MOBILITY AND SUBSISTENCE OF PREHISTORIC SOCIETIES IN SOUTHERN CENTRAL ASIA AND IRAN: A MULTI-ISOTOPIC APPROACH

A thesis in fulfillment of the requirements for the degree of Doctor of Philosophy in Ancient Near Eastern Archaeology

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dedicated to my father

"…Until the origins and cultural connections of this tradition are not understood,
we will continue to be impressed with what we do not yet know […].
And so it is that a new discovery, unanticipated by archaeologist,
both shows us how extensive is the darkness which surrounds us,
and gives us a starting point from which to ask more questions of the unknown."

Cuyler T. Young, Archaeologist

Table of Contents

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Addendum: This thesis was submitted in May 2021 and defended in September 2021, literature, which was published after this date, was added only exceptionally.

1. Introduction

Southern Central Asia has long been considered as periphery to the developments of the great empires of the Near East. As no written sources are handed down historically, its role in the international game has long been underestimated or even ignored.[1] The situation changed in the 2nd half of the 20th century with the excavations of sites like Anau, Namazga Depe, Altyn Depe, and Gonur Depe (cf. fig. 1.1). Impressing monumental buildings as the "tower" in Namazga (Khlopina 1981: 38–42), the "palace" in Gonur (Sarianidi 2005: 31), and the "caravanserai" or "qala" in Adji Kui (Barfield 2010: 163) came to light. Moreover, crafting areas with a highly specialized production of utilitarian and artistic items ("hill of craftsmen" in Altyn Depe Masson 1981: 64) made scientists rethink. The existence of huge fortification systems as in Adji Kui (Barfield, 2010: 188; Lamberg-Karlovsky 2013: 44) or Namazga Depe (Khlopina 1981: 39) pronounced a distinct social differentiation of the communities.[2] Luxurious items, as the famous Indus elephant seal from Gonur Depe (Sarianidi 2005: 258 fig. 114), or the grave finds from Adji Kui (e.g., Rossi-Osmida et al. 2020: 90 fig. 6) sprouted numerously from the ground. Their presence indicated widespread connections and a certain role in the interregional trade network (e.g., Hiebert 1994; Possehl 2002), and dispelled the last doubts. Today we know southern Central Asia has formed a crossroad during millennia between East and West, but its role in the evolution of civilizations is still not understood.

Mobility, migration and subsistence strategies of prehistoric societies have always been of major importance in archaeological research. In the meanwhile, the application of isotopic investigations represents well-established methods to follow questions on mobility, possible migrations, and dietary patterns. In this study the communities in southern Central Asia and Tepe Sialk will be described using $^{87}Sr/^{86}Sr$, $\delta^{18}O$, $\delta^{15}N$ and $\delta^{13}C$ analyses. Due to the correlation between the geological surroundings and human body metabolism strontium isotope analyses enable the identification of locals and non-locals, moreover movements between different geological regions in a lifespan of humans and animals can be reconstructed. Oxygen isotopic ratios derive from local meteoric water such as rain, snow, and moisture and are generally used to reconstruct drinking water sources. Although these are impacted by climatic and environmental conditions – thus blurring the data – basic characterizations are possible. The combination of both enables the description of small- and large-scale mobility and migratory impacts. Moreover, the results substantiate possible migration routes and distances, respectively existing interregional connections, not only through cultural distributions, trade and trade goods. The results provide precise information about human interactions, respectively social connections and active dynamics. On the other hand, the analyses of carbon and nitrogen isotopes out of bone collagen of the same human individuals supply data on dietary habits, as well as economical strategies and land-use. Next to the migratory impacts and dietary reconstructions, the overall standing question in this region concerns the mobility, respectively subsistence strategies like nomadism, pastoralism (including semi- and agro-pastoralism), transhumance, and seasonal movements. Agro-pastoralism comprises the combination of crop cultivation like cereals and pulses with animal husbandry of domestic sheep, goats, and cattle, as well as the exploitation of wild resources. Knipper summarized "Agro-pastoral communities were usually sedentary, and stock keeping either concentrated in the hinterlands of the settlements or involved seasonal mobility and transhumance. Farmers consumed a mixed diet with

[1] Recent studies raise the possibility that the Central Asian communities may have been known in Mesopotamian sources as the country of Marhashi (cf. Guichard 2021), but scientists did not reach a consensus yet.
[2] Assured fortification systems have been identified in Gonur Depe, Adji Kui, Namazga Depe, Ulug Depe, Altyn Depe, Kelleli, Taip, and Togolok in Turkmenistan; Sapallitepa, Molalitepa and Dzharkutan in Uzbekistan, and Dashly in Afghanistan (cf. Muradov 2021).

varying proportions of plant food and animal products, such as meat, milk, and dairy products, among which the vegetable component generally dominated. In contrast, pastoral communities were more mobile and dominant in the Eurasian steppes. Meat, fat, and dairy products from domestic animals encompassed most of their produced food." (Knipper 2020: 4 cf. also Bellwood 2005; Pearson et al. 2015; Makarewicz 2018). The communities in southern Central Asia were sedentary agriculturalists, archaeological remains evidence a high degree of specialization and several different lifestyles, practiced by separated groups of people, which existed within these societies (Vinogradova and Kuz'mina 1996; Hiebert, Moore 2004; Kohl 2007; Cattani 2008; Frachetti 2011, 2012; Luneau 2017, forthcoming). On the one hand pastoralists (sedentary or mobile?), moved for herding and breeding of animals, and maybe lived in nearby villages or seasonal campsites (Biscione 1976; Schetenko, Kutimov 1999; Kuzmina 2007; Kutimov 2014; Rouse, Cerasetti 2018), on the other hand, sedentary communities, specialized in agricultural developments (e.g., Spengler et al. 2014a, b). Especially with the growth of the settlements during the Oxus period, when an increasing population demand a certain security in the food supply, the establishment of functional structures seemed hardly necessary. Therefore, pastoral movements have always been considered to be an essential part of the provision of the communities in southern Central Asia. The same applies to Tepe Sialk and the communities on the Iranian Plateau. The incipient urbanisation during the Chalcolithic period, implicates further changes in the agricultural organization, the development of manuring techniques, as well as the exploitation of new territories (e.g., Hole 1987a, b; Bernbeck 2001; Weeks 2013).

The content of this thesis includes two main projects, organized, coordinated, and funded by different groups of researchers and institutions. One part represents the first multi-isotopic characterization of Bronze Age communities in southern Central Asia with a focus on the sites Ulug Depe in Turkmenistan, and Dzharkutan in Uzbekistan. The project was conducted in the Laboratoire Archéozoologie, Archéobotanique, Sociétés, Pratiques et Environnements (UMR 7209) and the Laboratoire Eco-anthropologie (UMR 7206) in the Muséum National d´Histoire Naturelle (MNHN) Centre national de la recherche scientifique (CNRS) in Paris. It also benefited from collaborations with French archaeological missions of the Ministry of Europe and Foreign Affairs, the French Archaeological delegation in Afghanistan (DAFA), and the General Directorates of Antiquities in Turkmenistan, Uzbekistan, Tajikistan and Iran. Thanks to the generosity of colleagues from the German Archaeological Institute and the Ludwig Maximilian University, it was possible to perform further analyses on contemporary samples from Tilla Bulak, Sapallitepa, and Bustan in southern Uzbekistan, Bashman 1 in central Uzbekistan, Saridzhar, and the nearby graveyards of Gelot and Darnaichi in southern Tajikistan. These lucky circumstances enable a broader view on the isotopic distribution in southern Central Asia. Moreover, a reliable amount of reference samples can be presented. The second part represents a sub-project of the multi-disciplinary approach focusing on the Ghirshman collection of Tepe Sialk from the Musée de l´Homme and the Institut de Paléontologie Humaine in Paris, involving scientists of the Muséum National d´Histoire Naturelle. Both approaches need to be published individually, which influenced the arrangement of this thesis. The original plan of this study was to follow cultural connections between southern Central Asia and Iran using isotopic applications. But a comparison between the sites turned out to be challenging, since the selection of the samples was performed long before the work on this thesis started and no chronological conformity is provided. The human samples from Central Asia date from the Early Bronze to the Middle Iron Age, while the human samples from Tepe Sialk cover the Neolithic, Chalcolithic and Iron Age periods. Unfortunately, no Bronze Age samples were available from Tepe Sialk, just as no earlier (Chalcolithic) or later (MIA/LIA) samples from Central Asia. Since no chronological overlapping exists correlations can only be drawn in a broader range and Tepe Sialk will be discussed separately.

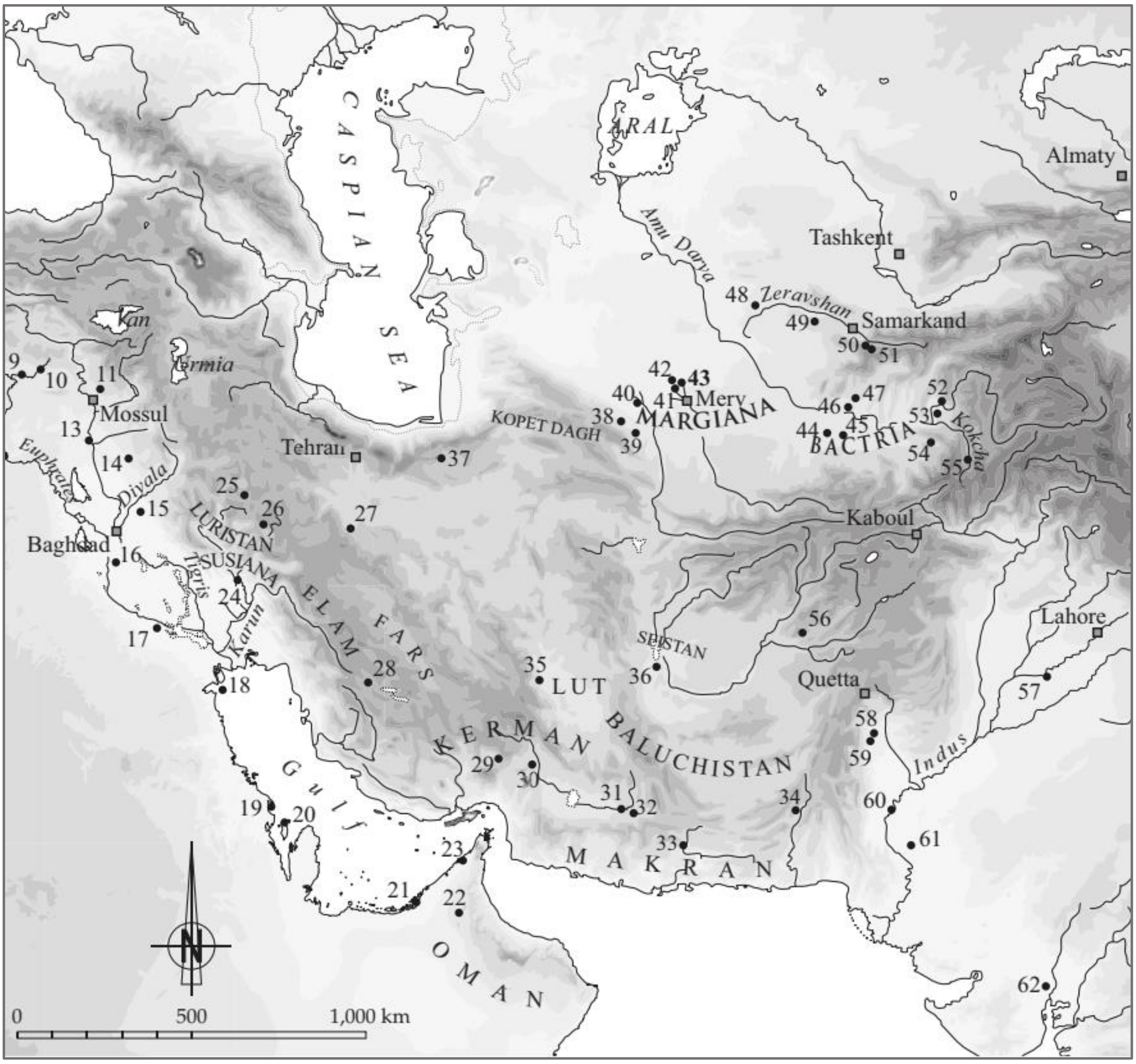


Fig. 1.1: The world of the Oxus Civilization after Lyonnet and Dubova 2021: 10 fig. 1.1. Sites: 9 Tell Brak; 10 Tell Leilan; 11 Tepe Gawra; 12 Mari; 13 Assur; 14 Nuzi; 15 T. Asmar/Eshnunna; 16 Babylon; 17 Ur; 18 Failaka; 19 Tarut; 20 Bahrain/Dilmun; 21 Umm an-Nar; 22 Hili; 23 Tell Abraq; 24 Susa; 25 Godin-Tepe; 26 Deh Hosein; 27 Tepe Sialk; 28 Anshan; 29 Tepe Yahya; 30 Jiroft; 31 Bampur; 32 Khurab; 33 Miri Qalat; 34 Mehi; 35 Shahdad; 36 Shahr-i Sokhta; 37 Tepe Hissar; 38 Namazga-Depe; 39 Altyn-Depe; 40 Geoksjur; 41 Togolok; 42 Kelleli; 43 Gonur-Depe; 44 Dashly-Tepe; 45 Bactra; 46 Sapallitepa; 47 Dzharkutan; 48 Zamanbaba; 49 Karnab (tin mines); 50 Sarazm; 51 Mushiston (tin mines); 52 Farkhor; 53 Shortughai; 54 Taluqan; 55 Sar-i Sang (lapis-lazuli mines); 56 Mundigak; 57 Harappa; 58 Mehrgarh and Sibri; 59 Nausharo; 60 Mohenjo Daro; 61 Chanhu Daro; 62 Lottal.

Hence, the main aspects of this thesis are the determination of bio-available local isotopic signals and in this context the evaluation of the applicability of isotope analyses in the particular region; the characterisation of mobility and subsistence patterns of the investigated archaeological sites; and the identification of potential migrants. Mobility of populations, respectively migration of single individuals or groups are lively discussed in archaeological circles and often described. Several theories and models exist, beside a short introduction the author decided for several reasons not to include general models in this study. Basically, the small sample number rendered comparative evaluations and generalization inaccurate, as only few other studies are available and could be used for comparisons. Moreover, several excellent doctoral theses already exist applying the methods and comparisons between different isotopic approaches (e.g., Knipper 2004; Tütken 2003; Katzernberg 2008; Gerling 2015). The method and reliability of isotopic results has long been established and will not be questioned here. The application of chemical analyses represents an irreversible destruction of archaeological material, which is especially valuable as the political situation in the investigated regions hardly enables the export of samples. Therefore, beside some minor experiments deviating from the standard lab methods concerning the different types of material and adaptation of the poorly preserved samples, this thesis desisted from methodical experiments concerning the general application of isotopes in archaeological material. Instead, the focus was laid on the background definition of the particular isotopes to obtain the most accurate description of the natural isotopic distribution as well as possible climatic impacts.

Different problems and changes appear during every PhD thesis, several factors also made the evaluation of the obtained data in this study challenging, including the small sample size of each site, as well as the chronological differences, very few comparative studies, and several uncertainties concerning the chronological classification. Harald Hauptmann once said "Inshallah – Mashallah – guaranty yok", a wisdom known and experienced by every PhD student and a sentence that accompanied this thesis every day. The work with sensible material and destructive methods regularly brings surprises, fears, and uncertainties. Additional complications were caused by the SARS COV2 pandemic, which impacted the access to libraries and labs so that several experiments could not be finished. Nevertheless, this doctoral thesis presents the first substantial multi-isotopic descriptions from southern Central Asia and provides the fundament of a biogeochemical data set for future studies.

The first chapter introduces the fundamental questions this thesis is based on, and the principal methods that have been applied. Chapter 2 provides a general overview on the archaeology of the two regions. After a short summary of the history and current state of research, follows an introduction on the methodical background of isotopic applications. Chapter 3 comprises the collection of the investigated samples and the applied lab methods, technical details of the lab equipment and adaptations of protocols. Chapter 4 presents the determination of bio-available local $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ signals. After a short discussion of the geological realities and the selection of suitable reference samples, the determined local $^{87}Sr/^{86}Sr$ ranges from southern Central Asia and Iran are discussed. The second part discusses the calculations for the determination of local $\delta^{18}O$ ranges of the investigated sites, as well as potential inaccuracies und problems. Chapter 5 focuses on Ulug Depe, chapter 7 on Dzharkutan, and chapter 9 on Tepe Sialk. For the sake of uniformity and comparability, these three chapters are structured as follows: short presentation of the archaeological background, subsistence and surrounding landscape, burial customs and the detailed description of the investigated burials. Followed by the reconstruction of spatial movements and mobility pattern according to $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ isotopes, and the nutrition habits of humans and animals based on $\delta^{15}N$ and $\delta^{13}C$ isotopes. In between two case studies were added to highlight the most amazing results of this thesis. Chapter 6 was added to demonstrate the combination of isotopic and paleogenetic investigations, which were performed on the same individuals from Ulug Depe. Chapter 8 presents another case study on the isotopic results of a very special LBA burial from Gelot in southern Tajikistan. Chapter 10 provides a comparative look in a broader view, discussing different studies of nutrition patterns, possible trade routes, and migratory movements. Chapter 11 summarizes the key conclusions that were drawn throughout this study. Finally, chapter 12 contains a summary of this thesis and the main results in English, German, and French. Last but not least, all produced data are itemized in the appendix.

Fig. 2.1: Reconstruction of Gonur North.[3]

2. Background

2.1. Archaeological background

This chapter will give a brief, general overview on the archaeological background of southern Central Asia and the Iranian Plateau during the time periods of interest for this study. Southern Central Asia and Iran represent complex archaeological situations with a long history of research. The examination of this wide range of geographic regions from Zagros to Hindukush, with hundreds of archaeological sites comprising time periods of 7 millennia would go beyond the scope of this thesis. Concerning Iran, the author decided to restrict the general introduction of the Central Iranian Plateau to a focus on the subsistence, ancestry, and inter-regional connections. The specific archaeological situation and the history of research of the investigated sites Ulug Depe, Dzharkutan and Tepe Sialk will be discussed in detail in the particular chapter. The history of research in this chapter focuses on the application of isotopic analyses, since excellent summaries on the history of research of the archaeology in southern Central Asia can be found e.g., in Luneau (2010) and Lhuillier (2010), on the Iranian Plateau in e.g., Nokandeh (2010) and Fahimi (2011). In the last decades, several international groups of researchers expanded our knowledge immensely through numerous new archaeological expeditions (the absolute current state of research is excellent presented in Lyonnet and Dubova 2021), but also the natural scientific part has caught up. Thanks to numerous results of paleogenetic, isotopic, archaeobotanical and -zoological studies, we have a much brighter picture of the subsistence, mobility and dynamic interactions. Before diving into the matter, some general issues have to be clarified and theoretical aspects defined, as between researchers some aspects are not concordant either.

2.1.1. Terminology

Many discussions have been led on the terminology and chronology, describing the cultural communities of southern Central Asia during the Bronze Age. The concept of the Oxus Civilization or BMAC (Bactria-Margiana-Archaeological Complex) was originally very narrow in terms of temporal extension

[3] After http://www.heritageinstitute.com/zoroastrianism/images/turkmenistan/

(Teufer 2018a) but has been expanded significantly by now (Salvatori 2016). In the meanwhile, three different terms have to be distinguished that stay in contrast and even opposition to each other, as up to today the boundaries, respectively the “core area” and the “area of influence” expand with every new discovery (Vahdati and Biscone 2021). The first discovered Bronze Age settlements in southern Central Asia were denoted by the term “Oxus Civilization”, comprising the cultural communities settled along the ancient Oxus river (today Amu Darya river). Due to ongoing studies and an expanding cultural area, Viktor Sarianidi coined the term “BMAC” – Bactria Margiana Archaeological Complex – in the 1970s (Sarianidi 1976). Bactria comprises the region north of the Hindukush to the Amu Darya River: today northern Afghanistan, southern Uzbekistan, and southern Tajikistan. Margiana is traditionally the region around the city of Merv and along the Murghab river in southern Turkmenistan (cf. fig. 1.1). Archaeologists still discuss the territorial boundaries of the BMAC and Oxus Civilization, respectively the terminological containments of “Bactria” and “Margiana” concerning the local distribution (cf. Lamberg-Karlovsky 2013; Salvatori 2016; Teufer 2018a). Especially the accumulation of settlements along the northern Kopet Dagh foothills led to discussions, as the region officially does not belong to the BMAC area, and differs indeed concerning the structure of the settlements (cf. e.g., Lamberg-Karlovsky 2013). But archaeological remains and also burial customs evidenced a clear affiliation (Lecomte 2013; Vahdati et al. 2020, Biscione and Vahdati 2021). Moreover, two recently investigated sites south of Kopet Dagh Mountains, Tepe Chalow (Vahdati et al. 2019), and Tepe Damghani (Francfort et al. 2014), indicate cultural analogues to southern Central Asia too. New surveys evidenced the spread of BMAC sites to Sistan and North-Khorasan, as well as into Quetta-Mehrgarh region in Pakistan (Thornton 2013a; Biscione and Vahdati 2018). For this reason, archaeologists created the new term of the GKC – “Greater Khorasan Civilization”, which comprises the traditional core area expanded to the Kopet Dagh mountain range, but also includes an area of influence in southern and eastern Iran (Vahdati et al. 2020, Biscione and Vahdati 2021). These issues concerning the territorial boundaries need to be further clarified by archaeologists and will not be discussed deeper here. In the context of this thesis, the term “Oxus civilization”, is used as a general description for the communities of southern Central Asia between 2400–1500 BCE including the core areas and the Kopet Dagh Mountains.

2.1.2. Chronology

Moreover, the chronological classification in southern Central Asia is not as clear as it would be desirable. Since a long time, archaeologists discussed the classification of the material of the particular periods in the different regions of Central Asia. Due to blurring boundaries, a clear distinction is often difficult (personal talks with Elise Luneau). Especially for the sites investigated in this study, the chronological classification led to problems, since German scientists follow a different chronology system for southern Uzbekistan and Tajikistan, than the French archaeologists established for southern Turkmenistan (cf. Teufer 2018: 77–78; Bendezu-Sarmiento and Lhuillier 2019: 99 fig. 1): implicating that the MBA graves from Ulug Depe belong to the Oxus occupation during the late MBA, and are contemporaneous to the MBA/LBA and LBA graves from Dzharkutan at the same time. This still ongoing discussion remains the matter of the excavators and cannot be solved here. Hence, this thesis will keep the terminology of the excavators for reasons of comparability with already published data. In general though it follows the most current state of research recently overworked and published in Lyonnet and Dubova 2021 (cf. tab. 2.1).

Of particular importance is the new correlation between the Namazga periods and the absolute chronological dates. The MBA and LBA layers are often hard to seperate since architectural structures were used continuously. But the pottery is distinguishable and can now be connected to the reworked absolute dates. The material from Central Asia studied here belongs thus to:

- the Namazga IV period (NMG IV), dating between 2800 and 2400 BCE, correlating to the Early Bronze Age (EBA)
- the Namazga V period (NMG V), dating between 2400 and 2000 BCE, correlating to the Middle Bronze Age (MBA)
- the Namazga VI period (NMG VI) dating between 2000 and 1700/1600 BCE, correlating to the Late Bronze Age (LBA)
- and the Early and Middle Iron Age (EIA, MIA), dating between ca. 1500 and 1000 BCE (Yaz I) and ca. 1000–540 BCE (Yaz II)

Dates	*Anau/ NMG*	*Gonur*	*Steppes*	*Hissar*	*Sarazm*	*Mundigak*	*Mehrgarh*	*Nausharo*
1500		III						
1600								
1700		II	Tazabag'jab Fedorovo					
1800	VI							
1900							VIII/Sibri	
2000		I	Petrovka/ Sintashta				Quetta hoard	IV
2100	V			III C				III
2200			Poltavka					
2300							Hiatus	
2400				III B	IV			II
2500								
2600	IV				III		VII C	I D
2700				III A		IV		
2800					II		VII, A, B	I A–C
2900				II B				
3000	III				I		VI	
3100						III		
3200							V	
3300						II		
3400								
3500	II			II A				
3600								
3700						I, 3–4	IV	
3800								
3900	I					I, 1–2		
4000							III	

Table 2.1: Comparative chronology of Central Asia after Lyonnet and Dubova 2021: 8 table 1 with references.

For the sake of a certain uniformity in this thesis the general terms of e.g., "Late Bronze Age" and "LBA" in correlation to the absolute dates will be used during the discussions, instead of the local terminology of "Namazga". Based on the absolute dates a comparison between the sites in Central Asia and Iran is possible, as the Iranian Plateau follows a different chronology as well, which differs among scholars. Especially the stratigraphic sequence of Tepe Sialk is still lively discussed (e.g., Pollard et al. 2013; Heidari 2016; Fahimi 2019; Fazeli and Nokandeh 2019), and could not be fully reconciled yet. The chronological sequence of Tepe Sialk used here will follow the work of Fazeli and Nokandeh for the early periods (cf. tab. 2.2 and Fazeli and Nokandeh 2019: 6 table 2.1 conform also with Helwing 2010: 8 tab. 1) and of Fahimi for the later periods (Fahimi 2019: 342 fig. 5). Hence, the material from Tepe Sialk studied here belongs to these periods: Sialk I corresponds to the Late Neolithic to Chalcolithic periods dating ca. 6000–5200 BCE. Sialk II includes the Transitional Chalcolithic periods dating to ca. 5200–4600 BCE, while Sialk III comprises the Chalcolithic period dating between 4000 and 3400 BCE. Sialk IV (ca. 3400–2900) correlates to the Early Bronze Age Phase, but was not studied here, as well as the later Bronze Age phases (ca. 3000–1500 BCE). After a gap of occupation, Sialk V period corresponds to the Early Iron Age (Iron I, ca. 1200–1000 BCE) followed by the Sialk VI period, the middle Iron Age (Iron II) dating to ca. 1000–800 BCE. A correlating table of the chronological periods of the sites investigated in this study can be found in chapter 3.1.

Period BCE		The Qazvin plain	The Tehran Plain	The Kashan Plain	Damghan/Shahrud
Early Bronze II (Kura-Araxes) 2900–2000		Šizār, Dorānābād	Arasto Tappe	?	Hesār III
Early Bronze I (Proto-Literate) 3400–2900		Šizār	Tappe Sofalin* Šogali*	Arismān C Sialk IV	Hesār IIB
Late Chalcolithic 3700–3400		Qabrestān III–IV* Esmā'il Abād* Šizār	Češme-'Ali* Tappe Pardis* Sofalin* Šogali*	Arismān B Sialk South III 6–7	Hesār IIA
Middle Chalcolithic 4000–3700		Qabrestān II Šizār	Češme-'Ali* Tepe Pardis Šogali*	Sialk South III 4–5	Hesār IC
Early Chalcolithic 4300–4000		Qabrestān I	Češme-'Ali* Tappe Pardis Šogali*	Sialk South III 1–3	Hesār IA-IB*
Transitional Chalcolithic	Late 4600–4300	?	Češme-'Ali* Esmā'il Abād* Kara Tepe* Šogali *	?	Šir Ažiān* Aq Tappe*
	Early 5200–4600	Ebrāhim Ābād Zāġe	Češme-'Ali Tepe Pardis Esmā'il Abād	Sialk North*	"Češme-'Ali" Phase*
Late Neolithic	Late 5600–5200	Čahār Bone Ebrāhim Ābād	Češme-'Ali* Tappe Pardis	Sialk North I 4–5*	Sang-e Čakmāġ
	Early 6000–5600	Čahār Bone	?	Sialk North I 1–3*	"Djeitun" Phase

Table 2.2: Comparative chronology of the Central Plateau after Fazeli et al. 2009: 10 table 7, *without ^{14}C dates.

2.1.3. Initial Situation in southern Central Asia

Due to the geographic situation between Iran in the west, the Indus Civilizations in the southeast, and the Eurasian pastoral communities in the north, Central Asia exhibits a colorful mix of different ethnics, languages, cultures, and gene pools (e.g., Hiebert and Lamberg-Karlovsky 1992; Lamberg-Karlovsky 1992; Hiebert 1994; Kircho 2014). Recent paleogenetic studies exhibit genetic ancestries in Iran, Anatolia, the Levante, and the northern steppes (Quintana-Murci 2004; Heyer et al. 2009; Haak et al. 2015; Damgaard et al. 2018a, b; Narasimhan et al. 2019). The location between harsh deserts and high mountain ranges formed natural passages, which enabled dynamic exchanges among the populations since

Neolithic times (e.g., Thomalsky et al. 2013), and later became the "Silk Road" or the historical *Great Khorasan Road* (Litvinskij 1998; De la Vaissière 2002; Wilkinson 2014). Central Asia represents therefore one of the regions where mobility and migrations of human populations had a deep impact on the development of the cultural communities (Khazanov 1984; Kohl 2007; Kuz'mina 2007). The strategically favorable location caused intensive cultural transformations of the different populations through all times and played a key role in linking cultures (Luneau 2016).

The Chalcolithic period (ca. 5000–4300 BCE) was characterized by small settlements with mainly one-room mud brick houses suggesting that core families or family clans constituted the basic social unit. Subsistence economies relied on small-scale farming and herding. With the beginning of the Early Bronze Age (ca. 2800–2500 BCE) remarkable changes towards a more complex social structure took place (Masson 1981; Kohl 1984, 2007). Villages grew larger, coming along with an increase in animal husbandry and the beginning of systematic irrigated agriculture. The first industry of cold hammered copper was established as well as the earliest fortification systems. Interregional trade is attested by the presence of exotic materials such as turquoise and lapis lazuli (Klopina 1981; Masson 1981; Kohl 1984, 2007; Lecomte 2013). Through the excavations at the graveyard of Farchor in recent years, the Early Bronze Age could finally also be verified in southern Tajikistan (Teufer et al. 2015; Vinogradova 2021).

Towards the end of the 3rd mill. BCE two main cultural entities coexisted in Central Asia: In the north – present day Southern Siberia, Kazakhstan, Kyrgyzstan and northern Uzbekistan – was the steppe territory, occupied by the Andronovo Cultural Community (ca. 2000–1200 BCE, c.f. Kohl 2007; Bendezu-Sarmiento et al. 2007; Kuz´mina 2007; Frachetti 2011; Luneau 2017). In the south – present-day southern Uzbekistan, Turkmenistan, Tajikistan, northern Afghanistan, and northeastern Iran – was the zone occupied by the Oxus Civilization or GKC (ca. 2400–1500 BCE, c.f. Hiebert 1994; Salvatori 2008a; Francfort 2009; Lamberg-Karlovsky 2013; Teufer 2015; Luneau 2014, 2019; Lyonnet and Dubova 2021). The Andronovo "tribes" are characterized by a mobile pastoralism, mainly based on animal husbandry of cattle and sheep/goat, but also on systematic agriculture and crop cultivation (Kuz´mina 2007; Frachetti 2012; Luneau 2017). Recent excavations of graves in Kumsai in southern Tajikistan discovered that the presence of material related to the Andronovo tradition coexisted with graves of the Oxus tradition. Some burials also show the merge of both traditions (e.g., Kanuith et al. 2006, Luneau personal communication[4]). The appearance of the Oxus Civilization is still not fully understood (Luneau 2017, 2019), but archaeological remains evidence urbanism and population growth, which caused major changes in southern Central Asian societies also affecting different aspects of the local subsistence economies (Francfort 1989; Moore et al. 1994; Nesbitt and O' Hara 2000; Francfort and Lecomte 2002; Lamberg-Karlovsky 2013). Organization systems grew into complex, centralized structures, larger settlements acted as structuring units for the surrounding land and main localities, where trade and distribution of human and animal food took place (Biscione 1976; Kohl 1984; Salvatori 2008b; Spengler et al. 2014a, 2016b). Agricultural developments were promoted through sophisticated irrigation systems and opened up new territories (e.g., Lisitsina 1969; Gentelle 1989; Hiebert 1994a,b; Nesbitt, O'Hara 2000; Francfort and Lecomte 2002). This period witnessed the growth of the first structured urban centers – among the biggest, Gonur Depe, Namazga Depe, Altyn Depe, Ulug Depe, Sapallitepa, and Dzharkutan – with thousands of inhabitants (cf. fig. 1.1, cited in order of the sites: Sarianidi 2007, 2005; Khlopina 1981; Masson 1981; Bendezu-Sarmiento 2013; Lecomte 2013; Askarov 1973, et al. 1983; Bendezu-Sarmiento et al. 2013; Huff et al. 2001; Huff 2010). The constructions of huge fortification systems and the archaeological and anthropological evaluation of more than

[4] https://www.dainst.blog/archaeology-in-eurasia/kumsaj-tadschikistan-bronzezeit/

4000 graves argue for a strong social inequality and the existence of a hierarchical structure within these societies (Askarov et al. 1993; Salvatori 2008b; Teufer 2015; Avanesova 2016; Bendezu-Sarmiento and Lhuillier 2016; Dubova et al. 2018).

Especially the huge number of exotic artefacts attracted the attention of archaeologists, as they were obviously "imported or, more probably, made locally under strong foreign influences by itinerant craftsmen – which point to an "interaction sphere" of unprecedented level" (Lyonnet and Dubova 2021: 14). For a better understanding Possehl created for this phenomenon the term "Middle Asian Interaction Sphere" or MAIS (Possehl 2002; and cf. fig. 2.2). A dynamic network of cultural interaction and interregional exchanges and trades, connected the Indus Civilization, the Syro-Anatolian area, Mesopotamia, the Iranian Plateau, the Persian Gulf region, and the Eurasian Steppes (Amiet 1986; Possehl 2002, 2007; Kohl 2007; Kaniuth 2010; Frachetti and Rouse 2012; Wilkinson 2014; Bonora 2021).

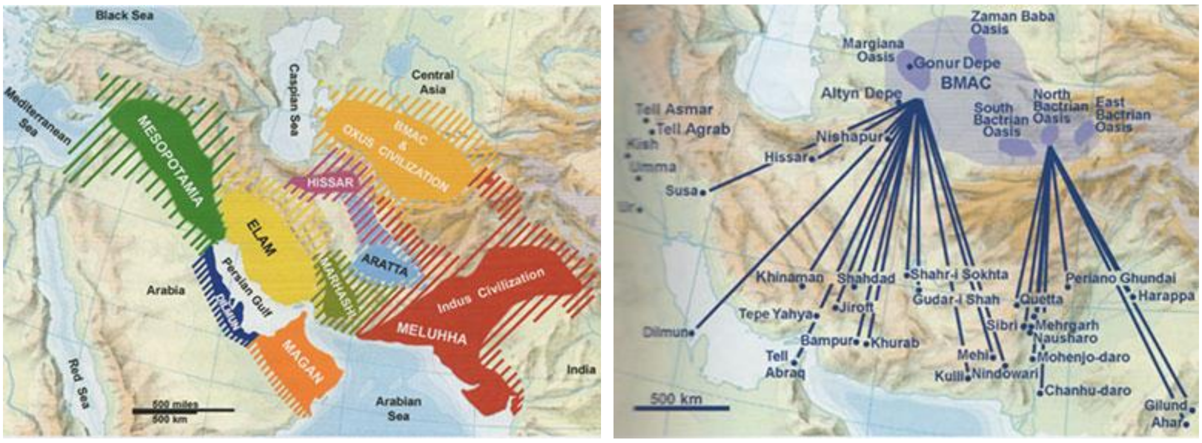


Fig. 2.2: Left: Middle Asian Interaction Sphere (MAIS). Right: Sites across Middle Asia have revealed BMAC, or BMAC-like, artifacts after Possehl 2007: 41 fig. 4, 5 with references.

The fall and disappearance of the Oxus Civilization is characterized by new significant changes concerning various sociocultural aspects (Luneau 2014, 2021), which extended at the beginning of the Early Iron Age. Around 1500 BCE, after a short, gradual transition period, without any sign of violence, an economic and ideological shift took place. Southern Central Asia was then occupied by a mosaic of smaller cultures, known as the "Yaz I Cultures" or *Handmade Painted Ware Cultures* (Lhuillier 2013a, b, 2016). It spread over a territory larger than the Oxus territory coming along with a radical transformation of the settlement pattern (Lhuillier 2013a). Archaeological remains evidenced a pattern back to smaller villages, small-scale, de-centralized organisation units and a more basic lifestyle, often related to adaptations of livestock husbandry and farming practices (Biscione 1976; Lecomte 2007b, 2011; Lhuillier 2013a, b, 2016). A specific handmade pottery, decorated with red geometric designs is characteristic of these periods (Lhuillier 2013b). Luxury goods, glyptic and all other forms of iconography are replaced by utilitarian objects, mostly agrarian tools. Material culture and architectural simplicity do not give any indication concerning the social organization; a social homogenization has been suggested (Bendezu-Sarmiento and Lhuillier 2015). But other expressions of social inequality may have existed, leaving no traces in archaeological remains.

The communities again evolved towards a new material culture during the pre-Achaemenid period, known as Yaz II (ca. 1000–540 BCE), and during the Achaemenid period as Yaz III culture (ca. 540–330 BCE). Although a continuity of the settlement pattern and social organization is evidenced, a new evolution of the material, especially in pottery, is obvious (Lhuillier and Boroffka in press). Several hypotheses, which are not mutually exclusive, could be considered: an internal evolution (as a response to climatic changes or an evolutionary adaptation due to an internal weakening of the Oxus Civilisation), or the arrival of a new population being the most popular explanations (Vidale 2017). Many questions remain, the theories on cultural roots, the intensity and impact of migration, as well as subsistence strategies and possible land use cause lively discussions among scholars. Most scientists assume a wide variation and the merging of different economical strategies, which are related to the mobility of humans and animals (Barnard 2008; Salvatori 2008b; Frachetti 2011, 2012; Lamberg-Karlovsky 2013; Luneau 2017; Rouse and Cerasetti 2018).

2.1.4. The Iranian Plateau

The earliest archeological remains on the Central Plateau date back to the lower Paleolithic (ca. 100.000 BCE), where people lived in shelters and caves (e.g., Coon 1951; Biglari et al. 2006, 2007; for a summary cf. Conard et al. 2013: 29–32). All known Paleolithic and early Neolithic sites are located in regions with good water sources and arable land, where rain-fed agriculture was possible. Moreover, natural opportunities like a high offer of wild plants and animals, favored a sedentary way of life, but people continued to gather and hunt (Hole 1987; Bernbeck 2001; Mathews and Fazeli Nashli 2022). Settlements were few and often widely spread along the fertile mountain valleys of Zagros, Elburz, and Kopet Dagh. The emergence of farming communities is evidenced on the Iranian Plateau since the 10th mill. BCE, documented at sites like Sheikh-e Abad (Matthews et al. 2013), Abdul Hossein and Ganj Dareh in the Kermanshah region (Smith 1974; Willcox 1978; van Zeist et al. 1984, Thomalsky 2014), or Tepe Sang-e Chakhmaq in Shahrud province (Masuda et al. 2013; Mashkour et al. 2014; Roustaei et al. 2015). Archaeological remains in Sheikh-e Abad provided no architecture in the first stages, but included traces of local wild plants, like almonds, pistachios and lentils, and a variety of wild animal bones mainly of wild sheep and goats (Whitlam et al. 2018). The later stages (around 8000 BCE) displayed architectural remains in form of small huts made of mud-bricks or *chineh* (Matthews et al. 2013). The introduction of clay as raw material for pottery or figurines, is evidenced soon after the earliest settlements emerged (cf. Weeks 2013). The continuous sequence from the Aceramic Neolithic (PPN) to the Neolithic (PN) is well documented also in Tepe Sang-e Chakhmaq, in the north-eastern area of the Iranian Highland (Masuda et al. 2013; Thornton 2013b; Roustaei et al. 2015; Roustaei and Mashkour 2016). The phenomenon of increasing sedentism is remarkable throughout the whole Iranian Plateau around 6000 BCE. The reasons are not clear yet, but the appearance of a certain economic complexity is a general characteristic of this time period (cf. e.g., Hole 1987; Bernbeck 2001; Weeks 2013; Roustaei and Mashkour 2016, Mathews and Fazeli Nashli 2022). The development of irrigation systems for a secured food provision, might have been an additional reason, also enabling the expansion into more arid regions. According to Hole a typical Neolithic settlement consisted “of only 50–100 inhabitants who lived in houses of unbaked brick, or in tents or brush shelters, and kept their livestock in pens. The form of the houses and their nucleation into small settlements has characterized rural villages until the present, some 9,000 years after they first appeared. During the Neolithic there is no apparent evidence of social differentiation among individuals, nor are there temples or other special structures” (Hole 2004: 2). The Neolithic sites on the Central Plateau revealed obsidian from central Anatolia, turquoise and lapiz lazuli from Afghanistan, and shells from the Persian Gulf, indicating widespread contacts already in the 7th/6th mill. BCE (Bernbeck 1995). Paleogenetic studies of early Neolithic human genomes from Abdul Hossein and the Wezmeh Cave in the Zagros Mountains revealed no relation to

Anatolian or European genomes, instead they were identified as a previously undescribed Neolithic population (Broushaki et al. 2016). The results showed a spreading of Iranian agriculturalists eastwards, as hunter gatherer populations in Neolithic SW-Asia adopted farming through an expansion from the Zagros region (Broushaki et al. 2016). Another study documented at multiple sites in the Indus valley a distinctive mixture of ancestry related to the Zagros agriculturalists (Narashiman et al. 2019). Recent investigations proved the existence of long-distance trade routes for raw materials like lapis lazuli, or turquoise and therefore a dynamic exchange between Afghanistan and Mesopotamia since the 7th mill. BCE (Thomalsky et al. 2013). Already in the 4th mill. BCE these inter-regional trade routes expanded from Afghanistan in the east to Egypt in the west, and from the Kazakh steppes in the north to the Indus valley in the south (cf. Thomalsky et al. 2013: 200 fig. 1). Many authors consider the formation of these trade networks along permanent established routes as the reasons for the emergence of complex society structures, respectively the rise of urban centers on the Central Plateau (e.g., Helwing 2006; Fazeli and Nokandeh 2019; Neumann forthcoming). Fazeli et al. (2009: 1–2) summarized the transition from pastoral hunting and gathering to sedentary agrarian economies during the Transitional Chalcolithic with a systematic pattern of: herding and breeding of domesticated sheep, goats, and cattle (Mashkour 1999); the development of irrigation systems for organized crop cultivation (Gillmore et al. 2009); the specialization in crafting industries with differentiated crafting areas; the beginning of standardized production; and according to mortuary practices, a certain social differentiation. The sociocultural changes are often associated with the influence of other, neighbored communities. The establishment of long-distance trade routes and connections is characteristic for this time period as well (e.g., Hole 1987; Bernbeck 2001; cf. fig. 2.3; Mathews and Fazeli Nashli 2022).

As the urbanization started in the second half of the fourth millennium BCE (e.g., Petrie 2013; Meyer et al. 2020), the Central Plateau is characterized by the appearance of the so-called proto-elamite horizon. The region maintained mutual connections to south-western Iran and the elamite capital Susa (cf. Potts 2016), as well as to the south and sites like Tal-e Malyan in Fars province (e.g., Sumner 2003), or Tepe Yahya in the Kerman region (e.g., Mutin, Lamberg-Karlovsky 2013). The term "proto-elamite" describes "a chronological period, a set of shared material culture, and/or a shared script or language. These attributes, however, do not allow a closely circumscribed social unit, culture, or even a political or ethnic group" (Helwing 2013: 93). Hence, archaeologists still discuss the definition of a proto-elamite period or rather phenomenon or horizon. Characteristic for the proto-elamite period is the development of an urban lifestyle, with complex administration structures, and a distinct system of division of work (Helwing 2013). According to the archaeological remains, the rise of the proto-elamite horizon correlated with the eastward expansion of the early states of lowland Mesopotamia. The evidence of "Uruk" influences, such as the mass-produced bevel-rim bowls, or seals and clay tablets with proto-elamite characters, were found in numerous sites: among the biggest e.g., Susa, Godin Tepe, and Tepe Sialk in the west, and Tepe Yahya in the south, representing the earliest complex urban societies of highland Iran (cf. Ghirshman 1938; Young 1969; Potts 2001). Although external cultural influences on the prehistoric highland Iranians are evidenced since the Late Neolithic periods, reflecting the presence of different cultural communities, it stays questionable how deep these foreign influences were adapted into the way of life of the local people and their daily life organization. The situation in Godin Tepe (Godin V cf. Young 1969, Weiss and Young 1975; Gopnik and Rothman 2011) reflects the concomitant presence of two different material cultures but in different spaces: on the one hand the local pottery, which was more frequent in the lower town (BKC), on the other hand the Uruk influenced pottery and glyptic tradition on the citadel (cf. Weiss and Young 1975). Potts (2009) suggested a possible adaptation of nutrition habits through the introduction of the bevel-rim bowls, which are often seen as unit of measurement, respectively vessels for portioning food, but processes of economic adaptations, culinary exchanges or dietary changes remain largely unknown. Miller (1990) mentioned one interesting point concerning the diversity of barley in correlation with the changes brought by the Uruk expansion. In the 4th mill. the more original form of 2-row barley was predominantly grown in the mountain regions of Iran, as it is more robust against climatic impacts and extreme habitats. Whereas in the lowlands of Mesopotamia, where the surroundings consisted of a dry, steppe-like environment, 6-row barley was cultivated, since artificial irrigation was necessary anyway. 6-row barley is more sensitive, but also more productive. Remains of 6-row barley were found on the citadel of Tall e–Malyan as well as Godin Tepe, so she concluded, that the residents of the citadel in Godin and Malyan adapted grain cultivation techniques from the Mesopotamian lowlands (Miller 1990: 5). Following Weiss and Youngs suggestion "that the foreigners, or the element of the local society most influenced by foreign ways or most closely in contact with foreigners, were living in somewhat isolated circumstances on the summit of the mound, while the people occupying the lower town, though touched by these outside influences, generally pursued older, more local cultural patterns, perhaps in more traditional ways" (Weiss and Young 1975: 13–14). The question remains how deep the cultural influences really impacted the local traditions and people in terms of agricultural techniques and economic strategies. It also remains open how these cultural influences looked like, whether it was the spread of material and a bureaucratic system, adapted by the locals, or if two different entities existed, "living somewhat isolated", or the merge of both.

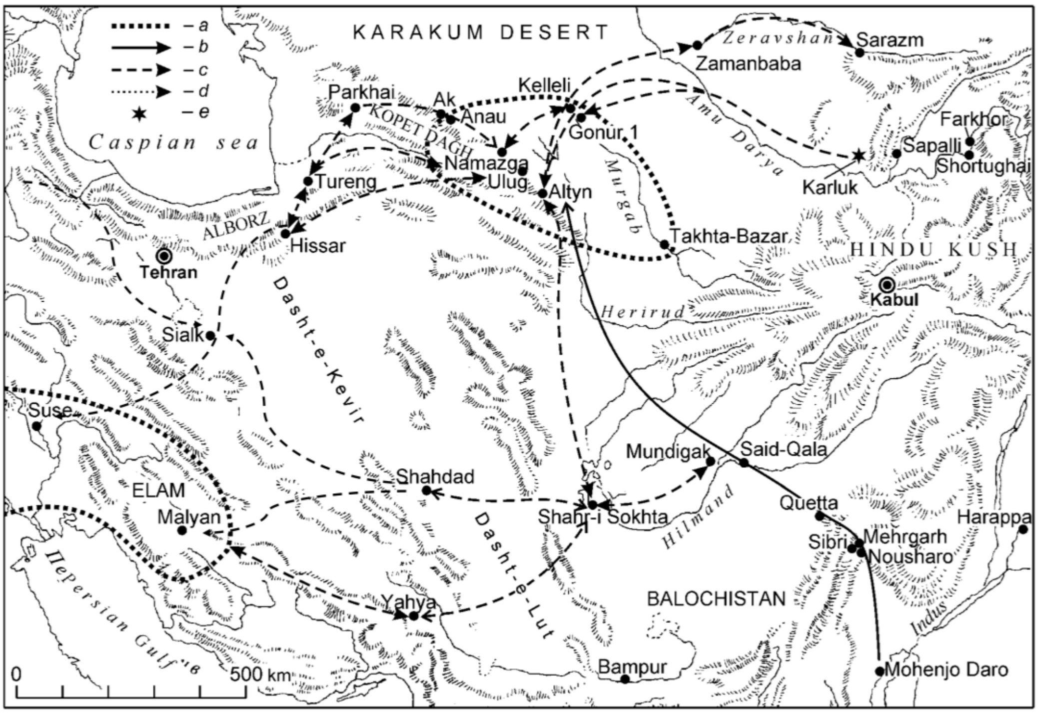


Fig. 2.3: Cultural interactions in the 3rd Mill. BC, a: proposed cultural regions; b: imports of Harappan seals and objects; c: cultural contacts and trade; d: proposed contacts manipulated after Kircho 2016: 1 fig 1.

2.2. Methodical background

2.2.1. History and current state of research

The beginning of applications of isotopic variations were established during the 50s and 60s of the last century by geochemists and biochemists. The first steps in archaeological questions were undertaken in the 70s by Smith and Epstein (1971) on carbon ratios of higher plants, followed by Vogel and van der Merwe (1977, 1978), and DeNiro and Epstein (1978) on carbon isotope metabolism in human collagen. Also, the distribution of nitrogen isotopes (DeNiro and Epstein 1978), and trophic level changes of marine and terrestrial animals (Schoeninger and DeNiro 1984) were established in these years. Krueger and Sullivan (1981, 1984) made first distinctions concerning the chemical phases in modern and fossil bones and the carbon isotope fractionation between diet and bones. The first investigations on prehistoric farmers and herders were carried out by Ambrose (1986) and Ambrose and DeNiro (1986). Also, first remarks on the impact of climatic issues were published in these years (Ambrose and DeNiro 1987). A detailed overview of further investigations all over the world is given by Katzenberg (2008: 413–415) and Gerling (2015: 44–45). Due to an enormous increase of isotopic studies in the last 20 years, especially on methods applying nitrogen and carbon isotopes of different archaeological contexts, only a summary of studies of surrounding regions will be given in the following, which are relevant to this thesis. The first isotopic investigations on steppe pastoralists in Central Asia were undertaken by O´Connell et al. (2003) on nutrition patterns of Eolithic to EIA populations in central Kazakhstan. Earlier and in the meanwhile well investigated are the Russian areas of Lake Baikal and southern Siberia, where Lam (1994) examined evidence for change in dietary patterns during the Baikal Neolithic. It was followed by studies of Katzenberg and Weber (1999) about the ecology and paleodiet in the Lake Baikal region of Siberia and later about the reconstruction of paleodiet of Early Bronze Age Siberians (Katzenberg et al. 2009). Nutrition pattern of prehistoric populations from southern Siberia were analysed by Svyatko et al. (2013), while Murphy and colleagues (2013) studied dietary components of Early Iron Age communities in this region. To the east Zhang and colleagues investigated dietary habits and millet consumption of Bronze Age communities in Xinjiang, western China (Zhang et al. 2009, 2010; Zhang and Li 2006; Zhang and Zhu 2011). The subsistence pattern of Bronze Age populations in the northern Kazakh steppes were studied by Ventresca Miller et al. (2014, 2018, 2020), while Lightfood and colleagues studied dietary diversity in Bronze Age communities in the central Kazakh steppes (Lightfood et al. 2013, 2015, 2016). In the meanwhile, the regions of the Caspian steppes and the northern Caucasus were systematically studied. Investigations on the seasonal practice, paleodiet, and climatic impacts on sedentary and pastoral populations were performed by e.g., Shishlina (et al. 2009, 2012, 2017), Gerling (2013, 2015), Hollund et al. (2009), Higham et al. (2010) and Knipper et al. (2020). Farming activities and dietary interferences of Neolithic and Bronze Age human and animal populations in the southern Caucasus were analysed by Messager et al. (2015) and Herrscher et al. (2018). Fundamental studies on nitrogen and carbon isotopes in Iran and southern Central Asia were undertaken by Bocherens, Mashkour and colleagues (2000) on faunal remains dating from Neolithic to Iron Age in the Qazvin Plains (Zagheh, Qabrestan and Sagzabad) on the Central Iranian Plateau, and from Geoktchik Depe, an Iron Age and Islamic site in southwestern Turkmenistan (Bocherens et al. 2006). Due to a detailed description of the different elements of the trophic groups and an exemplary ensemble of investigated animal taxa, they established the isotopic baseline in the region, which is irreplaceable for this work. Concerning nutrition studies in Iran, diachronic studies on the human population from Tepe Hissar in north-eastern Iran, including carbon and nitrogen analyses, were undertaken by Afshar (2014). A general investigation on isotopic ecology of humans from different sites and periods in ancient Iran were carried out by Rameroli et al. (2010). Another study, conducted by Iranian colleagues focused on paleodietary patterns of the IA population in Gohar Tepe (Sheikh Shoaee 2009; Sheikh Shoaee and Mousavi Kohpar 2017), as well as dietary gender differences (Sheikh Shoaee and Niknami 2018). Recent results were obtained by an international team lead by A. Vahdati and R. Biscione, who conducted several excavations at a new BMAC site in north-eastern Iran, Tepe Chalow on the southern foothills of the Kopet Dagh (Vahdati et al. 2019). Isotopic analyses on the diet of this population were performed, but not published yet (Soltysiak et al. submitted). The results were kindly provided by Arkadiusz Soltysiak, and are of great importance to this study, as Tepe Chalow represents another BMAC site in the direct vicinity of Ulug Depe.

Since an excellent summary of the history of research and applications of strontium isotopes in archaeological research is presented by Knipper 2004: 591–595, only a short summary there will be given here focusing on the Near East and Central and South Asia. The application of strontium and oxygen was established by geochemists since the 1950s when appropriate mass-spectrometers enabled precise measurements of isotopic compositions, focused on the dating of the formation of rocks. Ericson (1981, 1985) was the first who realized the potential of strontium isotopes for the reconstruction of mobility and land use of prehistoric societies. Luz (1984) and Longinelli (1984) recognized at the same time the potential of oxygen isotopes for the reconstruction of past climates through human and animal remains. Sealy and colleagues (1991) were not only the first who distinguished water and land-living animals based on their strontium isotopic composition; they were also able to identify the land-living animals according to the soil their food grew on. In the following years several studies on the dynamics of populations and migration patterns were undertaken (among many other cf. Price et al. 1994a, b, 2000, 2001, 2002; Sealy and Armstrong 1995; Grupe et al. 1997; Balasse et al. 2002, 2003; Burton et al. 2003; Bentley et al. 2004; Bentley and Knipper 2005; Bentley 2006). Methodical approaches on diagenetic processes, the impact of environmental conditions and preservation, respectively the grade of destruction of archaeological material represents an always present problem for all researchers. Essential studies in this field were undertaken e.g., by Budd et al. (2000), Hobbes et al. (2003) Tütken (2003, 2004, 2010), Maurer et al. (2012), and Styring et al. (2019). Many studies all over the world were carried out on the mobility of humans and animals, it would be too much to mention all the researchers here, although they for sure obtained elementary results and would deserve it. In any case the fundamental work of Price and his colleagues should be mentioned, who established the isotopic application on archaeological questions (1994a, b, 2000). His school generated scholars whose work extended our knowledge immensely, especially in methodical developments (Price et al. 2002; Knipper 2004). Models of seasonal mobility of prehistoric herders were obtained (Balasse et al. 2002), as well as migration patterns on prehistoric humans all over the world (e.g., Price et al. 2001, 2004). In terms of oxygen analyses fundamental research in questions of animal management, seasonal feeding practices and seasonality of birth as well as weaning practices of domestic animals were undertaken by Balasse and colleagues (2002, 2003, 2006, 2007, 2012).

Although isotopic analyses based on strontium and oxygen are meanwhile an accepted and well-established tool in archaeology, the investigated regions in the Near East and Central and South Asia are still rare. Extensive studies about important neighbors in the Indus Valley were carried out by Kenoyer and scholars respectively Chase with colleagues. Kenoyer (et al. 2013) examined based on strontium analyses the connections between the Indus Valley and Mesopotamia. Later they went more into detail and studied the patterns of selective urban migration in the Indus Valley applying lead and strontium analyses (Valentine et al. 2015). Chase (et al. 2014) analysed faunal remains and the pastoral land-use of the Indus Civilization in Bagasra in the lower Indus Valley. Further east, a working group from Beijing University established the first bioavailable strontium map for China (Wang and Tang 2020) and examined the mobility of pre-Silk Road populations in the Pamir Mountains (Wang et al. 2016) as well as multi-approaches on populations in the Lop Nur region in Central China (Wang et al. 2020). To the southwest, intensive studies were carried out by Gregorizka (2013) on residential mobility and social identity during the EBA on the Arabian Peninsula. She included material from Bahrain, UAE, the Failaka Island and Tepe Yahya in Iran in her studies. In the northwest, Gerling (2012, 2013, 2015) analysed a huge ensemble of human remains from the Pontic Steppe and the Volga Region and wrote a very detailed PhD thesis on the mobility and subsistence pattern between the 4th mill. BCE and the 3rd cent. BCE. She obtained important strontium and oxygen ranges which will be relevant for following discussions. Closer and quite important for this work are the studies of Makarewicz and her students who for years advanced intensive studies on the pastoral communities in Central Asia (cf. Ventresca Miller and Makarewicz 2018). Based on strontium and oxygen analyses, they examined the mobility of Bronze Age populations from northern Kazakhstan (Ventresca Miller et al. 2017, 2018), as well as their subsistence patterns, pastoral land-use and seasonal animal management (Ventresca Miller et al. 2014, 2019a, b, 2020; Ventresca Miller and Makarewicz 2018). Further they studied the dietary connectivity of urban and nomadic humans along Central Asia's Silk Road (Hermes et al. 2018), and the millet cultivation and sheep/goats mobility along the Inner Asian Mountain Corridor (Hermes et al. 2019). Concerning the examination on strontium and oxygen isotopes, Iran and southern Central Asia remains a little bit a blank area. One study (not accessible outside of Iran) was performed on subsistence patterns based on strontium analyses of the Parthian and Sasanian site of Valiran in the suburbs of Damavand city east of Tehran (Azizipour et al. 2010). Several isotopic and trace elements analyses on obsidian from north-western Iran were examined by Abedi and colleagues (2018), but strontium analyses on human or animal remains are still rare. Kasiri and Karimi (2017) performed strontium and trace element analyses on Iron Age humans from the Blue Mosque in Tabriz. Also investigated was site of Tepe Silveh, in Piranshahr region in north-western Iran revealing a high rate of immigrants of this Late Chalcolithic to BA site (Kasiri and Abedi 2020). Another study was performed on human remains from the Iron Age cemetery in Gohar Tepe on the Caspian Sea shore, also indicating a high rate of immigration for this site (Sheikhshoaee and Niknami 2018). Unfortunately, the Iranian data were conducted using a single collector ICP–MS (quadrupoles) and are therefore not comparable to the data discussed in this study.[5]

Not related to isotopic investigations but in any case, relevant to this thesis are paleogenetic studies (e.g., Heyer et al. 2009; Haak et al. 2015; Broushaki et al. 2016; Damgaard et al. 2018; Mehrjoo et al. 2019; Narasimhan et al. 2019). Results showed, that already multiple, genetically differentiated hunter gatherer populations in Neolithic SW-Asia adopted farming through an eastward expansion from the Zagros region (Broushaki et al. 2016). A large study of the Harvard University generated genome-wide data from 362 Bronze and Iron Age individuals from eastern Iran, Pakistan, Uzbekistan, Turkmenistan, Tajikistan, and Kazakhstan. They obtained a spread of genetic ancestry southward from the Eurasian Steppe, which correlates with archaeological expansion of pastoralist sites from the Steppe to Turan during the MBA. The Steppe communities were genetically mixed with the people of the Oxus Civilisation in the IA periods, but there is no evidence that the main Oxus population

[5] Because of having only one collector, this ICP-MS must change its voltage from AC to DC continuously to be able to measure different masses. As a result, the ^{87}Sr and ^{86}Sr are not measured at the same time with the same condition and therefore the precision of the $^{87}Sr/^{86}Sr$ cannot go beyond 4 digits. With the multi-collector ICP MS, such as the one used for this study, all masses are measured at the same time and therefore the NEPTUNE can provide the precision up to 6 decimal places.

contributed genetically to later South Asians. Instead, Steppe communities integrated farther south throughout the 2nd millennium BCE (Narasimhan et al. 2019).

2.2.2. Mobility and migration in theory

"Cultures do not migrate. People do!" (Anthony 1990: 908) is probably the most cited and famous sentence in terms of migration and perfectly reflects the discussion led among researchers, respectively not led. Because hardly tangible through archaeological remains, moreover unsystematic, migration was long ignored by archaeologists, or reduced to the spread of material cultures. Since isotopic and paleogenetic investigations offer scientists a reliable source to record regular and sporadic movements of humans and animals, this abstract matter became catchable and present-day indispensable. The subject of mobility and migration was never of more importance than today, where political events and economic, respectively ecological crises force millions of people all over the world to leave their homes and search for a better future in faraway countries. Per definition mobility and migration are existential elements of life on earth. All creatures are subject to migrations for reasons of foraging, space limitation, reproduction, evolutionary pressure, competition, climatic changes or maintaining power. Just as the migration of people and merging of cultures took place in any region of the world through all times. The definition of migration encloses all migratory movements, such as i.e., optional migrations like the search for better living, working or education conditions; structural migration like pastoralism and nomadism for the use of natural, economic and social resources; and even migrations forced by political, social and economic hardship (Nuscheler 1995: 44). The research history of mobility and migration concepts in archaeological contexts were described in detail by e.g., Anthony (1990: 896–897), Burmeister (2000: 539–540), Prien (2005: 11–48), Knipper (2004: 632–638). The underlying theories were discussed in great depth in Prien (2005: 12–23), a summary is provided by Gerling (2015: 73–82). The material investigated in this study turned out to be unsuitable for the application of theoretical models since the number of samples is too small and no comparative studies are available. Hence, only a short introduction into the general models will be given here.

The foundation for many following migration models was laid, when Ravenstein postulated eleven laws of migration in 1885, based on studies in Great Britain and the United States. He pointed out a mobility pattern, which included a usual short-distance pattern, but if long-distance migration took place, urban centres were mainly the destination of the migrants (Ravenstein 1885, 1889). Greabner shortly afterwards established the concept of cultural areas ("Kulturkreise") (Greabner 1911). Gordon Childe adapted this approach to postulate the expansion of Neolithic farming, he stated that migration and diffusion between defined societies were among the primary factors in intersocietal relations and social evolution (Childe 1925, 1930, 1958), but argued that archeological cultures nevertheless really do stand for "societies" (Childe 1958: 10). The fundamental problem of recording migration due to material legacies arises from the fact, that there is no inseparable connection between the human individual and material culture. For this reason, many different models and definitions exist in the meanwhile and were subject to different archaeological studies (e.g., Burmeister, 1998; 2000; Prien 2005; Wendrich and Barnard 2008; Anthony, 1990; 1992; 1997; 2000, Neustupný 1981, 1983; Chapman and Dolukhanov 1992; Chapman and Hamerow 1997a). Kristiansen postulated "Migration is likewise a covering concept of the movement of people, from whole populations to smaller groups" (Kristiansen 1989: 220). Anthony´s work is probably the most impacting. He summarizes "migration can be understood as a behaviour that is typically performed by defined subgroups (often kinrecruited) with specific goals, targeted on known destinations and likely to use familiar routes" (Anthony 1990: 895–896). Clark stated "migration is a relatively short-term, long-range process or event involving mass population movement" (Clark 1994: 306). Migration is generally seen as a necessary process, correlating with subsistence strategies like nomadism, or pastoralism. The terms of "mobility" and "migration" are often used simultaneously; indeed, both are tightly connected to each other and mobility patterns like nomadism or pastoralism are as well designated as structural migration. But in the general definition, different ways of movements are associated: migration generally implies a permanent spatial relocation of one or several individuals, subgroups, or complete populations (fig. 2.4; Clark 1994; Prien 2005), whereas mobility represents the wider variety of special movements and therefore the more complex dynamic interactions.

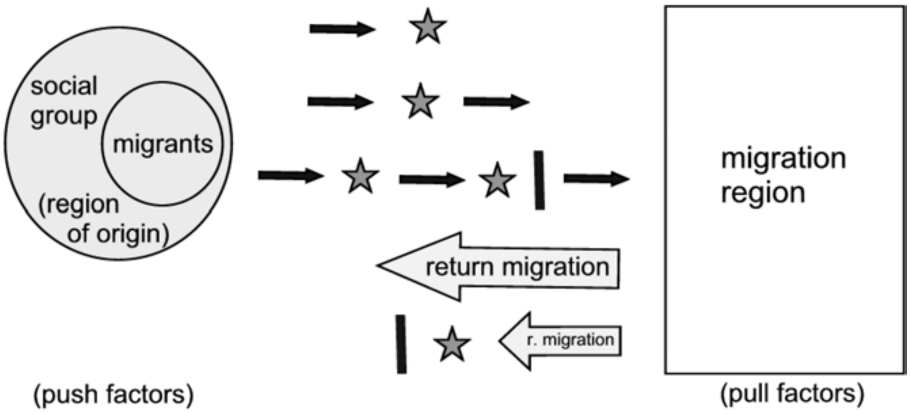


Fig. 2.4: General scheme of a migration process after Gerling 2015: 80 fig. 4.2. Stars symbolize temporary stays or residences.

