year, the same person may engage in both cultivation and animal herding at different times. This suggests that for groups living in the distal areas of the Murghab fan, there is no clear distinction between herding and agriculture. As Bir-David (1992) highlights regarding the modern Nayaka hunter-gatherers from South India, who often engage in additional subsistence activities such as small-scale agriculture, they "*simply obtain the resources afforded by their environment through whatever means happen to be suitable*." While we must be cautious about making direct parallels, this preliminary study on Murghab shepherds suggests that a combined economic strategy, without a clear division of societal roles, remains an effective approach to coping with an arid climate. The interchangeability of these two occupations allows the local population, mainly young men, to sustain their families and local communities. In the distal areas of the fan, where water is scarce, both pastoralism and agriculture alone are insufficient. This combined economic approach is crucial for managing periods of low yield and for providing agricultural products to sell at local markets.

Regrettably, unlike Mesopotamia, the lack of a writing system in this region during this relevant period of the Bronze Age results in an absence of records indicating the political and economic system, including how the water system was managed. As I argue in this thesis, in absence of any indication, applying a Mesopotamian model to the Murghab political system and water management in this context can lead to methodological and logical errors. Likewise, as for the political system, also religious aspect of the BMAC are almost unknow, including aspects related water. However, it is likely that water could easily become an element of worship, as seen in ancient Mesopotamia, Egypt, China, and India (Witzel 2015). In the Murghab several objects can be related to religious aspects. For instance, the function of terracotta flat violin-shaped female figurines is open to interpretation. Considering their limited length and probable suspension as pendants, these figurines might have held religious significance (Luneau and Shirazi 2020). Likewise, impressed seal might hold a different use in addition to an economic role. The presence of a perforated handle or a hole drilled through the longitudinal axis is a distinguishing feature of nearly all seal types attributed to the BMAC. The theory that a string could be passed through the hole, allowing these objects to be worn as pendants, implies a possible symbolic or apotropaic function, especially for seals with intricate iconographies, such as hybrid figures combining human and animal elements (Forni and

Arciero 2022). This interpretation is supported by the discovery of 112 seals within 109 burials at the Necropolis of Gonur (Sarianidi 1998a). However, none of these iconographies appear to be related to the element of water, nor have they been interpreted as such.

As for the political system, the findings of very rich tombs in Gonur, separated by the necropolis and termed the "Royal Necropolis" by Sarianidi (2007), suggest that forms of social inequality existed in the Murghab region. However, Sarianidi also admits that many of the tombs in the necropolis located west of Gonur North were looted in antiquity, which could bias our understanding of the social structure of the Murghab communities. Undoubtedly, as discussed in Chapter 3, these rich tombs indicate the presence of local elites whose social structure, power, and exercise of power remain largely unknown to us.

## 7.7 Stability and Predictability of the Water System

In an arid environment, one would expect that mainly water availability dictates farming. However, water availability is not the only determining factor for a successful yield. As discussed in Chapter 5 (section 5.8), crops have specific water demands at particular times of the year. Thus, seasonality of water intake is central to what is possible (Clemmens 2006).

In the context of irregular fluvial activity in the 2nd millennium BCE, agriculture might have been at risk in terms of water intake and time of delivery. As such, Lamberg-Karlovsky (2013) argued that water intake resulted in competition among communities, leading to possible conflict. However, from the excavated sites of the Murghab, there is little evidence for such conflicts. Nevertheless, the undeniable challenge of water availability remained a significant issue in agricultural and irrigation management. In this context, settlement distribution can offer a robust indication that BMAC communities had diverse strategies to deal with this issue.

In the Togolok area, among the ten paleochannels identified, two paleochannels stand out in terms of the number of sites along their courses. Out of the total number of sites recorded in the area, 34 settlements are located close to a water channel, thus likely using water from them. Of these 34 sites, 42% (n=14) are located along Paleochannel 7, while 23% (n=8) are located along Paleochannel 2 (Figure 7.4). The remaining five paleochannels from the Togolok area have a relatively small percentage of nearby sites. Thus, the majority (65%) are clustered along two paleochannels among the seven paleochannels identified in Togolok. This peculiar settlement distribution is also evident from the spatial density analysis[114] that shows the higher concentration of sites are the ones along Paleochannel 7 compared to all other areas (Figure 7.4). This settlement distribution along channels is in sharp contrast, however, with the Ojakly area.

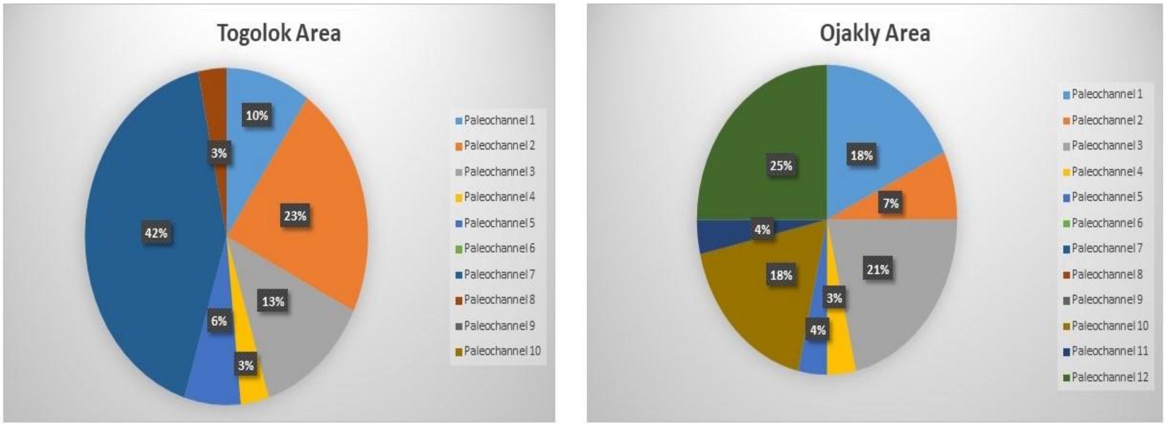


*Figure 7.4 The charts show the percentage of sites located along paleochannels in the Togolok and Ojakly areas.*

In the Ojakly area, there is more parity in the distribution of sites located along the paleochannels. Out of twelve paleochannels, only two (paleochannel 3 and 12) show a greater percentage of sites along the channels. However, these percentages are significantly lower than at Togolok and the number of sites along the channels are more

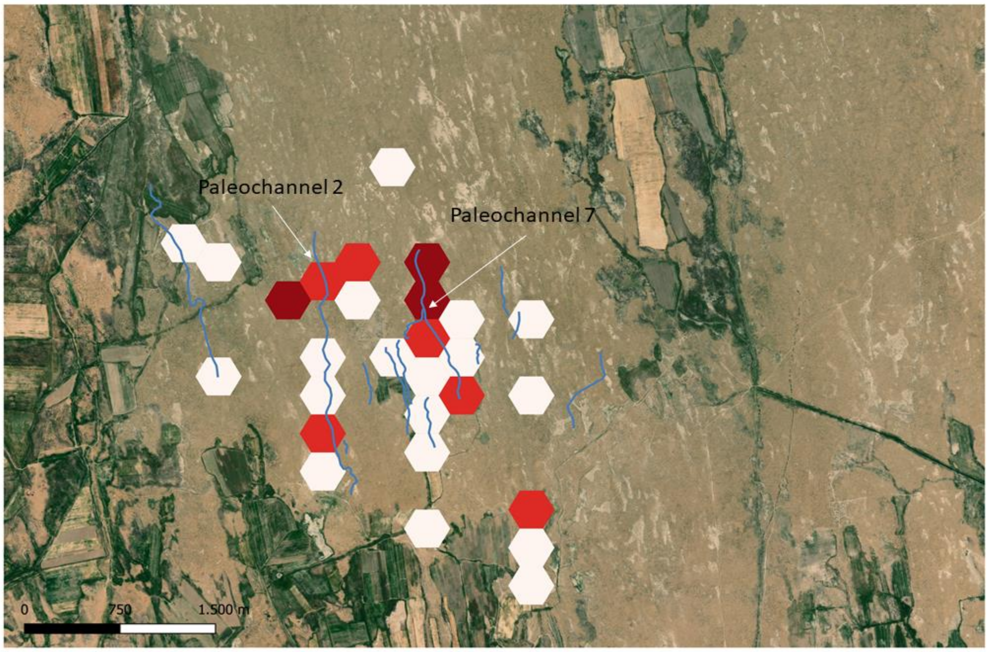
---

[114] Spatial density analysis involves the examination and distribution of given geographic features. It helps in understanding the intensity and the occurrences of a given phenomenon across space.

widely distributed. The spatial density analysis also suggests heterogeneity of sites distributed in the landscape, with only some areas (A, B and C) that show a greater concentration of sites (Figure 7.5). However, the distribution of sites across the paleochannel system is overall non-uniform. This suggest that there is little preference for specific channels among these rural communities.

Altogether, this analysis suggests that in dense settlement clusters like Togolok, the BMAC communities selected specific paleochannels for agricultural and other economic activities. Notably, Paleochannel 7, which contains 42% of all settlements situated along channels, is also the channel where the pottery workshop was located (Sarianidi 1990a).
In this context, the paleochannel preference might have been rooted in the flow regimes of these paleochannels. The stratigraphical analysis from the test trench excavated on Paleochannel 7 suggests a relatively stable water flow after the second half of the 4th millennium BCE (see section 6.5.3 in Chapter 6). The first 70 cm of channel stratigraphy, which likely relates to the Bronze Age and Iron Age periods, are indicative of a quite long period of relatively stable flow.

This data, along with the presence of numerous sites along this specific channel, suggests that the BMAC community of the Togolok area likely selected Paleochannel 7 for the stability of its water regime. The botanical data from Togolok 1 (see section 6.2.4 in Chapter 6) are indicative of variegated crop production of cereals, legumes, and other garden fruits. As such, BMAC farmers in the Togolok area concentrated field systems along specific channels that allowed them to cultivate a mix of crops and, at the same time, to secure a stable water intake across the seasons. As discussed in the previous paragraph, the seasonality of the water intake for specific crop production is crucial for a successful yield (Clemmens 2006), and a stable water flow is crucial for larger agricultural fields.



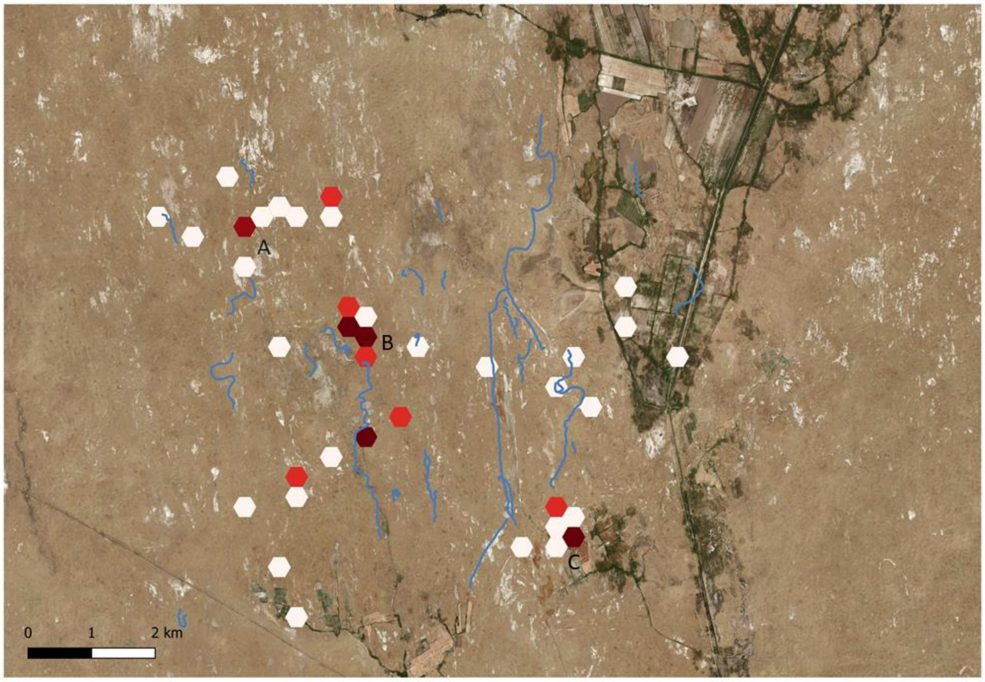


*Figure 7.5 The figure shows the spatial density analysis of the Togolok area (upper figure) and Ojakly area (lower figure). The two areas are indicative of a different settlement distribution along the channels. Darker hexagons represent areas of major concentration of sites.*

In the distal areas of Ojakly, by contrast, the paleochannel trench analysis (see section 5.8.3 in Chapter 5) indicates an unstable water flow regime by the end of the 3rd and the 2nd millennium BCE. This is consistent with the presence of sites, likely representing small farming communities (i.e., households) widely distributed across the river landscape to cope with an unstable hydrological system. This field system likely took place in the form of opportunistic farming or small-scale fields that could easily be relocated in case of lack of water from one year to another.

All in all, I suggest that areas with more stable channels would have seen an aggregation of sites, like at Togolok, while areas with unstable small watercourses in distal areas would experience a wider distribution of sites and opportunistic farming. This contrasts the landscape models proposed of either “oases” in a complete desert landscape or agricultural plain characterized by a homogenous model of land exploitation. These crucial aspects will be now discussed in the next paragraphs.

## 7.8 The Workforce and Canal System: a Preliminary Analysis

As discussed above, data from the paleochannel system in Togolok and Ojakly suggest a natural system of channels. Where possible, communities were strategically located along channels with stable flow and there is little evidence that BMAC communities were involved in large-scale earthwork projects, such as the building of large dams like in later periods in the Merv Oasis (Lyapin 1996; Cerasetti 2008:34–36).

As briefly introduced in Chapter 2 (section 2.3.4), in the Chalcolithic period in southern Turkmenistan, Lisitsina (1965:41–74) analyzed the hydrological system of Geoksyur Oasis in the Inklab alluvial fan, east of the Tedjen River (Figure 7.6). Near the nine archaeological sites of Geoksyur ranging from the 4th to the early 3rd millennium BCE, the scholar identified and described three canals, taking water from the main channel to the settlements that are about 8–10 ha in size (Lisitsina 1969:Figs. 3, 4). Two of these canals seem to depart from the same main channel. The main canal of Geoksyur 1 (canal 1) was 3.47 m wide and approximately 3 km long. In addition to canals, in the vicinity of

Geoksyur 4, Lisitsina also identified a water basin with a surface of 1,000 m$^2$. The reservoir was dated to the 4th millennium BCE and was connected to the channel through a small ditch. This evidence, which pre-dates settlements in the Murghab, are indicative of the ability and the know-how of these communities to build small-scale irrigation facilities in the 4th millennium BCE.

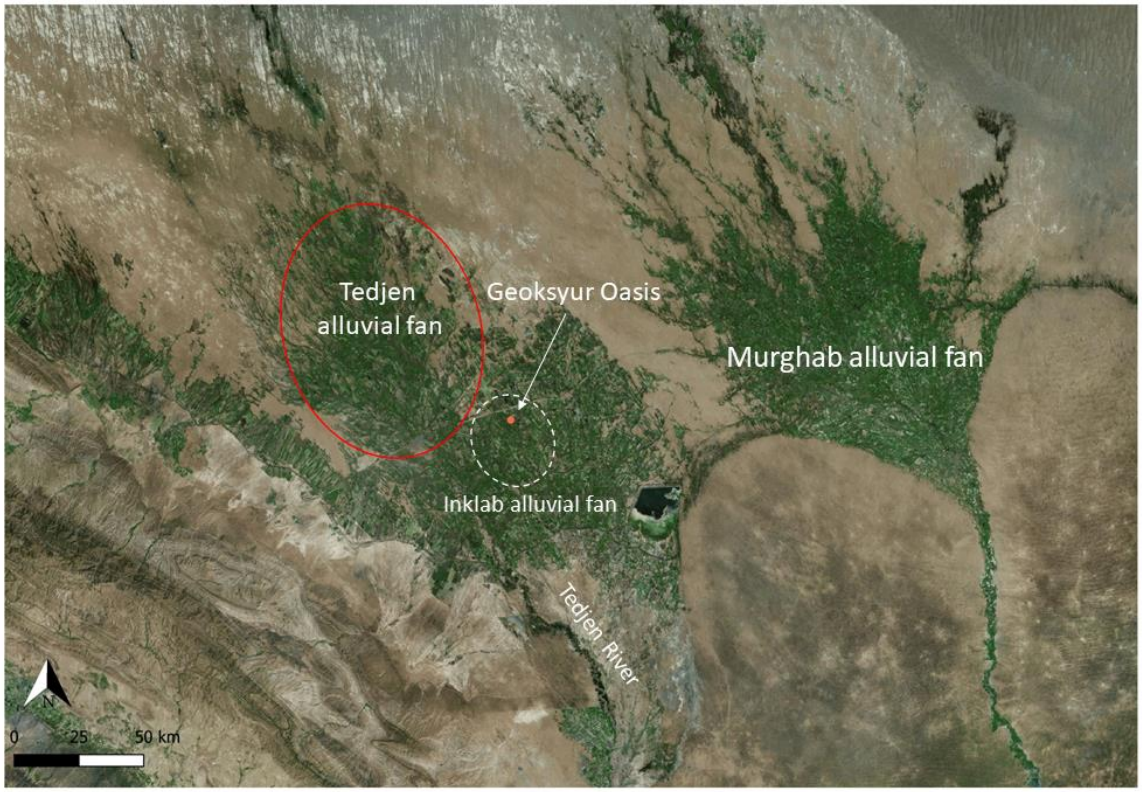


*Figure 7.6 The figure shows the location of the Geoksyur Oasis, located east of the Tedjen River. The former Inklab alluvial fan and the Tedjen alluvial fan are now almost merged due to the water intake from the Karakum Canal and the system of artificial canals.*

In the Murghab, at Gonur, the canal analyzed by Sataev (2008:65–66) appears to be wider (5 m in width) but less extensive compared to the system in the Tedjen alluvial fan. However, Sataev points out that the eastern side of the canal was abundant in sediments that might be indicative of the presence of a lateral tributary, thus suggesting the presence of additional canals. The cross-section of the canal, however, and its relatively small size can be compared to the ones from Geoksyur Oasis. Both canal structures are similar and are indicative that in the 4th and 3rd millennium BCE in the Murghab and Tedjen fans, man-made canals system were present. These small-scale canal systems could have been designed and managed by local communities, not necessarily necessitating centralized community control.

Labor calculations for canal earthworks at the Geoksyur Oasis have been based on Sumerian documents (Lisitsina 1965:128–129). Lisitsina estimates digging labor costs for Geoksyur canals of 3 $m^3$ per person per day. This would imply the use of good tools for canal digging. These tools, like a metal shovel found at Gonur cemetery in grave 3900 (Sarianidi 2010b:138, 193). The shovel consists of a flat part that could easily cut the soil during an excavation. Notably, similar modern shovels are still used in Turkmenistan to excavate small ditches (Figure 7.7). This evidence suggests that the local community possessed the necessary equipment to construct a canal system.

*Figure 7.7 The figure shows (left) the shovels recovered from grave 3900 in Gonur North (scale10 cm) and a modern shovel (right) that was used by the team during fieldowrk..*

Based on Lisitsina's calculation, with an estimate of 3 $m^3$ per person per day, a canal section of 3 m width and 2 m depth (3 × 3 × 2 m), which is equivalent to 18 $m^3$, would have required 6 persons per section per day. In this scenario, a team of 100 people would progress 48 m each day. With this calculation, a canal that is 2 km long would take 48 days to complete. Considering that earth movement also requires extra personnel for soil removal, a larger team consisting of 150 people would likely finish constructing a 2 km canal in approximately one and a half months. If one applies population density estimates from the Bronze Age region of southern Iraq that estimate a population from 248 to 1205 persons/ha (Postage 1994:table 5), it is plausible to argue that the main settlements in the Murghab would have had enough of a workforce to build such canals. Even taking into account the most conservative population estimates of 248 persons/ha, a site such as Gonur North with its 50 ha would have had a population of approximately 12,400 people, and Togolok 1 approximately 1240 inhabitants.

Although the presence of a complex system of canals has been envisioned in the past (Lamberg Karlovsky 2013; Salvatori et al. 2008), the data from the Togolok area may only suggest a system of small canals not visible otherwise from satellite images. Indeed, one cannot exclude that canals were present in the proximity of the main mound of Togolok 1, and future geomagnetic analysis, like at Gonur, might reveal their presence. In contrast, despite the analysis on workforce indicate that local communities could have constructed extensive canal systems like those in Mesopotamia, such large extended canal systems are notably absent from satellite analysis. This may suggest a deliberate decision to manage water resources differently compared to Mesopotamia where such canals are present. The bulk of the agricultural production was along natural channels that do not present any evidence of large artificial construction and in which irrigation was possible by diverting water to the nearby fields. Settlements in rural and distal areas, facing major instabilities in the river flow, unlikely had large canal systems. Rather, only a few channels might have been equipped with small lateral canals to irrigate the fields reconstructed in the SOBEK.

### 7.8.1 The Murghab Irrigation System and the Mesopotamian Model

The case studies of Togolok and Ojakly suggest that by the end of the 3rd and the 2nd millennium BCE, irrigation structures did not include large and complex canal systems. The parallels between Mesopotamian states and the Murghab have often led scholars to argue for the presence of a large canal systems (Salvatori et al. 2008). The monumentality of the Murghab settlements, in particular Gonur North, with its triple city walls and its system with water pipes within the settlements, have led scholars to argue for water management that required central control of the irrigation system (e.g., Lamberg Karlovsky 2013). In short, a system that would resemble that of Mesopotamia between the 3rd and 2nd millennium BCE.

In Mesopotamia itself, however, as argued by Rost (2017), the way the irrigation system was managed over arable land changed over time. For instance, during the 3rd millennium in the Early Dynastic States (2900–2350 BCE), there was a direct development of large fields with employed staff (Foster 1986), while in the Akkadian period (2350–2150 BCE), there was an indirect exploitation of arable land. During that period the lack of available records regarding irrigation management also suggests, as argued by Rost (2017), that the maintenance of irrigation systems was done by local groups. By contrast, the Ur III period (2112–2004 BCE) is characterized by substantial records, also regarding water management, that are once more indicative of centralized control over the system (Rost 2015). The texts, in particular, illustrate that assessment and maintenance, often on a seasonal basis, were done by different state-owned institutions. The king himself, Ur-Namma, boasted how he improved the water system through a renovation of several canals (Tinney 1999). These examples illustrate how water management can evolve over time in response to necessity.

The changes in the management of land and irrigation system in Mesopotamia between the 3rd and the 2nd millennium BCE, as argued by Rost (2017), show that centralized control over water is not necessary even for complex irrigation systems. Decades of research in the Murghab by Soviet and international teams have failed to detect large canal systems resembling the ones from Mesopotamia (Wilkinson et al. 2013b). In contrast, the evidence from the Murghab suggests a landscape characterized by natural and shallow channels that did not necessitate large irrigation canals system. Rather, the arable lands were concentrated along the channels, in contrast to a large (Mesopotamian) horizontal model.

The two case studies examined in this thesis strongly imply a distinct approach to land and irrigation management in the Murghab when compared to Mesopotamia. The unique characteristics of the channel system in the Murghab fan region prompted local communities to utilize land adjacent to the channels. It appears that this method of furrow irrigation alongside channels was the most efficient means of land management, rendering large irrigation canals unnecessary. Similarly, the small-scale crop fields, mobility, and opportunistic agriculture practiced in rural areas likely proved more effective than constructing extensive canals drawing water from distant, well-watered regions, as seen in Mesopotamia. Taken together, these two case studies urge us to reevaluate the Mesopotamian model frequently cited by scholars in recent decades, suggesting a need to focus and refine our understanding of land management practices. As such, the settlement model also requires reassessment, which will be elaborated upon in the following concluding paragraphs.

## 7.9 Conclusion

The investigation of the Murghab agricultural and paleochannel systems over the last decades has largely been devoted to the analysis of the Murghab system from an overall landscape perspective. Although this research has produced significant insights into the fluvial landscape (Cerasetti 2008; 2012), there remains a gap in the investigation of specific local areas. Furthermore, the models proposed by both Soviet scholars and the AMMD team have often resulted in overly uniform representations of the agricultural and irrigated landscapes during the Bronze Age. tedjConsequently, the present research aimed to overcome such generalized interpretations by focusing on micro-scale landscape dynamics. As such, the investigation with a multidisciplinary approach proved to be effective in the analysis of the local landscape, which data suggest heterogeneous water and agricultural management during the Bronze Age. However, such a heterogeneous picture of a landscape suggests a system from which general conclusions can ultimately be drawn about agricultural and water management between the 3rd and 2nd millennium BCE in the Murghab.

### 7.9.1 Towards a "Multiple Adaptation" Model

In Chapter 3, I introduced the two landscape models that were proposed for the Murghab over the last decades. After the initial "oasis" model proposed mainly by Soviet scholars (Sarianidi 1990a), landscape research by the AMMD proposed a "continuous" model that envisioned an extended agricultural plain over the fan (Salvatori et al. 2008). However, in contrast to the rigidity of these two models, which leave little space for any complexity, I argue that by narrowing down the analysis of the irrigation system to the micro-scale of local areas, a heterogeneous model of characteristics seems to emerge (summarized in Table 7.2).

The analysis of the settlement distribution and their distance from water resources in the Togolok and Ojakly areas suggests a diverse agricultural and subsistence economy. While the area of Togolok has many settlements along the channels, Ojakly presents a settlement pattern in which many of the settlements were located further away from watercourses. The greater distance from the paleochannels in the Ojakly area, in contrast to Togolok, suggests that part of the Ojakly communities, while well acquainted with cultivation, might have been involved in a herding economy to a large extent. The possible small-scale takyr areas, in addition to a major spread of settlements along several channels, are indicative of the small-scale organization of the rural systems with the use of often opportunistic cultivation.

In contrast to Ojakly, the Togolok data indicate that most settlements were located along the channels with larger field systems. Further, specific channels were selected by local groups, likely for their stability of water flow over the years. This is confirmed both by the stratigraphic analysis of the paleochannel trench as well as by the presence along the channel east of Togolok 1 of a great number of sites (the majority of the Togolok paleochannel system) along with pottery workshops. This suggests decision-making by local communities to exploit certain water resources over others. At Togolok it was crucial to have stable water resources to sustain larger populations. The stability of the water was met with a stable flow regime of selected channels as well as the presence of possible canals. Despite the lack of evidence for canal systems in the Murghab, it is likely that there were small canals that brought water to the fields in areas like Togolok.

| Characteristics | Dense Settlement Cluster Areas (Greener Areas) | Rural Areas |
|---|---|---|
| **Heterogenous settlement distribution along channels (i.e., clustering along specific channels)** | X | |
| **Homogenous settlement distribution along channels** | | X |
| **The majority of sites are located in proximity to water resources** | X | |
| **Extended agricultural areas** | X | |
| **Small-scale agricultural areas** | | X |
| **Presence of small-scale artificial canals** | X | |
| **Presence of an extended system of canals** | | |
| **Presence of a large-scale system with dams** | | |
| **Variegated botanical assemblages (cereals, legumes, grapes, etc.)** | X | |
| **Limited botanical assemblages (mainly cereals)** | | x |
| **Animal herding** | X | X |
| **Large pottery craft areas** | X | |

Table 7.2 The table shows the main characteristics that differentiate dense settlement cluster areas (like Togolok) characterized by a greener area (lush enclave), and rural areas (like Ojakly) between the end of the 3rd and the 2nd millennia BCE.

The selective settlement distribution concentrated along specific water channels at Togolok is opposed to an almost homogeneous distribution of settlements along the channels in rural areas. This different agricultural and irrigation farming approach can be related to the hydrological instability of the system in rural and distal areas of the fan. The analysis of the paleochannel trench in Ojakly, as well as proxy data from Egri Bogaz (Markofsky et al. 2017), suggest an irregular fluvial activity in the distal area of the fan by the end of the 3rd and the early 2nd millennium BCE. This instability of the hydrological system and the likely increased episodes of channel avulsion led local communities in rural areas to shift to an agricultural system based on small-scale farming and an agropastoral system in which a major interplay between herding and crop cultivation was the key to a resilient subsistence economy.

While this interplay between herding and crop cultivation was at the foundation of any BMAC community (either rural or dense settlement clusters), including ICW (Andronovo) sites such as Chopantam, botanical data from large settlement concentrations suggest a variegated agricultural system with the presence of cereals, legumes, and garden fruits. The botanical data from Togolok 1 is consistent with data from Gonur (Miller 1993; Sataev and Sataeva 2014). This system would have involved varieties of crops with different sowing, growing, and harvesting seasons, necessitating stable water intake at various times of the year, thus demanding careful water management. In this context, botanical and archaeozoological data, along with data from the Ojakly test trench and other paleochannel data from the Murghab (Cremaschi 1998), suggest that already by the end of the 3rd millennium BCE, the paleoclimate was likely characterized by increased aridity. As such, a system of stable channels and possible artificial canals in urban areas was crucial to sustain a larger population, such as in the Gonur, Togolok, or Takhirbaj areas. However, evidence from Togolok suggests that while a system of canals between channels could have been in place, these would have been small in scale.