Burmeister (2013: 36–37) defines mobility as a social or spatial change of single individuals or groups of people. Social mobility is subject of anthropological and applied social studies and will not be further discussed here. Spatial mobility concerns movements of humans and animals, but also the transfer of objects (Knipper 2004: 632). Two general types can be distinguished: the regular mobility in non-sedentary or partly sedentary societies; and the irregular mobility in sedentary communities (Champion 1990: 214). The definition stays vague since these two groups are not always clearly delimitable, and fully nomadic or entirely settled lifestyles can rarely be defined (fig. 2.5). Instead, a variety of different degrees of mobility exist, which were especially in Central Asia deeply connected to each other (Khazanov: 1984), not only through trade or the exchange of resources, but also through a genetic mix (Quintana-Murci 2004; Damgaard et al. 2018; Narasimhan et al. 2019). Sedentary communities are generally assumed to stay in one place, but including short term movements or sporadic mobility of subgroups like herders, traders, or craftsmen (Wendrich and Barnard 2008: 11). In connection with animal husbandry several transitional forms of mobility existed in sedentary communities, such as e.g., transhumance, sedentary pastoralism, or distant-pastures husbandry (Knipper 2004: 658). Mobility patterns like nomadism and semi-nomadism, as well as pure hunter-gatherer societies, are not assumed for the communities in southern Central Asia, and will therefore not further be discussed. A summary on the different lifestyles in the northern steppe communities is provided by Gerling (2015: 75–78), and a discussion of mobility and migration concepts in Central Eurasia is given by Frachetti (2011).

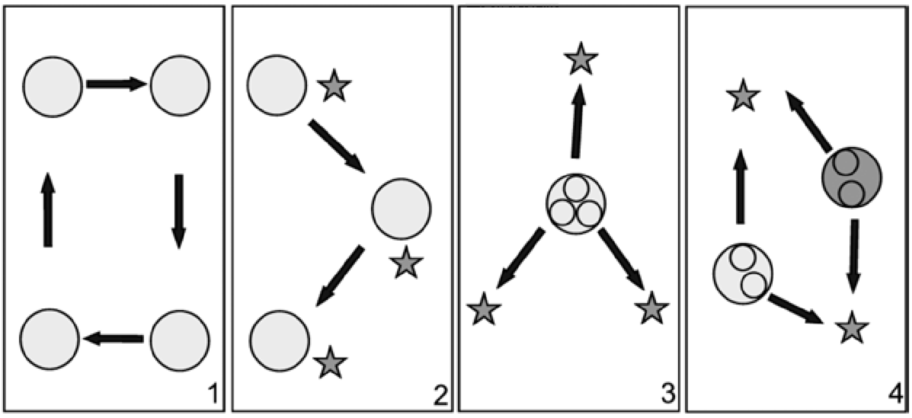


Fig. 2.5: General schemes of mobility patterns, where circles indicate social groups with small inner circles representing group segments and stars symbolize resources or pastures after Gerling 2015: 76 fig. 4.1.

2.2.3. Biological background

The mammals´ body is made of food and drink consumed during life, or better "you are what you eat" (Kohn 1999). The chemical differences of what we´re consuming during a lifetime are transmitted and recorded in the body tissues. The here relevant chemical elements carbon and nitrogen (C, N) enter the body mainly through food, while the elements oxygen and strontium (O, Sr) are mainly ingested through water (Tütken 2010: 33–36). Hence, the isotopic composition of body tissues as bones, teeth, nails, and hairs reflects the characteristics of the consumed food and ingested water.

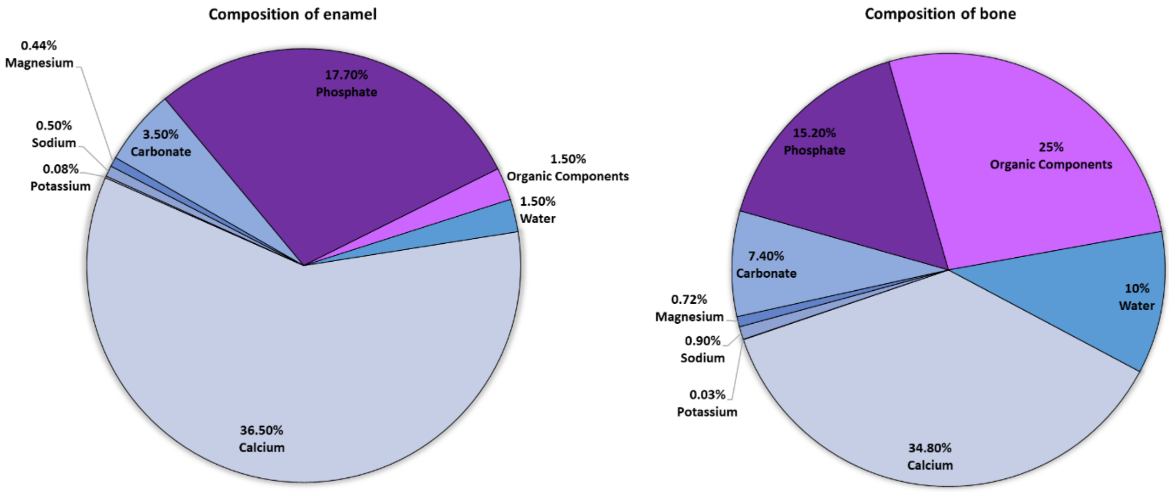


Fig. 2.6: Pie charts of the chemical composition of tooth enamel (left) and bone (right). Data taken from Chieruzzi et al. 2016: 3 table 1.

Bones are living tissue supplied with blood, and represent the stabilizing part of vertebra skeletons. They consist of a "soft" organic matrix (25%) and a "hard" bound mineral phase (65%) which enable a strong endoskeleton that is still light and flexible (cf. fig. 2.6). For an excellent description of the detailed histology and chemical composition of the body tissues and their metabolisms cf. Tütken 2003: 2–14, 2010: 33–36. The organic matrix is mainly buildup of the structural protein collagen, which consists of amino acids bound together in form of a triple helix known as the collagen helix. Collagen is synthesized out of the protein content in the food; the collagen helices mainly consist of carbon, nitrogen, and sulphur compounds, which accordingly determine the ratios of $\delta^{13}C/^{12}C$, $\delta^{15}N/^{14}N$ and $^{34}S/^{32}S$[6] isotopic composition of the collagen. The inorganic mineral phase mainly consists of calcium-phosphate compounds as Hydroxyapatite (60%) but also of other phosphatic minerals as Dahlit, Monetit, Whitlokit, and Brushit (Tütken 2003: 3). Hydroxyapatite [Calcium-hydrogen-phosphate $Ca_{10}(PO_4)_6(OH)_2$] is the basic substance of all hard tissues in the body and the main bone and tooth mineral (in enamel 95%, dentine 70%, bones 45%). It derives from body fluids bonding several trace elements as e.g., strontium (Katzenberg 2008: 416; Tütken 2010: 34) and is relatively simple extracted by chemical treatment, hence perfectly suitable for isotopic analyses.

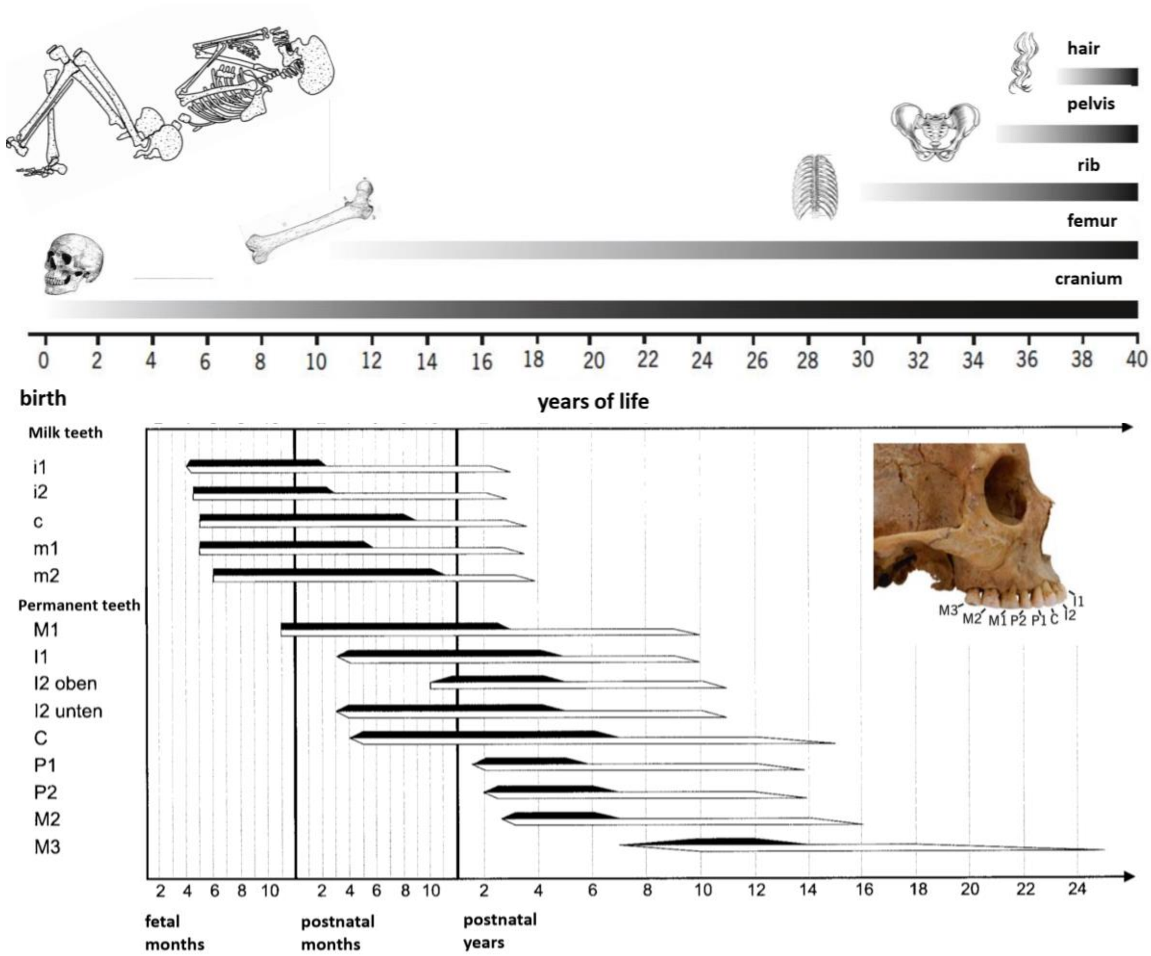


Fig. 2.7: Top: Formation periods of human bone tissues after Tütken 2010: 35 fig. 2. Bottom: Mineralization phases of tooth enamel (black) and dentine (white) after Knipper 2004: 602 fig. 6 and Tütken 2010: 35 fig. 2.

Bones are, in contrast to tooth enamel, remodeled throughout the whole life and store chemical information over the last years of life. The remodeling rate is depending on age, health and type of the bone, the isotopic composition of the bone reflects the long-term averages of the last years of life. The provided time span is depending on the analysed bone and can vary between 5 and 20 years (cf. fig 2.7; Tütken 2010: 35). The remodeling rate of cortical bones is 2–3% per year, while the rate of cancellous bones is around 24%. Hence, long-bones as femur, tibia or cranium have slow remodeling

[6] Analyses of sulphur have not been performed in this study and will therefore not be further discussed.

rates of 20 to 30 years, whereas ribs or pelvic bones have faster turnover rates of 5 to 10 years (Knipper 2004: 610–615; Tütken 2010: 35).

The teeth of mammals consist of a crown and a root. The crown, the visible part of the tooth, is consisting of a thin layer of enamel (1–2 mm), which is underlain by a thicker layer of dentine (2–3mm) (Hillson 1986, 1996, 2005). Tooth enamel is the hardest biologically formed tissue in the human body, consisting up to 97% of minerals such as apatite crystals. The highly mineralized tooth enamel has a much lower porosity than dentin and bone (Hillson 2005) and does therefore undergo little diagenetic processes, what renders them a very suitable material for isotopic investigations (cf. Tütken 2010). Humans undergo two phases of dentition: the primary teeth (deciduous or milk teeth) are already formed at the time of birth, erupting within the first 1–3 years of life. The secondary or permanent teeth also start formation before birth and replace the primary teeth between the ages of five and twenty (Hillson 1986; 2005). The first molars are the earliest and start mineralizing already before birth. The third molars are the last of the permanent teeth; however, they start variably between the 7^{th} and 14^{th} year of life and complete their genesis between the 12^{th} and 18^{th} (cf. fig. 2.7).

The mineralization of tooth enamel occurs continuously from the crown to the root. The same can be stated for dentine, although it follows a different metabolism. The mineralization of enamel takes place during the formation of the teeth in childhood and does not undergo any changes after. Therefore, this fixed elemental and isotopic composition reflects the food and drinking water consumed within the first years of life or childhood (Hillson 2005). Dentine builds up the most part of the root and the crown. Three types of dentine can be distinguished: primary, secondary and tertiary dentine. The structural organization and chemical composition of primary and secondary dentine are identical. But primary dentine represents the biggest fraction (cf. fig. 2.8) and is only synthesized until the root complete formation as it does not undergo remodelling after. On the other hand, secondary dentine, which is present only as a thin layer in the pulp, is synthesized at a lower rate than primary dentine and is continuously renewed during the whole life of the tooth. Tertiary dentin is the reparative form of dentine and synthesised only when the tooth undergoes pathological stimulations (Hillson 1996; Bleicher et al. 2015).

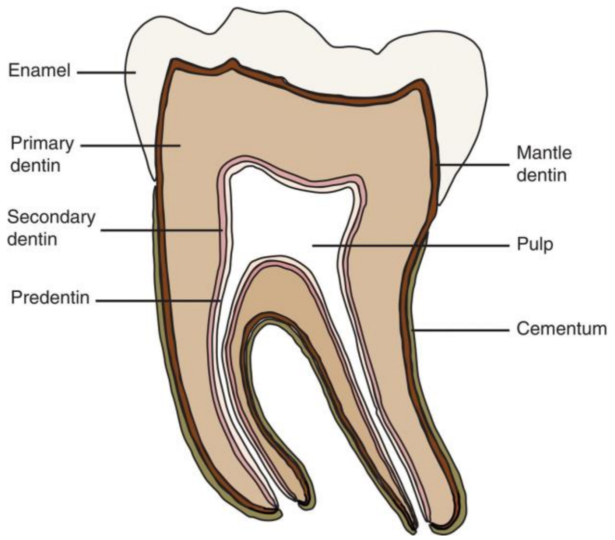


Fig. 2.8: General organization of a tooth after Goldberg 2014: fig.5.1.

2.2.4. Isotope analyses on archaeological material

Stable isotope analysis provides individual, quantitative evidence about past life. Human or animal body tissues reflect the isotopic composition of ingested food and water during lifetime. The fact that tooth enamel is synthesized during childhood and does not change afterwards, and that bones undergo a continuous modification during the whole life, allows to gather information on humans´ and animals' origin and mobility on the scale of lifetime (Sr, O). Furthermore, they enable the reconstruction of nutrition patterns of ancient populations (C, N), as well as the reconstruction of paleoenvironmental conditions (O, C) (fig. 2.9).

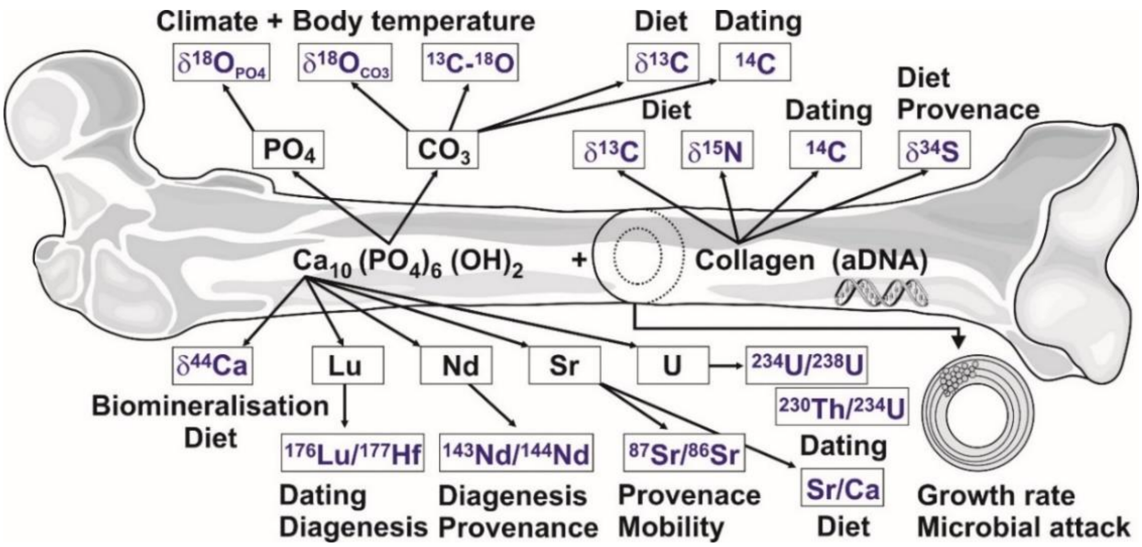


Fig. 2.9: Schema of elements and their isotopes in hydroxyapatite and the organic collagen matrix of bones which are relevant for nutritional and environmental reconstruction and their possible applications after Tütken 2010: 34 fig. 1.

2.2.4.1. Mobility and migration according to strontium and oxygen isotopes

The concept of mobility, respectively migration, is comprised of three distinct patterns, which can be identified through isotopic studies (Chapman and Hamerow 1997; Banard 2008). Long term migration, demonstrated by the movements of whole populations to a new region, which actually has more impact on the genetic diversity but can with luck be distinguished through isotope analyses (isotopes can only expose first-generation migrants). Lifetime mobility of single individuals or groups, including the movement between the place of birth to another place to live, can be clearly distinguished through isotopic studies. The same is true for yearly mobility or seasonal movements of single humans, groups, or populations. In the meanwhile, analyses of strontium ($^{87}Sr/^{86}Sr$) and oxygen ($^{18}O/^{16}O$) constitute a reliable method for tracking human and animal origins and mobility at a lifetime scale. Many studies were carried out to investigate and prove this approach on archeological material (among many others Ericson 1981, 1985; Longinelli 1984; Luz et al. 1984; Sealy and Armstrong 1995; Price et al. 1994a, b, 2002; Grupe et al. 1997, 2017; Poage and Chamberlain 2001; Knipper 2004; Slovak and Paytan 2011; Gerling 2015; Lightfood and O´Connell 2016; Ventresca Miller and Makarewicz 2018)

2.2.4.1.1. Basic Principle of $^{87}Sr/^{86}Sr$ isotopes

Strontium (Sr) belongs to the alkaline earth metals and is present in almost all rocks and soil types as a trace element in measurable contents. Strontium occurs naturally in four stable isotopes, of which three are not radiogenic (not evolved through radiogenic decay): ^{84}Sr (w0.56%), ^{86}Sr (w9.87%), and ^{88}Sr (w82.5%). ^{87}Sr is the only radiogenic daughter isotope of strontium, involving approximately 7.04% of total natural strontium. ^{87}Sr evolves through the radioactive decay of Rubidium 87 (^{87}Rb) with a half-life of 48.8 × 10^9 years (Faure 1986: 119; Stanley and Faure 1979). The ^{87}Sr content is thus correlated to the concentration of ^{87}Rb and influences the $^{87}Sr/^{86}Sr$ ratio. The more ^{87}Rb was present in the rock and the older the rock, hence the more time ^{87}Rb had to decay into ^{87}Sr, the higher is the content of ^{87}Sr. Regarding the earth's "only" approximately 4.6 × 10^9 years of history, the decay of ^{87}Rb into ^{87}Sr happens so slowly that it has no relevance to our "young" archaeological periods. Hence, the content of ^{87}Sr is measured against the content of the non-radiogenic ^{86}Sr isotopes to answer archaeological questions and can be considered as characteristic of the respective rock (Knipper 2004: 596–597). Old geological formations and felsic rocks, such as granitoids, are characterized by very high content of ^{87}Rb and have therefore a high $^{87}Sr/^{86}Sr$ ratio between 0.710 – 0.740 (e.g., Goldstein and Jacobsen 1988; Rudnick and Goldstein 1990; Fernandez et al. 2016). Nevertheless, old rocks or felsic rocks can reach values higher than 0.8 for rocks characterized by a very high ^{87}Rb content and low ^{87}Sr content resulting in a very high $^{87}Rb/^{87}Sr$ ratio. Younger rocks and basic rocks, like basalts, have a low ^{87}Rb content, resulting in lower $^{87}Sr/^{86}Sr$ ratios of 0.703 – 0.704 (Knipper 2004: 597; Bosch et al. 2014). At present the $^{87}Sr/^{86}Sr$ ratio of ocean water is 0.70918 (McArthur et al. 2000). This value is homogenous throughout the whole world. It is impacted by the weathering of the continental crust, volcanic activities and the dissolution of marine carbonates. The strontium content in the ground is depending on weathering minerals, ground and running waters, atmospheric precipitation and modern fertilizers (Faure and Mensing 2005).

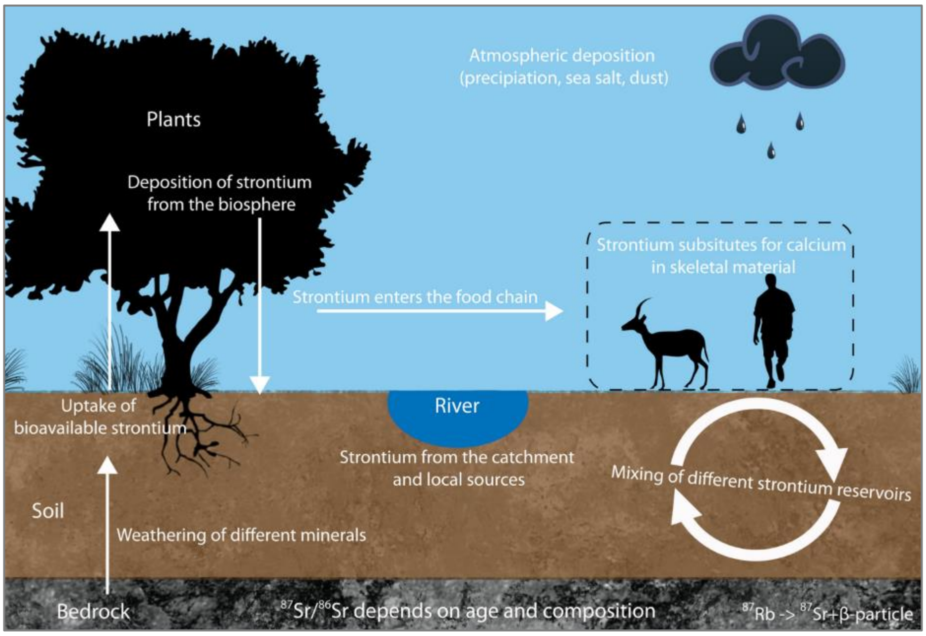


Fig. 2.10: Simplified sketch of the strontium cycle showing important processes that affect the strontium composition before it reaches the skeletal material of animals and humans after Willmes 2015: 25 Figure 1.1.

The ratio of $^{87}Sr/^{86}Sr$ in the mammals´ bodies depends on water sources and the mineral salts extracted from rocks by water (fig. 2.10). The water drunk and food eaten by an organism is thus directly connected to geological substrates of the habitat. Dissolved out of rocks by the groundwater strontium permeates through rivers and other water sources into the soils and therefore into the plants. Eaten by herbivores and omnivores it enters the human body and is incorporated into hydroxyapatite of hard tissues in substitution to Ca^{2+}. Strontium ions are chemically very similar to calcium ions (Ca ions) and can replace them in the crystal lattice. Although strontium does not have a relevance to mammals' metabolisms, a certain percentage is incorporated in different body tissues throughout the whole life and can be used to create an individual curriculum vitae.

The results of strontium isotope analysis describe the content of ^{87}Sr in a sample compared to the content of ^{86}Sr applicating the following equation and are expressed as $^{87}Sr/^{86}Sr$:

$$^{87}Sr/^{86}Sr = \left[\left(\frac{^{87}Sr/^{86}Sr_{sample}}{^{87}Sr/^{86}Sr_{standard}}\right) - 1\right] \times 1000$$

Due to fractionation processes some stable isotope ratios vary in geochemical and biological systems. Strontium, in contrast to the light isotopes of oxygen, carbon and nitrogen, is a heavy isotope, which does not undergo fractionation processes through natural processes, caused by temperature, body metabolism, or photosynthesis (Price 2007: 427). Hence, the $^{87}Sr/^{86}Sr$ ratios can be directly compared to the surrounding geological formations.

2.2.4.1.2. Basic Principle of $\delta^{18}O$ isotopes

Oxygen is one of the main elements for life on earth and with 21% the second most occurring element in the atmosphere. Plants synthesize oxygen through photosynthesis, humans and animals ingest oxygen through breathing (O_2), the intake of water (H_2O), and in a smaller percentage also in the form of food (Campbell 1997: 1255–1260). The inhaled oxygen is transported by the blood, ending up in the mitochondrial respiratory chain. Whereas the oxygen ingested through water and food is incorporated in the phosphate compound (PO_4^{3-}), the structural carbonate (CO_3^{2-}), and the OH-group of hydroxyapatites of bones and teeth. The ratio of the oxygen isotopes $^{18}O/^{16}O$ ($\delta^{18}O$) in homoeothermic mammals therefore mirrors the different sources of incorporated water, like drinking water and the water contained in edible plants (e.g., Balasse et al. 2002, 2009). These isotopes are also significant in relation to the surrounding habitat, as it reflects the constitution of local meteoric water, derived from precipitation as rain, snow, and moisture. Water from food and atmospheric oxygen can be considered as minor, secondary sources (Luz et al. 1984; Sjögren and Price 2012). Rainwater, respectively clouds contain both isotopes, $H_2{}^{18}O$ has a greater mass than $H_2{}^{16}O$ and therefore requires more energy to evaporate and more to stay in the atmosphere. After evaporating over the sea, clouds move into the continent and the heavier $H_2{}^{18}O$ will rain down earlier while $H_2{}^{16}O$ stays longer in the clouds (fig. 2.11). Hence, the oxygen composition is varied by different factors such as humidity, temperature, rain shadow effects, altitude, latitude, and distance from the sea (Longinelli 1984; White et al. 2004; Sjögren and Price 2012). It can be an evidence of local water sources and climate conditions in which an individual grew up and lived, and therefore another indicator for the origins and movements of humans and animals (Luz et al. 1984; White et al. 2004; Bentley and Knipper 2005; Sjögren and Price 2012).

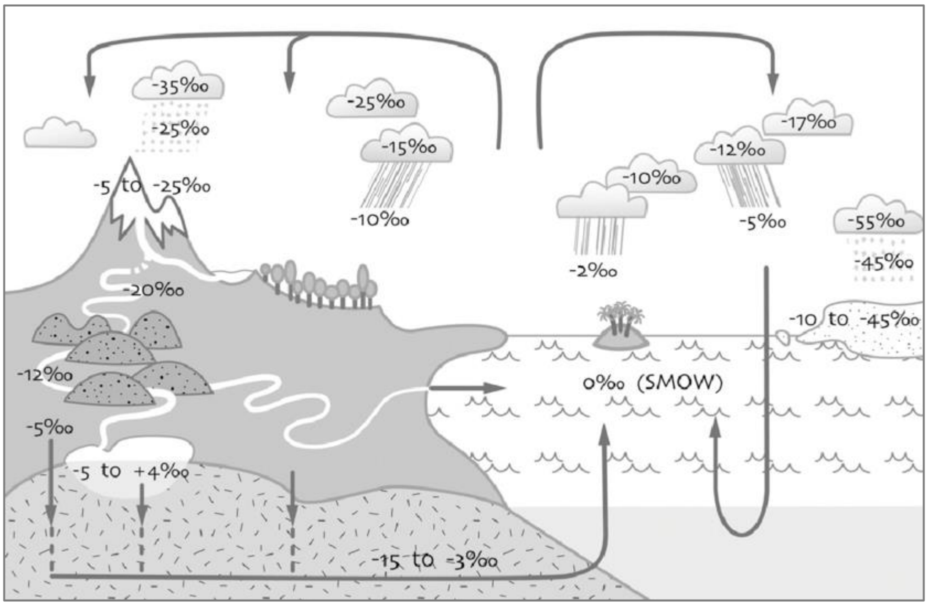


Fig. 2.11: Oxygen isotopes in hydrological cycles and geographic variation after Sjögren and Price 2012: 693 fig. 3.

Oxygen occurs in three stable isotopes: ^{16}O (99.76%), ^{17}O (0.04 %), and ^{18}O (0.2%) (Faure 1977: 430; Sjögren and Price 2013: 4). For isotopic measurements the content of ^{18}O against ^{16}O are compared to each other and expressed after the following equation (after Faure 1977: 430):

$$\delta^{18}O = \frac{(^{18}O/^{16}O_{sample} - ^{18}O/^{16}O_{standard})}{^{18}O/^{16}O_{standard}} \times 1000 \quad (\text{in ‰})$$

Oxygen isotope ratios in structural carbonate ($\delta^{18}O_{apa}$) are reported relative to the PDB (Pee Dee Belemnite) or V-PDB (Vienna Pee Dee Belemnite) standard. Whereas oxygen ratios in the phosphate group ($\delta^{18}O_{Phospate}$) are measured relative to the SMOW (Standard Mean Ocean Water) or V-SMOW (Vienna Standard Mean Ocean Water) standard. Both are linearly correlated to each other and can be converted for comparisons (Faure 1977: 431–432; Chenery et al. 2012: 309–319). In the past, the application of $\delta^{18}O_{Phospate}$ was more prevalent. Nowadays, although structural carbonate undergoes more diagenetic alterations (Katzenberg 2008: 417, Tütken 2010: 33), the use became more common, as the chemical extraction is much easier and cheaper, less material is needed and the results between laboratories are more comparable (e.g., Chenery et al. 2012).

The oxygen signal of an individual is not only impacted by the surrounding habitat but also by several physiological factors, such as individual metabolism and water intake, body temperature, or heat loss mechanisms (Makarevicz and Pederzani 2017). Moreover, culturally related manners like the intake of brewed, fermented, or cooked beverages can affect the oxygen ratios, as studies showed alterations of up to 1.5‰ (Brettell et al. 2012; Royer et al. 2017). Another factor alternating the $\delta^{18}O$ ratio is weaning: in body tissues milk is enriched of around 1–2‰ in $\delta^{18}O$ (White et al. 2004: 233). Additionally, seasonal variations have to be taken into account: The mineralization of body tissues generally covers a period of several years and might be impacted by seasonal changes through time. Central Asia is dominated by a dry, hot, and arid vegetation. Groundwater sources like springs, wells, rivers, or lakes may have been available on a seasonal basis differing over time (Ventresca Miller 2018). Moreover, many regions in the world as e.g., tropical zones have similar $\delta^{18}O$ values, ranging from approximately -2.0 to -8.0, rendering an isotopic distinction of these regions difficult (Bowen et al. 2005, Sjögren, Price 2013). Due to all these different impacts and the thereby resulting uncertainties, oxygen ratios represent the most challenging part of isotopic interpretation and will be treated with caution.

2.2.4.1.2.1. Variations in the $\delta^{18}O$ ratios

Oxygen in precipitation underlies different natural factors such as humidity, temperature, rain shadow effects, altitude, latitude, and distance from the sea (Longinelli 1984; White et al. 2004). Concerning the here investigated region, the impact of temperature and aridity represents the strongest effect. The $\delta^{18}O$ ratio of precipitation is increasing with higher temperature. Studies give for a moderate climate an approximate alteration between -0.4 and -0.6‰ per °C in the $\delta^{18}O$ ratio of precipitation (Siegenthaler and Oeschger 1980: 317; Rozanski et al. 1993). But high temperatures, respectively high aridity and a low rain-fall lead to adaptations of plants and animals, further impacting the human isotopic compositions. Plants that flourish in dry environments developed special mechanisms to avoid water loss (stoma) and cover their water supply through humidity such as dew, resulting in an enrichment of $\delta^{18}O$. Animals that live in dry habitats like gazelles, camels, but also ovicaprids adapted their metabolism and cover their water need mainly through the consumed plants. Again, both mechanisms depend on different factors as seasonal periods, the grade of heat and prevailing temperatures, thus the standardized calculation for hot and arid vegetations zones remains difficult.

The "continental effect" describes the correlation between $\delta^{18}O$ of precipitation and the distance from the sea. After the clouds formed over the ocean, with each rain shower over the continent, the heavier ^{18}O isotopes rain down first, while the lighter ^{16}O stay in the clouds. Hence, an increased distance to the sea causes a decrease in ^{18}O resulting in lower $\delta^{18}O$ ratios. Sharp established an approximated correlation of 1.5‰ in summer and 3‰ in winter for each 1000 km (Sharp 2007: 83).

The "altitude effect" describes the decrease of $\delta^{18}O$ in precipitation with increasing altitude, caused by similar reasons and the raining out of the heavier ^{18}O. Depending on the region different correlations between 0.2‰/100 m and 0.4‰/100 m were established (e.g., Siegenthaler and Oeschger 1980; Longinelli et al. 2006). Poage and Chamberlain compared different studies all over the world with elevations up to 5000 m and obtained a gradient of 0.26‰ per 100 m difference in altitude (Poage and Chamberlain 2001).

The "latitude effect" describes the decrease of $\delta^{18}O$ in precipitation with increasing latitude. It correlates with the temperature, the continental effect, and the rate of rain, hence the "washing out" of ^{18}O. Studies showed different correlations between approximately -0.5‰ per 1000 km (Sharp 2007: 83) and -2.1‰ (Lécolle 1985: 174).

2.2.4.2. Paleodiet according to nitrogen and carbon isotopes

Collagen is the main cell-wall protein in all mammals and it exists in all body tissues (even enamel with 1.5%, fig. 2.6). Hence, theoretically it can be extracted from all body tissues. Bone compacta yield an average content of 28.5% of collagen, tooth dentin 18% (Hedges and Reynard 2007; Tütken 2003). In archaeological science the extraction of collagen out of bone compacta is a common and comparable tool to gain insights on the diet of a person and nutrition pattern of population, established by many studies all over the world (among many others: Chisholm et al. 1983, 1989; Hare and Estep 1983; Ambrose 1987, 1993; DeNiro 1987; Grupe et al. 1987; Keegan, DeNiro 1988; Dorozynski, Anderson 1991; Schwarcz and Schoeninger 1991; Schoeninger and Moore 1992; Norr 1995; Koch 1998).

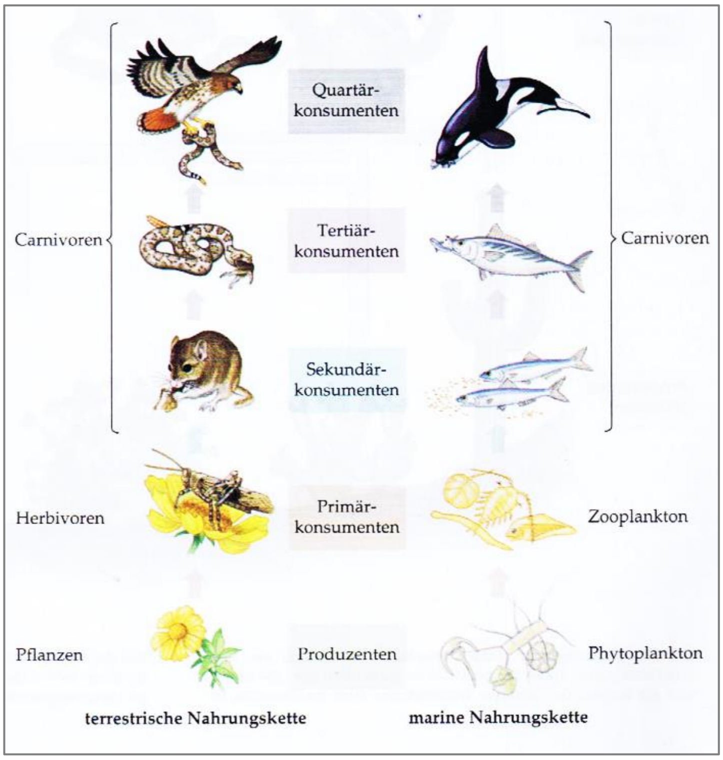


Fig. 2.12: Marine and terrestrial nutrition chain after Campbell 1997: 1247 fig. 49.1.

2.2.4.2.1. Basic Principles of $\delta^{15}N$ isotopic ratios

Nitrogen is one of the primary nutrients essential for the survival of all living organisms. Although nitrogen is very abundant in the atmosphere (N_2 78.08% with 0.36% ^{15}N and 99.64% ^{14}N), it is largely inaccessible in this form to most organisms. Nitrogen isotopes which can be further processed into amino acids, are critical to all mammals since they are the basic modules of all proteins, and can be ingested only through the intake of food, respectively out of the proteins in the food (cf. fig. 2.12). The ratio of nitrogen $^{15}N/^{14}N$ ($\delta^{15}N$) in bone collagen therefore provides information on the content of proteins in the diet. Plants form the basis of the nitrogen cycle. They are the only creatures which are able to bind the nitrogen and synthesize it into collagen for their cell-walls through a symbiosis with nitrogen fixing bacteria (Rhizobia). Humans and animals are depending on this ability of the plants to yield their essential nitrogen. Due to several fractionation processes during the metabolism, the $\delta^{15}N$ ratio is increasing with the trophic level of a species (cf. e.g., Campbell 1997: 1247–1249 and fig. 2.13).

As producers like plants, mushrooms, and lichen form the basis of the nutrition pyramid, they are commonly used to establish an isotopic baseline (cf. fig. 2.12), specific for the biological habitat, vegetation, and climate of an ecosystem. Wild and domestic herbivores as e.g., sheep/goats, cattle, deer, gazelles, onagers as specialists in food consumption represent the first step of the consumers in the food web. Omnivores represent the second step of the nutrition pyramid. Also called generalists, they cover a high variability in the animal kingdom, belonging to all species. Typical omnivores are next to humans, boars, bears, monkeys, but also crows, cockroaches, fish, ants and mushrooms can be omnivores. Also, foxes, wolfs and dogs, although preferable carnivores, but especially dogs when living contiguously to man are opportunistic generalists. The classification of carnivores depicts the topmost step of the food chain, but depending strongly on natural opportunities. Typical carnivores are cats, raptors or scavengers, but especially in sparse environments they sometimes tend to an omnivore diet. To summarize, omnivores show enriched $\delta^{15}N$ values compared to herbivores, and carnivores show enriched $\delta^{15}N$ values compared to omnivores. Assuming known and uniform values of the plants at the base of the food chain, a distinction can be made between herbivores, omnivores, and carnivores due to the “trophic level effect”. The trophic level effect causes an increasing $\delta^{15}N$ value of 3–5‰ with each step of the food chain (Bocherens and Drucker 2003; Hedges and Reynard 2007) and is the base for the calculation of the trophic level of an individual.

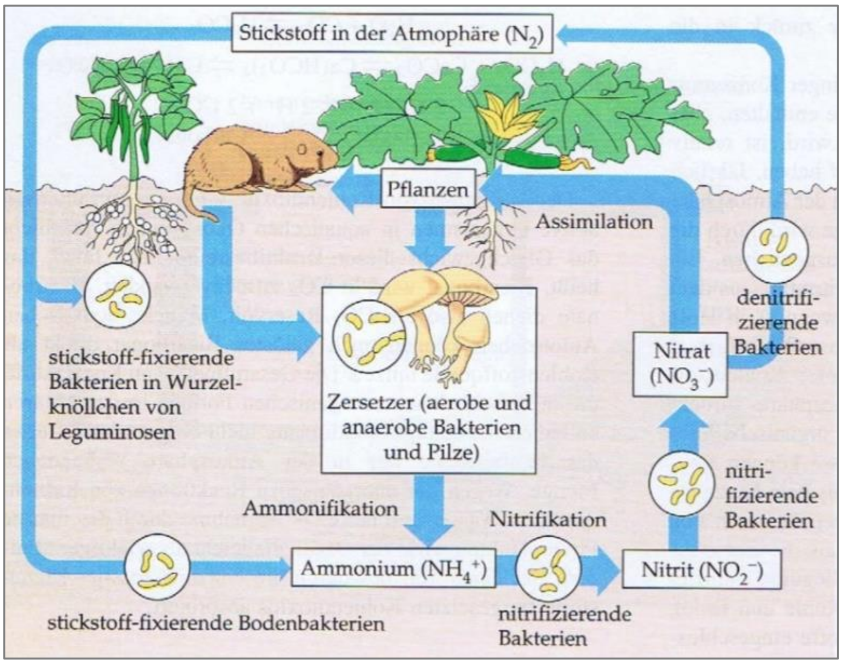


Fig. 2.13: Nitrogen cycle after Campbell 1997: 1258 fig. 49.11.

The $^{15}N/^{14}N$ ($\delta^{15}N$) ratios are measured and reported relative to the AIR standard (atmospheric nitrogen) after the following formula and expressed in parts per million (‰) (Faure 1977: 513–514; Schoeninger and DeNiro 1984: 630).

$$\delta^{15}N = \left[\left(\frac{^{15}N/^{14}N_{sample}}{^{15}N/^{14}N_{standard}}\right) - 1\right] \times 1000 \quad \text{(in ‰)}$$

Absolute $\delta^{15}N$ values of humans and animals not only depend on the content of proteins in the diet, but also on different factors as e.g. water accesability, temperature, salinity, or soil types (e.g. Bocherens and Drucker 2003, Schwarcz and Schoeninger 2011). Water stress in plants, caused by aridity and dryness due to low rainfall, can lead to an increase in $\delta^{15}N$, its consumption impacting the $\delta^{15}N$ ratios of herbivores and omnivores (Heaton 1987; Ambrose et al. 1991; Hollund et al. 2010; Schwarcz and Schoeninger 2011). Several studies also showed a correlation between a high salinity of the soil animals are grazing on and an enrichment in $\delta^{15}N$ (Heaton 1987; Britton et al. 2008). Moreover, the arise of manuring techniques and an increased application through times lead to an enrichment in $\delta^{15}N$ in animal and therefore also in human tissues (Frasier et al. 2011; Bogaard et al. 2013, 2016). The consumption of freshwater and marine fish also leads to an increase of the $\delta^{15}N$ values. Fish live in diverse marine and freshwater habitats and belong to different trophic levels (detritivore, omnivore, piscivore), resulting in highly variable $\delta^{15}N$ values (Katzenberg and Weber 1999; Katzenberg 2008; Göhring et al. 2016). Additionally, the consumption of fish is not always clearly detectable, since its part of the diet strongly depends on the availability, especially in dry environments, when rivers or lakes are seasonal. Also, the remains of fish in archaeological excavations are often overseen as they can mainly be detected through systematic sieving, which was rarely done especially in older excavations. Another factor procuring an enrichment of $\delta^{15}N$ is nursing (Katzenberg 2008; Reynard and Tuross 2015). The higher percentage of proteins in milk, and the fact that it´s being the sole ingredient of the nurslings diet lead to an increase between 2–3‰ of nursed children to their mother. But also depending on the species, different mammals´ mothers milk display very diverse contents of proteins (e.g. camel, cow 3–3.5%, human 4–4.5%, polar bear 33%). Finally, the consumption of legumes like lentils or peas, which were quite frequent in Central Asia and Iran in pre-history, leads to a decrease in $\delta^{15}N$. As symbionts of nitrogen fixing rhizobia, legumes provide lower $\delta^{15}N$ signatures, whereas non-leguminous plants are more enriched in $\delta^{15}N$, thus having higher $\delta^{15}N$ values. Consumers of legumes therefore have lower $\delta^{15}N$ values than those eating non-leguminous plants (Katzenberg 2008), but a mix of both can hardly be distinguished.

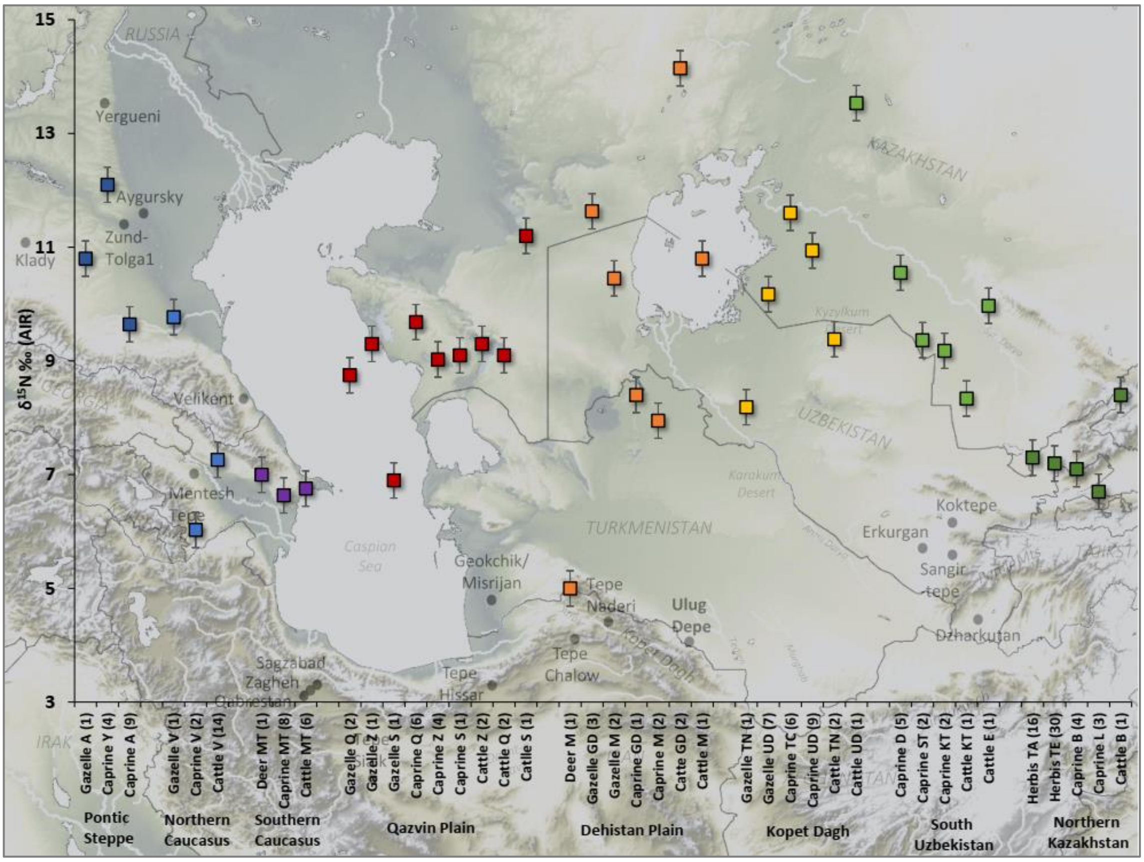


Fig. 2.14: Compilation of $\delta^{15}N$ averages of herbivores from Central Asia. References: Yergueni (Y) Zund-Tolga 1 after Shishlina et al. 2009; Velikent (V), Aygurskiy (A) after Hollund et al. 2010; Mentesh Tepe (MT) after Herrscher et al. 2018; Qabrestan (Q), Zagheh (Z), Sagzabad (S) after Bocherens et al. 2000; Tepe Chalow (TC) after Soltysiak at al. submitted, Geokchik Depe (GD), Misrijan (M) after Bocherens et al. 2006; Tashik, Temirkash after Motuzaite Matuzeviciute et al. 2015; Bestamak, Lisakovsk after Ventresca Miller et al. 2014.

Studies on European animals established for moderate climate zones $\delta^{15}N$ ranges of herbivores around 6–7‰ and carnivores around 9–10‰ (Hedges and Reynard 2007: 1241–1242). But climatic and regional differences have a strong impact, so that in Central Asia different ranges were obtained (fig. 2.14). Herbivores show an extremely wide range, strongly depending on the site and surrounding habitat. The lowest results were measured on ovicaprids from Mentesh Tepe between 5.7‰ and 8‰ (after Herrscher et al. 2018). This is also the case for Velikent in the northern Pontic steppe, where low ranges from 4.6‰ to 7.4‰ are known (after Hollund et al. 2010). A red deer from Novosvobodnaya/Klady in the northern Caucasus provided with 4.0‰ (after Shishlina et al. 2009) the lowest $\delta^{15}N$ ratio of an herbivore. The highest were obtained from cattle in ranges between 13‰ and 14‰ (cf. Bocherens et al. 2006), but also ovicaprids from Yergueni and Aygurskiy revealed quite high $\delta^{15}N$ ratios between 11‰ and 13‰ (cf. Shishlina 2009; Hollund et al. 2010).

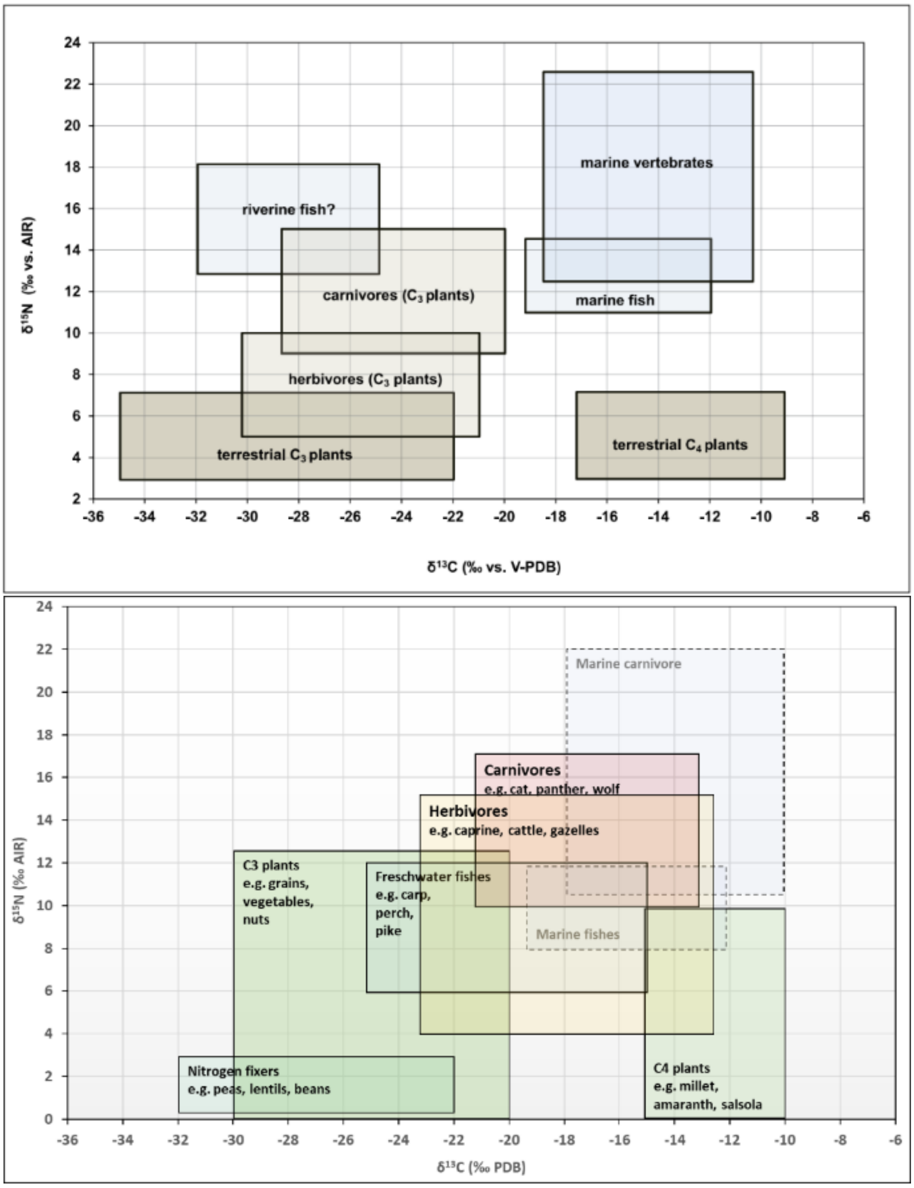


Fig. 2.15: Models for trophic level shifts in $\delta^{13}C$ and $\delta^{15}N$. Top: general model from Europe after Gerling 2015: 248 fig. 6.1. Bottom: modified for Central Asia with references from Katzernberg 1999; Bocherens et al. 2000, 2006; Ventresca-Miller et al. 2014, 2018; Herrscher et al. 2018 and the results of this thesis.

Summarized herbivores $\delta^{15}N$ ratios around the Caspian Sea range between 4‰ and 13‰ with a strong dependence on the surrounding habitat. Results of omnivores are less frequent, mainly wild boars were analysed, revealing $\delta^{15}N$ ranges between 9.7‰ and 13.2‰ (cf. Bocherens et al. 2000; 2006). Dogs showed a wide variety of $\delta^{15}N$ ratios between 7‰ and 12‰, ranging between all trophic steps. Single carnivores were analysed providing highly diverse $\delta^{15}N$ ratios. One cat from Geoktchik Depe (felix indet.) revealed a ratio of 16.4‰, a wolf from Sagzabad was in similar high ranges with 15.5‰. A golden jackal from Tepe Chalow instead revealed a ratio of 10.9‰, hence carnivores ranged between 10.0‰ and 16.5‰ (cf. Bocherens et al. 2000; 2006; Soltysiak submitted).

Fish are more independent of climate but due to very different nutrition forms they reveal highly variable $\delta^{15}N$ ranges. Analyses of freshwater fish were performed by Katzernberg (et al. 1999) on fish from Lake Baikal. Ventresca-Miller et al. (2014) analysed fish from northern Kazakh rivers, and Herrscher et al. (2018) from Mentesh Tepe in the Kura Valley. The fish showed ranges between 6‰ and 7.3‰ of detritivore, omnivores ranged between 8.4‰ and 11.9‰, while piscivores ranged between 7.8‰ and 12.5‰ (cf. Katzernberg and Weber 1999: 656; Ventresca Miller et al. 2014: 534; Herrscher et al. 2018: 8). Richards and Hedges (1999) proposed an average of 9‰ ±3‰ for freshwater fish and marine carnivores between 8‰ and 22‰. For consumers of pure marine food, the $\delta^{15}N$ average is proposed with 14‰ ±2.5 ‰ (Schoeninger and DeNiro 1984: 631; Chisholm et al. 1982: 1132). The illustration and comparison in fig. 2.15 demonstrate well the obvious alterations and the wider variety of both, $\delta^{15}N$ and $\delta^{13}C$ ratios. The results obtained in southern Central Asia and around the Caspian Sea show a strong dependence on climatic impacts (e.g., Knipper et al. 2020). Especially the results of plants indicating a complex adaptation to a hot and arid climate through a wide variety of $\delta^{15}N$ ratios, impacting a distinct enrichment of the first consumers of herbivores. The enrichment of $\delta^{15}N$ through external influences is also well reflected in the $\delta^{13}C$ results, displaying increased $\delta^{13}C$ ratios through all trophic groups.

2.2.4.2.2. Basic Principles of $\delta^{13}C$ isotopic ratios

The ratio of stable carbon $^{13}C/^{12}C$ isotopes ($\delta^{13}C$) in vertebrate hard tissue provides information on different components in the diet and varies characteristically between different ecosystems and photosynthetic pathways (Smith and Epstein 1971; DeNiro and Epstein 1978; Schoeninger and DeNiro 1984). Carbon, although one of the main building elements of living creatures, is relatively rare in the "earth-sphere". Carbon isotopes are present in all spheres in different conditions of aggregations, mostly in the Lithosphere (99.8% in form of carbonate sediments; Hydrosphere 0.045% as H_3CO_4 and dissolved CO_2), but only 0.001% in the Atmosphere (CO_2) and the Biosphere (in form of proteins, fats, carbohydrates). Producers as plants, mushrooms, or phytoplankton absorb CO_2 and convert it into glucose and other carbohydrates, fats, and proteins through photosynthesis. Consumers as humans and animals, feed on these nutrients and metabolize them to their own carbohydrates, fats and proteins (cf. fig. 2.16). Hence, the nature of the carbon isotopes in body tissues depends on the plants eaten by humans and animals (Lee-Thorp et al. 1989; Ambrose and Norr 1993).

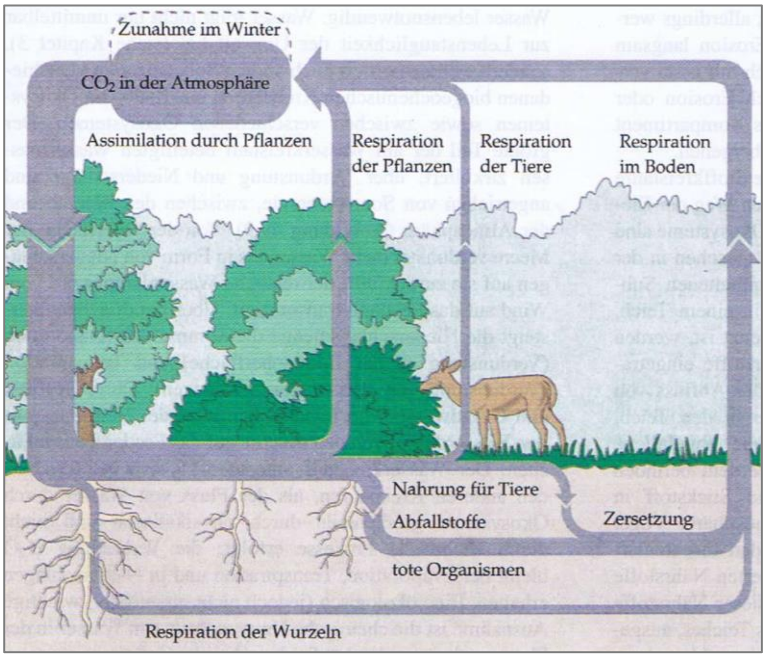


Fig. 2.16: Carbon cycle after Campbell 1997: 1256 fig. 49.10.

Plants can be generally distinguished according to the three different photosynthetic pathways. C3 plants synthesize glucose directly through the Calvin-Cycle as part of the photosynthesis. C4 plants bind CO_2 first and transport it into isolated compartments to avoid respiration before they run over into the Calvin-Cycle (cf. Campbell 1997: 214). CAM plants (Crassulacean acid metabolism) follow a special day-night cycle and are adapted to very arid regions, cactus plants e.g., belong to them, as well as bromeliads (pineapple) or agaves. As they are often uneatable, respectively not common in the studied regions, they will not be further discussed.

Most food crops such as cereals, fruits, and vegetables, nuts just as all marine plants use the C3-cycle. C4 plants flourish in arid vegetation zones. Common C4 plants are sedge and gras families (Cyperaceous, Poaceae), millet, amaranth, corn, sugar cane and several herb species such as rosemary or harmala. C3 plants fractionate CO_2 in a higher degree than their C4 cousins and reveal $\delta^{13}C$ ratios between -20‰ to -30‰, as the C4 cycle leads to a reduction between -13‰ and -16‰ due to the intermediate step of C4 plants (O'Leary 1988). In hot and arid vegetation zones even between -17‰ and -9‰ (Bentley and Knipper 2005: 632). Concerning the regions studied here, not many investigations on plants exist. Some floral remains from the Caucasus were analysed by Shishlina et al. (2017) and Herrscher et al. (2018), revealing average $\delta^{13}C$ values between -28.6‰ and -20.8‰ of C3 plants and between -12.6‰ and -12.1‰ of C4 plants. C3 plants from northern Kazakhstan, performed by Ventresca Miller et al. (2018), displayed $\delta^{13}C$ values ranging from -30‰ to -23.6‰, while C4 plants $\delta^{13}C$ values ranged between -15.2‰ and -14.5‰. According to the literature, the $\delta^{13}C$ ratios of the consumer range between 0–5‰ higher than the consumed food (Schoeninger and DeNiro 1984; Chisholm 1989). Average $\delta^{13}C$ ranges and the expected consumer ranges are summarized in tab. 2.3.

Diet	Average Carbon Isotopic Ratio	Expected Consumer Ratio
C3 plants only	- 26,5 ‰	- 21,5 ‰
C3 herbivore meat	-25.5‰	-20.5‰
C4 plants only	-12.5‰	-7.5‰
C4 herbivore meat	-11.5‰	-6.5‰
Marine plankton only	-19.5‰	-14.5‰
Marine herbivores´ meat	-18.5‰	-13.5‰
Marine carnivores' meat	-17.5‰	-12.5‰

Table 2.3: Carbon isotopes ratio breakdown spanning from plants to carnivores showing the +5‰ collagen enrichment factor after Chisholm 1989: 33–35.

Carbon has three naturally occurring isotopes (^{12}C 98,89%, ^{13}C 1,11%, ^{14}C 10^{-10}%), while only ^{13}C and ^{12}C are stable isotopes (the instable isotopes ^{10}C, ^{11}C, ^{15}C, ^{16}C existing only synthetic). For the reconstruction of paleodiet and past climatic conditions, the ratio of ^{13}C to ^{12}C is measured and expressed as $\delta^{13}C$ in parts per million (‰). The $\delta^{13}C$ ratio reported relative to the Vienna Pee Dee Belemnite carbonate standard (V-PDB) calculated after the following formula (after Faure 1977: 491).

$$\delta^{13}C = \frac{\left({}^{13}C/{}^{12}C_{sample} - {}^{13}C/{}^{12}C_{standard} \right)}{{}^{13}C/{}^{12}C_{standard}} \times 1000 \quad \text{(in ‰)}$$

Carbon can be extracted from collagen and bioapatite. The $\delta^{13}C$ ratio out of bone collagen reflects the contents of proteins in the diet (Bocherens and Drucker 2003). Structurally bound carbon in bioapatite derives from body fluids in general and comprises a mixture of all dietary components. The $\delta^{13}C$ ratio out of bone apatite therefore reflects the whole nutriment spectrum. The difference $\delta^{13}C_{Collagen}$ and $\delta^{13}C_{Apatite}$ ($\delta^{13}C_{apa\text{-}col}$) can be used to infer trophic levels of humans and animals (Krueger and Sullivan 1984; Lee-Thorp et al. 1989; Ambrose and Norr 1993; Balasse et al. 1999; Codron et al. 2018).

The $\delta^{13}C$ ratios are not only affected by the photosynthetic pathways, but also by factors as temperature and precipitation, as well as altitudes and seasonality (Bentley and Knipper 2005). An increasing temperature and aridity result in an alteration of +0.3 ‰ per °C. Plants growing in higher altitudes reveal, due to a lower partial pressure of CO_2, an alteration of approximately +1‰ per 1000 m difference in altitude. Also, the floral density of the habitat has an impact on the availability of CO_2 and therefore on the $\delta^{13}C$ ratios. Plants growing at the bottom of the forest show more depleted $\delta^{13}C$ of approximately 1–2‰ compared to plants growing on the top of the forest roof (Drucker et al. 2008).

2.2.4.2.3. Diagenesis

The term diagenesis describes the ambition of isotopes to penetrate from the surrounding milieu into the material. It represents another cause of possible alterations, that has the potential to critically impact isotopic results, as bones and tooth dentine are very sensible to this process – one that can strongly modify the original isotopic composition. Tütken (2003) wrote a very detailed PhD thesis about the diagenetic impact on different skeletal materials, which can be considered as the fundamental work, hence only a short summary will be given here.

When a vertebra dies and the physiological activities stop, the body is exposed to post-mortem weathering and decay processes such as autolysis, putrefaction, decomposition and skeletonization (cf. fig. 2.17 and Behrensmeyer 1978; Budd et al. 2000; Denys 2002; Hedges 2002; Tütken 2003). In addition to bone size, temperature and humidity play a rigorous role in the diagenetic processes of the skeletal remains. Furthermore, environmental conditions like macro- and microbiological activities, ion-availability, Eh (redox potential of the availability of electrons), pH (availability of protons), but also biological conditions as the bone density impact the diagenetic processes (Tütken 2003, 2010: 37; Maurer et al. 2012: 227). The diagenetic processes are not fully understood yet, but the degree of the alternation is depending on ground conditions as aridity, temperature, soil watering. Sites with active water movements prove a higher dissolution of the buried material, whereas cold temperatures decrease the dissolution (Hedges 2002). Especially extreme conditions as very hot or very cold climate, can reduce or prevent the microbiological attack which is the opening door for diagenetic alterations. Based on the intensity of these chemical and geological factors the diagenetic alterations can endure over decades or might not take place at all (Tütken et al. 2004: 92). Depending on the conservation of the bones, but also age and origin, diagenesis effects, especially of "young", well preserved material (compared to dinosaurs or neandertals even our Neolithic samples can be considered to be young), can be more or less completely eliminated by careful mechanical ablation of the topmost layers (~2 mm) of the bone compacta followed by a specific leaching treatment with NaOCl and NaOH or acetic acid solutions (Hedges 2002: 322; Hoppe et al. 2003: 26; Tütken 2003: 217). But potential diagenetic alterations always have to be taken into account when interpreting isotopic data.

The strong homogeneity in strontium results for Ulug Depe bones attracts attention, as all of them fall within a very narrow range. It may be feared that these results are caused by contamination through diagenetic processes. Although Ulug Depe bones were in quite good conditions and leaching with strong acid should remove the diagenetic impact for isotopic measurements, the proof and comparison with the concentration of strontium in ppm was not performed in this study. But both chemical extractions and the MC–ICP–MS measurements were conducted in multiple sessions over a period of two years with each session incorporating samples of different material, species, and origins. Therefore, systematic mistakes within the analytical process can be excluded.

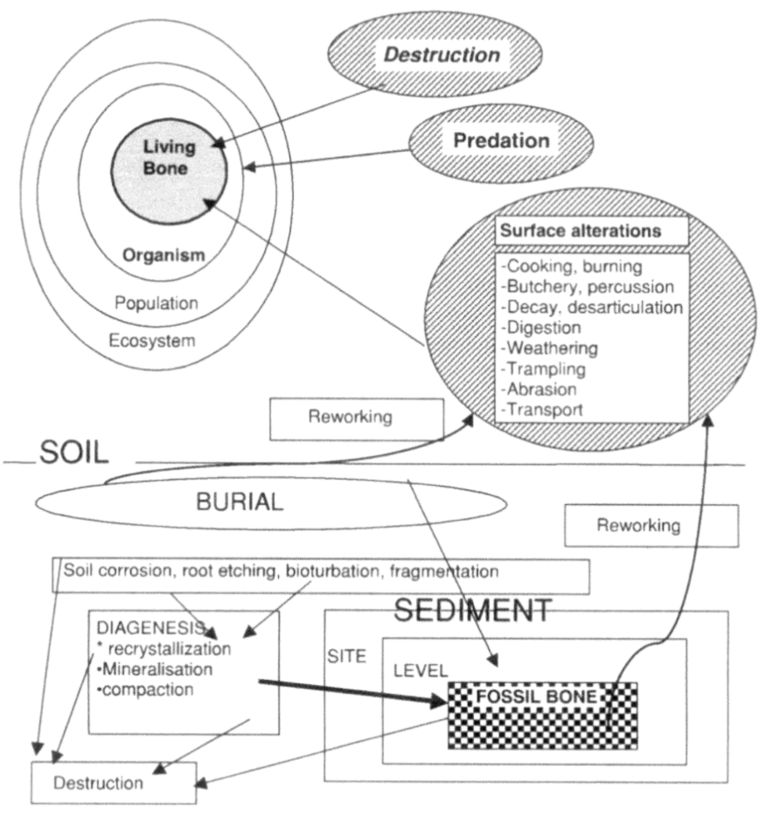


Fig. 2.17: Schema of post-mortal, taphonomic processes impacting the fossilization before, during and after burying after Deny 2002: 470 fig. 1.

3. Material and Methods

3.1. Material

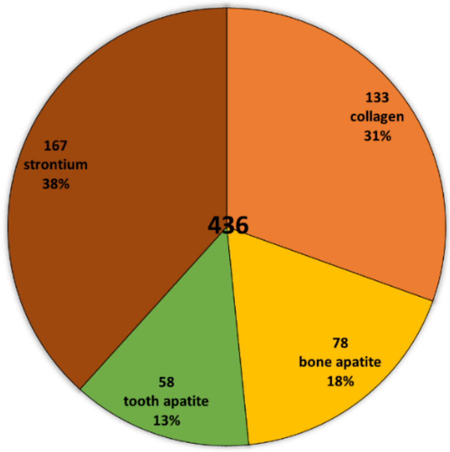


Fig. 3.1: Pie chart of performed isotope analyses.

The project of isotopic investigations in southern Central Asia and Iran existed already several years before the work on this thesis started. The provided material was selected during different missions of archaeologists in the last years. The human material from Ulug Depe, Dzharkutan, Sapallitepa and Bustan were kindly provided by Julio Sarmiento-Bendezu and Johanna Lhuillier from the Centre national de la recherche and heads of the Mission archéologique franco-turkmène (MAFTur) and the Mission archéologique Franco-Ouzbèke Protohistoire (MAFOuz-P). The material from Tilla Bulak was granted by Kai Kaniuth from the Ludwig-Maximilian-University Munich, head of the excavation in Tilla Bulak. Elise Luneau from the German Archaeological Institute (DAI) liberally accomplished the material from Uzbekistan with the samples from Bashman 1 and Mike Teufer from the DAI kindly provided the human material from Gelot, Darnaichi and Saridzhar. The human remains from Tepe Sialk were supplied by the Musée de l´Homme and kindly selected by Amelie Chimens. All faunal remains were liberally provided by Marjan Mashkour out of the collection of the Muséum National d´Histoire Naturelle (MNHN) and of the Institut de Paléontologie Humaine (IPH), the botanical samples were generously selected by Margareta Tengberg out of the collection of the Muséum National d´Histoire Naturelle. The selection of the samples and the export out of the countries was undertaken in the years the excavations took place. Due to the initial situation and also political events in the studied region, a further export was not possible afterwards.

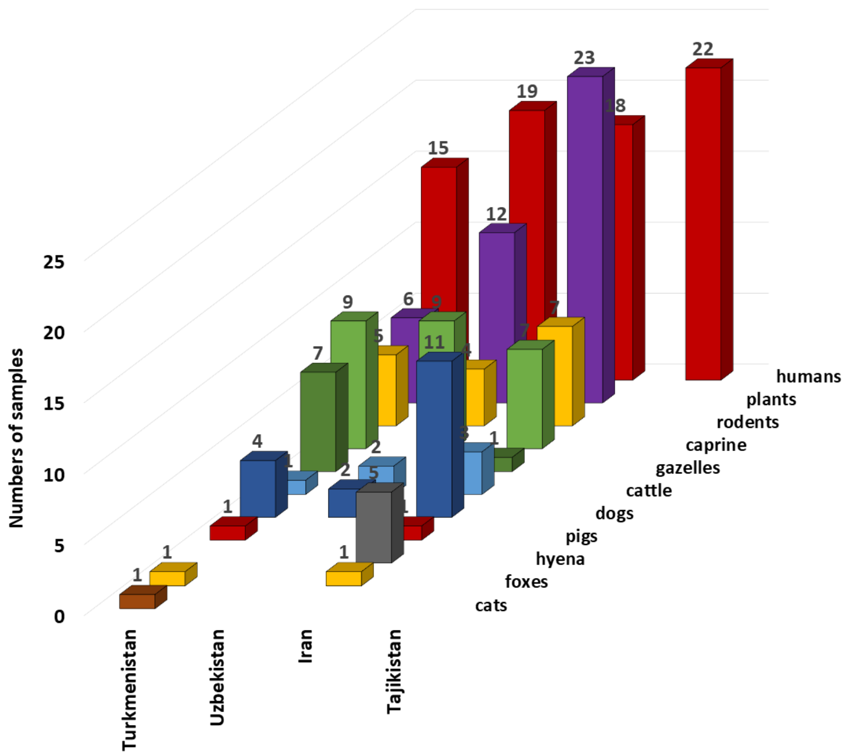


Fig. 3.2: Compilation of all analysed samples from southern Central Asia and Iran.

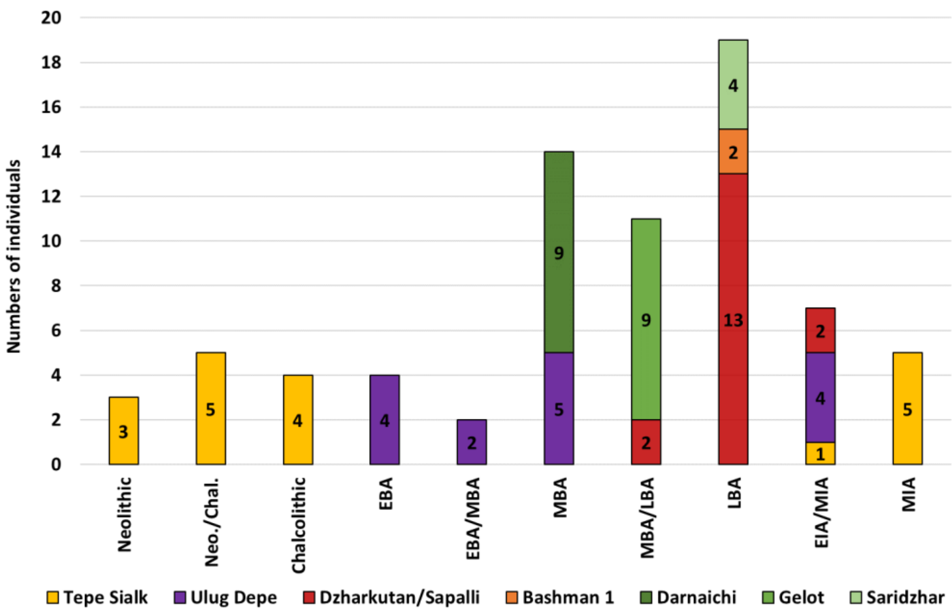


Fig. 3.3: Compilation of all analysed human samples after periods and sites.

A total of 74 humans, 102 animals and 55 plants from southern Central Asia and Iran were analysed in different isotopic compositions (cf. fig. 3.2 and Appendix I table 1–4). Strontium analyses were performed on 167 samples, collagen analyses on 133 samples, as well as 78 analyses of bone apatite and 58 analyses of tooth enamel apatite (fig. 3.1). As summarized in fig. 3.3 and table 3.1 the human samples cover periods from Neolithic to Middle Iron Age. The highest number are humans from the LBA, the transition and the MBA from Central Asia, while Sialk samples cover the very early (Neolithic, Chalcolithic) and the very late periods (MIA).

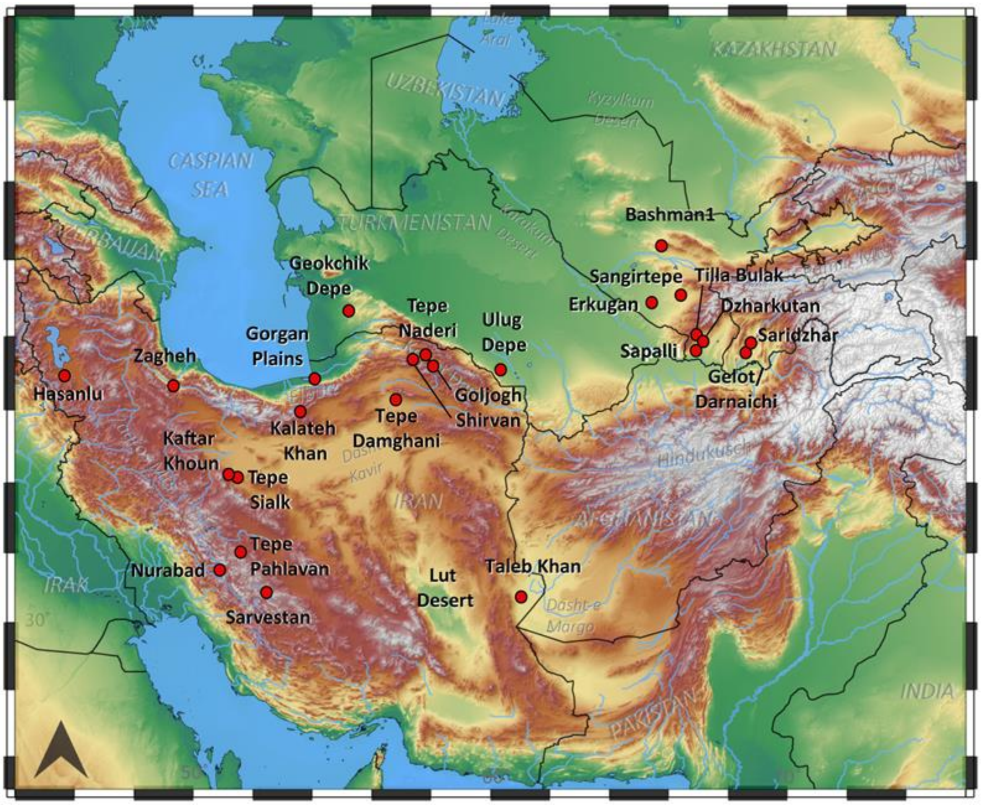


Fig. 3.4: Topographic map of Iran and southern Central Asia with the sites investigated in this study.

The geographic locations of all sites investigated in this study are shown in fig. 3.4. Analyses were performed on samples from Ulug Depe and Geokchik Depe in southern Turkmenistan. Further, samples from Dzharkutan, Sapallitepa, and Bustan in southern Uzbekistan, as well as from Bashman 1, Erkurgan, Sangir-tepe, and Koktepe in central Uzbekistan. Additional references were available from Gelot, Darnaichi, and Saridzhar in southern Tajikistan. The Iranian material includes the sites Tepe Sialk, Khaftar Khoun, and Zagheh on the Central Plateau, Hasanlu in north-western Iran, Shirvan, Tepe Naderi, and Tepe Damghani in north-eastern Iran. Further, single samples from Kalateh Khan in the Semnan Province, Tepe Taleb Khan in Sistan, Nurabad and Tepe Pahlavan in Fars province were analysed. Additional investigations to establish the respective isotopic baseline were performed on plants from Lut desert and the the Gorgan Plains.

Central Asia						Iran		
Period	Phase	cal. BC	Turkmenistan	Uzbekistan	Tajikistan	Period	cal. BC	Sialk
Middle Iron Age	Yaz II	1000-540	**Ulug Depe Geokchik Depe**	**Dzharkutan**		Iron II	1000-800	**Sialk VI**
Early Iron Age	Yaz I	1500-1000				Iron I	1200-1000	**Sialk V**
Late Bronze Age	NMG VI	2000-1600		**Dzharkutan Sapalli Tilla Bulak Bashman 1 Bustan**	**Gelot/ Darnaichi Saridzhar**	Late Bronze Age		Hiatus
Middle Bronze Age	NMG V	2400-2000	**Ulug Depe**		**Gelot/ Darnaichi**	Early Bronze Age II	2900-2000	?
Early Bronze Age	NMG IV	2800-2400	**Ulug Depe**			Early Bronze Age I	3400-2900	Sialk IV
Late Chalcolithic	NMG III	3200-2800	Ulug Depe			Late Chalcolithic	3700-3400	**Sialk South III 6-7**
Middle Chalcolithic	NMG II	3800-3200	Ulug Depe			Middle Chalcolithic	4000-3700	**Sialk South III 4-5**
Early Chalcolithic	NMG I	4000-3800	Ulug Depe			Early Chalcolithic	4300-4000	**Sialk South III 1-3**
Proto-Chalcolithic	Anau I	ca. 5200-4800	Ulug Depe			Late Transitional Chalcolithic	4600-4300	?
						Early Transitional Chalcolithic	5200-4600	**Sialk North II**
Neolithic	Djeitun	ca. 6200-5000	Ulug Depe			Late Late Neolithic	5600-5200	**Sialk North I 4-5**
						Early Late Neolithic	6000-5600	Sialk North I 1-3

Table 3.1: Table of Chronology of Central Asia and the Central Plateau showing the divergent terminology and absolute dates. Central Asia Neolithic/Proto-Chalcolithic after Lecomte 2011: 223 table 1, Chalcolithic – LBA after Lyonnet, Dubova 2021: 8 table 1, Yaz after Luneau 2014: table 1. Iranian periods Sialk I – IV after Fazeli 2009: 10 table 7; Sialk V/VI after Fahimi 2019: 342 fig. 5, periods in bold comprise the periods analysed in this study.

3.1.1. Material from southern Turkmenistan

The samples of humans and animals from southern Turkmenistan are listed in Appendix I table 1 and summarized in fig. 3.5 and 3.6. The human material from Ulug Depe was collected and provided by Julio Sarmiento-Bendezu and Johanna Lhuillier in the course of the Mission archéologique franco-turkmène (MAFTur) (e.g., Lecomte 2007a, 2011, 2013; Bendezu-Sarmiento 2013; Bendezu-Sarmiento and Lhuillier 2015, 2016, 2019). The remains of in total 15 human individuals were analysed: four burials (2 men, 1 not determined adult, 1 child) dating back to the EBA (NMG IV), roughly between 2800–2500 BCE; two individuals (1 woman, 1 child) belong to the transition from the EBA to the MBA (NMG IV–NMG V, ca. 2500/2400 BCE); five individuals (1 man, 1 woman, 2 not determined adults, 1 child) date to the late MBA (NMG V, ca. 2200–2000 BCE); four individuals (2 women, 2 children) to the transition from the Early to the Middle Iron Age (EIA–MIA, ca. 800–1000 BCE). The Ulug group consists of three adult men, four adult women, four undetermined adults and five children.

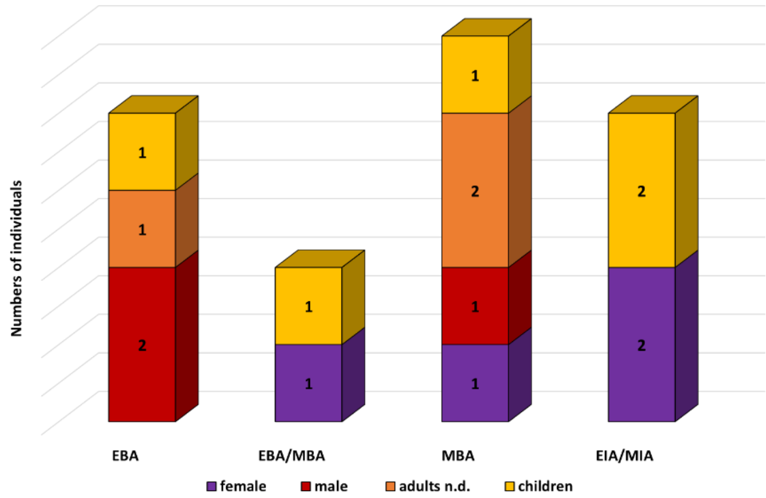


Fig. 3.5: Bar chart Ulug humans after periods and gender.

The reference material consists of diverse bones and teeth that can be attributed to different animal taxa and plant species. The faunal remains from Ulug Depe were provided by Marjan Mashkour out of the collection of the Muséum National d´Histoire Naturelle (MNHN) and of the Institut de Paléontologie Humaine (IPH), the botanical samples were selected by Margareta Tengberg out of the collection of the Muséum National d´Histoire Naturelle (Mashkour 2013a, 2015; Tengberg 2013, et al. 2020). In order to determine the local strontium range three rodents (*Mus* sp.), two carnivores (*Canis fam.*, *Panthera sp.*), and six plants in the form of carbonized grains (*Hordeum vulg., Triticum aest.*) and wood (*Juniperus* sp.*, Tamaris sp.*) were analysed. The animal collection used for collagen analyses consisted of 24 samples: nine sheep and goat (*caprine*), seven samples of gazelles (*Gazella sub.*), one cattle (*Bos taurus*), four dogs (*Canis fam.*), one fox (*Vulpes vulpes*), one big cat (*Panthera sp.*), and one pig (*Sus scrofa*). To extend the information of the regional strontium distribution two rodents from Geoktchik Depe were additionally analysed (Lecomte 2005, 2007b). The material from Geokchik Depe was as well selected and studied by Marjan Mashkour (Mashkour 1998, et al. 2016b). At this site remains from the Iron Age just as from the Islamic period were found. The here analysed animals date to the MIA period.

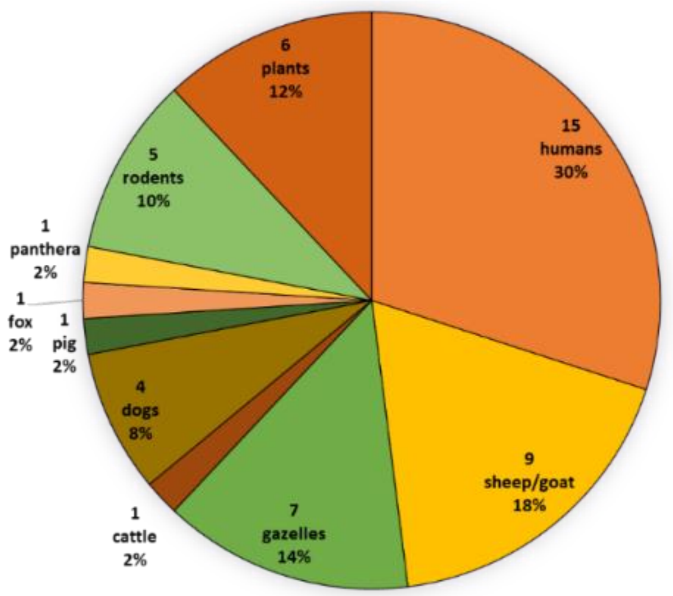


Fig. 3.6: Pie chart of the composition of all samples from Turkmenistan.

3.1.2. Material from southern and central Uzbekistan

The analysed humans and animals from Dzharkutan, Sapallitepa, Bustan, and Bashman 1, are listed in Appendix I table 2 and summarized in fig. 3.7 and 3.8. The human material from Dzharkutan, Sapallitepa and Bustan were provided by Julio Sarmiento-Bendezu and Johanna Lhuillier collected during the Mission archéologique Franco-Ouzbèke Protohistoire (MAFOuz-P) and Mission Archéologique Franco–Ouzbèke de Sogdiane (MAFOUZ-Sogdiane) in cooperation with the Archeological Institute of Samarkand (e.g., Bendezu-Sarmiento and Mustafakulov 2009, 2013; Bendezu-Sarmiento and Lhuillier 2015, 2019). The material of all sites was poorly preserved, as the harsh prevailing conditions led to a strong elutriation of the stabilizing elements resulting in a high porosity. The 14 individuals from Dzharkutan date back to the transition of the MBA to the LBA, to the LBA, and to the transition of the EIA to the MIA. A woman and a not determined adult dated back to the end of the 3rd/beginning of the 2nd mill. BCE (MBA/LBA). Furthermore, 10 individuals (1 man, 4 women, 4 n.d. adults, 1 child) dating back to the LBA, ca. 1900 and 1700 BCE, while two individuals, a woman and a child, date back to the transition of the EIA to the MIA (1263–1216 cal. BCE). The group consists in total of six adult women, one man, four undetermined adults and two children.

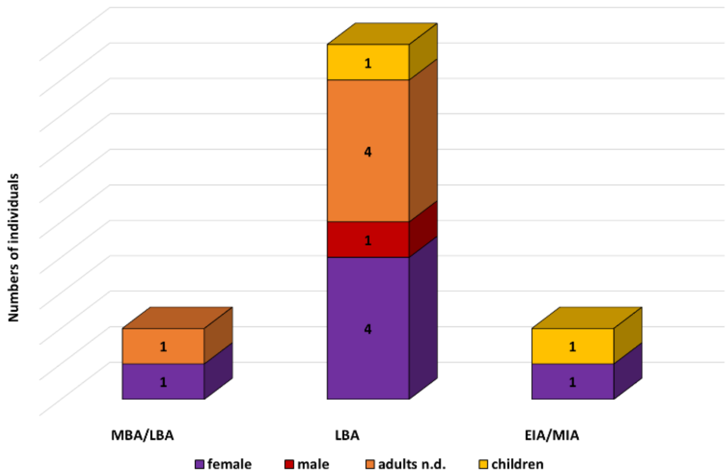


Fig. 3.7: Bar chart Dzharkutan humans after periods and gender.

Further individuals from nearby Sapallitepa (Askarov 1973) and Bustan (Avanesova 2016) were analysed: the burials 8 and 20 from Sapallitepa, both adult, not sexed individuals, date back to the end of the 3rd/beginning of the 2nd mill. BCE. The eponymous site of the Sapalli Culture, is located about 40 km southwest of Dzharkutan, not far from the northern bank of the Amu Darya River, in the valley where Ulanbulaksaj and Amu Darya converge. Sapallitepa was another cultural center in the region coinciding with the earliest phase of Dzharkutan. The hills of Bustan are located 5 km south of Dzharkutan. The site dates to the final episode of the Bronze Age (Avanesova 2016). The investigated remains of burial 23 were poorly preserved and not sufficient for collagen and tooth enamel carbonate.

Additionally, two individuals from Bashman 1 in central Uzbekistan were examined. The samples were collected by Elise Luneau during the years 2019/2020 and kindly provided for further investigations. The excavated structures of Bashman 1 are culturally related to the Andronovo Culture and date to ca. 1600–1400 BCE. Two cist graves of an adult and a young child originating from this context were selected for isotopic analyses (Luneau personal communication).

The faunal and botanical samples from all Uzbek sites were collected and studied by Marjan Mashkour and Margareta Tengberg (Mashkour et al. 2016a; Tengberg et al. 2020). References for strontium analyses consist of two samples of mice (*Mus* sp.) and five botanical samples: three samples of barley (*Hordeum vulg.*), one of a willow (*Salix* sp.), and another one of a tamarisk (*Tamaris sp.*). Two rodents from Sangir-tepe and Erkurgan were also analysed for strontium (Mashkour et al. 2016a). Further plant samples were added from Tilla Bulak west of Dzharkutan (Kaniuth 2007, 2009, 2016): Seven samples of barley (*Hordeum vulg.*) and wheat (*Triticum aestivum)* were collected and studied by Michael Peters during excavations in 2009 and 2010 (Peters in Kaniuth 2009: 89–91) and provided by Kai Kaniuth. The examined animal ensemble for collagen consisted only of five ovicaprids. To gain a certain number of references, four ovicaprids from Sangir-tepe and Koktepe, two cattle from Erkurgan and Koktepe, and two dogs from Sangir-tepe and Erkurgan were selected (Mashkour et al. 2016a). Sangir-tepe, Erkurgan and Koktepe are contemporaneous settlements in southcentral Uzbekistan (fig. 3.4).

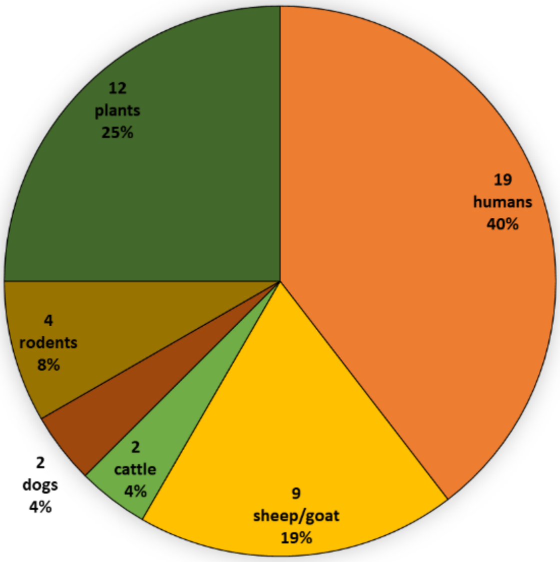


Fig. 3.8: Pie chart of the composition of all samples from Uzbekistan.

3.1.3. Material from Iran

The samples from Iran are listed in Appendix I table 3 and summarized in fig. 3.9 and 3.10. The human material from Tepe Sialk was excavated by R. Ghirshman during the 1930´s (Ghirshman 1938, 1939) and stored in the collection of the Musée del Homme, CNRS, Paris, during the last decades. The remains are poorly preserved, due to harsh environmental conditions of this site, long storage periods, and restauration procedures. Therefore, the content of carbonate and the preservation of collagen was not sufficient for all individuals and an extraction only achievable through the adaptations of the lab methods (cf. chapter 3.2.).

Additionally, the processing was rendered even more difficult because of the glue applied for restauration. It can be assumed that after 70 years of storage, the glue infiltered the whole bone and is not completely solvable and removable through organic solvents. In some cases, several samples even had to be discarded, due to glue, made of animal proteins ("animal glue"), especially used in the decades after the 2nd world war. Hence no isotopic analyses were performed on these samples.

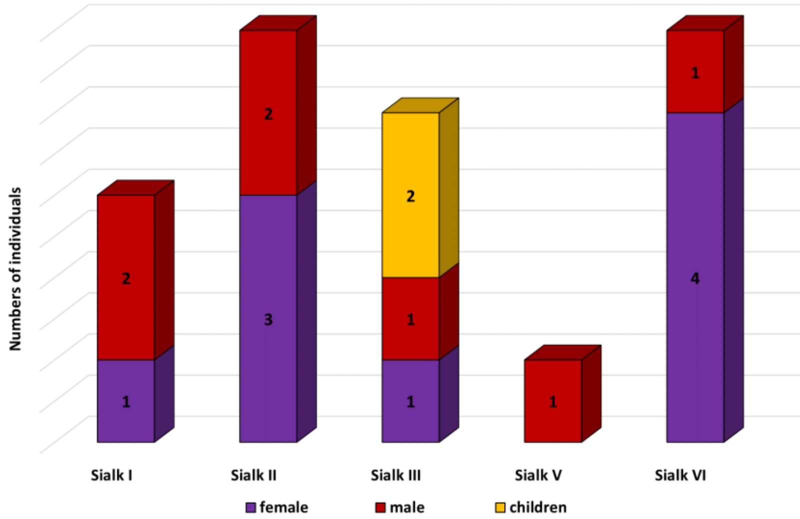


Fig. 3.9: Bar chart of humans from Tepe Sialk after periods and gender.

A total of 18 human individuals from Tepe Sialk were analysed for the present study: three individuals, two adult men and one woman, date back to the 5th mill. BCE corresponding to the archaic Sialk I period (ca. 5600–5200 BCE after Fazeli, Nokandeh 2019); five individuals, two adult men, and three adult woman, assignable to the transitional chalcolithic Sialk II period (around 5200 BCE); four tombs of an adult women, an adult man and two children are attributed to the Sialk III period (ca. 4300–3400 BCE after Fazeli, Nokandeh 2019); one adult male can be dated to the Sialk V period, (ca. 1200 and 1000 BCE after Fahimi 2019) corresponding to the Early Iron Age (Iron I); and five individuals, four adult women, one man, are attributed to the Sialk VI period, corresponding to the Middle Iron Age (ca. 1000–800 BCE after Fahimi 2019). Hence, the group consists of nine adult women, seven adult men, and two children.

The faunal and botanical remains from all Iranian sites investigated in this work were collected and studied by Marjan Mashkour, Margareta Tengberg and collaborators of different archaeological projects supported by ICHHTO Iran (geographic locations of the sites are shown in fig. 3.4 and 4.9–4.13). Concerning animals the following species were analysed: seven ovicaprids (*Capra aegagrus, Ovis vignei*), 3 cattle (*Bos taurus*), one gazelle (*Gazella sub.*), and one buffalo (*Bubalus* sp.) as herbivores. Further, eleven dogs (*Canis fam.*) and one pig (*Sus scrofa*), as well as one fox (*Vulpes vulpes*), one cat (*Felix sylvestris*), and five hyenas (*Hyena* sp.). In order to determine the local strontium range of Tepe Sialk analyses on five samples of sheep/goats, two canids, a fox and a hyena were performed (Mashkour 2004a, b, et al. 2019). To get a better picture of the surroundings four samples of coprolites of hyenas from Kaftar Khoun close to Tepe Sialk were added (Monchot and Mashkour 2010; Djamali et al. 2020). Additionally, 40 plants and eight rodents (*Mus* sp.) were added to establish the isotopic baselines. As the material allowed, five modern samples from Khorasan Province were analysed for strontium. The samples were collected by Marjan Mashkour and Margareta Tengberg in the surroundings of modern Shirvan city during the excavation field season in Tappeh Naderi in 2018 directed by Ali Vahdati (ICHHTO). Analyses were performed on one bone samples from a modern hyena (*Hyena* sp.) and one modern tamarisk (*Tamaris* sp.*)* from Shirvan itself, as well as three modern plants from the Goljogh river region (*Asteraceae* and *Alhagi*). Single samples of rodents (*Mus* sp.) from several sites in Iran were analysed to extend the map of strontium results. To complete the picture of north-eastern Iran Tepe Pahlavan (Vahdati 2010; BeyzaeiDoust et al. 2017), Tepe Damghani (Mashkour 2008; Francfort et al. 2014) in North-Khorasan, and a bit further Kalateh Khan in the Semnan Province

(Mashkour 2007, et al. 2016b) were investigated. Further rodents were analysed from Hasanlu in north-western Iran (Davoudi 2017) and Tepe Zagheh on the Qazvin Plains (Mashkour et al. 1999, 2001, 2002). Of special importance is the sample of one rodent from Tepe Taleb Khan (Fathi and Mashkour 2018), the only sample from south-eastern Iran, providing an impression of the bio-available strontium signal around Shahr-i Sokhte. In the western part of Iran one rodent was analysed from Sarvestan Palace (Mashkour and Askari 2017) in addition to one rodent and three modern dried plants (Pistacia, Amygdalus, cereal) from Nurabad in the Fars province (Mashkour 2006). Moreover, strontium analyses were performed on charred plants (species not determined) collected along the Gorgan Wall by Marjan Mashkour during the excavation field season in 2016 (Mashkour 2013b, Mashkour et al. in press). Moreover, modern plants from the Lut desert were provided. The material was collected by Marjan Mashkour and Alexander Rudov (Lyons et al. 2020; Rudov et al. 2020) during an expedition in 2016 in the southern Lut Desert under the direction of Hossein Akhani (Trescher 2017). A total of 21 modern, dried plants were provided and analysed for nitrogen and carbon isotopes, while seven were additionally analysed for strontium. The species were classified by Margareta Tengberg and included six samples of rosemary (*Salsola* sp.), seven samples of tamarisks (*Tamaris* sp.), four sample of hammada (*Amaranthacea*) and three sample of calligonum (*Calligonum* sp.).

The group of reference animals for collagen consisted of four goats and one sheep, one pig and one fox from Tepe Sialk (Mashkour 2004a, b, et al. 2019). Additionally, two cattle and one gazelle from Tepe Naderi (Mashkour and Fathi 2019), one goat from Tepe Pahlavan (Beyzaei Doust et al. 2017) and one buffalo from the Gorgan Wall (Mashkour 2013b, Mashkour et al. in press) were analysed to get a certain number of herbivores. Several analyses of dogs from different sites in Iran were performed: seven from Hasanlu (Davoudi 2017), and one each from Tepe Naderi (Mashkour and Fathi 2019), Nishapur (Khazaeli 2014), and Qoli Darvish (Khazaeli et al. 2017). One cat was analysed from Neolithic Tepe Sang-e Chakhmaq (Mashkour et al. 2014; Rousatei et al. 2015), located about 1 km north of the village of Bastam on the south-eastern flank of the Elburs Mountains in Semnan Province.

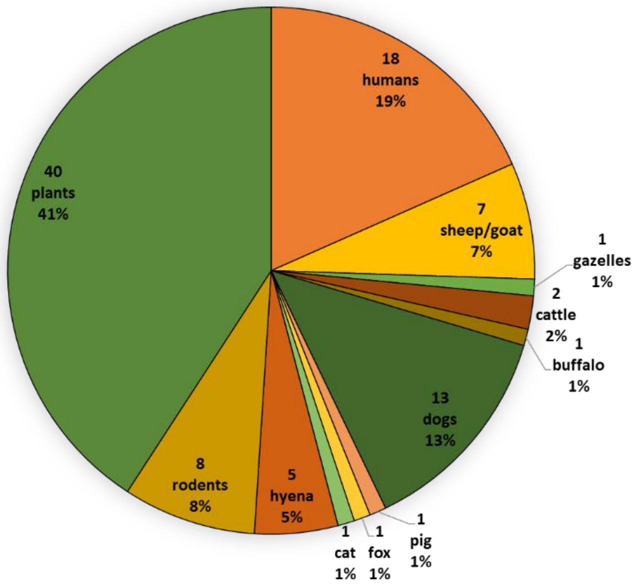


Fig. 3.10: Pie chart of the composition of all samples from Iran.

3.1.4. Material from southern Tajikistan

The human material from southern Tajikistan was provided by Mike Teufer and Elise Luneau, selected in the course of the archaeological research project in the southern Tajik Yakh-Su Valley. The excavations were carried out as a cooperation between the Institute of History, Archeology and Ethnography of the Academy of Sciences of Tajikistan, the Institute for Oriental Studies of the Russian Academy of Sciences (Moscow), the Eurasia Department of the German Archaeological Institute (Berlin), the Institute for the History of Material Culture (St. Petersburg), and the Museo Nazionale d'Arte Orientale (Rome). The excavations in Gelot-Darnaichi were conducted between 2007 and 2013 (for a summary cf. Vinogradova and Kutimov 2018: 39–88). The graveyards of Gelot and neighbouring Darnaichi are located on the banks of the Yakh-Su River in the Kulyab District south of the Khodzhasartes Mountains in the very south-east of Tajikistan (Teufer and Vinogradova 2010; Lombardo et al. 2014, Vinogradova and Kutimov 2018). The settlement of Saridzhar is located ca. 20 km further north (Teufer 2018b). Several Bronze Age burials were discovered, dating between 2450 and 1900 cal. BCE, respectively between 1800–1400 cal. BCE from Saridzhar (Teufer et al. 2014). The material of 21 humans was provided for the present study (cf. fig. 3.11 and Appendix I table 4). Analyses of carbon and oxygen isotopes were carried out on all samples, but since no nutrition analyses were performed, the group will only serve as reference population. Because of their conspicuous oxygen results two individuals were chosen for strontium analyses.

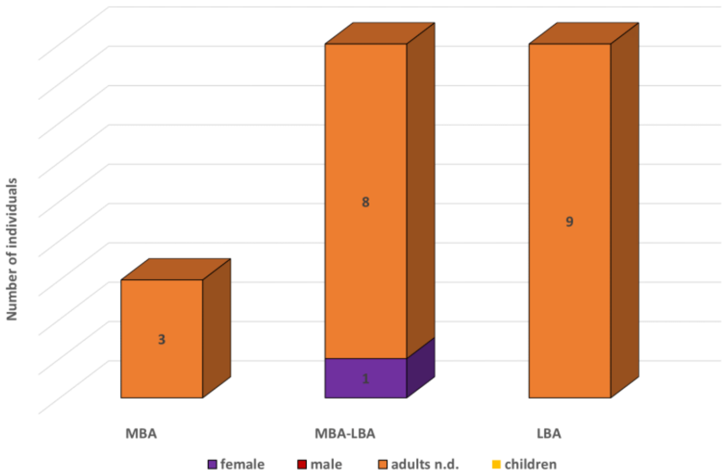


Fig. 3.11: Bar chart of the composition of all samples from Tajikistan.

3.2. Methods

The analyses of the skeletal material were performed in two individual procedures: those on collagen (protein fraction out of human bones) and those on structural carbonate (mineral phase out of tooth enamel). In cases where only teeth were at hand, tooth dentine was analysed instead, to gain some results at least. In order to prevent complications with the influence of fertilizers or imported diets of modern animals (Böhlke et al. 2000; Bentley et al. 2005; Maurer et al. 2012) all faunal samples were collected during the excavations in levels well dated to the Bronze or Iron Ages. To avoid a mixed signal of different individual charred cereals, one grain of each cereal sample has been selected for analysis.

3.2.1. Cleaning and sample preparation

Depending on the material, the cleaning, leaching and rinsing procedures differed, respectively were adjusted to the material: If possible, bone compacta were taken out of the medium layers, at places where compacta was thickest. The following amounts were inserted as samples for the isotope preparation:

Table 2.4: Amounts of inserted samples

Material	Collagen	Strontium	Carbonate
Bone Compacta	75–250 mg	20–25 mg	25–50 mg
Tooth enamel	-	15–25 mg	5–15 mg
Tooth dentine	-	10–20 mg	-
Dried plants	500 mg	1–2 g	-
Charred grains	-	10–25 mg	-

All steps were performed in a sterile atmosphere, tools were sterilized with ethanol and in the ultrasonic bath. The different materials were cleaned and prepared after the following protocols:

Bone compacta samples:

- cleaning of dirt and calcifications with toothbrush and diamond drill (removal of macroscopic dirt, colored parts and the topmost layers)
- sampling with a micro saw at the best-preserved part
- pulverization with agate mortar and pestle, divided into two grain sizes by a micro-sieve (cf. fig. 3.12): the bigger size was the initial substance for the collagen and strontium extraction, while the powder was used for the carbonate preparation
- leaching procedure as described below for the particular extraction

Enamel samples:

- cleaning of dirt and calcifications with a toothbrush and a diamond drill (removal of macroscopic dirt, colored, and carious parts)
- sampling with a diamond drill in horizontal lines from the uppermost part of the tooth crown
- rinsing in ultrapure distilled H_2O in an ultrasonic bath and oven-drying

Dentine samples:

- cleaning of dirt and calcifications with a toothbrush and a diamond drill (removal of macroscopic dirt, colored, and carious parts)
- sampling with diamond drill in horizontal lines at the middle part of the tooth
- rinsing in ultrapure distilled H_2O in an ultrasonic bath and oven-drying

Fig. 3.12: Cleaning and leaching from left to right: cleaning and crushing of bones with mortar and pistil; fractions of bone compacta; diamond drill for taking samples (pictures taken by the author during the lab work).

Charred plants:

- mechanical cleaning of sand and dust with needle and tweezers under the microscope
- careful crushing
- treatment with 6 M HCl for 24 hours after Styring et al. 2019
- transformation into ash in a ceramic beaker at 750°C for 12 hours (cf. fig. 3.13)
- dissolution in 1 ml 13 N HNO_3 in the ultrasonic bath
- evaporation of the acid solution on a hot plate (100°C) overnight

Fig. 3.13: Preparation of charred plants from left to right: charred grain samples; Volca V50 Oven for burning samples; remains of burnt plant samples (pictures taken by the author during the lab work).

Dried plants for strontium:

- mechanical cleaning of sand and dust with needle and tweezers under the microscope
- careful cutting into small pieces with a scalpel
- rinsing with ultrapure distilled H_2O in an ultrasonic bath at 65°C (changing the solution every 10 min until solution stayed clear, cf. fig. 3.14)
- dissolution in 2 ml aqua regia (3:1 13 N HNO_3 and 11 N HCl) + 2 drops H_2O_2 (30%) for 24–48 hours
- centrifugation (5 min 15.000 rpm) to remove macroscopic residues
- evaporation of the acid solutions on a hot plate (100°C)
- further dissolution in 2 ml 13 N HNO_3
- evaporation of the acid solution on a hot plate (100°C)

Dried plants for collagen:

- mechanical cleaning of sand and dust with needle and tweezers under the microscope
- rinsing in ultrapure distilled H_2O in an ultrasonic bath and oven-drying
- careful cutting into small pieces with a scalpel
- pulverization with an automatic mortar

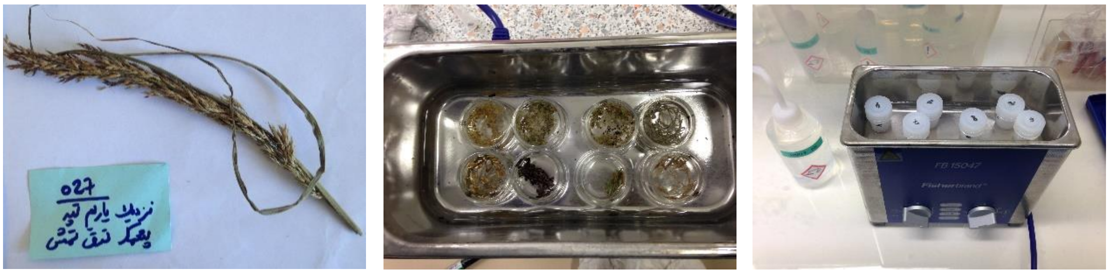


Fig. 3.14: Cleaning and leaching of dried plants for strontium from left to right: sample before preparation; dried plants rinsing with H_2O MilliQ in the ultrasonic bath; leaching procedure of all samples in the ultrasonic bath (pictures taken by the author during the lab work).

3.2.2. Preparation and purification of strontium ($^{87}Sr/^{86}Sr$)

The leaching procedure to remove the contribution of diagenetic strontium in teeth and bones was undertaken with 5% Acetic Acid in an ultrasonic bath (45°C) for 30 minutes followed by several rinsing steps with ultrapure distilled H_2O in an ultrasonic bath, changing the solution every 10 minutes until it became clear (ca. 5–10 times). Although not necessary, as tooth enamel does not undergo diagenetic changes, tooth enamel samples were also treated after the same procedure to achieve the exact same background treatment of all samples for ICP–MS measurements.

The cleaned, leached and oven dried samples were transferred into a clean Teflon beaker and dissolved in 1 ml 13 N HNO_3 in the ultrasonic bath at 65°C. Acid has been evaporated overnight at 100°C and samples were resolved in 2 ml 2 N HNO_3. Strontium was extracted through a Teflon column using "Sr-Eichrom" resin (Pin et al. 1994) after the following protocol (cf. fig. 3.15):

- washing columns 6 times alternately with 5 ml 6 N HCl and 0.05 N HNO_3
- conditioning step with 3 ml 2 N HNO_3
- uploading the samples

to remove other elements than strontium, columns were treated with:

- 2 ml 2 N HNO_3
- 3 ml 7 N HNO_3
- 0.5 ml 3 N HNO_3
- extraction of strontium with 4 ml 0.05 N HNO_3

The lab work executed for strontium extraction has been carried out in the clean isotope laboratory of the Geoscience Montpellier (CNRS – University of Montpellier). The measurements were realized using a Thermo Scientific MC–ICP–MS (MultiCollector–Inductively Coupled Plasma Mass Spectrometer) Neptune Plus at the AETE–ISO Platform from the OSU–OREME (Montpellier). The samples were adjusted to a signal of minimum 3 V and maximum 50 V. In the case when the signal was too low, samples were evaporated again and dissolved in 1–2 ml 0.05 N HNO_3. Ulug and Dzharkutan human samples were measured in cycles of 40 measurements per sample, Sialk humans and all references were measured in cycles of 60 measurements per cycle. To assess the reproducibility and accuracy of the isotopic ratios, standards were repeatedly run every five samples. All ratios were normalized using a value of 0.1194 for the $^{88}Sr/^{86}Sr$ ratio. The standard average values were 0.710243 ± 6 (2σ) (n = 20) for the NBS987 Sr standard.

Fig. 3.15: Strontium extraction from left to right: samples drying on the hot plate; chemical extraction of strontium; MC–ICP MS in the laboratory of the Geoscience in Montpellier (pictures taken by the author during the lab work).

3.2.3. Extraction of Collagen

The extraction of collagen was performed according to the strategy of Longin (1971) modified by Bocherens et al. (1991). The cleaned and weighed samples were transferred into centrifuge tubes and treated after the following protocol (cf. fig 3.16):

- stirring in 5 ml 1 M HCl for 1 hour at room temperature (if discoloration persisted solution was changed and procedure repeated)
  - DZH 1006, 1028-1, 1034-4, 1051, SK17-23 were treated with 0.5 M HCl for 2 hours
  - Sialk samples 27270, 27271, 27272, 27274, 27275, 27295 were treated with 0.25 M HCl for 4 hours (but only 27272, 27295 were successful)
- rinsing with distilled H_2O until pH ~2 (4–5 times, centrifugation: 3500 rpm 5 min)
- removal of contaminants with 0.125 M NaOH for 20–40 min stirred at room temperature (if discoloration persisted NaOH solution was changed every 10 min until became clear (2h–o/n)
- rinsing with distilled H_2O until pH 7–8 (4–5 times, centrifugation: 3500 rpm 5 min)
- gelatinization in 0.01 M HCl (pH2) for 18–24h at 95°C
- freezing with liquid Nitrogen and freeze-dried for 1–2 days

Fig. 3.16: Collagen extraction from left to right: leaching with HCl; samples before gelatinization; freezing in fluent nitrogen; freeze dryer loaded with samples; final product of pure collagen (pictures taken by the author during the lab work).

The laboratory work of collagen has been carried out in the Cosmochemistry Laboratory of the Mass Spectrometry Service of the National Museum of Natural History (SSMIM) in Paris. The inserted amount of collagen sample weighed between 340 µg and 650 µg. The measurements were undertaken with a Thermo Scientific Mass-spectrometer DeltaV-Advantage with a Flash 2000 Organic Elemental Analyzer (fig. 3.17). Based on replicate analysis of the international standard IAEA 600, the analytical error is estimated to be 0.02‰ (σ) for $\delta^{13}C$ and 0.34‰ (σ) for $\delta^{15}N$. Bone carbon values are compared to the universally accepted standard Pee Dee Belemnite (PDB) and bone nitrogen values are put in relation to the atmospheric nitrogen standard ambient inhalable reservoir (AIR). A substance with an isotope ratio less than that of the standard will have a negative δ value, and is said to be depleted relative to the standard. A substance that is enriched relative to the standard will have a positive δ value.

Fig. 3.17: Equipment in the Mass Spectrometry Service of the National Museum of Natural History in Paris from left to right: Mettler Toledo special accuracy weighing machine, Thermo Scientific MS DeltaV-Advantage; DeltaV-Advantage MS with Kiel IV device (pictures taken by the author during the lab work).

3.2.4. Preparation of structural carbonate

The preparation of structural carbonate was performed on teeth and bones from all sites. Due to the state of preservation of the bones from Ulug Depe, Dzharkutan, and Tepe Sialk varying amounts of mechanical cleaned bone compacta has been inserted as sample: Ulug bones 10–15 mg; Dzharkutan, Tepe Sialk bones 20–30 mg; for all sites 5–10 mg of pure tooth enamel has been used. The preparation of carbonate was performed after the protocol of Balasse at al. (2005):

- removal of diagenetic carbonate of bone samples with 2–3% NaOCl for 48h at room temperature (vortexed every 4–6h)
- rinsing with distilled H_2O (4–5 times, centrifuge: 3 min 15000 rpm)
- extraction of carbonate with 1M CH_3COOH for 1 hour at room temperature (vortexed every 20 minutes)
- rinsing with distilled H_2O (4–5 times, centrifuge: 3 min 15000 rpm)
- drying at 50–70°C for 24–36 hours until all water was thoroughly evaporated

The laboratory work executed for carbonate preparation has been carried out in the Cosmochemistry Laboratory of the Mass Spectrometry Service of the National Museum of Natural History (SSMIM) in Paris. The inserted amount of sample consisted of 580–620µg of bioapatite. The measurements were performed in an automated cryogenic distillation system (Kiel IV device) interfaced with a DeltaV-Advantage isotope ratio mass spectrometer (fig. 3.17). The analytical precision estimated from repeated analyses of the carbonate standard Marbre LM (normalized to NBS19) was lower than 0.06‰ for $\delta^{18}O$ values and lower than 0.03‰ for $\delta^{13}C$ values. Oxygen measurements are expressed as $\delta^{18}O$ which refers to the ratio $\delta^{18}O/^{16}O$ in the given sample relative to a standard in parts per thousand (‰). A substance with an isotope ratio less than that of the standard will have a negative δ value, and is said to be depleted relative to the standard. A substance that is enriched relative to the standard will have a positive δ value (Bowen et al. 2003).

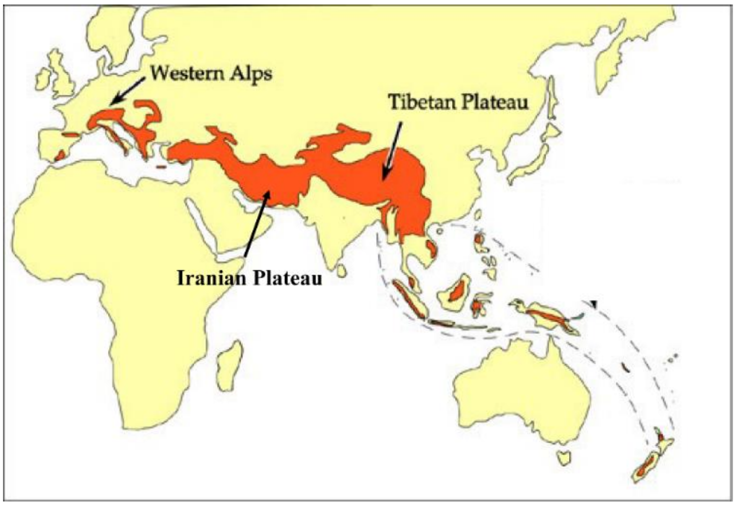


Fig. 4.1: The Alpine-Himalayan orogen stretches from Spain to New Zealand manipulated after Rosenbaum, Lister 2002: 1 fig. 2.

4. Determination of local ranges

4.1. Geological realities

Strontium belongs to the heavy elements, mainly bound as trace element in different minerals of geological formation. The composition of $^{87}Sr/^{86}Sr$ does not underlie fractionation processes, and remains both unaffected by weathering and biological processes such as photosynthesis, or body metabolism (e.g., Bentley 2006). Since strontium isotopes are assimilated in body tissues without alteration and fractionation processes, and human tooth enamel mineralization does not allow any changes afterwards, information is stored permanently in the tooth enamel of an individual (cf. chapter 2.2.). Therefore, $^{87}Sr/^{86}Sr$ isotopes are perfectly suitable for mobility studies of humans and animals. For the identification of one´s origin, the determination of the local, bioavailable isotopic signature is one of the most important issues. But archaeological sites do not show a specific $^{87}Sr/^{86}Sr$ value, instead a bioavailable range, which needs to be determined for every site or region. Therefore, the geographic distribution of isotopes was one of the main issues of this thesis and the basis for all following investigations. Early in the beginning of isotopic research on archaeological material, scientists recognized a strong correlation of isotopic ratios with the geographic location and prevailing natural conditions (e.g., Ericson 1981, 1985; Sealy 19991; Price et al. 1994a, b, 2000, 2001, 2002). Tepe Sialk, as well as Ulug Depe and Dzharkutan are located along the *Alpine Belt* on the Iranian Plateau. The Iranian Plateau describes a geological termination, which extends over an area of 2.5 million km^2, far beyond today's political borders, including the area from the Zagros Mountains in the west to Hindukush in the east (fig. 4.1). Today it covers the national territories of Iran, Afghanistan, Pakistan, and Turkmenistan. In the north it is limited by the Caucasus Mountains, the Caspian Sea and the Karakarum Desert, in the south, respectively southwest by the Persian Gulf, the street of Hormus, and the Gulf of Oman. The landscape is characterized by a high topographical, geological, and ecological diversity. The plateau is formed by the tectonic movements of the Arabic plate against the Eurasian and the Indian plate. The high mountain ranges as the Zagros, the Kuhruz, Elborz, Kopet Dagh and Hindukush were formed through the “Alpine Orogeny” along the Alpine Belt. A process started during Cretaceous and is ongoing till today (Rosenbaum and Lister 2002). Due to the geological location along the turning circle, and the high mountain ranges, which surround the plateau like a crown, rain clouds are prevented from passing. Therefore, some extremely dry regions have formed and some of the hottest places on earth developed in the lowlands of the plateau, such as the Kavir Desert, Lut Desert, or Margo Desert (Rosenbaum and Lister 2002: 1–2). Wide areas of Central Asia are dominated by a dry, hot and arid steppe vegetation, groundwater sources like springs, wells, rivers, or lakes are generally rare, and often seasonal. The here investigated regions are all located in rather hot and arid vegetation zones (fig. 4.2), the climate in Ulug Depe is similar to the Karakum Desert but more moderate through the influence of the Kopet Dagh Mountains. Average annual temperature is 16°C, maximum is 48 °C, minimum is -26°C; the annual precipitation is 228 mm. (Orlovsky 1994: 31–33). The climate of the lower Surkhan Darya region is characterized by seasonal rainfalls in winter and early spring, giving an early and short growing season. From May to October climate is dry and hot. Average annual precipitation is 200–240 mm, the mean annual temperature is +16.8°C, maximum +47°C and minimum -32°C (Mukin 1997: 767). The western sub-province of the Kashan province shows an average annual rain- and snowfall of 137 mm and annual average temperatures around 19°C, with cold temperatures around 0°C in winters and up to 50°C in the summer months (Zanjani 2012: 2).

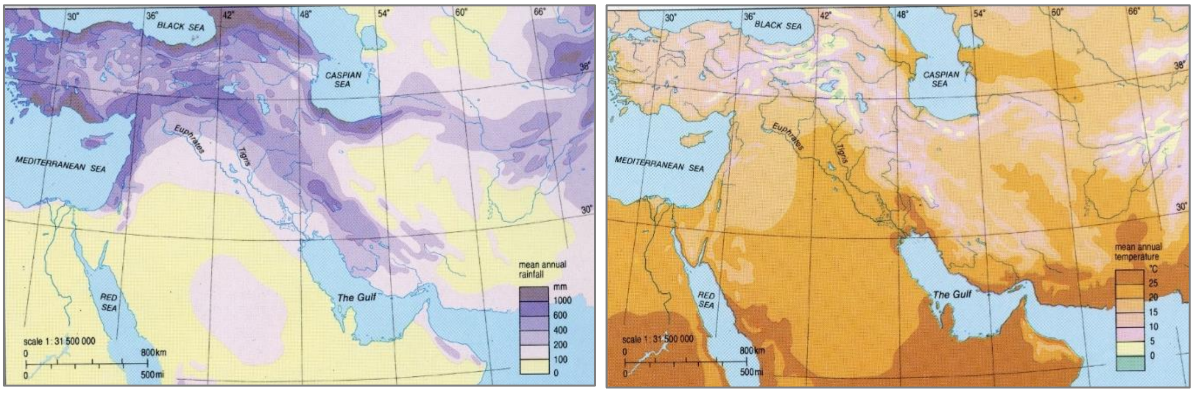


Fig. 4.2: Map of mean annual rainfall (left) and mean annual temperature (right) of the Near East and southern Central Asia after Roaf 1998: 22–23.

4.1.1. Kopet Dagh foothills

Ulug Depe is located in the northern sub montane plains of the Kopet Dagh mountain range. The Kopet Dagh range is part of the alpine folded mountains developed by the collision of the Eurasian and the Iranian tectonic plates. The region has high seismic activity (Fet 1994: 198). The chain is formed by a number of separate anticlinal ranges comprised of Cretaceous and Paleogene sediments as sandstone, limestone, clay, and marl (fig. 4.3). In the north, the Kopet Dagh is limited by the sub montane plain, rising from 50 to 300 m. The sub montane region is formed from alluvial fan deposits and younger Quaternary loess deposits represented by different types of loam layers. The Central Karakum lies directly northward from the sub montane plain of the Kopet Dagh. Almost 80% of Turkmenistan is covered by the Karakum Desert (“black sand”). The Karakum reaches air temperatures up to 45°C degrees and ground temperatures up to 70°C degrees (Babae 1994: 6–7).

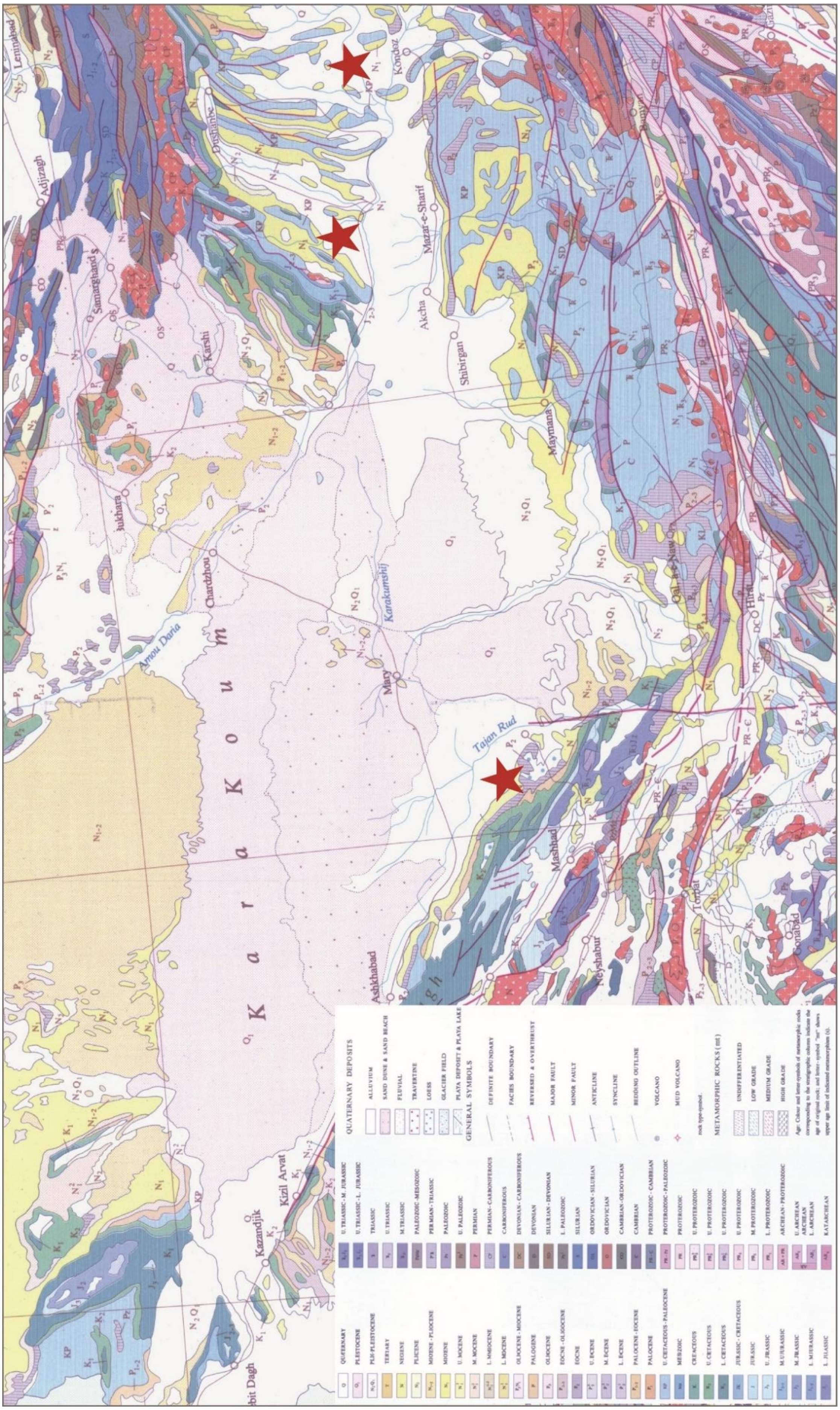


Fig. 4.3: Geological map of southern Central Asia after Haghipour et al. 2009, red stars mark the investigated regions.

After Fet the surrounding area of Ulug is characterized by three types of deserts: 1. "*Sand-clay deserts* with intermittent sand massifs and clay areas (usually takyrs). This desert type occupies the alluvial plain; strata of groundwater lie relatively close to the surface." 2. "The *Stony submontane deserts* are formed on alluvial fan deposits in the piedmont area of Kopet Dagh, they accumulate rubble and gravel and have low levels of substrate salinization. Soils here are desert sierozems (gray desert soils) covered by sagebrush or ephemerous vegetation. Groundwater is usually scattered and does not form strata." And 3. "The *Loess (and gravel-loess) deserts* are widespread in piedmont areas and are the transitional zone from the plain to the low mountain belts. Extremely fertile soils, which are mostly used for agriculture with artificial irrigation" (Babae 1994: 15).

4.1.2. The Surkhan Darya region

The Surkhan Darya valley is located at the eastern foothills of the Kugitang Mountains, where the stream of the Surkhan Darya flows from north to south along the Kugitang range (highest range up to 3.137 m), which belongs to the Ghissar Mountains, rising in the easternmost part of Turkmenistan east of the Amu Darya River. The Kugitang mountain chain is comprised mainly of Mesozoic (Jurassic) limestone and intrusive (Paleozoic?) granite and forms steep slope eastward toward Uzbekistan (fig. 4.3; cf. Babae 1994: 12; Kaniuth 2021: 460). The valley around Dzharkutan (in 350 m altitude a.s.l.) is bounded to the west by the Karachagyl mountain chain, only a few kilometres from Dzharkutan and continues to the plateau where Tilla Bulak is located some 500 m above the Surkhan Darya valley. The Karachagyl chain consists of folded Mesozoic (Jurassic, Cretaceous) and Neogene sediments and sedimentary rocks (mud-rock), while quaternary sediments of gravel and loess fill the intermediate depressions (Kaniuth 2021: 460).