In this context, by the end of the Middle and the early Late Bronze Age, the increasing aridity led to a "multiple adaptation model" of land management in which different agricultural and irrigation practices coexisted together. In this model, while areas such as Togolok were equipped with small canals, and more stable field systems, rural areas were characterized by small fields, often opportunistic, within an increasing arid environment. This data suggests the presence in the Murghab of two different adaptive models to the changing environment by the 2nd millennium BCE. Areas like Togolok, enhanced by human management, had more reliable water resources and were marked by channels leading to larger fields, orchards, and gardens cultivating crops like grapes. The disparity with rural regions, devoid of such evidence, suggests that these settlement concentration areas can be likened to a concept of a "lush enclave," greener in comparison to more rural areas. However, this concept diverges from the traditional "oasis model" proposed previously. As argued in this thesis (see more extensive discussion in Chapter 3), this model envisioned clusters of sites (i.e., oases) surrounded by arid landscapes, with pastoralism serving as the primary subsistence economy in the surrounding areas. Nonetheless, investigations by the AMMD and current research indicate the existence of a channel system with sites positioned along them during the late 3rd and 2nd millennia BCE in rural regions beyond fortified settlements. In this context, I argue for a new landscape concept characterized by more humid zones (lush enclaves) found at major centers such as Togolok, Gonur, or Adji Kui 1 and 9, alternating with areas featuring channels and smaller cultivated fields where increasing aridity was more pronounced. In this model, while areas like Togolok were equipped with sophisticated agricultural and water management resources and could cope with increasing aridity, rural communities relied on greater mobility and opportunistic agriculture into their cultivation and water management strategy.

Figure 7.8 visually summarizes this "multiple adaptation model" proposed in this thesis. The local analysis from Togolok and Ojakly brought out the need for a model that considers the landscape's diversity during the Bronze Age and takes into account its local agricultural dynamics. In addition, the findings from this investigation strongly indicate that a singular landscape model of land management is problematic and no longer applicable.

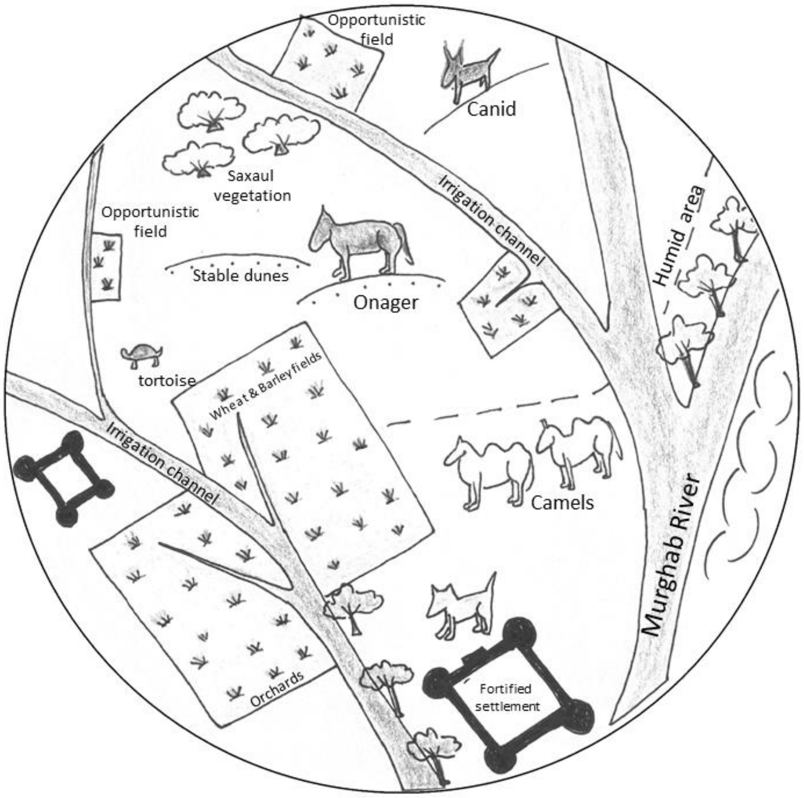


*Figure 7.8 The figure illustrates a simplified reconstruction of the "multiple adaptation model," depicting various agricultural practices prevalent in the Murghab region towards the end of the 3rd and early 2nd millennium BCE. This model includes the presence of extended agricultural fields in greener zones alongside opportunistic agriculture in rural areas. The figure draws inspiration from Hiebert's reconstruction model (1994a: Fig. 8.2) with illustrations by S. Leonardi.*

This landscape, in which different models of land exploitation coexisted together, eventually gave way to an almost complete abandonment of the northeast Murghab alluvial fan by the end of the 2nd millennium BCE due to a lack of available water resources. Data from the region, as well as the micro-scale data from the Togolok and Ojakly survey discussed in this thesis, are indicative that by the end of the 2nd and the 1st millennium BCE, a large portion of the northeastern alluvial fan was abandoned, and the population migrated southward (Salvatori 2008). Likewise, only a reduced number of channels were still active, permitting a limited occupation of the territory.

The 2nd millennium BCE is, therefore, a crucial one for the future configuration of the region in terms of agriculture and water management. This period has been understood as a period of de-urbanization in which major settlements, such as Gonur North, were abandoned in favor of smaller settlements. It has also been described as a period of intense crisis for the BMAC. While I argue that the correct word for this period might be a “transformation” rather than collapse, as suggested elsewhere (Luneau 2016; 2019), I also argue that this period was a period of intense resilience by the BMAC communities. This resilience led to a dynamism that can be interpreted as a model of multiple agricultural strategies in which communities responded differently to the same environmental stress that characterized the late 3rd and 2nd millennium BCE. In the same landscape, lush enclaves cohabited along with areas with more persistent aridity. This led to a dynamism in terms of agriculture, irrigation, and settlement distribution that this research has tried to disentangle. However, with all the limitations given by doctoral research, this study nonetheless has the merit to be indicative that a homogenous model of the agricultural landscape is misleading. In this context, and in the future research agenda of the region, a holistic approach to landscape investigation is crucial to disentangle the complexity of local landscape models.

### 7.9.2 Future Directions: a Suggestion

The present research focused on the local agricultural and hydrological systems of two local areas of the Murghab. As such, it has provided evidence that a micro-scale investigation of specific areas of the region can provide crucial details to disentangle pivotal characteristics of the agricultural and water management of BMAC communities. By applying a multidisciplinary approach and targeting local areas, the present research has brought to light the complexity of an agricultural and irrigation system by the end of the 3rd and 2nd millennium BCE. This research demonstrates that a macro-scale regional landscape model is inadequate to pinpoint the complexity of the Murghab in a crucial period that paved the way for major changes in landscape management, material culture, and the trading system in the subsequent Iron Age.

The Soviet domination of Central Asia, as well as the fear in the West of the spread of communist ideology, prevented any genuine collaboration between archaeologists in Central Asia for most of the 20th century. As a result, at least for the Murghab, landscape reconstruction of the paleochannel systems have always been neglected by Soviet scholars mainly interested in other aspects. However, as this thesis demonstrates, a landscape perspective is crucial to understand the BMAC phenomena during a period of a complex transition. The interrelationship between local communities and landscape dynamics can only be fully understood through a local lens. As such, it is crucial that future archaeological research in the region focus on the local dynamics at the micro-scale level rather than a solely macro-regional investigation.

As future prospects in post-doctoral research, my focus would be on the examination of small-scale settlements and their related channels and canal system. The Murghab alluvial fan underwent a profound transformation during the 2nd millennium BCE, as elucidated in this thesis. Nevertheless, these minor occupations have received scant attention in previous research. However, as demonstrated in these chapters, their study is pivotal for enhancing our understanding of the landscape and social transformations that characterized this era. Consequently, small-scale investigations employing test trenches capable of collecting radiocarbon dating of often ephemeral occupations, alongside archaeobotanical and archaeozoological analyses, would significantly augment our comprehension of the role played by these hamlet sites. Botanical samples can be analyzed for isotopic data to understand changes in irrigation practices across the Murghab landscape and identify areas or communities differently impacted by water stress. While this thesis have highlighted differences between clustered sites and rural areas, post-doctoral work could further explore differences with small-scale settlements. Similarly, isotopic analysis of zooarchaeological remains can investigate variations in animal husbandry in the Bronze Age and the development of a specific pastureland system as investigated in southern Turkenstan (Kroll et al. 2022). These data would form a crucial dataset to understand mobility and agricultural patterns in the Murghab region. This research would also illuminate the evolution of settlement patterns and their relationship with the hydrological system. Furthermore, examining the hydrological system through test trenches and Optically Stimulated Luminescence (OSL) analysis of paleochannels would greatly enhance our knowledge of the BMAC.

In addition to the investigation of the settlement patterns and the hydrological system, investigating small-scale sites would refine our pottery chronology as well. Currently, pottery chronology mainly derives from major tepe sites like Gonur. However, chronological sequences from small-scale sites would improve our understanding of local pottery trajectories, which are largely unknown in the Murghab. Additionally, analyzing clay sources compared to pottery from these sites would provide valuable provenance data. As discussed in Chapter 5, recent pottery analyses from these sites suggest local clay sources (Rouse et al. 2019). However, this analysis was based on a limited number of samples and an extended analysis from several small sites could shed light on pottery production areas and how small communities had specific pottery practice.

Regarding remote sensing, the Murghab region lacks data that can be acquired through drone research. In the last decade, drones have gained momentum in archaeological research and are now widely used in excavations and surveys (Campana 2017). Future post-doctoral research would benefit from employing drones to survey selected regions. The last air survey in the Murghab was conducted by helicopter within the AMMD project in the early 1990s (Guabev et al. 1998). The new technologies allow drones to be equipped with various cameras, enabling multi-acquisition of landscape data. Notably, LiDAR (Light Detection and Ranging) technology, which has become common in archaeology (Risbøl and Gustavsen 2018), could be applied via drones in the Murghab to a) target specific areas and b) maximize results. This technology can enhance the detection of very small mounds, often representing the small-scale settlements discussed above. As argued in Chapter 3, archaeological research in the Murghab has primarily focused on major mounds, with quality data on small-scale occupations lacking. the automated detection of these small mounds using LiDAR imagery will significantly enhance our understanding of settlement distribution across the Murghab.

Drones equipped with different cameras can also be crucial in detecting buried canals. As argued in this thesis, satellite images have failed to detect small-scale canals, particularly in clustered areas. Recent investigations in the Murghab revealed the presence of more channels (Bulawka and Orengo 2024) and using drones in targeted areas can increase our knowledge of the canal system. In particular, recognizing small-scale canals would allow us to investigate how artificial irrigation systems changed between the Middle and Late Bronze Age. As argued in this thesis, clustered areas like Togolok likely used artificial canals to bring water to the fields and citadels. The presence of water pipes suggests a system where water circulated within the citadels, likely requiring canals to bring in or drain water. Drones equipped with specific cameras can contribute to investigating such crucial systems and understanding how changes in irrigation practices withn major sites reflect social and economic trajectories.

In addition to landscape studies, an in-depth investigation of the pipeline systems discovered at Gonur North can enhance our understanding of water management in the Murghab. Despite their importance, these systems have received limited attention from excavators. To date, there has been no specific investigation or detailed mapping of these pipelines. A detailed reconstruction, including potential radiocarbon dating, would significantly enhance our understanding of the techniques employed by BMAC communities. This research could also shed light on possible interpretations related to the social, economic, and cultural dynamics associated with water usage within these citadels. Although cultic hypotheses have been proposed by Sarianidi and Dubova (2012) for the Gonur water system, there remains a lack of detailed data supporting such interpretations.

While this proposed agenda for future research in the Murghab at the post-doctoral level, might seem obvious to scholars studying other regions, these data are still completely lacking in the Murghab. Despite the region being the core area of the BMAC phenomenon and playing a central role in the trading system of Bronze Age Central Asia (Lyonnet and Dubova 2021a), its landscape investigation is still in its infancy compared to neighboring regions of West Asia or the Indus Valley.

A further aspect that deserves attention is the “origin” of the BMAC and the presence of a Chalcolithic/Early Bronze Age occupation in the Murghab (Khol 1984; Sarianidi 1990a; Salvatori et al. 2008). In Chapter 3 (section 3.1), I addressed the limited evidence of pre-Middle Bronze Age occupation in the Murghab region. Indeed, only a few sites have evidence for Chalcolithic or Early Bronze Age materials. For example, at the Kelleli site, grey wares potentially linked to the Late Chalcolithic (Namazga III period) have been identified at the basal level (Kohl 1984; Masimov 1979), along with findings of Geoksyur-style painted pottery, similar to those discovered at Adji Kui 9 (Rossi-Osmida 2007:124). Similar evidence has been found in Gonur North (Lyonnet and Dubova 2021b:20). However, as for the Togolok and Ojakly area, no evidence from the Chalcolithic/Early Bronze Age has been found (Sarianidi 1990a; Cerasetti et al. 2019, 2022; Rouse and Cerasetti 2014). As discussed in Chapter 6, the OSL dates retrieved from the paleochannel east of Togolok 1 show a Chalcolithic period flow. This evidence suggests the presence of an active fluvial system during this period in the Murghab. This sparks the question of “why” Chalcolithic and Early Bronze Age evidence is rare in the alluvial fan, despite favorable land and the presence of a more stable hydrological system compared to the Late Bronze Age. Future investigation of the main Bronze Age sites of the region, such as Togolok 1, along with a controlled stratigraphical $^{14}$C sequence of these settlements, will be crucial in this respect. Geoarchaeological investigation of the hydrological system will also be equally crucial to broaden the picture of possible early frequentation of the region.

An imperative step for a future archaeological agenda in the region is, therefore, the investigation of the landscape development of the Murghab between the Bronze and Iron Ages. This is a crucial step for understanding the long-term agricultural and landscape management processes that later characterized this important historical region of Margiana.

# Acknowledgments

Embarking on a Ph.D. journey is a lengthy endeavor, but one rarely travels it alone. This path is marked by highs and lows: moments of immense satisfaction and joy in your work, contrasted with times when you might feel like giving up and opening a bar on a Caribbean island. During these fluctuations, friends and colleagues are invaluable; they inspire you, uplift your spirits with a simple conversation at the coffee machine, and provide new ideas, perspectives, and critical encouragement for your research. In this context, a Ph.D. is a collective effort and a testament to collective memory. Science is inherently collaborative, and the notion of the "lone scientist" in the tower is a romanticized myth. Throughout my Ph.D. journey, many individuals inspired and contributed to this research. While completing this thesis is a personal achievement, their contributions were essential in elevating my work.

First and foremost, I extend my gratitude to my two supervisors, Bleda Düring and Peter Akkermans. Bleda, thank you for patiently reading and discussing my thesis multiple times, encouraging me to improve, and helping me give my best. Peter, thank you for encouraging me to view my research from different perspectives and highlighting aspects I might have overlooked.

I am also grateful to those who brought me to Central Asia region and supported my research. Barbara Cerasetti, thank you for sharing your knowledge and passion for Turkmenistan's archaeology. Lynne Rouse, I appreciate your allowing me to join your project and aiding my research in Turkmenistan. Daniela Müller, thank you for your contributions to the geoarchaeological and OSL analyses, and Ayushi Nayak, for conducting the isotope analysis. A heartfelt thank you to the late Maurizio Tosi, who introduced me for the first time as a student to Central Asian and Iranian archaeology from the moment I walked into his office at Bologna University, your lectures have been truly inspiring to me

I extend my sincere gratitude to those who shared their data and findings with me: Robert Spengler, Traci Billings, and Rita dal Martello for the archaeobotanical part; Elise Luneau for pottery analysis; and Tuna Kalayci for advising on statistical analysis. Your research and advice were crucial to my interpretations. I also want to thank my colleague Luca Forni, who worked alongside me in Turkmenistan for many years, and all the students and local workers who dedicated their time during fieldworks. Additionally, I appreciate the local Turkmen authorities who allowed me to conduct my research there. Fieldworks for this project would not have been possible without the support of National Geographic Society Grant, Leiden University Fund (LUF) and Asian Modernities and Traditions Grant (Leiden University).

My journey would not have been the same without my colleagues and friends, from my first officemates, Aris Politopoulos, Mark Locicero, and Sufyan Al Karaimeh, to my latest officemates, Mink van IJzendoorn, Sam Botan, and especially Riia Timonen. I also thank my Leiden friends in random order, Maria Hadjigavriel, Martina Revello Lami, Tijm Lanjouw, Victor Klinkenberg, Irini Sifogeorgakis, Femke Reidsma, Alex Brandsen, Giulia Russo, Georg Cyrus, Giacomo Fontana, José María Castro, Miguel Cabral, and many others I met during my years. I am sure I am forgetting people, but if we ever discussed, shared, or laughed together over a beer…dear reader, know that you contributed to this research, and I thank you deeply. I also thank all my friends and best friends across Europe and Italy. There's no need to mention each of you by name—you know how grateful I am. *Grazie!*

Finally, I owe this achievement to my family, who always encouraged me to follow my dreams. Thank you for your unwavering support.

# References

Abate, N., Lasaponara R. (2019).

Preventive Archaeology Based on Open Remote Sensing Data Tools: The Cases of Sant'Arsenio (SA) and Foggia (FG), Italy, *Sustainability* 11 (15), 41-45.

Adams, R. M. (1957).

Settlements in Ancient Akkad, *Archaeology* 10 (4), 270–273.

Adams, R. M. (1958).

Survey of ancient water courses and settlements in Central Iraq, *Sumer* 14, 101–103.

Adams, R. M. (1965).

*Land Behind Baghdad: A History of Settlement on the Diyala Plains,* Chicago: University of Chicago Press.

Adams, R. M. (1981).

*Heartland of Cities: Surveys of Ancient Settlement and Land use on the Central Floodplain of the Euphrates*, Chicago: University of Chicago Press.

Adrianov, B. V. (1969).

*Drevnie Orositelnye Sistemy Priaralya*, Moskva: Hayka.

Adrianov, B. V. (2016).

*Ancient Irrigation System of the Aral Sea Area: The History, Origin and Development of Irrigated Agriculture*, edited by Mantellini S., Oxford: Oxbow Books.

Akkermans, P.M.M.G., Kerner S., Plicht J., Dann R.J., Bangsgaard P., Nieuwenhuyse O.P., Russell A., Kaneda A. (2015).

Cultural Transformation and the 8.2 ka Event in Upper Mesopotamia, in Kerner S., Dann R., Bangsgaard P. (eds), *Climate and Ancient Societies*, Charlottenlund: Museum Tusculanum Pres, 97-112.

Alexandrowicz, W. P. (2021).

Spatial distribution and diversification of mollusc communities in flood sediments within the river valley based on the examples from Baskid Maly Range (West Carpathians, Southern Poland), *Carpathian Journal of Earth and Environmental Sciences* 16 (2), 315 – 328.

Allen, J. R. L. (1963).

The classification of cross-stratified units with notes on their origin, *Sedimentology* 2, 93-114.

Altmaier, A., Kany, C. (2002).

Digital surface model generation from CORONA satellite images, ISPRS, *Journal of Photogrammetry & Remote Sensing* 56, 221-235.

Alyekshin, V. A. (1980).

*K robleme geneticheskoy svyazi yuzhno turkmenskikh kompleksov epokhi bronzy*, *Kratkie Soobshcheniya* 161, 24-31.

Amiet, P. (1977).

Bactriane proto-historique, *Syria* LIV 1–2, 89–121.

Amiet, P. (1988).

Elam et Bactriane, in Gardin J. C. (ed), *L'Asie centrale et ses rapports avec les civilisations orientales des origines a l'Age du Fer. Actes du colloque franco-sovietique*, Paris:de Boccard, 27–30.

An, C. B., Lu Y., Zhao J., Tao S., Dong W., Li H., Jin M., Wang Z., (2011).

A high-resolution record of Holocene environmental and climatic changes from Lake Balikun (Xinjiang, China): implications for central Asia, *Holocene* 22, 43-52.

Anthony, D. W., Brown D., Brown E., Goodman A., Kokhlov A., Kosintsev P., Kuznetsov P., Mochalov O., Murphy E., Peterson D., Pike-Tay A., Popova L., Rosen A., Russel N., Weisskopf A. (2015).

The Samara Valley Project: Late Bronze Age Economy and Ritual in the Russian Steppes, *Eurasia Antiqua* 11, 395–417.

Araus, J., Febrero A., Buxó R., Rodríguez-Ariza M., Molina F., Camalich M., Martín D., Voltas J. (1997).

Identification of ancient irrigation practices based on the Carbon Isotope discrimination of plant seeds: a case study from the South-East Iberian Peninsula, *Journal of Archaeological Science* 24, 729–40.

Araus, J., Febrero A., Catala M., Molist M., Voltas J., Romagosa I. (1999).

Crop water availability in early agriculture: evidence from Carbon Isotope discrimination of seeds from a tenth millennium BP site on the Euphrates, *Global Change Biology* 5, 201–12.

Araus, J., Slafer G., Buxó R., Romagosa I. (2003).

Productivity in prehistoric agriculture: physiological models for the quantification of cereal yields as an alternative to traditional approaches, *Journal of Archaeological Science* 30, 681–93.

Araus, J., Ferrio, J., Buxó, R., Voltas, J. (2007).

The historical perspective of dryland agriculture: lessons learned from 10,000 years of wheat cultivation, *Journal of Experimental Botany* 58 (2), 131–45.

Arciero, R., Forni L. (2018).

La prima urbanizzazione in Turkmenistan: coesistenza tra nomadi e sedentari nel delta interno del fiume Murghab—risultati preliminari delle indagini archeologiche ed etnografiche presso il sito di Togolok 1, in Ferrari A., Pupulin E., Ruffilli M., Tomelleri V. (eds), *Armenia, Caucaso e Asia Centrale: Ricerche 2017, Euroasiatica. Quaderni di Studi su Balcani, Anatolia, Iran, Caucaso e Asia Centrale 7,* Venezia: Edizioni Ca' Foscari, 11–38.

Atamuradov, K.I. (1994).

Paleogeography of Turkmenistan, in Fet V., Atamuradov K. I. (eds), *Biogeography and Ecology of Turkmenistan*, Dordrecht: Springer Science and Business, 49-64.

Avanesova, N. A. (2021).

The Zeravshan regional variant of the Bactria-Margiana Archaeological Complex: interaction between two cultural worlds, in Lyonnet B., Dubova N.A. (eds), *The World of the Oxus Civilization*, New York: Routledge, 665-697.

Babaev, A. G., Vitkovskya, T. P. (1985).

Hydrogeological conditions and freshwater resources of the Karakum, *Problems of Desert Development* 2, 3-8.

Babaev, A.G. (1994).

Landscapes of Turkmenistan, in Fet V ., Atamuradov K. I. (eds), *Biogeography and Ecology of Turkmenistan*, Dordrecht: Springer Science and Business, 5-22.

Bader, A., Gaibov V., Gubaev A., Koshelenko G. (1996).

The Oasis of Merv: the dynamics of its settling and irrigation, *Ancient Civilization from Scythia to Siberia* 3, 49-60.

Bakels, C.C. (2003).

The contents of ceramic vessels in the Bactria-Margiana Archaeological Complex, Turkmenistan, *Electronic Journal of Vedic Studies* 9 (1c), 1-4.

Banning, E. B. (2002).

*Archaeological Survey*, New York: Plenum Publisher.

Barendse, R. J. (2009).

*Arabian Seas 1700-1763*, Leiden: Brill.

Bates, J., Choi J. (2023).

Different strategies in Indus agriculture: the goals and outcomes of farming choices, *Antiquity* 97 (396): 1488–1500.

Bazilevich, N. I., Degopik I. Ya., Kryukov P. A. (1956).

Elementy gidrologicheskogo rezhima i vodno-khimicheskogo sostava Takyrskikh ravnin v takyrakh Yugo-Zapadnoy Turkmenii [Elements of the Hydrological Regime and Water Chemistry of Takyric Plains], *Takyry Yugo-Zapadnoy Turkmenii*, Nauk SSSR, Moskva: Akad,91–103.

Beazley, G. A. (1920).

Surveys in Mesopotamia during the war, *Geographical Journal* 55, 109-127.

Beck, A., Philip G., Abdulkarim M., Donoghue D. (2007a).

Evaluation of Corona and Ikonos high resolution satellite imagery for archaeological prospection in western Syria, *Antiquity* 81, 161–175.

Beck, A, Wilkinson K, Philip G. (2007b).

Some techniques for improving the detection of archaeological features from satellite imagery, in Ehlers M., Michel U. (eds), *Remote Sensing for Environmental Monitoring, GIS Applications, and Geology VII*, Proceedings of SPIE, Florence: SPIE, 6749, 1-12.

Becker, H. (2007).

*First test of Caesium-Magnetometry in the Murghab Delta Project*, Unpublished AMMD Report.

Bendezu-Sarmiento, J., Mustafakulov S. (2013).

Le site proto-urbain de Dzharkutan durant les ages du bronze et du fer. Recherches de la Mission archeologique franco-ouzbeque-Protohistoire, *Cahiers d'Asie centrale* 21–22, 207–236.

Bendezu-Sarmiento, J., Lhuillier J. (2019).

Habitat and Occupancy during the Bronze Age in Central Asia Recent work at the sites of Ulug-depe (Turkmenistan) and Dzharkutan (Uzbekistan). in Baumer C., Novák M. (eds), *Urban Cultures of Central Asia from the Bronze Age to the*

*Karakhanids Learnings and conclusions from new archaeological investigations and discoveries*, Wiesbaden: Harrassowitz Verlag, 97-114.

Berkelhammer, M., Sinha A., Stott L., Cheng H., Pausata F.S.R., Yoshimura K. (2012).

An abrupt shift in the Indian monsoon 4000 years ago, in Giosan L., Fuller D.Q., Kathleen N., Flad R.K., Clift P.D. (eds), Climates, Landscapes, and Civilizations, American Geophysical Union: Washington, D.C., 75–87.

Berking, J. (ed) (2018).

*Water management in Ancient Civilizations*, Berlin: Topoi.

Berking, J., Beckers B., Reimann T., Pollock S., Bernbeck R. (2017).

Modern impacts on an ancient landscape, the piedmont plain in south-west Turkmenistan, *WIREs Water* 4, 1-20.

Bernbeck, R. (2008).

An Archaeology of multisited communities, in Barnard H., Wendrich W. (eds), *The Archaeology of Mobility: Old World and New World Nomadism*, Los Angeles: Cotsen Institute of Archaeology, 43-77.

Bewley, R. H., Kennedy D. L. (2013).

Historical aerial imagery in Jordan and the Wider Middle East, in Hanson W. S., Oltean I. A. (eds), *Archaeology from Historical Aerial and Satellite Archives*, Heidelberg: Springer, 221-242.

Bezori, G., Astori B., Guzzetti F. (2002).

GPS and photogrammetric methodologies for an archaeological survey, in Warmbein B. (ed), *Proceedings of the Conference Space Applications for Heritage Conservation*, Strasbourg: European Space Agency, 1-8.

Billings, T., Cerasetti B., Forni L., Arciero R., Dal Martello R., Carra M., Boivin N., Spengler III R. N. (2022).

Agriculture in the black sands of the Karakum: an archaeobotanical analysis from Togolok 1, Turkmenistan (2nd millennium B.C), *Frontiers in Ecology and Evolution* 10, 1-22.

Bini, M., Zanchetta G., Perşoiu A., Cartier R., Català A., Cacho I., Dean J. R., Di Rita F., Drysdale R. N., Finnè M., Isola I., Jalali B., Lirer F., Magri D., Masi A., Marks L., Mercuri A.M., Peyron O., Sadori L., Sicre M., Welc F., Zielhofer C., Brisset E. (2019).

The 4.2 ka BP Event in the Mediterranean region: an overview, *Climate of the Past* 15, 555–577.

Bintliff, J. L., Snodgrass A. M. (1985).

The Cambridge/ Bradford boeotian expedition: the first four years, *Journal of Field Archaeology* 12, 123-161.

Bintliff, J. L., Snodgrass A. M. (1988).

Off-site pottery distributions: a regional and interregional perspective, *Current Anthropology* 29, 506-513.

Bird-David, N. (1992).

Beyond ‘The Hunting and Gathering Mode of Subsistence’: Culture-Sensitive Observations on the Nayaka and Other Modern Hunter-Gatherers, *Man* 27(1), 19–44.

Biscione, R. (1977).

The crisis of Central Asia urbanization in II millenium BC and villages as an alternative system, in Christophe J., Deshayes J. (eds), *Le plateau iranien et l'asie centrale des origines à la conquête islamique: leurs relations à la lumière des documents archéologiques*, Paris: Éditions du Centre national de la recherche scientifique, 113-127.

Biscione, R., Tosi M. (1979).

*Protostoria degli Stati Turanici. Aspetti dell'Evoluzione Urbana e Forme d'Insediamento nel Popolamento dell'Asia Centrale nell'Età del Bronzo (2500-1000 a. C.) alla luce dei Dati Archeologici*, 20 (39), Napoli: Istituto Orientale di Napoli.

Biscione, R., Vahdati A. A. (2011).

Excavation at Tepe Chalow, Northern Khorasan, Iran, *Studi Micenei ed Egeo-Anatolici* 53, 236– 241.

Biscione, R., Vahdati A. A. (2021).

The BMAC presence in eastern Iran: state of affairs in December 2018 – towards the Greater Khorasan Civilization?, in Lyonnet B., Dubova N.A. (eds), *The World of the Oxus Civilization*, New York: Routledge, 527-550.

Blair, T.C., McPherson J.G. (2009).

Processes and forms of alluvial fans, in Parsons A.J., Abrahams A.D. (eds) *Geomorphology of Desert Environments*, Heidelberg: Springer, 9-14.