4.1.3. The Kashan Plains

The Central Iranian Plateau comprises five large plains: the north-western plains of Qazvin and Tehran, the Semnan plains in the east, the flat region around Qom, bordering the Kavir desert, and the southern Oasis of Kashan. The plains of Kashan are divided by the mountains into two different climatic and vegetational regions: the arid eastern lowlands and the more moderate western highlands (e.g., Shirazi, Tengberg 2012; Zanjani 2012). The western valley is formed by volcanic and intrusive rock outcrops as a natural pathway along the eastern foothills of Karakas Mountains, which follows from the northern plains of Qom to Kerman province in the south (fig. 4.3; cf. Zanjani 2012: 1–2). For a detailed description of the topography and geology of the region cf. Heydari-Guran (2014: 19–24). The western sub-province shows an average annual rain- and snowfall of 137 mm and annual average temperatures around 19°C, with cold temperatures around 0°C in winters and up to 50°C in the summer months. Rivers are in general rare, small, and temporary (Zanjani 2012: 2). Geomorphological soundings proved the former existence of a river which flowed between the two mounds of Sialk, and assured the water supply of the settlement (Heidari 2002). Further water sources are several springs in the surroundings, the biggest and, due to its beautiful gardens famous till today, is the Fin spring (*Fin čašma*), 4 km south of Tepe Sialk.

4.2. Determination of the bio-available local $^{87}Sr/^{86}Sr$

The isotopic composition of an individual is impacted by several physiological factors, but mainly by the surrounding habitat. Studies discuss different methods and calculations of how to get the most reliable local bio-available $^{87}Sr/^{86}Sr$ range, as an accurate basis for comparisons (Price et al. 2002; Knipper 2004; Bentley et al. 2004; Gerling 2015). The number of reference samples, respectively the kind of species and therefore the range of influence represents crucial preconditions. For reliable results a combination of i.e., faunal and botanical remains, sediment or soil, and water samples provide a good basis of the biologically available $^{87}Sr/^{86}Sr$ at a site (e.g., Knipper 2004: 627; Bentley et al. 2004). Several studies were carried out on different combinations of reference material approaches and provided persuading results (Price et al. 2002; Bentley et al. 2004; Bentley and Knipper 2005; Gregorizka 2013; Gerling 2015; Ventresca-Miller et al. 2017).

The local $^{87}Sr/^{86}Sr$ signals obtained in this study for southern Central Asia and Iran were calculated following the traditional method of expanding the mean value with 2 standard deviations after Price et al. (2002: 132). Approaches like the calculation of the local $^{87}Sr/^{86}Sr$ signature using Microsoft Excel Macro Isoplot (e.g., Vohberger 2011), as well as other statistical evaluations (IsoConc, MixSiar) which have not been applied in this study, since the number of samples was too small for statistically accurate results (personal communication with Arash Sharifi).

4.2.1. Definition of locals and non-locals

Several different methods on the determination of locals and non-locals have been applied (e.g., Grupe et al. 1997; Price et al. 2004; Bentley et al. 2004). The research in this subject is lively discussed and new insights deliver more reliable approaches (e.g., Styring et al. 2019). Common and often applied are intra-individual comparisons of tooth enamel and bone ratios. In the best case in correlation with available $^{87}Sr/^{86}Sr$ out of biological material, like plants and animals (Bentley and Knipper 2005). Furthermore, the determination of the local signal through geological sediments, soils, or rocks, is possible, but bearing some uncertainties as bedrocks often consist of a variety of minerals and rocks, which differ in the $^{87}Sr/^{86}Sr$ ratios. Additionally, they undergo different weathering processes, hence, analyses of surrounding sediments or bedrocks deliver comparable results of the bio-available $^{87}Sr/^{86}Sr$ signature, but might slightly differ to ancient compositions (Price et al. 2002: 122). Moreover, comparisons with groundwater or surface water, like rivers, or lakes are possible, but seasonal variations or small-scale geological variability might be responsible for variations in the $^{87}Sr/^{86}Sr$ signature in water samples (Knipper 2004: 620). A detailed overview is given in Knipper 2004: 616–624. She summarized three main criteria to identify immigrants in archaeological material according to the $^{87}Sr/^{86}Sr$ ratio of tooth enamel and bones: 1) An intra-individual difference of 0.001 in the $^{87}Sr/^{86}Sr$ ratio between bone and tooth enamel (e.g., Grupe et al. 1997: 520; Price et al. 2004: 30). 2) The aberration of ± 2 standard deviations of the enamel ratios from the mean of all bone data (Price et al. 2002: 131). 3) The aberration of ± 2 standard deviations from the mean enamel ratios of faunal remains from the same site (Price et al. 2002: 124–125; Bentley and Knipper 2005). But she pointed out, that a purely mathematic approach does not always deliver true insights (e.g., Knipper 2004: 624–626), hence a systematic investigation of the wider environment or possible regions of origin represent the optimal basis for reliable results (Knipper 2004: 627). The different combinations and possibilities of interpretation of tooth enamel and bone signals are summarized in fig. 4.4.

$^{87}Sr/^{86}Sr$ isotopic signal		Bones		
		local	non-local	
Teeth	local	1. lifelong local (A) 2. migrant from a geologically similar region (B)	1. Birth at the place of funeral, relocation in geologically altering region, return short before death (D) 2. Birth in geologically similar region to the funeral place, migration to a geologically differing region, arrival at the place of funeral short before death (E)	
Teeth	non-local	Immigrant from a geologically different region after completion of tooth formation and long residence at the place of death (C)	similar	different
			lifelong local, migration to the place of funeral short before death (F)	Several relocations, arrival at the place of funeral short before death (G)
			imported diet	

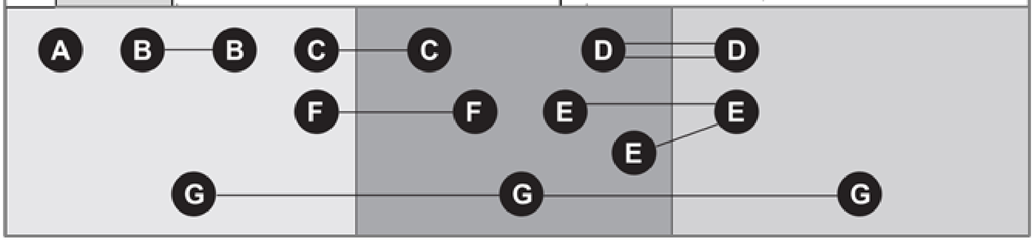


Fig. 4.4: Possibilities of interpretation of tooth enamel and bone strontium alterations manipulated after Knipper 2004: 631 fig. 19.

4.3. Selection of samples

The determination and reliability of the bio-available local signal of a site strongly depends on the available material. Especially concerning older excavations, it is often not easy (sometimes even impossible), to obtain suitable material. The samples should have been selected during the excavations and date to the corresponding period to avoid complications with the influence of fertilizers and modern pollution (good overviews in this issue are given in Böhlke and Horan 2000; Price et al. 2002; Bentley and Knipper 2005). Proven as precise and reliable are for example water and soil samples, local plants, sedentary mammals, or reptiles (cf. chapter above). More usual, in contrast, is the situation that sheep, goats and cattle, represent the main animal bone repertoire of excavations. Especially in pastoral communities, they might provide a wide signal as they travelled around with the humans and reflect a similar wide signal, and not necessarily a precise range of the settlement. Knipper recommend the use of pigs, since they were relatively common animals in human company in the Near and Middle East. Pigs are considered to be little mobile, and were therefore rather unlikely herded to farther pastures, but obtained their food from the settlement itself or from a relatively limited area around the settlement. Hence, they appear to be best suited for determining the isotopy of the local bioavailable $^{87}Sr/^{86}Sr$ (Knipper 2004: 623). But availability determines the protocol, for the determination of the local $^{87}Sr/^{86}Sr$ signals obtained during this study, mainly rodents, and charred plants were taken, moreover, ovicaprids, one dog and several wild carnivores were added (large felid, fox, hyena, considering wild predators might have widespread territories). When only human material was available, tooth dentine is suitable, as it strongly underlies diagenetic changes, and can be considered as a mirror of the isotopic composition of the surrounding soil. The method has been proven by several studies (e.g., Gerling 2015) and provided reliable data. In this study, the local $^{87}Sr/^{86}Sr$ range of Bashman 1 was determined by human dentine samples, and the $^{87}Sr/^{86}Sr$ range of Dzharkutan was verified by two dentine samples. Several $^{87}Sr/^{86}Sr$ results of single rodents were additionally obtained during this study, especially from Iran, but can hardly be considered as reliable local signals. Too many different factors impacting one random result. Therefore, the single results will serve as indicators for the isotopic $^{87}Sr/^{86}Sr$ distribution of the archaeological sites, but may also be considered as fortuitous.

4.4. The local $^{87}Sr/^{86}Sr$ signals from southern Central Asia

The itemized results of all references from Ulug Depe, Dzharkutan, Tilla Bulak, Sangir-tepe, and Erkurgan are described in Appendix table 4, and illustrated in fig. 4.5. The geographic locations of the sites are shown in fig. 3.4. The local $^{87}Sr/^{86}Sr$ signals obtained from southern Central Asia were calculated expanding the mean value with 2 standard deviations after Price et al. (2002: 132). The deviations were negligible small, error bars were overlapped by the applied symbols in the figures. Hence, symbols encompass the error margins at 2σ level for the $^{87}Sr/^{86}Sr$ ratios and 1σ level for $\delta^{18}O$ ratios.

4.4.1. Ulug Depe

Ulug Depe is located at the northern foothills of Kopet Dagh Mountains in southern Turkmeinstan (fig. 3.4 and fig. 5.5, the geographic location of Ulug Depe is in detailed discussed in chapter 5). The material used for the determination of the bio-available local $^{87}Sr/^{86}Sr$ range of Ulug Depe consisted in total of 11 samples: three samples of mice (*Mus* sp.), two carnivores and six carbonized samples of ancient plants. The plants are represented by four samples of barley (*Hordeum vulgare),* supposed to be grown locally; one sample of juniper wood (*Juniperus* sp.), a mountainous species; and one sample of tamarisk (*Tamaris* sp.), with a high variety of adaptation, but in this region mainly growing along rivers and in the plain. The carnivores are represented by a dog (*Canis familiaris*), assumed to have lived close to the humans; and a large felid (*Panthera* sp.) whose habitat was the wilderness. The results moved between 0.707885 (± 0.000004, mouse R-CH5) and 0.708045 (± 0.000003, juniper SK18-02) with an average of 0.707964 ± 0.000045, resulting in a local $^{87}Sr/^{86}Sr$ range for Ulug Depe of **0.707874 – 0.708054** (2σ, n = 11) (fig. 4.5).

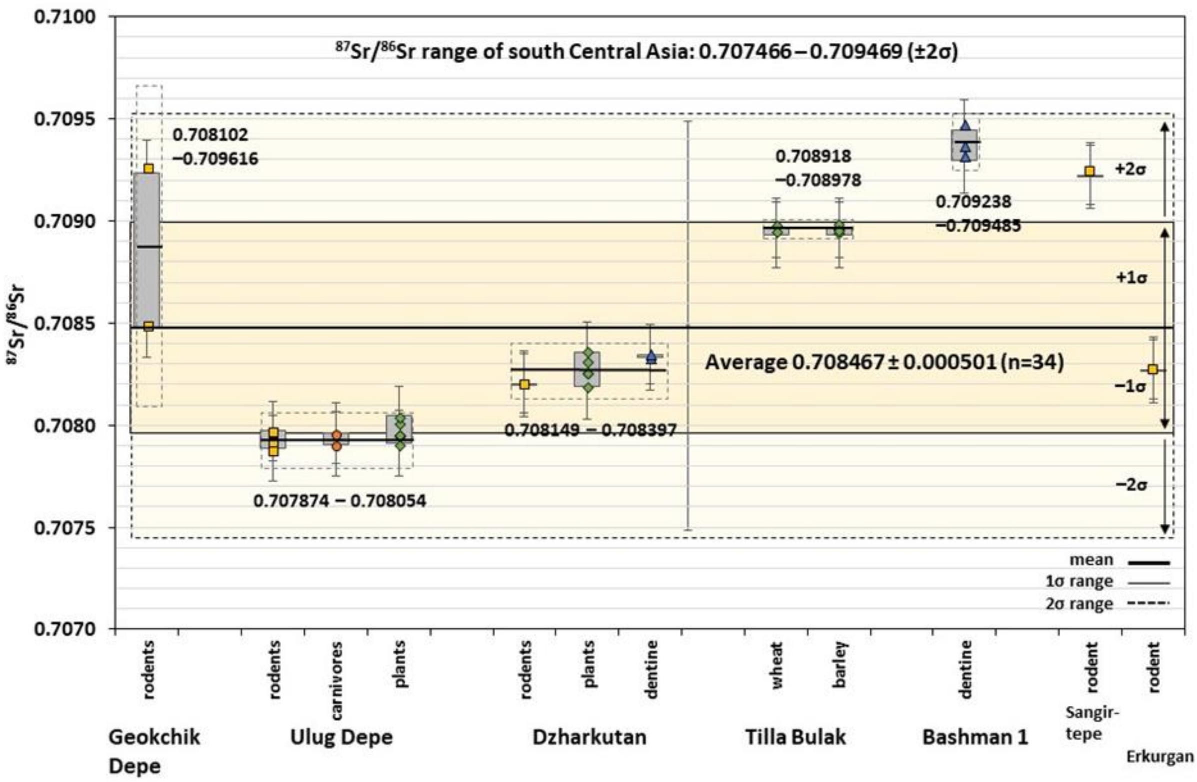


Fig. 4.5: Local $^{87}Sr/^{86}Sr$ signals from southern Central Asia (sites are in geographical order from west to east): orange circles correspond to animals, blue triangles to human dentine, green rhombs to plants, yellow squares to rodents. Grey boxes mark the measured results of the references, dashed boxes mark the calculated local $^{87}Sr/^{86}Sr$ signals including the error margins at 2σ level, yellow box marks the calculated regional range (dark ± 1σ, light ± 2σ).

4.4.2. Dzharkutan

Dzharkutan is located in the southern valley of the Surkhan Darya river in southern Uzbekistan (fig. 3.4 and fig. 7.3, the geographic location of Dzharkutan is in detailed discussed in chapter 7). The samples used for the determination of the bio-available local $^{87}Sr/^{86}Sr$ range of Dzharkutan included two samples of rodents, five botanical samples and two human dentine samples. The plants consisted of three samples of barley (*Hordeum vulg.*), most probably locally grown; one sample of willow (*Salix* sp.), riverine and probably locally grown too; and one sample of tamarisk (*Tamaris* sp.). In addition to the two rodents (*Mus* sp.), the dentine of burial DZH 1049 and 1051 were added to gain a certain number of references. The results ranged between 0.708191 (± 0.000004, willow SK18-07) and 0.708356 (± 0.000003, barley SK18-09-1) with an average of 0.708273 ± 0.000062, resulting in a local $^{87}Sr/^{86}Sr$ range for Dzharkutan **0.708149 – 0.708397** (2σ, n = 9) (fig. 4.5).

4.4.3. Tilla Bulak

To get a better idea of the surrounding situations, further faunal samples were added from Tilla Bulak, a small village 25 km west of Dzharkutan (fig. 3.4 and 7.3; Kaniuth 2007, 2009, 2016). Tilla Bulak is situated in the Pashkurt plains some 500 m above the eastern Surkhan Darya valley, separated through a small mountain chain. A walkable path exists there, which ends near Dzharkutan. It represents a new settlement chamber of the same time period, dating to 2000–1750 BCE (Kaniuth 2016). The analyses of seven samples of wheat and barley (Peters in Kaniuth 2009: 89–91) resulted in a range between 0.708930 (± 0.000011, barley SK18-79) and 0.708968 (± 0.000008, barley SK18-75) with an average of 0.708948 ± 0.000015, resulting in a narrow, but significantly different local $^{87}Sr/^{86}Sr$ range of **0.708918 – 0.708978** (2σ, n = 7) (fig. 4.5). The lower Surkhan Darya valley is formed by two alluvial fans: Dzharkutan and Bustan were fed by the Sherabad River, which comes from the Derbent region; Tilla Bulak was fed by the Ulanbulaksaj River, which runs through the Pashkhurt valley and continues to Sapallitepa. The two groundwater sources are reflected and well distinguishable through the differences of the local strontium signals of Tilla Bulak and Dzharkutan. Although we have no determined local signals, it can be assumed that the local strontium range of Sapallitepa is in a similar range as that of Tilla Bulak, while Bustan most likely shows a similar local strontium range to Dzharkutan.

4.4.4. Bashman 1

The site Bashman 1 is located in the northern range of the Nuratau Mountains in the district of Koshrabad in central Uzbekistan (fig. 3.4). The material was collected by Elise Luneau in the course of an archaeological field project of the German Archaeological Institute in 2018. The two human individuals from Bashman 1 were tested for their strontium ratios. The results of the dentine samples were close to each other (0.709297 ± 0.000005 and 0.709343 ± 0.000005), giving, due to diagenesis, an impression of the strontium distribution in the surrounding. The enamel ratio of the child was also close to the two dentine ratios; as it was a young child (below 7 years), it seems acceptable to assume it was born in the region and to include the result in the local range, to gain more reliable data. Then, the results range between 0.709297 (± 0.000005) and 0.709445 (± 0.000007) with an average of 0.709362 ± 0.000062 resulting in a local $^{87}Sr/^{86}Sr$ signal of **0.709238 – 0.709485** (2σ, n = 3) (fig. 4.5).

4.4.5. Geoktchik Depe

The site of Geoktchik Depe is located in the Dehistan Plain, in southwestern Turkmenistan, adjacent to the eastern Caspian Sea Shore, which is today an arid and hot region (Lecomte 2005, 2007b, cf. fig. 3.4). Two mice provided for strontium analyses displayed with 0.708480 and 0.709237 two completely different strontium ratios, with an average of 0.7088585 ± 0.000378. More samples will be necessary to gain a more precise result. Until now, Geoktchik Depe shows a wide $^{87}Sr/^{86}Sr$ signal of **0.7081015 – 0.7096155** (2σ, n = 2) (fig. 4.5).

4.4.6. Other sites in Central Asia

Further references consist of the bone material of two rodents (*Mus* sp.): one from Sangir-tepe, and one from Erkurgan (Mashkour et al. 2016). Erkurgan and Sangir-tepe are located in the Kashka-Darya

Province in southcentral Uzbekistan (cf. fig. 3.4). Erkurgan is located in an inner-continental, fertile region with moderate climate. Sangir-tepe is located on the western foothills of the Gissar Mountains at 500 m a.s.l. With a $^{87}Sr/^{86}Sr$ ratio of 0.709224 ±0.000006 (1σ) the rodent from Sangir-tepe was near the upper limit of Tilla Bulak, while the rodent from Erkurgan was with 0.708273 ± 0.000003 (1σ) in the same range as the one of Ulug Depe (fig. 4.5).

4.5. The local $^{87}Sr/^{86}Sr$ signals from Iran

The itemized results of all references from Iran are described in Appendix table 5, and illustrated in fig. 4.6, the sites are shown in fig. 3.4 and fig. 4.7 – 4.11. The local $^{87}Sr/^{86}Sr$ signals obtained from Iran were as well calculated expanding the mean value with 2 standard deviations (2σ) after Price et al. (2002: 132). The results from the Gorgan Wall demonstrated, that the calculated local range obtained with this equation does not always conform with the bio-available range as the equation is based on the average and the standard deviation. To get a more reliable local range for this region, the highest and lowest result were expanded with two standard deviations. The deviations were negligible small, error bars were overlapped by the applied symbols in the figures. Hence, symbols encompass the error margins at 2σ level for the $^{87}Sr/^{86}Sr$ ratios and 1σ level for $\delta^{18}O$ ratios.

4.5.1. Tepe Sialk

Tepe Sialk is located on the Central Iranian High Plateau in the southwestern suburbs of Kashan city. (cf. fig. 3.4, the geographic location of Tepe Sialk is in detailed discussed in chapter 9). The samples used for the determination of the bio-available local $^{87}Sr/^{86}Sr$ range of Tepe Sialk consisted of three samples of ovicaprids, two goats, one sheep, and two canids, a fox, and a hyena, as well as six samples of human dentine. The $^{87}Sr/^{86}Sr$ ratios ranged between 0.707956 and 0.708256 with an average of 0.708070 (± 0.000095, n = 11) resulting in a local $^{87}Sr/^{86}Sr$ range of **0.707880 – 0.708260** in Tepe Sialk. Additionally, three samples of coprolites of hyenas from Kaftar Khoun, a wild area 5 km west of Tepe Sialk, were analysed (Monchot and Mashkour 2010; Djamali et al. 2020). Hyenas are territorial scavengers and predators, in rich environments their territories cover an area of around 10 km^2, while in dry and arid regions territories can be up to 1000 km^2. The $^{87}Sr/^{86}Sr$ results from Kaftar Khanoum hyenas indicate the animals as inhabitants of the direct surroundings. The obtained range for this site of 0.707919 – 0.708155 with an average of 0.708011 (± 0.000096, n = 3) resulted with a local $^{87}Sr/^{86}Sr$ range of **0.707820 – 0.708203** in the exact same range than Tepe Sialk (fig. 4.6).

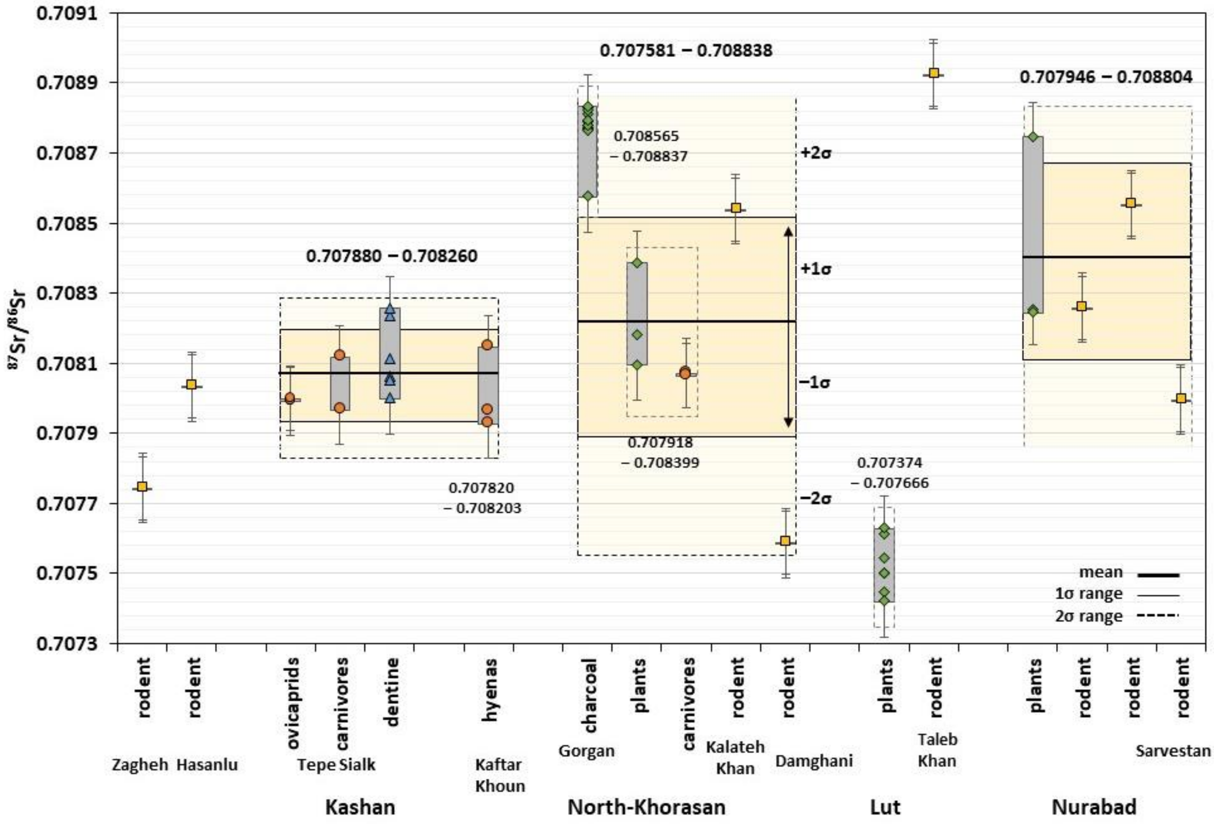


Fig. 4.6: Local $^{87}Sr/^{86}Sr$ signals from Iran: orange circles correspond to animals, blue triangles to human dentine, green rhombs to plants, yellow squares to rodents. Grey boxes mark the measured results of the references, dashed boxes mark the calculated local $^{87}Sr/^{86}Sr$ signals including the error margins at 2σ level, yellow box marks the calculated regional ranges (dark ± 1σ, light ± 2σ).

4.5.2. Along the Gorgan Wall

The collection from Iranian samples also included 12 samples of charred plants from the Gorgan Plains in north-eastern Iran (Mashkour 2013b, et al. in press; Sauer 2017, et al. 2013, Rudov et al. 2020). The material collected at different stations of Dasht Qaleh, Qaleh Kharabch, Fort 4, Ban Saran Fort, Qelich Qoineh along the Gorgan Wall (fig. 4.7) resulted in values between 0.708573 (± 0.000004) and 0.708831 (± 0.000003) with an average of 0.708774 ± 0.000065 ending in a calculated local $^{87}Sr/^{86}Sr$ range of 0.708645 – 0.708904. The case of the Gorgan Wall demonstrates that the mathematic equation does not always conform with the reality of the bio-available signal, as the lowest result, obviously bio-available, is not included in the calculated range. Hence, the expanding of the maximum and minimum with 2 standard deviations deliver a more accurate result of **0.708565 – 0.708837** (2σ, n = 12, fig. 4.6).

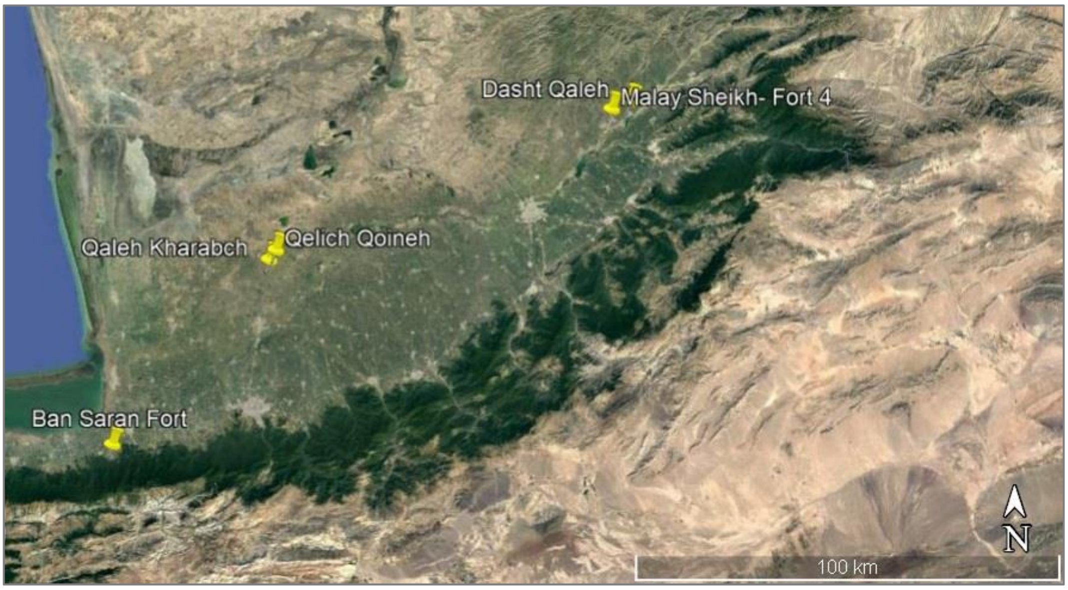


Fig. 4.7: Geographic locations of the investigated sites in the Gorgan Plains (©Google Earth maps).

4.5.3. North-Khorasan

From North Khorasan province in northeastern Iran analyses of different species of modern plants and animals in the region around Shirvan were carried out. Shirvan city is located only 190 km linear distance from Ulug Depe on the southern side of the Kopet Dagh Mountains and provides interesting results concerning the distribution of strontium in this region (fig. 3.4, 4.8). The river of Gholjogh, a branch of the Atrak river, is located about 20 km of north of Shirvan city. Two modern samples were collected and analysed from Shirvan: the tooth enamel of a hyena and the dried wood of a tamarisk. The $^{87}Sr/^{86}Sr$ results of the tamarisk with 0.708064 ± 0.000003 (1σ) and the value of the hyena of 0.708072 ± 0.000006 (1σ) combined to a very small $^{87}Sr/^{86}Sr$ range of 0.708058 – 0.708084 (2σ, n = 2). From Gholjogh three samples of modern, dried plants were analysed (*Asteraceae* and *Alhagi*). They showed the lowest value of 0.708094 ± 0.000002 (1σ) and the highest value of 0.708385 ± 0.000007 (1σ), resulting in a local $^{87}Sr/^{86}Sr$ signal of 0.708090 – 0.708399 (2σ, n = 3). Both ranges can be summarized in an average of 0.708159 ± 0.000120 providing a calculated local $^{87}Sr/^{86}Sr$ signal for Shirvan region of **0.707918 – 0.708399** (2σ, n = 5) (fig. 4.6).

The north-eastern areas are completed by one rodent from Kalateh Khan (fig. 4.8), a Neolithic site in the Shahroud Plain south of the Gorgan Plains, in south Khorasan province (Mashkour and Mohaseb 2016; Roustaei 2016, Cucchi et al. 2020). Although unexpected, but very nice, the $^{87}Sr/^{86}Sr$ result fits with 0.708538 ± 0.000003 (1σ) well in the determined local signal of the Gorgan plains (fig. 4.6). Another rodent was analysed from Tepe Damghani, a Bronze Age site in Semnan province, which is culturally related to southern Central Asia and the Oxus Civilisation (Mashkour 2008; Francfort et al. 2014; Vahdati et al. 2014). Although geographically close, the results were with $^{87}Sr/^{86}Sr$ 0.707587± 0.000003 (1σ) completely different to all the other results obtained in the region (fig. 4.6).

All measured ratios from North Khorasan can be summarized, resulting in an average of 0.708538 ±0.000357 (including the Gorgan Wall) and a calculated local range of 0.707581 – 0.708838 (2σ, n = 19) (fig. 4.6).

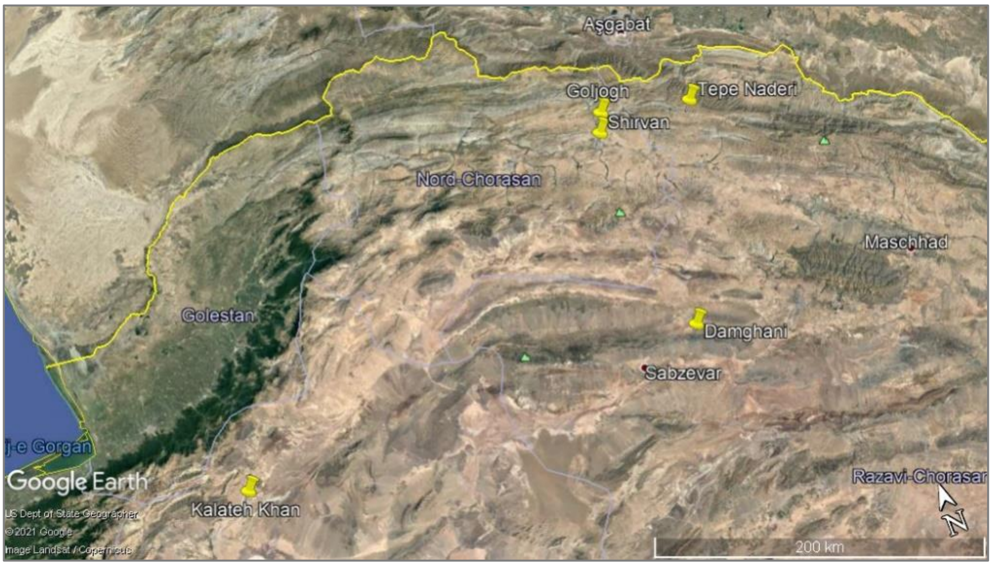


Fig. 4.8: Geographic location of the investigated sites in north-eastern Iran.

4.5.4. Nurabad

The two mounds of Nurabad are located in the outskirts of the modern town Nurabad in the fertile Dasht-e Nurabad in Fars province (fig. 3.4; Mashkour 2006; Potts and Roustaei 2006, Weeks et al. 2006). Analyses were performed on one Indian gerbil (*Gerbillinae* sp.), and charred grains of an indetermined cereal, an almond tree (*Amygdalus* sp.) and a pistachio tree (*Pistacia* sp.). The results ranged between 0.708244 (± 0.000003, almond tree) and 0.708746 (± 0.000007, cereal) with an average of 0.708375 ± 0.000215 resulting in a wide $^{87}Sr/^{86}Sr$ range of **0.707946 – 0.708804** (2σ, n = 4) (fig. 4.6). Additional samples from western Fars province which can be added to the local range of Nurabad: two rodents, one from Tepe Pahlavan northwest of Nurabad (Vahdati 2010) and one from Sarvestan Palace 90 km south of Shiraz (Mashkour and Askari 2017, cf. fig. 4.9). Both results fit with 0.708552 ± 0.000003 (1σ) (Pahlavan) and 0.707995 ± 0.000003 (1σ) (Sarvestan) well in the local $^{87}Sr/^{86}Sr$ signal of Nurabad.

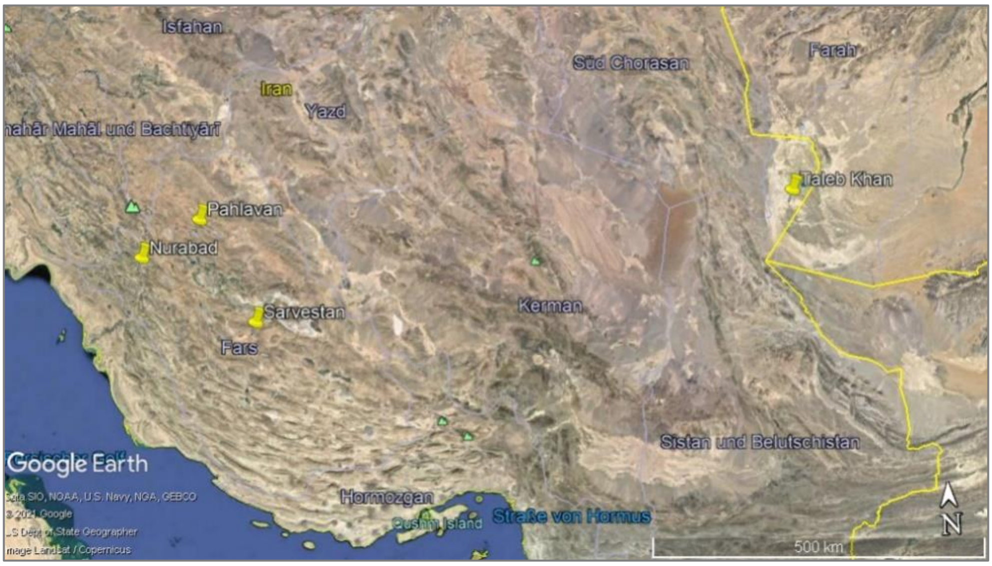


Fig. 4.9: Geographic location of the investigated sites in southern Iran.

4.5.5. Lut Desert

In 2016 a group of different scientists under the direction of Hossein Akhani made an expedition to Lut desert (Trescher 2017) and investigated one of the hottest places on earth with temperatures up to 70°C and an annual rain fall less than 50 mm (with a potential evaporation of 5000 mm). Plants growing in these exceptional dry and hostile environments can be considered as absolute extreme, demonstrating the apogee of outcome (Rudov et al. 2020). The collection of seven modern, dried plants included two samples of rosemary (*Salsola* sp.), three samples of tamarisks (*Tamaris* sp.), one sample of hammada (*Amaranthacea*) and one sample of calligonum (*Calligonum* sp.). The investigated region in Lut desert covered an area of approximately 200 km^2 in the eastern vicinity of Shahdad (fig. 4.10, cf. Lyons et al. 2020). According to the strontium results, the landscape turned out to be quite homogeneous. The results ranged between 0.707418 (± 0.000005, tamarisk) and 0.707628 (± 0.000003, hammada) with an average of 0.707520 ± 0.000073 resulting in a local $^{87}Sr/^{86}Sr$ signal of **0.707374 – 0.707666** (2σ, n = 7) (fig. 4.6).

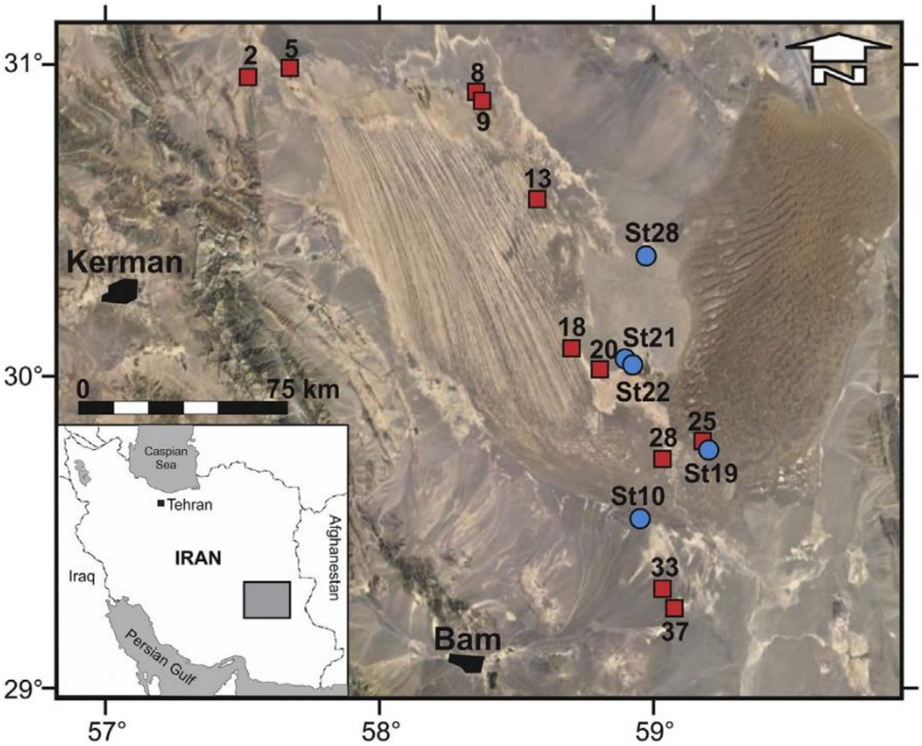


Fig. 4.10: Map of the different stations in Lut Desert after Lyons et al. 2020: 2 fig. 1.

4.5.6. Other sites in Iran

More references are represented by bone material of rodents (*Mus* sp.) from different archaeological sites all over Iran. The material was studied and provided by Marjan Mashkour in collaboration within different archaeological projects supported by ICHHTO Iran.

The only sample from eastern Iran was a rodent from Tepe Taleb Khan close to Shahr-i Sokhte in Sistan province (fig. 4.9, Fathi and Mashkour 2018; Kavosh et al. 2020). Shahr-i Sokhte and Taleb Khan owed their existence the Helmand River, in whose northern delta they were located on the Ram Rud terrace (Tosi 1968). The $^{87}Sr/^{86}Sr$ result was with 0.708923 ± 0.000005 (1σ) in a higher range, especially compared to the results obtained from Lut desert (fig. 4.6). Up to now only two samples from north-western Iran were analysed (fig. 4.11; more are in planning), one rodent from Hasanlu south of Lake Urmia (Davoudi 2017), and one from Tepe Zagheh on the Qazvin Plains (Mashkour 2001, 2002, et al. 1999). The $^{87}Sr/^{86}Sr$ result from Hasanlu of 0.708033 ± 0.000010 (1σ) and 0.707743 ± 0.000004 (1σ) from Zagheh will stay separated until more comparable results are available (fig. 4.6).

Fig. 4.11: Geographic location of the investigated sites in north-western Iran.

4.6. The bio-available local oxygen $\delta^{18}O$

The distribution of isotopes in the environment can be predicted using models of isotope fractionating processes and data describing environmental conditions through space and time, resulting in an isotopic landscape model (Bowen 2012). "Stable isotopes of hydrogen (H), carbon (C), nitrogen (N), oxygen (O), and heavy elements like strontium (Sr) vary in concentration within environmental substrates depending on spatially and temporally distributed Earth systems processes. The resulting geographically patterned variation in isotopic compositions of a substrate is known as an 'isoscape'." (Bowen et al. 2009: 109). The *Online Isotopes in Precipitation Calculator* (OIPC, www.waterisotopes.org) of the University of Utah and the *Global Network of Isotopes in Precipitation* (GNIP, http://isohis.iaea.org) provide users modern annual precipitation averaged $\delta^{18}O$ values ($\delta^{18}O_W$, cf. fig. 4.12). The estimations are based on the modern values recorded at around 348 stations and only go back to 1960. The precipitation and climatic condition during the prehistoric times were not necessarily similar to today's climate and so the oxygen isotopes of precipitation may differ from modern values. However, to provide an informative basis, it became a common tool to use these isotopic landscape models on archaeological material to gain insights into paleoclimates and individuals´ place of origin (e.g., Grupe et al. 2017; Bowen 2012).

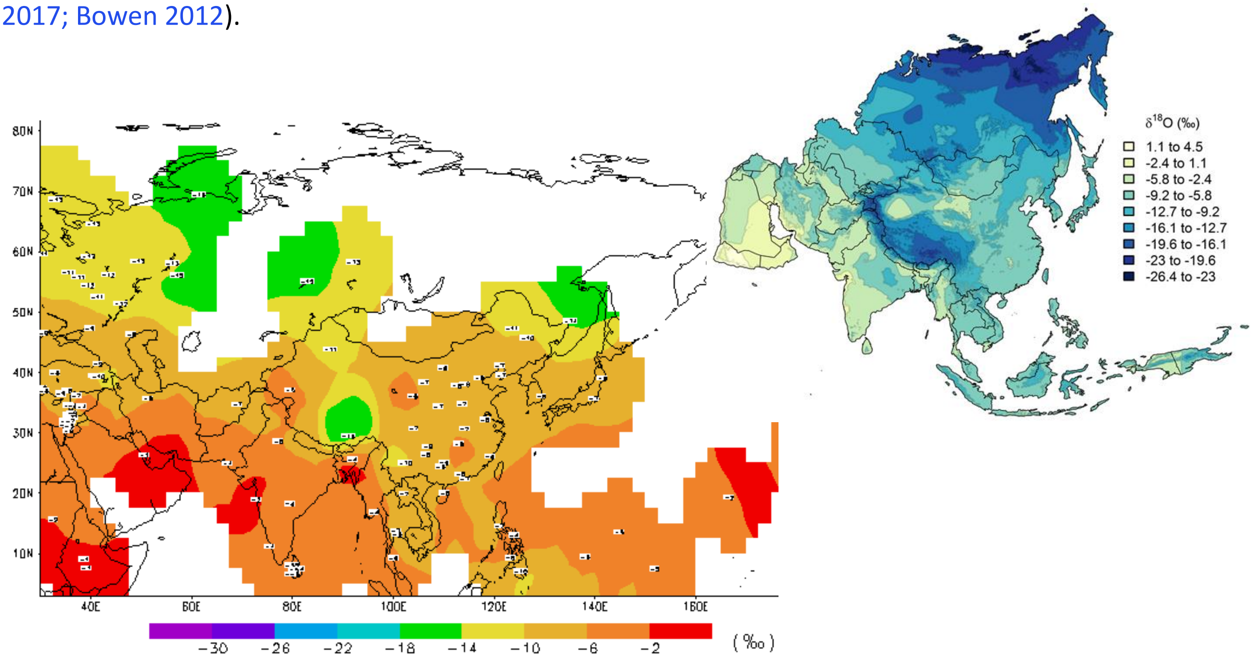


Fig. 4.12: Left: Weighted annual $d^{18}O_{Water}$ averages with monitoring stations after IAEA/WMO (2015). Global Network of Isotopes in Precipitation (GNIP) accessible at: https://nucleus.iaea.org/wiser. Right after the OIPC accessible at www.waterisotopes.org (last access 21.12.2020).

The $\delta^{18}O_W$ values provided by the data-bases are expressed after the V–SMOV standard, the conversion from V-SMOW to V-PDB followed the formula after Coblen et al. (1988):

$$\delta^{18}O_{apa}\ \text{(V-SMOW)} = 1.03091 \times \delta^{18}O_{apa}\ \text{(V-PDB)} + 30.91$$

Two monitoring station deliver relevant data for southern Central Asia and Iran. The next monitoring stations close to Dzharkutan are located in Kabul with annual average $\delta^{18}O_W$ of -7.15‰ (± 1.5‰). Tepe Sialk is covered by the station in Teheran with an annual average $\delta^{18}O_W$ of -6.29‰ (± 2.3‰), Ulug Depe lies in between (after GNIP, cf. fig. 4.12).

4.6.1. Selection of reference samples

Gaining data for the background of the bio-available $\delta^{18}O$ range, is much more complicated since oxygen isotopes in organic tissues strongly undergo fractionation processes and require a special treatment after the collection.[7] Studies proved that the most reliable data are delivered by water and modern plant samples, but both are rare to find in Museum collections. Instead, $\delta^{18}O$ results out of bone apatite of animals, in Ulug one dog, and the big cat, in case of Tepe Sialk and Dzharkutan sheep, and goats were used as references.

4.6.2. Determination of local $\delta^{18}O$ signals

In addition to the available $\delta^{18}O$ water values, references can be provided by carbonate analyses of animal bones and teeth. For adequate comparisons humans and animals have to be recalculated into values of drinking water ($\delta^{18}O_{DW}$). In their study Chenery et al. (2012) established a direct relationship between the $\delta^{18}O_{apa}$ and the $\delta^{18}O_{Phosphate}$ values in human tooth enamel after the following equation:

$$\boldsymbol{\delta^{18}O_{Phosphate}\ (V\text{-}SMOW) = 1.0322 \times \delta^{18}O_{apa}\ (V\text{-}SMOW) - 9.6849}$$

They combined this correlation with the drinking water equation of Daux et al. (2008), and developed a direct calculation of $\delta^{18}O$ drinking water out of human bioapatite $\delta^{18}O_{apa}$ ratios after the following equation:

$$\boldsymbol{\delta^{18}O_{DW}\ (\text{‰}\ V\text{-}SMOW) = 1.590 \times \delta^{18}O_{apa}\ (V\text{-}SMOW) - 48.634}$$

Animals differ in metabolism and nutrition. From Ulug Depe, a big cat and a dog were analysed for $\delta^{18}O_{apa}$ ratios as a reference for local water sources. Dogs follow a comparable metabolism as humans who cover their water need through drinking of water out of surface water sources (lakes, rivers, dwells). Big cats are hypercarnivores and cover their water need also, if available through drinking, but also through the blood of their prey and might therefore be enriched in $\delta^{18}O$. But in general, both metabolisms are comparable to humans. The $\delta^{18}O_{Phosphate}$ has been calculated after the metabolism of medium sized mammals according to Iacumin et al. (1996) after the following equation:

$$\boldsymbol{\delta^{18}O_{Phosphate}\ (V\text{-}SMOW) = 0.98 \times \delta^{18}O_{apa}\ (V\text{-}SMOW) - 8.5}$$

and calculated after Daux et al. (2008) into $\delta^{18}O$ of Drinking Water:

$$\boldsymbol{\delta^{18}O_{DW}\ (\text{‰}\ V\text{-}SMOW) = 1.54 \times \delta^{18}O_{Phosphate}\ (\text{‰}\ V\text{-}SMOW) - 33.72}$$

[7] The determination of oxygen backgrounds has been discussed extensively with Arash Sharifi, specialist for isotopic fractionation and climatic impacts at Rosenstiel School of Marine and Atmospheric Science, University of Miami, i.e. recent plant samples must be immediately frozen after collecting, to avoid fractionation processes and changes in the isotopic composition.

From Dzharkutan and Tepe Sialk sheep and goats were analysed for $\delta^{18}O_{apa}$ to gain some reference values. But ovicaprids, in general herbivores, and, cover their water need mainly through the consumption of plants especially in arid regions. Plants are enriched in ^{18}O as their water supply is covered by humidity. Therefore, herbivores show an enrichment in ^{18}O and are not directly comparable to humans. After the study of D´Angela and Longinelli (1990) the $\delta^{18}O_{Phosphate}$ can be calculated for sheep after the following equation to be comparable with human results:

$$\delta^{18}O_{Phosphate}\ (V\text{–}SMOV) = 1.48 \times \delta^{18}O_{W} + 27.21$$

From Tepe Sialk one boar was also analysed. Although it was a wild boar, and a formula only exists for domestic pigs, the calculation followed the formula of Longinelli (1984) for domestic pigs:

$$\delta^{18}O_{Phosphate}\ (V\text{–}SMOV) = 0.86 \times \delta^{18}O_{W} + 22.71$$

Several further formulas are also existing for the metabolism of other species as deer, cattle, or horses (cf. Longinelli 1984¸ D´Angela and Longinelli 1990; Huertas et al. 1995), which are not relevant for this study. A good overview is given in Gerling 2015: 129–134.

4.6.2.1. The local $\delta^{18}O$ range of Ulug Depe

As already mentioned, no monitoring stations are installed in southern Central Asia. The available data from the data bases are estimated averages of surrounding regions. Additionally, no water samples were available for more reliable data, hence the determination of the local oxygen range will be calculated of measured results of animals and humans, correlated with the estimations of the databases. According to the literature the average variation of the $\delta^{18}O$ ratios in human bones, caused by the use of local water sources of a single site, was determined with a range of between 0.5‰ and 3‰ (Lightfoot et al. 2016; White et al. 2004). The OIPC provides a calculated annual average $\delta^{18}O$ value of precipitation for Ulug Depe of $\delta^{18}O_W$ -5.1‰. The GNIP database gives values around -6 to -7‰, Kabul with an annual average $\delta^{18}O_W$ of -7.15‰ (± 1.5‰) and Teheran with an annual average $\delta^{18}O_W$ of -6.29‰ (± 2.3‰). The $\delta^{18}O_{apa}$ results of the dog of -3‰ (± 0.061‰ V-PDB) and the big cat with -1.6‰ (± 0.054‰ V-PDB) were calculated according to Iacumin et al. (1996) into $\delta^{18}O_{Phosphate}$ and after Daux et al. (2008) into $\delta^{18}O$ of drinking water resulting in $\delta^{18}O_{DW}$ -4.8‰ (V-SMOW) of the dog and $\delta^{18}O_{DW}$ -2.6‰ (V-SMOW) of the big cat (cf. Appendix table 11). According to strontium both fell in the local range of Ulug Depe. The natural habitats of wild cats are, depending on the species, the mountains (mountain lion), but also the desertic steppe regions (lion, leopard, cheetah) where gazelles are available as prey. The oxygen results indicate that the big cat from Ulug Depe lived in the desertic surroundings.

The $\delta^{18}O_{DW}$ of the human bones show a clear accumulation between -3.7‰ and -5.8‰, especially distinct is a child (ULG 80), between 2 and 4 years old. The enamel $\delta^{18}O_{apa}$ ratio of the second molar, synthesized between the 1st to 4th years in life, was -2.6‰ (± 0.03‰), the bone $\delta^{18}O_{apa}$ was -2.2‰ (± 0.02‰). Both timespans overlap due to the young age of death. According to the strontium analyses both results fell within the local strontium range of Ulug Depe, therefore we can assume the child did not move and both ratios result from the local water source of Ulug Depe. After Iacumin et al. (1996) and Daux et al. (2008) they result in $\delta^{18}O_{DW}$ -4.2‰ (V-PDB) of the enamel sample and $\delta^{18}O_{DW}$ -3.7‰ (V-PDB) of the bone sample. Summarizing, the combination of the values of the humans, the dog, and the databases, the range between -4‰ and -7‰ (± 1.1‰) can be considered as the approximate $\delta^{18}O_{DW}$ range of Ulug Depe. Recalculating the fractionation steps after Chenery et al. (2012) the $\delta^{18}O_{DW}$ should end up with $\delta^{18}O_{apa}$ ratios from -2.6‰ and -3.4‰ (average -3.0‰ ± 1.5‰) in human body tissues. Ulug human bones, who all fell in the local strontium range, provided measured $\delta^{18}O_{apa}$ ratios between -2.2‰ and -5.3‰ with an average of -3.6‰ (± 0.9‰ n = 14). The human bone $\delta^{18}O_{apa}$ average as well as the calculated average of $\delta^{18}O_{DW}$ of -5.7‰ (± 1.6‰ n = 14) fit quite well and verify the approximate $\delta^{18}O_{W}$ range of Ulug Depe between -7‰ and -4‰ (cf. fig. 4.13 and 5.14).

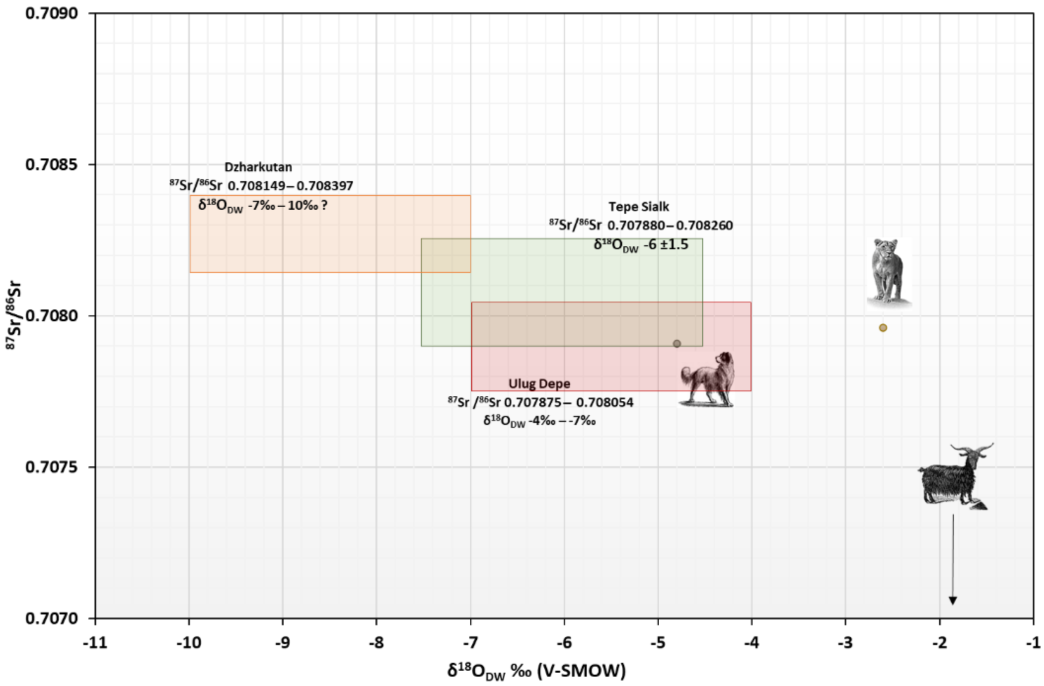


Fig. 4.13: Model of the local $\delta^{18}O_{DW}$ ranges of Ulug Depe, Dzharkutan and Tepe Sialk.

4.6.2.2. The local $\delta^{18}O$ range of Dzharkutan

For the bio-available $\delta^{18}O$ range in Dzharkutan two sheep were analysed for $\delta^{18}O_{apa}$, caused by the absent of better references, revealing $\delta^{18}O_{apa}$ ratios of -1.9‰ (± 0.038‰) and -1.7‰ (± 0.031‰). The results differ distinctly from the humans, indicating that the sheep used a different water source. Ovicaprids, in general herbivores, and especially in arid regions, cover their water need mainly through the consumption of plants. Hence, herbivores show an enrichment in ^{18}O and are not directly comparable to humans. Results have been therefore calculated into $\delta^{18}O_{Phosphate}$ after the equation for domestic sheep provided in the study of D´Angela and Longinelli (1990) and after Daux et al. (2008) into $\delta^{18}O_{DW}$ (V-SMOW), revealing ratios of -3.1‰ and -2.9‰. Humans displayed, calculated after Coblen et al. (1988), Iacumin et al. (1996), and Daux et al. (2008), $\delta^{18}O_{DW}$ ratios between -10.9‰ and -7.6‰ with an average of -9.3‰ (± 0.9‰, n = 20) (cf. Appendix table 11). The differences confirm that the ovicaprids from Dzharkutan used a different water source and are not suitable for the determination of the local oxygen range.

The OIPC data base provides a $\delta^{18}O_{W}$ average of -4.3‰ (V-SMOW) for Dzharkutan in an altitude of 369 m a.s.l. (-5.6‰ for Tilla Bulak in 900 m a.s.l.), the GNIP data base gives a range between -6‰ and -8‰ (Kabul monitoring station annual average $\delta^{18}O_{W}$ value of -7.15‰ V-SMOW). The human bone

$\delta^{18}O_{DW}$ ratios, the "living part", ranged between -6.1‰ and -10.3‰, eight out of 13 formed a very narrow cluster between -7.5‰ and -9.5‰ (cf. fig. 4.13 and 7.11). But due to the inaccuracy of modern isotopic landscape models (Bowen et al. 2012, Gerling 2015; Grupe et al. 2017; Makarevicz 2018; Ventresca Miller 2018) and the lack of precise precipitation references for this region, the here calculated approximate bio-available $\delta^{18}O_W$ range between -7.0‰ and -10‰ in Dzharkutan might need to be extended in one or the other direction.

4.6.2.3. The local $\delta^{18}O$ range of Tepe Sialk

The situation for the determination of the bioavailable oxygen range in Tepe Sialk is similar to Dzharkutan, since no suitable samples were available as reference. Hence, analyses of six ovicaprids and one pig were performed. The six ovicaprids provided $\delta^{18}O_{apa}$ ratios between -0.9‰ and 2.9‰ (average 1.4‰ ± 1.2‰ n = 6). The wild boar displayed a $\delta^{18}O_{apa}$ ratio of 3.6‰. The high variation within the results of the ovicaprids indicates changes of the habitat. When calculating the $\delta^{18}O_{Phosphate}$ for sheep after D´Angela and Longinelli (1990), the results fell between 25.9‰ and 31.5‰ (V-SMOW). The pig, calculated after Longinelli (1984) for domestic pigs (cf. chapter above) resulted in a $\delta^{18}O_{Phosphate}$ ratio of 25.8 (V-SMOW), while the humans from Sialk showed (calculated for medium sized mammals after Iacumin et al. 1996 cf. Appendix table 11) $\delta^{18}O_{Phosphate}$ ratios between 15.2‰ and 19.3‰ (V-SMOW), confirming also here that the ovicaprids used a different water source and are not suitable for the determination of the local oxygen range of Tepe Sialk.

The OIPC data base gives a $\delta^{18}O_W$ average of -6‰ for Tepe Sialk in an altitude of 960 m a.s.l., the GNIP data base also provides a range around -6‰ (Teheran monitoring station annual average $\delta^{18}O_W$ of -6.29‰). Both ratios fit more or less well to the human averages (bone samples average $\delta^{18}O_{DW}$ -7.6‰ (± 1.2‰), tooth enamel samples average $\delta^{18}O_{DW}$ -7.8‰ (± 2.2‰)), but regarding the distribution of the single individuals (cf. fig. 4.13 and 9.15), an accumulation around -6 (± 1.5‰) is visible and indicates the reliability of the local oxygen range.

4.7. Summary and future perspective

As already mentioned, the $^{87}Sr/^{86}Sr$ map of Central Asia and Iran still exhibits some blanks. The published data and the here obtained results are summarized in the map below (fig. 4.14). Attempts for defining the local ranges in various sites in the Indus Valley, the Arabian Peninsula, the northern steppes, Iran, and Mesopotamia the region has provided useful measurements. The local $^{87}Sr/^{86}Sr$ range of Harappa in the Indus Valley, determined by Kenoyer et al. (2013), with 0.7158–0.7189 covers the upper range of the strontium scale. In a similar high range is the local $^{87}Sr/^{86}Sr$ range of Jirzankal on the eastern Pamir Plateau (0.7102–0.7106 after Wang et al. 2016). The Pamir highlands are geologically characterized by granitoid, resulting in high $^{87}Sr/^{86}Sr$ ratios, while the upper Indus Valley displayed, due to the widely ramified network of several tributary streams of the Indus River, a wide range on the upper strontium scale (Kenoyer et al. 2013). The local $^{87}Sr/^{86}Sr$ range of Allahdino near Karachi in Pakistan varies from 0.707806–0.710022 (Gregoricka 2013). The study on the mobility of sheep, goats, and cattle of nearby Bagasra in Gujarat (India) conducted by Chase et al. (2014) provided results in the same range. The local strontium ranges of Balakot near Karachi in the Indus Delta, Failaka Island off the coast of today Kuwait, as well as the northeastern coast of the United Arabic Emirates and Bahrain, are all in ranges between 0.7079–0.7095 (after Gregoricka 2013), hence in similar ranges as the Central Asian sites. Close are also the measured $^{87}Sr/^{86}Sr$ signals of Tepe Yahya in south-western Iran (0.707928–0.708585 after Gregoricka 2013) and two samples from Ur in south Mesopotamia (0.7080–0.7081 after Kenoyer et al. 2013). Whereas the investigated sites north and west of the Caspian Sea, the Pontic and Caucasian steppes, as well as the Andronovo sites Bestamak and Lisakovsk in the northern Kazakh steppes, all displayed $^{87}Sr/^{86}Sr$ ratios from 0.7090 to 0.7099 (after Gerling 2015; Ventresca Miller et al. 2017).

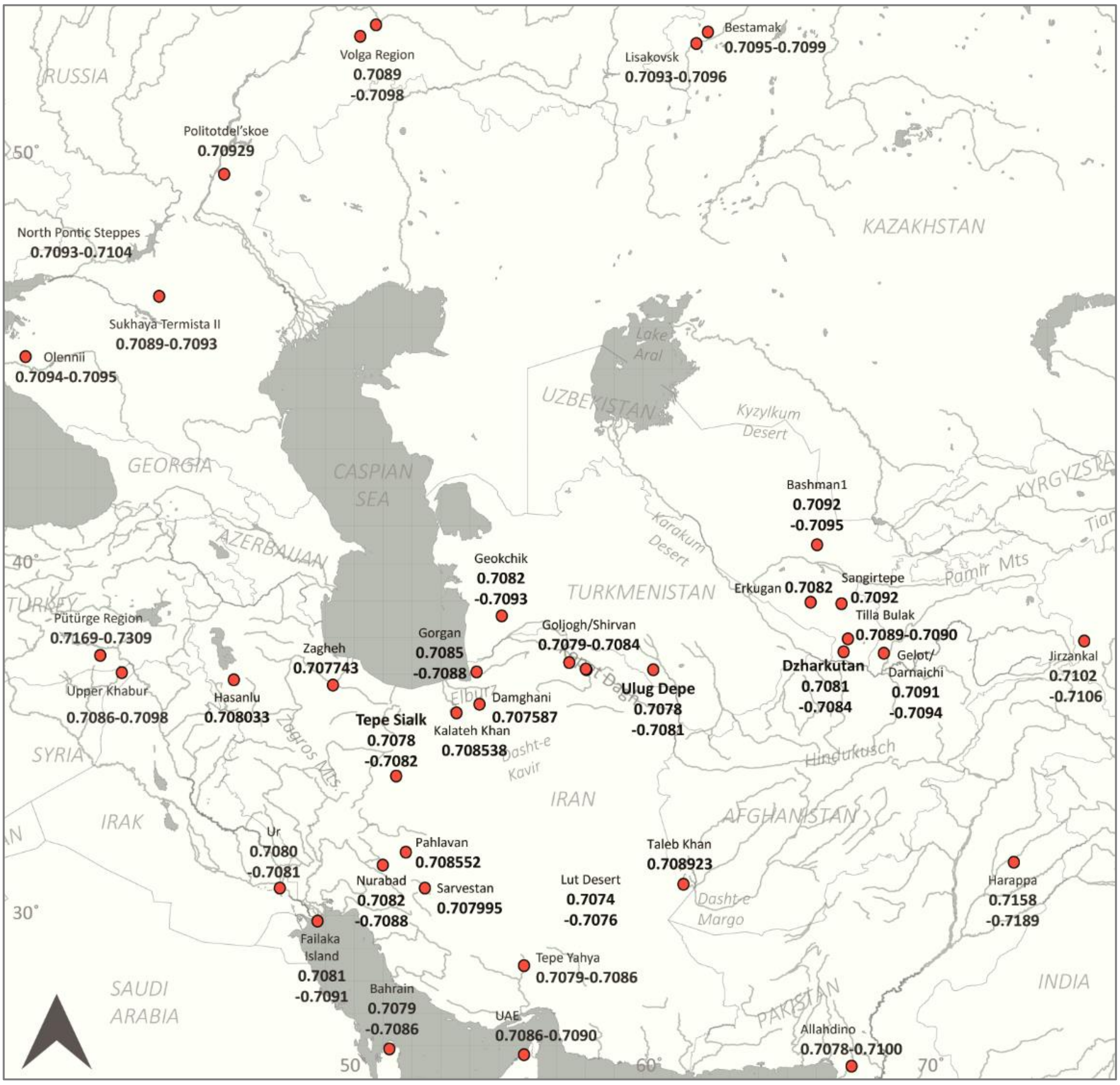


Fig. 4.14: Collected $^{87}Sr/^{86}Sr$ data: Jirzankal after Wang et al. 2016; Harappa, Ur after Kenoyer et al. 2013; Bahrain, UAE, Failaka Island, Tepe Yahya, Allahdino after Gregoricka 2013; Upper Khabour and Pütürge Region after Kibaroğlu et al. 2017; Northern Pontic Steppe (including signals of Babina Mogila, Drana Kokhta, Ordzhonikidze, Alexandropol', Zolotaya Balka), Olennii, Sukhaya Termista II, Politotdel'skoe, and Volga Region (including Kalinovka I, Nikolaevka III, Podlesnyi) after Gerling 2015; Bestamak, Lisakovsk after Ventresca Miller et al. 2017. For Gelot-Darnaichi the ranges of the human bones are stated as the bioavailable strontium range.