Blodeaux, P., Seminara G. (1985).

A unified bar-bend theory of river meanders, *Journal of Fluid Mechanics* 157, 449-70.

Boazar, M., Yazdanpanah M., Abdeshahi A. (2019).

Response to water crisis: How do Iranian farmers think about and intent in relation to switching from rice to less water-dependent crops?, *Journal of Hydrology* 570, 523-530.

Bogaard, A., Fraser R., Heaton T. H. E., Wallace M., Vaiglova P., Charles M., Jones G., Evershed R. P., Styring A. K., Andersen N. H., Arbogast R.-M., Bartosiewicz L., Gardeisen A., Kanstrup M., Maier U., Marinova E., Ninov L., Schäfer M., Stephan E. (2013).

Crop manuring and intensive land management by Europe's first farmers, *PNAS Nexus* 110 (31), 12589-12594.

Boggs, S. (2001).

*Principles of Sedimentology and Stratigraphy*, London: Pearson.

Bolelov, S. B. (2016).

Boris Vasilevich Andrianov and the study of irrigation in ancient Khorezm, in Adrianov B. V., *Ancient Irrigation System of the Aral Sea Area: The History, Origin and Development of Irrigated Agriculture*, edited by Mantellini S., Oxford: Oxbow Books, 7-9.

Bondioli, L., Tosi M. (1998).

Introduction, in Gubaev A., Koshelenko G. Tosi M. (eds), *The Archaeological Map of the Murghab Delta: Preliminary Reports 1990-1995*, Roma: IsIAO, IX-XIX.

Bonora, G.L. (2021).

The Oxus Civilization and the Northern Steppes, in Lyonnet B., Dubova N. A. (eds), *The World of the Oxus Civilization*, New York: Routledge 734-776.

Bonora, G. L., Vidale M. (2008).

An aspect of the early Iron Age (Yaz I) period in Margiana: ceramic production at Site No. 999, in Salvatori S., Tosi M., Cerasetti B. (eds), *The Bronze Age and Early Iron Age in the Margiana Lowlands: Facts and methodological proposals for a redefinition of the research strategies,* Oxford: BAR, 153-194.

Bonora, G. L., Vidale M. (2013).

The Middle Chalcolithic in southern Turkmenistan and the archaeological record of Ilgynly-Depe, in Petrie C. A. (ed), *Ancient Iran and its Neighbours, Local developments and Long-Range Interactions in the Fourth Millennium BC,* Oxford: Oxbow Books, 140-165.

Bonora, G. L., Rossi Osmida G., Cengia A.R. (2020).

A general overview of the Oxus Civilization graveyard of Adji Kui in Margiana (south Turkmenistan), *East and West* 2 (61), 47-80.

Boomer, I., Wünnemann B., Mackay A.W., Austin P., Sorrel P., Reinhardt C., Keyser D., Guichard F., Fontugne, M. (2009).

Advances in understanding the late Holocene history of the Aral Sea region, *Quaternary International* 194 (1–2), 79-90.

Boroffka, N., Cierny J., Lutz J., Parzinger H., Pernicka E., Weisgerber G. (2002).

Bronze Age tin from Central Asia: preliminary notes, in Boyle K., Renfrew C., Levine M. (eds), *Ancient Interactions: East and West in Eurasia*, Cambridge: McDonald Institute for Archaeological Research, 135–159.

Boroffka, N., Oberhansli H., Sorrel P., Demory F., Reinhardt C., Wünnemann B., Alimov K., Baratov S., Rakhimov K., Saparov N., Shirinov T., Krivonogov S. K., Röhl U. (2006).

Archaeology and climate: settlement and lake level changes at the Aral Sea, *Geoarchaeology* 21, 721-734.

Bowen, R. L. (1958).

Irrigation in the ancient Qataban, in Bowen R. L., Albright F. P. (eds), *Archaeological Discoveries in South Arabia*, Baltimore: Johns Hopkins University, 43-131.

Bradford, J. (1957).

*Ancient Landscapes*, Oxford: Bell.

Bradley, J. B., Fahenstock R.K., Rowekamp E. T. (1972).

Coarse sediment transport by flood flows on Knik River, Alaska, *Bulletin of Geological Society of America* 83, 1261-1284.

Brice, J. C. (1984).

Planform properties of meandering rivers, in Elliott C. M. (ed), *River Meandering,* New Orleans: American Society of Civil Engineers, 1-15.

Bridge, J.S. (2003).

*Rivers and Floodplains: Forms, Processes, and Sedimentary Record: Massachusetts,* Malden: Blackwell Publishing.

Briere, P.R. (2000).

Playa, playa lake, sabkha: proposed definitions for old terms, *Journal of Arid Environments* 45 (1), 1-7.

Bristow, C. S. (1987).

Brahmaputra River: channel migration and deposition, in Ethridge F G., Flores R. M., Harvey M. D. (eds), *Recent Developments in Fluvial Sedimentology*, Claremore: SEPM Special Pubblication 39, 63-74.

Bristow, C. S., Skelly R. L., Ethridge F. G. (1999).

Crevasse splays from the rapidly aggrading, sand-bed, braided Niobrara River, Nebraska: effect of base-level rise, *Sedimentology* 46 (6), 1029-1048.

Broadmeadow, M., Griffiths H. (1993).

Carbon isotope discrimination and the coupling of CO2 fluxes within forest canopies, in Ehleringer J., Hall A., Farquhar G. (eds), *Stable Isotopes and Plant Carbon-Water Relations*, London: Academic Press, 109–30.

Brown, A.G. (1997).

*Alluvial Geoarchaeology*, Cambridge: Cambridge University Press.

Brusgaard, N., Fokkens H., Kootker L. M. (2019).

An isotopic perspective on the socio-economic significance of livestock in Bronze Age West-Frisia, the Netherlands (2000–800 BCE), *Journal of Archaeological Science: Reports* 27 (101944), 1-10.

Buccellati, G. (2008).

The origin of the tribe and of "Indrustial" agropastoralism in Syro-Mesopotamia, in Barnard H., Wendrich W. (eds), *The Archaeology of Mobility: Old World and New World Nomadism*, Los Angeles: Cotsen Institute of Archaeology at UCLA, 141-159.

Buławka, N., Orengo, H. A. (2024).

Application of multi-temporal and multisource satellite imagery in the study of irrigated landscapes in arid climates, *Remote Sensing* 16, 1-25.

Bull, W. B. (1977).

The alluvial-fan environment, *Progress in Physical Geography: Earth and Environment* 1 (2), 222-270.

Byung-Kee, B., Ullrich S. E. (2008).

Barley for food: characteristics, improvement, and renewed interest, *Journal of Cereal Science* 48, 233-242.

Cadbury, D. (2006).

*Space Race: The Epic Battle Between America and the Soviet Union for Dominance of Space*, New York: Harper Collins Publishers.

Callahan, E. M. (2013).

*To Rule of the Roof of the World: Power and Patronage in Afghan Kyrgyz Society*. Ph.D Thesis, Boston University, Boston, USA.

Callander, R.A. (1978).

River meandering, *Annual Review of Fluid Mechanics* 10, 129-58.

Campana, S. (2017).

Drones in archaeology: State-of-the-art and future perspectives, *Archaeological Prospection* 24(4), 275-296.

Campana, S., Francovich R. Marasco M. (2006).

Remote sensing and ground-truthing of a medieval mound (Tuscany-Italy), in Campana S., Forte M. (eds), *From Space to Place: 2nd International Conference on Remote Sensing in Archaeology*, Oxford: British Archaeology Reports, 491-496.

Cappers, R. T. J. (2006).

*Roman Footprints at Berenike: Archaeobotanical Evidence of Subsistence and Trade in the Eastern Desert of Egypt*, Los Angeles: Cotsen Institute of Archaeology.

Cappers, R. T. J., Fantone F., Neef R., van Doorn C. J. G. (2012).

Archaeobotanical evidence of the fungus covered smut (Ustilago hordei) in Jordan and Egypt, *Anacleta Praehistorica Leidensia* 43/44, 159-164.

Carson, M.A., Lapointe M. F. (1983).

The inherent asymmetry of river meander planform, *Journal of Geology* 91, 41-56.

Cattani, M. (2008a).

Excavations at sites No. 1211 and No. 1219 (Final Bronze Age), in Salvatori S., Tosi M., Cerasetti B. (eds), *The Bronze Age and Early Iron Age in the Margiana Lowlands: Facts and Methodological Proposals for a Redefinition of the Research Strategies*, Oxford: BAR, 119-132.

Cattani, M. (2008b).

The final phase of the Bronze Age and the “Andronovo Question” in Margiana, in Salvatori S., Tosi M., Cerasetti B. (eds), *The Bronze Age and Early Iron Age in the Margiana Lowlands: Facts and methodological proposals for a redefinition of the research strategies*, Oxford: BAR, 133-152.

Cattani, M., Genito B. (1998).

The pottery chronological seriation of the Murghab Delta from the end of the Bronze Age to the Achaemenid period: a preliminary note, in Gubaev A., Koshelenko G., Tosi M. (eds), *The Archaeological Map of the Murghab Delta: Preliminary Reports 1990-1995*, Roma: IsIAO, 75-87.

Cattani, M., Salvatori S. (2008).

Transects and other techniques for systematic sampling, in Salvatori S., Tosi M., Cerasetti B. (eds), *The Bronze Age and Early Iron Age in the Margiana Lowlands: Facts and Methodological Proposals for a Redefinition of the Research Strategies,* Oxford: BAR, 1-27.

Cattani, M., Cerasetti B., Salvatori S., Tosi, M. (2008).

The Murghab delta in Central Asia 1990-2001: the GIS from research resource to reasoning tool for the study of settlement change in long-term fluctuations, in Salvatori S., Tosi M., Cerasetti B. (eds), *The Bronze Age and Early Iron Age in the Margiana Lowlands: Facts and Methodological Proposals for a Redefinition of the Research Strategies*, Oxford: BAR, 39-45.

Cerasetti, B. (1998).

Preliminary report on ornamental elements of "Incised Coarse Ware", in Gubaev A., Koshelenko G., Tosi M. (eds), *The Archaeological Map of the Murghab Delta: Preliminary Reports 1990-1995*, Roma: IsIAO, 67-74.

Cerasetti, B. (2008).

A GIS for the archaeology of the Murghab Delta, in Salvatori, S., Tosi M., Cerasetti B. (eds), *The Bronze Age and Early Iron Age in the Margiana Lowlands: Facts and Methodological Proposals for a Redefinition of the Research Strategies*, Oxford: BAR, 29-38.

Cerasetti, B. (2012).

Remote sensing and survey of the Murghab Alluvial Fan, southern Turkmenistan: The coexistence of nomadic herders and sedentary farmers in the Late Bronze Age and Early Iron Age, in Matthews R., Curtis J. (eds), *Mega-cities & Mega-sites, The Archaeology of Consumption & Disposal Landscape, Transport & Communication, Proceedings of the 7th International Congress on the*

*Archaeology of the Ancient Near East 12 April – 16 April 2010*, Wiesbaden: Harrassowitz Verlag, 539-558.

Cerasetti, B. (2021).

Who interacted with whom? Redefining the interaction between BMAC people and mobile pastoralists in Bronze Age southern Turkmenistan, in Lyonnet B., Dubova N. A. (eds), *The World of the Oxus Civilization*, New York: Routledge, 487-495.

Cerasetti, B., Mauri M. (2002).

The Murghab Delta palaeochannel reconstruction on the basis of remote sensing from space, *Space Applications for Heritage Conservation*, Strasbourg (France), November 2002, 1-9.

Cerasetti, B., Codini G.B., Rouse L.M. (2014).

Walking in the Murghab alluvial fan (southern Turkmenistan): an integrated approach between old and new interpretation about the interaction between settled and nomadic people, in Lamberg-Karlovsky C. C., Genito B., Cerasetti B. (eds), *'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, 105-114.

Cerasetti, B., Arciero R., Carra M. L., Curci A., De Grossi Mazzorin J., Forni L., Luneau E., Rouse L.M., Spengler R. N. (2019).

Bronze and Iron Age urbanization in Turkmenistan. Preliminary results from the excavation of Togolok 1 on the Murghab alluvial fan, in Baumer C., Novák M. (eds), *Urban Cultures of Central Asia from the Bronze Age to the Karakhanids Learnings and conclusions from new archaeological investigations and discoveries*, Wiesbaden: Harrassowitz Verlag, 63-72.

Cerasetti, B., Arciero R., Billings T. N., Cattani M., D'Ippolito L., Forni L., Luneau E., Olson K.G., Potenza A.C., Rouse L.M., Spengler III, R.N. (2022).

The Rise and decline of the desert cities. The last stages of the BMAC at Togolok 1 (Southern Turkmenistan), in Baumer C., Novák M., Rutishauser S. (eds), *Cultures in Contact Central Asia as Focus of Trade, Cultural Exchange and Knowledge Transmission*, Wiesbaden: Harrassowitz Verlag, 89-116.

Cerasetti, B., Arciero R., Forni L., Rouse L.M., Carra M., Luneau E., Spengler III, R.N (Forthcoming).

Interactions between sedentary and mobile peoples in the Bronze Age of southern Central Asia: Excavations at Togolok 1 in the Murghab region, in Boroffka N. (ed) *Farmers, Traders and Herders: The Bronze Age in Central Asia and*

*Khorasan (3rd – 2nd Millennium BCE)*, Berlin: Deutsches Archäologisches Institut, Eurasien-Abteilung/Dietrich Reimer Verlag.

Cerasetti B., Luneau E. (Forthcoming).

The transitional period from Bronze to Iron Age in Turkmenistan: the Late and Final Bronze Ages, in Kurbanov A., Wordsworth P. (eds) The Oxford Handbook of the Archaeology of Turkmenistan,Oxford: Oxford Press.

Cez, L. (2019).

Le paysage fluvial et irrigué de Sarazm dans la moyenne vallée du Zeravchan, Tadjikistan, Asie centrale, *Projets de Paysage* 20, 1-21.

Challis, K., Priestnall G., Gardner A., Henderson J., O'Hara S. (2002).

Corona remotely-sensed imagery in dryland archaeology: the islamic city of Raqqa, Syria, *Journal of Field Archaeology* 29, 139–153.

Chang, H.H. (1988).

On the cause of river meandering, in White W. R. (ed), *International Conference on river regime*, Hoboken: Wiley, 83-93.

Chang, C., Tourtellotte P., Baipakov K. M., Grigoriev F. P. (2002).

*The Evolution of Steppe Communities from Bronze Age Through Medieval Periods in Southeastern Kazakhstan (Zhetysu)*, Sweet Briar: Sweet Briar College.

Charles, M., Hoppé C., Jones G., Bogaard A., Hodgson J. (2003).

Using weed functional attributes for the identification of irrigation regimes in Jordan, *Journal of Archaeological Science* 30, 1429–1441.

Chen, W., Xuanqing Z., Naihua H., Yonghong M. (1996).

Compiling the map of shallow-buried palaeochannels on the North China Plain, *Geomorphology* 18 (1), 47–52.

Cheng, H., Sinha A., Verheyden S., Nader F. H., Li X. L., Zhang P. Z., Yin J. J., Yi L., Peng Y. B., Rao Z. G., Ning Y. F., Edwards R. L. (2015).

The climate variability in northern Levant over the past 20,000 years, *Geophysical Research Letters*, 42, 8641–8650.

Cherry, J. F. (1983).

Frogs round the pond: perspectives on current archaeological survey projects in the Mediterranean area, in Keller D. R., Rupp D. W (eds), *Archaeological Survey in the Mediterranean Area*, Oxford: BAR, 375–416.

Church, M. (2006).

Bed material transport and the morphology of alluvial river channels, *Annual Review of Earth and Planetary Sciences* 34, 325-354.

Civil, M. (1994).

*The Farmer's Instructions: A Sumerian Agricultural Manual*, Barcelona: Editorial Ausa.

Clemmens, A. J. (2006).

Improving irrigated agriculture performance through an understanding of the water delivery process, *Irrigation and Drainage* 55, 223–234.

Clezious, S., Gaibov V., Annaev T. (1998).

Off-site archaeological transects in Northen Margiana, in Gubaev, A., Koshelenko G., Tosi M. (eds), *The Archaeological Map of the Murghab Delta: Preliminary Reports 1990-1995*, Roma: IsIAO, 26-34.

Collier, P. (1994).

Innovative military mapping using aerial photography in the First World War: Sinai, Palestine and Mesopotamia 1914–1919, *The Cartographic Journal* 31 (2), 100-104.

Conolly, J., Lake, M. (2006).

*Geographical Information Systems in Archaeology*, Cambridge: Cambridge University Press.

Coombes, P., Barber K. (2005).

Environmental determinism in Holocene research: causality or coincidence?, *Area* 37 (3), 303–11.

Costantini, L. (1977).

Le piante, in Basaglia P., Tucci G., Goss B., Salvatori, S. (eds), *La Città Bruciata del Deserto Salato*, Venezia: Erizzo, 159-228.

Costanzo, S., Forti, L., Morandi Bonacossi, D., Zerboni, A. (2023).

A thin section micromorphology photomicrographs dataset of the infilling of the sennacherib assyrian canal system (Kurdistan region of Iraq), *Data in Brief* 49, 1093, 1-7.

Cotellucci, A., Pellegrino L., Costa E., Bruno M., Dela Pierre F., Aquilano D., Destefanis E., Pastero L. (2023).

Effect of different evaporation rates on gypsum habit: mineralogical implications for natural gypsum deposits, *Crystal Growth & Design* 23 (12), 9094-9102.

Cowan, P. J. (2007).

Geographic usage of the terms Middle Asia and Central Asia, *Journal of Arid Environments* 62(2), 359–363.

Crawford, O. G. S. (1923).

Air survey and archaeology, *Geographical Journal* 23, 324-366.

Cremaschi, M. (1998).

Palaeohydrography and Middle Holocene desertification in the northern fringe of the Murghab Delta, in Gubaev A., Koshelenko G., Tosi M. (eds), *The Archaeological Map of the Murghab Delta: Preliminary Reports 1990-1995*, Roma: IsIAO, 15-25.

Crumley, C. (1995).

Hetararchy and the analysis of complex societies, *Archaeological Papers of the American Anthropological Association* 34, 1-5.h

Cullen, H.M., de Menocal P.B., Hemming S., Brown F.H., Guilderson T., Sirocko F. (2000).

Climate change and the collapse of the Akkadian empire: Evidence from the deep sea, *Geology* 28, 379–382.

Dalfes, H. N., Kukla G., Weiss H. (1997).

*Third Millennium BC Climate Change and Old World Collapse*, Heidelberg: Springer.

Da Pelo, P., D’Orazio T. (2013).

Automatic and semi-automatic approaches to support archaeological trace extraction and digitalization, in Lasaponara R., Masini N., Biscione M., Hernandez M. (eds), *Proceedings of the 4th EARSeL Workshop on Cultural and Natural Heritage "Earth observation: a window on the past"*, Matera (Italy), 6–7 June 2013, Hannover: EARSeL, 347–362.

Defelice, M. S. (2002).

Catch weed bedstraw or cleavers, Galium aparine L.—A Very ‘‘Sticky’’ subject, *Weed Technology*, 16, 467–472.

Dewar, R. E. (1991).

Incorporating variation in occupation span into settlement-pattern analysis. *American Antiquity* 56 (4), 604–620.

Dewar, R. E. (1994).

Contending with contemporaneity: A reply to kintigh, *American Antiquity* 59(1), 149–152.

Di Cosmo, Nicola (2002).

*Ancient China and Its Enemies: The Rise of Nomadic Power in East Asian History*, Cambridge: Cambridge University Press.

Dixit, Y., Hodell, D.A., Petrie, C.A. (2014).

Abrupt weakening of the summer monsoon in northwest India ~4100 yr ago, *Geology* 42 (4), 339–342.

Dolukhanov, P. M. (1981).

The ecological prerequisites for early farming in southern Turkmenia, in Kohl P. L. (ed), *The Bronze Age Civilization of Central Asia: Recent Soviet Discoveries*, New York: M. E. Sharpe Inc, 350-358.

Dolukhanov, P. M. (2010).

Archaeology in colonial and postcolonial U.S.S.R, in Lydon J., Rizvi U.Z. (eds), *Handbook of Postcolonial Archaeology*, New Yourk: Routledge, 113-123.

Dolukhanov, P. M. (2016).

Central Asian archaeology: the Russian and soviet times, in Andrianov B. V, Ancient Irrigation Systems of the Aral Sea Area: The History, Origin, and Development of Irrigated Agriculture, edited by S. Mantellini, Oxford: Oxbow Books, 1-6.

Doumani Dupuy, P.N., Luneau E., Rouse L.M. (2021).

Pluralising power: ceramics and social differentiation in Bronze Age central Eurasia, *World Archaeology* 53, 779-808.

Dregne, H.E. (1976).

*Soils of Arid Regions*, New York: Elsevier.

Dubova, N. A. (2019).

Gonur Depe - City of Kings and Gods, and the Capital of Margush Country (Modern Turkmenistan). Its discovery by Professor Victor Sarianidi and recent finds, in Baumer C., Novák M. (eds), *Urban Cultures of Central Asia from the Bronze Age to the Karakhanids*, Wiesbaden: Harrassowitz Verlag, 29-53.

Dubova, N. A. (2021).

The Royal Necropolis at Gonur Depe: an attempt at systematization (plan, construction, rituals), in Lyonnet B., Dubova N. A. (eds), *The World of the Oxus Civilization*, New York: Routledge, 333-366.

Dubova, N. A., Antonova E. V., Muradov R. G., Sataev R. M., Tishkin A. A. (2018).

Foreword, in Dubova N. A. (ed), *Trudy Margianskoj Ekspeditsii*, vol. 7, Moskva: Starij Sad, 1-8.

du Plessis, A. (2019).

*Water as an Inescapable Risk. Current Global Water Availability, Quality and Risks with a Specific Focus on South Africa*, Heidelberg Springer Water.

Edgar, A. L. (2004).

*Tribal Nation: The Making of Soviet Turkmenistan*, Princeton: Princeton University Press.

Emeljanenko, T. (1994).

Nomadic year cycles and cultural life of Central Asian livestock-breeders before the 20th century, in van Leeuwen C., Emeljanenko T., Popova L. (eds), *Nomads in Central Asia: Animal husbandry and culture in transition (19th-20th Century)*, Amsterdam: Royal Tropical Institute, 37-68.

Emerson, R. W. (2023).

Mann-Whitney U test and t-test, *Journal of Visual Impairment & Blindness* 117 (1), 99-100.

Endo, E., Shoda S., Frachetti M., Kaliyeva Z., Kiyasbek G., Zhuniskhanov A., Liu X., Dupuy P.D. (2023).

Pottery impressions reveal earlier westward dispersal of foxtail millet in inner Asian mountain corridor, *Agronomy* 13, 1706, 1-13.

Ertsen, M. W. (2010).

Structuring properties of irrigation systems: understanding relations between humans and hydraulics through modeling, *Water History* 2, 165–183.

Ertsen, M. W. (2016).

*Improvising Planned Development on the Gezira Plain, Sudan, 1900-1980,* Heidelberg: Springer.

Ertsen, M. W., Kaptijn E. (2015).

A narrow place can contain a thousand friends: irrigation as a response to climate in the Zerqa Triangle, Jordan, in Kerner S., Dann R., Bangsgaard P.J. (eds), *Climate and Ancient Societies*, Copenhagen: Museum Tusculanum Press, 137-155.

EU Communication (2021).

*Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions, Forging a climate-resilient Europe.* The new EU Strategy on Adaptation to Climate Change, SEC:89.

FAO (1998).

*World Reference Base for Soil Resource*, World Soil Resources Report 84, Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

FAO (2012).

*AQUASTAT Country Profile – Turkmenistan Report*, Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

Farrington, I. (1980).

The archaeology of irrigation canals, with special reference to Peru, *World Archaeology* 11 (3), 287–305.

Fattahi, M. (2015).

OSL dating of the miam qanat (KARIZ) system in NE Iran, *Journal of Archaeological Science* 59, 54-63.

Fernea, R. (1970).

*Shaykh and Effendi Changing Patterns of Authority Among the El Shabana of Southern Iraq*, Cambridge: Harvard University Press.

Ferrio, J. P., Araus J. L., Buxo R., Voltas J., Bort, J. (2005).

Water management practices and climate in ancient agriculture: inferences from the stable isotope composition of archaeobotanical remains, *Vegetation History and Archaeobotany* 14, 510–517.

Fet, G. (1994).

Vegetation of Southwest Kopetdagh, in Fet, V., Atamuradov, K. I. (eds), *Biogeography and EcoIogy of Turkmenistan*, Dordrecht: Springer Science and Business, 149-172.

Fiorentino, G., Caracuta V., Calcagnile L., D’Elia M., Matthiae P., Mavelli F., Quarta G. (2008).

Third millennium BC climate change in Syria highlighted by carbon stable isotope analysis of 14C-AMS dated plant remains from Ebla, *Palaeogeography, Palaeoclimatology, Palaeoecology* 266, 51–58.

Fiorentino, G., Caracuta V., Casiello G., Longobardi F., Sacco A. (2012).

Studying ancient crop Provenance: Implications from δ13C and δ15N values of charred arley in a Middle Bronze Age silo at Ebla (NW Syria), *Rapid Communications in Mass Spectrometry* 26, 327–335.

Fleskens, L., Ataev, A., Mamedov, B., Spaan, W. P. (2007).

Desert water harvesting from Takyr surfaces: assessing the potential of traditional and experimental technologies in the Karakum, *Land Degradation & Development* 18, 17-39.

Flohr, P., Mülder, G., Jenkins, E. (2011).

Carbon stable isotope analysis of cereals remains as a way to reconstruct water availability: preliminary results, *Water History* 3, 121–44.

Flohr, P., Jenkins, E., Williams, H.R.S., Jamjoum K., Nuimat S., Müldne G. (2019).

What can crop stable isotopes ever do for us? An experimental perspective on using cereal carbon stable isotope values for reconstructing water availability in semi-arid and arid environments, *Vegetation History and Archaeobotany* 28, 497–512.

Foley, R. A. (1981).

Off-site archaeology: an alternative approach for the short-sited, in Hodder I., Isaac G., Hammond N. (eds), *Patterns of the Past: Studies in Honour of David Clarke*, Cambridge: Cambridge University Press, 157-183.

Fontugne, M., Zajtseva G. I., Lyonnet B., Dubova N. A., Burova N. D. (2021).

Radiocarbon dates related to the BMAC/Oxus Civilization, in Lyonnet B., Dubova N.A. (eds), *The World of the Oxus Civilization*, New York: Routledge, 863-91.

Forni, L. (2017).

Bronze Age Terracotta Anthropomorphic and Zoomorphic Figurines from the Murghab Region (Turkmenistan): New Evidence and Interpretations”, *Ocnus. Quaderni della Scuola di Specializzazione in Beni Archeologici* 25, 9-18.

Forni, L, Arciero R. (2022).

Identity and interaction at Togolok 1 in the Murghab region (Southern Turkmenistan) during the Bronze Age, in Coppini C., Cyrus G., Golestaneh H. (eds) *Bridging the Gap: Disciplines, Times, and Spaces in Dialogue. Sessions 4 and 6 from the conference Broadening Horizons 6 held at the Freie Universität Berlin, 24-28 June 2019,* 3, Oxford: Archaeopress, 25-40.

Foster, B.R. (1986).

Agriculture and accountability in ancient Mesopotamia, in H. Weiss (ed), *The Origins of Cities in Dry-farming Syria and Mesopotamia in the Third Millennium B.C.*, Guilford: Four Quarters Pub. Co., 109–128.

Fouache, E., Besenval R., Cosandey C., Cousso, C., Ghilardi M., Huot S., Lamothe M. (2012).

Palaeochannels of the Balkh River (northern Afghanistan) and human occupation since the Bronze Age period, *Journal of Archaeological Science* 39, 3415-3427.

Fouache, E., Cez L., Andrieu- Ponel V., Rante R. (2021).

Environmental changes in Bactria and Sogdiana (Central Asia Afghanistan and Uzbekistan) from the Neolithic to the Bronze Age, in Lyonnet B., Dubova N.A. (eds), *The World of the Oxus Civilization,* New York: Routledge, 82-109.

Fowler, M. (1996).

Declassified intelligence satellite photographs, *Aerial Archaeology Research Group News* 13, 30–35.

Frachetti, M., Spengler R., Fritz G., Mar'yashev A. (2010).

Earliest direct evidence for broomcorn millet and wheat in the central Eurasian steppe region, *Antiquity* 84 (326), 993-1010.

Frachetti, M. D. (2012).

Multi-regional emergence of mobile pastoralism and non-uniform institutional complexity across Eurasia, *Current Anthropology* 53 (1), 2–38.

Francfort, H. P. (1984).

The early periods of Shortughaï (Harappan) and the western bactrian culture of Dashly, in Allchin B. (ed), *South Asian Archaeology 1981,* Cambridge: Cambridge University Press, 170– 175.

Francfort, H. P. (2009).

L’âge du bronze en Asie centrale. La civilisation de l’Oxus, *Anthropology of the Middle East* 4 (1), 91-111.

Francfort, H. P., Tremblay X. (2010).

Marhaši et la Civilisation de l‘Oxus, *Iranica Antiqua* 45, 51– 224.

Frenez, D. (2018).

Manufacturing and trade of asian elephant ivory in Bronze Age middle asia: evidence from Gonur Depe (Margiana, Turkmenistan), *Archaeological Research in Asia* 15, 13– 33.

Fribus, A.V. (2020).

Rural settlements in the ancient delta of the Murghab River and problems of interaction between Bronze Age farmers and mobile pastoralists in the South of Central Asia, in Guboglo M.N., Kufterin V.V. (eds), *Nature, Man, Society: from Past to Present, Collection of papers in honor of Nadezhda Dubova's jubilee*, Institute of Ethnology and Anthropology, Moscow: RAS, 45-52.

Galbraith, R.F., Roberts R.G., Laslett G.M., Yoshida H., Olley J.M., (1999).

Optical dating of single grains of quartz from Jinmium rock shelter, northern Australia. Part I: experimental design and statistical models, *Archaeometry* 41, 339-364.

Garner, G. (2021).

Metal sources (tin and copper) and the BMAC, in Lyonnet B., Dubova N.A. (eds), *The World of the Oxus Civilization*, New York: Routledge, 799-826.

Gayduchenko, L. L. (2002).

Organic remains from fortified settlements and necropolis of the “country of towns”, in Jones-Bley K., Zdanovich D.G. (eds), *Complex Societies of Central Eurasia From the 3rd to the 1st Millennium BC: Regional Specifics in Light of Global Models*, Washington: Monograph Series, 400–416.

Genito, B. (1998).

The Iron Age in Merv oasis, in Gubaev A., Koshelenko G., Tosi M. (1998), *The Archaeological Map of the Murghab Delta: Preliminary Reports 1990-1995*, Roma: IsIAO, 89-96.

Gerasimov, I. P. (1954).

*Cherty skhodstva i razlichiya v prirode pusryn*. Priroda 2.

Gerasimov, I. P. (1978).

Ancient rivers in the deserts of soviet Central Asia, in Brice W. C. (ed), *The Environmental History of the Near and Middle East Since the Last Ice Age, School of Geography*, Manchester: Manchester Academic Press, 319-334.

Ghassemi, M. R., Garzanti E. (2019).

Geology and geomorphology of Turkmenistan: a review, *Geopersia* 9 (1), 125-140.

Giardino, M. J. (2011).

A history of NASA remote sensing contributions to archaeology, *Journal of Archaeological Science* 38(9), 2003-2009.

Gibson, Mc. (2020).

Introduction, in Lawrence, D., Altaweel, M. Philip, G. (eds), *Studies in honoring Tony J. Wilkinson, New agenda in remote sensing and landscape archaeology in the Near East: Studies in Honor of T.J. Wilkinson*, Chicago: The Oriental Institute of the University of Chicago, 1-6.

Gintzburger, G., Toderich K. N., Mardanov B. K., Mahmudov M.M. (2003).

*Rengelands of the arid and semi-arid zones of Uzbekistan*, Paris: Cirad-Icarda.

Goldberg, P., Macphail R. I. (2006).

*Practical and Theoretical Geoarchaeology*, Hoboken: Blackwell Publishing.

Goudie, A. S. (2003).

*Great Warm Deserts of the World: Landscapes and Evolution Geomorphological Landscapes of the World*, Oxford: Oxford University Press.

Grubov, V.I. (1966).

Chenopodiaceae, Rasteniya Tsentralnoi Azii Nauk, Leningrad 2: 1-135.

Gubaev, A., Koshelenko, G., Tosi, M. (1998).

*The Archaeological Map of the Murghab Delta: Preliminary Reports 1990-1995*, Roma: IsIAO.

Guichard, M. (2021).

The Oxus Civilization and Mesopotamia: A philologist's point of view, in Lyonnet B., Dubova N. A. (eds), *The World of the Oxus Civilization*, New York: Routledge, 66-81.

Guljamov, Ya. G., Islamov U., Askarov A. (1966).

*Pervobytnaja kul'tura i vozniknovenie oroshaemogo zemledelija v nizov'jakh Zerafshana*, Tashkent:Fan.

Halkon, P. (2006).

Reconstructing an Iron Age and Roman Landscape: new research, in Foulness Valley, East Yorkshire, England, in Campana S., Forte M. (eds), *From Space to Place: 2nd International Conference on Remote Sensing in Archaeology*, Oxford: Archeopress:, 235-242.

Halstead, P., O'Shea J. (1989).

Introduction: cultural responses to risk and uncertainty, in Halstead P., O'Shea J. (eds), *Bad Year Economics: Cultural Responses to Risk and Uncertainty, New Directions in Archaeology*, Cambridge:Cambridge University Press 1-7.

Hamzeh, M.A., Mahmudy-Gharaie M. H., Alizadeh-Lahijani H., Moussavi-Harami R., Djamali M., Naderi-Beni A. (2016).

Paleolimnology of Lake Hamoun (East Iran): implication for past climate changes and possible impacts on human settlements, *PALOIS* 31, 1-14.

Harris, D. R., Masson V. M., Berezkin Y. E., Charles M. P., Gosden C., Hillman G. C., Kasparov A. K., Korobkova G. F., Kurbansakhatov K., Legge A. J. (1993).

Investigating early agriculture in Central Asia: new research at Jeitun, Turkmenistan, *Antiquity* 67, 324–338.

Heaton, T. H. E., Jones G., Halstead P., Tsipropoulos T. (2009).

Variations in the 13C/12C ratios of modern wheat grain, and implications for interpreting data from Bronze Age Assiros Toumba, Greece, *Journal of Archaeological Science* 36 (10), 2224–33.

Heinecke, L., Mischke S., Adler K., Barth A., Biskaborn B.K., Plessen B., Nitze I., Kuhn G., Rajabov I., Herzschuh U. (2016).

Late pleistocene to Holocene climate and limnological changes at Lake Karakul (Pamir Mountains, Tajikistan), *Climate of the Past Discussions*, 1-30.

Hermes Taylor, R., Frachetti M. D., Doumani Dupuy Paula N., Mar'yashev A., Nebel A., Makarewicz C. A. (2019).

Early integration of pastoralism and millet cultivation in Bronze Age Eurasia, *Proceedings of the Royal Society B* 286 (1912), 20191273, 1-9.

Hidy, D., Haszpra L., Barcza Z., Vermeulen A., Tuba Z., Nagy Z. (2009).

Modelling of carbon isotope discrimination by vegetation, *Photosynthetica* 47 (3), 457–70.

Hiebert, F. T. (1994a).

*Origins of the Bronze Age Oasis Civilization in Central Asia*, Cambridge: Peabody Museum of Archaeology and Ethnology.

Hiebert, F. T. (1994b).

Production evidence for the origins of the Oxus Civilization, *Antiquity* 68(259), 372-387.

Hiebert, F. T., Moore, K. M. (2004).

A small steppe site near Gonur, in Kosarev M. F., Kozhin P. M., Dubova N. A (eds), *U istokov tsivilizatsii: Sbornik statej k 75-letiyu Viktora Ivanovicha Sarianidi* [Near the Sources of Civilizations: the issue in honor of the 75th anniversary of Victor Sarianidi], Moskva: Staryj sad, 294-302.

Hiebert, F.T., Lamberg- Karlovsky C. C. (1992).

Central Asia and the Indo- Iranian borderlands, *Iran* 30, 1– 15.

Hobbs, J.J. (1990).

*Bedouin Life in the Egyptian Wilderness*. Austin: University of Texas Press.

Hollander, M., Wolfe D.A., Chicken E. (2015).

*Nonparametric Statistical Methods*, Hoboken: John Wiley & Sons Inc.

Hopkirk, P. (1990).

*The Great Game: On Secret Service in High Asia*, London:John Murray.

Hritz, C. (2010).

Tracing settlements pattern and channel system in southern Mesopotamia using remote sensing, *Journal of Field Archaeology* 35, 184-203.

Hritz, C. (2014).

Contributing of GIS and Satellite-based Remote Sensing to Landscape Archaeology in the Middle East, *Journal of Archaeological Research* 22, 229-276.

Hritz, C., Wilkinson T.J. (2006).

Using Shuttle Radar Topography to map ancient water channels in Mesopotamia, *Antiquity* 80 (308), 415–424.

Hritz, C. Darweesh, N., Pournelle, J. (2020).

Resilient landscapes: riparian evolution in the wetlands of southern Iraq, in Lawrence D., Altaweel M., Philip G. (eds), *New Agenda in Remote Sensing and*

*Landscape Archaeology in the Near East: Studies in Honor of T.J. Wilkinson*, Chicago: The Oriental Institute of the University of Chicago, 228-266.

Hu, N., Li X., Luo L., Zhang L. (2017).

Ancient irrigation canals mapped from Corona imageries and their implications in Juyan Oasis along the Silk Road, *Sustainability* 9, 1283, 1-14.

Hübner, C., Novák M., Winkelman S. (2019).

The Swiss IAW-EurAsia Project on Urban Development and Land use in Gonur Depe (Turkmenistan), in Baumer C., Novák M. (eds) *Urban Cultures of Central Asia from the Bronze Age to the Karakhanids Learnings and conclusions from new archaeological investigations and discoveries*, Wiesbaden: Harrassowitz Verlag, 55-61.

Hunt, R. C. (1988).

Size and the structure of authority in canal irrigation systems, *Journal of Anthropological Research* 44 (4), 335-355.

Jacobberger, P.A., (1988).

Mapping abandoned river channels in Mali through directional filtering of thematic mapper data, *Remote Sensing of Environment* 26, 161–170.

Jacobsen, T. (1960).

The Waters of Ur, *Iraq* 22, 174–185.

Jacobsen, T., Adams R. M. (1958).

Salt and silt in ancient Mesopotamian agriculture, *Science* 128 (3334), 1251–1258.

Jacobson, P., Jacobson K., Seely M. (1995).

*Ephemeral Rivers and Their Catchments: Sustaining People and Development in Western Namibia*, Windhoek: Desert Research Foundation of Namibia.

Jacobson-Tepfer, E. (2008).

The emergence of cultures of mobility in the altai mountains of mongolia: evidence from the intersection of rock art and paleoenvironment, in Barnard H, Wendrich W. (eds), *The Archaeology of Mobility Old World and New World Nomadism*, Los Angeles: Cotsen Institute of Archaeology University of California, 200-229.

Jacobson-Tepfer, E., Kubarev V. D., Tseveendorj D. (2007).

Mongolie du Nord-Ouest: Haut Tsagaan Gol, *Répertoire des pétroglyphes d'Asie Centrale* 7, 380-444.

Ji, Z., de Vriend H., Hu C. (2003).

*Application of SOBEK model in the Yellow River estuary*, Proceedings of the International Conference on Estuaries and Coasts 2003, Hangzhou: Zhejiang University Press, 909-915.

Jones, G., Charles M., Colledge S., Halstead P. (1995).

Towards the archaeobotanical recognition of winter-cereal irrigation: an investigation of modern weed ecology in northern Spain, in Kroll H., Pasternak R. (eds), *Res Archaeobotanicae: 9th Symposium IWGP*, Kiel: Institut für Ur- und Frühgeschichte der Christian-Albrecht-Universität, 49–68.

Jopling, A.V., Walker R. G. (1968).

Morphology and origin of ripple-drift cross-lamination, with examples from the Pleistocene of Massachusetts, *Journal of Sedimentary Research* 38 (4): 971–984.

Jotheri, J. (2016).

*Holocene avulsion history of the Euphrates and Tigris rivers in the Mesopotamian Floodplain*. Ph.D Thesis, Durham University, Durham, UK.

Jotheri, J. (2018).

Recognition criteria for canals and rivers in the Mesopotamian floodplain, in Zhuang Y., Altaweel M. (eds), *Water Societies and Technologies from the Past and Present*, London: UCL Press, 109-126.

Jotheri, J., Altaweel M., Tuji A., Anma R., Pennington B., Rost S., Watanabe, C. (2018).

Holocene fluvial and anthropogenic processes in the region of Uruk in southern Mesopotamia, *Quaternary International* 483, 57-69.

Jotheri, J., Feadha M., Al-Janabi J., Alabdan R. (2022).

Landscape Archaeology of Southern Mesopotamia: Identifying features in the dried marshes, *Sustainability* 1 (2), 1-20.

Jotheri, J., Allen, M. B. (2020).

Recognition of ancient channels and archaeological sites in the Mesopotamian floodplain using satellite imagery and digital topography, in Lawrence D., Altaweel M., Philip G. (eds), *New Agenda in Remote Sensing and Landscape Archaeology in the Near East: Studies in Honor of T.J. Wilkinson*, Chicago: The Oriental Institute of the University of Chicago Illinoi, 283-305.

Joseph, G. (2005).

*Fundamental of Remote Sensing*, Hyderabad: Oriental Blackman.

Kakroodi, A. A., Kroonenberg S. B., Hoogendoorn R. M., Mohammd Khani H., Yamani M., Ghassemi M. R., Lahijani H.A.K. (2012).

Rapid Holocene sea-level changes along the Iranian Caspian coast, *Quaternary International* 263, 93–103.

Kalayci, T., Lasaponara R., Wainwright J., Masini N. (2019).

Multispectral Contrast of Archaeological Features: A Quantitative Evaluation, *Remote Sensing* 11 (913), 1-23.

Kalutskov, V. N., Glukhov A. I. (2014).

Landshafty okrestnostej Gonura, in Sarianidi V. I., Kozhin P. M., Kosarev M. F., Dubova N. A (eds), *Trudy Margianskoy Arkheologicheskoy Ekspeditsii 5, Issledovaniya Gonur Depe* v 2011–2013, Moscow: Staryj Sad, 158–165.

Kamakhina, G.L. (1994).

Kopetdagh-Khorassan flora: Regional features of Central Kopetdagh, in Fet, V., Atamuradov, K. I. (eds), *Biogeography and EcoIogy of Turkmenistan*, Dordrecht: Springer Science and Business, 129-148.

Kanstrup, M., Thomsen, I. K., Andersen, A. J., Bogaard, A., Christensen, B. T. (2011).

Abundance of 13C and 15N in emmer, spelt and naked barley grown on differently manured soils: towards a method for identifying past manuring practice, *Rapid Communications in Mass Spectrometry* 25, 2879–288.

Kaptijn, E. (2009).

*Life on the Watershed. Reconstructing Subsistencei in A Steppe Region Using Archaeological Survey: A Diachronic Perspective*. Ph.D thesis, Leiden University, Leiden, The Netherlands.

Kaptijn, E. (2015).

Irrigation and human niche construction. An example of socio-spatial organization in the Zerqa Triangle, Jordan, *Water History* 7, 441–454.

Kavosh, H. A., Vidale M., Nashli H. F. (2019).

*Teppeh Graziani, Sistan, Iran: Stratigraphy, Formation Processes and Chronology of a Suburban Site of Shahr-i Sokhta, Prehistoric Sistan 2,* Roma: Serie Orientale.

Kellerhals, R., Church M., Bray D. I. (1976).

Classification of river processes, *Journal of the Hydraulics Division American Society of Civil Engineers* 93, 63-84.

Kennedy, A. (1925).

*Petra: Its History And Monuments*, London: Country Life.

Kennedy, D. L. (1998).

Declassified satellite photographs and archaeology in the Middle East: Case studies from Turkey, *Antiquity* 72, 553–571.

Kennedy, D. L., Bewley R.H., Radcliffe R. (2011).

Aerial archaeology in the Middle East. Progress and achievement in Jordan (1997-2008)…and the future, in Cerasudo G. (ed) *Archeologia Aerea 4/5 (100 anni de Archeologia aerea in Italia: Atti del Convegno Internazionale* (Roma 15/17, Aprile 2009),Lecce: Claudio Grenzi Editore, 333-337.

Kennedy, H., Moore, O. (1999).

Some ancient and medieval texts about Merv, in Herrmann G. (ed), *Monuments of Merv: Traditional Buildings of the Karakum*, London: Society of Antiquaries of London, 120–32.

Khalaf, N., Insoll T. (2019).

Monitoring islamic archaeological landscapes in Ethiopia using open source satellite imagery, *Journal of Field Archaeology* 44, 401–419.

Kharin, N. G. (1994).

Desertification of the arid lands of Turkmenistan, in Fet V., Atamuradov K. I. (eds), *Biogeography and EcoIogy of Turkmenistan*, Dordrecht: Springer Science and Business, 65-76.

Khazanov, A. M. (2005).

Nomads and cities in the Eurasian steppe region and adjacent countries: a historical overview, in Leder S., Streck B., *Shifts and Drifts in Nomad-Sedentary Relations*, Wiesbaden: Ludwig Reichert Verlag, 163-178.

Kirchner, H. (2009).

Original design, tribal management and modifications in medieval hydraulic systems in the balearic islands (Spain), *World Archaeology* 41, 151–68.

Kircho, L.B. (2021).

The rise of early urban civilization in southwestern Central Asia.From the Middle Chalcolithic to the Middle Bronze Age in southern Turkmenistan, in Lyonnet B., Dubova N. A. (eds), *The World of the Oxus Civilization*, New York: Routledge, 110-142.

Knighton, D. (1998).

*Fluvial Forms and Process: A perspective*, New Yourk: Routledge.

Knighton, A. D., Nanson G. C. (1993). Anastomosis and the continuum of channel pattern, *Earth Surface Processes and Landforms* 18, 613–625.

Kohl, P. (1984).

*Central Asia Palaeolithic Beginnings to the Iron Age: L'Asie Centrale Des Origines l'Age Du Fer*, Paris: Éditions Recherche sur les Civilisations.

Kohl, P. L. (2002).

Archaeological Transformations: Crossing the Pastoral/Agricultural Bridge, *Iranica Antiqua* 37, 151-190.

Kohl, P. L. (2007).

*The making of Bronze Age Eurasia*, Cambridge: Cambridge University Press.

Kozlov, N. P (1991).

*Earth's Nature from Space*, New Delhi: Amerind Publishing Co.

Kramer, C. (1977).

Pots and people, in Levine L.D., Cuyler Young T. (eds), *Mountains and Lowland: essay in the Archaeology of Greater Mesopotamia*, Malibu: Undena Publication, 91-112.

Kraus, S. (2021).

Archaeometallurgical studies on BMAC artifacts, in Lyonnet B., Dubova N. A. (eds), *The World of the Oxus Civilization*, New York: Routledge, 779-798.

Kroll, S., Bendezu-Sarmiento J., Lhuillier J., Luneau E., Kaniuth K., Teufer M., Mustafakulov S., Khasanov M., Vinogradova N., Avanesova N., Fiorillo D., Tengberg M., Sharifi A., Bon C., Bosh D., Mashkour., (2022).

Mobility and land use in the Greater Khorasan Civilization: Isotopic approaches (87Sr/86Sr, δ18O) on human populations from southern Central Asia, *Journal of Archaeological Science: Reports* 103622, 1-15.

Kuftin, B.A. (1956).

“Polevoj otchet o rabote XIV otrjada JuTAKE po izucheniju kul’tury pervobytno-oshchinykh osedlozemledel’cheskikh poselenii epokhy medy i bronzy v 1952 g”. *Trudy Juzhno-Turkmenistanskoj Arkheologicheskoj Kompleksnoj Ekspeditsii* 7, 260-290.

Kühne, H. (ed) (2018).

*Water for Assyria*, Wiesbaden: Harrassowitz.

Kurukulasuriya, P., Mendelson, R. (2006).

*Crop Selection: Adapting to Climate Change in Africa, CEEPA Discussion Paper No. 26. Centre for Environmental Economics and Policy in Africa*, Pretoria: University of Pretoria.

Kuz’mina, E. E. (1991).

Die urgeschichtliche metallurgie der Andronovo-Kultur, Bergbau, *Metallurgie und Metallbearbeitung, Zeitschrift für Archäologie* 25, 29– 48.

Kuz’mina, E. E. (1994).

*“Otkuda prishli Indoarii? Material’naja kul’tura plemen andronovskoj obshchnosti i proiskhozhdenie indoirantsev”*, Moskva: Kalina.

Kuz’mina, E. E. (2007).

*The Origin of the Indo-Iranians*, Indo-European Etymological Dictionary Series 3, Leiden: Brill.

Kuz’mina, E. E., Lyapin. A. A. (1984).

New finds of steppe ceramics in the Murghab, In Masson V. M. (ed), *Problemy arkheologii Turkmenistana*, Ashkhabad: Ylym (Akademia Nauk Turkmen SSR), 6–22.

Lalymenko, N. K. (1989).

Use of surface runoff in crop development of takyr lands, *Problems of Desert Development* 2, 83–86.

Lamberg-Karlovsky, C.C. (1994a).

The Bronze Age khanates of Central Asia, *Antiquity* 68, 398-405.

Lamberg-Karlovsky, C. C. (1994b).

Foreword: Initiating an archaeological dialogue: The USA-USSR archaeological exchange, in Hiebert F. (ed), *Origin of the Bronze Age Oasis Civilization in*

*Central Asia*, Cambridge: Peabody Museum of Archaeology and Ethnology, 16-34.

Lamberg-Karlovsky, C. C. (2003).

Civilization, state or tribes? Bactria and Margiana in the Bronze Age, *The Review of Archaeology* 24, 11-19.

Lamberg-Karlovsky, C.C. (2013).

The Oxus Civilization, *Cuadernos de Prehistoria y Arqueología de la Universidad Autónoma de Madrid* 39, 21–63.

Lamberg-Karlovsky, C.C. (2016).

Irrigation among the Shaykhs and Kings, in Andrianov B. V, *Ancient Irrigation Systems of the Aral Sea Area: The History, Origin, and Development of Irrigated Agriculture,* edited and by Mantellini S., Oxford: Oxbow Books, 23-48.

Lamothe, M., Auclair M., Hamzaoui C., Huot S. (2003).

Towards a prediction of long-term anomalous fading of feldspar IRSL, *Radiation Measurements* 37 (4-5), 493-498.

Lasaponara, R., Masini N. (2012).

Remote sensing in archaeology: from visual data interpretation to digital data manipulation, in Lasaponara R., Masini N. (eds), *Satellite remote sensing: a new tool for archaeology,* Heidelberg: Springer, 3-16.

Laserna, M. R. (2003).

*Sensitive analysis of a SOBEK hydrodynamic model for wetland management*. MSc Thesis, IHE Institute for Water Education, Delft, The Netherlands.

Lauterbach, S., Witt R., Plessen B., Dulski P., Prasad S., Mingram J., Gleixner G., Hettler-Riedel S., Stebich M., Schnetger B., Schwalb A., Schwarz A. (2014).

Climatic imprint of the mid-latitude Westerlies in the Central Tian Shan of Kyrgyzstan and teleconnections to North Atlantic climate variability during the last 6000 years, *The Holocene* 24 (8), 970–984.

Lavrov, A.P., Larin E.V., Sanin, S.A. (1976).

*Rayonirovanie takyrov Turkmenistana dlya sel'skohozyaistvennih zeleyè* , Ashgabat:Ylym.

Lawler, A. (2007).

Society for American archaeology meetin: climate spurred later Indus decline, *Science* 316, 978–979.

Lebedeva-Verba, M. P., Gerasimova M. I. (2010).

Micromorphology of takyrs and the desert “Papyrus” of southwestern Turkmenia, *Eurasian Soil Science* 43 (11), 1220–1229.

Leopold, L. B., Wolman M. G. (1957).

River channel patterns: braided, meandering and straight, *United States Geological Survey, Professional paper* 282B, 39-85.

Leonard, W. H., Martin J. H. (1963).

*Cereal Crops*, New York: MacMillan Publishing.

Leroy, S.A.G., Marret, F., Gibert, E., Chalie, F., Reyss, J. L., Arpe, K., (2007).

River inflow and salinity changes in the Caspian Sea during the last 5500 years, *Quaternary Science Reviews* 26, 3359-3383.

Leroy, S. A. G., Lopez- Merino L., Tudryn A., Chalié F., Gasse F. (2014).

Late Pleistocene and Holocene palaeoenvironments in and around the Middle Caspian Basin as reconstructed from a deep- sea core, *Quaternary Science Review* 101, 91– 110.

Lezhinsky, G. T. (1974).

*Resursy vremennogo poverhnostnogo stoka pustin’ Srednei Asii I Zapadnogo Kazakhstana*, Ashgabat:Ylym.

Lillesand, T., Kiefer, R., Chipman, J. (2008).

*Remote Sensing and Image Interpretation*, Hoboken:Wiley.

Lioubimtseva, E., Simon B., Faure H., Faure-Denard L., Adams J. M. (1998).

Impacts of climatic change on carbon storage in the Sahara- Gobi Desert belt since the Late Glacial Maximum, *Global and Planetary Change* 16 (17), 95– 105.

Lioubimtseva, E., Henebry G. M. (2009).

Climate and environmental change in arid Central Asia: Impacts, vulnerability, and adaptations, *Journal of Arid Environments* 73, 963–977.

Lioubimtseva, E., Kariyeva J., Henebry G. M. (2014).

Climate Change in Turkmenistan, in Zonn I. S., Kostianoy A. G. (eds), *The Turkmen Lake Altyn Asyr and Water Resources in Turkmenistan*, The Handbook of Environmental Chemistry 28, Heidelberg: Springer, 39-57.

Lisitsina, G. N. (1965).

*Oroshayemoye Zemledleliye Epokhi Eneolita na Yuge Turkmenii*, Moskva: Nauka.

Lisitsina, G. N. (1969).

The Earliest Irrigation in Turkmenia, *Antiquity* 43, 279-288.

Lisitsina, G. N. (1976).

Arid soils: the source of archaeological information, *Journal of Archaeological Science* 3, 55-60.

Lisitsina, G. N. (1978).

*Stanovlenie i razvitie oroshaemogo zemledeliya v yudjnoy Turkmenii*, Moskva: Nauka.

Lister, D., Jones M. (2013).

Is naked barley an eastern or a western crop? The combined evidence of archaeobotany and genetics, *Vegetation History and Archaeobotany* 22 (5), 439–446.

Lombard, P. (2021).

The Oxus Civilization/BMAC and Its interaction with the Arabian Gulf: A review of the evidence, in Lyonnet B., Dubova N. A. (eds), *The World of the Oxus Civilization*, Routledge: New York, 607-634.

Luneau, E. (2010).

*L'Âge du Bronze Final en Asie Centrale Méridionale (1750-1500/1450 avant n.e.)*. Ph.D Thesis, UMR 7041 – ARSCA, Université Paris 1 - Panthéon-Sorbonne, Paris, France.

Luneau, E. (2014).

*La fin de la civilisation de l'Oxus. Transformations et recompositions des sociétés de l'âge du Bronze final en Asie centrale méridionale*, Paris:De Boccard.

Luneau, E. (2016).

The fall of the Oxus civilization and the role of exchanges with the neighboring societies during the first half of the second Millennium B.C., in Lefèvre V., Didier A., Mutin B. (eds), *South Asian Archaeology 2012, Man and environment in Prehistoric and Protohistoric South Asia: New Perspectives,* Turnhout: Brepols, 169–183.

Luneau, E. (2019).

Climate Change and the Rise and Fall of the Oxus Civilization in Southern Central Asia, in Yang L., Bork H.-R., Fang X., Mischke S. (eds), *Socio-Environmental Dynamics along the Historical Silk Road*, Heildeberg: Springer, 275-299.

Luneau, E. (2021a).

The end of Oxus Civilization, in Lyonnet B. and Dubova N.A. (eds), *The World of the Oxus Civilization*, New York: Routledge, 496-524.

Luneau, E. (2021b).

Effondrement ou évolution de la civilisation de l'Oxus ? Une révision de la transition de l'âge du Bronze à l'âge du Fer en Asie centrale méridionale, *Les nouvelles de l'archéologie* 163, 36-43.

Luneau, E., Shirazi, R. (2020).

Figurines féminines nues protohistoriques d'Asie Centrale et d'Iran oriental. Typologie, usages et symbolique, in Donnat, S., Hunziker-Rodewald, R., Weygand, I. (eds), *Figurines féminines nues Proche-Orient, Égypte, Nubie, Méditerranée Orientale, Asie Centrale (VIIIe millénaire av. J.-C. – IVe siècle ap J.-C.)*, Paris: Éditions de Boccard, 153–173.

Lyapin, A. A. (1990).

Paleogeografiya del'ty Murgaba (Bronzovy t zhelezny veka, *Problemy Osvoeniya Pustyn'*, 3, 57-65.

Lyapin, A. A. (1996).

Early Murgap Dams, *Problems of Desert Development* 1, 13-21.

Lyapin, A. A. (2014).

K istorii oroshenija v del'te Murgaba [On the history of irrigation in the Murghab region], in Sarianidi V.I. (ed), *Trudy Margianskoj Arkheologicheskoj Ekspeditsii*, vol. 5, Moskva: Staryj Sad, 60– 91.

Lyonnet, B., Dubova N. A. (2021a).

Questioning the Oxus Civilization or Bactria- Margiana Archaeological Culture (BMAC): an overview, in Lyonnet B., Dubova N. A. (eds), *The World of the Oxus Civilization*, New York: Routledge, 7-65.

Lyonnet, B., Dubova, N. A. (2021b).

*The World of the Oxus Civilization*, New York: Routledge.

Lyonnet, B. (2005).

Another possible interpretation of the Bactria- Margiana Culture (BMAC) of Central Asia: the Tin trade, in Jarrige C., Lekesvre V. (eds), *South Asian Archaeology 2001*, Paris: Éditions Recherche sur les Civilisations, 191– 200.

MacFarland, T.W., Yates, J.M. (2016).

Mann–Whitney U Test, in Mac Farland T.W., Yates J.M. (eds), *Introduction to Nonparametric Statistics for the Biological Sciences Using R*, Heidelberg: Springer, 103-132.