Further investigations were conducted on clay samples from the regions of the Upper Khabur, the Upper Tigris and the Harran Plain, just as the Pütürge Mountains. While the clay samples from the Khabur and Tigris plains showed $^{87}Sr/^{86}Sr$ ratios from 0.7086 to 0.7098, the Pütürge region is characterized by Precambrian metamorphic rocks, resulting in much higher strontium ratios, ranging from 0.7123 to 0.7220 (after Kibaroğlu et al. 2017). The overlap of these measurements clearly demonstrates that we can presently work on a micro-regional scale, but not on a large regional scale.

The geographic region of southern Central Asia and Iran comprise a large area with very diverse geological realities, making cross-regional evaluations difficult and inaccurate. If the studied region includes a closed system with clear boarders, isotopic maps can be evaluated. The perfect example, and for all who are working in the Near East a desirable but far away situation, is the work of the British scientists. Evans and colleagues published the first biosphere $^{87}Sr/^{86}Sr$ map for Great Britain (Evans et al. 2010), which was based on the sampling of water, soil, plant, snail shells and dentine. In the meanwhile, also the generating of the $\delta^{18}O$ distribution is perfectly elaborated and provides a reliable basis for mobility and migration studies (fig. 4.15).

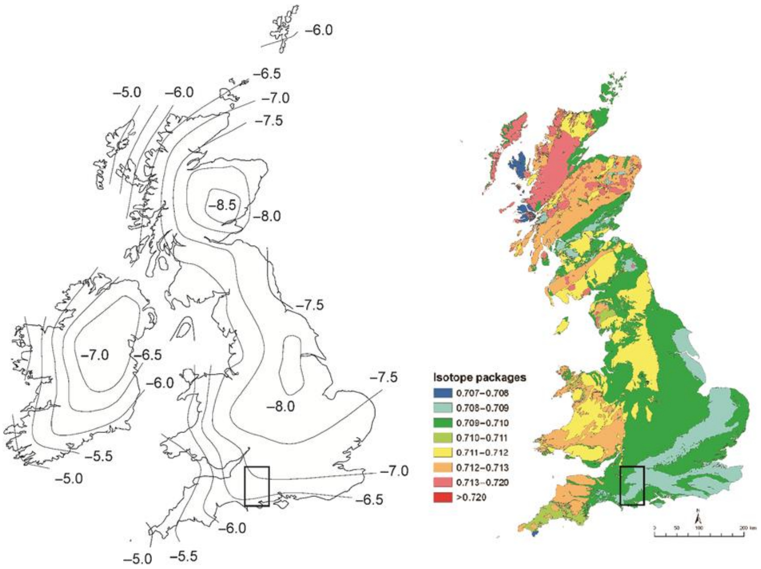


Fig. 4.15: Map of $\delta^{18}O$ (V-SMOW) in groundwaters of the British Isles (left) and Strontium ($^{87}Sr/^{86}Sr$) biosphere map of Great Britain (right) after Madgwick 2019: 6 fig. 4.

In the course of this thesis, we started the $^{87}Sr/^{86}Sr$ iso-scaping of southern Central Asia. Thanks to the great work of Arash Sharifi, who generated the data and transferred them into a validated map (fig. 4.16), we took the first steps. The background strontium isotope values for the region were reconstructed by interpolating the available data for the geological units using the Kriging Method. The table of the $^{87}Sr/^{86}Sr$ isotope values of the geological units can be found in the Appendix table 10. Although the accuracy of this reconstruction is limited to the available data and their locations (higher $^{87}Sr/^{86}Sr$ ratios (~0.70800–0.70850) have been observed to the north of Dzharkutan while lower values (~0.70605–0.70700) were seen near Ulug Depe). The map delivers a reliable data base for comparative studies, further evaluations on the Iranian data, respectively the region around Tepe Sialk, are in progress and will accomplish the picture.

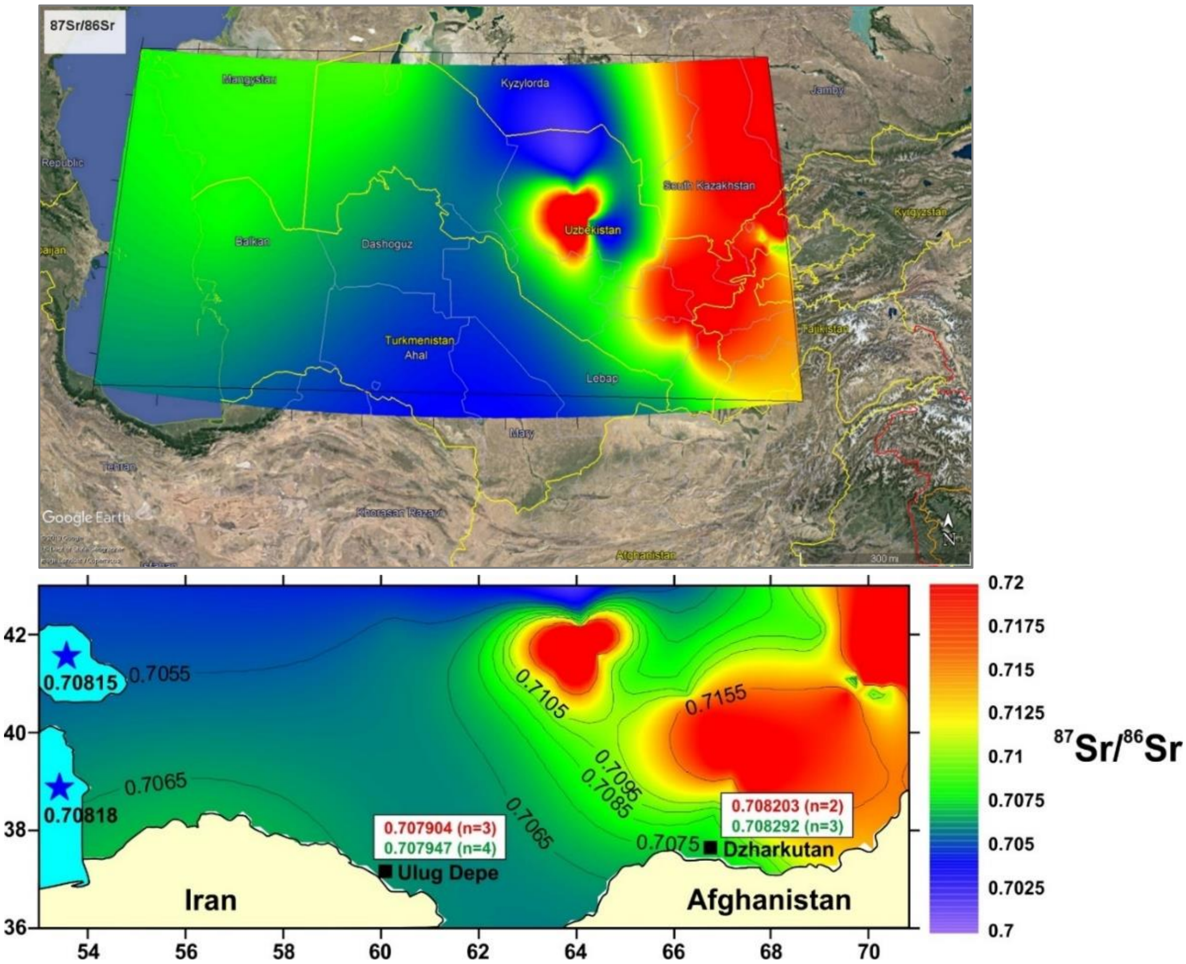


Fig. 4.16: $^{87}Sr/^{86}Sr$ isotope values of the geological units. Blue stars denote the isotopic values of Caspian Sea water. Values in red and green denote the local mean values obtained on rodents (*Mus* sp.) and barley (*Hordeum vulg.*) respectively (courtesy of Arash Sharifi).

Fig. 5.1: View from the north on the mound of Ulug Depe with the Kopet Dagh Mountains in the background (©MAFTur).

5. Ulug Depe

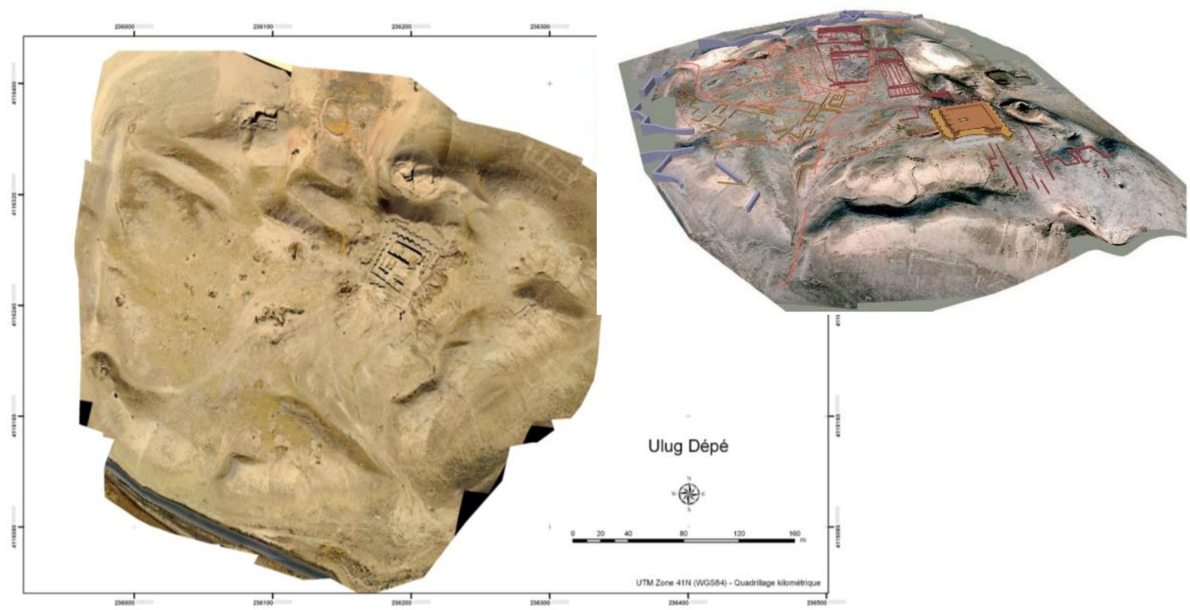
5.1. Preface

The extensive French expedition in Ulug Depe was supported by the specialists from the MNHN, who collected a remarkable number of animal and plant remains and brought them to France for further studies. Therefore, it was possible to choose references of animals and plants from the museum collections in a high variety. Additionally, the material from Ulug Depe was in very good conditions, all isotopic analyses were sufficient in quality and suitable for further investigation. Hence, Ulug Depe can be considered as the prime example of this thesis, while the other sites required a lot more improvisation.

5.2. The site Ulug Depe

Ulug Depe (37°9'19.26"N 60°1'43.23"E) is located in the northern sub montane plains of the Kopet Dagh Mountains in the south of Turkmenistan, 175 km east of the capital Ashgabat and 6 km south of the village Dushak in Kaahka Etrap. The site is situated at 288 m a.s.l., in the dry steppe area between the Kopet Dagh Mountains and Karakarum Desert. The foothill zone stretches along the southern border of Turkmenistan and reaches 3117 m a.s.l. at Kuh-i Hazar ca. 40 km south of Ulug Depe.

The mound of Ulug Depe attracts attention as it is very prominent in the flat sub-mountain region of northern Kopet Dagh. Earlier it was documented by a soviet archaeologist, the Russian pioneer Victor Sarianidi. He was the first who carried out four excavation campaigns during the 1960s and 70s, while he established the first chronology of the site with systematically placed small trenches (Lecomte 2013: 167–169). After the region was opened to western scholars, a French archaeological expedition from the CNRS in collaboration with the Turkmenistan Directorate for Protection, Study, and Conservation of Historical and Cultural Heritage continued to work in Ulug Depe (MAFTUR: Mission Archéologique Franco-Turkmène). Between 2001 and 2011 the mission was led by Olivier Lecomte, Muhammed Mamedov, and Ahmed Khalmyradow. They included specialists of various scientific disciplines as paleo-botany, archaeozoology, bioanthropology, and geomorphology. A magnetic survey was undertaken in 2003, revealing traces of a number of monumental buildings like a huge Iron Age citadel. Since 2012 the project continued under the direction of Julio Bendezu-Sarmiento and Muhammed Mamedow, with a focus on the chronological framework and the inter-cultural exchanges (e.g., Bendezu-Sarmiento and Lhuillier 2019; Bendezu-Sarmiento 2020). Intensive excavations were undertaken in the northern part of the hill, revealing crafting and housing areas. The political situation in Turkmenistan enabled only a few further investigations on the site during the last years, preventing also the export of human and animal skeletal material.



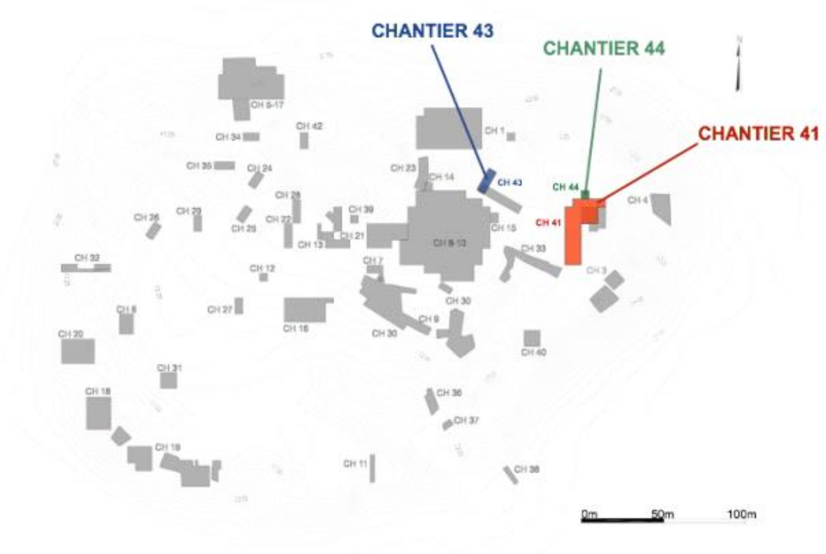


Fig. 5.2: Top: topographic plan of Ulug Depe after Bendezu-Sarmiento et al. 2019: 6 fig.2 and reconstruction of the Iron Age settlement after Lecomte 2013: 172 fig. 5. Bottom: distribution of the excavated areas (unpublished excavation report courtesy of MAFTur).

5.2.1. Archaeological Background

Ulug Depe represents one of the major sites along the northern foothills of the Kopet Dagh Mountains with a stratigraphic sequence from the Early Chalcolithic or even Late Neolithic (5^{th} – 4^{th} mill. BCE) to the Middle Iron Age (MIA, Yaz II, ca. 1000–540 BCE) (fig. 5.2; Lecomte 2007a, 2011, 2013). Through the millennia Ulug Depe was occupied by several “cultural communities” and experienced partly deep changes and developments concerning the structure and organization of the settlement.

Neolithic layers have not been excavated yet, but a large number of sherds and lithic tools prove the presence of a Neolithic occupation (Lecomte 2011: 223). The Chalcolithic period (4000–2800 BCE) in Ulug is characterized by first social changes towards a more centralized system. The construction of a fortification wall and also the separation of crafting areas (appearance of hammered copper and accumulations of pottery kilns close to the settlement cf. Lecomte 2011: 223–224) reflect the changing understanding of property and territorial management, as well as social differentiation. A large number of clay-figurines (male, female and all kind of animals cf. Lecomte 2013: 186 fig. 18) indicate religious believes and ritual activities.

During the transition from the Chalcolithic to the Bronze Age an urban revolution took place and settlements can now be divided into different areas: houses with several rooms and courtyards form residential quarters; casting facilities and kilns constitute remnants of crafting areas and monumental buildings indicate cultic districts (Lecomte 2007a, 2011, 2013). Architectural remains evidence the former existence of houses agglutinated against the rampart in the northern part of the city, that were rebuilt identically during the Late Chalcolithic and the EBA. The beginning of irrigated agriculture can be traced in the nearer surroundings in this period (Lecomte 2011: 223). During the Early Bronze Age (Namazga IV, NMG IV, ca. 2800–2500 BCE) the traditions of the precedent period continued, the fortification wall was enlarged and several gates were installed (Lecomte 2011: 225). The pottery production followed the technical traditions of the late Chalcolithic, but quality increased due to the frequent use of the potter’s wheel. A remarkable number of domestic tools (spindle wools, loom weights) evidence a specialized textile production, notably carpet production (Lecomte 2015: 6).

The Middle and Late Bronze Age (NMG V and NMG VI) constitute the period of the actual Oxus occupation in Ulug Depe. These two cannot really be separated, as the appearance of the Oxus Civilization started around 2400 BCE (mid of the MBA until mid LBA) and lasted till ca. 1500 BCE, but layers of the LBA are missing in Ulug Depe. The LBA is only represented by single graves in Ulug, but no occupation layers are known up to now. The discussion is still open, if Ulug Depe was abandoned for unknown reasons between ca. 1800/1700 and 1500 BCE, or there are other reasons that are to be found somewhere else (cf. Bendezu-Sarmiento and Lhuillier 2019). With the appearance and development of the Oxus Civilization, Ulug Depe enjoyed a period of particular prosperity (ca. 2200–1700 BCE). The settlement pattern follows the previous constructions, but what is remarkable is the growth of the population. Due to the fortification wall, limiting space inside the city, people also occupied the area outside the ramparts (Lecomte 2011: 225–226). The remains of impressive public monuments, as the high terraces like in Altyn Depe (Lecomte 2011: 225; Bendezu-Sarmiento and Lhuillier 2019: 522–523), were discovered in the north-eastern part of the mound. Archaeological remains indicate a high specialization of crafting industries as pottery, stonemasonry and metalwork, which were developed for the production of utilitarian as well as artistic items in high numbers. Especially remarkable concerning the technological development is the establishment of a quasi-standardized, non-painted ware (Bendezu-Sarmiento and Lhuillier 2016: 524 fig. 2). Stamp seals and seal impressions evidence dynamic trade interactions. Numerous finds of gold, lapis lazuli, carnelian and alabaster vessels reflect the widespread connections of the communities in Ulug Depe (Bendezu-Sarmiento and Lhuillier 2016: 527 fig. 4–6).

Fig. 5.3: The citadel from Ulug Depe after Lecomte 2013: 170 fig. 3.

After this period Ulug Depe became an important settlement of the *Handmade Painted Ware Cultures* ("Yaz" cultures), and thus a powerful city during the Early Iron Age and afterwards during the Middle Iron Age (Lhuillier 2013, 2016). Residential buildings have been found in the lower part (Lecomte 2007b), as well as a vast citadel with storage rooms in the upper, northern part of the site (Lecomte 2011, Lhuillier 2013, 2016). This citadel led to many discussions as it was built with a specific internal structure with distinct projections and niches (cf. fig. 5.3; Lecomte 2011: 231; 2013: 170). Many parallels have been drawn, the strongest and most obvious analogues can be found in Iran and are attributed to the Medes (Boucharlat et al. 2005; Roaf 2008; Lecomte 2011). Similar constructions are known, the most famous from Nush-e Jan, but also from Godin Tepe, Tell Gubba and Tepe Sialk (Roaf 2008: 10 fig. 2). Until today the "Median empire" is considered a hot potato in scholar circles. Hardly tangible, as "no common cultural entity" exists (Boucharlat 2020: 403), even in the Iranian heartland, where it´s origin is assumed, the discussion is still open (cf. Kroll 2019; Naseri and Malikzadeh 2019; Boucharlat 2020). As a student of Michael Roaf, I would never doubt the existence of the "Median Empire", but in fact, we know very little about the Medes and where they came from. It was taken notice of the existence of this discussion but it won´t be considered further in the interpretation of the data concerning the interactions between the Iranian Plateau and southern Turkmenistan.

Fig. 5.4: Top: Kopet Dagh mountain vegetation (©UNESCO/Kopet Dagh Biosphere Reserve, Islamic Republic of Iran)[8]. Bottom: View from Ulug Depe to the west in the desertic-steppe surroundings (taken by the author during the campaign 2019).

5.2.2. Landscape and subsistence

"Ulug Depe" means the great hill in Turkmen language, and the eponymous silhouette of Ulug Depe rises about 30 m high in the landscape and covers an area of around 13 ha (Lecomte 2011: 222). The view from Ulug Depe is always drawn to the high rising mountains in the south. In all other directions

[8] https://www.unesco.de/kultur-und-natur/biosphaerenreservate/biosphaerenreservate-weltweit/unesco-biosphaerenreservat-1 (last access 31.1.2021).

an apparently infinite wideness of flat, dry steppe with randomly dispersed small shrubs expands (fig. 5.4). Geomorphological investigations showed, that Ulug Depe was situated directly next to the riverbed of the Kelet River in ancient times, which runs through the Kopet Dagh in the direction of Nishapur and presents a natural pathway through the mountains to the south (fig. 5.5 and Lecomte 2013: 168). The Kelet River descends from 2500 m in the mountains, fed by several tributary streams and snow melting water ensuring a fair supply even in the hot summer months. Today the Kelet River runs further north close to the village of Dushak (Lecomte 2011, 2013).

Intensive studies on the landscape, vegetation and fauna were carried out by Fet and Atamuradov 1994; Moore et al. 1994; Miller 2003, 1999; Spengler et al. 2014; Tengberg 2013, et al. 2020. Characteristic for this region is a short period of spring rains in-between the dry and hot summer months which boosts a seasonal explosion of plant and animal life. Dominant is an east Mediterranean flora with elements of low mountain subtropical flora and highland flora of xerophytes. Most common species are Asteraceae and Poaceae, followed by Fabaceae, Brassicaceae and Chenopodiaceae. Characteristic vegetation types include coniferous evergreen woodland of juniper species, ephemeroid herb vegetation, as well as unique fruit and relict nut forests (Tengberg et al. 2020). The alpine regions of the Kopet Dagh Mountains exhibit up to today a high variety of wild fruit trees like pomegranates, grapes, figs, apple, pear, several species of cherries, prune, different almond species, and hawthorns (Kurbanov 1994: 105–128). The biodiversity of the fauna is equally rich and includes species as leopards, mountain lions, wild boars, lynx, wolves, bears, deer, onagers, gazelles, different species of wild caprine like ibex or urial, and numerous birds, fish, reptiles, and amphibians (Rustamov and Sopye 1994: 205–251). In ancient times the vegetation was similar to today´s or even richer as human interventions and agricultural development changed the landscape entailing the disappearance of several wild species (Tengberg et al. 2020).

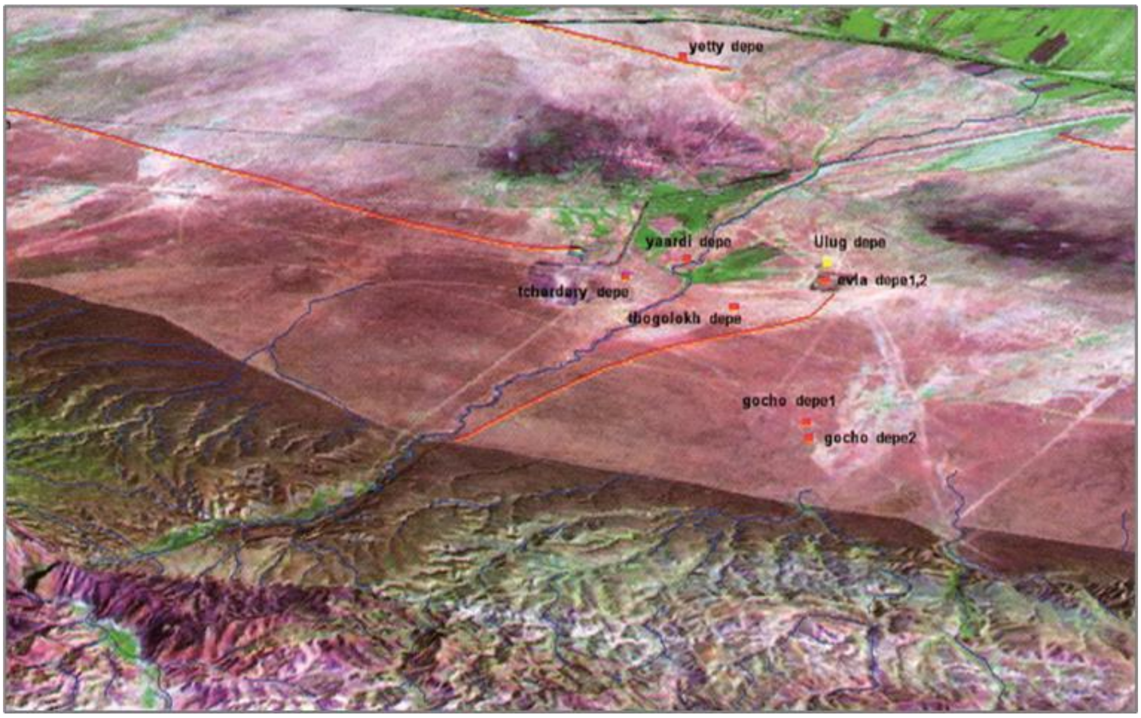


Fig. 5.5: Model of the location of Ulug Depe in foothills of Kopet Dagh and the course of Kelet River after Lecomte 2011: 225 fig. bottom.

The analysis of seed and fruit remains from different contexts in Ulug Depe conducted by Margareta Tengberg and her team, is still ongoing. First results on the Bronze Age remains are published in Tengberg 2013, and a recent study on botanical and animal remains of the Iron Age is published in Tengberg et al. 2020. The results show the importance of the cultivation of free-threshing wheat (*Triticum* cf *aestivum*) and barley (*Hordeum vulgare*) since Chalcolithic times. During the earlier periods (Chalcolithic, Bronze Age) barley represents the main identified cereal, whereas wheat seems to be predominant during the later periods (Tengberg et al. 2020). Other identified crops are, according to the period, lentils (*Lens culinaris*) and peas (*Pisum sativum*), flax (*Linum usitatissimum*) and grapes (*Vitis vinifera*) (Tengberg 2013, et al. 2020). Although known from Bronze Age sites in the neighbored Murghab Delta (Spengler et al. 2014), no millet has been identified from Ulug Depe so far (Tengberg et al. 2020). Remarkable is the presence of juniper wood in the anthracological ensemble, as in this region juniper trees were (are) only found in the Kopet Dagh mountains. Still, it was commonly used as construction material in Ulug (samples mainly came from collapsed roof constructions cf. Tengberg et al. 2020). This ubiquitous utilisation indicates a frequent provision with raw material and therefore dynamic interactions with the mountainous regions.

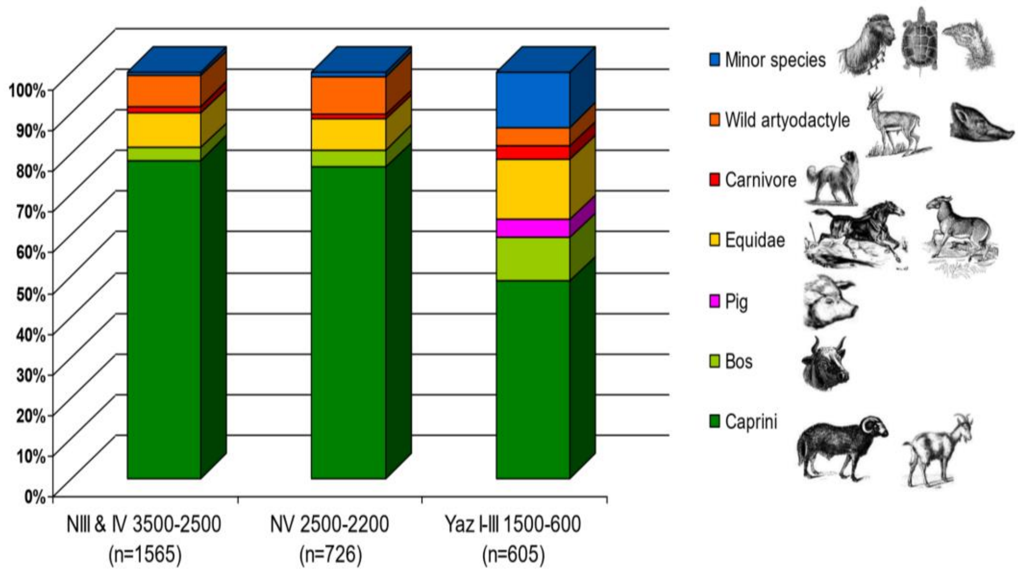


Fig. 5.6: Preliminary results of identified animal bones from Ulug Depe (courtesy of Marjan Mashkour).

The diversity of fauna was equally rich and included wild species such as large felids, canids, bears, boars, red deer, onagers, gazelles, urial sheep and bezoar goats, and numerous birds, fish, reptiles and amphibians. Archeozoological remains showed a dominance of domestic sheep/goats and cattle (fig. 5.6; Mashkour 2013a; Lhuillier and Mashkour 2017; Tengberg et al. 2020). Equids and pigs were present but to a minor degree. The majority of bone remains can be allocated to domestic herbivores. The ovicaprids (sheep/goat) were dominant during the Namazga III to V period. During the later Yaz periods they decreased due to the increase of cattle exploitation, equids, minor species and pigs. The main wild species represented in the fauna were gazelles and equids (mostly onagers). These wild herbivores lived in steppe areas and were maybe captured in the immediate vicinity of the site. However, few remains of wild sheep and goats indicate that people travelled further for hunting toward the more mountainous areas, probably toward the south, to the piedmont of the Kopet Dagh. In the later periods of Ulug Depe pigs, most probably domestic, were represented in a higher proportion in the faunal assemblage (Mashkour in collective 2015; Tengberg et al. 2020). Striking is the lack of young ovicaprids (below 6 months) especially during the Iron Age, indicating that the secondary production of milk, or wool was more important during these periods than the production of meat (Mashkour in Tengberg et al. 2020).

Fig. 5.7: Intramural EBA burial in Ulug Depe (ULG 55) after Bendezu-Sarmiento 2013: 507 fig. 3F.

5.2.3. Burial customs

In general, the mortuary practices observed in Ulug Depe mirror those known from other settlements along the foothills of the Kopet Dagh, respectively the burial traditions well known from sites like Gonur Depe, Dzharkutan or Sapallitepa (Lecomte 2011; Bendezu-Sarmiento 2013; Bendezu-Sarmiento and Lhuillier 2014, 2015, 2016). During Chalcolithic and Bronze Age periods, the dead remain close to the living. Although possibly existent, no associated graveyards were discovered until now. The dead were buried next to houses, or in nearby ruined houses (Lecomte 2011: 224). No significant changes in the burial rituals can be observed between the Chalcolithic period and the early phases of the Bronze Age (Bendezu-Sarmiento and Lhuillier 2015: 281). Most burials were single individual burials in roundish pit constructions, often with a mud-brick enclosure; bodies were put in flexed positions, the head often oriented towards the north or north-west. For sure remarkable are the extremely flexed positions of several individuals (cf. fig. 5.10), indicating a forced treatment of the body after death (Bendezu-Sarmiento 2013: 504). Accompanying furniture (mainly pottery vessels, beads, small tools) was deposited on the feet, the hips or the head. In some cases, faunal remains were found in the burials. During the earlier periods (EBA, NMG IV) grave goods were more common, decreasing towards the later. Children were buried under the floor of houses, in positions similar to those of the adults (Bendezu-Sarmiento 2013: 503–505). The discovery of a very special grave in 2014 attracted attention, when next to the high terrace on the north-wester side of the mound, a multiple burial came to light. It was badly disturbed by water streams, caused by raining water, which flushed the inventory downhill, as well as through ancient looting (cf. Bendezu-Sarmiento and Lhuillier 2016: 524–527). Several individuals had been buried, but only scattered remains of at least 5 individuals were found. One woman was identified for sure, the others were too badly preserved for identification. Together with the human bones a huge ensemble of luxury grave goods was discovered, such as pottery (15 vessels) and alabaster (8 vessels), beads in high variety of shapes and materials like gold, lapis lazuli, carnelian, agate, turquoise, or frit (fig. 5.8; Bendezu-Sarmiento and Lhuillier 2016: 524–527). Moreover, fragments of silver (a pin and possibly a belt accessory), next to huge amounts of faunal remains, and traces of wall-paintings were discovered (unpublished excavation report 2019). The prominent location of the burial, as well as analogues among the accompanying furniture to sites in Iran like Shahr-i Sokhta and Tepe Yahya (alabaster vessels), Tepe Sialk (vertical zigzags alternating with figurative motifs cf. Bendezu-Sarmiento and Lhuillier 2016: 525 fig. 3; Ghirshman, 1938. Pl. XII, XVII, XXI, LXVI). Moreover, artefacts with analogues to Afghanistan, Pakistan, and the Indus valley (gold, lapis lazuli, carnelian beads) were found. All this is evidence for a higher social class, ruling in Ulug Depe, which was involved in the international trade system. Unfortunately, no samples of this grave could be analysed for this study, but the cultural transfer indicated by the burial inventory in any case delivers a bases for migration studies.

Fig. 5.8: Alabaster vessels and beads of the rich burial found during the campaign 2014 after Bendezu-Sarmiento, Lhuillier 2016: 526–527 fig 4, 6.

With the beginning of the Iron Age graves disappeared almost completely in southern Central Asia. It is not yet clear how these radical changes can be explained. One often suggested explanation is the emergence of a new religion, the Zoroastrianism (e.g., Sarianidi 1998; Bendezu-Sarmiento and Lhuillier 2015). But up to now convincing arguments for this theory are missing and the discussion is still open. In fact, a decrease of burials is remarkable during these periods, but single exceptions from Ulug Depe and Dzharkutan show, that if bodies were present and articulated, no grave goods at all were found, as well as no burial constructions or other accompanying furniture (Bendezu-Sarmiento and Lhuillier 2015: 282–284). These changes cannot be dismissed and are often explained not only by a change of mentality of the people, and the expansion of the northern steppe people towards the south (e.g., Narashiman et al. 2019). The Iron Age samples investigated in this study are small, but might deliver further information on the mobility and subsistence of these people, as well as the migratory impact.

5.2.4. The protagonists

The burials of the early period (EBA, fig. 5.9) were all abundantly outfitted with several pottery and alabaster vessels, as well as beads, other small objects, and can thus be considered as the “rich” graves from Ulug (e.g., Bendezu-Sarmiento 2006: 29; 2013: 506–8). Burial 53 was an adult man (> 40 years) who was buried together with a 1–3 years old baby (ULG 54, cf. fig. 5.9). ^{14}C analyses date the grave between 2864 and 2506 cal. BCE. The man was buried in an oval shaped earth pit burial, extremely crouched on the right side, north-south orientated with the head in the north and the hands in front of the face. The grave goods included one big storage jar, two small vessels at the feet and a cup in his hands, as well as one animal figurine and beads (Bendezu-Sarmiento 2006: 29, 2013: 506). The baby was laid down ca. 50 cm west of the feet of the man, also in an extremely crouched position, but without any funeral inventory. In the literature burial ULG 55 is described as one of the special burials (cf. fig. 5.7, 5.9 and Bendezu-Sarmiento 2013: 503–505). The adult man (> 40 years) was buried in a ground pit next to a housing structure. He was put in extreme crouched position on the right side with the hands in front of the thorax and the chin. The body was south-west orientated with the head in the west-northwest, view to the west. Next to limbs, spine and hands two vessels of pottery were found, just as one alabaster vessel, beads and some scattered faunal remains (Bendezu-Sarmiento 2013: 507). Burial ULG 56 was a multiple burial with six individuals, badly disturbed and looted. This very special burial will be discussed in detail in chapter 6.

Fig. 5.9: EBA burials in Ulug Depe (left to right: ULG 53, 54, 55) after Bendezu-Sarmiento 2013: 506 fig. 3 A, C, 508 fig. 4B (© MAFTur).

The two EBA–MBA burials (ULG 90, 92) were two single burials of a woman and a juvenile, in simple pit constructions without grave inventories, found in trench 17 on the north-western side of the mound. Three of the five MBA graves were single burials (ULG 61, 66, 83) of adults, two in extremely crouched, respectively folded positions (fig. 5.10), all in simple pit constructions lacking grave goods. Burial ULG 62 was a multiple burial with 3 adults and 1 child (one adult was provided as sample), which was badly disturbed, only scattered remains of the individuals could be documented (fig. 5.10 bottom left). Burial ULG 76 was a child burial in extremely crouched position, also laid to rest in a pit construction without grave goods (fig. 5.10 bottom right).

Fig. 5.10: MBA burials from Ulug Depe (top: ULG 61, 66, bottom ULG 62, 76) after Bendezu-Sarmiento 2013: 507–510 fig. 3 D, E, fig. 4 I, fig. 5 B (© MAFTur).

The four Iron Age burials (ULG 59, 80, 82, 100) included two adult women and two children. Burial ULG 59, one of the women (over 40 years of age), was found in trench 12, at the bottom of a pit (possibly a silo). Her body was put in an extremely crouched position on the left side in E–W orientation, head towards the east (fig. 5.11 left). No associated grave goods were found, but the body displayed several fractures, the right leg even a double fracture, healed during lifetime and leaving a distortion, indicating that the individual walked with a limp (Bendezu-Sarmiento and Lhuillier 2015: 284). ULG 82, the other adult woman, was found in trench 1 on the western part of the citadel in an earth pit without funeral inventory. This burial did not reveal any characteristic items and was at first dated to the MBA by means of stratigraphy, but ^{14}C analyses mandated by Julio Bendezu-Sarmiento in 2019, corrected the dating to 913–810 cal. BCE, and therefore between the Early and Middle Iron Age (personal communication from Julio Bendezu-Sarmiento).

Fig. 5.11: EIA–MIA burials from Ulug Depe (from left to right: ULG 59, 100, 80) after Bendezu-Sarmiento, Lhuillier 2015: 284–287 fig 5, 9, 10 (© MAFTur).

Grave no. 100, the 4–5-year-old child, discovered in trench 16, consisted of a north-south oriented L-shaped burial pit, which was encased under a mudbrick and clay platform dating to the MIA

(Bendezu-Sarmiento and Lhuillier 2015: 284). The body was laid down on the right side in crouched position, head towards the south. No grave goods have been found (fig. 5.11 middle). The child ULG 80, ca. 2–4 years old, was discovered inside a silo within trench 3. The oval-shaped pit was northeast-southwest oriented. The body was completely distorted lying on the stomach (ventral position), the head tilted back with the face up, hands below the shoulders and the right foot twisted towards the head. No associated funeral inventory was found (fig. 5.11 right; Bendezu-Sarmiento and Lhuillier 2015: 286).

5.3. Mobility and migration in Ulug Depe

Parts of this chapter have already been published in:

*Kroll, S.K., Bendezu-Sarmiento, J., Lhuillier, J., Luneau, É., Kaniuth, K., Teufer, M., Mustafakulov, S., Khasanov, M., Vinogradova, N., Avanesova, N., Fiorillo, D., Tengberg, M., Sharifi, A., Bon, C., Bosch, D., Mashkour, M. (**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 Sceince: Reports 46 (2022) 103622* doi.org/10.1016/j.jasrep.2022.103622

The reconstruction of mobility and dietary patterns are the two main issues that are focused in this study. Questions of mobility were addressed using strontium ($^{87}Sr/^{86}Sr$) and oxygen ($\delta^{18}O$) isotope analysis. Dietary and subsistence pattern were reconstructed through nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C_{col}$, $\delta^{13}C_{apa}$) isotopes. The isotopic investigations provide insights on the impact of mobility on the communities in Ulug Depe, as well as on the food supply of humans and animals. Migratory impacts, respectively direct cultural exchanges via personal interactions bring up a different question. The presence of a permanent water source was without doubt decisive for the choice of a settling ground in this region since the Neolithic. Another aspect of high strategic importance is the possibility to cross the mountain chain in a north-south direction along the Kelet River course and thus to gain direct access to the Iranian plateau with its various resources. The material found in Ulug Depe mirrors these cultural influences, and the geographic location might be an additional reason for a certain migratory impact.

5.3.1. Results of strontium ($^{87}Sr/^{86}Sr$) and oxygen ($\delta^{18}O$)

The itemized results of all samples from Ulug Depe are listed in the Appendix table 6, a summary of strontium and carbonate results is presented in table 5.1. The results follow the geological and chronological classification of the samples. The material from Ulug Depe was well preserved, the samples used for the extraction of structural carbonate and strontium out of tooth enamel and bone compacta were sufficient for all individuals beside one: the amount and preservation of the sample ULG 59 was not sufficient for the extraction of carbonate out of bone compacta, respectively tooth dentine.

The error values (2σ level) measured for the $^{87}Sr/^{86}Sr$ ratios of Ulug Depe samples ranged from 0.000004 to 0.000008. The standard deviation of $\sigma\ \delta^{13}C = 0.03‰$ for carbon and $\sigma\ \delta^{18}O = 0.06‰$ for oxygen was fulfilled for all samples so that all results could be included in the present study. The statistical variance (Levene, ANOVA, Kruskal-Wallis) was calculated when the numbers of samples was n ≥ 10. A Levene test showed that there was no homogeneity of variances in the $^{87}Sr/^{86}Sr$ values between Ulug Depe and Dzharkutan ($F(2.16) = 1.85$, $p < 0.02$). The one-way ANOVA proved that the differences between the sites are significant ($F(2.72) = 1.84$, $p < 0.001$), but the differences between the periods in Ulug Depe are statistically not relevant ($F(2.46) = 1.97$, $p = 0.105$). The differences in $\delta^{18}O$ between Ulug Depe and Dzharkutan were statistically not significant according to the Levene test ($F(1.86) = 1.75$, $p = 0.069$). The one-way ANOVA proved the $\delta^{18}O$ values of Ulug people neither without statistically significant differences between the periods ($F(2.49) = 1.59$, $p = 0.191$) nor between the gender ($F(2.48) = 1.16$, $p = 0.364$). The deviations were negligible small, error bars were overlapped by the applied symbols in the figures. Hence, symbols encompass the error margins at 2σ level for the $^{87}Sr/^{86}Sr$ ratios and 1σ level for $\delta^{18}O$ ratios.

Table 5.1: Summary of human $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{apa}$ results from Ulug Depe*

	$^{87}Sr/^{86}Sr$					$\delta^{18}O_{apa}$ (‰ V-PDB)					
Period	**n**	**Min**	**Max**	**Mean**	**± 2б**	**n**	**Min**	**Max**	**Interval**	**Mean**	**± б**
Ulug EBA E	**4**	0.707856	0.709960	**0.708638**	± 0.000796	**4**	-5.0	-3.4	1.6	**-4.2**	± 0.58
Ulug EBA B	**4**	0.707890	0.707948	**0.707919**	± 0.000021	**4**	-5.3	-3.2	2.1	**-4.4**	± 0.81
Ulug EBA/MBA E	**2**	0.707857	0.708061	**0.707959**	± 0.000102	**2**	-6.9	-3.3	3.6	**-5.1**	± 1.80
Ulug EBA/MBA B	**2**	0.707864	0.707864	**0.707866**	± 0.000001	**2**	-4.8	-3.1	1.7	**-4.0**	± 0.85
Ulug MBA E	**5**	0.707819	0.707880	**0.707850**	± 0.000023	**5**	-5.8	-3.4	2.4	**-4.3**	± 0.86
Ulug MBA B	**5**	0.707865	0.707899	**0.707883**	± 0.000013	**5**	-4.3	-2.4	1.9	**-3.1**	± 0.69
Ulug EIA/MIA E	**4**	0.707835	0.708255	**0.708031**	± 0.000164	**4**	-4.4	-2.6	1.8	**-3.5**	± 0.64
Ulug EIA/MIA B	**4**	0.707898	0.708540	**0.708066**	± 0.000274	**3**	-3.6	-2.2	1.4	**-3.0**	± 0.58

*Aberration: E corresponds to tooth enamel samples, B to bone samples

The $^{87}Sr/^{86}Sr$ ratios of all human samples from Ulug Depe ranged between 0.707819 and 0.709960 with a mean of 0.708031 (± 0.000401‰ n = 30; fig. 5.12); the enamel samples displayed a mean of 0.708123 (± 0.000528, n = 15), bone samples of 0.707939 (± 0.000162 n = 15). The $^{18}O/^{16}O$ ratios out of structural carbonate ($\delta^{18}O_{apa}$) of all samples ranged from -6.9‰ to -2.2‰ with an interval of 4.7‰ and an average of -3.9 (± 1.09‰ n = 29; fig. 5.13). Enamel samples provided a $\delta^{18}O_{apa}$ average of -4.1‰ (± 1.0‰ n = 15), bone samples showed a mean of -3.6‰ (± 0.9‰ n = 14). The four EBA (NMG IV) individuals displayed enamel $^{87}Sr/^{86}Sr$ ratios between 0.707856 and 0.709960 with a mean of 0.708638 (± 0.000796, n = 4), and $\delta^{18}O_{apa}$ enamel ratios between -5.0‰ and -3.4‰ with an interval of 1.6‰ and an average of -4.2‰ (± 0.58‰ n = 4). The bone $^{87}Sr/^{86}Sr$ ratios ranged between 0.707890 and 0.709480 with a mean of 0.707919 (± 0.000021, n = 4), while $\delta^{18}O_{apa}$ bone ratios fell between -5.3‰ and -3.2‰ with an interval of 2.1‰ and an average of -4.4‰ (± 0.81‰ n = 4). The two individuals from the transition of the EBA to the MBA (NMG IV–V) provided enamel $^{87}Sr/^{86}Sr$ ratios between 0.707857 and 0.708061 with mean of 0.707959 (± 0.000102, n = 2), and enamel $\delta^{18}O_{apa}$ ratios from -6.9‰ to -3.3‰ with a spacing of 3.6‰ and an average of -5.1‰ (± 1.8‰ n = 2). While bone $^{87}Sr/^{86}Sr$ ratios ranged between 0.707864 and 0.707867 with a mean of 0.707866 (± 0.000001, n = 2), and bone $\delta^{18}O_{apa}$ between -4.8‰ and -3.1‰ with an interval of 3.6‰ and an average of -4.0‰ (± 0.85‰ n = 2). The five MBA (late NMG V) individuals ranged in enamel $^{87}Sr/^{86}Sr$ between 0.707819 and 0.707880 with a mean of 0.707850 (± 0.000023, n = 5), in enamel $\delta^{18}O_{apa}$ between -5.8‰ and -3.4‰ with a spacing of 2.4‰ and an average of -4.3‰ (± 0.86‰ n = 5), whereas bone $^{87}Sr/^{86}Sr$ ratios were between

0.707865 and 0.707899 with a mean of 0.707883 (± 0.000013, n = 5) and bone $\delta^{18}O_{apa}$ ratios between -4.3‰ and -2.4‰ with a spacing of 1.9‰ and an average of -3.1‰ (± 0.69‰ n = 5).

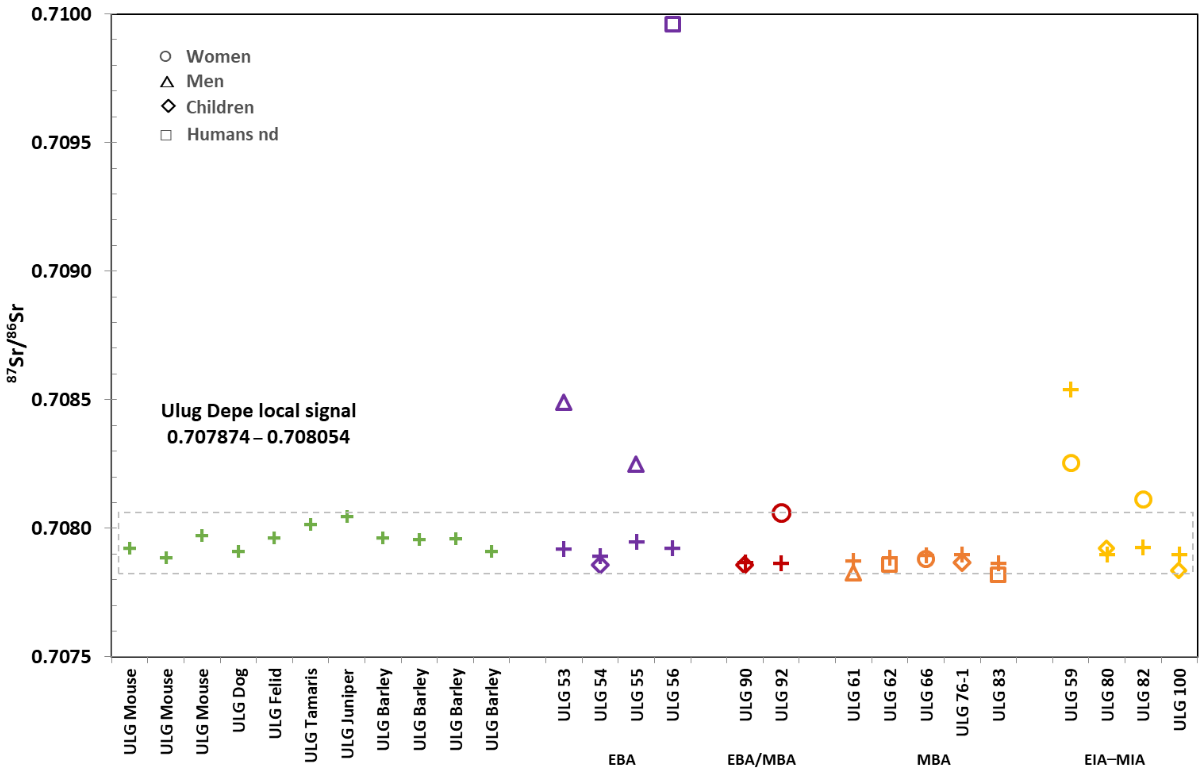


Fig. 5.12: $^{87}Sr/^{86}Sr$ results of Ulug humans and references with human intra-individual variations. Plus correspond to bone samples, enamel samples are plotted with the sign of the particular gender. Symbols encompass the error margins at 2σ level, dashed box marks the local $^{87}Sr/^{86}Sr$ signals including the error margins at 2σ level.

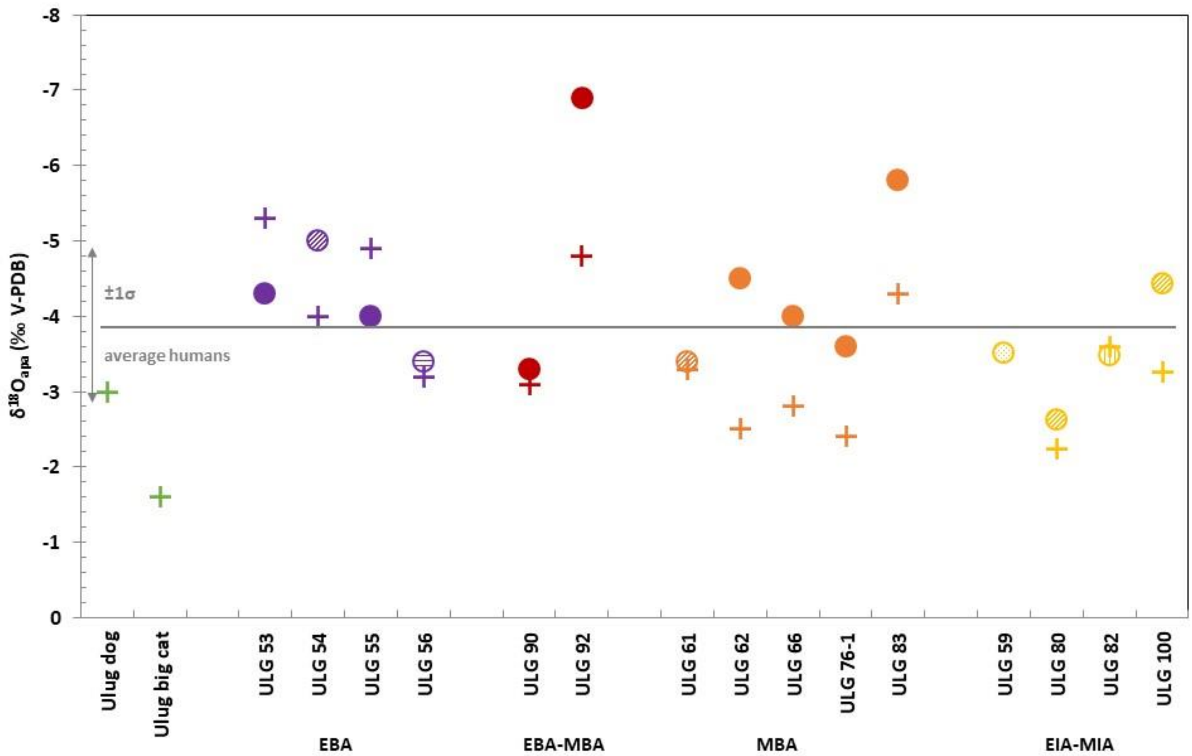


Fig. 5.13: Intra-individual variations of $\delta^{18}O_{apa}$ of humans and carnivores from Ulug Depe: plus correspond to bone samples, circles to tooth enamel (black M3, dark grey M2, light grey M1, empty M not determined, vertical stripes PM, horizontal stripes C, dots I). The symbols encompass the error margins at 1σ level for $\delta^{18}O$ ratios.

The two adult women and the two children from transition of the EIA to MIA (Yaz I–II) provided enamel $^{87}Sr/^{86}Sr$ ratios between 0.707835 and 0.708255 with a mean of 0.708031 (± 0.000164, n = 4) and enamel $\delta^{18}O_{apa}$ results between -4.4‰ and -2.6‰, with a spacing of 1.8‰ and an average of -3.5‰ (± 0.64‰ n = 4). Their bone $^{87}Sr/^{86}Sr$ ratios ranged between 0.707898 and 0.708540 with a mean of 0.708066 (± 0.000274, n = 4), $\delta^{18}O_{apa}$ bone ratios between -3.6‰ and -2.2‰ with an interval of 1.4‰ and a mean of -3.0‰ (± 0.58‰ n = 4).

5.3.2. Reconstruction of human spatial movements

5.3.2.1. Migration based on strontium $^{87}Sr/^{86}Sr$

The homogeneity of the strontium results reflects the geological uniformity of the landscape around Ulug Depe, and suggests that all the analysed individuals, buried over centuries on the mound, lived their last years, at least, in Ulug Depe or the surrounding area (fig. 5.12, 5.14). Although sample sizes were very small, the $^{87}Sr/^{86}Sr$ ratios of tooth enamel indicated that especially the EBA was a period of exceptional mobility. No adult enamel $^{87}Sr/^{86}Sr$ ratio falls within the local range of Ulug Depe (cf. chapter 4.4.1.). The only analysed individual of this time period born in Ulug Depe was the child ULG 54. The three non-locals do not show the same $^{87}Sr/^{86}Sr$ ratios, suggesting they were of different origins. The early periods in Ulug Depe not only display a high rate of immigration but also long-distance migration (see chapter 7).

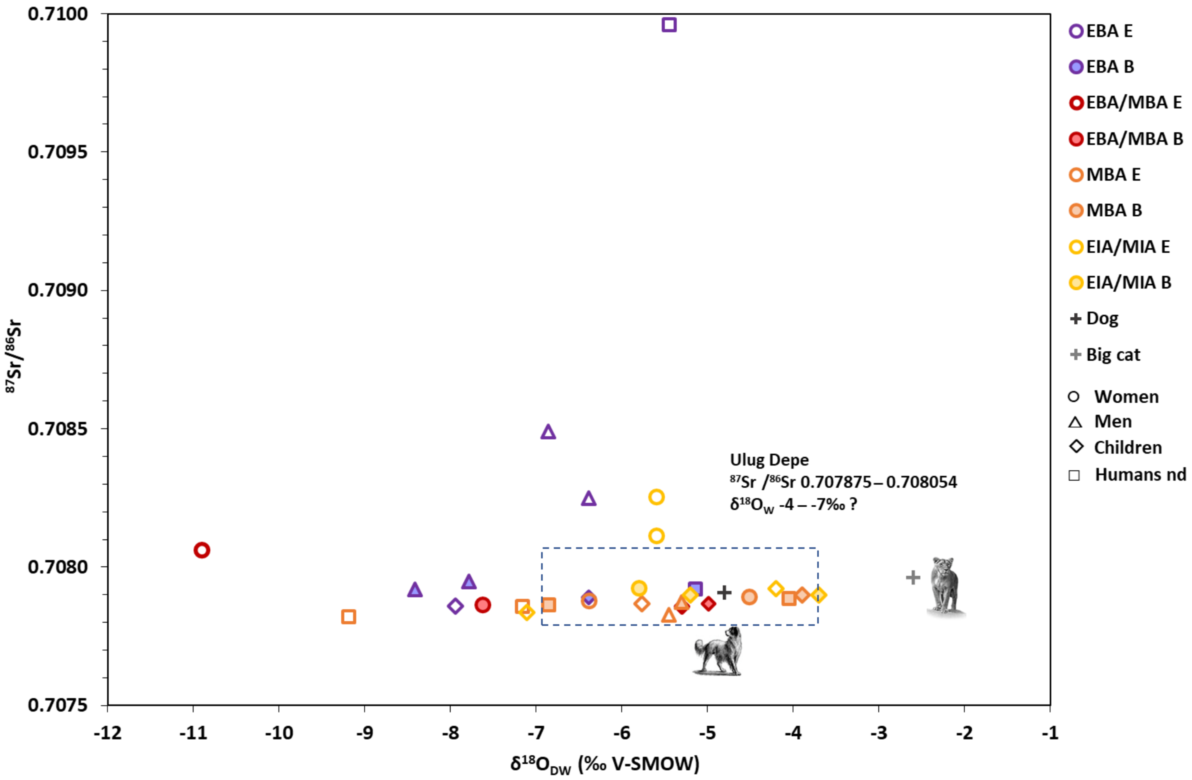


Fig. 5.14: Scatterplot $^{87}Sr/^{86}Sr$ versus $\delta^{18}O_{DW}$ ratios of Ulug Depe humans. The symbols encompass the error margins at 2σ level for the $^{87}Sr/^{86}Sr$ ratios and 1σ level for $\delta^{18}O$ ratio, dashed box marks the approximate local $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{DW}$ range of Ulug Depe including the error margins at 1σ ($\delta^{18}O_{DW}$) and 2σ ($^{87}Sr/^{86}Sr$) levels.

The two individuals from the transition of the EBA to the MBA were, based on the $^{87}Sr/^{86}Sr$ ratio, both in the local $^{87}Sr/^{86}Sr$ range, but one (ULG 92) displayed in correlation to the $\delta^{18}O$ result a different origin (cf. fig. 5.14). A somehow striking homogeneity of the MBA individuals is conspicuous, although representing the most numbers of samples none of the MBA samples fell further out of the local $^{87}Sr/^{86}Sr$ range, especially significant the tooth enamel samples, indicating no immigration took place.

Remarkably, Ulug Depe bones featured a narrow range of strontium ratios, all situated on the lower limit of the local signal, in the same range as mice and cereals (cf. fig. 4.14). The results suggest that the geological formation in the wider surroundings of Ulug Depe is quite homogeneous. There was no difference between the dog and the wild felid: the dog, as a domesticated animal, probably belonged to the locals in Ulug Depe; the big cat, as a wild animal, supposedly lived in the general area of the Kopet Dagh Mountains. Both were found in Ulug Depe and fall into the same strontium range as the (local) mice. If they moved through different regions and environments, there were no significant effects on the strontium signal.

5.3.2.2. Mobility based on oxygen $\delta^{18}O$

The $\delta^{18}O_{apa}$ isotopic ratio of all Ulug human samples ranged between -6.9‰ and -2.2‰ with an interval of 4.7‰ and average of -3.9‰ (± 1.09‰, n = 29). In general, ratios were in the upper part of the oxygen scale, suggesting a hot and arid climate in this region (Longinelli 1984; White et al. 2004). The tooth enamel samples showed a $\delta^{18}O_{apa}$ average of -4.1‰ (± 1.1‰, n = 15) and an interval of 4.3‰. Bone samples displayed a $\delta^{18}O_{apa}$ average of -3.6‰ (± 0.9‰, n = 14) and an interval of 3.1‰. The bone samples, synthesized during the last years in life represent the active part. The small inter-individual variations of Ulug bone samples indicates that the people ingested water from particular water sources and not from multiple sources spread across the landscape (single site between 0.5 and 3‰ after Lightfoot et al. 2016; White et al. 2004). The higher tooth enamel interval evidences that the water sources of the respective individuals place of origin varied a bit more.

To gain results comparable to the available published data, the $\delta^{18}O_{apa}$ results were calculated after Coplen et al. 1988, Iacumin et al. 1996 and Daux et al. 2008 into $\delta^{18}O_{DW}$ (cf. chapter 4.7.2.1.; Appendix table 11). The $\delta^{18}O_{DW}$ of bones ranged between -3.7‰ and -8.4‰ with an average of -5.7‰ (± 1.5‰, n = 14), $\delta^{18}O_{DW}$ of tooth enamel ranged between -10.9‰ and -4.2‰ with an average of -6.6‰ (± 1.6‰, n = 15). Tooth enamel samples displayed a $\delta^{18}O_{DW}$ interval of 6.7‰, bone samples of 4.7‰. It is distinct that in particular individuals from the earlier periods fell further out of the calculated $\delta^{18}O_{W}$ range (fig. 5.14). The $\delta^{18}O_{apa}$ bone ratios indicate, that during the earlier periods people moved more to higher, colder regions, than during the later periods. The results of the MBA individuals indicate rather little mobility and a more extensive exploitation of the direct surrounding environment of Ulug Depe.

The calculation of differences in altitude through $\delta^{18}O$ variations may shed more light on the spatial movements. The intra-individual $\delta^{18}O_{apa}$ variations of all humans sum up to an average of 1.0‰ (± 0.65‰), by far the maximum showed ULG 92, a LBA/MBA woman (non-local), with an interval of 2.1‰. All others ranged much lower. Through correlating the altitude with the $\delta^{18}O_{W}$ values of the OIPC after Bowen 2010 an average of 0.3‰ per 100 m difference in altitude can be calculated (cf. fig. 5.15). The literature provides an average of 0.26‰ per 100 m (Poage and Chamberlain 2001). This implicates a maximum of 700 m difference in altitude for Ulug´s inhabitants (except ULG 92, cf. chapter

5.3.), and therefore rather little mobility. For comparison, a rough evaluation of time series of ovicaprids displayed intra-individual $\delta^{18}O_{apa}$ variations up to 10‰ of the animals (see chapter 5.3.3.). An averaged intra-individual interval of 1‰ of the humans therefore confirms rather little mobility. The intervals are constant over time, no significant differences are definable between the periods.

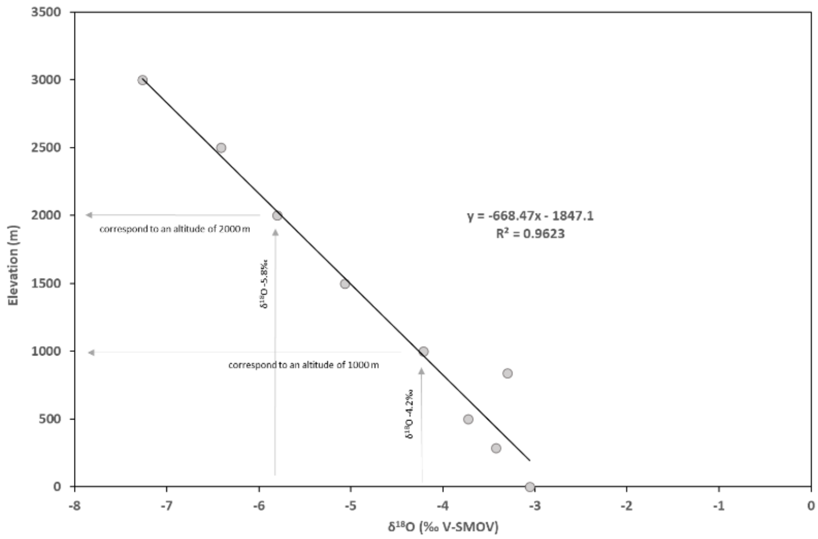


Fig. 5.15: Ulug Depe differences in altitude correlating to the annual averaged $\delta^{18}O_W$ values of the OIPC (www.waterisotopes.org, last access 21.12.2020).

5.3.2.3. Gender and social differences

The "foreigners" from Ulug Depe were two men and one not further determined adult from the EBA, one woman from the EBA/MBA and the two women from EIA–MIA. In general, this is an equal distribution, but it is distinct, that all (determined) MIA individuals are women and all EBA individuals are men. If this indicates a pattern, like a rising matrimonial immigration of woman during the Iron Age will stay questionable until more samples, especially of men, can be analysed. The children were all born and buried in Ulug Depe, no special features can be identified.

It is not clear if the degree of mobility is connected to the social composition of the population, respectively the funerary inventories indicating the social rank of the individuals. In Ulug Depe not all the graves were rich; indeed, some had no grave goods and some had been looted. It must be considered that the prevailing burial traditions of the particular time period and the one-sidedly selected samples, do not allow a reliable conclusion. The EBA men, who were buried in complex burial constructions with rich grave goods, were all foreigners – conspicuously, but comparable female burials are missing. The same applies to the women from the Iron Age periods, both were foreigners, buried without grave goods or special burial features, following the typical burial tradition of the Yaz period, but graves of males were not available for comparisons. Both situations are striking, but are only points of embarkment for further investigations.

5.3.3. Reconstruction of animal mobility: time series of herbivores

Fig. 5.16: Intra-tooth sequential sampling applied to the ovicaprids molar (courtesy of Marie Balasse and Denis Fiorillo ©SSMIM).

This chapter (also applies to chapter 5.4.4.1.) represents just a rough and first evaluation of the data, as the itemized results, as well as the detailed lab methods, will be discussed elsewhere (Mashkour, Sheikhi, Kroll publication in progress), because the analyses were not directly part of this thesis. But the results are very important for the interpretation of the human mobility and should not be disregarded. The Intra-tooth sequential sampling was performed by Shiva Sheikhi and Marjan Mashkour in the bioarcheology laboratory of the University of Tehran on 15 domestic ovicaprids and 8 wild herbivores (gazelles) from Ulug Depe (cf. fig. 5.16). The stable isotope analyses out of tooth enamel carbonate ($\delta^{18}O_{apa}$, $\delta^{13}C_{apa}$) were performed at the SSMIM/MNHN in Paris. The animals date to the LC (NMG III), MBA (NMG V), MIA (Yaz II/III) periods (cf. also Lhuillier and Mashkour 2017). As gazelles are wild animals they are influenced by seasonal climatic conditions on their search for natural food and water sources, including seasonal movements between cold winter and hot summer months. The eight analysed animals from Ulug Depe showed an intra-individual $\delta^{18}O_{apa}$ spacing up to 10‰, confirming distinct changes between several water sources and movements between summer and winter pastures (fig. 5.17). Although the radius of movement of the wild gazelles draws further circles, the domestic sheep and goats displayed the same pattern with an intra-individual $\delta^{18}O_{apa}$ spacing up to 8‰, substantiating similar seasonal movements of the domestic animals. Especially during the early and later periods (EBA, EIA–MIA) the pattern of the ovicaprids is equally distinct as the gazelles´.

Oxygen ratios between -4 and -6‰ are found in all domestic animals somehow recurrently in the first and last period of life (fig. 5.17), but not in the results of the gazelles. Till today pastoral and nomadic communities, as well as wild animals like gazelles, have specific places, safe from weather, enemies, predators, with a secured food and water supply, where they return yearly for the birth and breeding of their young. Sheep and goats time for pairing is, depending on the region, generally in autumn, birth is between February and June, but under human care these cycles might differ. According to the data most ovicaprids from Ulug Depe were born in the late winter to early spring months, somewhere in the plains along the foothills of Kopet Dagh (with lower $\delta^{18}O_{apa}$ between -6‰ and -2‰) and moved to higher pastures during the summer.

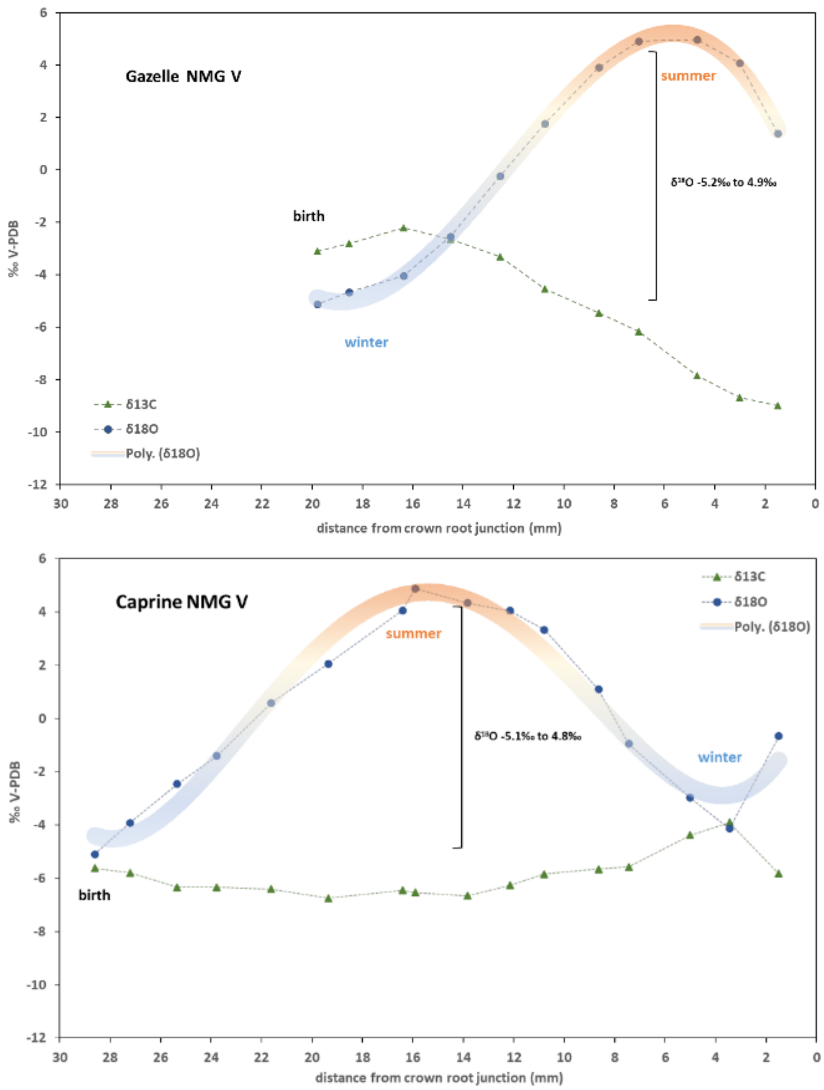


Fig. 5.17: Intra-tooth variation in carbon $\delta^{13}C_{apa}$ and $\delta^{18}O_{apa}$ (PDB) isotope ratios of enamel bioapatite of MBA (NMG V) gazelles (top) and ovicaprids (bottom).

5.4. Subsistence in Ulug Depe

The subsistence economies of the communities during the periods under discussion have already been outlined in chapter 5.2.2. The questions concerning Ulug Depe´s inhabitants are, next to the mobility and migration impacts, the components and composition of the diet, as well as subsistence strategies like herding and feeding practices. Systematic pastoralism as a food-producing economy was long considered to be an essential part of the subsistence of the settlement. The early appearance of irrigation systems suggests a high specialization for Ulug Depe´s inhabitants in this sector among many others, and therefore a rather sedentary lifestyle. Botanical analyses revealed an intensive cultivation of cereals, lentils, peas, and grapes. The cultivation of domestic cereals as wheat and barley in this dry and arid region required sophisticated irrigation systems. In this regard the establishment of effective structures seems essential, considering the growth of the settlements during the late 3rd mill. BCE, when an increasing population demanded a certain security of food supply, as well as a systematic management of the flocks. The results of carbon and nitrogen analyses provide insights on the dietary habits of humans and animals from Ulug Depe, land-use, flock management, as well as prevailing climatic conditions of the investigated region.

5.4.1. Results of nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C_{col}$, $\delta^{13}C_{apa}$) isotopes

The minimum of %C = 13% and %N = 5% content of Nitrogen and CO_2 for a sufficient quality of the collagen were fulfilled by all samples (Ambrose 1990), as well as the calculated atomic ratio of Carbon to Nitrogen C/N resulting in the optimum range between 2.8 and 3.2 (DeNiro 1985). With a maximum standard deviation of σ $\delta^{13}C$ = 0.03‰ for carbon and collagen yields greater than 1%, all results from Ulug Depe could be included in the present study. The itemized results from Ulug Depe are listed in table 6 in the appendix, a summary of collagen and carbonate results is presented in table 5.2. Error bars were not added to the graphs, as they are negligible and smaller than the plotted symbols. According to a Kruskal-Wallis test the differences between the three sites were not significant for both $\delta^{13}C_{col}$ and $\delta^{15}N$ ($\delta^{15}N$: H(3) = -137.475, p = 0.728; $\delta^{13}C_{col}$: H(3) = -137,209, p = 1.383). The one-way ANOVA analysis did attest no significantly different $\delta^{13}C_{col}$ values (F(3.58) = 2.51, p = 0.112) and $\delta^{15}N$ values (F(3.58) = 2.80, p = 0.089) of Ulug Depe samples of different periods, or gender ($\delta^{15}N$: F(3.58) = 5.49, p = 0.015; $\delta^{13}C_{col}$: F(3.58) = 2.03; p = 0.169).

The $^{15}N/^{14}N$ ratio out of collagen ($\delta^{15}N$) of all human samples from Ulug Depe through all periods showed the lowest value at 11.2‰, the highest at 14.9‰, with an interval of 3.7‰ and an average of 13.3‰ (± 1.0‰, n = 15). The ratio of carbon isotopes $^{13}C/^{12}C$ derived from collagen ($\delta^{13}C_{col}$) showed the highest $\delta^{13}C_{col}$ value at -16.1‰, the lowest at -20.5‰, with an interval of 4.4‰ and an average of -19.4‰ (± 1.1‰, n = 15). The four EBA individuals showed the lowest $\delta^{15}N$ results at 11.2‰, the highest at 14.2‰, and an average of 12.3‰ (± 1.2‰, n = 4), while $\delta^{13}C_{col}$ ratios ranged between -20.2‰ and -19.7‰ with an average of -19.9‰ (± 0.2‰, n = 4). The two individuals from the transition of the early to the middle Bronze Age (EBA–MBA), a woman and a juvenile, displayed $\delta^{15}N$ results of 13.7‰ and 14.9‰ (average 14.3‰ ± 0.6, n = 2) and $\delta^{13}C_{col}$ ratios of -19.1‰ and -19.7‰ (average -19.4‰ ± 0.3, n = 2). The five MBA individuals showed a $\delta^{15}N$ minimum at 12.4‰, a maximum at 14.1‰, and an average of 13.4‰ (± 0.6‰, n = 5). $\delta^{13}C_{col}$ results ranged between -18.6‰ and -20.5‰ with an average of -20.0‰ (± 0.7‰, n = 5). The two adult women and the two children from the Iron Age (EIA–MIA) provided the lowest result at 13.3‰, the highest at 14.0‰, and an average of 13.8‰ (± 0.3‰, n = 4), while $\delta^{13}C_{col}$ ranged between -19.7‰ and -16.1‰ with an average of -18.2‰ (± 1.5‰, n = 4).

The analyses of $^{13}C/^{12}C$ out of structural carbonate ($\delta^{13}C_{apa}$) were performed on tooth enamel and bone compacta, all individuals ranged between -14.5‰ and -8.3‰ with an average of -12.9‰ (± 1.4‰, n = 29). The four EBA individuals provided the lowest $\delta^{13}C_{apa}$ enamel result at -13.9‰, the highest at -13.3‰ and an average of -13.6‰ (± 0.2‰, n = 4), bones showed the lowest $\delta^{13}C_{apa}$ at -14.5‰, the highest at -13.3‰, and an average of -14.1‰ (± 0.5‰, n = 4). The two individuals from the transition of the early to the middle Bronze Age (EBA/MBA) displayed $\delta^{13}C_{apa}$ enamel results of -12.9‰ and -12.4‰ (average -12.7‰ ± 0.2, n = 2); bones showed results of -14.0‰ and -12.9‰ (average -13.5‰ ± 0.5, n = 2). The five MBA $\delta^{13}C_{apa}$ enamel results ranged between -13.6‰ and -12.6‰ with an average of -13.1‰ (± 0.4‰, n = 5), $\delta^{13}C_{apa}$ bones fell between -14.0‰ and -12.9‰ with an average of -13.3‰ (± 0.4‰, n = 5). The two adult women and the two children from the Iron Age (EIA–MIA) showed $\delta^{13}C_{apa}$ enamel results between -13.6‰ and -9.1‰, with an average of -11.5‰ (± 1.6‰, n = 4) while bones ranged between -12.6‰ and -8.3‰ with a mean of -10.6‰ (± 1.8‰, n = 3). ULG 59´s preservation was not sufficient for the preparation of bone apatite.

Table 5.2: Summary of $\delta^{15}N$ and $\delta^{13}C_{apa}$ results out of collagen from Ulug Depe

Trophic group	Species	n	$\delta^{15}N$ Collagen (‰ AIR)					$\delta^{13}C$ Collagen (‰ V-PDB)				
			Min	Max	Mean	± σ	Average	Min	Max	Mean	± σ	Average
	Barley ULG	**1**	3.6		-	-		-27.2		-	-	
Plants	**C3 Lut**	**7**	0.1	13.2	**5.7**	± 4.3	**5.0**	-28.5	-25.2	**-26.6**	± 1.1	**-27.0**
	C4 Lut	**13**	1.7	11.2	**5.5**	± 3.4		-14.2	-12.1	**-13.2**	± 0.7	**-13.0**
	Gazelles	**7**	8.7	11.7	**10.2**	± 1.0		-17.6	-13.4	**-15.8**	± 1.5	
Herbivores	**Sheep/goats**	**9**	9.3	12.6	**10.9**	± 1.2	**10.5**	-19.6	-14.5	**-17.6**	± 1.6	**-16.5**
	Cattle ULG	**1**	13.5		-	-		-16.1		-	-	
	Cattle GD*	**3**	13.2	15.1	**13.5**	± 1.8		-17.1	-13.9	**-16.0**	± 1.5	
	Dogs	**4**	10.1	12.7	**11.9**	± 1.0		-18.9	-20.0	**-19.3**	0.4	
Omnivores	**Pig**	**1**	12.5		-	-	**12.5**	-20.9		-	-	**-20.0**
	Wild boar*	**4**	12.4	13.2	**12.9**	± 0.3		-19.8	-20.9	**-20.4**	± 0.4	
	Fox	**1**	14.6		-	-		-13.2		-	-	
Carnivores	**Big cat**	**1**	14.0		-	-	**15.0**	-16.1		-	-	**-15.0**
	Cat*	**1**	16.4		-	-		-16.5		-	-	
	Ulug EBA	**4**	11.2	14.2	**12.3**	± 1.21		-20.2	-19.7	**-19.9**	± 0.19	
Humans	**Ulug EBA/MBA**	**2**	13.7	14.9	**14.3**	± 0.58	**13.5**	-19.7	-19.1	**-19.4**	± 0.32	**-19.0**
	Ulug MBA	**5**	12.4	14.1	**13.4**	± 0.59		-20.5	-18.6	**-20.0**	± 0.69	
	Ulug EIA-MIA	**4**	13.3	14.0	**13.8**	± 0.30		-19.7	-16.1	**-18.2**	± 1.48	

*after Bocherens et al. 2006

Sheep and goats from Ulug Depe showed a $\delta^{15}N$ minimum value of 9.3‰, a maximum value of 12.6‰, and an average of 10.9‰ (± 1.2‰, n = 9); $\delta^{13}C_{col}$ values ranged between -19.6‰ and -14.5‰ with an average of -17.6‰ (± 1.6‰, n = 9). For gazelles a $\delta^{15}N$ minimum of 8.7‰, a maximum of 11.6‰, and an average of 10.2‰ (± 1.0‰, n = 7) was obtained; $\delta^{13}C_{col}$ ranged from -13.4‰ to -17.6‰ with an average of -15.8‰ (± 1.5‰, n = 7). The canids had a $\delta^{15}N$ minimum of 10.1‰, a maximum of 12.7‰, and an average of 11.9‰ (± 1.0‰, n = 4), while $\delta^{13}C_{col}$ results ranged between -18.9‰ and -20.0‰ with an average of -19.3‰ (± 0.4‰, n = 4). The single samples of the pig had a $\delta^{15}N$ value of 12.5‰ and $\delta^{13}C_{col}$ -20.9‰, the cattle showed a $\delta^{15}N$ ratio of 13.5‰ and $\delta^{13}C_{col}$ of -16.1‰, the fox 14.7‰ and -13.2‰, and the large felid had a $\delta^{15}N$ ratio of 14.0‰ and $\delta^{13}C_{col}$ of -16.1‰. Analyses of structural carbonate ($\delta^{13}C_{apa}$) were performed on bone compacta of one of the dogs (SK16-18) and the large felid (SK16-25), revealing $\delta^{13}C_{apa}$ results of -13.2‰ ± 0.03‰ (dog) and -11.4‰ ± 0.02‰ (big cat).

5.4.2. The isotopic baseline of Ulug Depe

The analyses of animals and the establishment of the isotopic baseline of the region in question is necessary for a reliable categorization of the human nutrition. The collagen results of 24 animals from Ulug Depe were included in the present study, consisting of nine domestic ovicaprids, seven gazelles, four dogs, one pig, one fox, one wild cat (probably a lion, but the determination is not a hundred per-cent sure), and one sample of charred barley grains (fig. 5.18). Isotopic signatures of plant material from southern Central Asia are currently unknown,[9] therefore comparative results were taken to complement the general baseline. The one barley sample analysed from Ulug Depe revealed ratios of $\delta^{13}C_{col}$ -27.2‰ and $\delta^{15}N$ of 3.6‰. The C3 plants from Lut desert (mainly salsola and calligonum) displayed $\delta^{13}C_{col}$ between -28.6‰ and -25.2‰ with an average of -26.7‰ (± 1.1‰ n = 7), while $\delta^{15}N$ ranged from 0.2‰ to 13.2‰ with an average of 5.7‰ (± 4.3‰ n = 7). The C4 plants (mainly tamarisks) ranged in $\delta^{13}C_{col}$ from -14.2‰ to -12.2‰ with an average of 13.2‰ (± 0.7‰, n = 13), $\delta^{15}N$ ratios ranged between -1.7‰ and 11.3‰ with an average of 5.5‰ (± 3.4‰ n = 13). The remains of ancient plants from the Caucasian steppes (mainly *Poaceae*) were analysed by Shishlina et al. (2017) and Herrscher et al. (2018), revealing average $\delta^{13}C$ values between -28.6‰ and -20.8‰ and $\delta^{15}N$ ratios of 9‰ for C3 plants and between -12.6‰ and -12.1‰ and $\delta^{15}N$ values up to 7.5‰ for C4 plants. Studies on C3 plants from Bestamak in northern Kazakhstan (mainly *Brassicaceae*), performed by Ventresca Miller et al. (2018), revealed $\delta^{13}C$ values ranging from -30‰ to -23.6‰, and $\delta^{15}N$ values up to 10‰, while the C4 plants´ $\delta^{13}C$ values ranged between -15.2‰ and -14.5‰, $\delta^{15}N$ values up to 4‰. Hence Lut plants display a higher variety and therefore a more reliable baseline than the far away Kazakh steppes and southern Caucasia. Sheep and goats, representing domestic herbivores, lived in the nearer surroundings of the humans and were most likely the main meat source. Their $\delta^{13}C_{col}$ ranged between -14.5‰ and -19.6‰ with an average of -17.6‰ (± 1.6‰ n = 9), the $\delta^{15}N$ ratios between 9.3‰ and 12.6‰ with an average of 10.9‰ (± 1.2‰ n = 9). Gazelles are herbivores, who completely live and graze in the wilderness. They yielded $\delta^{13}C_{col}$ values between -13.5‰ and -17.6‰ with an average of -15.8‰ (± 1.5‰ n = 7), $\delta^{15}N$ ratios ranged from 8.7‰ to 11.7‰ with an average of 10.2‰ (± 1.0‰ n = 7). The cattle, a ruminant and specialist in grass digestion, showed a $\delta^{13}C_{col}$ ratio of -16.1‰ and a $\delta^{15}N$ ratio of 13.5‰. The herbivores provided with values between -13.4‰ and -19.6‰, a wide spectrum of $\delta^{13}C$ ratios, but most were in the range of a mixed dietary intake of C3 and C4 plants. Some gazelles displayed ratios of a diet mainly consisting of C4 plants. Comparative analyses indicate significant high $\delta^{15}N$ ratios especially for gazelles and cattle.

The omnivores, four dogs and one pig, that probably lived together with the humans, ranged in the $\delta^{13}C_{col}$ ratios between -18‰ and -21‰ (average -19.3‰ ± 0.41‰ n = 4). The four dogs showed $\delta^{15}N$ ratios from 10.1‰ to 12.7‰ with an average of 11.9‰ (± 1.0‰ n = 4), the pig´s ratio being 12.6‰. These $\delta^{13}C_{col}$ results reflect a diet mainly based on C3 plants, as the $\delta^{15}N$ ratios are too low for carnivores, but in a good range for omnivores (fig. 5.18). The single fox showed a $\delta^{13}C_{col}$ ratio of -13.2‰ and a $\delta^{15}N$ of 14.7‰. Foxes as opportunistic feeder consume, depending on the season and opportunities, small mammals, birds, insects, eggs, fruits, and herbs. The fox from Ulug Depe is in the upper range of the nitrogen values. The big cat (*Panthera* sp.) revealed a $\delta^{13}C_{col}$ ratio of -15.7‰ and a $\delta^{15}N$ ratio of 14.0‰. The $\delta^{13}C_{col}$ indicates, similar to the fox, a life in the wilderness and a diet mainly consisting of C4 plants (if) or better of animals that consumed mainly C4 plants. The $\delta^{15}N$ ratio could be higher, but due to their biological predisposition cats (*Felidae*) detract 80–90% of their energy out of meat. Therefore, they are pure carnivores and represent a showcase specimen of the topmost step of the nutrition pyramid. Expecting that the big cat’s prey mainly consisted of wild animals as gazelles, deer, or wild boars (comparable results can be found in Bocherens et al. 2000, 2006) the trophic shift from predator to prey was however fulfilled. The cat (*Felidae indet.*) from Geoktchik Depe showed a $\delta^{15}N$ value of 16.4‰ (Bocherens et al. 2006), the highest ratio measured for a carnivore in the region and will therefore also be consulted as reference in the following discussion.

[9] Analyses of the plant material from the three sites were not performed anymore due to the Corona pandemic.

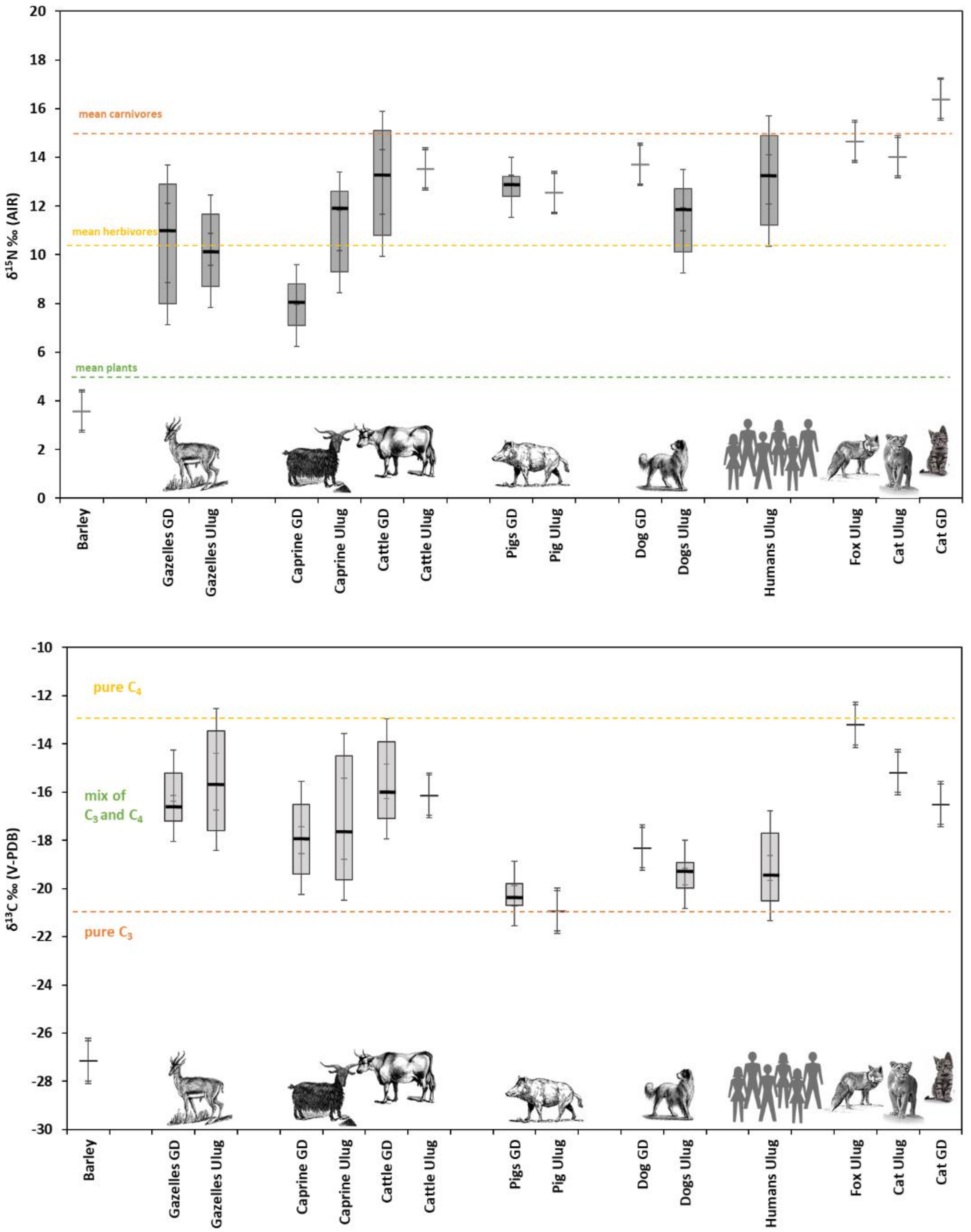


Fig. 5.18: Boxplot of $\delta^{15}N$ (top) and $\delta^{13}C_{apa}$ (bottom) results from Ulug Depe with references from Geokchik Depe after Bocherens et al. 2006. Black bars mark the averages.

Thanks to the large number of animal samples, the establishment of reliable and precise trophic steps in Ulug Depe was possible. Concerning the $\delta^{13}C_{col}$ ratios, a good distinction between wild and domestic animals can be made: gazelles, as well as the wild carnivores all displayed $\delta^{13}C_{col}$ ratios below -18‰ (average -15.6‰ ± 1.5‰), while domestic animals as sheep, goats, cattle, and dogs ranged between -20‰ and -14.5‰. The $\delta^{15}N$ steps are small and overlap, which is mainly caused by the highly variable dogs. By averaging the δ^{15}N ratios of the trophic groups, we receive a basis of plants at 5.5‰ (± 3.5‰, average of Ulug´s barley and Lut plants), the first step (herbivores) around 10.5‰ (± 0.5‰), the second (omnivores) around 12.5‰ (± 0.6‰), and the last (carnivores) around 15.0‰ (± 1.0‰). This results in averaged δ^{15}N intervals of 2.5‰ from herbivores to omnivores and 4.5‰ from herbivore to carnivores.

5.4.2.1. A possible climatic impact?

All analysed animals from Ulug Depe display remarkably high δ^{15}N results, a fact that needs to be discussed further. Different results from animals of Bronze and Iron Age sites along the north-eastern border of the Indo-Iranian Borderland, which formed a cultural area in these times, are available (c.f. fig. 5.19 with references). Comparative analyses showed, that the results of the herbivores from Ulug Depe revealed similar high δ^{15}N ratios as those of animals from Geokchik Depe in southwestern Turkmenistan (mainly gazelles and cattle, cf. Bocherens et al. 2006) and Tepe Chalow on the southern foothills of the Kopet Dagh Mountains (Soltysiak et al. submitted). Accordant high ranges have been only measured of gazelles and ovicaprids from the Pontic Steppe on the northwestern side of the Caspian Sea (Shishlina et al. 2009) and of ovicaprids from Qabrestan on the Iranian Central Plateau (Bocherens et al. 2000). The δ^{15}N ratios were significantly higher than those we know from other sites in Iran (Bocherens et al. 2000; Rameroli et al. 2010; Afshar 2014), southern Caucasus (Messager et al. 2015; Herrscher et al. 2018), northern Caucasus (Hollund et al. 2010; Gerling et al. 2015) or northern Kazakhstan (Ventresca Miller et al. 2014).

In general, the results from Ulug Depe demonstrate a high variability of δ^{15}N values of the different consumers, especially of herbivores and carnivores. Not only a high content of proteins in the nutrition, also water stress in plants, dryness due to low rainfall (Heaton 1987; Ambrose et al. 1991; Hollund et al. 2010; Rameroli et al. 2010; Schwarcz, Schoeninger 2011), and a high grade of salinity of the soil animals are grazing on (Heaton 1987; Britton et al. 2008), can lead to an increase in δ^{15}N values in herbivores. Additionally, manuring techniques and an increase of manuring practices through times might be an additional reason for increasing δ^{15}N values (Frasier et al. 2011; Bogaard et al. 2013, 2016). But to take a manuring factor into account, it needs to be considered that a special logistic effort coming along with a higher consumption of energy, and therefore it was probably limited to cereals, lentils and other vegetables grown for the human food supply. For Ulug Depe, several wild herbivores (gazelles) were analysed, that supposedly lived in the wilderness and rarely had access to manured fields or food. At least here, as humans of all periods and the different species of animals, wild and domesticated, all displayed the increased δ^{15}N values, the reasons seem to be more general. Especially the herbivores from Ulug Depe showed a high variability in the δ^{15}N values, which might have been caused by the consumption of these water stressed plants and different environments of pastures. Studies demonstrated that herbivores consuming plants from wet- or marshlands, or saline environments showed an enrichment of the δ^{15}N values between 1.6‰ and 3.5‰ compared to non-saline grazing habitats (Britton et al. 2008).

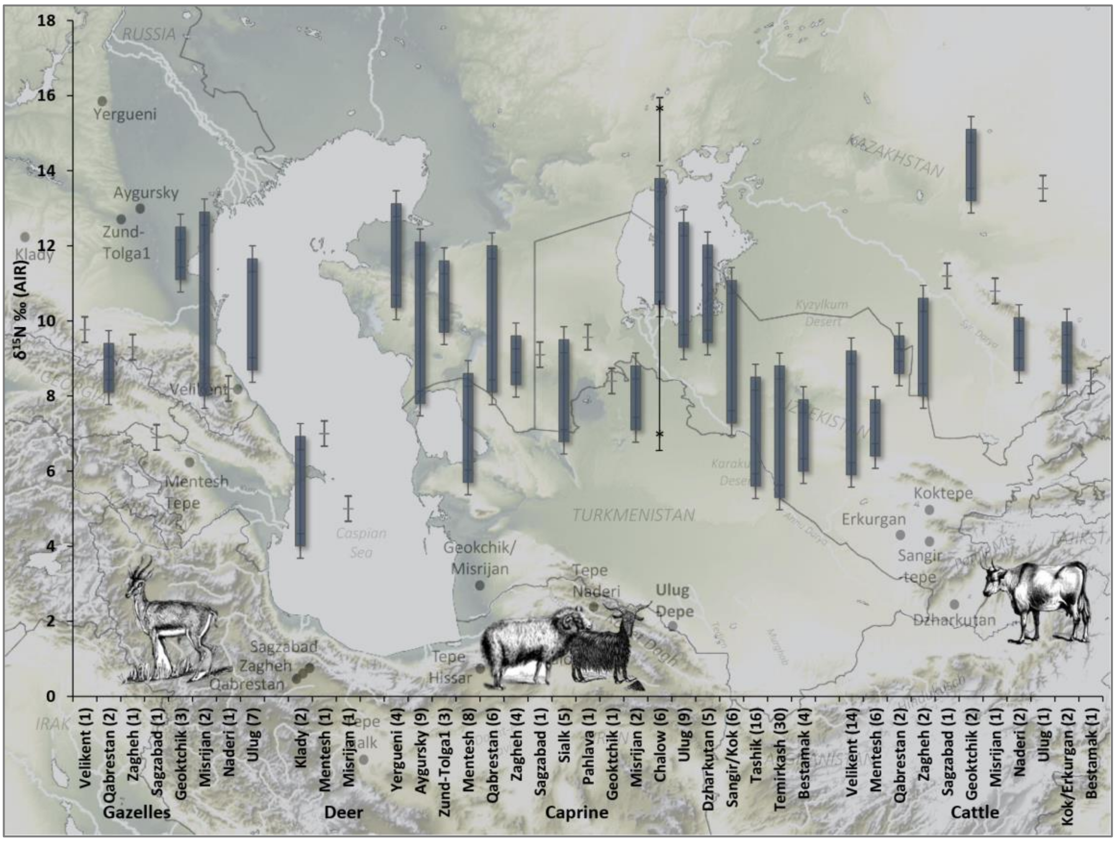


Fig. 5.19: Map of the investigated region with the sites mentioned in the graphic. Graphic: distribution of collected data of $\delta^{15}N$ averages from herbivores (numbers in parenthesis) around the Caspian Sea. References: Yergueni (Y) Zund-Tolga 1 after Shishlina et al. 2009; Velikent (V), Aygurskiy (A) after Hollund et al. 2010; Mentesh Tepe (MT) after Herrscher et al. 2018; Qabrestan (Q), Zagheh (Z), Sagzabad (S) after Bocherens et al. 2000; Tepe Chalow (TC) after Soltysiak at al. submitted, Geokchik Depe (GD), Misrijan (M) after Bocherens et al. 2006; Tashik, Temirkash after Motuzaite Matuzeviciute et al. 2015; Bestamak, Lisakovsk after Ventresca Miller et al. 2014.

Reflecting these facts on the geographic location of Ulug Depe and the prevailing vegetation and climate, the increased $\delta^{15}N$ values are rather depending on natural conditions. Average values of herbivores from adjacent regions as northern Kazakhstan, Iran or southern Caucasus were between 6‰ and 8‰ (Bocherens et al. 2000; Ventresca Miller et al. 2014; Herrscher et al. 2018), further away in western Anatolia even less (between 4‰ and 7‰, cf. Irvine 2020). Ulug Depe herbivores displayed averages of 10–12‰, and therefore an enrichment in $\delta^{15}N$ around 4‰ (cattle 5.5‰). This high factor might have been caused by an accumulation of the consumption of plants stressed by high temperatures, water deficiency, and a high degree of salinity of the soil due to strong winds and erosion (further studies in progress).

5.4.3. Reconstruction of human's dietary habits

Taking all individuals together, the $\delta^{13}C_{col}$ values ranged from -20.5‰ to -16.1‰ with an average of -19.4‰ (± 1.14‰, n = 15), while the $\delta^{15}N$ ratios fell between 11.2‰ and 14.9‰ with an average of 13.3‰ (± 1.01‰, n = 15). Concerning the chronological periods and biological criteria the $\delta^{13}C_{col}$ averages of the Bronze Age periods showed almost no differences (fig. 5.20). All averages ranged between -19‰ and -20‰ (EBA average -19.9‰ (± 0.19‰ n = 4), EBA–MBA average -19.4‰ (± 0.32‰ n = 2), MBA average -20.0‰ (± 0.69‰ n = 5)), indicating a constant diet during the earlier periods. The four

Iron Age individuals displayed an average of -18.2‰ (± 1.48‰ n = 4), that mainly results because of ULG 100, a 4–5-year-old child, with an outstanding $\delta^{13}C_{col}$ value of -16.1‰. In general, carbon ratios of the BA humans were in the typical range for a diet mainly based on C3 plants but with a certain percentage of C4 plants, while the IA samples showed a wider range more towards C4 signals (between -16‰ and -19.7‰). Botanical analyses showed no traces of millet or its cultivation in Ulug Depe, suggesting that humans cultivated and consumed mainly C3 plants as wheat, barley, and lentils. The vicinity of the Kopet Dagh Mountains enabled the access of humans and animals to further wild C3 species such as walnut, pistachio, almond, pear, prune, cherry and apple (Tengberg 2013, et al. 2020). The mixed signal of single individuals provides a diet consisted also of a small percentage of C4 plants, especially in the earlier periods, when apparently no millet was cultivated, might be caused by the consumption of wild herbal C4 plants, occurring in this region in a high variety (e.g. amaranths, rosemary, harmala), and animals whose diet consisted of these wild C4 plants.

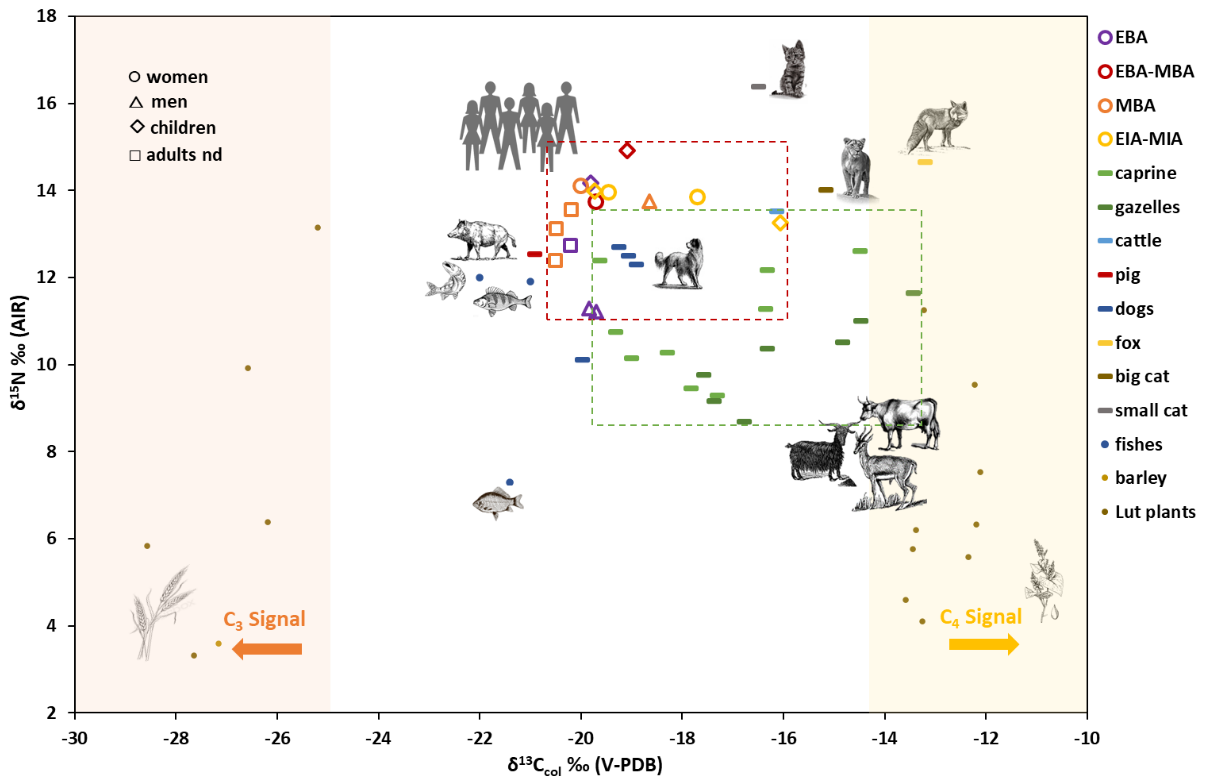


Fig. 5.20: Scatterplot of $\delta^{15}N$ versus $\delta^{13}C_{col}$ results out of collagen of all samples from Ulug Depe with plants from Lut, fish from Lake Baikal (LB) after Katzernberg et al. 1999, small cat from Geokchik Depe (GD) after Bocherens et al. 2006. The symbols encompass the error margins at 1σ level for $\delta^{15}N$ and $\delta^{13}C_{col}$ ratios.

The $\delta^{15}N$ ratio displayed a bit more variety: the four EBA individuals showed the lowest average of 12.3‰ (± 1.21‰ n = 4); the two individuals from the transition of the EBA to MBA, a woman and a child, show, due to the high value of the child, the highest average of 14.3‰ (± 0.58‰ n = 2), while the MBA group and the two adult women and the two children of the Iron Age periods rank between them, with averages of 13.4‰ (± 0.59‰ n = 5) and 13.8‰ (± 0.30‰ n = 4). Excluding the children, who showed the more outstanding values, the averages of the adults get even closer (EBA 11.7‰ (n = 3); EBA–MBA: 13.7‰ (n = 1); MBA 13.3‰ (n = 4); EIA–MIA 13.9‰ (n = 2)). The $\delta^{15}N$ analysis indicates that general patterns of dietary intake were relatively uniform between the Bronze and the Iron Ages. The averages neither demonstrate a constant trend nor significant changes, which might as well be caused by the small number of samples. The $\delta^{15}N$ ratios of two adult men of the earlier periods showed significant differences to the later. These EBA men over 40 years (ULG 53, ULG 55) displayed, compared to the rest of the group, low $\delta^{15}N$ values (and low $\delta^{13}C_{apa-col}$ intervals, see below). Anthropological analyses did not show any evidence for disease. Interestingly, both men are immigrants (cf. chapter 5.3.2.1.), and the different nutrition pattern could indicate another cultural background, possibly connected to different dietary habits. But as the numbers of samples is too small, it is not meaningful at the present state of research, to talk about a higher or lower consumption of animal protein, during the earlier periods. In general, the nitrogen ratios fell into comparatively high ranges, although the consumption of aquatic resources is also increasing the $\delta^{15}N$ values (Katzenberg 2008; Göhring et al. 2016), the matter is not deeper considered here. Water resources were and are rare in this arid region (Tengberg 2013, et al. 2020; Spengler et al. 2014a; Berking et al. 2017), and even though geomorphological investigations have identified the ancient bed of the Kelet River close to the site (Lecomte 2013), only a very little number of fish bones were found in Ulug Depe.[10] Even though fish, shells, or crabs were for sure a gratefully taken alternative, they probably did not constitute a remarkable content of the diet, due to a limited/seasonal availability around Ulug Depe.

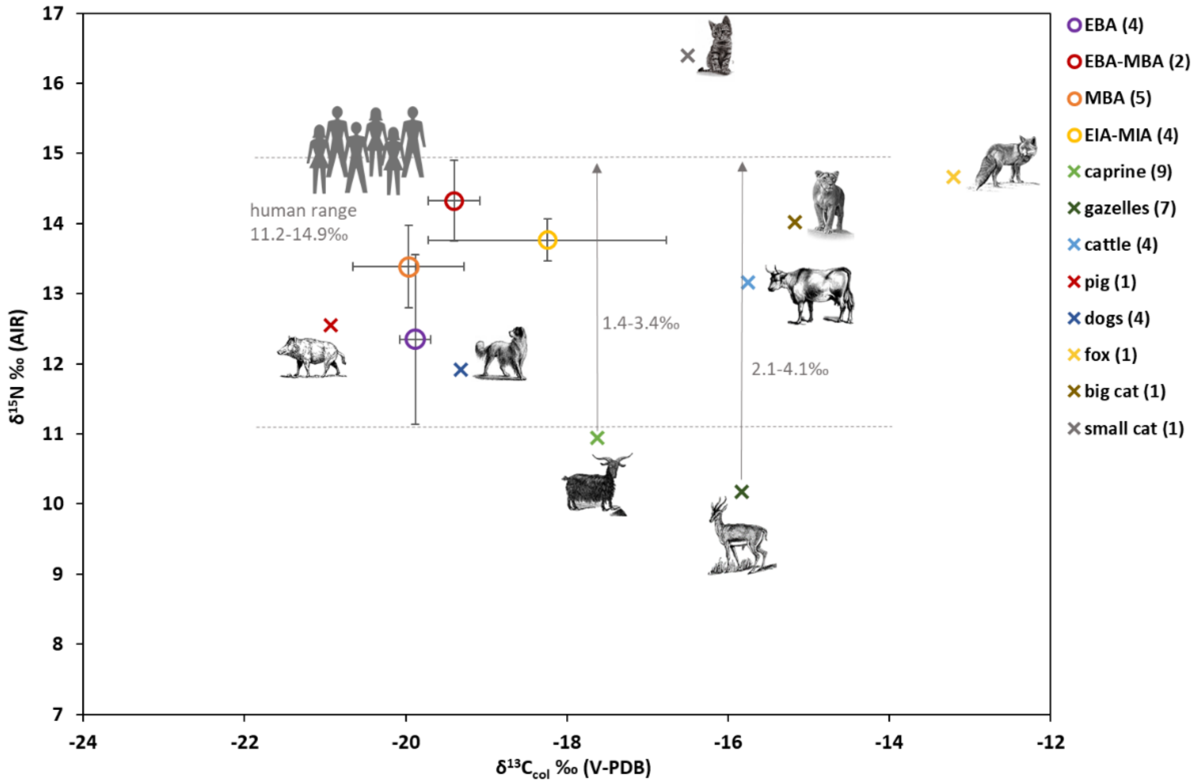


Fig. 5.21: Scatterplot of $\delta^{15}N$ and $\delta^{13}C_{col}$ averages (numbers in parenthesis) of all samples from Ulug with intervals between the species, small cat from Geokchik Depe after Bocherens et al. 2006.

When categorizing the humans within the trophic groups, most fall in the range of omnivores but some (mainly women and children) have similar high ratios to the ones of lion and fox. In contrary, the intervals between humans and sheep/goat, respectively gazelles, representing the trophic step of the primary and secondary consumers in the food web, were relatively small (fig. 5.21). The adult humans from Ulug Depe revealed intervals between 0.8‰ and 3.7‰ to the herbivores (EBA: sheep/goats 0.8‰, gazelles 1.5‰ (n = 3); EBA–MBA: sheep/goats 2.8‰, gazelles 3.5‰ (n = 1); MBA: sheep/goats 2.4‰, gazelles 3.1‰ (n = 4); EIA–MIA: sheep/goats 3‰, gazelles 3.7‰ (n = 2)). Considering an increase between 3–5‰ per trophic level (Bocherens and Drucker 2003; Hedges and Reynard 2007), the averages demonstrating small intervals, indicating in general a low content of animal protein in the diet.

[10] Cf. Mashkour 2013a, it must be mentioned, that sieving was not performed systematically during the excavation.

The very small intervals and overlapping values between humans and domestic ovicaprids suggest that in Ulug Depe livestock was mainly reserved as a resource and for secondary production and not necessarily as a primary food source. Whereas the little higher intervals between humans and wild animals as gazelles, deer, equids, or wild ovicaprids (further comparable results can be found in Bocherens et al. 2000, 2006) propose a higher consumption of wild herbivores and therefore a higher percentage of hunting activities to ensure the provision of meat. According to the archeozoological analyses, wild prey as gazelles and equids played an important role, especially during the early periods (Mashkour 2013a; collective 2015). An additional reason for the small intervals might be the consumption of legumes as a common part of the nutrition. Botanical analyses revealed a remarkable number of lentils and peas through all periods also in Ulug Depe. As symbionts of nitrogen fixing rhizobia legumes provide lower $\delta^{15}N$ signatures, whereas non-leguminous plants are more enriched in $\delta^{15}N$ and have higher $\delta^{15}N$ values. Consumers of legumes therefore have lower $\delta^{15}N$ values than those consuming non-leguminous plants (Katzenberg 2008). The consumption of legumes might have affected the nitrogen values of Ulug Depe´s people and possibly contributed to the small intervals between humans and domestic ovicaprids.

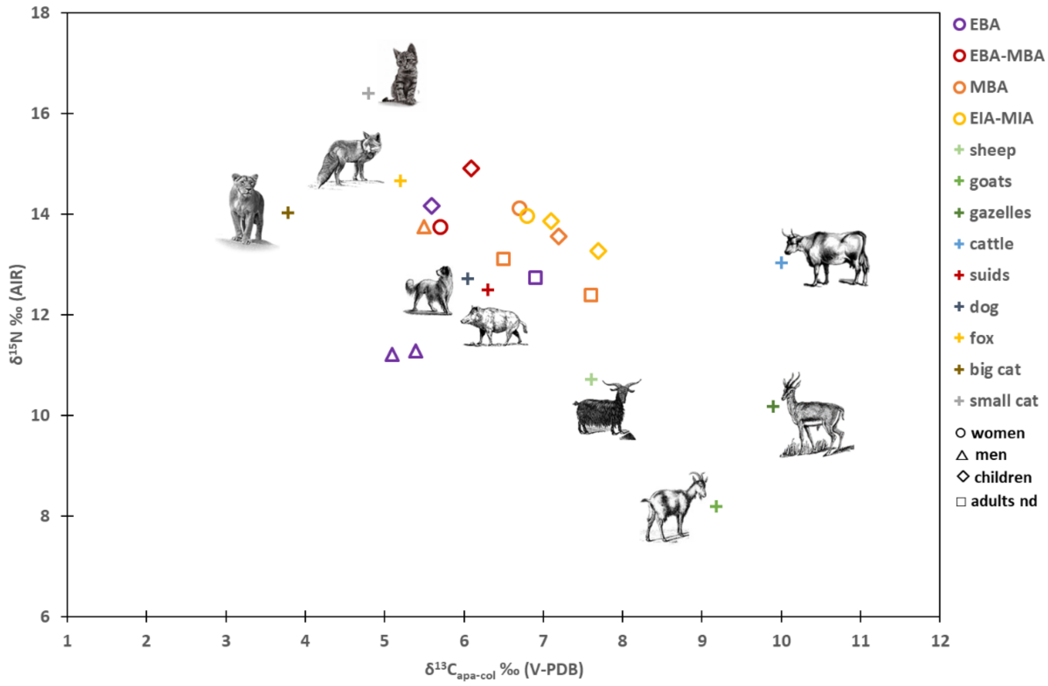


Fig. 5.22: Scatterplot of $\delta^{15}N$ versus $\delta^{13}C_{apa-col}$ of humans and animals. $\delta^{13}C_{apa-col}$ of fox, gazelles, and cattle after Codron et al. 2018: 3985–3986. The symbols encompass the error margins at 1σ level for $\delta^{15}N$ and $\delta^{13}C_{col}$ ratios.

5.4.3.1. Trophic level shifts ($\delta^{13}C_{carb-col}$)

The calculated difference between the $\delta^{13}C$ ratio of bone collagen ($\delta^{13}C_{col}$) and the $\delta^{13}C$ ratio of bone apatite ($\delta^{13}C_{apa}$) describes the proportion of animal proteins to proteins of the whole food spectrum ($\delta^{13}C_{apa-col}$) and give a rough impression of the trophic level of a species (Sullivan and Krueger 1981; Codron et al. 2018). Ulug Depe individuals provided $\delta^{13}C_{apa-col}$ results between 5.1‰ and 7.6‰ with an interval of 2.5‰, while most women, not determined adults, and children ranged between 6‰ and 7.7‰ (9 out of 14; fig. 5.22, Appendix table 6). Although the study of Codron and colleagues (2017) provides a large number of reference species, single animals from Ulug, Dzharkutan, and Sialk, were added for a comparative basis: the wild felid and the dog from Ulug displayed $\delta^{13}C_{apa\text{-}col}$ differences of 3.8‰ and 6.0‰, two sheep from Dzharkutan and one from Sialk provided $\delta^{13}C_{apa\text{-}col}$ spacings between 7.0‰ and 8.2‰, five goats from Sialk range between 6.2‰ and 12.0‰. Codron obtained averaged $\delta^{13}C_{apa\text{-}col}$ ranges for herbivores between 6‰ and 11‰, omnivores around 5–6‰, carnivores between 2.9‰ to 5.5‰ (high values result mainly from hyenas), and primates around 5.5‰ (Codron at al. 2017: 3985–3986). In Ulug Depe also the inter-individual $\delta^{13}C_{apa\text{-}col}$ differences (maximum 2.5‰) were comparably small, indicating that personal preferences were not significant (maybe due to availability?). Most individuals fell in a very small range more towards the results of herbivores (6–11‰), indicating a higher intake of plants and terrestrial resources. In a way, this matches the small distances of the $\delta^{15}N$ results between humans and sheep/goats and confirms a diet rather poor in animal proteins. Available studies from earlier and contemporaneous populations as the Bronze Age population from Mentesh Tepe in Azerbaijan provided $\delta^{13}C_{apa\text{-}col}$ results between 5‰ and 10‰ (Herrscher et al. 2018), and the Neolithic population from Nevali Cori in eastern Anatolia ranged between 5.6‰ and 9.8‰ (Lösch et al. 2006). Both providing a more diverse dietary intake based on plants and terrestrial resources and variable dietary pattern, possibly connected to the mobility of the people (Lösch et al. 2006; Herrscher et al. 2018). Whereas the results of Ulug´s individuals are arguing for a homogeneous nutrition during centuries with little changes in the general proportion of dietary intake.

5.4.3.2. Gender and social differences

Classified after gender and age, it is conspicuous that especially the $\delta^{13}C_{col}$ of the two Iron Age children differed towards higher values, while the averages of women, men, and not determined adults fall within similar ranges (women -19.7‰ ± 0.19‰ n = 4; men -19.4‰ ± 0.53‰ n = 3; adults n.d. -20.4‰ ± 0.14‰ n = 3). Concerning the $\delta^{15}N$ ratios women stand out as they revealed all high results, men and not determined adults instead had lower values. The results indicate that Ulug´s women had a diet similar or richer in proteins than the men. Interestingly, the three determined men displayed the lowest $\delta^{13}C_{apa\text{-}col}$ results in the group, but the small number of samples denies a reliable statement and further conclusions about gender differences in the dietary habits. The children of all periods fall, independent of the age, in the range of the adults, indicating no distinct difference between the nutrition of adults and children. The baby ULG 54 (1–2 years) and the child ULG 90 (ca. 3 years) were the only children whose $\delta^{15}N$ values were higher than 14‰ and $\delta^{13}C_{apa\text{-}col}$ results around 5–6‰. These results suggest a higher consumption of proteins and could be an indication that the children were breastfed (cf. Katzenberg 2008; Reynard and Tuross 2015). All other children were older and displayed, similar to the adults, a higher intake of vegetables.

5.4.4. Feeding and herding practices

Farmers and herders, possibly sedentary pastoralists, occupied Ulug Depe during the early periods. A growing population during the MBA implies more people to feed, respectively a larger demand of cereals, vegetables, meat, and dairy products, coming along with essential developments of herding and feeding practices. As mentioned above, the MBA cattle from Ulug Depe showed a high $\delta^{15}N$ value of

13.5‰, comparative values in this range were only measured of two cattle from Geokchik Depe (between 13.2‰ and 15.1‰; Bocherens et al. 2006). All other analysed individuals displayed distinct lower values between 6‰ and 10.5‰ (cf. fig. 5.19 and Bocherens et al. 2000; Shishlina et al. 2009; Hollund et al. 2010; Herrscher et al. 2018). Following the model of Hiebert's reconstruction of the oasis environment of the Bronze Age Margiana (fig. 5.23) cattle were not taken along on the seasonal movements between pastures, instead were situated in the fauna of the direct surroundings of the settlements. The cattle from Ulug Depe (and Geokchik Depe) revealed different nitrogen and carbon distributions than the sheep and goats. This might be an indication for different feeding and grazing habitats and practices. In the surroundings of Ulug Depe a drought-tolerant flora is dominant, that grow on dry and saline soils, comprising shrub taxa which are able to alternate between C3 and C4 cycles. The three cattle showed $\delta^{13}C_{col}$ ratios of -13.9‰, -16.1‰ and -17.1‰ and therefore a significant percentage of C4 plants in the diet. Water stress, aridity, and a high salinity of the soil can lead to increased $\delta^{15}N$ values in plants (cf. Shishlina et al. 2017; Ventresca Miller et al. 2018). As ruminants the cattle were able to extract enough energy out of this poor diet. This indicates that the distinct isotopic ratio of the cattle is the result of the exploitation of Ulug Depe´s (and Geokchik Depe´s) surrounding flora as fodder material.

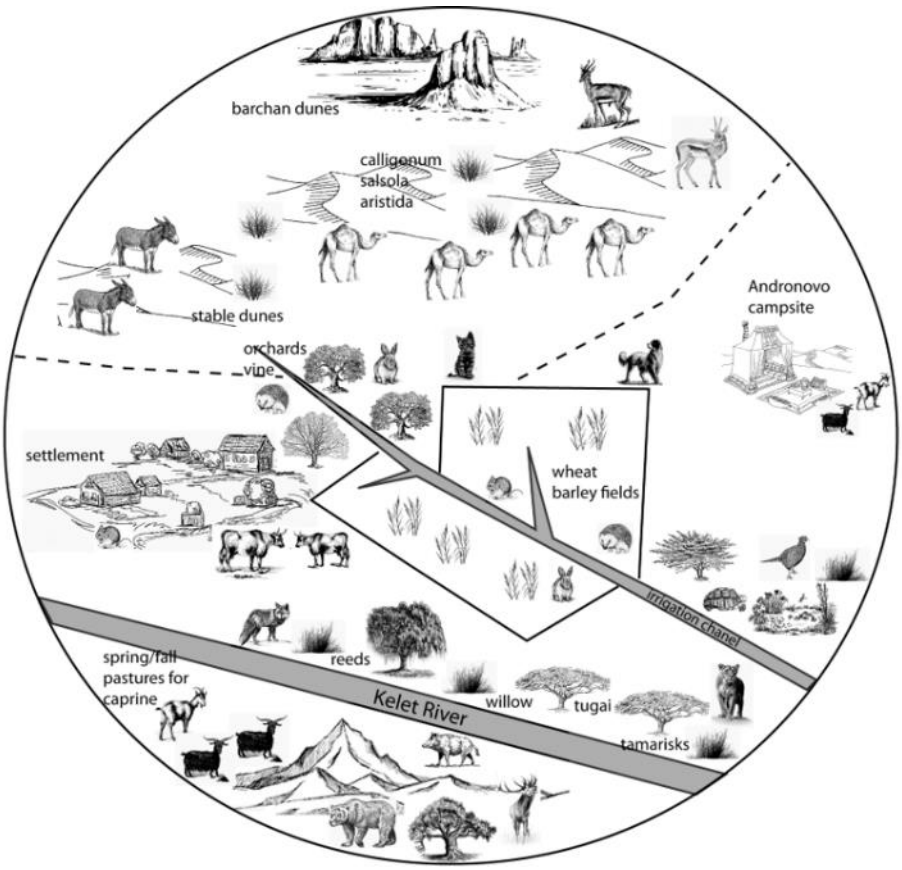


Fig. 5.23: Reconstruction of the foothill environment manipulated after Hiebert 1994 fig. 8.2.

The domestic ovicaprids from Ulug Depe are clearly distinguishable in 2 groups (fig. 5.24): intermediate $\delta^{13}C_{col}$ and low $\delta^{15}N$ values (averages -18.4‰ and 10.0‰); and high $\delta^{13}C_{col}$ and $\delta^{15}N$ values (averages -15.8‰, 12.4‰). Quite obvious is the correlation between the dating of the animals within the two groups: the first group, 5 ovicaprids (in the same range as the gazelles and one dog) – 4 out of

5 date back to the EBA, one to the EIA–MIA; the second group, 3 ovicaprids (1 cattle) – all date back to the MBA. The first group displayed a mixed intake of C3 and C4 plants (around 20% content of C4 plants) and low $\delta^{15}N$ values, in similar ranges with the wild gazelles. The second group showed a higher content of C4 plants (around 40%) and increased $\delta^{15}N$ ratios. This indicates different ways of livestock husbandry and a change of feeding and herding practices between the EBA and the MBA. Nitrogen and carbon ratios of the EBA ovicaprids provide a similar pattern as the one of the wild gazelles, while the later periods both showed increased $\delta^{13}C_{col}$ and $\delta^{15}N$ ratios. This could be interpreted as an evidence for the cultivation of millet as fodder material, and an indication for the development of manuring techniques during the MBA (Bogaard et al. 2013, 2016). Studies of plant cultivation and the mobility of sheep/goats, purchased by Hermes et al. (2019), indicate an intensive management of cultivated millet for foddering practices of pastoral communities in BA Kazakh steppes. No millet has been found in Ulug Depe itself, it is therefore not possible that the sedentary agriculturalists in Ulug Depe cultivated the millet for the fodder. But, different herding methods and movements between diverse biological habitats could be an explanation. The one ovicaprid from the EIA–MIA was in the same range as the ovicaprids from the EBA, as well with a higher percentage of C3 plants in the diet, indicating another change of the feeding and herding practices during the Iron Ages.

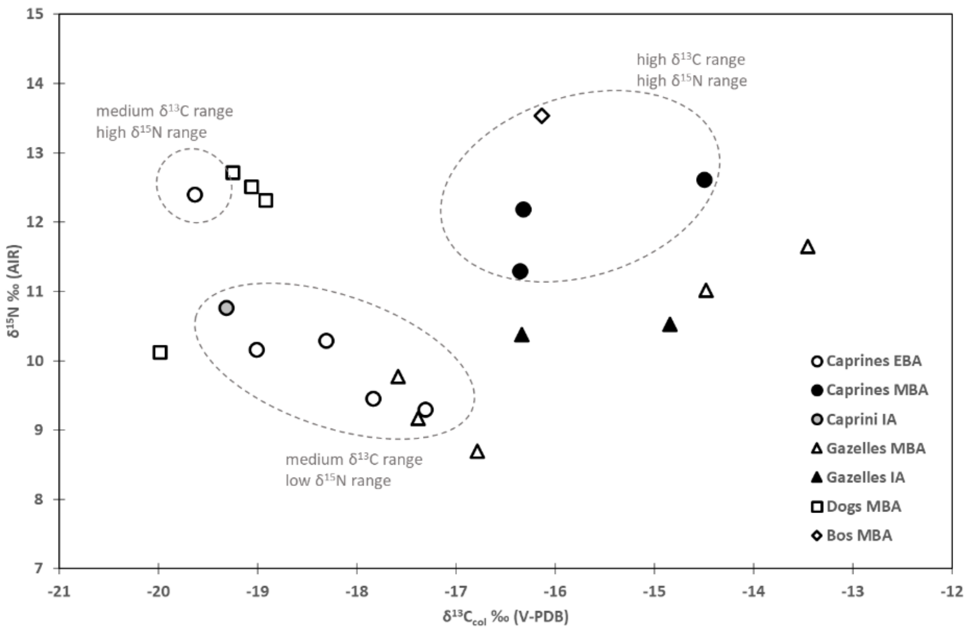


Fig. 5.24: Distribution of the groups of the ovicaprids from Ulug Depe. The symbols encompass the error margins at 1σ level for $\delta^{15}N$ and $\delta^{13}C_{col}$ ratios.

5.4.4.1. Reconstruction according to intra-tooth sequential sampling

As already mentioned in chapter 5.3.3. the processing of the time series is not fully finished yet, but preliminary evaluation evidences a clear correlation between the $\delta^{13}C_{apa}$ and the $\delta^{18}O_{apa}$ results (fig. 5.25). All measured individuals show a more or less distinct increase of the $\delta^{18}O_{apa}$ ratios connected to a decrease of the $\delta^{13}C_{apa}$ ratios. This indicates a change in the diet between the colder winter months (lower $\delta^{18}O_{apa}$ ratios) with a diet consisting of a higher percentage of C4 plants (lower $\delta^{13}C_{apa}$ ratios) and the hotter summer months (higher $\delta^{18}O_{apa}$ ratios) with a lower consumption of C4 plants (higher

$\delta^{13}C_{apa}$ results). During the MBA (NMG V) periods wild herbivores show a clear change to C4 plants consumption with a decrease of temperature (fig. 5.25 bottom right). In the winter months the wild gazelles´ diet consisted of around 75% of C4 plants while during the hotter months C3 plants make up most part of the diet, while the percentage of C4 plants ranged around 5–15%. The averages show a spacing of around 10‰ in the $\delta^{13}C_{apa}$ values, demonstrating a change in the diet of pure C3 diet in the hotter months to almost zero in the colder months. Chalcolithic domesticated ovicaprids showed the same pattern as wild gazelles. Visible is a correlation between an increased consumption of C4 plants with a decrease of temperature. Domestic animals´ diet in general is characterized by a higher percentage of C3 plants, while the increase of C4 plants during the colder months is only around 15%. Temperature effects on the oxygen results are visible in the values of the domestic animals as well: a spacing of 8‰ confirms the evidence of a stronger temperature change between summer and winter in the chalcolithic period and consumptions of several different drinking water sources.