Madella, M., Jones M. K., Echlin P., Powers-Jones A., Moore M. (2009).

Plant water availability and analytical microscopy of phytoliths: implications for ancient irrigation in arid zones, *Quaternary International* 193 (1–2), 32-40.

Maddison, D. (2006).

*The Perception of and Adaptation toCclimate Change in Africa*, CEEPA Discussion Paper No. 10, Centre for Environmental Economics and Policy in Africa, Pretoria: University of Pretoria.

Magny, M., Vanniére B., Calo C., Millet L., Leroux A., Peyron O., Zanchetta G., La Mantia T., Tinner W. (2011).

Holocene hydrological changes in south-western Mediterranean as recorded by lake-level fluctuations at Lago Preola, a coastal lake in southern Sicily, Italy, *Quaternary Science Reviews* 30, 2459–2475.

Maheu, A., Caissie D., St-Hilaire A., El-Jabi N., (2013).

River evaporation and corresponding heat fluxes in forested catchments, *Hydrological Processes*, 28, 5725– 5738.

Makaske, B. (2001).

Anastomosing rivers: a review of their classification, origin and sedimentary products, *Earth-Science Reviews* 53, 149–196.

Malatesta, L.C., Castelltort S., Mantellini S., Picotti V., Hajdas I., Simpson G., Berdimuradov A. E., Tosi M., Willett S.D., (2012).

Dating the irrigation system of the samarkand oasis: a geoarchaeological study, *Radiocarbon*, 54:1, 91–105.

Maman, S., Tsoar H., Blumberg D. G., Mamedov B., Porat N. (2011a).

Central Asian ergs: a study by remote sensing and geographic information systems, *Aeolian Research* 3 (3), 353– 366.

Maman, S., Orlovsky L., Blumberg D. G., Berliner P., Mamedov B. (2011b).

A landcover change study of takyr surfaces in Turkmenistan, *Journal of Arid Environments* 75, 842-850.

Mantellini, S., Rondelli B., Stride S. (2008).

Analytical approach for representing the water landscape evolution in Samarkand Oasis (Uzbekistan), in Jerem E., Redo F., Szeverenyi V., *On the Road to Reconstructing the Past: Computer Applications and Quantitative Methods in Archaeology (CAA),* Budapest: CAA, 387-396.

Marcolongo, B., Mozzi, P. (1998).

Outline of recent geological history of the Kopet-Dagh mountains and the southern Kara-Kum, in Gubaev A., Koshelenko G., Tosi M. (eds) *The Archaeological Map of the Murghab Delta: Preliminary Reports 1990-1995*, Roma: IsIAO, 1-14.

Markofsky, S. (2010).

*Illuminating the Black Sands: Survey and Settlement in the Bronze Age Murghab Delta, Turkmenistan*. Ph.D thesis, University College London-UCL, London, Uk.

Markofsky, S., Bevan A. (2012).

Directional analysis of surface artefact distributions: a case study from the Murghab Delta, Turkmenistan, *Journal of Archaeological Science* 39, 428-439.

Markofsky, S. (2017).

Perspectives on an alluvial margin: settlement patterns in the northern Murghab Delta, Turkmenistan, *Iran* 53 (1), 65-92.

Markofsky, S., Ninfo, A., Balbo, A., Conesa, F. C., Madella, M. (2017).

An investigation of local scale human/landscape dynamics in the endorheic alluvial fan of the Murghab River, Turkmenistan, *Quaternary International*, 1-19.

Masimov, I. S. (1979).

Izuchenie pamatnikov epokhi bronzi nizovii Murgaba, *Sovetskaya Arkheologiya*, 111-131.

Masimov, I. S. (1981).

The study of Bronze Age sites in the lower Murghab, in Kohl Ph. L. (ed), *The Bronze Age Civilization of Central Asia. Recent Soviet Discoveries*, New York: M. E. Sharpe Inc, 194-220.

Masimov, I. S., Salvatori S., Udeumoradov B. (1998).

Preliminary analysis of the Bronze Age material collected by the Margiana Archaeological Project and a first chronological assessment, in Gubaev A., Koshelenko G., Tosi M. (eds), *The Archaeological Map of the Murghab Delta: Preliminary Reports 1990-1995*, Roma: IsIAO, 35-46.

Masimov, I.S., Salvatori S. (2008).

Unpublished stamp-seals from the north-western Murghab Delta, in Salvatori S., Tosi M., Cerasetti B. (eds), *The Bronze Age and Early Iron Age in the Margiana Lowlands: Facts and Methodological Proposals for a Redefinition of the Research Strategies*, Oxford: BAR, 99-110.

Masini, N., Gizzi F.T., Biscione M., Fundone V., Sedile M., Sileo M., Pecci A., Lacovara B., Lasaponara R. (2018).

Medieval archaeology under the canopy with LiDAR. The (Re)discovery of a medieval fortified settlement in Southern Italy, *Remote Sensing* 10, 1598, 1-26.

Masson, V. M. (1959).

Drevnezemledel'cheskaya Kul'tura Margiany, 73, *Materialy i Issledovaniya po Arkheologii SSSR*, Moskva: Akademia Nauk SSSR, 30-43.

Masson, V. M. (1967).

*Protogorodskaya kultura Altyn-depe*, Moskva: Archeologicheskie Ostrytiya 1966, goda.

Masson, V. M. (1988).

*Altyn Depe*, Hoboken: Wiley.

Masson, V. M. (2002).

Cultures of the steppe Bronze Age and urban civilizations in the south of Central Asia, in Jones-Bley K., Zdanovich D. G. (eds), *Complex societies of Central Eurasia from the 3rd to the 1st millennium BC: regional specifics in light of global models*, Washington: Institute or the Study of Man, 547–57.

Masson, V. M., Sarianidi V. I. (1972).

*Central Asia: Turkmenia before the Achaemenids*, London: Thames & Hudson.

Mayewski, P. A., Rohling, E. E., Stager, J. C., Karlén, W., Maasch, K. A., Meeker, L. D., Meyerson, E. A., Gasse, F., van Kreveld, S., Holmgren, K., Lee-Thorp, J. (2004).

Holocene climate variability, *Quaternary Research* 62, 3, 243–255.

McIntosh, R.J. (1983).

Floodplain geomorphology and human occupation of the upper inland Delta of the Niger, *Geographical Journal* 149, 182–201.

McIntosh, R.J., Tainter, J.A., McIntosh, S.K. (2000).

Climate, history, and human action, in McIntosh R.J., Tainter J.A., McIntosh S.K. (eds), *The Way the Wind Blows: Climate, History, and Human Action*, New York: Historical Ecology Series, 1–42.

Meyer-Melikyan, N. R., Avetov N. A. (1998).

Analysis of floral remains in the ceramic vessel from the Gonur Temenos, in Sarianidi V. I. (ed), *Margiana and Protozoroastrism*, Athens: Kapon Editions, 176-177.

Miall, A.D. (1977).

A review of the braided river depositional environment, *Earth-Science Reviews* 13, 1-62.

Miller, N. F. (1993).

Preliminary archaeobotanical results from the 1989 excavation at the Central Asian site of Gonur Depe, Turkmenistan, *Informational Bulletin of the International Association of the Study of Cultures of Central Asia* 19, 149-163.

Miller, N. F. (1999).

Agricultural development in western Central Asia in the Chalcolithic and Bronze Ages, *Vegetation History and Archaeobotany* 8, 13-19.

Miller, N. F. (2008).

Sweeter than wine? The use of the grape in early Western Asia, *Antiquity* 82, 937–946.

Miller, N.F., Smart T.L. (1984).

Intentional burning of dung as fuel: A mechanism for the incorporation of charred seeds into the archaeological record, *Journal of Ethnobiology* 4, 15–28

Miller, N. F., Marston J. M. (2012).

Archaeological fuel remains as indicators of ancient west Asian agropastoral and land-use systems, *Journal of Arid Environments* 8, 97-103.

Miller, N. F., Spengler R. N., Frachetti F. (2016).

Millet cultivation across Eurasia: origins, spread, and influence of seasonal climate, *The Holocene* 26, 10, 1566-1575.

Minashina, N. G. (1978).

*Melioratsiya zasolennykh pochv*, Moskva: Kolos.

Minnis, P.E. (1996).

Notes on economic uncertainty and human behavior in the prehistoric North American Southwest, in Tainter J.A., Tainter B.B. (eds), *Evolving Complexity and Environmental Risk in the Prehistoric Southwest*, Santa Fe: Institute Studies in the Sciences of Complexity Proceedings 24, 57–78.

Mischke, S., Rajabov I., Mustaeva N., Zhang C., Herzschuh U., Boomer I., Brown E.T., Andersen N.,Myrbo A., Ito E., Schudack M. E. (2010).

Modern hydrology and Late Holocene history of Lake Karakul, eastern Pamirs (Tajikistan): A reconnaissance study, *Paleogeography, Palaeoclimatology, Palaeoecology* 289, 10– 24.

Mitgartz B.B., Shevchenko N. G. (eds) (1972).

*Gidrogeologiya SSR, T. XXXXVIII. Turkmenskaya SSR*, Moskva:Nedra.

Mohammed-Aslam, M., Balasubramanian, A. (2010).

History of river channel modifications: a review, *Journal of Ecology and the Natural Environment* 2 (10), 207–212.

Moore, K., Miller N., Hiebert F. T., Meadow R. (1994).

Agriculture and herding in the early oasis settlements of the Oxus Civilization, *Antiquity* 68 (259), 418-427.

Morandi Bonacossi, D. (2017).

Water for Assyria: irrigation and water management in the Assyrian Empire, in Morandi Bonacossi D., Petit L. P. (eds), *Nineveh the Great City: Symbol of Beauty ad Power*, Leiden: Sidestone Press, 132-136.

Mori, L. (2020).

Water and power: what is left? An introduction to the workshop “Waterscapes: new perspectives on hydrocultural landscapes in the ancient Near East”, *Water History* 12, 11–22.

Morton, J. (2007).

The impact of climate change on smallholder and subsistence agriculture, *PNAS*, 104(50), 19680-19685.

Motuzaite Matuzeviciute, G., Ananyevskaya, E., Sakalauskaite, J., Soltobaev, O., Tabaldiev, K. (2022).

The integration of millet into the diet of Central Asian populations in the third millennium BC, *Antiquity* 96(387), 560-574.

Muradov, R. G. (2021).

The architecture of the Bactria-Margiana Archaeological Culture, in Lyonnet B., Dubova N. A. (eds), *The World of the Oxus Civilization*, New York: Routledge, 145-177.

Murphy-Bokern, F. L. S., Watson C. A. (ed) (2017).

*Legumes in Cropping Systems*, London: CABI Publishing.

Musa, Z. N., Popescu I. I., Mynett A. (2015).

Sensitivity Analysis of the 2D SOBEK Hydrodynamic Model of the Niger River, The Hague: IAHR World Congress, 1-8.

Mutin, B., Lamberg-Karlovsky, C.C. (2021).

The relationship between the Oxus Civilization and the Indo-Iranian Borderlands, in Lyonnet B., Dubova N. A. (eds), *The World of the Oxus Civilization*, New York:Routledge, 551-587.

Nanson, G. C. (2013).

Anabranching and anastomosing rivers, in Shroder J.F., Wohl E. (eds), *Treatise on Geomorphology: Volume 9: Fluvial Geomorphology,* London: Elsevier, 330-345.

Nanson, G.C., Gibling M.R. (1978).

Anabranching rivers, in Fairbridge R. W., Bourgeois S. (eds), *Sedimentology*, Encyclopedia of Earth Science, Heidelberg: Springer, 17-20.

Narasimhan, V. M., Patterson N., Moorjani P., Rohland N. *et al.* (2019).

The formation of human populations in South and Central Asia, *Science* 365, eaat7487, 1-15.

Nelson, J. M., Smith J. D. (1989).

Evolution and stability of erodible channel beds, in Ikeda S., Parkers G. (eds), *River Meandering*, Hoboken: Wiley, 321-77.

Newson, P., Baker G., Daly P., Mattingly D., Gilbertson D. (2007).

The Wadi Faynan field systems, in Barker G., Gilbertson D., Mattingly D. (eds), *Archaeology and Desertification: The Wadi Faynan Landscape Survey, Southern Jordan*, Oxford: Council for British Research in the Levant (CBRL),141-174.

Ninfo, A. (2007).

Missione Turkmenistan 2006, *Quaderni del Dottorato, Dipartimento di Geografia, Università di Padova* 1, 113-125.

Ninfo, A., Perego, A., (2006).

*Evoluzione geomorfologica del delta interno del Murghab: relazione missione Turkmenistan 2006 University of Pisa*, Unpublished Field Report Submitted to Italian Ministry of Foreign Affairs, Rome, Italy, 1-9.

Niyazklychev, K. (1973).

*Zemledlel'cheskii kalandar I skotovostvo u Turkmen*-*chovdurov v kontse 19-nachale 20 v*, Ashkhabad: Ylym.

O'Connell, T., Levine M., Hedges R. (2003).

The importance of fish in the diet of Central Eurasian peoples from the Mesolithic to the Early Iron Age, in Levine M., Renfrew C., Boyle K. (eds), *Prehistoric Steppe Adaption and the Horse*, Cambridge: Mc Donald Institute Monographs, 253–268.

O'Donovan, E. (1882).

*The Merv Oasis*, Vol II, London: Smith.

Olson, S. A., Williams-Sether T. (2010).

*Streamflow characteristics at stream gages in northern Afghanistan and selected locations*, U.S Geological Survey Data Series, 529.

Olson, K. G, Rouse L. M. (2018).

A Beginner's guide to mesoscale survey with quadrotor-UAV systems, *Advances in Archaeological Practice* 6 (4), 357-371.

Orengo, H. A., Petrie C. A. (2017).

Large-scale, multi-temporal remote sensing of palaeo-river networks: A sase study from northwest India and its implications for the Indus Civilisation, *Remote Senings* 9 (735), 1-20.

Orlovsky, N.S. (1994).

Climate of Turkmenistan, in Fet V., Atamuradov K. I., *Biogeography and Ecology of Turkmenistan,* Dordrech: Springer Science and Busines, 23-48.

Orlovsky, L., Dourikov M., Babev A. G. (2004).

Temporal dynamics and productivity of biogenic soil crusts in the central Karakum Desert, Turkmenistan, *Journal of Arid Environments* 56, 579-601.

Ovezberdyev, K. (1962).

Materialy po etnografii turkmen-sarykov Pendinskogo oazica', *Trudy Instituta istorii, arkheologii i etnogratfii AN Turkmenskoy SSR,* t. VI, 50-63.

Parcak, S. H. (2009).

*Satellite Remote Sensing for Archaeology*, New York: Routledge.

Pashkevich, G (2003).

Paleoethnobotanical evidence of agriculture in the steppe and forest steppe of East Europe in the Late Neolithic and Bronze Age, in Levine M., Renfrew C., Boyle K. (eds), *Prehistoric Steppe Adaptation and the Horse*, London: McDonald Institute for Archaeological Research, 287–297.

Pearsall, D. M. (2015).

*Paleoethnobotany: A Handbook of Procedures*, Walnut Creek: Left Coast Press Inc.

Peterson, L. (1982).

*A field Guide to Edible Wild Plants*, Boston: Houghton Miffiin.

Petrie, C. A. (2019).

Diversity, variability, adaptation and ‘fragility’ in the Indus Civilization, in Yoffee N. (ed), *The Evolution of Fragility: Setting the Terms*, Cambridge: McDonald Institute for Archaeological Research, 109–133.

Petrie, C. A., Singh R. N., Bates J., Dixit, Y., French C. A., Hodell D. A., Singh D. P. (2017).

Adaptation to variable environments, resilience to climate change: investigating land, water and settlement in Indus Northwest India, *Current Anthropology* 58, 1-30.

Petrie, C., Lynam F. (2020).

Revisiting settlement contemporaneity and exploring stability and instability: case studies from the Indus Civilization, *Journal of Field Archaeology* 45 (1), 1–15.

Philip, G., Beck A., Galiatsatos N. (2002).

CORONA satellite photography: an archaeological application from the Middle East, *Antiquity* 76, 109–118.

Piperno, D. (2006).

*Phytoliths: A Comprehensive Guide for Archaeologists and Paleoecologists*, Lanham: Altamira Press.

Pittman, H. (2019).

Bronze Age interaction on the iranian plateau: from Kerman to the Oxus through seals, in Meyer J. W., Vila E., Mashkour M., Casanova M., Vallet R. (eds), *The*

*Iranian Plateau During the Bronze Age. Development of Urbanisation, Production and Trade*, Lyon: Mom editions, 267– 288.

Plog, S., Plog F., Wait W. (1978).

Decision making in modern survey, *Advances in Archaeological Methods and Theory* 1, 385-421.

Postage, N. (1994).

How many sumerians per hectare? Probing the anatomy of an early city, *Cambridge Archaeological Journal* 4 (1), 47-65.

Potts, D. T. (2001).

*Excavations at Tepe Yahya, Iran 1967– 1975: The Third Millennium*, Vol. III, Cambridge: Peabody Museum of Archaeology and Ethnology.

Potts, D. T. (2008).

Puzur- Inšušinak and the Oxus Civilization (BMAC): reflections on Šimaški and the geo-political landscape of Iran and Central Asia in the Ur III Period, *Zeitschrift für Assyriologie und Vorderasiatische Archäologie* 98, 165– 194.

Pournelle, J. R., (2003).

*Marshland of Cities: Deltaic Landscapes and the Evolution of Early Mesopotamian Civilization*. Ph.D Thesis, Department of Anthropology, University of California, San Diego, USA.

Pournelle, J. R. (2007).

From KLM to Corona: using satellite photography toward a new understanding of 5th/4th millennium BC landscapes in southern Mesopotamia, in Stone E. (ed), *Settlement and Society: Ecology, Urbanism, Trade and Technology in Ancient Mesopotamia*, Los Angeles: Cotsen Institute, 26-62.

Powell, M. A. (1985).

Salt, seed, and yields in sumerian agriculture: a critique of the theory of progressive salinization, *Zeitschrift für Assyriologie und Vorderasiatische Archäologie* 75 (1), 7–38.

Powell, W., Frachetti M., Pulak C., Bankoff H.A., Barjamovic G., Johnson M., Mathur R., Pigott V.C., Price M., Aslihan Yener K.A. (2022).

Tin from Uluburun shipwreck shows small-scale commodity exchange fueled continental tin supply across Late Bronze Age Eurasia, *Science Advanced* 8, 3766, 1-10.

Prasolov, L. I. (1933).

Zemel’niy fond dl’a rastenievodstva v SSSR s tochki zreniya geographii pochv, *Rastenievodstvo SSSR*, vol. 1. Moskva-Leningrad: Sel’khozgiz, 70-84.

Preusser, F., Meru M., Rosentau A. (2014).

Comparing different Post-IR IRSL approaches for the dating of Holocene Coastal foredunes from Ruhnu Island, Estonia, *Geochronometria* 41 (4), 342–351.

Prinsen, G. F., Becker B. P. J. (2011).

Application of SOBEK hydraulic surface water models in the Netherlands hydrological modelling instrument, *Irrigation and Drainage* 60, 35–41.

Pumpelly, R. (ed) (1908).

*Explorations in Turkestan. Expedition 1904*, *Prehistoric Civilizations of Anau*, 2, Washington.

Puschnigg, G. (2020).

Merv and Margiana, in Mairs R. (ed), *The Graeco-Bactrian and Indo-Greek World*, New York: Routledge, 335-356.

P’yankova, L.T. (1989).

Pottery complexes of Bronze Age Margiana (Gonur and Togolok 21), *Information Bulletin of the International Association for the Study of the Cultures of Central Asia* 16, 27-54.

P’yankova, L.T. (1993).

Pottery of Margiana and Bactria in the Bronze Age, *Information Bulletin of the International Association for the Study of the Cultures of Central Asia* 19, 109–27.

P'yankova, L.T., (1994).

Central Asia in the Bronze Age: sedentary and nomadic cultures, *Antiquity* 68, 355–372.

Railsback, L. B., Liang F., Brook G. A., Riavo N., Voarintsoa G., Sletten H. R., Marais E., Hardt B., Cheng H., Edwards R. L. (2018).

The timing, two-pulsed nature, and variable climatic expression of the 4.2 ka event: a review and new high-resolution stalagmite data from Namibia, *Quaternary Science Review* 186, 78–90.

Rashidian, E. (2021).

Rivers in the making; the definition of "Nahr" as a hybrid watercourse based on geoarchaeological evidence from Southwestern Iran, *Water History* 13, 235–259.

Rayne, L. (2015).

Imperial irrigated landscape in the Balikh Valley, *Water History* 7, 419-440.

Rayne, L., Donoghue D. (2018).

A remote sensing approach for mapping the development of ancient water management in the Near East, *Remote Sensing* 10 (2042), 1-21.

Ricketts, R. D., Johnson T. C., Brown E. T., Rasmussen K. A., Romanovsky V. V. (2001).

The Holocene paleolimnology of Lake Issyk-Kul, Kyrgyzstan: Trace element and stable isotope composition of ostracodes, Palaeogeography, Palaeoclimatology, *Palaeoecology* 176 (1), 207–227.

Riehl, S. (2008).

Climate and agriculture in the ancient Near East: a synthesis of the archaeobotanical and stable carbon isotope evidence, *Vegetation History and Archaeobotany* 17 (1), 43–51.

Riehl, S., Bryson R., Pustovoytov K. (2008).

Changing growing conditions for crops during the Near Eastern Bronze Age (3000–1200 BC): the stable carbon isotope evidence, *Journal of Archaeological Science* 35, 1–12.

Risbøl, O., Gustavsen, L. (2018).

LiDAR from drones employed for mapping archaeology – Potential, benefits and challenges, *Archaeological Prospection*, 25(4), 329-338.

Rost, S. (2015).

*Watercourse Management and Political Centralization in Third-Millennium B.C. Southern Mesopotamia: A Case Study of the Umma Province of the Ur III Period (2112–2004 B.C.)*. Ph.D Thesis, Stony Brook University, New York, USA.

Rost, S. (2017).

Water management in Mesopotamia from the sixth till the first millennium B.C., *WIREs Water* 4: 1-23.

Rossi-Osmida, G. (ed) (2002).

*Margiana. Gonur-depe Necropolis. 10 years of excavations by Ligabue Study and Research Centre,* Vicenza: Il Punto.

Rossi-Osmida, G. (2007).

*Citadella delle Statuette Vol I*, Vicenza: Il Punto.

Rossi-Osmida, G. (2011).

Citadella delle Statuette Vol II, Vicenza: Il Punto.

Rouse, L. M. (2015).

*A Line in the Sand: Archaeological Evidence for the Interactions of Settled Farmers and Mobile Pastoralists in the Late Bronze Age (1950 - 1500 BC) Murghab alluvial fan, Turkmenistan*. Ph.D Thesis, Washington University in Saint. Louis, Saint. Louis, USA.

Rouse, L. M. (2020).

Silent partners: archaeology insights on mobility, interaction and civilization in Central Asia's past, *Central Asian Survey*, 1-22.

Rouse, L. M., Cerasetti B. (2014).

Ojakly: A Late Bronze Age mobile pastoralist site in the Murghab Region, Turkmenistan, *Journal of Field Archaeology* 39, 1, 32-50.

Rouse L. M., Cerasetti B. (2017).

Micro-dynamics and macro-patterns: exploring new archaeological data for the late Holocene human-water relationship in the Murghab alluvial fan, Turkmenistan, *Quaternary International* 437, 20-34.

Rouse, L. M., Cerasetti B. (2018).

Mixing metaphors: sedentary-mobile interactions and local-global connections in prehistoric Turkmenistan, *Antiquity* 92, 363, 674-689.

Rouse, L. M., Grillo K. M., Piermartiri R., Rotondaro E., Cogo-Moreira H., Bargossi G. M., Cerasetti B. (2019).

Not just "nomadic jars": the Late Bronze Age ceramic assemblage from the mobile pastoralist site of Ojakly, Murghab region, Turkmenistan, *Archaeological Research in Asia* 18, 100-119.

Rouse, L. M., Woldekiros H. S., Cerasetti B. (2022a).

Faunal remains from Ojakly, a Late Bronze Age mobile pastoralist campsite in the Murghab region, Turkmenistan, *Journal of Archaeological Science: Reports* 44, 1-12.

Rouse, L. M., Doumani Dupuy P. N., Brite E. B., (2022b).

The Agro-pastoralism debate in Central Eurasia: arguments in favor of a nuanced perspective on socio-economy in archaeological context, *Journal of Anthropological Archaeology* 67, 1-18.

Rudaya, N., Tarasov P., Dorofeyuk N., Solovieva N., Kalugin I., Andreev A., Daryin A., Diekmann B., Riedel F., Tserendash N., Wagner M. (2008).

Holocene environments and climate in the Mongolian Altai reconstructed from the Hoton-Nur pollen and diatom records: a step towards better understanding climate dynamics in Central Asia, *Quaternary Science Reviews* 28, 540–554.

Rühl, L., Herbig C., Stobbe A. (2015).

Archaeobotanical analysis of plant use at Kamennyi Ambar, a Bronze Age fortified settlement of the Sintashta culture in the southern Trans-Urals steppe, Russia, *Vegetation History and Archaeobotany* 24, 413–426.

Rust, B. R. (1978).

A classification of alluvial channel systems, in Miall, A.D. (ed), *Fluvial Sedimentology*, Calgary: Canadian Society of Petroleum Geologists Memoir, 187–198.

Rustamov, I. G. (1994).

Vegetation of the deserts of Turkmenistan, in Fet V., Atamuradov K. I. (eds), *Biogeography and Ecology of Turkmenistan*, Dordrecht: Springer Science and Business, 77–104.

Rychagov, G. I. (1997).

Holocene oscillations of the Caspian Sea, and forecasts based on palaeogeographical reconstructions, *Quaternary International* 41-42, 167–172.

Sabori, H., Talai H., Garazhian O., Bolandi R., Bayani N. (2018).

The reviews of post depositional processes: case study of Tepe Ferizi in the Sabzevar plain, North-Eastern Iran, *Journal of Historical Archaeology and Anthropological Science* 3 (3), 456–465.

Sala, R. (2014).

Methodological problems concerning the correlation between paleoclimatic and archaeological data, in Lamberg-Karlovsky C.C., Genito B., Cerasetti B. (eds), *My Life is like the Summer Rose. Maurizio Tosi e l'Archeologia como modo di vivere*, Oxford: BAR, 677–684.

Sallaberger, W., Ur J.A. (2004).

Tell Beydar: Nabada in its regional setting, in Milano L., Sallaberger W., Talon P., Van Lerberghe K. (eds). *Third Millennium Cuneiform Texts from Tell Beydar (Seasons 1996-2002)*, Turnhout: Brepols Publisher, 51-71.

Salvatori, S. (1998).

Margiana Archaeological Map: the Bronze Age settlements pattern, in Gubaev A., Koshelenko G., Tosi M. (eds) *The Archaeological Map of the Murghab Delta: Preliminary Reports 1990-1995*, Roma: IsIAO, 57-65.

Salvatori, S. (2000).

Bactria and Margiana seals: a new assessment of their chronological position and a typological survey, *East and West* 50, 97–145.

Salvatori, S. (2002).

The project for the archaeological map of the Murghab Delta (Turkmenistan): stratigraphic trial trenches at Adzhi Kui 1 and 9, *Ancient Civilizations from Scythia to Siberia: an international journal of comparative studies in history and archaeology* 1-2 (7), 107–178.

Salvatori, S. (2008a).

The Margiana settlement pattern from the Middle Bronze Age to the Parthian-Sasanian Period: a contribution to the study of complexity, in Salvatori S., Tosi M., Cerasetti B. (eds), *The Bronze Age and Early Iron Age in the Margiana Lowlands: Facts and Methodological Proposals for a Redefinition of the Research Strategies*, Oxford: BAR, 57–74.

Salvatori, S. (2008b).

Cultural variability in the Bronze Age Oxus Civilisation and its relations with the surrounding regions of Central Asia and Iran, in Salvatori S., Tosi M., Cerasetti B. (eds), *The Bronze Age and Early Iron Age in the Margiana Lowlands: Facts and Methodological Proposals for a Redefinition of the Research Strategies*, Oxford: BAR, 75–98.

Salvatori, S. (2010).

Thinking around Grave 3245 in the 'Royal Graveyard' of Gonur (Murghab Delta, Turkmenistan), in Kozhin P. M., Kosarev M. F., Dubova N. A. (eds), *Na puti otkrytija tsivilizatsii* [On the track of uncovering a civilization]. Trudy Margianskoj Arkheologicheskoj Ekspeditsii, vol. 3, St. Petersburg: Aletejja, 244–257.

Salvatori, S. (2016).

Bactria-Margiana Archaeological Complex: How Terminology Hides Historical Processes, in Dubova N. A. (ed), *Trudy Margianskoj Arkheologicheskoj Ekspeditsii, vol. 6*, Moskva: Staryj Sad, 449–460.

Salvatori, S., Tosi, M., Cerasetti B. (2008).

*The Bronze Age and Early Iron Age in the Margiana Lowlands: Facts and Methodological Proposals for a Redefinition of the Research Strategies*, Oxford: BAR.

Salvatori, S., Tosi M. (2008).