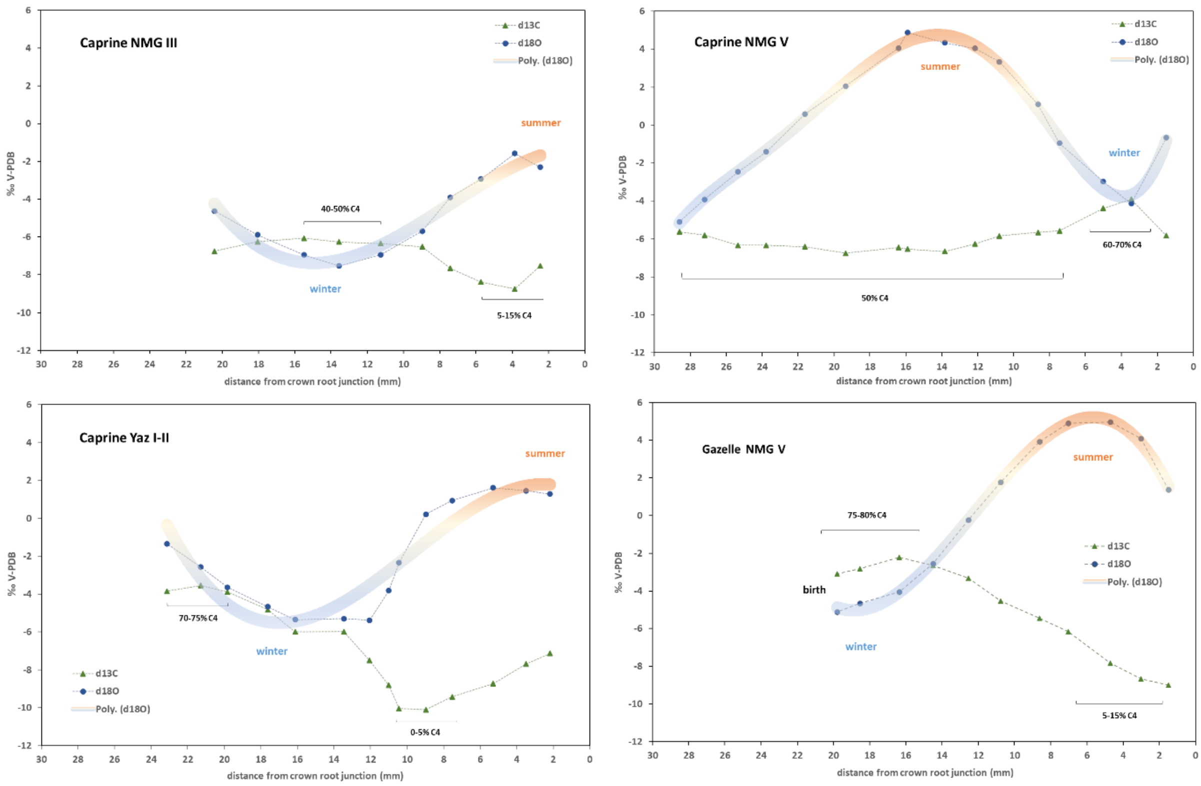


Fig. 5.25: Intra-tooth variation in carbon $\delta^{13}C_{apa}$ and $\delta^{18}O_{apa}$ isotope ratios of enamel bioapatite of ovicaprids and gazelles from Ulug Depe sorted after periods.

The non-uniform patterns of the time series of the different but contemporaneous individuals are usually interpretated as variable practices of animal management and different food and water sources connected to a certain mobility (cf. Herrscher et al. 2018; Makarewicz 2018; Hermes et al. 2019). The consumption of millet by the animals, respectively the systematic agricultural production of millet as fodder material (cf. Hermes et al. 2019) can be excluded due to the simple fact that no traces of millet have been found in botanical ensemble of Ulug Depe (Tengberg et al. 2020). However, the surrounding environment highlights the necessity to move to higher, more fertile regions to provide an adequate food supply for the animals. Therefore, pastoral movements have always been considered to be an essential part of the provision of the southern Central Asian communities. The results of the animals confirm seasonal movements. In case of Ulug Depe to the Kopet Dagh mountains in the hot summer month where an abundant natural food offer of wild C3 plants was present, and in the winter month back to the foothills where the surrounding steppe vegetation consisted of a distinct percentage of C4 plants.

5.5. Discussion and summary

In the surroundings of Ulug Depe a harsh and dry environment is dominant, high temperatures, respectively water stress for humans and animals, especially during the hot summer month, were familiar and accepted conditions for settling and existence in this region. During the earlier periods (EBA, EBA–MBA) Ulug Depe was a small settlement, with a population practicing small-scale farming and a lifestyle concentrated more on the daily food supply. Organization units rather consisted of self-sustaining families or clans than a centralized system (Lecomte 2011). The $^{87}Sr/^{86}Sr$ isotopic results demonstrate an exceptional high rate of immigration. The $\delta^{18}O$ isotopes evidenced the use of different groundwater sources, and an additional land-use in higher or colder climate zones. During the 3rd mill. BCE, the life of the people was certainly tightly connected to their animals as stock, food supply and material property, but in Ulug Depe they were obviously not the main food source. Nutrition analyses propose, Ulug Depe people in general had a diet rather poor in animal proteins, indicating humans mainly kept domestic animals as a resource and for secondary production than as a direct food source. Results propose a meat intake that rather consisted of wild animals and therefore a certain percentage of hunting activities through all periods. Carbon results were in the range of a diet mainly based on C3 plants as wheat, barley, lentils, peas, and several other wild species (Tengberg 2013, et al. 2020). Domestic herbivores of the EBA period displayed intermediate $\delta^{13}C_{col}$ and low $\delta^{15}N$ values (-18.4‰, 10.0‰) demonstrating a mixed intake of C3 and C4 plants, with a higher content of C3 plants. The isotopic ratios were similar to those of the wild gazelles, arguing for a more natural way of feeding and herding, supporting the image of a basic lifestyle of humans impacted by the collection of natural resources, while tracking seasonal food and water reservoirs together with the animals.

The appearance of the Oxus Civilization towards the end of the 3rd mill. BCE caused major sociocultural changes and economic shifts in southern Central Asia; the settlements became centers with complex, large-scale economic organizations (e.g., Luneau 2017). In Ulug Depe the prosperity and growth of the city, and an increase of trade and trade goods, strongly impacted the subsistence and economical strategies. The striking homogeneity of the $^{87}Sr/^{86}Sr$ results indicate, that no immigration took place. This is hardly believable, since this is the urban phase of Ulug Depe characterized by widespread connections, and stays therefore questionable until more data are available. $\delta^{18}O$ results proved a limited catchment area and therefore a more extensive use of the surrounding landscape. Nutrition analyses revealed that, similar to the EBA people, the diet was based on very little animal protein such as meat or dairy products. Domestic herbivores of this period showed high $\delta^{13}C_{col}$ and high $\delta^{15}N$ values (averages -15.8‰ and 12.4‰) and indicate a change in feeding practices between the EBA and the MBA. Sheep and goats displayed a higher content of C4 plants in the diet and increased $\delta^{15}N$ ratios, while values of gazelles of the same period stayed in lower $\delta^{15}N$ ranges. Increased $\delta^{15}N$ values and $\delta^{13}C_{col}$ values could be an evidence for the cultivation of millet as fodder material, and an indication for the development of manuring techniques during the MBA (cf. Hermes et al. 2019; Soltysiak et al. submitted). But considering this, several questions appear: the humans of Ulug Depe did not show any increase or changes in the $\delta^{15}N$ ratios from the early to the later periods, which could support or indicate the use and intake of fertilized grown food. And until now, no millet at all has been found in Ulug Depe.[11] This small change might therefore rather be caused by different herding methods, and movements between altitudes, water sources, biological habitats, and plant offerings. But here, the next problem arises: in general, it is suggested for pastoral communities that dairy products of their animals such as milk, butter, yogurt, or cheese, formed the main diet (e.g., Makarevic 2018, Knipper et al. 2020). That was obviously not the case for Ulug Depe´s people. The surrounding environment highlights the necessity to move to higher, more fertile regions to provide an adequate food supply for the animals. Some people clearly had to move with their animals to higher regions and practice pastoral herding, but the results of Ulug Depe's individuals argue for a mainly sedentary population with little mobility. In this context, the question arises: How was the supply of the settlement organized in this period? The strontium and oxygen results of the group of people buried inside the city of Ulug Depe do not give indications for further movements. It is not clear if we are talking about a group of privileged people, living, organizing, and ruling in Ulug Depe. The results of sheep and goats provide a different pattern of dietary intake, use of water sources, and seasonal movements than the humans. Excavations brought huge monumental building and housing areas to light, but no stables to keep and protect the flocks.[12] All these aspects lead back to the fact that a high degree of specialization was distinct for this time period and several different lifestyles, practiced by separate groups of people, existed within these societies (Vinogradova and Kuz'mina 1996; P'yankova 2002; Hiebert and Moore 2004; Kohl 2007; Cattani 2008; Lamberg-Karlovsky 2013; Kutimov 2014; Spengler et al. 2014a; Luneau 2017, 2021; Rouse, Cerasetti 2018). On the one hand pastoralists, who herded and bred animals, possibly lived in nearby villages along the Kopet Dagh or seasonal campsites in the mountains (Schetenko, Kutimov 1999; Kuzmina 2007; Kutimov 2014, Rouse, Cerasetti 2018). In contrast the inhabitants of Ulug Depe representing sedentary urbanites, respectively maybe specialized agriculturalists as the neighbored communities in the Murghab Delta (Spengler et al. 2014a). The earliest traces of irrigated agriculture in the surroundings are contributed to the Chalcolithic period, confirming a long tradition of agricultural development in Ulug Depe (Lecomte 2011). Raffaele Biscione postulated already in the 1970ies a hierarchical structure, respectively a system of division of work among the settlements along the foothills of the Kopet Dagh Mountains, with higher-ranking centres as organization units, medium size settlements, specialized in crop cultivation and irrigation techniques, while small villages were responsible for hunting and herding (Biscione 1976: 115–117). Depending on the size and the geographic location Biscione classified Namazga Depe and Altyn Depe as higher-ranking centres (around 40 ha). Ulug Depe and Hapuz-depe represent medium size settlements for agricultural provision (with ca. 10 ha) and e.g., Shor-depe or Kosha-depe as small villages were responsible for hunting and herding (with sizes between 0.5–2 ha). Due to the geographic location Biscione attributed Ulug Depe an additional role as commercial hub between the cities west and south of it and the settlements in the Margiana (Biscione 1976: 117). It is therefore quite attractive, that the isotopic results display an economy of Ulug Depe´s inhabitants mainly based on crop cultivation, agricultural development and probably trade, and rather little on herding and breeding of animals.

Changes also occurred with the fall and disappearance of the Oxus Civilisation in the first half of the 2nd mill. BCE (Luneau 2016, 2019). After a short, gradual transition period archaeological remains evidence another cultural and social shift within the societies in southern Central Asia and a radical transformation of the settlement pattern: existing settlements were abandoned while new

[11] It has to be mentioned, that only a small part of the archaeobotanical remains from Ulug Depe have been studied yet, as the work is still in progress.

[12] Clearly identified stables inside of cities are rare and were only found in the context of horses (Cantrell, Finkelstein 2006; Kroll 2012, 2018); sheep, goats and cattle herds probably stayed outside of the cities, maybe in paddocks or meadows, which are difficult to distinguish through archaeological excavations: especially in the vicinity of Ulug Depe because of the destruction through modern agricultural activities and thick alluvial deposits.

settlements appeared, small villages replaced large proto-urban sites, burials together with grave goods disappeared, and valuable artistic items were replaced by utilitarian items (Lecomte 2007b, 2011, 2013, Lhuillier 2013, 2019; Bendezu-Sarmiento and Lhuillier 2015). The group of Iron Age humans from Ulug Depe consists of two women and two children, due to the small sample number (children often differ in the dietary intake and metabolism), averages are not representative, but all individuals showed similar $\delta^{15}N$ ratios than the Bronze Age humans, as well as the intervals of $\delta^{13}C_{carb\text{-}coll}$ (all above 6‰). Hence, no significant changes of the content of animal proteins and dairy products are traceable, the same is the case concerning the proportion of plants and terrestrial resources. Whereas the $\delta^{13}C_{col}$ ratios displayed a wider range (between -16‰ and -19.7‰) and indicate a higher intake of C4 plants. This stays in contrast to the botanical analyses, which do not provide any traces for the cultivation of millet as an additional component in the diet, but might be an indication for an adaptation to a new economy, respectively for affecting climatic changes which are often associated with the disappearance of the Oxus Civilization.

6. A case study: The stranger from Ulug Depe (ULG 56)

The content of this chapter was presented in a talk at the EURASIA Conference in Bern (January 2024) and will be published in the course of the conference proceedings:

*Kroll, S.K., Bon, C., Bosch, D., Lhuillier, J., Bendezu-Sarmiento, J., Mashkour, M. (**in preparation**) The stranger from Ulug – a long way from home. In: C. Baumer, M. Novak, S. Rutishauser (eds.) Mobility and Archaeogenetics in Central Asia: People – Goods – Ideas. Proceedings of the Third International Congress on Central Asian Archaeology held at the University of Bern, 11-13 January 2024, Harrassowitz, Wiesbaden.*

This chapter was added at this point, to demonstrate the combination of isotopic and paleogenetic investigations, which were performed in the course of the TransAsia project on the individuals from Ulug Depe. Moreover, the results of burial 56 were the most amazing and surprising in this study and should be discussed in detail. ULG 56, an adult (age and gender not further determined) person, was buried in a multiple burial of six individuals, including two adults (n.d.) and four children under 8 years. The grave was looted and badly disturbed, therefore it was not possible to distinguish, if the people were buried collectively or after each other (fig. 6.1). The individuals were not complete, several tibiae, fibulae and food bones were found at the bottom of the tomb, and only scattered remains of grave goods (single sherds of pottery and alabaster) could be documented. Unfortunately, only this one adult individual of the burial was sampled for the present study, due to the poor conditions of the grave further determinations were not possible (Bendezu-Sarmiento 2013: 503–505).

Fig. 6.1: Remains of burial ULG 56 after Bendezu-Sarmiento et al. 2013: 510.

6.1. Isotopic results ($\delta^{18}O_{apa}$, $^{87}Sr/^{86}Sr$)

Interestingly, the isotopic results of bone strontium and oxygen were not conspicuous, the $^{87}Sr/^{86}Sr$ ratio fell together with the other individuals within the local strontium range of Ulug Depe (fig. 6.2), the ratios of enamel $\delta^{18}O_{apa}$ -3.4‰ (± 0.047) and bone $\delta^{18}O_{apa}$ -3.2‰ (± 0.029) (cf. Appendix tab. 6) could indicate almost no mobility during lifetime. But the $^{87}Sr/^{86}Sr$ ratio of the tooth enamel of

0.709960 (± 0.000004) was faraway of all results measured during this study (fig. 6.2). Results in this ranges are rare to find. Close are the $^{87}Sr/^{86}Sr$ results of the mobility study of animals by Chase et al. (2014) in Bagasra in the Indus valley. Also, one cattle from Balakhod in Pakistan fell into the same $^{87}Sr/^{86}Sr$ range (Gregoricka 2013). And with a given local $^{87}Sr/^{86}Sr$ range of 0,707806 – 0,710022 of Allahdino in Pakistan, ULG 56 would fit into it (Gregoricka 2013). This comparison would perfectly confirm standing theories about the connection and movements between the great cultures of the Indus valley and the Oxus civilization in southern Central Asia. But in the course of this project aDNA analyses were carried out by Aurore Monnereau and Celine Bon. The results showed us a completely different picture of the situation:

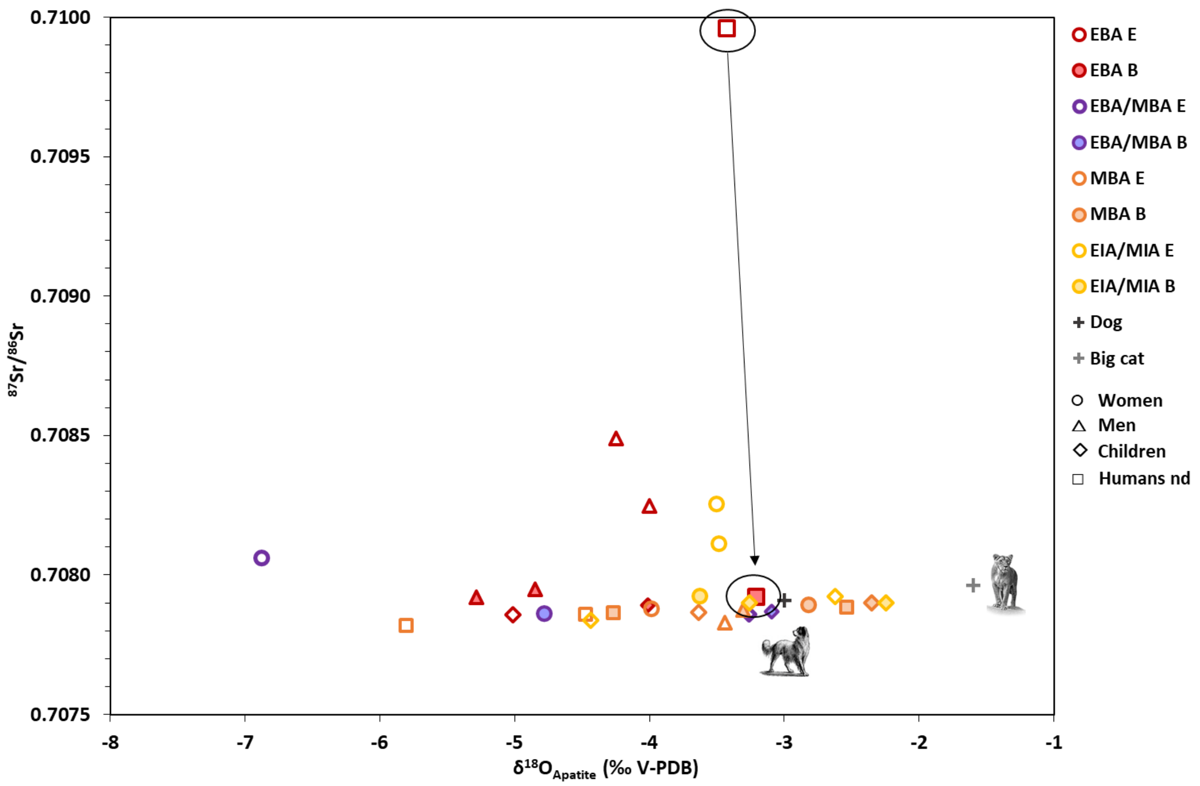


Fig. 6.2: Scatterplot of $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{apa}$ results of ULG 56. The symbols encompass the error margins at 2σ level for the $^{87}Sr/^{86}Sr$ ratios and 1σ level for $\delta^{18}O$ ratio.

6.2. Results of paleogenetic analyses (by Celine Bon)

"Contrary to isotopes, DNA markers are inherited from ancestors and thus provide information on the population origin of the individuals. From one generation to another, genome is transmitted with a small number of mutations (around 70/3.2 billion of base pair (bp)): through the succession of generation, it amounts to a mean of 1/1000 differences between two human genomes. The genome is transmitted by both parents, except for two markers: the Y chromosome and the mitochondrial (mt) DNA. The Y chromosome is transmitted by father to sons, while the mt DNA is transmitted by mother to child. Thus, the sequence of the mt DNA of one individual is the same as its mother, its maternal grandmother, her mother and so on – except for a few mutations that may have occurred. This kind of event is quite rare, as the mutation rate of the mitochondrial DNA is low (0.017 × 10-6 substitution per site and per year, thus around 7 × 10-3 substitutions per genome and per generation) (for a review see

Pakendorf, Stoneking 2005), but is slightly higher in the non-coding region of the mt genome, namely the control region. This region (~1100 bp long) has a mutation rate of estimated between 0.075 × 10-6 and 0.47 × 10-6 substitutions/site/year. Thus, individuals displaying the same sequence (haplotype) share a recent (on an evolutionary point of view) maternal ancestor; individuals that share some mutations but not all of them belong to the same haplogroup. In population genetics, "populations" are defined by the frequent interbreeding between its members. Members of the same population share more genetic markers than with members of other populations (e.g., Der Sarkissian et al. 2015). Because most of the society are patrilocal (at the wedding, wives go and live in their husband family village), the signal of genetic structure is more blurred in the maternally inherited mitochondrial DNA than in the Y chromosome or autosomal genome (Wilkins 2006; Heyer et al. 2012). Mt haplogroups may be shared between different populations due to female migration. Nonetheless, mt DNA is a long-time favourite in ancient DNA studies because it is more easily conserved through time. Indeed, the Y chromosome has only on copy by cell; an autosomal chromosome, two copy/cell, while the mitochondrial DNA has several hundreds to thousands copy/cell. Thus, the probability of survival through time of a mt marker is far better than those of an autosomal marker (Willerslev and Cooper 2005).

The results displayed, that ULG 56 had a V1b mitochondrial haplogroup, which is found in Western Europe. To the best of our knowledge, no V1b ancient individual has been evidenced up to now; however, individuals exhibiting a V haplogroup are found exclusively in Western Europe, restricted to Northern Europe for V1 (fig. 6.3), suggesting an origin in this area. The V haplogroup is still rare in modern southwestern populations. In modern Central Asian populations, this haplogroup is sporadically evidenced: 1 Persian (out of 352 Iranians) in (Derenko et al. 2013), 1 Turkish (out of 40) in (Quintana-Murci et al. 2004), 1 Kyrgyz (out of 54) in (Peng et al. 2018). It is, however, frequent in north-western Eurasian populations and amounts to 58.6% in Swedish Sami (Ingman and Gyllensten 2007)." (this chapter was contributed to the publication mentioned above by Celine Bon, detailed information on the lab methods and itemized results of the aDNA sequencing can be consulted in the article).

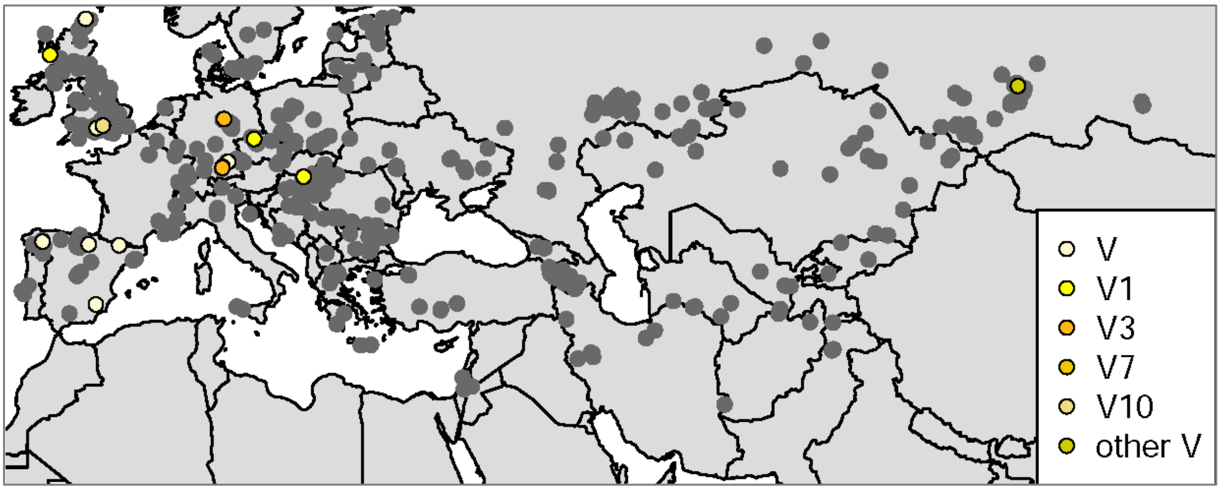


Fig. 6.3: Distribution of the V haplogroups in Central Asia and Europe (courtesy of Celine Bon).

6.3. Combination of paleogenetic and isotopic results

The DNA results provoke a rethinking and a further search for comparable isotopic studies. Suitable $^{87}Sr/^{86}Sr$ results have been found in investigations of Andronovo people in the northern Kazakh steppes

(Ventresca Miller et al. 2017), as well as Holocene hunter gatherers from Lake Baikal, that displayed similar $^{87}Sr/^{86}Sr$ ratios and indicate a possible origin (Haverkort et al. 2008). Quite beautiful in this context is, that studies of Vikings in eastern Sweden also displayed similar $^{87}Sr/^{86}Sr$ results to ULG 56 (Krzewinska et al. 2018). The paleogenetic analyses were performed on the mitochondrial haplogroup, which is passed through maternal inheritance. Hence it is not clear if the mother of ULG 56 came from the far north or ULG 56 itself. According to the scientific results it is for example also possible that ULG 56 was born in the northern Kazakh steppes, but the mother migrated from northern Europe to Kazakhstan.

6.4. Conclusion

The importance of long-distance interactions is especially evident in the earliest periods of the EBA in Ulug Depe. In fact, it is a time of great change in southern Central Asia that began during the Chalcolithic period, with cultural exchanges and movements involving Iranian, Pakistani and Afghan sites (Amiet 1986; Jarrige 2013). The proto-urban dynamics, which had its apogee during the Bronze Age, began its genesis during the end of the Chalcolithic in the Kopet Dagh area (Masson 1981). In contrast to these connections to the west and south of Central Asia, we know very little about the connections that must have existed with the steppe part of Central Asia. The northernmost protohistoric site of the 3rd mill. that we know of is Sarazm in the Zeravshan Valley in north-western present-day Tajikistan, where archaeological evidence of contact with Baluchistan and the Iranian Plateau have been discovered (Besenval 1987; Lyonnet 1996). In this context, the individual ULG 56 of Ulug Depe might fill this gap. Although we do not have many information about this person, and the real origin remains unclear, we know he/she came from far north and lived the last years before death in Ulug Depe. The isotopic and paleogenetic results of this grave provide a real proof for long-distance migration, and gives an idea about what distance one person in the 3rd millennium BCE can cover over a lifetime and how far the cultural connections and influences of the EBA people really went.

Fig. 7.1: View from the east to the hill of Dzharkutan with the Kugitang Mountains in the background (©MAFOuz-Protohistoire).

7. Dzharkutan

7.1. Preface

Dzharkutan represents in a way the "poor cousin" of this thesis. On the one hand the results turned out to be quite special, on the other hand nothing fits together, everything is different, worsened by the lack of suitable reference material. To begin, the historical situation of Dzharkutan and other sites in the Surkhan Darya valley is different, as no previous occupation layers are known in the region up to now. Hence, no chronological developments can be investigated, instead a more detailed view on the situation during the LBA can be provided.

7.2. The site Dzharkutan

Dzharkutan (37°37'30.49"N 66°57'31.32"E) is located in southern Uzbekistan, in the southern valley of the Surkhan Darya river, ca. 4 km south of the village Akkurgan close to the modern city of Sherabad, and 60 km north-west of the district capital Termiz. The Surkhan Darya plains are enclosed by the Kugitang mountains to the west, in the east the plain is bounded by the Babatag, in the north by the Hissar Mountains and in the south the Amu Darya forms the border with Afghanistan.

The first Bronze Age settlements in the Surkhan Darya valley were identified by researchers of the Fine Arts Institute in Tashkent and the Samarkand Institute of Archaeology. They discovered Molalitepe (Beljaeva and Khakimov 1973) and Sapallitepa (Al'baum 1969; Askarov 1971, 1973) at the end of the 1960s (cf. Kaniuth 2021). Dzharkutan was discovered in spring 1973 by S.R. Pidaev and V.N. Pilipko. The impressing size of the sites made scientists curious, so the first field season was undertaken in autumn of the same year under direction of Ali A. Askarov from the Archaeological Institute Uzbekistan. He undertook several further excavations (Askarov 1977, 1980, 1981), the later together with Temur S. Shirinov, who inherited the project (Askarov and Shirinov 1991, 1994; Shirinov and Baratov 1997). They excavated certain residential districts inside and around the citadel and further monumental buildings as the “temple”, as well as the huge areas of the cemeteries (cf. Askarov and Shirinov 1994; Shirinov 2002). Between 1993 and 2003 a cooperation of the German Archaeological Institute (DAI) and the Archaeological Institute Uzbekistan under the direction of Dietrich Huff and Shapulat Shajdullaev continued the work, mainly focusing on housing areas of the mounds IV, VI, VIII, and X (Huff, Shajdullaev 1999; Huff 2000a; 2000b; 2001; Huff et al. 2001; Kaniuth 2006; Teufer 2015). The last intensive excavations were undertaken between 2006 and 2013 by a French-Uzbek cooperation under the direction of Julio Bendezu-Sarmiento and Samariddin Mustafakulov (Mission archéologique franco–ouzbèke – protohistoire (MAFOuz–Protohistoire)). After a survey in 2006, excavations in Necropolis 3 followed in the subsequent years (Bendezu-Sarmiento and Mustafakulov 2008; Bendezu-Sarmiento 2013). From 2009 on systematic investigations on the citadel were carried out (Mustafokulov et al. 2012, 2013; Bendezu-Sarmiento and Mustafakulov 2013).

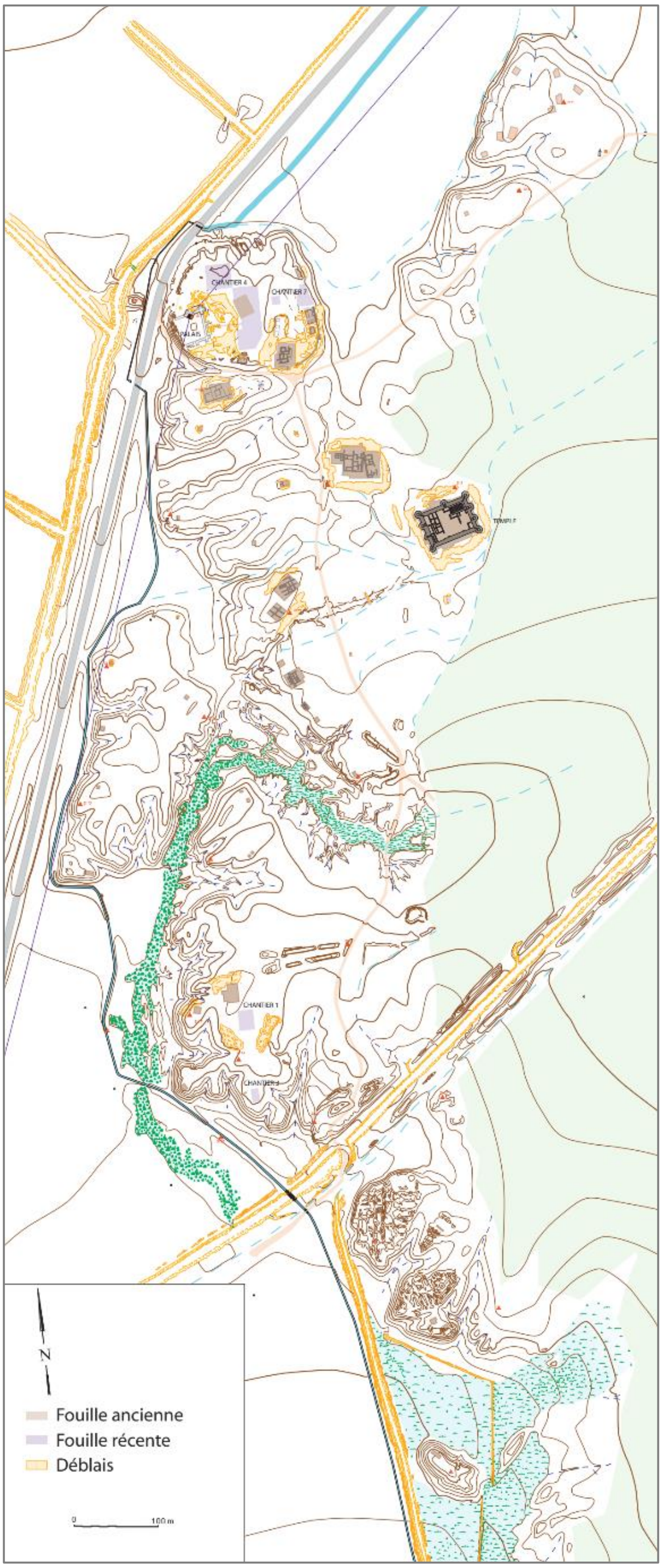


Fig. 7.2: Topographic plan after Bendezu-Sarmiento, Lhuillier 2019: 107 fig. 10.

7.2.1. Archaeological Background

Dzharkutan is the biggest known site of the "Sapalli Culture" in the Surkhan Darya valley. The Sapalli Culture arose as a local variation of the Oxus Civilisation in northern Bactria. Since no previous occupation layers are known from any site, the generally accepted opinion is, that the settlements in the Surkhan Darya valley (e.g., Dzharkutan Sapalli, Bustan, Molali, Tilla Bulak) were founded during the expansion of the Oxus towards east at the end of the 2nd mill. BCE (e.g., Kaniuth 2021: 457). The ongoing urbanisation at the peak of their existence is remarkable in the structure and size of the settlements, resulting in a strong social organisation with high standards of technology, crafts, and sophisticated farming economy (Askarov 1981). The stratigraphic sequence is therefore comparably short, starts at the beginning of the 2nd mill. BCE and ends at the beginning of the 1st mill. BCE. The reasons for the abandoning of the settlement at the end of the early Iron Age (ca. 1000–900 BCE) are unknown (Bendezu-Sarmiento and Mustafakulov 2013; Lhuillier 2016). Askarov and Shirinov postulated three building phases, which are distinguishable in the building constructions as well as in the finds and the pottery (Dzharkutan I–III).[13] The settlement was about 40–50 ha in size (Huff et al. 2010: 23), including more than two dozen of small hills with traces of occupation (Shirinov 2002: 86) and large graveyards in the south and southwest. Ten hills have been further investigated (I–X), mostly dating to the 20th–18th century BCE; mound VII and VIII date a little later into the 17th–15th century. The most imposing monuments are for sure the temple and the palace. The citadel was located on the northernmost hill with a size of about 4 ha. The citadel was the only hill surrounded by a fortification construction. The palace was situated inside the citadel with a size of 42 × 42 m and a 4 m thick outer wall with 13 towers, and several living quarters (Shirinov 2002: 3–9 fig. 3, 4). South-east of the citadel, a bit isolated on mound 6, was lay the "fire temple". An impressive building with 44.5 × 60 m in size, including an altar in a sacral room connected through doors to several utility rooms with water reservoirs (wells), and a winery (Shirinov 2002: 50). The temple was built with strong walls of 4.5 m thickness as well (Shirinov 2002: 33–86). Several living and workshop areas could be distinguished on hill V, VII, VIII, and Shirinov is speaking of a social differentiation between the residents of the particular hills (Shirinov 2002: 86). The houses were all equipped with hearth, pits, and storage jars. On hill I and II in the very north-eastern part, the areas of the craftsmen were situated. Traces of pottery productions were discovered, such as two big kilns, a great number of different types of pottery and slag, mainly mass-produced tableware, but also fine grave ware (Shirinov 2002: 109). The region of southern Uzbekistan provided next to a strategical smart location between the settlements in southern Tajikistan, northern Afghanistan, and the Margiana, also a good basis for settling. The numerous rivers and tributary streams enable agriculture, providing enough food for humans and animals. The rich mineral resources found in the nearby mountains might also have contributed to settling in this area (salt, copper, tin, lead, and iron are readily available, but no pre-medieval exploitation has yet been documented, cf. Kaniuth 2021: 460). The people lived sedentary lives specialized in agriculture, but animal herding was a substantial part of the subsistence strategies as well.

In Dzharkutan, in contrast to Ulug Depe, some artefacts, mainly ceramics, of the nomadic Andronovo type from the steppes (Luneau 2017) and a related culture of farmer-breeders from the Pamir foothills of south-western Tajikistan, the Vakhsh culture (Luneau et al. 2013) have been uncovered in the settlement (Bendezu-Sarmiento et al. 2009). The "classic Vakhsh culture" showed, especially concerning the construction of burial mounds (*kurgans*), strong analogues to the eastern Bronze Age

[13] Shirinov is correlating the phases to the other sites in the Surkhan Darya valley: DZH Ia the so-called Dzharkutan phase; DZH Ib the Dzharkutan-Sapalli phase; DZH II the Dzharkutan-Kuzali phase and DZH III the Molali-Bustan phase (Shirinov 2002: 141). The terminology was replaced when C14 dates proved the sites as quasi contemporaneous (cf. Teufer 2014).

communities in the Altai and Xingjang Mountains (Teufer 2021: 728–729). It can therefore be considered as a part of the interregional transactions between the Central Asian oasis cultures and western China, respectively along the Inner Asian Mountain Corridor (Frachetti 2012; Teufer 2021). Pottery types of this culture have also been found in several tombs from Gelot-Darnaichi. But whereas the classical Vakhsh culture buried their deceased in kurgans, no burial mounds have been found in Gelot-Darnaichi (Teufer 2021). Therefore, a distinction between the classical Vakhsh culture and the newly defined "Pjandzh culture" seemed reasonable, while Gelot-Darnaichi belonged to the latter (Teufer 2018: 161–166). The "Pjandzh culture" was first suggested by Henri Paul Francfort (Francfort 2016: 471) and is characterized by "the combination of a local Bactrian tradition with deep Mesopotamian and Elamite influences" (Vinogradova 2021: 660).

Fig. 7.3: Impression of the Surkhan Darya valley landscape, top: Kugitang Mountains, bottom: steep banks of the Surkhan Darya river.[14]

7.2.2. Landscape and subsistence

The Surkhan Darya valley is characterized by two different ecoregions: the northern Gissaro-Alai open woodlands ecoregion (PA1306) and the southern Badkhiz-Karabil semi-desert ecoregion (PA808).[15] The hilly plateau of Badkhiz-Karabil lies north of the northernmost Afghan range of the Hindukush. The climate of the semi-desert Badkhiz-Karabil region is characterized by seasonal rainfall in winter and early spring, resulting in an early and short growing season. From May to October the climate is dry and hot. Average annual precipitation is 200–240 mm, the mean annual temperature +16.8°C, with a maximum of +47°C and a minimum of -32°C. Wide areas are covered by a unique xeric savanna ecosystem, dominated by wild pistachio trees (fig. 7.3). The vegetation is dominated by annual

[14] after https://www.people-travels.com/about-uzbekistan/uzbekistan-nature-reserves/surkhan-state-nature-reserve.html and http://explorers.uz/en/sights/surhanskiygosudarstvennii_zapovednik.html (last access 01.02.2021).

[15] https://www.worldwildlife.org/ecoregions/pa0808; https://www.worldwildlife.org/ecoregions/pa1306; (last access 09.06.2020).

(ephemeral) and perennial (ephemeroid) grasses and forbs, with the dominant species belonging to Poaceae, Brassicaceae, Asteraceae, or Caryophyllaceae. Most taxa represent typical desert or arid foothill species, but in general the surroundings of Dzharkutan provide a richer vegetation than Ulug Depe or Sialk. The diversity of mammals, reptiles, birds and fish in the Surkhan Darya valley is even richer than Kopet Dagh mountains, but is mainly represented by the same species as leopards, lions, wild boars, wolves, bears, vultures, eagles, buzzards and many more (cf. Fet 2020). The current of Surkhan Darya is strong and the banks are steep, making it difficult to install irrigation systems. Hence people settled along the slower and shallower Sherabad River and its tributary streams. Dzharkutan is located at the Bustansai, a dry tributary of Amu Darya (fig. 7.4, Askarov 1981: 13; Kaniuth 2021: 458).

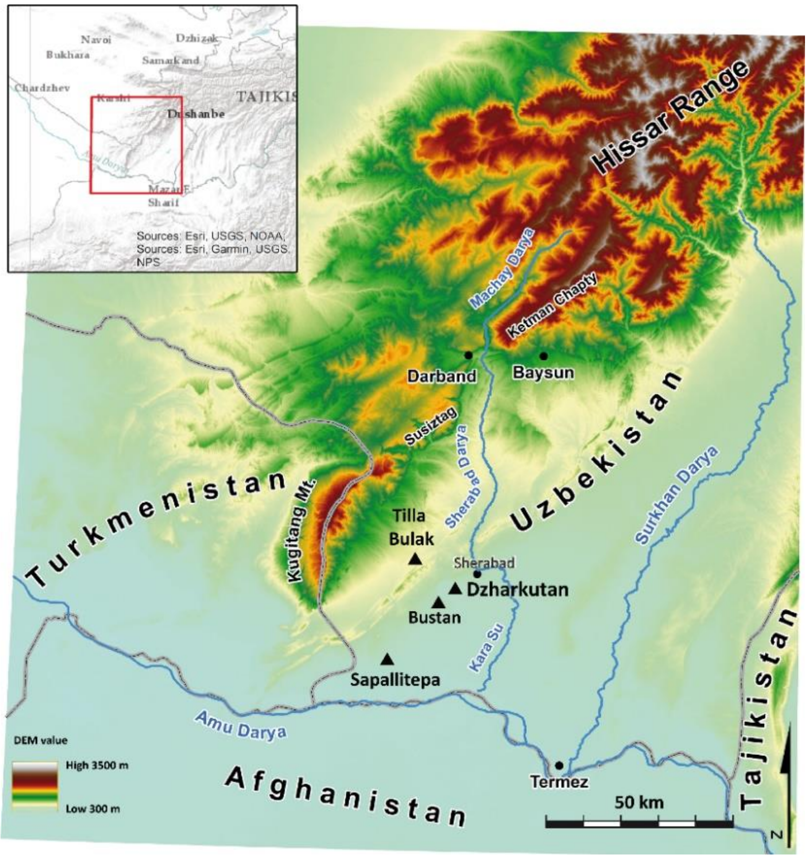


Fig. 7.4: Topographic map of southern Uzbekistan manipulated after Stančo, Pažout 2020: 2 fig. 1.

Several big streams such as the Sherabad, or the Ulanbulakaj enabled perennial irrigation of the fields. Agriculture in Dzharkutan was based on runoff irrigation systems along the Sherabad River (Kaniuth 2021: 458). Due to modern agricultural activities in the surroundings of Dzharkutan only little traces of ancient structures remained. But according to Shirinov archaeological investigations along the lower Amu Darya showed irregular squared shaped fields with sizes from 0.5 up to some hectares that meander along the river; the geographic situation in Dzharkutan proposes a similar system (Shirinov 2002: 156). Analysis of seed and fruit remains from different contexts in Dzharkutan showed the importance of the cultivation of wheat (*Triticum* cf *aestivum*), and barley (*Hordeum vulgare*). But also, lentils (*Lens culinaris*), peas (*Pisum sativum*), and grapes (*Vitis vinifera*) were present (Tengberg 2013). Quite important is the very small evidence of millet[16] in the later layers of Dzharkutan (see chapter below). A remarkable number of tools used not only for tilling fields but also for further

[16] The discovered remains of millet were very fragmentary and only consisting of small pieces. It is not sure yet which species of millet was present – wild or cultivated (personal communication from Margareta Tengberg).

processing of crops (grinding stones, mortars, etc.) indicate a specialized economy, and a high importance of farming (Shirinov 2002: 155–156). Of course, herding and hunting was also an essential part of food provisioning through all periods. Most identified animals were domestic sheep and goat, but in contrast to Ulug Depe, cattle played a more important role, especially during the Iron Age (fig. 7.5; Mashkour 2013a, et al. 2016). Also present in the animal remains were buffalos, pigs, donkeys, dogs and a small quantity of camels. Equids are represented by wild and domestic species, their increase during the Iron Age is due to the increase of horses in general. Hunting activities played a certain role through all periods, animals as gazelles, deer, wild donkey (kulan), boar, and minor species as hares, and birds, but also bones of predators as badger, hyena, lynx, fox and jackal were part of the prey (Mashkour 2013a, et al. 2016; Shirinov 2002: 156). Although the vicinity of the rivers probably provided fish, snails, or crabs, no fish bones were identified from Dzharkutan.

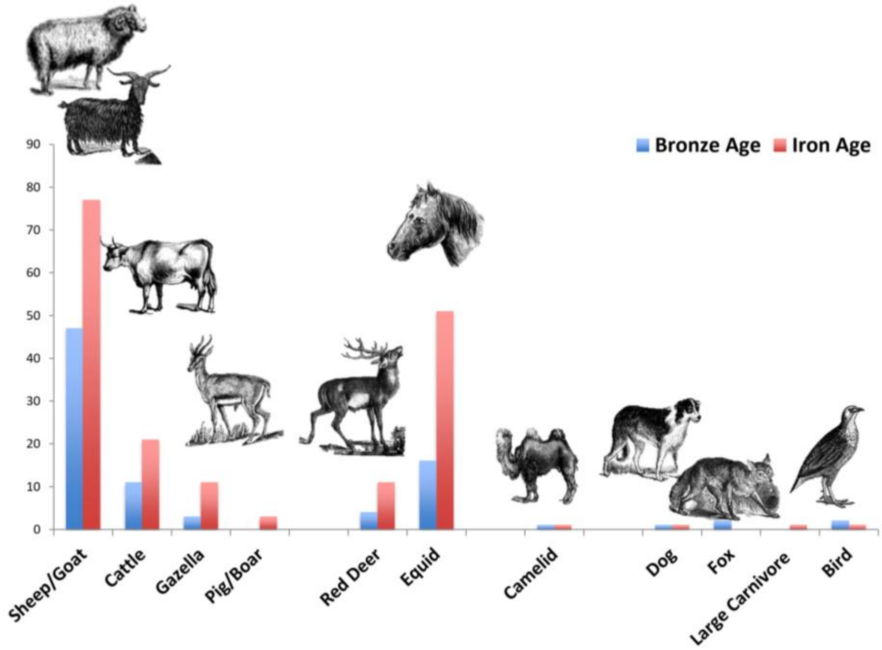


Fig. 7.5: Preliminary results of identified animal bones from Dzharkutan (courtesy of Marjan Mashkour).

7.2.3. Burial customs

The graveyards of Dzharkutan expanded on the southern and western boundary of the settlement, divided today by a deep flute, with more than 10.000 burials (Shirinov 2002: 115) (different descriptions can be found in the literature: Askarov and Shirinov described them in the beginning as one (Askarov 1984, Shirinov 2002), Huff later identified three graveyards (Huff et al. 2010), while the French mission divided them into seven (Bendezu-Sarmiento et al. 2007; 2009)). During the Bronze Age inhumations were the predominant mortuary practice. Remarkable is the huge variety of types of burials as well as their positioning. Burials were discovered everywhere, in the palace, the temple, along the outer walls of the citadel and under the floors of the houses. People were buried in ground pits, large pits, shafts, chambers, cists and jars, sometimes even in burial chambers with mud brick constructions. In Dzharkutan the excavated graves were mainly inhumation burials in catacombs with a vertical entrance chamber and a lateral burial chamber (Shirinov 2002: 112–127; Huff et al. 2010: 25–26). The bodies were in positions from slightly flexed to almost folded, women on the left side and men on the right side. Widely-used were single, double, and multiple burials in graveyards as well as intramural burials. Also, cenotaphs were present (Shirinov 2002: 115). Despite the presence of huge graveyards, the tradition of intramural graves was widespread in the Bactrian Culture as well. Grave goods were also present in a high diversity: from very rich to no grave goods. The majority of the grave goods were pottery, jewelry, needles, beads, rings, seals, arrowheads, and small metal objects. Needles, beads, or rings were found in women´s graves. For men arrowheads of flint or obsidian or small bronze objects were sometimes put to the body (Huff et al. 2010: 26; Bendezu-Sarmiento 2013: 523–526). Luxury materials as gold, silver, bronze, obsidian, alabaster, carnelian, lapis lazuli, malachite, turquoise were quite usual. On all sites of the Oxus Civilisation a significantly high number of children´s burials were documented. After the collapse of the LBA/EIA a complete change of the burial customs is noticeable. Mortuary practices may be taken as the main characteristic of the whole Iron Age, which is also called the *Sine Sepulchro Cultural Complex*: burials disappeared, with a few exceptions, a good summary on the current state of research in the region is given in Bendezu-Sarmiento and Lhuillier (2015).

7.2.4. The protagonists

The analysed individuals from Dzharkutan mainly date into late MBA and the LBA, and therefore into the phase of prosperity of the Oxus Civilization, respectively the Sapalli culture in southern Uzbekistan. Unfortunately, pictures are not available for all burials, but most follow the burial traditions explained above. The burials of this time period investigated here have all been discovered at the Necropolis 3 (Bendezu-Sarmiento and Mustafakulov 2009, 2013; Bendezu-Sarmiento 2013). The two MBA–LBA graves, one woman and one not determined adult (DZH 1001B, 1028, fig. 7.6), were both found in trench 1, and although looted, both provided a rich ensemble of funeral inventories and burial constructions with a mud-brick enclosure. DZH 1001B, was a woman found in a very special situation. The grave´s inventory included 15 vessels of pottery, one bronze pin, one bracelet made of several stone beads, as well as faunal remains. But the body was completely deranged, the thorax was missing, the head was lain next to the backbone, while the rest was perfectly accumulated below the vessels (cf. fig. 7.6 middle).

Fig. 7.6: MBA–LBA burials from Dzharkutan trench 1: left and middle burial 1001B after Bendezu-Sarmiento, Mustafakulov 2009: 58–59 fig. 2, 4; right burial 1028 after Bendezu-Sarmiento, Grizeaud 2010: 39 fig. 5.

Burial 1028, a multiple burial with four individuals, provided a woman and a child for isotopic analyses (1028-1, 1028-2). This burial was disturbed as well, the bodies were not articulated anymore, with the bones being scattered in the eastern part of the pit, but at least one adult was originally buried in a crouched position on the right side. The accompanying inventory is comprised of three big pottery vessels, one bronze bottle, two bracelets with beads of lapis-lazuli and faience, as well as the fragment of a bronze vessel, and two heart-shaped small elements made out of bone (cf. Bendezu-Sarmiento 2013: 526 fig. 17C).

The ten LBA burials included four individuals in single burials (1006, 1019, 1025, 1049), which were looted, thus only scattered remains of the individuals have been found. They were either found without funeral inventory, or some traces of pottery sherds (cf. Bendezu-Sarmiento 2013: 523–528). Burial 999, a young man, was found in a roundish earth-pit in trench 2. The body was laid in flexed position on the right side, in east-west direction, head facing the west. Behind his back five big pottery vessels were put, plus one bowl in his hands (fig. 7.7 top right, cf. Bendezu-Sarmiento and Mustafakulov 2009: 59). Burial 1001A, a young woman in an oval shaped pit, was also looted and badly disturbed. The body was scattered in the western part of the pit, in the north-eastern part four pottery vessels were placed, another lay next to her head. Additionally, a spindle whorl was found (fig. 7.7 bottom, cf Bendezu-Sarmiento and Mustafakulov 2009: 58). Burial 1022, a not determined adult, was also looted. The accompanying inventory included 14 pottery vessels, one bronze pin, 20 lapis lazuli and faience beads, and two silver earrings (or rings). Also looted and disturbed was Burial 1033, a woman over 40 years, buried with 10 pottery vessels and one bronze pin. The richest and best-preserved grave was burial 1051 of a young woman. She was buried in a round earth pit with mud-brick enclosure, body in flexed position on the left side in north-south direction. Together with her 13 pottery vessels, two earrings (bronze rings), one bracelet (bronze ring), and several faunal remains were discovered (fig. 7.7 top left, cf. Bendezu-Sarmiento 2013: 523–524).

Fig. 7.7: LBA burials from Dzharkutan: top left: burial 1051 after Bendezu-Sarmiento 2013: 525 fig. 16A; top right burial 999 after Bendezu-Sarmiento and Mustafakulov 2009: 59 fig. 3; bottom burial 1001A after ibid.: 58 fig. 1.

The investigated Iron Age burial was a secondary multiple burial located in a large silo in trench 4 on the citadel (fig. 7.8; Bendezu-Sarmiento and Mustafakulov 2013: 232; Bendezu-Sarmiento and Lhuillier 2015: 287–289). The scattered remains of four individuals were discovered: an adult woman and an adult man, as well as two children (3–4 years and 10–14 years old), all only partially preserved. The woman and the young child have been used for isotopic analyses (1034-1, 1034-4). The pit was already installed during the Bronze Age, but continued till the Iron Age. The woman was the best-preserved individual, probably originally placed on her right side, but the second adult was placed on top of her, so that the body was not articulated anymore. The bones of the small child were found dispersed. The special feature of this burial are large bite marks in the femur of the second individual, evidencing a pre-treatment of decomposition before the final placement in the silo (cf. Bendezu-Sarmiento and Lhuillier 2015: 289 fig. 17).

Fig. 7.8: EIA–MIA burial stage 1, 3, and 4 of the multiple burial 1034 from Dzharkutan. After Bendezu-Sarmiento and Lhuillier 2015: 287–289: fig. 13, 14, 16.

7.3. Mobility and migration in the Surkhan Darya valley

Parts of this chapter have already been published in:

Kroll, S.K., Bendezu-Sarmiento, J., Lhuillier, J., Luneau, É., Kaniuth, K., Teufer, M., Mustafakulov, S., Khasanov, M., Vinogradova, N., Avanesova, N., Fiorillo, D., Tengberg, M., Sharifi, A., Bon, C., Bosch, D., Mashkour, M. (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 Sceince: Reports 46 (2022) 103622 doi.org/10.1016/j.jasrep.2022.103622

The key aspect of this chapter is the characterisation of mobility, mobility patterns and possible migrations between the settlements in the Surkhan Darya valley during the Bronze and Iron Age. The case of Dzharkutan generated intense discussions between archaeologists in a distinct way. With the rise of the Sapalli Culture at the end of the 3rd mill. BCE in northern Bactria several new settlements developed in the Surkhan Darya valley. The establishment of these new settlements and networks are often associated with an increased mobility of the populations (Frachetti 2012; Bendezu-Sarmiento and Mustafakulov 2013; Salvatori 2016). Some scholars consider Dzharkutan as the capital and center of organization of the region, similar to Gonur Depe in the Margiana, concomitant with the hypothesis that on the graveyards of Dzharkutan, the dead from all over the region, both from the valley and from the surrounding mountains, were buried (Bendezu-Sarmiento and Mustafakulov 2013). This hypothesis is highly controversial, but it can in any case be followed up by isotopic investigations, which might provide further information. Moreover, the reference material enables the investigation of the cultural connections to southern Tajikistan and the Vakhsh culture, and will further provide information about the interactions to the north, which are indicated by pottery sherds influenced by the nomadic Andronovo style (Luneau 2017).

7.3.1. Results of strontium ($^{87}Sr/^{86}Sr$) and oxygen ($\delta^{16}O$)

The itemized results of all humans and animals from Dzharkutan, Sapallitepa, Bustan and Bashman1 are listed in the Appendix table 7. A summary of $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{apa}$ results is presented in table 7.1. Of the 14 individuals from Dzharkutan, the extraction of strontium and preparation of apatite was successful for 13 individuals. Concerning burial DZH 1006, only a very small bone fragment was available, therefore the analyses of collagen, strontium and enamel apatite were not performed for this individual. The preparation of structural carbonate was also not sufficient for the bone sample from Sapallitepa and all samples from Bashman 1. The Levene test proved no homogeneity of variances in $^{87}Sr/^{86}Sr$ between Dzharkutan and Ulug Depe ($F(2.16) = 1.85$, $p < 0.02$). The one-way ANOVA proved that the differences between the sites are significant ($F(2.72) = 1.84$, $p < 0.001$), but the differences between the periods in Dzharkutan are statistically not relevant ($F(2.71) = 0.48$, $p = 0.782$). Statistics on gender were not performed for Dzharkutan samples, because the ensemble included only one male individual. According to the Levene test, a homogeneity of variance in $\delta^{18}O$ between Dzharkutan and Ulug Depe ($F(0.53) = 0.57$, $p = 0.069$) can be observed, the one-way ANOVA proved that the differences between the periods in $\delta^{18}O$ values of Dzharkutan people were statistically not significant ($F(2.68) = 4.56$, $p = 0.005$). The deviations were negligible small, error bars were overlapped by the applied symbols in the figures. Hence, symbols encompass the error margins at 2σ level for the $^{87}Sr/^{86}Sr$ ratios and 1σ level for $\delta^{18}O$ ratios.

Table 7.1: Summary of human $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{apa}$ results from Uzbekistan*

	$^{87}Sr/^{86}Sr$					$\delta^{18}O_{apa}$ (‰ V-PDB)					
Period	**n**	**Min**	**Max**	**Mean**	**± 26**	**n**	**Min**	**Max**	**Interval**	**Mean**	**± 6**
DZH MBA/LBA E	**2**	0.708055	0.708487	**0.708271**	± 0.000216	**2**	-6.3	-5.0	1.3	**-5.7**	± 0.65
DZH MBA/LBA B	**2**	0.708343	0.708358	**0.708351**	± 0.000008	**2**	-6.0	-5.1	0.9	**-5.6**	± 0.45
DZH LBA E	**9**	0.708052	0.709200	**0.708266**	± 0.000334	**9**	-6.9	-5.8	1.1	**-6.4**	± 0.32
DZH LBA B	**9**	0.708160	0.708474	**0.708349**	± 0.000082	**10**	-6.5	-4.1	2.4	**-5.4**	± 0.63
DZH EIA/MIA E	**2**	0.708040	0.708171	**0.708105**	± 0.000065	**2**	-5.0	-5.0	0.0	**-5.0**	± 0.00
DZH EIA/MIA B	**2**	0.708153	0.708176	**0.708164**	± 0.000011	**2**	-5.5	-3.8	1.7	**-4.6**	± 0.86
Sapalli LBA E	**1**	0.70903		-	-	**1**	-6.8		-	-	-
Sapalli LBA B	**2**	0.707893	0.708418	**0.708156**	± 0.000262	-	-	-	-	-	-
Bustan LBA E	**1**	-	-	-	-	**1**	-6.9		-	-	-
Bustan LBA B	**1**	0.707893		-	-	**1**	-5.7		-	-	-
Bashman1 E	**2**	0.709445	0.710410	**0.709928**	± 0.000482	-	-	-	-	-	-
Bashman1 D	**2**	0.709297	0.709343	**0.709320**	± 0.000023	-	-	-	-	-	-

*Aberration: E correspond to tooth enamel samples, B to bone samples

The $^{87}Sr/^{86}Sr$ ratio of all human samples from Dzharkutan ranged between 0.708040 and 0.709200 with a mean of 0.708281 (± 0.000224, n = 26); enamel samples provided an average of 0.708242 (± 0.000298, n = 13), bone samples of 0.708321 (± 0.000095, n = 13) (fig. 7.9). The $\delta^{18}O_{apa}$ results of all humans ranged between -6.9‰ and -3.8‰ with an interval of 3.1‰ and an average -5.7‰ (± 0.77‰, n = 27), enamel samples displayed a $\delta^{18}O_{apa}$ average of -6.1‰ (±0.65‰, n = 13), bone samples of -5.3‰ (± 0.71‰, n = 14) (fig. 7.10). The two MBA/LBA (NMG V) individuals provided enamel $^{87}Sr/^{86}Sr$ ratios between 0.708055 and 0.708487 with a mean of 0.708271 (± 0.000216, n = 2), and $\delta^{18}O_{apa}$ enamel results from -6.3‰ to -5.0‰ with a spacing of 1.3‰ and a mean of -5.7‰ (± 0.65‰, n = 2). Bone samples ranged in $^{87}Sr/^{86}Sr$ between 0.708343 and 0.708358 with a mean of 0.708351 (± 0.000008, n = 2), and in $\delta^{18}O_{apa}$ from -6.0‰ to -5.1‰ with an interval of 0.9‰ and an average of -5.6‰ (± 0.45‰, n = 2).

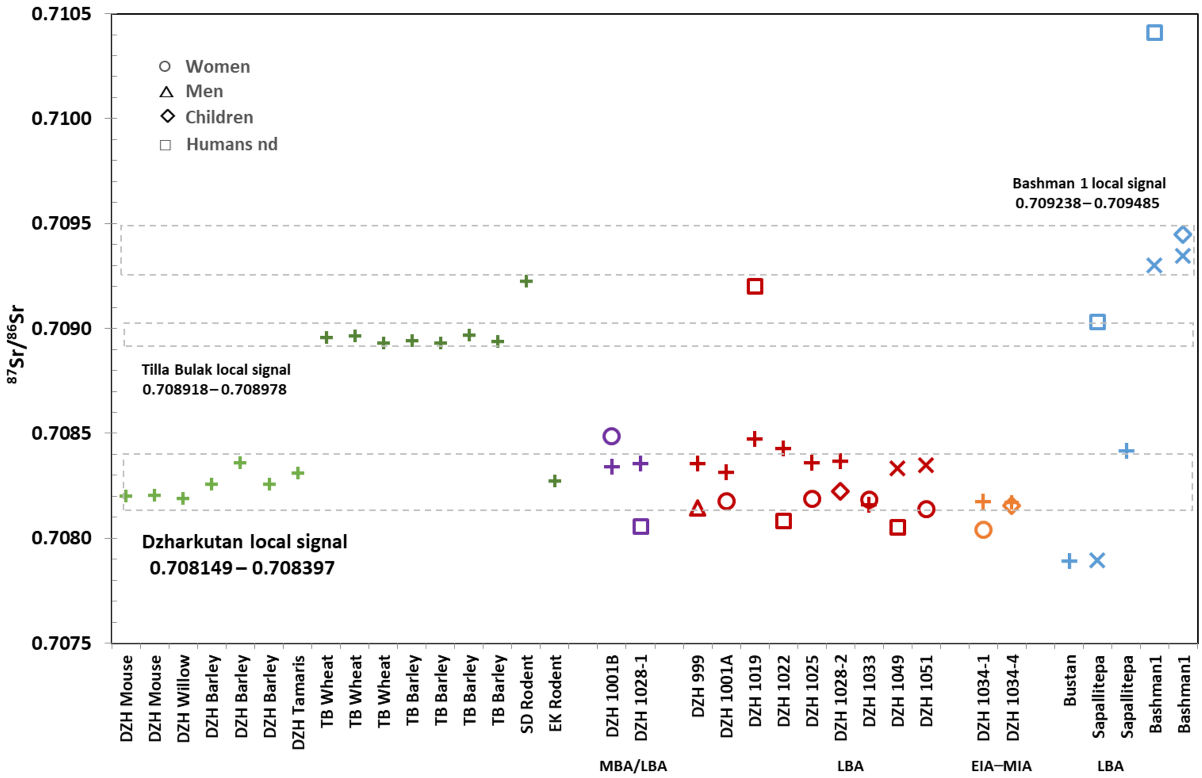


Fig. 7.9: $^{87}Sr/^{86}Sr$ results from Uzbekistan with human intra-individual variations. Bone samples are marked with plus, X marks the dentine samples, tooth enamel samples are given with the particular gender. Symbols encompass the error margins at 2σ level, dashed boxes mark the local $^{87}Sr/^{86}Sr$ signals including the error margins at 2σ level.

The nine individuals of the LBA (NMG VI) displayed enamel $^{87}Sr/^{86}Sr$ ratios between 0.708052 and 0.709200 with a mean of 0.708266 (± 0.000334, n = 9), and $\delta^{18}O_{apa}$ enamel results between -6.9‰ and -5.8‰ with an interval of 1.1‰ and a mean of -6.4‰ (± 0.32‰, n = 9). Bone samples ranged in $^{87}Sr/^{86}Sr$ from 0.708160 to 0.708474 with a mean of 0.708352 (± 0.000092, n = 7), while $\delta^{18}O_{apa}$ ratios were between -6.5‰ and -4.1‰ with a spacing of 2.4‰ and a mean of -5.4‰ (± 0.63‰, n = 9). The two individuals of the EIA–MIA, a woman and a child, showed in $^{87}Sr/^{86}Sr$ out of enamel results between 0.708040 and 0.708171 with a mean of 0.708105 (± 0.000065, n = 2), enamel $\delta^{18}O_{apa}$ ratios were both -5.0‰ (± 0.1‰, n = 2). Bone samples ranged in $^{87}Sr/^{86}Sr$ between 0.708153 and 0.708176 with a mean of 0.708164 (± 0.000011, n = 2), in $\delta^{18}O_{apa}$ between -5.5‰ and -3.8‰ with a spacing of 1.7‰ and a mean of -4.6‰ (± 0.86‰, n = 2).