Introduction, in Salvatori S., Tosi M., Cerasetti B.(eds), *The Bronze Age and Early Iron Age in the Margiana Lowlands: Facts and Methodological Proposals for a Redefinition of the Research Strategies*, Oxford: BAR, 57–74.

Salvini, R., Guastaldi E., Coscini N., Del Seppia N. (2006).

Ricostruzione del Peleoalveo del Fiume Serchio (Lucca, Italia) tramite rilivei LIDAR, Foto aeree ed immagini Quick Bird, *Italian Journal of Quaternary Sciences* 19 (2), 299–310.

Sarianidi, V. I. (1975).

Stepnye plemena epokhi bronzy v Margiane, *Sovietskaya Arkheologia* 2, 20–29.

Sarianidi, V. I. (1981).

Margiana in the Bronze Age, in Kohl, Ph. L. (ed), *The Bronze Age Civilization of Central Asia. Recent Soviet Discoveries*, New York: M. E. Sharpe Inc, 165–193.

Sarianidi, V. I. (1982).

Ob odnoj gruppe drevnebaktrijskoj gliptiki, Drevnjaja Indija i nauka, Moskva: Nauka, 297–306.

Sarianidi, V. I. (1986).

Le complexe cultuel de Togolok 21 en Margiane, *Arts Asiatiques* 41, 5–21.

Sarianidi, V. I. (1990a).

*Drevnosty Strany Margush*, Ashgabad: Sily.

Sarianidi, V. I. (1990b).

Togolok 21, an Indo-Iranian Temple in the Karakum, *Bulletin of the Asia Institute* 4, 159–165.

Sarianidi, V. I. (1991).

Temples of Ancient Margiana, *Pakistan Archaeology* 26, 175–187.

Sarianidi, V. I (1994).

Temples of Bronze Age Margiana: traditions of ritual architecture, *Antiquity* 68, 388–397.

Sarianidi, V. I. (1998a).

*Myths of Ancient Bactria and Margiana on its Seals and Amulets*, Moscow: Pentagraphic Limited.

Sarianidi, V. I. (1998b).

*Margiana and Protozoroastrianism*, Athens: Kapon Editions.

Sarianidi, V. I. (2002).

The fortification and palace of northern Gonur, *Iran* 40, 75-87.

Sarianidi, V. I. (2005).

*Gonur Depe: City of Kings and Gods*, Ashgabat: Miras.

Sarianidi, V. I. (2006).

“Tsarskij nekropol” na Severnom Gonure, *Vestnik Drevnej Istorii* 2 (257), 155–192.

Sarianidi, V. I. (2007).

*Necropolis of Gonur*, Athens: Kapon Edition.

Sarianidi, V. I. (2008a).

The palace –temple complex of North Gonur, *Anthropology & Archeology of Eurasia* 47(1), 8–35.

Sarianidi, V. I. (2008b).

*Margush: Mystery and True of the Great Culture*, Ashgabat: Türkmend övlethabarlary.

Sarianidi, V. I. (2009).

*Margus. Mistery and True of the Great Culture, Asgabat*: Turkmen dowlet nesiryat gullugy.

Sarianidi, V. I. (2010a).

*On the Track of Uncovering a Civilization*, St. Petersburg: Aletheia.

Sarianidi, V.I. (2010b).

*Long Before Zaratushtra: Archaeological Evidences of Protozoroastrianizm in Bactria and Margiana*, Moscow: Staryi Sad.

Sarianidi, V.I., Dubova N.A. (2012).

Goňurdepe suw üpjüçiligi we onuň dolandyrylyşy, *Türkmenistanda Ylym we Tehnika* 2, 115-121.

Sarianidi, V. I., Boroffka N., Dubova N. A. (2012).

Cultural contacts of Margiana, Turkmenistan, in the 3rd Millennium BC: new evidence from Gonur Depe, burial 4150, *Gandhāran Studies* 6 (1), 1–17.

Sarianidi, V. I, Boroffka N., Dubova N. A. (2014).

Kul'turnye kontakty Margiany (Turkmenistan) v III tys. do n.e. Novye dannye po Gonur- Depe (pogrebenie no. 4150) [Margiana (Turkmenistan) cultural contacts in the 3rd millennium BC: new data from Gonur Depe (tomb no. 4150)], in Sarianidi V.I., *Trudy Margianskoj Arkheologicheskoj Ekspeditsii*, vol. 4, Moskva: Staryj Sad, 127–137.

Sataev, R. M. (2008).

Raskopki drevnego irrigatsionnogo kanala [Excavations of an ancient irrigation canal], in Sarianidi, V. I., Kozhin, P. M., Kosarev, N. A., Dubova, N. A. (eds), *Trudy Margianskoj Arkheologicheskoj Ekspeditsii* Vol. 2, Moskva: Staryj Sad, 65–66.

Sataev, R. M. (2018).

Predvaritel'nye itogi izuchenija stratigrafii dvortsa Severnogo Gonura, in Dubova N. A. (ed), *Trudy Margianskoj Arkheologicheskoj Ekspeditsii* vol. 7, Moskva: Staryj Sad, 80–86.

Sataev, R. M. (2021a).

Animal Exploitation at Gonur Depe, in Lyonnet B., Dubova N.A. (eds), *The World of the Oxus Civilization*, New York: Routledge, 438-456.

Sataev, R. M. (2021b).

Animal burials at Gonur Depe, in Lyonnet B., Dubova N.A. (eds), *The World of the Oxus Civilization,* New York: Routledge, 386-404.

Sataev, R.M., Sataeva, L. (2014).

Results of archaeozoological and archaeobotanical researches at the Bronze Age site Gonur Depe (Turkmenistan), in Bieliński P., Gawlikowski M., Koliński R., Ławecka D., Sołtysiak, A., Wygnańska, Z. (eds), *Proceedings of the 8th International Congress on the Archaeology of the Ancient Near East: 30 April - 4 May 2012*, Warsaw: University of Warsaw, 367-370.

Sataev, R. M., Sataeva L. (2012).

Arkheobotanicheskiye issledovaniya na Gonur Depe, in Sarianidi V. I., Kozhin P. M., Kosarev M. F., Dubova N. A. (eds), *Transactions of Margiana Archaeological Expedition, Gonur Depe studies 2008-2011*, Vol 4, Moscow: Russian Accademy of Science, 159-162.

Sataeva, L., Sataev R. M. (2014).

Wood using at the Bronze Age site Gonur-Depe. (Ancient Margiana, South Turkmenistan), in Stucky R. A., Kaelin O., Mathys H.P. (eds), *Proceedings of the 9th International Congress on the Archaeology of the Ancient Near East: June 9-13,* 3, Basel: University of Basel, 643–645.

Schacht, R. M. (1984).

The contemporaneity problem, *American Antiquity* 49 (4), 678–695.

Schawartz, G., Falconer S. (1994).

*Rural Approaches to Social Complexity. Archaeological Views from the Countryside*, Washington: Smithsonian Institution Press, 1-9.

Schmidt, E. F. (1937).

*Excavations at Tepe- Hissar Damghan,* Philadelphia: University of Pennsylvania Press.

Schmitt, R. (1990).

Bisotun III. Darius's inscription, *Encyclopedia Iranica* Vol. IV (3), 299-305.

Schumm, S.A. (1963).

Sinuosity of alluvial rivers on the Great Plains, *Bulletin of the Geological Society of Americas* 74, 1089-100.

Schumm, S.A. (1968).

Speculations concerning paleohydraulic controls on terrestrial sedimentation, *Geological Society of America Bulletin* 79, 1573–1588.

Schumm, S.A., (1985).

Patterns of alluvial rivers, *Annual Review of Earth and Planetary Sciences* 13, 5–27.

Schwerin von, S., Richards-Rissetto H., Remondino F., Spera M. G., Auer M., Billen N., Loos L., Stelson L., Reindel M. (2016).

Airborne LiDAR acquisition, post-processing and accuracy-checking for a 3D WebGIS of Copan, Honduras, *Journal of Archaeological Science* 5, 85-104.

Seely, M., Henderson J., Heyns P., Jacobson P., Nakale T., Nantanga K., Schachtschneider K. (2003).

Ephemeral and endoreic river systems: relevance and management challenges, in Truton A., Ashton P., Cloete E. (eds), *Transboundary rivers, sovereignty and development Hydropolitical drivers in the Okavango River basin*, Pretoria:University of Pretoria, 187–212.

Seminara, G., Tubino M. (1989).

Altrernate bars and meandering: free, forced and mixed interactaions, in Ikeda S., Parkers G. (eds), *River Meandering*, Hoboken: Wiley, 267-320.

Seo, S. N., Mendelsohn R. (ed) (2006).

*Climate Change Impacts on Animal Husbandry in Africa: A Ricardian analysi*s, CEEPA Discussion Paper No. 9. Centre for Environmental Economics and Policy in Africa, Pretoria: University of Pretoria.

Shaikh Baikloo Islam, B., Chaychi Amirkhiz A., Al-Din Niknami K. (2020).

Late Holocene climatic events, the main factor of the cultural decline in North Central Iran during the Bronze Age, *Documenta Praehistorica* 470, 446-460.

Sharifi, A., Pourmand A., Canuel E. A., Ferer-Tyler E., Peterson L. C., Aichner B., Feakins S. J., Daryaee T., Djamali M., Naderi Beni A., Lahijani H. A. K., Swart P. K. (2015).

Abrupt climate variability since the last deglaciation based on a high-resolution, multi-proxy peat record from NW Iran: the hand that rocked the Cradle of Civilization?, *Quaternary Science Reviews* 123, 215-230.

Smith, D.G., Smith N.D. (1980).

Sedimentation in anastomosed river systems: examples from alluvial valleys near Banff, Alberta, *Journal of Sedimentary Petrology* 50, 157–164.

Sohn, H. G., Kim G. H., Yom J. H. (2004).

Mathematical modelling of historical reconnaissance CORONA KH-4B imagery, *The Photogrammetric Record* 19, 105, 51-66.

Spengler, R. N. (2015).

Agriculture in the Central Asian Bronze Age, *Journal of World Prehistory* 28, 215–253.

Spengler, R. N. (2019a).

*Fruits from the Sand: The Silk Road Origins of the Foods We Eat*, Oakland: University of California Press.

Spengler, R. N. (2019b).

Dung burning in the archaeobotanical record of West Asia: where are we now?, *Vegetation History and Archaeobotany* 28, 215–227.

Spengler, R. N., Willcox G. (2013).

Archaeobotanical results from Sarazm, Tajikistan, an Early Bronze Age village on the edge: agriculture and exchange, *Journal of Environmental Archaeology* 18 (3), 211–221.

Spengler, R. N., Frachetti M.D., Fritz G.J. (2013).

Ecotopes and herd foraging practices in the Bronze and Iron Age, steppe and mountain ecotone of Central Asia, *Journal of Ethnobiology* 33, 125–147.

Spengler, R. N., Cerasetti B., Tengberg M., Cattani M., Rouse L. M. (2014).

Agriculturalists and pastoralists: Bronze Age economy of the Murghab alluvial fan, southern Central Asia, *Journal of Vegetation History and Archaeobotany* 23 (6), 805- 820.

Spengler, R. N., Ryabogina N., Tarasov P. E., Wagner M. (2016).

The spread of agriculture into northern Central Asia: Timing, pathways, and environmental feedback, *The Holocene* 26 (10) 1527– 1540.

Spengler, R. N., de Nigris I., Cerasetti B., Carra M. L., Rouse L. M. (2018).

The breadth of dietary economy in Bronze Age Central Asia: Case study from Adji Kui 1 in the Murghab region of Turkmenistan, *Journal of Archaeological Science Reports* 22, 372–381.

Spengler, R. N., Ventresca Miller A., Schmaus T., Motuzaitė Matuzevičiūtė G., Miller B. K., Wilkin S., Treal Taylor W. T., Li Y., Roberts P., Boivin N. (2021).

An imagined past? Nomadic narratives in Central Asian archaeology, *Current Anthropology* 62 (3), 251-286.

Staubwasser, M., Sirocko F., Grootes P.M., Segl M., (2003).

Climate change at the 4.2 ka BP termination of the Indus valley civilization and Holocene south Asian monsoon variability, *Geophysical Research Letters* 30, 1425–1425.

Stein, A. (1921).

Air photography of ancient sites, *The Geographical Journal* 54 (3), 200.

Stein, A. (1938).

An Archaeological journey in Western Iran, *The Geographical Journal* 92 (4), 313-342.

Stein, A. (1940).

Surveys on the roman frontier in 'Iraq and Trans-Jordan, *The Geographical Journal* 95 (6), 428-438.

Steinkeller, P. (2001).

New light on the hydrology and topography of Southern Babylonia in the Third Millennium, *Zeitschrift für Assyriologie* 91, 22–84.

Steinkeller, P. (2006).

New Light on Marhaši and Its Contacts with Makkan and Babylonia, *Journal of Magan Studies* 1, 1– 17.

Steinkeller, P. (2007).

City and countryside in third-millennium southern Babylonia, in Stone E. C. (ed), *Settlement and Society: Essays Dedicated to Robert McCormick Adams*, Chicago: Oriental Institute of the University of Chicago, 185–211.

Steinkeller, P. (2016).

The role of Iran in the inter-regional exchange of metals: tin, copper, silver and gold in the second half of the Millennium BC, in Maekawa K. (ed), *Ancient Iran: New Perspectives from Archaeology and Cuneiform Studies, Proceedings of the International Colloquium held at the Center for Eurasian Cultural Studies, Kyoto University, December 6-7, 2014,* Kyoto: Kazuya Maekawa, 127– 150.

Stewart, C. E. (1881).

The Country of the Tekke Turkomans, and the Tejend and Murghab Rivers, Proceedings of the Royal Geographical Society and Monthly Record of Geography, Sep., 1881, 3 (9), 513-546.

Stokes, H., Mülder G., Jenkins E. (2011).

An investigation into the archaeological application of carbon Stable isotope analysis used to establish crop water availability: solutions and ways forward, in Mithen S., Black E. (eds), *Water, Life and Civilization: Climate, Environment, and Society in the Jordan Valley*, Cambridge: Cambridge University Press, 373–80.

Sumner, W. M. (1990).

An Archaeological sstimation of population trends Since 6000 BC in the Kur River Basin, Fars Province, Iran, in Taddei M., Callieri P. F. (eds), *South Asian Archaeology 1987*, Vol. I. Roma: IsMEO, 3–16.

Suslov, S. P. (1961).

*Physical Geograpy of Asiatic Russia*, San Francisco: W.H. Freeman and Company.

Tamburrino, A. (2010).

Water technology in ancient Mesopotamia, in Mays L. W. (ed), *Ancient Water Technologies*, Heidelberg: Springer, 29-52.

Taylor, C. (1973).

*The Cambridgeshire Landscape: Cambridgeshire and the Southern Fens*, London: Hodder & Stoughton.

Taylor, J., (2000).

Cultural depositional processes and post-depositional problems, in Franchovich R., Patterson H. (eds), *Extracting Meaning from Ploughsoil Assemblages*, Oxford: Oxbow Books, 16-28.

Tianduowa, Z., Woodson K.C., Ertsen M.W. (2018).

Reconstructing ancient hohokam irrigation systems in the middle gila river valley, Arizona, United States of America, *Human Ecology* 46, 735–746.

Tieszen, L. (1991).

Natural variations in the carbon isotope values of plants: implications for archaeology, ecology, and paleoecology, *Journal of Archaeological Science* 18: 227–48.

Tinney, S. (1999).

Ur-Namma the canal-digger: context, continuity and change in Sumerian literature, *Journal of Cuneiform Studies* 51, 31–54.

Tirsch, D. (2014).

Barchanoid ridge, in Hargitai H., Kereszturi Á. (ed), *Encyclopedia of Planetary Landforms*, Heidelberg: Springer, 2-14.

Tolstov, S. P. (1948).

Drevniy Khorezm, *Opyt istoriko-arkheologicheskogo issledovaniya*, Moskva: Sad, 73-82.

Tolstov, S. P. (1952).

Khorezminskaya arkheologo-etnograficheskaya ekspeditsiya AN SSSR (1945-1948 gg.), *Trudy Khorezmskoy arkheologo-etnograficheskoy ekspeditsii. To, 1 Arkheologicheskeie Etnograficheskeie Roboty Khorezmskoy Ekspeditsii* 1945-1948, Moskva: I T.A. Jdanko

Tolstov, S. P. (1960).

Result of the work of the koresmian archaeological and ethonographic expedition of the USSR Accademy of Science 1951-1956, *Journal of the Asia Society of Bombay* 33, 1-24.

Tolstov, S.P., Kes A.S. (1960).

Nizov'ja Amudari, Sarykamysh, Uzboj: istorija formirovanija i zaselenija. Materialy Khorezmskoj Ekspeditsii [Lower Amu Darya, Sarykamysh, Uzboi: history of their formation and of settlement], vol. III. Moscow: Nauka.

Toonen, W. H. J., Macklin M. G., Dawkes G., Durcan J. A., Leman M., Nikolayev Y., Yegorov A. (2020).

A hydromorphic revaluation of the forgotten river civilizations of Central Asia, *PNAS* 117 (52), 32982-32988.

Tosi, M., Cerasetti, B. (2010).

Once Upon a Time...a brief reflection on the History of “The Archaeological Map of the Murghab Delta (AMMD)” Project in relation to the fundamental role of V.I. Sarianidi, in Kozhin P. M., Kosarev M. F., Dubova N. A. (eds), *On the Track of Uncovering a Civilization. A volume in honour of the 80th-anniversary of Victor Sarianidi, Transactions of the Margiana Archaeological Expedition*, Sant Petersburg: Aletheia, 86-103.

Tsvetsinskaya, E. A., Vainbergw B.I., Glushkoz E.V. (2002).

An integrated assessment of landscape evolution, long-term climate variability, and land use in the Amudarya Prisarykamysh delta, *Journal of Arid Environments* 51, 363–381.

Udeumuradov, B. N. (1993).

Altyn-Depe i Margiana, *Svyazi*, *khronologiya*, *proiskhozhdenie*, Ashgabat: Ylym, 22-38.

Udeumuradov, B.N. (2002).

Ceramic Material from Gonur Depe Necropolis, in G. Rossi Osmida (ed), *Margiana: Gonur Depe Necropolis: 10 Years of Excavations by Ligabue Study and Research Centre*, Venice: Il Punto, 133–143.

Ur, J. A. (2002).

Settlement and landscape in northern Mesopotamia: the Tell Hamoukar Survey 2000-2001, *Akkadica* 123, 57-88.

Ur, J. A. (2003).

Corona satellite photography and ancient road networks: a northern Mesopotamian case study, *Antiquity* 77, 102–115.

Ur, J. A. (2005).

Sennacherib's northern Assyrian canals: new insights from satellite imagery and aerial photography, *Iraq* 67 (1), 317-345.

Ur, J. A. (2013).

CORONA Satellite imagery and ancient Near Eastern landscapes, in Comer D.C., Harrower M. J. (eds), *Mapping Archaeological Landscapes from Space*, Heidelberg: Springer, 21-31.

Ur, J. A., Wilkinson T.J. (2008).

Settlement and economic landscapes of Tell Beydar and its hinterland, in Lebeau M., Suleiman A. (eds), *Beydar Studies* I, Turnhout: Brepols, 305-327.

Ur, J. A., Reade, J. (2015).

The hydraulic landscape of Nimrud, *Mesopotamia* 50, 25-51.

Varushchenko, S. I., Varushchenko A. N., Klige R. K. (1987).

*Izmenenija rezhima Kaspijskogo morja i besstochnikh vodoemov v paleovremeni*, Moskva: Nauka.

Vepraskas, M. J., Lindbo D. L., Stolt M. H. (2018).

Redoximorphic features, in Stoops G., Marcelino V., Mees F. (eds), *Interpretation of Micromorphological Features of Soils and Regoliths*, Amsterdam: Elsevier, 425-445.

Vervoort, R.W.A., Annen Y.L. (2006).

Paleochannels in northern New South Wales: inversion of electromagnetic induction data to infer hydrologically relevant stratigraphy, *Australian Journal of Soil Research* 44, 35–45.

Vickery, R. (1995).

*A Dictionary of Plant Lore*, Oxford: Oxford University Press.

Vidale, M. (2017).

*Treasures from the Oxus*, London: I.B. Tauris & Co.

Vidale, M. (2018).

Irrigation and canals in ancient Iran, resurrecting Wittfogel?, in Calieri P., Rossi A. (eds), *Civiltà dell'Iran, Atti del Convegno Internazionale Roma 22-23 febbraio 2013*, Roma: Scienze e Lettere, 27-53.

Vinogradov, B. V. (1962).

Geograficheskie zakonomernosti dalneyshey ekstrapolyatsii priznakov deshifrirovaniya landshaftovanalogov, *Primenenie aerometodov dlya izucheniya gruntovykh vod.*, Moskva: Sad.

Vinogradov, A. V., Mamedov E. D. (1975).

Pervobytnyj Ljavljakan, etapy drevnejshego zaselenija i osvoenija vnutrennikh Kyzylkumov, in Itina M.A (ed) *Materialy Khorezmskoj Ekspeditsii*, Vol. 10. Moskva: Nauka, 20-33.

Vinogradova, N. M. (2021).

The formation of the Oxus Civilization/BMAC in Southern Tajikistan, in Lyonnet B., Dubova N. A. (eds), *The World of the Oxus Civilization*, New York: Routledge, 535-664.

Vinogradova, N. M., Kuz'mina E. E. (1996).

Contacts between the steppe and agricultural tribes of Central Asia in the Bronze Age, *Anthropology & Archeology of Eurasia* 34, 29–54.

Vitkovskaya, T. P. (1990).

Takyrs as geomorphological elements of local runoff and their role in water balance of deserts, *Problems of Desert Development*, 6, 54–59.

Wallace, M., Charles M. (2013).

What goes in doesn’t always come out: the impact of the ruminant digestive system of sheep on plant material, and its importance for the interpretation of dung-derived archaeobotanical assemblages, *Environmental Archaeology* 18,18–30.

Wallace, M., Jones G., Charles M., Fraser R., Halstead P., Heaton T. H., Bogaard A. (2013).

Stable carbon isotope analysis as a direct means of inferring crop water status and water management practices, *World Archaeology* 45 (3), 388-409.

Walling, D. E., Quine T.A., He Q. (1992).

Investigating contemporary rates of floodplain sedimentation, in Carling P.A., Petts G.E. (eds), *Lowland floodplain Rivers*, Chichester: Wiley, 165-184.

Wang, X., Guo Z., Wu L., Zhu C., He H. (2012).

Extraction of palaeochannel information from remote sensing imagery in the east of Chaohu Lake, China, *Frontiers of Earth Science* 6, 75–82.

Weiss, H. (2016).

Global megadrought, societal collapse and resilience at 4.2– 3.9 ka BP across the Mediterranean and West Asia, *Climate Change and Cultural Evolution* 24, 62–63.

Wendrich, W., Barnard H. (2008).

The archaeology of mobility: definition and research approache, in Barnard H., Wendrich W. (eds), *The Archaeology of Mobility: Old World and New World Nomadism*, Los Angeles: Cotsen Institute of Archaeology at UCLA, 1-21.

Widdel, M., Hritz C., Ur J., Wilkinson T. J. (2013).

Land use of the model communities, in Wilkison T. J., Gibson M., Widell M. (eds). *Models of Mesopotamian Landscapes. How Small-Scale Processes Contributed to the Growth and Early Civilizations*, Oxford: Archeopress, 56-80.

Widera, M., Kowalaska E., Fortuna M. (2017).

A Miocene anastomosing river system in the area of Konin Lignite Mine, central Poland, *Annales Societatis Geologorum Poloniae* 87, 157–168.

Widera, M., Chomiak L., Zielińsky T. (2019).

Sedimentary processes and paleochannel pattern of an anastomosing river system: an example from the upper Neogene of Central Poland, *Journal of Sedimentary Research* 89, 487–507.

Wilkinson, T. J. (1982).

The Definition of ancient manured zones by means of extensive sherd sampling techniques, *Journal of Field Archaeology* 9, 323-33.

Wilkinson, T. J. (1989).

Extensive sherd scatters and land-use intensity: some recent results, *Journal of Field Archaeology* 16, 31-46.

Wilkinson, T. J. (2003).

*Archaeological Landscapes of the Near East*, Tucson: University of Arizona Press.

Wilkinson, T. J. (2014).

A perspective on the "continuous landscape" of the Murghab Region, in Lamberg-Karlowsky C. C., Genito B., Cerasetti B. (eds), *'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, 105-114.

Wilkinson, T. J., Tucker, D. J. (1995).

*Settlement Development in the North Jazira, Iraq. A study of the Archaeological Landscape*, Warminster: Aris Phillips.

Wilkinson, T. J., Ur J. A., Casana J. (2004).

From nucleation to dispersal: trends in settlement pattern in the northern fertile crescent, in Cherry J., Alcock S. (eds), *Side-by-Side Survey: Comparative Regional Studies in the Mediterranean World*, Oxford: Oxbow Books, 198-205.

Wilkinson, T. l, Gibson M., Christians J. H., Widen M., Schloen D., Kouchoukos N., Woods C., Sanders l., Simunich K.L., Altaweel M., Ur J. A., Hritz C., Lauinger J., Paulette T., Tenney J. (2007).

Modelling settlement systems in a dynamic environment: case studies from Mesopotamia, in Kohler T. A., van der Leeuw S. E. (eds), *The Model-Based Archaeology of Socionatural Systems*, Santa Fe: School for Advanced Research Press, 175-208.

Wilkinson, T. J., Rayne L. (2010).

Hydraulic landscapes and imperial power in the Near East, *Water History* 2 (2), 115–144.

Wilkinson, T.J., French C., Ur, J., Semple M. (2010).

The geoarchaeology of route systems in northern Syria, *Geoarchaeology* 25, 745–771.

Wilkinson, T. J., Boucharlat R., Ertsen M.W., Gillmore G., Kennet D., Magee P., Rezakhani K., De Schacht T. (2012).

From human niche construction to imperial power: long-term trends in ancient Iranian water systems, *Water History* 4, 155–176.

Wilkinson, T. J., Christiansen J., Altaweel M., Widell M. (2013a).

Output from the agent-based modelling program, in Wilkinson T. J., Gibson M., Widell M. (eds), *Model of Mesopotamian Landscapes: How Small-Scale Processes Contributed to the Growth of Early Civilizations*, Oxford: Archeopress, 177-203.

Wilkison, T. J., Gibson M., Widell M. (2013b).

*Models of Mesopotamian Landscapes. How Small-Scale Processes Contributed to the Growth and Early Civilizations*, Oxford: Archeopress.

Wilkinson, T. J., Rayne L., Jotheri J. (2015).

Hydraulic landscapes in Mesopotamia: the role of human niche construction, *Water History* 7, 397–418.

Willcox, G. (1989.)

Étude archéobotanique, in Francfort H-P (ed) *Fouilles de Shortughaï, recherches sur l'Asie Centrale protohistorique (Mémoires de la Mission Archéologique Française en Asie Centrale 2*) vol. 1, Paris: Editions de Boccard, 175–185.

Williams, T. J. (2012).

Unmanned aerial vehicle photography: exploring the medieval city of Merv, on the Silk Roads of Central Asia, *Archaeology International* 15, 54-68.

Williams, T. J. (2018).

Flowing into the city: approaches to water management in the early Islamic city of Sultan Kala, Turkmenistan, in Zhuang Y., Altaweel M. (eds), *Water Societies and Technologies from the Past and Present*, London: UCL Press, 157-179.

Winkelmann, S. (2014).

Trading religions from Bronze Age Iran to Bactria, in Wick P., Rabens V. (eds), *Religion and Trade. Religious Formation, Transformation and Cross-Cultural Exchange between East and West*, Leiden: Brill, 199-232.

Winterhalder, B. (1980).

Environmental analysis in human evolution and adaptation research, *Human Ecology* 8 (2), 135–70.

Witzel, M. (2015).

Water in Mythology, *Dædalus, the Journal of the American Academy of Arts & Sciences*, 18-26.

Wossink, A. (2009).

*Challenging Climate Change: Competition and Cooperation among Pastoralists and Agriculturalists in Northern Mesopotamia (c. 3000-1600 BC),* Leiden: Sidestone Press.

Wright, J. (2008).

Non-graphic information systems and diachronic transnformations in Margiana, in Salvatori S., Tosi M., Cerasetti B. (eds) *The Bronze Age and Early Iron Age in the Margiana Lowlands: Facts and methodological proposals for a redefinition of the research strategies*, Oxford: BAR, 47-56.

Xu, Q., Shi W., Xie X., Zhang C., Manger W. L., Wang J., Rao S. (2019).

Multichannel systems in an ancient river-dominated delta: case study of the lower Yanchang Formation, southwest Ordos Basin, China, *Canadian Journal of Earth Sciences* 56 (10), 1027-1040.

Yacoub, S. (2011).

Geomorphology of the Mesopotamia floodplain, *Iraqi Bulletin of Geology and Mining* 4, 7-32.

Yoffee, N. (1997).

Robert McCormick Adams: An archaeological biography, *American Antiquity* 62 (3), 399-413.

Yonechi, F., Maung W. (1986).

Subdivision on the anastomosing river channel with a proposal of the irrawaddy type, *The Science Reports of the Tohoku University* 36 (2), 102–113.

Zaina, F. (2019).

A risk assessment for cultural heritage in southern Iraq: framing drivers, threats and actions affecting archaeological sites, *Conservation and Management of Archaeological Sites* 21, 184-206.

Zonn, I. S. (2014).

Karakum canal: artificial river in a Desert, in. Zonn I. S., Kostianoy A. G. (eds), *The Turkmen Lake Altyn Asyr and Water Resources in Turkmenistan*, Heidelberg: Springer, 96-106.

# Appendices

## - *Appendix 1*

Table 1.1. Paleochannel traces in the Ojakly area were identified through remote sensing analysis. When these traces are likely part of the same channel, they have been grouped under a single paleochannel number (Paleochannel #).

| **Paleochannel Traces #** | **Paleochannel #** | **Characteristics:**<br>RA (Research Area) |
|---|---|---|
| OJK_Ch_IXa<br>OJK_Ch_IXb | Paleochannel 1 | The paleochannel traces are located to the east of the RA. Additionally, OJK_Ch_IXb is situated next to OJK_Ch9, just a few meters away. It is likely that OJK_Ch_IXb represents the result of an avulsion process. |
| OJK_Ch_X | Paleochannel 2 | |
| OJK_Ch_XIa<br>OJK_Ch_XIb<br>OJK_Ch_XIc | Paleochannel 3 | The paleochannel traces of OJK_Ch_XIa, OJK_Ch_XIb, and OJK_Ch_XIc are located in the central-eastern part of the RA. They are interconnected and likely represent different stages of the same channel. |
| OJK_Ch_XIIIa | Paleochannel 4 | The paleochannel trace is located 100 m west of OJK_Ch_XIIIb on the center-north of the RA. |
| OJK_Ch_XIIIb<br>OJK_Ch_XIIIc | Paleochannel 5 | The paleochannel traces OJK_Ch_XIIIb and OJK_Ch_XIIIc are located in the north-central part of the RA. Both traces likely represent the same channel. |
| OJK_Ch_XIV | Paleochannel 6 | The small paleochannel trace is located in the center-north of the RA. Considering its flow direction, it may have been connected to OJK_Ch_XXIV. |
| OJK_Ch_XXIV | Paleochannel 7 | The paleochannel traces are located in the center-north of the RA. Their position just north of OJK_Ch_XIV might suggest that they were part of the same paleochannel. |
| OJK_Ch_I | Paleochannel 8 | The paleochannel trace, OJK_Ch_I, is located in the |

| | | |
|---|---|---|
| | | center-east of the RA. It is one of the main channels east of Ojakly |
| OJK_Ch_IIa<br>OJK_Ch_IIb<br>OJK_Ch_IIc | Paleochannel 9 | The paleochannel trace OJK_Ch_IIa is located in the center of the RA. Traces OJK_Ch_IIb and OJK_Ch_IIc could be interpreted as resulting from the avulsion process. Considering the flow direction, it might be possible that they were part of the same paleochannel, along with OJK_Ch_XXVII to the north. |
| OJK_Ch_IVa | Paleochannel 10 | The paleochannel trace of OJK_Ch_IVa represent the largest paleochannel trace in the RA and is located in the central area. |
| OJK_Ch_IIII | Paleochannel 11 | The paleochannel trace OJK_Ch_IIII represents an isolated meander trace located south of Ojakly in the central area of the RA. |
| OJK_Ch_IVb<br>OJK_Ch_IVc | Paleochannel 12 | The paleochannel traces of OJK_Ch_IVb and OJK_Ch_IVc are located in the central-south area of the RA, partially crossing OJK_Ch_IVa. it is likely they were part of the same paleochannel representing an avulsion process. |
| OJK_Ch_Va<br>OJK_Ch_Vb | Paleochannel 13 | The paleochannel traces OJK_Ch_Va and OJK_Ch_Vb are located in the center-west area of the RA. Their position and the continuity of the traces suggest that they were part of the same paleochannel. |
| OJK_Ch_Vc | Paleochannel 14 | The paleochannel trace OJK Ch5c is a small trace east of OJK_Ch_Va. |
| OJK_Ch_VI | Paleochannel 15 | Paleochannel trace OJK_Ch_VI, together with OJK_Ch4, is one of the longest paleochannel traces detected in the RA. It is considered one of the channels |

| | | |
|---|---|---|
| | | that supplied water to the Late Bronze Age site of Auchin 1. Considering its position and flow direction, it might have been connected with OJK_Ch_Vb, forming a single paleochannel. |
| OJK_Ch_VIIa<br>OJK_Ch_VIIb<br>OJK_Ch_VIIc | Paleochannel 16 | The paleochannel traces of OJK_Ch_VIIa, 7b, and 7c are located in the center-northwest of the RA. The flow direction of the paleochannels and their close proximity suggest that they were part of the same channel, likely formed through an avulsion process. Moreover, considering their positions, they may have been part of the same channel as OJK_Ch_VIIIa and 8b to the south. |
| OJK_Ch_VIIIa<br>OJK_Ch_VIIIb | Paleochannel 17 | The paleochannel traces of OJK_Ch_VIIIa and 8b are located in the center-northwest of the RA. The flow direction of the paleochannels and their close proximity suggest that they were part of the same channel, likely formed through an avulsion process. Moreover, considering their positions, they may have been part of the same channel as OJK_Ch_VIIa and 7b to the north. |
| OJK_Ch_XVIII | Paleochannel 18 | The meandering paleochannel trace of OJK_Ch_XVIII is located to the east of the RA. Considering its flow direction, it might have been connected with OJK_Ch_XVII, forming part of the same channel. |
| OJK_Ch_XVII | Paleochannel 19 | The paleochannel trace of OJK_Ch_XVII is located to the east of the RA, and it is north of OJK_Ch_XVIII. Both traces, OJK_Ch_XVII and OJK_Ch_XVIII, might have been part of the same channel. |

| | | |
|---|---|---|
| OJK_Ch_XIX | Paleochannel 20 | The small trace, OJK_Ch_XIX, is located southwest of the RA. However, a long trace of what appears to be a paleochannel to the south is visible on CORONA images, though it is of modern origin. |
| OJK_Ch_XXa<br>OJK_Ch_XXb<br>OJK_Ch_XXc | Paleochannel 21 | The paleochannel trace OJK-Ch20 is located on the north-east of the RA. |
| OJK_Ch_XXI | Paleochannel 22 | The paleochannel trace OJK_Ch_XXI is located in the northeast of the RA. Considering the flow direction, this channel likely supplied water to the Late Bronze Age site of Auchin 1. |
| OJK_Ch_XXIIa<br>OJK_Ch_XXIIb | Paleochannel 23 | The two small paleochannel traces, OJK_Ch_XXIIa and OJK_Ch_XXIIb, are located in the northeast of the RA. OJK_Ch_XXIIa is situated to the north of OJK_Ch_XXIIb, and considering the flow direction, they may have been part of the same channel. Moreover, the flow direction of the paleochannel traces suggests that they carried water to the Late Bronze Age site of Auchin 1. Interestingly, OJK_Ch_XXIIa presents the only possible traces of small artificial canals used for irrigation. |
| OJK_Ch_XXIII | Paleochannel 24 | The paleochannel trace of OJK_Ch_XXIII is located north-east of the RA. Its flow direction suggests it was taking water to the Late Bronze Age site of Auchin 1. |
| OJK_Ch_XXIV | Paleochannel 25 | The paleochannel trace of OJK_Ch_XXIV is located on the north-west of the RA. |
| OJK_Ch_XXVI | Paleochannel 26 | The paleochannel trace OJK_Ch_XXVI is a trace locate on the north-east of the RA. |
| OJK_Ch_XXVII | Paleochannel 27 | The paleochannel trace of |

| | | |
|---|---|---|
| | | OJK_Ch_XXVII is located in the center of the RA and is the closest paleochannel trace east of Ojakly. Considering the flow direction, it might have been connected with OJK_Ch_XIIa and OJK_Ch_XIIb. |
| OJK_Ch_XIIa<br>OJK_Ch_XIIb | Paleochannel 28 | The paleochannel traces OJK_Ch_XIIa and OJK_Ch_XIIb are located in the center of the RA. The location and flow direction of these traces suggest that they were part of the same paleochannel, possibly formed through an avultion process. Moreover, the flow direction suggests that this paleochannel may have been connected with OJK_Ch_XXVII. |

Table 1.2 The table presents the sites recorded in the Ojakly Area by this project.

| **Site number and Type** | **Survey Area** | **Paleochannel** | **Distance from the paleochannel** | **Chronology** | **Size** |
|---|---|---|---|---|---|
| **1747**<br>Large Cluster | Area 11 | Paleochannel 10 and Paleochannel 27 | 650 meters | LBA | 0.5–1 ha |

**Description**

Site 1747 lies equidistant between Paleochannel 10 and Paleochannel 27, approximately 650 meters from each. This site, spanning roughly 1 hectare, stands out for its slightly elevated terrain hosting a concentration of pottery, marking it as a Large Cluster site. Notably absent is any sign of a takyr surface, with the area characterized by sparse vegetation featuring small shrubs and saxsaul trees. In contrast to nearby Site 1748, no kiln fragments remnants were uncovered, nor were there any traces of architectural structures. Its position atop a modest rise suggests a potentially more enduring or seasonally occupied settlement.

**Photo**

| Site number and Type | Survey Area | Paleochannel | Distance from the paleochannel | Chronology | Size |
|---|---|---|---|---|---|
| **1748**<br>Large Cluster | Area 11 | Paleochannel 10 | 310 meters | LBA | 0.5–1 ha |

**Description**

Site No. 1748 is designated as a Large Cluster site situated atop a gently elevated terrain. A distinct feature of this site is the presence of kiln fragments scattered across its expanse, indicating a zone of pottery production. Additionally, both ICW (Andronovo) pottery and BMAC pottery have been found here. These findings strongly suggest a more enduring occupation, likely associated with its proximity to the channel.

**Photo**

| **Site number and Type** | **Survey Area** | **Paleochannel** | **Distance from the paleochannel** | **Chronology** | **Size** |
|---|---|---|---|---|---|
| **1749**<br>Small Cluster | Area 11 | Paleochannel 10 | 190 meters | LBA | 0.1–0.5 ha |

**Description**

Site 1749, classified as a Small Cluster site, sits across from Site 1750 on the left bank of Paleochannel 10, approximately 190 meters from its former bank. Encompassing around 0.1-0.5 hectares, the site features a flat sand-takyr surface. Notably, the assemblages found here exhibit less fragmentation compared to other sites, potentially indicating less erosional processes. It has been suggested elsewhere that the presence of small fragmented materials may signal significant aeolian processes (Markofsky 2010:172).

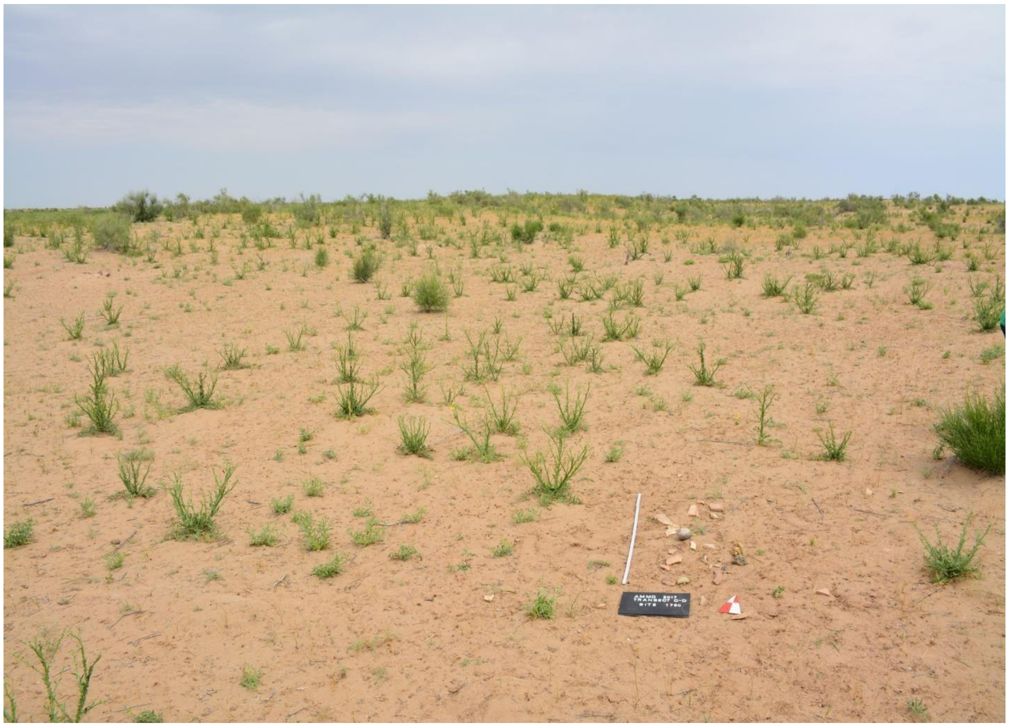
**Photo**

| Site number and Type | Survey Area | Paleochannel | Distance from the paleochannel | Chronology | Size |
|---|---|---|---|---|---|
| **1750**<br>Large Cluster | Area 11 | Paleochannel 10 | 150 meters | MBA-LBA | 0.5–1 ha |

**Description**

Site 1750 was discovered on the right bank of Paleochannel 10, around 150 meters from its former bank. Positioned on a slightly elevated terrain, this site was designated as a Large Cluster. It is distinguished by the concentration of pottery within an area with sparse vegetation. Notably, there are no takyr surfaces present, and no signs of potential permanent structures were observed.

**Photo**



| Site number and Type | Survey Area | Paleochannel | Distance from the paleochannel | Chronology | Size |
|---|---|---|---|---|---|
| **1751**<br>Small Cluster | Area 11<br>Area 10 | Paleochannel 13 | 300 meters | LBA | 0.1–0.5 ha |

**Description**

Site 1751 is a Small Cluster site situated roughly 300 meters to the left of Paleochannel 13. The pottery is predominantly scattered across a flat takyr surface, sparsely vegetated and covering an area of approximately 0.1-0.5 hectares. Apart from the pottery cluster, no other evidence was discovered. It is noteworthy that Site 1751, along with sites 1753 and 1752, are all located within 500 m from Paleochannel 13. Interestingly, this site also features ICW (Andronovo) pottery.

**Photo**

| Site number and Type | Survey Area | Paleochannel | Distance from the paleochannel | Chronology | Size |
|---|---|---|---|---|---|
| **1752**<br>Small Cluster | Area 11<br>Area 10 | Paleochannel 13 | 90 meters | LBA | 0.1–0.5 ha |

**Description**

Site 1752 is a Small Cluster site positioned in a gently elevated and sparsely vegetated region, approximately 90 m to the left of the paleomeander of Paleochannel 13. A notable concentration of pottery was found within small interdunal depressions at this site. Remarkably, there were no takyr surfaces linked to this area.

**Photo**

| Site number and Type | Survey Area | Paleochannel | Distance from the paleochannel | Chronology | Size |
|---|---|---|---|---|---|
| **1753**<br>Low Mound | Area 11<br>Area 10 | Paleochannel 13 | 125 meters | MBA-LBA | 1-2 ha |

**Description**

Site 1753 is located approximately 125 meters to the west of paleochannel 13, and at 250 meters distance from site 1752. Both sites, 1752 and 1753, were located along paleochannel 13. The site cover approximately 1-2 hectares, within an elevated area with a takyr surface at the edges. The site was identified by the large amount of pottery covering almost the entire area. No structures, bricks, or any kiln fragments were recorded that might suggest the presence of a production area. However, the size of the area might suggest a more permanent occupation like farmstead linked to agricultural activities, rather than a very short-term occupation.

**Photo**

| Site number and Type | Survey Area | Paleochannel | Distance from the paleochannel | Chronology | Size |
|---|---|---|---|---|---|
| **1754**<br>Small Cluster | Area 10 | Paleochannel 13 | 30 meters | LBA | 0.1-0.5 ha |

**Description**

Site 1754 is a Small Cluster situated within an interdunal region. It features a small sand-takyr surface and pottery spread across an area of approximately 0.1-0.5 hectares. Located roughly 30 meters from Paleochannel 13, the site likely served as a temporary occupation site, possibly utilized for herding or small-scale agricultural activities.

**Photo**

| Site number and Type | Survey Area | Paleochannel | Distance from the paleochannel | Chronology | Size |
|---|---|---|---|---|---|
| **1755**<br>Small Cluster | Area 10 | Paleochannel 13 | 200 meters | LBA | 0.1-0.5 ha |

**Description**

Site 1755 is a Small Cluster site positioned approximately 200 meters from Paleochannel 13. It is distinguished by the presence of pottery scattered across a vegetated area populated with small shrubs and saxaul trees, covering an area of about 0.1-0.5 hectares.

**Photo**

| Site number and Type | Survey Area | Paleochannel | Distance from the paleochannel | Chronology | Size |
|---|---|---|---|---|---|
| **1766**<br>Large Cluster | Area 10<br>Area 11 | Paleochannel 13 | 40 meters | LBA | 0.5-1 ha |

**Description**

Site 1766 occupies a slightly elevated terrain roughly 40 meters from Paleochannel 13. It was identified as a Large Cluster spanning approximately 0.5-1 hectare, notable for a substantial pottery concentration similar to Site 1749, albeit with less fragmented pottery. Notably, numerous kiln wasters are scattered throughout the area. Despite this, no discernible kiln structures were identified on the surface. Nevertheless, it is probable that pottery kilns were present in the vicinity.

**Photo**

| Site number and Type | Survey Area | Paleochannel | Distance from the paleochannel | Chronology | Size |
|---|---|---|---|---|---|
| **1767**<br>Small Cluster | Area 9 | Paleochannel 13 | 190 meters | LBA | 0.1-0.5 ha |

**Description**

Site 1767 is a Small Cluster site positioned roughly 190 meters from Paleochannel 13, situated on the edge of an agricultural zone at the time of the survey. This site is marked by a concentration of pottery on an uncultivated takyr surface. While the site covers approximately 0.1-0.5 hectares, it is possible that a portion of it has been impacted by agricultural activities. Notably, Site 1767 exhibits evidence of both ICW (Andronovo) pottery and BMAC pottery assemblage.

**Photo**

| Site number and Type | Survey Area | Paleochannel | Distance from the paleochannel | Chronology | Size |
|---|---|---|---|---|---|
| **1768**<br>Small Cluster | Area 6 | Paleochannel 28 | 80 meters | LBA | 0.1-0.5 ha |

**Description**

Site 1768 is a Small Cluster site positioned roughly 80 meters from Paleochannel 28. It is notable for the dispersion of pottery across a sparsely vegetated takyr surface spanning approximately 0.1-0.5 hectares. Interestingly, the pottery at this site exhibits less fragmentation compared to other sites in the vicinity.

**Photo**

Table 1.3. The table provides a description of the west and south profiles of the test trench excavated in Paleochannel 13, located in the Ojakly area.

| **Unit number*** | |
|---|---|
| **West Profile Trench (Paleochannel 13) Ojakly Area** | |
| 1 | The first unit layer is characterized by a clay-silt loam (takyr surface) of grayish color (10YR 6/1) of ca. 15 cm. |
| 2 | Between -15 and -50 cm there is a silty-sand layer (10YR 6/3) with visible cross-lamination. |
| 3 | Between -24 and -48 cm a small silt unit layer (10YR 8/2). |
| 4 | Between -50 and -60 cm there is a small layer of silt (10YR 5/6). |
| 5 | Between -60 and -87 cm there is a unit layer of sand (10YR 8/4) with visible ripple cross-bedding. |
| 6 | Between -87 and -115 cm there is a unit layer of silt (10YR 7/3) |
| 7 | Between -110 and -115 cm, mainly on the north side of the profile there is a unit of reddish silt layer different in color (5YR 6/8) from the preceding one. |
| 8 | Between -115 and -140 cm there is a unit layer of silt (10YR 7/3) that shows wave cross-lamination. |
| 9 | Between -140 and -170 there is a compact clay unit layer (10YR 7/2) characterized by aggregation of sediments of ca. 2-3 cm. |
| 10 | Between -170 and -180 cm there is a small unit layer of silty sand (10YR 7/1). |
| 11 | Between -180 and -228 cm there is a compact unit layer of silty clay (10YR 5/6). |
| **South Profile Trench (Paleochannel 13) Ojakly Area** | |
| 1 | The first unit layer is characterized by a clay-silt loam (takyr surface) of grayish color (10YR 6/1) of ca. 15 cm. |
| 2 | Between -15 and -24 cm there is a sloping silty-sand unit layer (10YR 6/3) of ca. 9cm towards the west side of the profile. |
| 3 | Between -24 and -49 cm there is a well-sorted silt unit layer (10YR 8/2). |
| 4 | Small inclusion unit layer of ca. 3 cm characterized by silty sand (10YR 8/3). |
| 5 | Small inclusion unit layer of ca. 5 cm characterized by well-sorted silt layer (10YR 8/2). |
| 6 | Small unit layer of ca. 3 cm characterized by very darker silt (5YR 6/6). |
| 7 | Between -60 and -85 cm there is a sand unit layer (10YR 6/6) with visible ripple cross-bedding. |
| 8 | Between -85 and -165 cm there is a large unit layer of silt (5YR 5/6) with the inclusion of charcoal at about ca. -95 cm. |
| 9 | Between -140 and -165 cm there is a compact clay unit layer (10YR 7/2) |
| 10 | Between -165 and -175 cm there is a small unit layer of light color silty sand (10YR |

| | |
|---|---|
| | 8/3) |
| 11 | Between -168 and -175 cm, only on the west side of the profile, there is a small inclusion of silt layer (10YR 7/3). |
| 12 | Between -175 and -228 cm there is a compact silty clay unit (10YR 5/6) |

*Refer to Figures 5.45 and 5.46 in Chapter 5 for the unite numbers

**From this layer an OSL sample was taken.

## - *Appendix 2*

Table 2. The table present the overview of the OSL results from Ojakly and Togolok trenches.

| Sample code | Depth (cm) | Mineral | Grain size (µm) | $n_{accepted}$/$n_{total}$ | $D_{total}$ (Gy ka$^{-1}$) | OD (%)$^{+}$ | $D_e$ IR$_{50}$ (Gy) | $D_e$ pIRIR$_{150}$ (Gy) | $D_{e\_corrected}$ IR$_{50}$ (Gy)* | $D_{e\_corrected}$ pIRIR$_{150}$ (Gy)* |
|---|---|---|---|---|---|---|---|---|---|---|
| OJK18-1 | 76 | F | 63-100 | 12/12 | 2.9 ± 0.1 | 27.2 ± 5.7 | 9.9 ± 0.3 | 18.8 ± 1.5 | 12.6 ± 0.3 | 21.4 ± 1.7 |
| OJK18-2 | 123 | PM | 4-11 | 7/7 | 3.6 ± 0.2 | - | 11.3 ± 0.2 | 19.0 ± 0.4 | 14.4 ± 0.2 | 21.7 ± 0.4 |
| OJK18-3 | 202 | PM | 4-11 | 7/7 | 4.1 ± 0.2 | - | 12.4 ± 0.2 | 26.0 ± 0.6 | 15.9 ± 0.2 | 30.0 ± 0.5 |
| OJK18-4 | 255 | F | 100-150 | 12/12 | 3.1 ± 0.2 | 8.8 ± 2.1 | 10.1 ± 0.2 | 17.9 ± 0.5 | 12.9 ± 0.3 | 20.3 ± 0.6 |
| TGK18-1 | 72 | F | 63-100 | 12/12 | 2.9 ± 0.1 | 8.3 ± 2.1 | 11.9 ± 0.2 | 24.3 ± 0.7 | 16.3 ± 0.3 | 29.3 ± 0.8 |
| TGK18-2 | 142 | PM | 4-11 | 7/7 | 4.1 ± 0.2 | - | 15.3 ± 0.2 | 54.2 ± 1.4 | 21.0 ± 0.3 | 68.6 ± 1.7 |
| TGK18-3 | 184 | F | 150-250 | 12/12 | 3.1 ± 0.1 | 6.9 ± 1.8 | 13.5 ± 0.3 | 19.3 ± 0.4 | 18.5 ± 0.4 | 23.0 ± 0.5 |

| Sample code | Grain size (µm) | $D_{total}$ (Gy ka$^{-1}$) | OD (%)$^{+}$ | $D_e$ IR$_{50}$ (Gy) | $D_e$ pIRIR$_{150}$ (Gy) | $D_{e\_corrected}$ IR$_{50}$ (Gy)* | $D_{e\_corrected}$ pIRIR$_{150}$ (Gy)* | Age IR$_{50}$ (ka) | Age pIRIR$_{150}$ (ka) | Age$_{corrected}$ IR$_{50}$ (ka)* | Age$_{corrected}$ pIRIR$_{150}$ (ka)* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OJK18-1 | 63-100 | 2.9 ± 0.1 | 27.2 ± 5.7 | 9.9 ± 0.3 | 18.8 ± 1.5 | 12.6 ± 0.3 | 21.4 ± 1.7 | 3.4 ± 0.2 | 6.4 ±0.6 | 4.3 ±0.1 | 7.4 ±0.6 |
| OJK18-2 | 4-11 | 3.6 ± 0.2 | - | 11.3 ± 0.2 | 19.0 ± 0.4 | 14.4 ± 0.2 | 21.7 ± 0.4 | 3.2 ± 0.2 | 5.4 ±0.3 | 4.0 ±0.1 | 6.1 ±0.2 |
| OJK18-3 | 4-11 | 4.1 ± 0.2 | - | 12.4 ± 0.2 | 26.0 ± 0.6 | 15.9 ± 0.2 | 30.0 ± 0.5 | 3.0 ± 0.2 | 6.4 ±0.4 | 3.9 ±0.1 | 7.3 ±0.2 |
| OJK18-4 | 100-150 | 3.1 ± 0.2 | 8.8 ± 2.1 | 10.1 ± 0.2 | 17.9 ± 0.5 | 12.9 ± 0.3 | 20.3 ± 0.6 | 3.3 ± 0.2 | 5.8 ±0.4 | 4.2 ±0.1 | 6.6 ±0.2 |
| TGK18-1 | 63-100 | 2.9 ± 0.1 | 8.3 ± 2.1 | 11.9 ± 0.2 | 24.3 ± 0.7 | 16.3 ± 0.3 | 29.3 ± 0.8 | 4.1 ± 0.2 | 8.3 ±0.4 | 5.6 ±0.1 | 10.1 ±0.3 |
| TGK18-2 | 4-11 | 4.1 ± 0.2 | - | 15.3 ± 0.2 | 54.2 ± 1.4 | 21.0 ± 0.3 | 68.6 ± 1.7 | 3.8 ± 0.2 | 13.3 ±0.7 | 5.1 ±0.2 | 16.8 ±0.5 |
| TGK18-3 | 150-250 | 3.1 ± 0.1 | 6.9 ± 1.8 | 13.5 ± 0.3 | 19.3 ± 0.4 | 18.5 ± 0.4 | 23.0 ± 0.5 | 4.3 ± 0.2 | 6.2 ± 0.3 | 6.0 ±0.1 | 7.4 ±0.2 |

$^{+}$ Overdispersion of pIRIR$_{150}$ $D_e$ values.

* g-values of 3.0 ± 1.0 (pIRIR$_{(50)}$) and 1.6 ± 1.2 (pIRIR$_{150}$) were used for OJK and 2.4 ± 0.9 (pIRIR$_{(50)}$) and 1.2 ± 1.2 (pIRIR$_{150}$) TGK. Correction following Lamothe et al. 2003.

$D_e$ values are calculated using the Central Age Model (Galbraith 1999).

| Sample code | Depth (cm) | WC field* (%) | WC used* (%) | Radionuclide concentrations | | | $D_{cosmic}$ (Gy ka$^{-1}$) | $D_{total}$ F and PM# (Gy ka$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| | | | | U (ppm) | Th (ppm) | K (%) | | |
| OJK18-1 | 76 | 1.9 | 5 ± 3 | 1.7 ± 0.3 | 6.2 ± 0.4 | 1.6 ± 0.1 | 0.19 ± 0.02 | 2.9 ± 0.1 |
| OJK18-2 | 123 | 3.0 | 5 ± 3 | 1.8 ± 0.3 | 7.5 ± 0.5 | 1.8 ± 0.2 | 0.18 ± 0.02 | 3.6 ± 0.2 |
| OJK18-3 | 202 | 10.9 | 10 ± 5 | 2.3 ± 0.4 | 9.4 ± 0.6 | 2.3 ± 0.2 | 0.17 ± 0.02 | 4.1 ± 0.2 |
| OJK18-4 | 255 | 2.3 | 5 ± 3 | 1.9 ± 0.3 | 6.0 ± 0.4 | 1.8 ± 0.2 | 0.16 ± 0.02 | 3.1 ± 0.2 |
| TGK18-1 | 72 | 1.0 | 5 ± 3 | 1.9 ± 0.2 | 6.7 ± 0.4 | 1.5 ± 0.1 | 0.20 ± 0.02 | 2.9 ± 0.1 |
| TGK18-2 | 142 | 7.2 | 10 ± 5 | 3.0 ± 0.4 | 9.3 ± 0.6 | 2.3 ± 0.1 | 0.18 ± 0.02 | 4.1 ± 0.2 |
| TGK18-3 | 184 | 1.0 | 5 ± 3 | 1.7 ± 0.2 | 6.9 ± 0.5 | 1.7 ± 0.1 | 0.17 ± 0.02 | 3.1 ± 0.1 |

* Water content as measured in the field and as used for $D_e$ determination.

# Alpha efficiency of 0.05 ± 0.01 and potassium content of 12.5 ± 0.5 % were assumed.

## - *Appendix 3*

Table 3.1 Paleochannel traces in the Togolok area were identified through remote sensing analysis. When these traces are likely part of the same channel, they have been grouped under a single paleochannel number (Paleochannel #).

| **Paleochannel Traces #** | **Paleochannel #** | **Characteristics:**<br>RA (Research Area) |
|---|---|---|
| TGK1_Ch_XIVa<br>TGK1_Ch_XIVb | Paleochannel 1 | TGK1_Ch_XIVa is the longest paleochannel trace, located approximately 1.8 km west of Togolok 1. Another small paleochannel trace (TGK1_Ch_XIVb) is situated on the southwest side of TGK1_Ch_XIV and exhibits evidence of a channel bar, suggesting it may have been part of the same paleochannel at an earlier stage. |
| TGK1_Ch_II<br>TGK1_Ch_III | Paleochannel 2 | The paleochannel trace TGK1_Ch_II is approximately 500m from Togolok 1 and is the main paleochannel trace discovered in the RA. The second smallest trace, TGK1_Ch_III, is located 100m east of TGK1_Ch_II. It may represent an old river channel migration. |
| TGK1_Ch_IV | Paleochannel 3 | TGK1_Ch_IV is a small river trace located southwest of Togolok 1. Based on its flow direction, it likely passed on the west side of Togolok 1. |
| TGK1_Ch_V | Paleochannel 4 | The TGK1_Ch_V trace is located 410m southeast of Togolok 1 and was currently part of a cultivated takyr. |
| TGK1_Ch_VI<br>TGK1_Ch_VIII | Paleochannel 5 | TGK1_Ch_VI is located just 50m from TGK1_Ch_V, and its trace passes on the west side of Togolok 1 (Tepe 2) and seems to be connected to TGK1_Ch_VIII. |
| TGK1_Ch_VII | Paleochannel 6 | TGK1_Ch_VII is a small paleochannel trace located 500m south-east of Togolok 1 (Tepe 2). |
| TGK1_Ch_IX | Paleochannel 7 | TGK1_Ch_IX is located 600m from Togolok 1 |
| TGK1_Ch_X* | Paleochannel 8 | TGK1_Ch_X is located southeast of TGK1_Ch_IX and intersects the latter. Therefore, it could be a later channel. |
| TGK1_Ch_XI | Paleochannel 9 | TGK1_Ch_XI is located 1300m to the east of Togolok 1. |

| | | |
|---|---|---|
| TGK1_Ch_XII | Paleochannel 10 | TGK1_Ch_XII is the eastern paleochannel of the Togolok Area, and it appears to flow towards a modern cultivated area to the northeast. |
| TGK1_Ch_XIII | Paleochannel 11 | TGK1_Ch_XIII is a small paleochannel trace on the south-east of Togolok 1. |

*Although the present paleochannel was identified via satellite images, it was not possible to verify its structure on the ground.

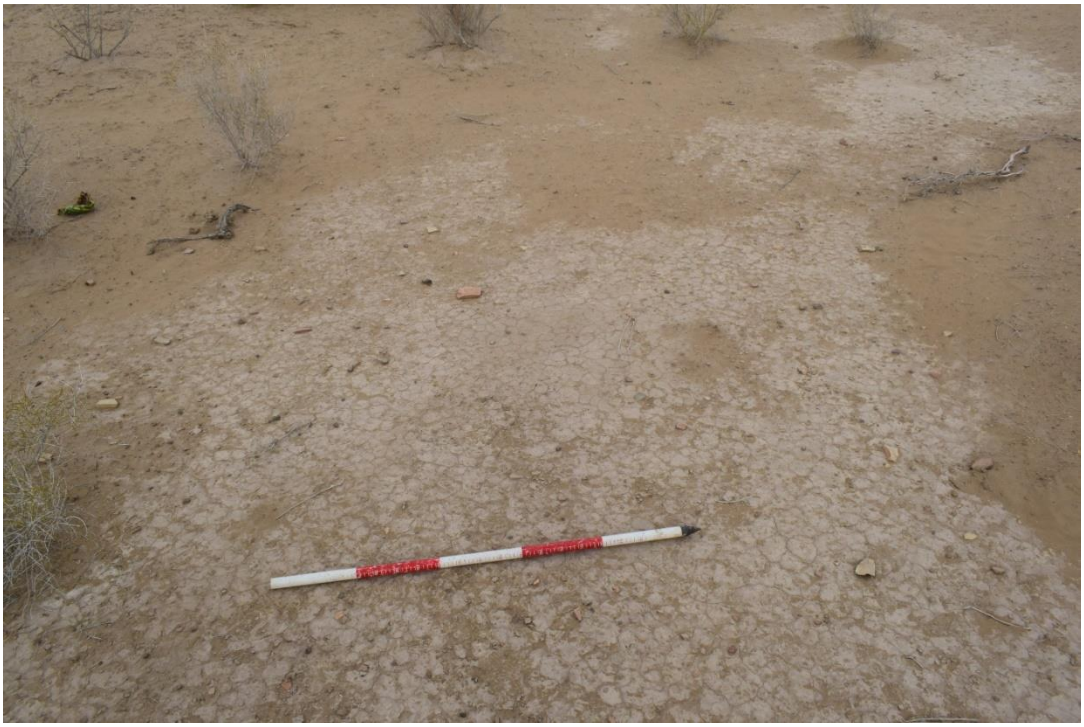
Table 3.2. The Tables present the sites recorded in Togolok Area by this project

| Site number and Type | Survey Area | Paleochannel | Distance from the paleochannel | Chronology | Size |
|---|---|---|---|---|---|
| **1756**<br>Large Cluster | Area 2 | Paleochannel 7 | 86 meters | LBA | 0.5-1 ha |

**Description**

Site 1756 is situated in the central-northern are of Paleochannel 7, along its left former bank. It features a gently flat surface scattered with a significant collection of scattered pottery. The surface is distinguished by takyr, surrounded by sandy soil.

**Photo**



| **Site number and Type** | **Survey Area** | **Paleochannel** | **Distance from the paleochannel** | **Chronology** | **Size** |
|---|---|---|---|---|---|
| **1757**<br>Low Mound | Area 2 | Paleochannel 7 | 55 meters | LBA | 1-2 ha |

**Description**

Site 1757 is situated in the northern section of Paleochannel 7 and stands out for the significant presence of scattered pottery on a small, elevated area. Furthermore, various traces of kiln fragments along with pottery were discovered. The surroundings are marked by sandy takyr surfaces.

**Photo**

| Site number and Type | Survey Area | Paleochannel | Distance from the paleochannel | Chronology | Size |
|---|---|---|---|---|---|
| **1758**<br>Small Cluster | Area 2 | Paleochannel 7 | 32 meters | LBA | 0.1-0.5 ha |

**Description**

Site 1758 given its proximity to the channel trace and its directional flow, it is probable that the site was situated along the right former bank of Paleochannel 7. The site is distinguished by a takyr surface, surrounded by sand, and marked by the presence of small aggregates of pottery.

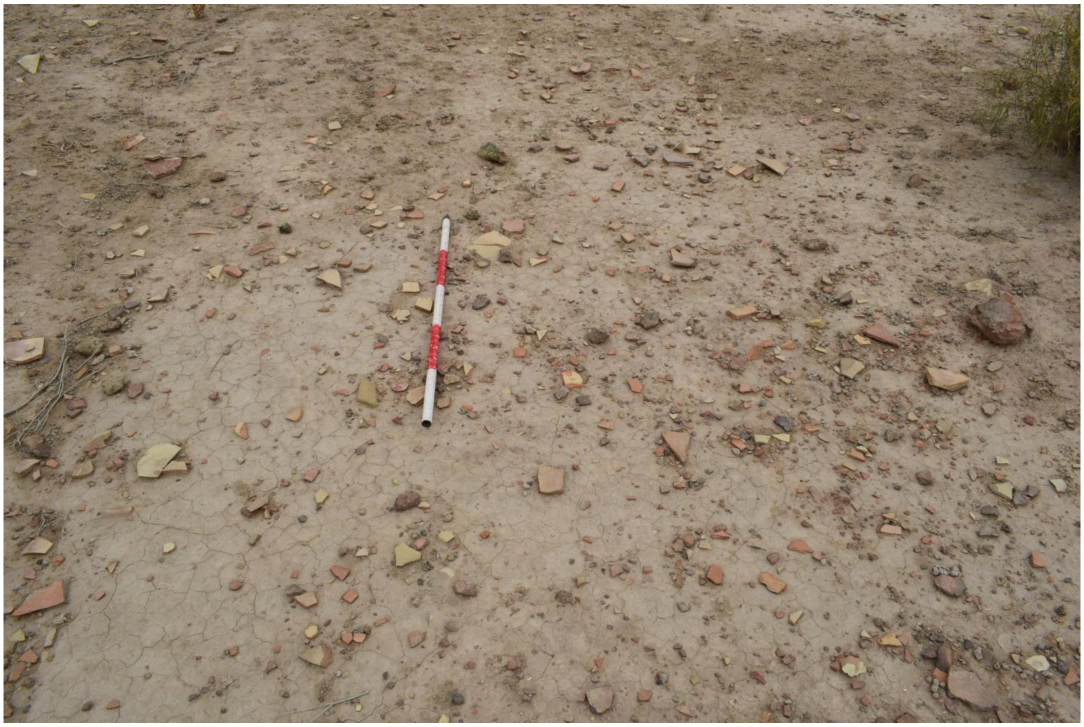
**Photo**

| Site number and type | Survey Area | Paleochannel | Distance from the paleochannel | Chronology | Size |
|---|---|---|---|---|---|
| **1759**<br>Large Cluster | Area 2 | Paleochannel 7 | 59 meters | LBA/IA1 | 0.5-1 ha |

**Description**

Site 1759 is positioned on the right paleobank of Paleochannel 2. The site is characterized by a collection of scattered pottery, predominantly on a takyr surface, surrounded by sandy terrain. Particularly noteworthy is the presence of kiln wasters on the surface, similar to Site 1757.

**Photo**



| Site number and Type | Survey Area | Paleochannel | Distance from the paleochannel | Chronology | Size |
|---|---|---|---|---|---|
| **1760**<br>Large Cluster | Area 2 | Paleochannel 7 | 49 meters | IA1 | 0.5- 1 ha |

**Description**

Site 1760 is situated on the left paleobank of Paleochannel 2, approximately 49 meters from the paleochannel. The site primarily consists of sandy terrain, with occasional patches of takyr nearby. Despite the abundant presence of scattered ceramics, no evidence of permanent structures was observed on the surface.

**Photo**

| Site number and Type | Survey Area | Paleochannel | Distance from the paleochannel | Chronology | Size |
|---|---|---|---|---|---|
| **1761**<br>Large Cluster | Area 4 | Paleochannel 7 | 48 meters | IA1 | 0.5-1 ha |

**Description**

Site 1761 is situated on the southern left paleobank of Paleochannel 7. It occupies a gently flat surface characterized by the presence of pottery and the absence of any permanent structures. While a takyr surface was observed, the area is primarily composed of sandy terrain.

**Photo**

| Site number and Type | Survey Area | Paleochannel | Distance from the paleochannel | Chronology | Size |
|---|---|---|---|---|---|
| **1762**<br>Small Cluster | Area 5 | Paleochannel 8 | 32 meters | LBA/IA1 | 0.1-0.5 ha |

**Description**

Site 1762 is the sole site identified in Area 5, situated near Paleochannel 8. It features a Takyr surface with a gentle slope towards the center and sandy terrain surrounding it. Scattered pottery was observed both around the site and within its center.

**Photo**

| Site number and Type | Survey Area | Paleochannel | Distance from the paleochannel | Chronology | Size |
|---|---|---|---|---|---|
| **1763**<br>Large Cluster | Area 2 | Paleochannel 2 | 65 meters | LBA/IA1 | 0.5-1 ha |

**Description**

Site 1763 is situated on the right paleobank of Paleochannel 2, positioned approximately 65 meters from the channel itself and 100 meters from Site 1764. Like Site 1764, it is also located 415 meters from Togolok 21. The site features a gently flat surface with minimal indications of a takyr surface. No evidence of permanent structures was identified on the surface.

**Photo**

| Site number and Type | Survey Area | Paleochannel | Distance from the paleochannel | Chronology | Size |
|---|---|---|---|---|---|
| **1764**<br>Small Cluster | Area 2 | Paleochannel 2 | 20 meters | LBA | 0.1-0.5 ha |

**Description**

Site 1764 is positioned in the southern area of Paleochannel 2, situated on its left paleobank at a distance of 20 meters. It is in close proximity to Togolok 21, just 412 meters to the north, and 100 meters from Site 1763. The site occupies a flat terrain with a sparse takyr surface. Notably, no evidence of permanent structures was discerned on the surface.

**Photo**

| Site number and Type | Survey Area | Paleochannel | Distance from the paleochannel | Chronology | Size |
|---|---|---|---|---|---|
| **1765**<br>Large Cluster | Area 2 | Paleochannel 2 | 93 meters | LBA/IA1 | 0.5-1 ha |

**Description**

Site 1765 is situated centrally along the left paleobank of Paleochannel 2, at a distance of 93 meters. It occupies a gently flat surface where scattered pottery fragments were discovered. Notably, no takyr surface was evident in the vicinity, and there were no visible structures on the surface.

**Photo**

Table 3.3. The table provides a description of the west and south profiles of the test trench excavated in Paleochannel 7, located in the Togolok area.

| **Unit number*** | |
|---|---|
| **West Profile Trench (Paleochannel 7) Togolok Area** | |
| 1 | The first layer of ca. 5 cm is characterized by a compact layer of clay-silt loam (takyr surface) of grayish color (10YR 6/1). |
| 2 | Between -5 and -70 cm there is a silty sand compacted unit layer. This layer is darker grey color (10YR 5/1) on the top, until about -50 cm, and lighter grey color (10YR 6/3) from -50 to -70 cm, probably with more sand fraction. This layer was also characterized by the presence of small shells. In addition, there was the presence of a small "root" channel between -50 and -60 cm on the south side of the trench profile. |
| 3** | Between -70 cm and -82cm there is a fine sand unit layer (10YR 7/4) with few laminations visible. |
| 4 | Between ca. -82 and -88 cm there is a unit layer of silty clay (10YR 7/4). |
| 5 | Between ca. -88 and 95 cm there is a layer of sand (10YR 7/4) with visible small cross-bedding lamination. |
| 6 | Between ca. -95 and -100 cm there is a small unit layer of silty-clay (10YR 7/4). |
| 7 | Between -100 and -169 cm there is a very cohesive polyhedral unit layer of clay (10YR 6/4). On the top left of this layer there was evidence of small charcoal. |
| 8** | Between -169 and -194 cm there is a unit layer of sand/very fine sand (10YR 5/6) with no particular lamination visible. |
| **South Profile Trench (Paleochannel 7) Togolok Area** | |
| 1 | The first layer of ca. 5 cm characterized by a compact layer of clay-silt loam (takyr surface) of grayish color (10YR 6/1). |
| 2 | Between – 7 and-74 cm there is a compact unit layer of silty sand. The layer is darker grey color (10YR 5/1) on the top and a lighter grey color (10YR 6/2) on the bottom profile with a possible increase in sand fraction. |
| 3 | Between -74 and -82 cm there is a fine sand unit layer (10YR 7/3) with visible cross-lamination. |
| 4 | Between ca. -85 and -92 cm there is a unit layer of sand (10YR 7/2) within unit layer 5. This layer shows visible cross-laminations |
| 5 | Between -82 and – 100 cm there is a unit layer of silty-clay (10YR 7/4). This layer present macro layers of sand in it (units 4,6,7). |
| 6 | Between ca. -87 and -92 cm there is a unit layer of sand (10YR 7/2) within unit layer 5. This layer shows visible cross-laminations. |
| 7 | Between ca. -94 and -96 cm there is a unit layer of sand (10YR 7/2) within unit layer 5. This layer shows visible cross-laminations. |
| 8** | Between -100 and -170 cm there is a very cohesive polyhedral unit layer of clay |

| | |
|---|---|
| | (10YR 6/4). |
| 9 | Between -170 and -194 cm there is a unit layer of sand/very fine sand (10YR 5/6) with no particular lamination visible. |

*Refer to Figures 6.42 and 6.43 in Chapter 6 for the unit numbers.

**From this layer OSL sample was taken.

# Glossary

The following list aims to offer definitions of selected terms within the thesis. Some definitions may be broad and not exhaustive, as certain fluvial terms are subject to debate (e.g., anabranching). Nonetheless, the purpose is to provide a brief comprehension of the terms.

- **Alluvial fan**: Alluvial fan is a fan-shaped deposit of sediment formed where a stream flattens, slows, and spreads typically onto a plain.
- **Anabranching**: Anabraching is a type of river channel pattern characterized by multiple interconnected channels separated by stable islands or bars, often found in floodplains with a low gradient.
- **Avulsion**: Avulsion refers to a sudden redirection of a channel course to a new path. This typically happens during episodes of flood, resulting in the abandonment of the old channel and the creation of a new one.
- **Bank**: In a river system, the bank refers to the sloping sides of a channel. Riverbanks confine the water within its channel path.
- **Barchanoids**: In arid environments, barchanoids are crescent-shaped sand dunes with an elongated form.
- **Braided**: Braided is a type of river channel pattern characterized by numerous interconnected channels separated by small and often temporary islands or bars, usually found in floodplains with variable discharge.
- **Catchment area**: The catchment area is of land from which water drains into a particular body of water.
- **Channel bar**: A channel bar is a depositional landform typically found within a river channel, often forming inside meanders or in areas of reduced flow velocity. These bars can vary in size and shape
- **Crevasse splays**: Crevasse splays form during periods of high discharge when a river breaches its levee, depositing sediment onto the floodplain. Due to this event, small streams can also form.
- **Cross-lamination**: Lamination consists essentially of parallel stratification, with laminated structures inclined in different directions.
- **Cross-section**: A diagram commonly used in geology and hydrology to depict the structure of landforms or bodies of water, such as a river channel.
- **Discharge**: Discharge is the volume of water flowing through a river channel. This is indicated per unit of time typically measured in cubic meters per second ($m^3/s$).
- **Furrow irrigation**: A method of irrigation in which water is distributed in small channels or furrows between rows of crops. This method is still used in modern Turkmenistan.
- **Hand auger**: Hand auger is a tool used for drilling small holes in soil in geological and environmental fieldwork. It can be operated by hand or machine.

- **Herringbone canals**: Irrigation canals designed in a herringbone pattern to distribute water across agricultural fields. This structure is common in Mesopotamia.
- **Khak**: In Turkmenistan, 'khak' refers to an artificial structure dug into the Takyr surface to collect water, which can be stored for between 2 and 4 months.
- **Lamination**: Lamination in river sediment refers to the presence of distinct, thin layers or beds of sedimentary material. These laminations are typically the result of changes in sedimentary processes, such as fluctuations in water flow velocity, and they are observable in cross-sections of the channel.
- **Levee**: An embankment built along the banks of a river to prevent flooding and confine the river within its channel.
- **Lithofacies**: In the context of rivers, lithofacies refers to distinctive sedimentary units within a specific formation that share similar characteristics. They represent specific depositional processes within a river system and can vary spatially and temporally along the river channel.
- **Marshes**: Marshes are wetland areas or regions characterized by shallow water with the presence of small vegetation such as grasses and sedges. South Mesopotamia is a typical region known for its marshes.
- **Ostracode shells**: Hard, calcareous shells of tiny aquatic crustaceans called ostracods.
- **Overbank deposition**: Overbank deposition is a process by which sediment carried by a river channel is deposited beyond the confines of its main channel. This happens during periods of high flow regime when a river channel exceeds its channel capacity. In this case, the deposited sediment forms layers of alluvium.
- **Oxbow**: An oxbow is a U-shaped body of water typically formed when a meandering river is cut off from the main channel. This process often occurs during periods of flooding.
- **River ripples**: River ripples are small-scale sedimentary structures that form on the bed of a river channel due to the interaction of flowing water with loose sediment particles. They usually develop perpendicular to the direction of water flow and can vary in size and spacing depending on factors such as flow velocity, sediment grain size, and channel morphology. Typically, they form under relatively low to moderate flow regimes and can be seen in channel sections.
- **Saxaul**: Saxaul is a type of drought-resistant shrub or small tree found in Central Asian deserts, often used for forage and fuel. It can be divided into two main varieties: black saxaul and white saxaul.
- **Takyr:** A takyr is a type of flat, clay-rich desert surface characterized by polygonal crack structures, commonly found in arid regions. In regions other than Central Asia, similar features may be referred to as 'playas' or 'sabkhas.' During periods of high precipitation, water accumulates on takyr surfaces.
- **Tepe or Depe**: Tepe or Depe is a mound formed by the accumulated debris from human occupation. They often represent ancient settlements.

- **Tributary channel**: A tributary channel is a smaller river channel that flows into a larger main one. Tributaries contribute water, sediment, and increase the discharge of the main watercourse, thereby influencing its characteristics
- **Tugai**: Tugai is a typical riparian forest or woodland found along the banks of rivers and streams in Central Asia. It is characterized by a diverse assemblage of trees and shrubs.

# English Summary

The Murghab region in Turkmenistan was the core area of the *Bactria-Margiana Archaeological Complex* (BMAC) or *Oxus Civilization* during the Bronze Age, a significant complex society marked by impressive citadels, such as at Gonur Depe, exquisite artifacts and evidence for trade with neighboring regions like Iran, the Indus Valley, and Mesopotamia. Remarkably, this occurred during the second millennium BCE, in which there is evidence for a shift towards a more arid climate, making the Murghab hydrological system a focal point for research. However, despite a number studies of the Murghab fan system, detailed investigations of what happened in particular regions are almost absent.

This study therefore examines the role of various local communities within the Murghab River's alluvial fan during the Middle and Late Bronze Age (2400-1300 BCE), investigating how environmental and hydrological factors led to particular settlement configurations and specific agricultural practices. Utilizing a holistic approach, including remote sensing reconstruction of the hydrological system, archaeological survey, geoarchaeological investigations, and OSL analysis of ancient fluvial systems, I focused on two micro regions: Togolok and Ojakly. The findings indicate that dense settlement clusters and more rural areas responded differently to climate change, reflected in their agricultural practices and the proximity of sites to water sources. Neighboring communities in this region were faced with diverse effects of climate changes, which were addressed with diverse social and economic strategies. The instability of the hydrological system, particularly evident in the stratigraphic analysis of the test trench made near Ojakly, might explain both the proliferation of small-scale sites during the Late Bronze Age and their ephemeral nature, which might have been linked to the increased mobility in these communities. Botanical evidence indicates that these rural communities engaged in low-investment, opportunistic agriculture, with pastoralism being an important economic activity. Conversely, areas like Togolok - characterized by a dense settlements cluster – had a more stable hydrological system and were able to cultivate a wider variety of crops and produce several harvests per year. Additionally, this study challenges the reliability of using pottery assemblages to infer subsistence

economies. While there are distinct Namazga and ICW (Andronovo) pottery types present during the Late Bronze Age, the idea that these translate into particular types of agricultural and social practices needs to be challenged.  Consequently, there is no clear economic dichotomy between sites with these pottery assemblages as has been previously suggested.

Ultimately, the study proposes a "multiple adaptation model" to address the complexity of agricultural exploitation and societal formats during this period of climate transformation, rather than a single, uniform use of the land. As such, this study contributes to broader research into the economic and social resilience in Central Asia during the Bronze Age.

# Nederlandse Samenvatting

De Murghab regio in Turkmenistan was het hartland van het *Bactria-Margiana Archeologische Complex* (BMAC) ook bekend als de *Oxus*-beschaving in de Bronstijd. De BMAC was een belangrijke en complexe samenleving, wat zich uit in onder andere indrukwekkende burchten, zoals die van Gonur Depe, hoogstaande artefacten, en bewijs voor handel met omliggende regio's zoals Iran, de Indusvallei, en Mesopotamië. Opmerkelijk bestond de BMAC in het tweede millennium v.Chr., ten tijde van een aridificatie van het klimaat. Om deze reden is het hydrologische systeem van Murghab een belangrijke focus voor onderzoek binnen de studies van de BMAC. Ondanks een aantal onderzoeken van de Murghab riviermonding ontbreken er echter gedetailleerde studies naar wat er in bepaalde regio’s gebeurde in de Bronstijd.

Dit onderzoek richt zich daarom op de rol van verschillende lokale gemeenschappen binnen de monding van de Murghab-rivier tijdens de Midden- en Late Bronstijd (2400-1300 v.Chr.), waarbij wordt onderzocht hoe omgevings- en hydrologische factoren leidden tot specifieke nederzettingsconfiguraties en bepaalde landbouwpraktijken. Met behulp van een holistische benadering – waaronder een *remote sensing*-reconstructie van het hydrologische systeem, archeologische surveys, geoarcheologische onderzoek, OSL dateringen van oude fluviale systemen – richtte ik me op twee microregio's: Togolok en Ojakly. De resultaten geven aan dat dichte nederzettingsclusters en meer rurale gebieden verschillend reageerden op klimaatverandering, wat tot uiting kwam in hun landbouwpraktijken en de nabijheid van nederzettingen tot waterbronnen. Naburige gemeenschappen in deze regio werden geconfronteerd met variabele effecten van klimaatverandering, in antwoord waarop diverse sociale en economische strategieën werden gebruikt. De instabiliteit van het hydrologische systeem – met name zichtbaar in de stratigrafische analyse van de proefsleuf bij Ojakly – geeft een verklaring voor het grote aantal van kleinschalige locaties tijdens de Late Bronstijd die waarschijnlijk kortstondig bewoond waren, en suggereren een toegenomen mobiliteit in deze gemeenschappen. Botanische data laten zien dat deze plattelandsgemeenschappen zich bezighielden met opportunistische landbouw die arbeidsextensief was, en dat pastoralisme een belangrijke economische activiteit was.

Omgekeerd hadden gebieden als Togolok – gekenmerkt door een dichtere bewoning – een stabieler hydrologisch systeem waarin een grotere variatie aan gewassen kon worden verbouwd en meerdere oogsten per jaar mogelijk waren. Verder, stelt dit onderzoek de gelijkstelling van aardewerkassemblages met bepaalde landbouwsystemen ter discussie. Hoewel er verschillende Namazga- en ICW (Andronovo) aardewerktypen aanwezig zijn tijdens de Late Bronstijd, moet het idee dat deze corresponderen met specifieke soorten landbouw- en sociale praktijken worden betwist; er is namelijk geen duidelijk economisch verschil tussen sites met deze aardewerkassemblages, zoals eerder is gesuggereerd.

Uiteindelijk stelt dit onderzoek een "meervoudig adaptatiemodel" voor om de complexiteit van landbouwgebruiken en sociale structuren tijdens deze periode van klimaattransformatie te verklaren, in plaats van een uniform gebruik van het land. Ten slotte draagt dit onderzoek bij aan het bredere onderzoek naar de economische en sociale veerkracht in Centraal-Azië tijdens de Bronstijd.

# Curriculum Vitae

Roberto Arciero (Maddaloni, 1984) grew up in Capua, southern Italy. After spending a school year as an exchange student in Honduras (Central America) during his high school period, he moved to northern Italy and obtained a bachelor's degree in Ancient History from Alma Mater Studiorum - University of Bologna. During his undergraduate studies, Roberto spent a semester at the National University of Ireland – Maynooth through the Erasmus program. He then completed a two-year master's degree in Archaeology at Bologna University, graduating cum laude, with a dissertation that explored the role of honey and dates in North Africa and West Asia during prehistoric periods. Concurrently, he participated in numerous excavations and field schools in Italy, Greece, Oman, Eritrea, and Central Asia region (Turkmenistan and Uzbekistan), where he developed a keen interest in the archaeology of this latter region.

After an internship at the Italian Cultural Institute of the Italian Embassy in Stockholm (Sweden), and two years working in contract archaeology in Italy, Roberto moved to Leiden University (The Netherlands). There, he began his Ph.D. at the Faculty of Archaeology under the supervision of Prof. Dr. Bleda Düring and Prof. Dr. Peter Akkermans. His dissertation examines the role and transformation of agricultural practices and water management in the Murghab alluvial fan (southern Turkmenistan) during the Bronze Age. He presented his research at numerous conferences across Europe and Central Asia, also as a guest speaker. He co-authored six articles and wrote several pieces for popular magazines. Over the period 2017-2021, he was also employed as a teaching assistant at the Faculty of Archaeology, where he designed and taught tutorials for various first-year bachelor courses and was employed as lecturer for one third-year bachelor course.

During his Ph.D., Roberto secured fieldwork research grants from the National Geographic Society, Leiden University Fund (LUF), and the Asian Modernities and Traditions Grant (Leiden University). He also received conference and travel grants from the Leiden University Fund (LUF), the European Association of Archaeologists, the Netherlands Institute for the Near East (NINO), and the Society for the Exploration of EurAsia. Additionally, he worked on a project from ISMEO — The International

Association for Mediterranean and Oriental Studies, digitizing and georeferencing ancient maps and aerial photos of the Murghab region.

In the past two years, Roberto has also developed an interest in Contemporary Archaeology. He recently (2023) co-authored a multidisciplinary grant proposal (RESPIRE Project), funded by the National Geographic Society under the Meridian Grant. In this project, he is responsible for the archaeological component, investigating plastic debris as contemporary material culture from three case study beaches on Lampedusa Island (Italy). The preliminary result of this project were presented at the European Association of Archaeologists Conference in Rome in August 2024.