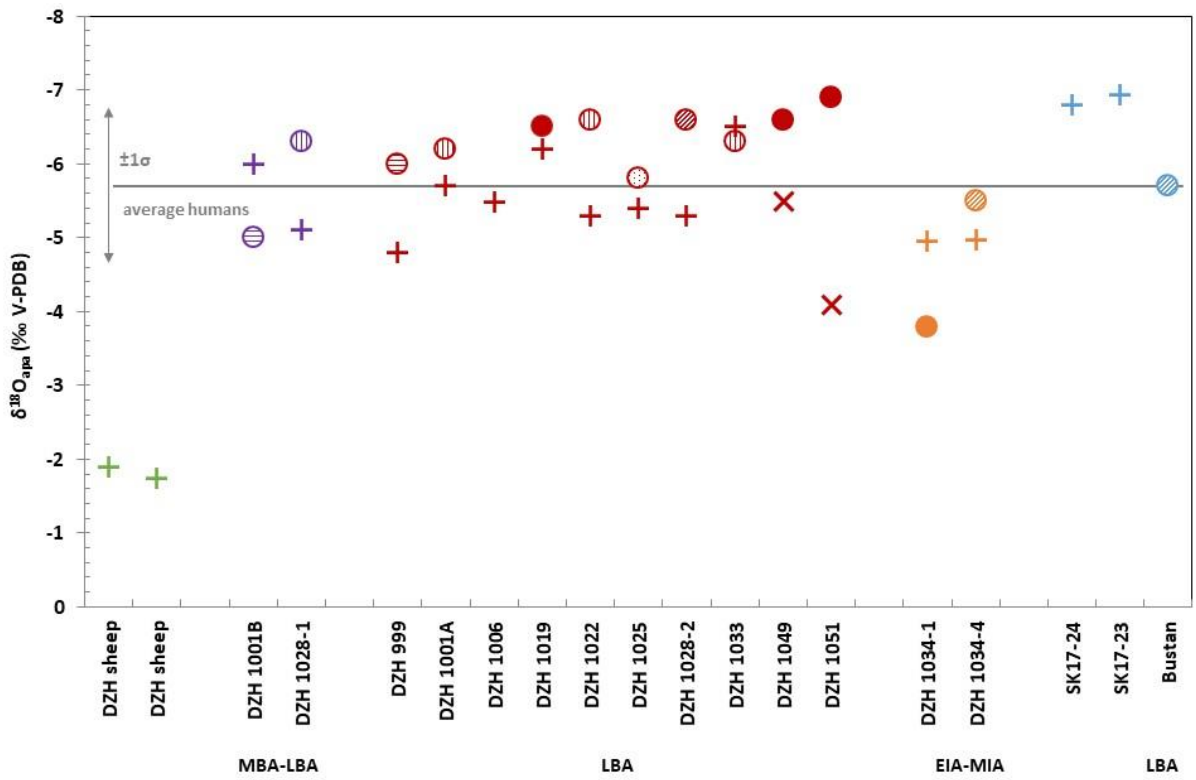


Fig. 7.10: Intra-individual variations of $\delta^{18}O_{apa}$ of humans and sheep from Dzharkutan: plus correspond to bone samples, circles to tooth enamel (black M3, dark grey M2, light grey M1, empty M not determined, vertical stripes PM, horizontal stripes C, dots I). The symbols encompass the error margins at 1σ level for $\delta^{18}O$ ratios.

The two individuals from LBA Sapallitepa provided one enamel $^{87}Sr/^{86}Sr$ ratios of 0.709030 (± 0.000026), and the corresponding $\delta^{18}O_{apa}$ ratio of -6.8‰ (± 0.3‰); analyses of the single bone sample resulted in a $^{87}Sr/^{86}Sr$ ratio of 0.708418 (± 0.000006). The bone sample of the single individual from Bustan had a $^{87}Sr/^{86}Sr$ ratio of 0.707893 (± 0.000007) and a $\delta^{18}O_{apa}$ ratio of -5.7‰ (± 0.3‰). The enamel sample yielded a $\delta^{18}O_{apa}$ ratio of -6.9‰ (± 0.4‰) but was not sufficiently preserved for strontium analyses. The two individuals from Bashman1 in central Uzbekistan ranged in their enamel $^{87}Sr/^{86}Sr$ ratios between 0.709445 and 0.710410 with a mean of 0.709928 (± 0.000482, n = 2).

7.3.2. Reconstruction of human spatial movements

7.3.2.1. Migration according to strontium $^{87}Sr/^{86}Sr$

When only taking the $^{87}Sr/^{86}Sr$ results (fig. 7.9) into consideration, the variety and distribution of the individuals from Dzharkutan seem higher than in Ulug Depe. A minimum of 5 out of 11 enamel ratios were close, but in respect of the local range (cf. chapter 4.4.2.), further four individuals are close to the lower limit, one to the upper. This would suggest an incredible migration rate of at least 45%. Only one enamel ratio, DZH 1019, an adult of undetermined sex, fell further out of the local $^{87}Sr/^{86}Sr$ range. However, when comparing the distribution of $^{87}Sr/^{86}Sr$ ratios in correlation with the $\delta^{18}O_{apa}$ ratios of bone and enamel samples, two clusters become clearly visible: the bones form a cluster on the upper limit of the local range which correlates with the cereals and the tamarisk; the teeth form a cluster on the lower limit of the local range that correlates with the rodents and the willow (fig. 7.9 and 4.15). Both clusters only partly fall into the local range, but the results of each group fit together well. This makes it difficult to consider these 45% as actual foreigners, as none of the BA people (beside DZH 1019) fell further out of the clusters or into other local ranges. The clusters instead demonstrate a homogeneous group of people who lived in the same place, were born in the same place and were all buried in Dzharkutan. The individuals all date into the transition of the MBA to the LBA and to the LBA, the results indicating a certain continuity over this time period, and rather little migratory impact on this population.

In contrast, the single samples from LBA Sapallitepa and Bustan display a higher variety in their results. The two samples from Sapallitepa show two distinct different $^{87}Sr/^{86}Sr$ ratios (fig. 7.9): the enamel $^{87}Sr/^{86}Sr$ ratio of Burial no. 8 is close to the local signal of Tilla Bulak; the $^{87}Sr/^{86}Sr$ bone ratio of Burial no. 20 is at the upper limit of Dzharkutan. The bone $^{87}Sr/^{86}Sr$ ratio from Bustan (Burial no. 23) fell within the local $^{87}Sr/^{86}Sr$ range of Ulug Depe. In correlation, the enamel $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results of Burial no. 1019 from Dzharkutan and Burial no. 8 from Sapallitepa fit within the accumulation of Gelot/Darnaichi, and the Saridzhar people (fig. 7.11). It seems likely, that these individuals spent their childhood at the place, where the people who were buried in Gelot and Darnaichi had lived, but moved to Dzharkutan and Sapallitepa during their lifetime. If this is a coincidence, or whether constant, dynamic interactions really existed, will remain contested until a larger number of samples is available. Nevertheless, the high variation in the results proves an active mobility among the inhabitants of the Surkhan Darya valley.

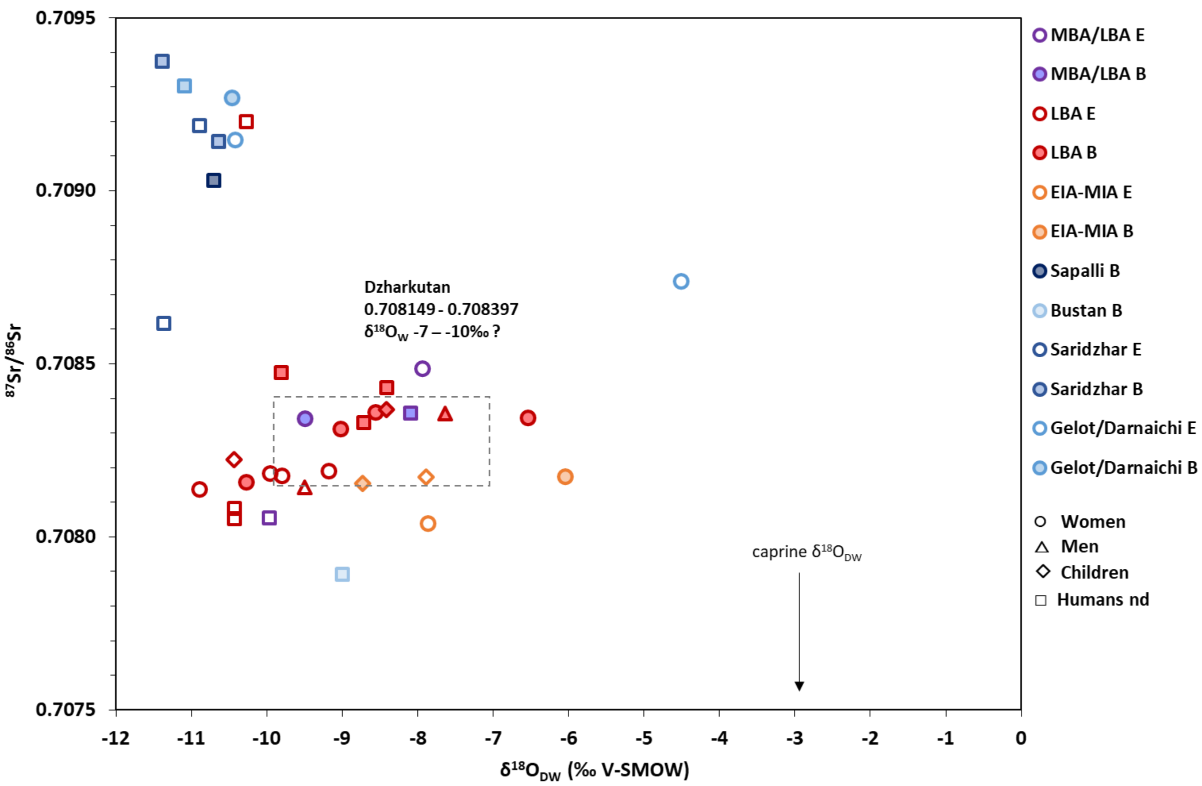


Fig. 7.11: Scatterplot of $^{87}Sr/^{86}Sr$ vs $\delta^{18}O_{DW}$ ratios of humans from Dzharkutan, Sapalli, Bustan, Gelot, Darnaichi, and Saridzhar. The symbols encompass the error margins at 2σ level for the $^{87}Sr/^{86}Sr$ ratios and 1σ level for $\delta^{18}O$ ratio, dashed box marks the approximate local $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{DW}$ range of Dzharkutan including the error margins at 1σ ($\delta^{18}O_{DW}$) and 2σ ($^{87}Sr/^{86}Sr$) levels.

Quite obvious instead, are the isotopic differences between the Bronze and the Iron Age individuals in Dzharkutan. While all Bronze Age individuals showed a distinct pattern in their isotopic ratios, the woman and the child (3–4 years) from the later period are within the local $^{87}Sr/^{86}Sr$ signatures but differ significantly in their oxygen ratios from the BA individuals, indicating the use of additional water sources, and therefore a higher degree of mobility during the Iron Age (fig. 7.11).

7.3.2.2. Mobility according to oxygen $\delta^{18}O$

The $\delta^{18}O_{apa}$ isotopic ratios of all Dzharkutan human samples ranged between -6.9‰ and -3.8‰ with an interval of 3.1‰ and an average of -5.7‰ (± 0.77‰ n = 27). The two individuals from Sapalli and Bustan fall into the same range (fig. 7.10). The results are generally lower than in Ulug Depe, suggesting a more moderate, less arid climate. The Dzharkutan tooth enamel samples showed a $\delta^{18}O_{apa}$ average of -6.1‰ (± 0.7‰ n = 13) and an interval of 1.9‰. Bone samples displayed a $\delta^{18}O_{carb}$ average of -5.3‰ (± 0.7‰ n = 14) and an interval of 2.7‰. The intervals of 1.9‰, 2.7‰ respectively, are even smaller than in Ulug Depe, indicating that Dzharkutan people also ingested water from particular water sources and not from multiple sources across the valley (White et al. 2004; Lightfoot et al. 2016). The surrounding landscape of Dzharkutan was characterized by the flood plains of Sherabad, Surkhan Darya, Amu Darya, and several tributary streams in walkable distances of 1–2 days. Hence, the signals of Dzharkutan people could be expected to display a higher variety.

The calculated $\delta^{18}O_{DW}$ ratios ranged between -10.9‰ and -6.1‰, tooth enamel displayed an average of -9.6‰ (± 1.0‰), bone samples of -8.5‰ (± 1.1‰) (after Coplen et al. 1988, Iacumin et al. 1996, Daux et al. 2008; cf. Appendix table 11). Tooth enamel samples displayed a $\delta^{18}O_{DW}$ interval of 4.8‰, bone samples of 4.2‰. Especially the enamel interval proved the existence of a catchment area of people's origin much smaller than in Ulug and Sialk. The approximate determined $\delta^{18}O_{W}$ range for Dzharkutan is according to the OIPC between -4.3‰ and -5.8‰, and corresponding to the GNIP around -7‰ (cf. chapter 4.7.2.2). It is conspicuous that only two out of 27 samples fell inside that estimated local range. This could indicate that people used different water sources in higher or colder regions. But this discrepancy might also be caused by the lack of monitoring stations in the nearer surroundings, hence the inaccuracy of isotopic landscape models. Hence, this problem remains unsolved until precise reference samples are available. Really distinct instead, is the shift between bones and tooth enamel samples. Already indicated by the strontium results, the oxygen results confirm movements between the place of birth and residence during a lifetime within a limited area.

Concerning the calculation of altitude differences through the $\delta^{18}O$ intervals, most individuals, 7 out of 13, displayed intra-individual $\delta^{18}O_{apa}$ variations of around 1.2‰, the average of all individuals being 1.0‰ (± 0.65‰). Again, especially the Bronze Age individuals seem quite homogeneous. According to the correlation of altitude and $\delta^{18}O_{W}$ values of the OIPC (Bowen 2010), an average of 0.3‰ per 100 m difference in altitude can be calculated for Dzharkutan as well (cf. fig. 7.12; 0.26‰/100 m after Poage and Chamberlain 2001). This applies to an altitude difference of around 400–500 m of the Dzharkutan people. Hence, the small intra-individual variations confirm rather little mobility of the latter. The conclusions drawn from the results of Dzharkutan inhabitants implicated, biased by archaeological theories, a high diversity in the results, respectively a higher migratory impact. Instead, the results suggest complex mobility or subsistence patterns for the Bronze Age Dzharkutan population, but rather little mobility and a more extensive land-use of the direct surroundings.

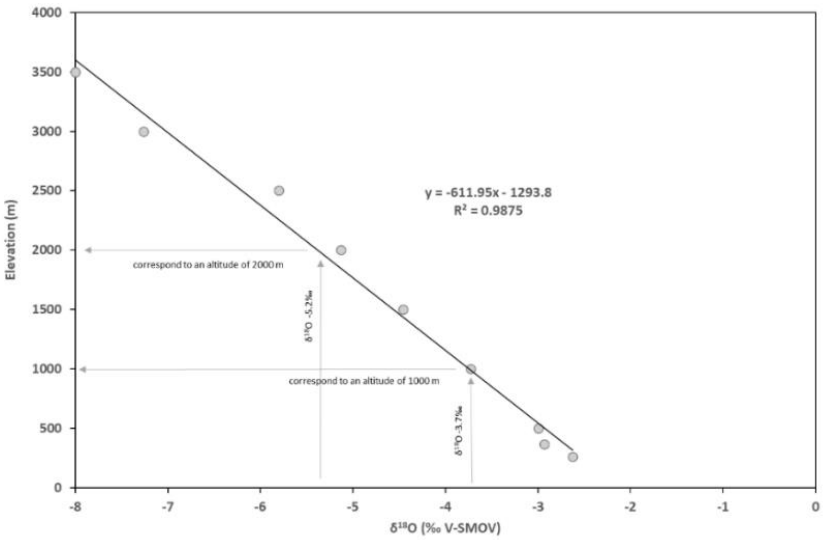


Fig. 7.12: Dzharkutan differences in altitude correlating to the annual averaged $\delta^{18}O_W$ values after the OIPC (www.waterisotopes.org, last access 21.12.2020).

7.3.2.3. Gender and social differences

The selection of samples excluded a gender specific interpretation as only one man was part of the Dzharkutan group. This one man did not differ in the $^{87}Sr/^{86}Sr$ or $\delta^{18}O_{apa}$ results. The rest of the group, six women and five not determined adults, reflect a homogeneous group of people. The absence of real foreigners, beside DZH 1019 (adult n.d.), makes an interpretation even more difficult. Moreover, the one very rich grave (DZH 1051) did not stand out of the group concerning the $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{apa}$ results. Hence, if there is a pattern in the mobility caused by gender or social composition cannot be reconstructed at the present state of research.

7.4. Subsistence in the Surkhan Darya valley

The strong dependence of southern Central Asian societies on water resources is well proven through the distribution of ancient settlements and paleochannels as well as by the importance of runoffs securing their subsistence, mainly provided by irrigated agriculture (Francfort and Lecomte 2002, Fouache et al. 2021). The environmental habitat around Dzharkutan is completely different to the one of Ulug Depe. The region is more fertile and several big streams as the Sherabad, or the Ulanbulakaj enabled perennial irrigation (Kaniuth 2021: 458). The archaeological remains indicate, that the subsistence of the people settled in the Surkhan Darya valley was mainly based on crop cultivation like wheat, barley, lentils, and peas, but also on animal husbandry, herding and breeding of sheep and goats, just as cattle were an important part of the economic strategy. The question concerning the supply of a settlement like Dzharkutan, with a growing population, caused by ongoing urbanization processes, respectively an adequate food supply for humans and animals, in this region automatically includes the question of pastoralism as well. The results of collagen provide insights on the dietary habits of humans and animals from Dzharkutan, as well as land-use, and flock management.

7.4.1. Results of nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C_{col}$, $\delta^{13}C_{apa}$) isotopes

Of all 14 individuals from Dzharkutan, the conditions for the extraction of collagen were sufficient for 11 individuals while the preparation of apatite was successful for 13 individuals. The extraction of collagen was not sufficient for the MBA/LBA individuals DZH 1028-1 and 1006, and the IA individual DZH 1034-4. For all other results, the minimum of %C = 13% and %N = 5% for a good quality of collagen was fulfilled (Ambrose 1990). Hence, the atomic ratio of Carbon to Nitrogen C/N, with an optimum range between 2.8 and 3.2 (DeNiro 1985), resulted in ratios between 2.9 and 3.4. The itemized results including standard errors are listed in the Appendix table 7, a summary of the averages of all species is given in table 7.2. Error bars were not added to the graphs, as they are negligible and smaller than the plotted symbols. According to a Kruskal-Wallis H-test the differences among all sites were not significant for both $\delta^{13}C_{col}$ and $\delta^{15}N$ ($\delta^{15}N$: H(3) = -137.475, p = 0.728; $\delta^{13}C_{col}$: H(3) = -137,209, p = 1.383). The one-way ANOVA analysis did attest no significantly different $\delta^{13}C_{col}$ values (F(4.46) = 0.69, p = 0.528) and $\delta^{15}N$ values (F(4.46) = 1.59, p = 0.261) of Dzharkutan samples between the different periods. Statistics on gender were not performed for Dzharkutan samples, because the ensemble included only one male individual.

Table 7.2: Summary of human and animal collagen results from southern Uzbekistan

Trophic group	Species	n	$\delta^{15}N$ Collagen (‰ AIR)					$\delta^{13}C$ Collagen (‰ V-PDB)				
			Min	Max	Mean	± б	Average	Min	Max	Mean	± б	Average
Plants	Barley ULG	1	3.6		-	-	5.0	-27.2		-	-	-27.0
	C3 Lut	7	0.1	13.2	**5.7**	± 4.3		-28.5	-25.2	**-26.6**	± 1.1	
	C4 Lut	13	1.7	11.2	**5.5**	± 3.4		-14.2	-12.1	**-13.2**	± 0.7	-13.0
Herbivores	Gazelles ULG	7	8.7	11.7	**10.2**	± 1.0	10.0	-17.6	-13.4	**-15.8**	± 1.5	-16.5
	Sheep/goats	9	7.1	9.6	**10.0**	± 1.1		-19.2	-16.2	**-18.2**	± 1.5	
	Cattle	2	8.3	10.1	**9.2**	± 0.8		-15.6	-15.4	**-15.5**	± 0.1	
Omnivores	Dogs	2	7.2	12.5	**10.3**	± 1.0	12.0	-19.2	-15.8	**-17.8**	± 1.3	-20.0
	Pig ULG	1	12.5		-	-		-20.9		-	-	
	Wild boar*	4	12.4	13.2	**12.9**	± 0.3		-19.8	-20.9	**-20.4**	± 0.4	
Carnivores	Fox	1	14.6		-	-	15.0	-13.2		-	-	-15.0
	Big cat	1	14.0		-	-		-16.1		-	-	
	Cat*	1	16.4		-	-		-16.5		-	-	
Humans	DZH MBA/LBA	1	11.9		-	-	12.2	-19.8		-	-	-18.9
	DZH LBA	9	11.1	13.1	**12.0**	± 0.55		-21.0	-16.4	**-19.2**	± 1.28	
	DZH EIA-MIA	1	13.1		-	-		-17.7		-	-	
	Sapalli LBA	2	10.2	13.3	**11.8**	± 1.55		-19.0	-18.5	**-18.8**	± 0.25	

*after Bocherens et al. 2006

The $^{15}N/^{14}N$ ratio out of collagen ($\delta^{15}N$) of all human individuals through all periods ranged between 11.1‰ and 13.1‰ with an interval of 2.0‰ and an average of 12.1‰ (± 0.6‰, n = 11). The ratio of carbon isotopes $^{13}C/^{12}C$ out of collagen ($\delta^{13}C_{col}$) ranged between -16.4‰ and -19.9‰ with an interval of 3.5‰ and an average of -19.2‰ (± 1.3‰, n = 11). The one MBA/LBA woman showed a $\delta^{15}N$ ratio of 11.9‰, while $\delta^{13}C_{col}$ was -19.8‰. The nine LBA individuals ranged in their $\delta^{15}N$ between 11.1‰ and 13.1‰ with a mean of 12.0 (± 0.6‰, n = 9), in the $\delta^{13}C_{col}$ between -21.0‰ and -16.4‰ with an average of -19.2‰ (± 1.3‰, n = 9). Including four women who ranged in $\delta^{15}N$ between 11.1‰ and 12.1‰ (average 11.8‰ ± 0.4‰, n = 4) and in $\delta^{13}C_{col}$ between -18.0‰ and -19.5‰ (average -19.1‰ ± 0.9‰, n = 4). The one man displayed a $\delta^{15}N$ result of 13.1‰ and a $\delta^{13}C_{col}$ ratio of -21.0‰, while the child had a $\delta^{15}N$ ratio of 11.9‰ and a $\delta^{13}C_{col}$ of -19.8‰. The three not determined adults ranged in $\delta^{15}N$ between 11.4‰ and 12.5‰ with an average of 12.0‰ (± 0.5‰, n = 3), $\delta^{13}C_{col}$ ranged between -16.4‰ and -19.9‰ with an average -18.6‰ (± 1.5‰, n = 3). The MIA woman displayed a $\delta^{15}N$ ratio of 13.1‰ and a $\delta^{13}C_{col}$ ratio of -17.7‰. The two LBA individuals from Sapallitepa revealed $\delta^{15}N$ results of 13.3‰ and 10.2‰ (average 11.8‰ ± 1.5‰, n = 2) and $\delta^{13}C_{col}$ results of -18.5‰ and -19.0‰ (average – 18.8‰ ± 0.3‰, n = 2).

The $^{13}C/^{12}C$ ratio out of structural carbonate ($\delta^{13}C_{apa}$) of all individuals through all periods ranged between -13.6‰ and -9.6‰ with an average of -11.9‰ (± 1.3‰, n = 28): the two MBA/LBA individuals showed $\delta^{13}C_{apa}$ enamel results of -13.3‰ and -13.6‰ with an average of -13.4‰ (± 0.1‰, n = 2); $\delta^{13}C_{apa}$ bone results ranged between -11.5‰ and -11.3‰ with an average of -11.4‰ (± 0.1‰, n = 2). The nine individuals of the LBA ranged in the $\delta^{13}C_{apa}$ enamel values between -13.2‰ and -9.6‰ with an average of -12.1‰ (± 1.2‰, n = 9), $\delta^{13}C_{apa}$ bone ratios were in a similar range of -13.4‰ and -9.6‰ with an average of -12.3‰ (± 1.2‰, n = 9). The two individuals of the EIA–MIA showed $\delta^{13}C_{apa}$ enamel ratios of -10.3‰ and -9.6‰ (average -9.9‰ ± 0.4‰, n = 2), $\delta^{13}C_{apa}$ bone values fell between -11.8‰ and -11.0‰ with an average of -11.4‰ (± 0.4‰, n = 2). The preparation of structural carbonate was not sufficient for all individuals; therefore, carbon results are not available for the bone samples from Sapallitepa and all samples from Bashman1. The one enamel sample from Sapallitepa showed a $\delta^{13}C_{apa}$ ratio of -9.9‰, the one individual from Bustan had a $\delta^{13}C_{apa}$ enamel value of -7.1‰ and a $\delta^{13}C_{apa}$ bone value of -11.6‰.

The provided animal samples from Dzharkutan itself are rare, only five ovicaprids were available for the present study, therefore additional analyses were performed on further four ovicaprids, two bovines and two dogs from Sangir-tepe, Erkurgan, Padayatak and Koktepe. Sheep and goats from Dzharkutan displayed a $\delta^{15}N$ minimum value of 9.4‰, a maximum value of 12.0‰ and an average of 10.6‰ (± 0.9‰, n = 5). The $\delta^{13}C_{col}$ ratios ranged between -18.9‰ and -15.1‰ with a mean of -17.1‰ (± 1.5‰, n = 5). Two of the Dzharkutan sheep were analysed for bone $\delta^{13}C_{apa}$ revealing results of -10.2‰ and -10.5‰ (average -10.4‰ ± 0.1‰). The ovicaprids from Sangir-tepe, Padayatak and Koktepe revealed $\delta^{15}N$ ratios between 7.3‰ and 11.1‰ with an average of 9.3‰ (± 1.6‰ n = 4) and $\delta^{13}C_{col}$ ratios between -15.0‰ and -19.1‰ with an average of -17.8‰ (± 1.7‰, n = 4). The two cattle from Erkurgan and Koktepe displayed $\delta^{15}N$ ratios of 8.3‰ and 10.0‰ (average 9.2‰ ± 0.8‰, n = 2) and $\delta^{13}C_{col}$ ratios of -15.4‰ and -15.6‰ (average -15.5‰ ± 0.1‰, n = 2), while the two dogs from Sangir-tepe and Erkurgan ranged between 9.5‰ and 11.0‰ in $\delta^{15}N$ (average 10.3‰ ± 0.8‰, n = 2) and between -15.2‰ and -17.8‰ in $\delta^{13}C_{col}$ (average -16.5‰ ± 1.3‰, n = 2).

7.4.2. The isotopic baseline of Dzharkutan

The available animals from Dzharkutan were so small in numbers, that the establishment of an isotopic baseline was only possible with the supplement of other sites in Uzbekistan. Analyses were performed on five ovicaprids from Dzharkutan. Additionally, four ovicaprids from Sangir-tepe, Paydatak, and Koktepe in central Uzbekistan were analysed. The ovicaprids from Dzharkutan revealed $\delta^{13}C_{col}$ ratios between -15.1‰ and -18.9‰ with an average of -17.1‰ (± 1.5‰, n = 5) and $\delta^{15}N$ ratios between 9.4‰ and 12.0‰ with an average of 10.6‰ (± 0.9‰, n = 5). The other four ovicaprids displayed $\delta^{13}C_{col}$ values from -15.0‰ to -19.1‰ (average -17.8‰ ± 1.7‰, n = 4) and $\delta^{15}N$ values between 7.3‰ and 11.1‰ (average 9.3‰ ± 1.6‰). More herbivores, two cattle from Koktepe and Erkurgan, were analysed, revealing a $\delta^{13}C_{col}$ average of -15.5‰ (± 0.1‰, n = 2) and a $\delta^{15}N$ average of 9.2‰ (± 0.8‰, n = 2). Two dogs from Sangir-tepe and Erkurgan represent the only omnivores/carnivores, providing $\delta^{13}C_{col}$ ratios of -15.2 and -17.8 (average -16.5‰ ± 1.3‰) and $\delta^{15}N$ ratios of 9.5‰ and 11.0‰ (average 10.3‰ ± 1.0‰) (cf. fig. 7.13).

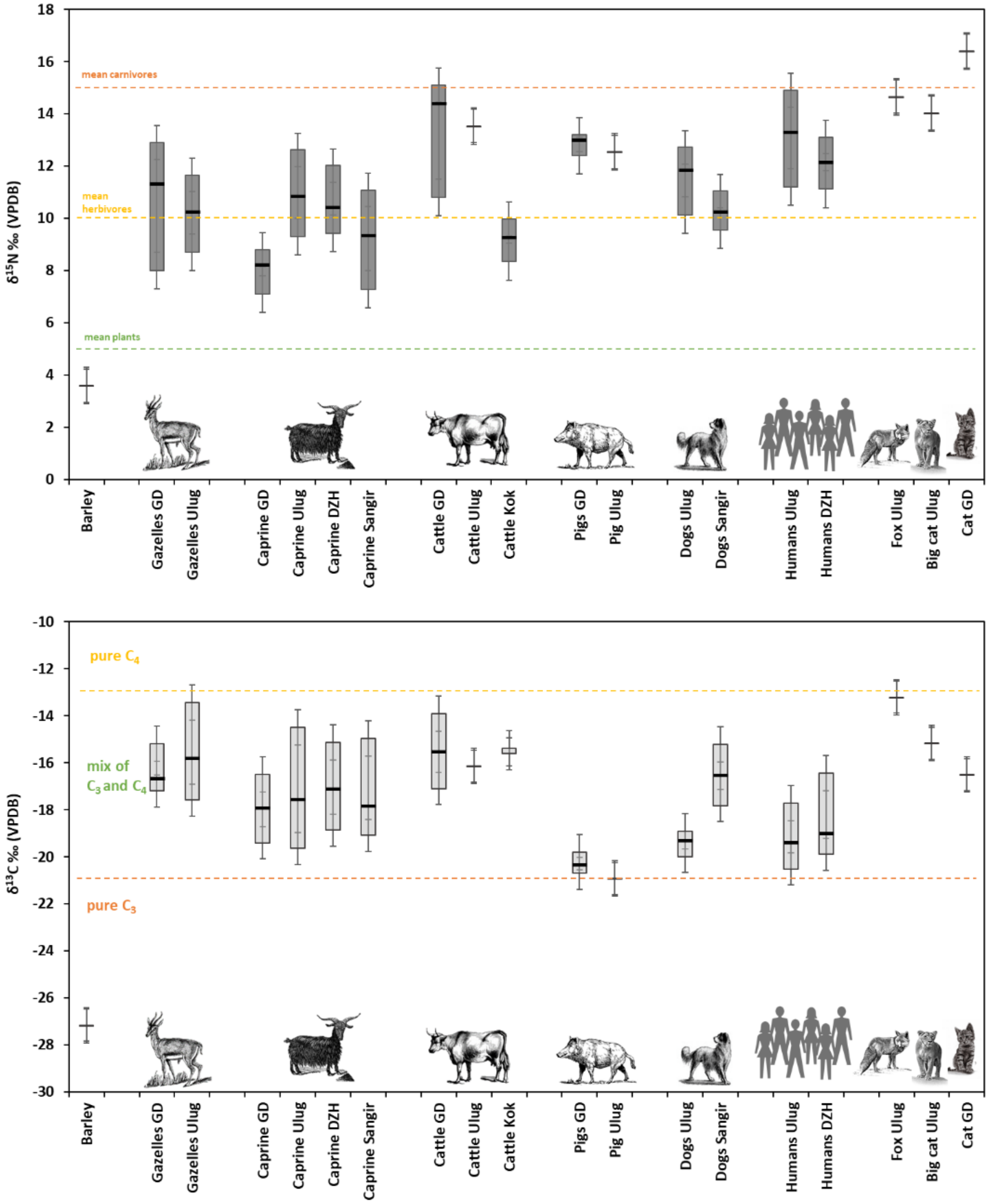


Fig. 7.13: Boxplot of $\delta^{15}N$ (top) and $\delta^{13}C$ (bottom) results from Dzharkutan (DZH) with references from Ulug Depe (UD) and Geokchik Depe (GD) after Bocherens et al. 2006. Black bars mark the averages.

Selecting comparable material for the establishment of the trophic baseline in Dzharkutan turned out to be a bit tricky. The five ovicaprids from Dzharkutan (average 10.6‰ ± 0.9‰) fell in a comparable high $\delta^{15}N$ range as the ovicaprids from Ulug Depe (average 10.9‰ ± 1.2‰). But the results of the herbivores from the other sites in Uzbekistan were in lower ranges (average 9.3‰ ± 1.6‰). It is very difficult to make a decision based on five samples, whether Dzharkutan animals showed a similar enrichment in the $\delta^{15}N$ content due to aridity, high temperature and salinity, as the animals from Ulug Depe did. The environmental conditions of the five Uzbek sites are quite diverse, rendering regional differences in the isotopic constitution most likely. But due to the lack of more suitable data, the results of the animals from Ulug Depe were used to complement the isotopic baseline of Dzharkutan. Summarizing all data, the trophic steps of $\delta^{15}N$ averages can be established at 10.0‰ of the herbivores, while the plant average of 5.5‰ and the carnivore average of 15‰ was adopted from Ulug Depe, respectively Geokchik Depe (fig. 7.13).

7.4.3. Reconstruction of human's dietary habits

Summing up all collagen results from Dzharkutan, individuals ranged in $\delta^{13}C_{col}$ between -16.4‰ and -21‰ with an average of -19.2‰ (± 1.3‰, n = 11), while $\delta^{15}N$ ratios ranged between 11.1‰ and 13.1‰ with an average of 12.1‰ (± 0.6‰, n = 11). The two individuals from Sapallitepa provided $\delta^{13}C_{col}$ ratios of -18.5‰ and -19.0‰ (average -18.8‰ ± 0.3‰, n = 2) and $\delta^{15}N$ ratios of 10.2‰ and 13.3‰ with an average of 11.8‰ (± 1.6‰, n = 2).

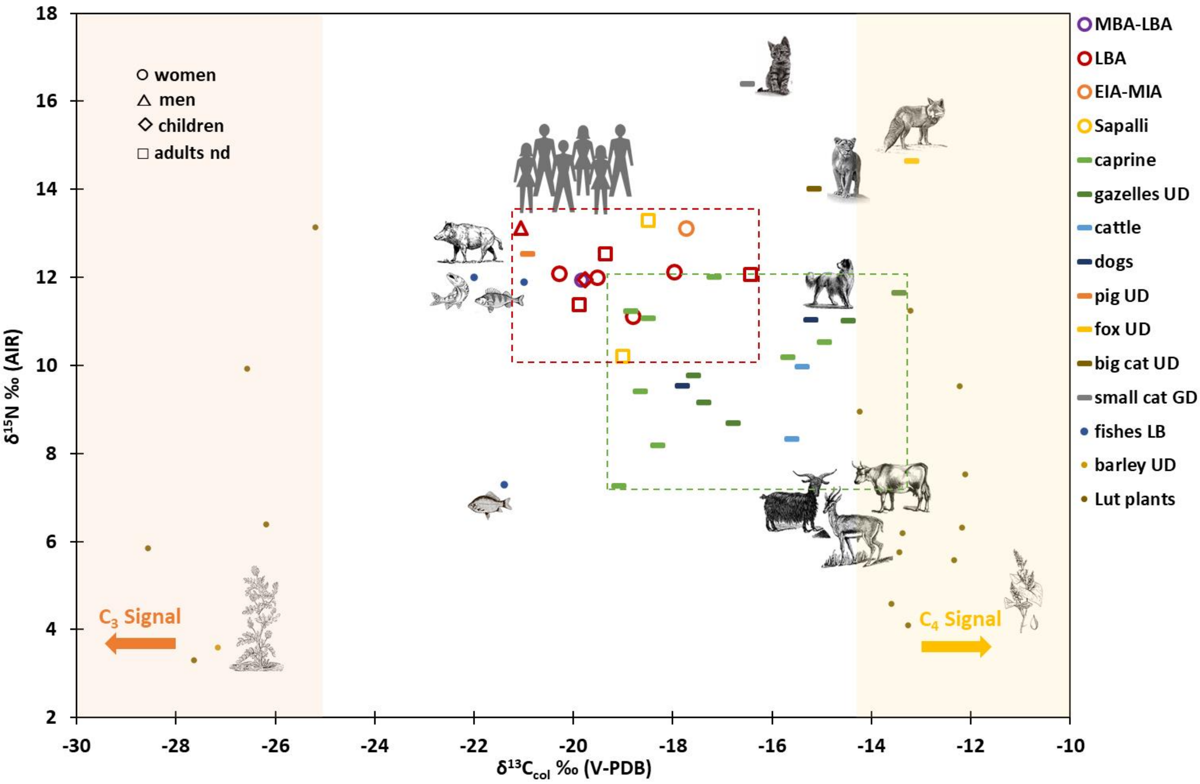


Fig. 7.14: Scatterplot of $\delta^{15}N$ versus $\delta^{13}C_{col}$ results out of collagen of all samples with references from Lut, Ulug Depe (UD), fish from Lake Baikal (LB) after Katzenberg et al. 1999, small cat from Geokchik Depe (GD) after Bocherens et al. 2006. The symbols encompass the error margins at 1σ level for $\delta^{15}N$ and $\delta^{13}C_{col}$ ratios.

Concerning the chronological periods, no reliable statements are possible as the number of samples of the earliest and latest period was too small (n = 1), but it is conspicuous that all analysed individuals from the Surkhan Darya valley (Sapalli and Dzharkutan) fell within a very narrow range of δ^{15}N results (fig. 7.14), indicating a constant nutrition in the region through all periods. Two individuals, one not determined adult from the LBA (DZH 1019) and the woman from the IA (DZH 1034-1) showed increased δ^{13}C$_{col}$ ratios, indicating a relatively high percentage of C4 plants in the diet. The rest of the group fell into the typical range of a diet mainly based on C3 plants, but all containing a certain percentage of C4 plants in the diet. Similar to Ulug Depe, this is most likely referable to the strongly enriched signals of the herbivores as primary food source. Important to highlight is, that the one IA person (woman) indeed revealed a strong enrichment in δ^{13}C. This fact maintains the botanical analyses and indicates a higher consumption of C4 plants, in the case of Dzharkutan possibly cultivated millet in the later period. Although the indication is obvious, it stays questionable if this is referable to changing climatic conditions (cf. Luneau 2019), to cultural changes coming along with the fall of the Oxus civilization (e.g., Luneau 2014b, 2021), or developments of the agricultural production and practices (e.g., Spengler et al. 2014; Hermes et al. 2019).

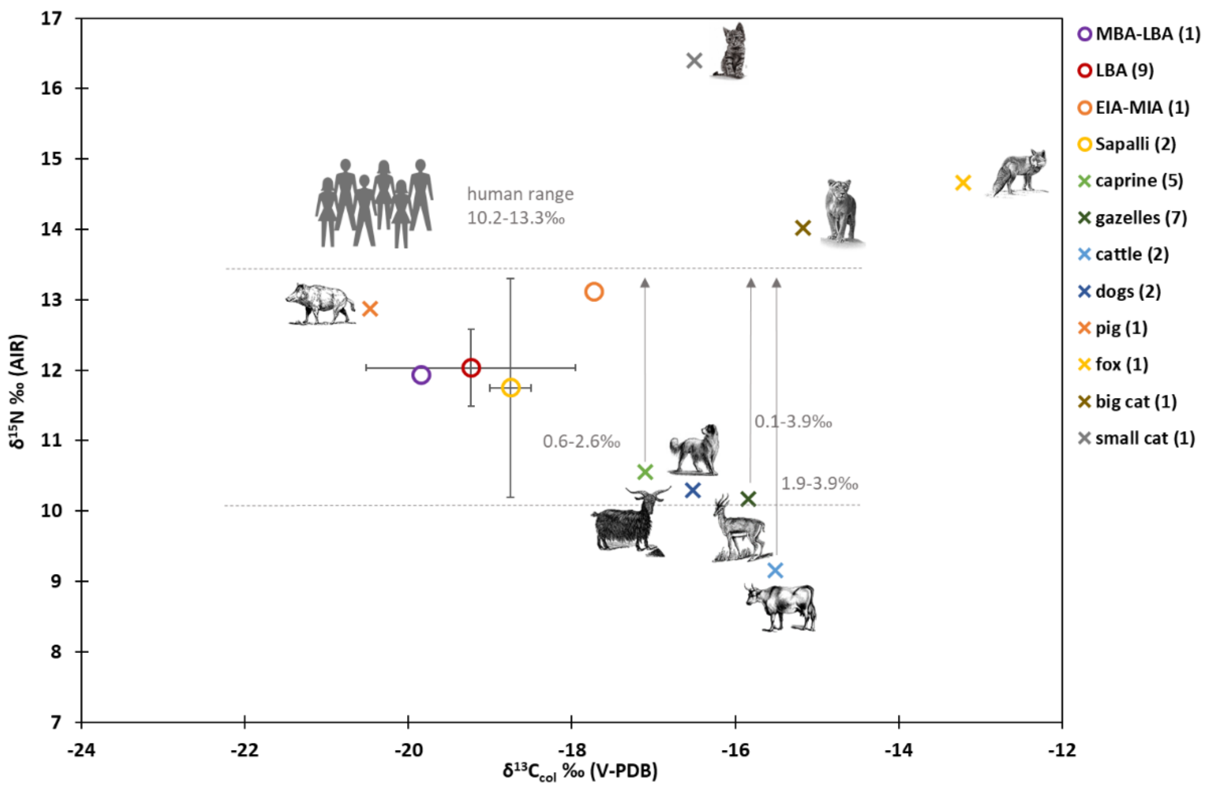


Fig. 7.15: Scatterplot of δ^{15}N and δ^{13}C$_{col}$ averages (numbers in parenthesis) with intervals between the species of samples from Dzharkutan with references from Ulug Depe, small cat from Geokchik Depe (GD) after Bocherens et al. 2006.

Calculating the intervals between humans and ovicaprids, respectively comparing the results of humans and animals, the overlapping is quite obvious, and the intervals between Dzharkutan humans and their sheep/goat were the smallest of the three sites (fig. 7.15). The five ovicaprids´ δ^{15}N average of 10.6‰ differs to the average of the humans (12.1‰) by 1.5‰ (maximum interval 3.7‰). Compared to the other sites, the intervals are even smaller than in Ulug, indicating that Dzharkutan´s people also had a diet mainly based on vegetarian components and rather little on animal products as meat, milk or yoghurt. Although the surroundings of Dzharkutan are crossed by several big rivers carrying water all year round, fish, shells, or crabs as a component in the diet are, according to the isotopic results, rather unlikely. Most sweet water fish, especially frequently occurring omnivore and piscivore species as perch or pikes provided δ^{15}N ratios in the same range as Dzharkutan´s humans (cf.

Katzenberg et al. 1999). Moreover, the archaeological evidence did not provide a true indication for a certain percentage of water animals in the diet. No wild animals are available from the region, but comparing Dzharkutan humans to the results of wild animals from other regions like the Caspian Sea Shore, the Qazvin Plains or Mentesh Tepe (cf. Bocherens et al. 2000: 7–9, 2006: 257; Herrscher et al. 2018: 8), the intervals slightly increase. Used as references were: a buffalo from the Gorgan Wall with $\delta^{15}N$ ratio of 6.9‰, a wild goat from Sagzabad with a $\delta^{15}N$ ratio of 7.9‰, and several red deer revealed $\delta^{15}N$ ratios between 4‰ and 7‰ (cf. Bocherens 2006: 257; Herrscher et al. 2018: 8; Shishlina et al. 2009: 485). Gazelles are, at least in Ulug, Geoktchik, and Qazvin, not distinguishable from the domestic herbivores, hence not really discussable. But the resulting intervals of 4‰ to 8‰ between humans and wild animals, respectively an averaged interval of 5.8‰, indicate that the pattern of Ulug Depe is recuring in Dzharkutan and hunting activities played a more important role as people rather consumed wild animals than their own flocks.

7.4.3.1. Trophic level shifts ($\delta^{13}C_{carb-col}$)

The individuals from Dzharkutan (11) and Sapalli (1) provided $\delta^{13}C_{apa-col}$ results between 10.7‰ and 3.3‰ with an interval of 7.4‰ (fig. 7.16). It is important to mention that 9 out of 11 individuals ranged between 6.0 and 10.7, in the same range as the analysed ovicaprids and according to Codron in the range of herbivores (Codron et al. 2018). Only two individuals (DZH 1019 and 1033) displayed the lower results, suggesting a higher intake of animal proteins, correlating more to the carnivore ranges. This fact confirms the small spacing between humans and animals and proposes a diet characterized by a high percentage of plants and terrestrial resources.

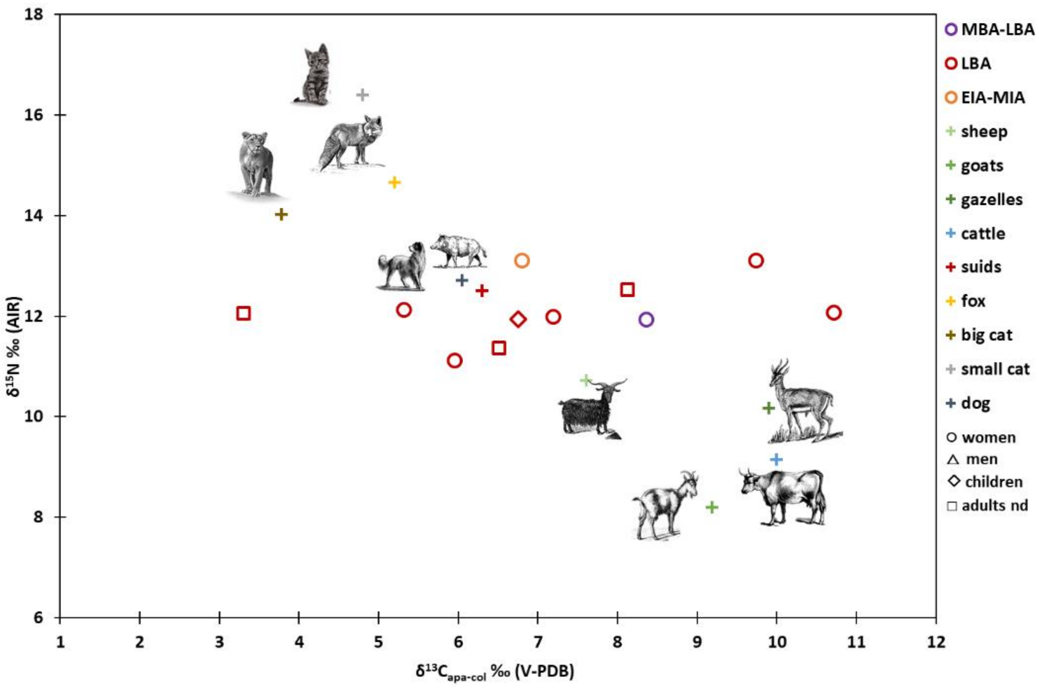


Fig. 7.16: Scatterplot of $\delta^{15}N$ versus $\delta^{13}C_{apa-col}$ of humans from Dzharkutan, including animals from Ulug Depe, and $\delta^{13}C_{apa-col}$ of fox, gazelles, and cattle after Codron et al. 2018: 3985–3986. The symbols encompass the error margins at 1σ level for $\delta^{15}N$ and $\delta^{13}C_{col}$ ratios.

In general, Dzharkutan´s humans showed a more diverse dietary intake of faunal resources than Ulug Depe inhabitants. A correlation between the high isotopic variety and movements through different habitats can be excluded in Dzharkutan, since strontium and oxygen results do not indicate a high mobility of the people. Based on different types of resources identified at Dzharkutan, and the more fertile surroundings compared to e.g., Ulug Depe, the consumption of a mixture of C3 plants, like wheat, barley, lentils, and peas, is proven, further the intake of wild species like fruits, berries, or nuts, available in the vicinity of the settlement, can be proposed.

7.4.3.2. Gender and social differences

As already mentioned above the very small isotopic ranges measured from Dzharkutan´s humans do not deliver clear insights on social differences. The one very rich grave of a LBA woman (DZH 1051) stood out of the group concerning the diet, as all isotopic results ($\delta^{15}N$, $\delta^{13}C_{col}$, $\delta^{13}C_{apa-col}$) fell within the lower limit of the group, indicating a diet containing a low percentage of animal protein, but the consumption of a high variety of plants and terrestrial resources, mainly consisting of C3 plants as cereals and vegetables. Hence, richness of grave inventories, arising with a certain social rank of a person, does not correlate with a richer nutrition (in today's eyes "richer" usually implicates a higher intake of meat). Biological criteria such as gender and age did not give any further insight. The only analysed man fell in the upper range of the $\delta^{15}N$ ratios, but one sample does not provide enough information for reliable statements. Moreover, no distinct differences are visible between the women, the indetermined adults and the child. Hence, similar to mobility, if there was a pattern in Dzharkutan concerning the nutrition, that was caused by gender or social composition, cannot be answered at the present state of research.

7.4.4. Feeding and herding practices

The insights on feeding and herding practices are very limited for Dzharkutan and the Surkhan Darya valley, because the number of analysed ovicaprids was small. Still, two patterns are quite obvious: First, the $\delta^{13}C_{col}$ ratios of all herbivores displayed a distinct enrichment compared to Ulug Depe and Sialk, indicating in general a higher percentage of C4 plants in the diet. Second, inter-individual variations were distinctly different, indicating variable feeding and herding practices, often associated with a certain mobility of the animals and different grazing habitats (e.g., Makarewicz 2018). No time series to prove the pattern have been performed yet, but in order to gain an additional indicator the $\delta^{18}O_{apa}$ isotopic ratio of two sheep from Dzharkutan can be used (cf. chapter 4.6.2.2), revealing $\delta^{18}O_{apa}$ ratios of -1.9‰ (± 0.038‰) and -1.7‰ (± 0.031‰). The results differ distinctly from the humans, substantiating that the ovicaprids used a different water source. The ovicaprids date to the LBA layers, but it remains difficult to assume if the enrichment in ^{13}C is caused by the consumption of millet, because traces of millet are missing in the archaeological remains. Of course, it is possible that millet was already consumed during the LBA, possibly cultivated in neighboured villages, or came through trade, but as long as archaeological evidences are absent, the results remain initial indications for further investigations.

7.5. Discussion and summary

The Late Bronze Age settlements in the Surkhan Darya valley and southern Tajikistan represent contrasting cultural centers, which appeared and grew with the rise of the Oxus civilization, following a common and short history. The chronological range covers the transition of the MBA to LBA, the LBA, and single samples from the EIA–MIA. The sites belonged to the Sapalli culture, the local northern Bactrian variant of the Oxus Civilisation, who followed a sedentary lifestyle, and farming activities are considered to be a key aspect of the food supply. Paleogenetic investigations revealed individuals shared more or less the same ancestry (Narashiman et al. 2019), suggesting a frequent gene flow among these settlements. The isotope results of the settlements in the Surkhan Darya valley indicate an active mobility and confirm that the exchange of artifacts and technologies was accompanied by individual resettlements. But the results of Dzharkutan people indicate a homogeneous group with little mobility and almost no immigration. The mobility pattern turned out to be different: $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results of bones and tooth enamel samples displayed homogeneous clusters on the upper and lower limit of the local $^{87}Sr/^{86}Sr$ range. Isotope analyses suggest complex patterns of mobility or subsistence for the people who were buried in Dzharkutan, where movements between a person's place of birth and residence were a regular feature, observable throughout the centuries.

The small $\delta^{18}O$ intervals between the individuals propose the intake of water from some main sources, respectively two particular water sources, and therefore rather little mobility of Dzharkutan´s people. The ecosystem of the Surkhan Darya valley created an adaptable landscape for farming, herding, breeding and an adequate food supply for humans and animals in the direct surroundings. But the clusters of teeth and bones, indicate a movement between the place of birth and a given residence during lifetime in a limited area. The question arises, which cluster can be considered as the local one of Dzharkutan? In which direction did the movements go? Were they born in Dzharkutan and went somewhere else to live and only came back to be buried in Dzharkutan? Or were they born in another place and moved to Dzharkutan to live, die and be buried there? The real cause for this unusual pattern of movements remains unexplained, until more results can be evaluated. But let´s try to at least follow some hints: the $^{87}Sr/^{86}Sr$ results of the cereals and the tamarisk were in the same range as the human bone ratios. Whereas the enamel samples fell into the same range with the rodents and the willow (cf. fig. 4.15). Rodents are mainly sedentary animals with a life span of 2–5 years, both were found in Dzharkutan and can probably be considered as locals. Cereals were grown along the rivers, where irrigation was possible. Therefore, it makes sense to assume the mice and the human enamel samples as the local ones. This is also confirmed by the fact that several enamel samples were M3 molars, which are synthesized during later childhood, indicating that these people were born and spend their childhood in Dzharkutan, being on the move later during adulthood. It seems plausible to consider the fact that settlements ensuring the provision around urban centers were common in this time period (e.g., Gonur Depe cf. Hübner et al. 2019; Dvorak et al. 2020). Hence, residential changes, maybe because of work, contributing to the society, during the adulthood would make sense.

The nutrition, respectively the $\delta^{15}N$ results confirm the pattern of a homogeneous diet of the individuals concerning the intake of animal protein, indicating a constant nutrition in the region through the periods. The intervals between humans and herbivores are even smaller than in Ulug Depe, indicating that Dzharkutan´s people had a diet mainly based on vegetarian components and rather little on animal products as meat, milk or yoghurt as well. The intervals to wild herbivores indicate that hunting activities played an important role through centuries; people consumed rather wild animals, whereas flocks were most likely reserved for secondary production of e.g., wool. However, people differed significantly concerning the intake of terrestrial resources, evidencing the consumption of a large repertoire of botanical species available in Dzharkutan. Most individuals fall within the typical range of a diet mainly based on C3 plants, but a certain percentage of C4 plants in the diet is distinct. The question of a pastoral or semi-pastoral lifestyle of the LBA inhabitants in Dzharkutan is difficult to answer, since the very special pattern of the $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results is not truly explainable at the present state of research. Although indications are strong, more analyses are necessary to prove, if this pattern mirrors the system of satellite settlements, that people lived and worked in ensuring the supply of the larger urban centers.

The complex society change, respectively the fall of the Oxus Civilisation and the following Yaz cultures are characterized by a general more basic lifestyle. The isotopic results of the Iron Age individuals evidence, analogue to Ulug Depe a different pattern of mobility as well as nutrition habits. Both IA individuals fell in the same strontium range as the LBA group, but oxygen differed distinctly to higher values indicating the use of different water sources. The one obtained $\delta^{13}C_{col}$ result of the woman displayed with a ratio of -17.7‰ a content of around 35% of C4 plants in the diet. Next to wheat and barley, botanical analyses of collected material brought also very few traces of millet to light as well. This fact maintains the impression of the isotopes and a higher consumption of C4 plants, maybe cultivated millet,[17] of the Iron Age humans (cf. chapter 10.4). Moreover, it might be an indication for a further development of the variety of cultivated crops in Dzharkutan.

[17] The remains of millet were poorly preserved and very fragmented, a sure determination of the genus was therefore not possible.

8. Another case study: The Lady from Gelot

The contents of the chapters 8.1. and 8.3. were presented in a talk at the EURASIA Conference in Bern (2020) and published in the course of the conference proceedings:

Kroll, S.K., Teufer, M., Vinogradova, N.M., Kutimov, Y., Lombardo, G., Bosch, D., Mashkour, M. (2022) Isotopic studies and archaeological evidence in Bronze Age Tajikistan: The Lady from Gelot. In: C. Baumer, M. Novak, S. Rutishauser (eds.) Cultures in Contact Central Asia as Focus of Trade, Cultural Exchange and Knowledge Transmission. Proceedings of the Second International Congress on Central Asian Archaeology held at the University of Bern, 13-15 February 2020, Harrassowitz, Wiesbaden.

The key aspect of this chapter is next to a short presentation of the obtained results from Gelot, Darnaichi and Saridzhar (cf. Teufer 2010, 2018b; Vinogradova and Kutimov 2018) to demonstrate the method of determination of one´s origin through strontium and oxygen analyses, in correlation with the archaeological evidence of a single, very special burial context. Already during the excavation, the discovery of grave 2 from excavation 6 (G2 N6, fig. 8.1) in Gelot delivered fundamental new insights concerning the chronological classification and the cultural constitution of the Bronze Age in southern Tajikistan (newest insights cf. Teufer 2021, Vinogradova 2021).

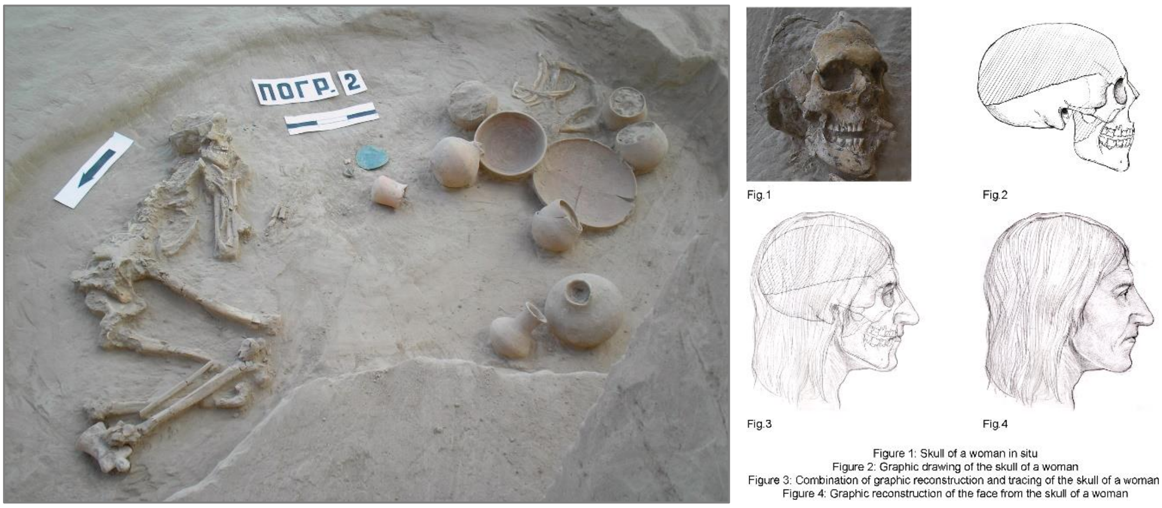


Fig. 8.1: Left: Burial 2 Excavation 6 from Gelot (Archaeological Expedition in Southern Tajikistan of the Academies of Science of Russia and Tajikistan). Right: Graphic reconstruction of the Lady from Gelot (courtesy of Aleksey Nechvaloda).

8.1. Short introduction

The insights obtained by the excavations in Gelot-Darnaichi have led to a fundamental revaluation of the Bronze Age in southern Tajikistan (Teufer 2021, Vinogradova 2021). For the first time, the existence of a Middle Bronze Age is evidenced and proven by ^{14}C data. The sequence of the burials at

Gelot-Darnaichi clearly demonstrated, that grave 2 from excavation 6 was not related to the beginning of the occupation of the graveyard (Teufer 2021: 715 tab. 25.1), but belonged to a group of graves with wheel-made pottery inventories. The youngest burial of this group was grave 2 from excavation 4, already representing a typical burial of the Sapalli-Dzharkutan culture (Teufer 2015, Kaniuth 2021). Grave 2 from excavation 6 – the burial of the Lady von Gelot – was slightly older. Radiocarbon results evidenced a time period between 2128–1981 cal. BCE (1σ), respectively 2135–1965 cal. BCE (2σ) (Teufer et al. 2014: 116). The burial dated immediately before the start of the expansion of the Sapalli culture, which in Gelot-Darnaichi was only attested by grave 2 from excavation 4 (Teufer 2021: 714). Furthermore, burial nr. 2 from Gelot has a special importance, as it represents the first burial investigated with all available scientific methods providing precise data complementing the archaeological evidence from southern Tajikistan. Buried was an approximately 40-year-old woman in a catacomb type oval burial chamber, the entrance was closed by a mud brick construction (fig. 8.2).

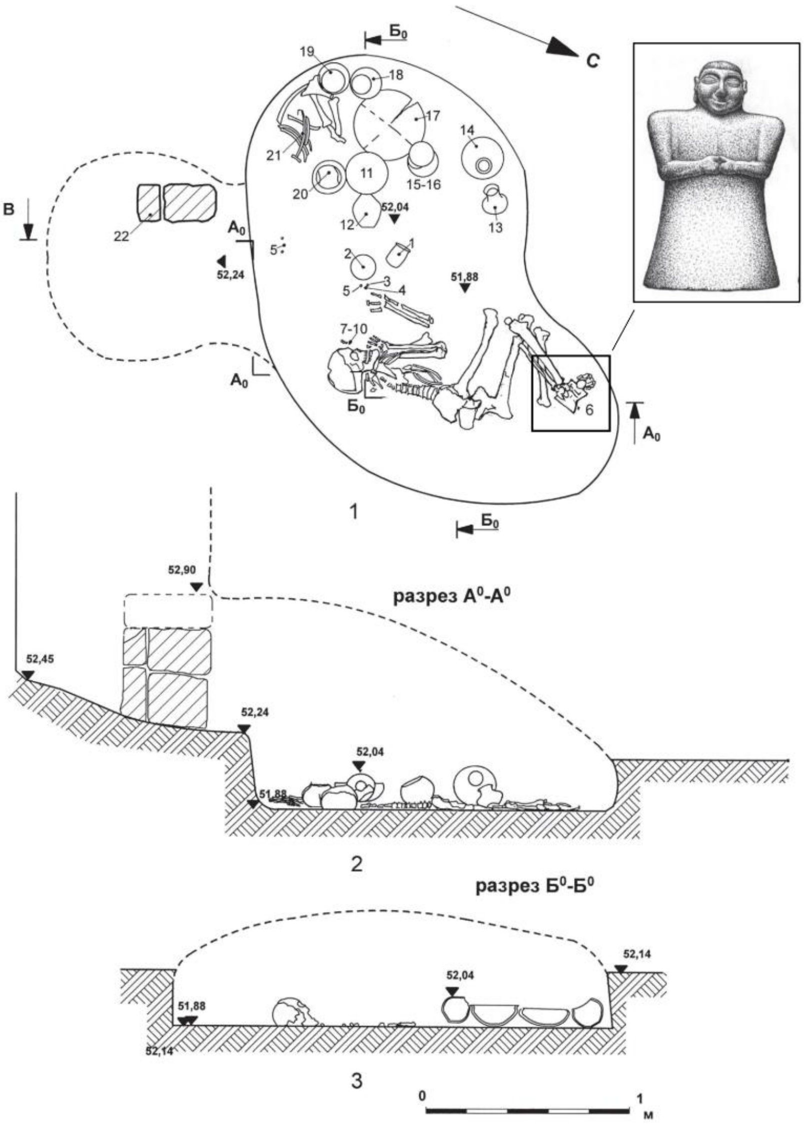


Fig. 8.2: Plan of burial 2 excavation 6 manipulated after Vinogradova, Winkelmann 2016: 364 fig. 3, 6.

The skeleton was placed in crouched position on the left side in the north-eastern part of the chamber. In the south-western part the skeleton of a sheep and 11 pottery vessels were found. A detailed description of the burial, respectively the typological categorization and the iconographic attributes of the grave inventory with further references can be found in Vinogradova (2021: 646–647) and Lombardo et al. (2014: 9–12) and will only briefly be summarized here: The pottery ensemble belonged to the Sapalli–Dzharkutan phase, respectively the late NMG V/early NMG VI period (Teufer 2010). Comparable vessels are known from burials at Sapalli, Dashly I, Altyn Depe, Gonur, but also from Tepe Chalow and Tepe Damghani in northeastern Iran (Lombardo et al. 2014; Vinogradova 2021). Near her left hand a circular bronze mirror and fragments of several small bronze objects were placed. Beside her head beads of lapis lazuli and gold were found. Close to the mirror a fragment of a marble seal with a rosette in relief was discovered. The rosette motif is well known from metal examples from Altyn Depe and Shahr-i Sokhta. Analogues to the barrel-shaped Lapis lazuli beads were found in large numbers in several Bronze Age sites like Susa, Shahr-i Sokhta, Altyn-Depe or Gonur Depe (Lombardo et al. 2014: 15). But the most remarkable, and until today unique artefact in the region, was a marble anthropomorphic figurine discovered below her right foot. Although the size alters and the context of finding was different, it shows iconographic analogues to Early Dynastic worshipper figurines from e.g., Tell Assmar and Mari, but also to the grave statuettes from Shahdad or Dzharkutan (Lombardo et al. 2014: 15; Vinogradova 2021: 465). Moreover, parallels with the “priest-king” statue from Mohenjo-Daro can be drawn (Vinogradova 2021: 465). The excavators ascribed the Gelot statuette as “probably manufactured in Bactria by local artisans and from local stone (anhydrite) under the influence of Mesopotamian standards. It belonged to a common cultural artistic substratum of which Eastern Iran and Northern Afghanistan were part and provided the links with Mesopotamia and Elam” (Lombardo et al. 2014: 16).

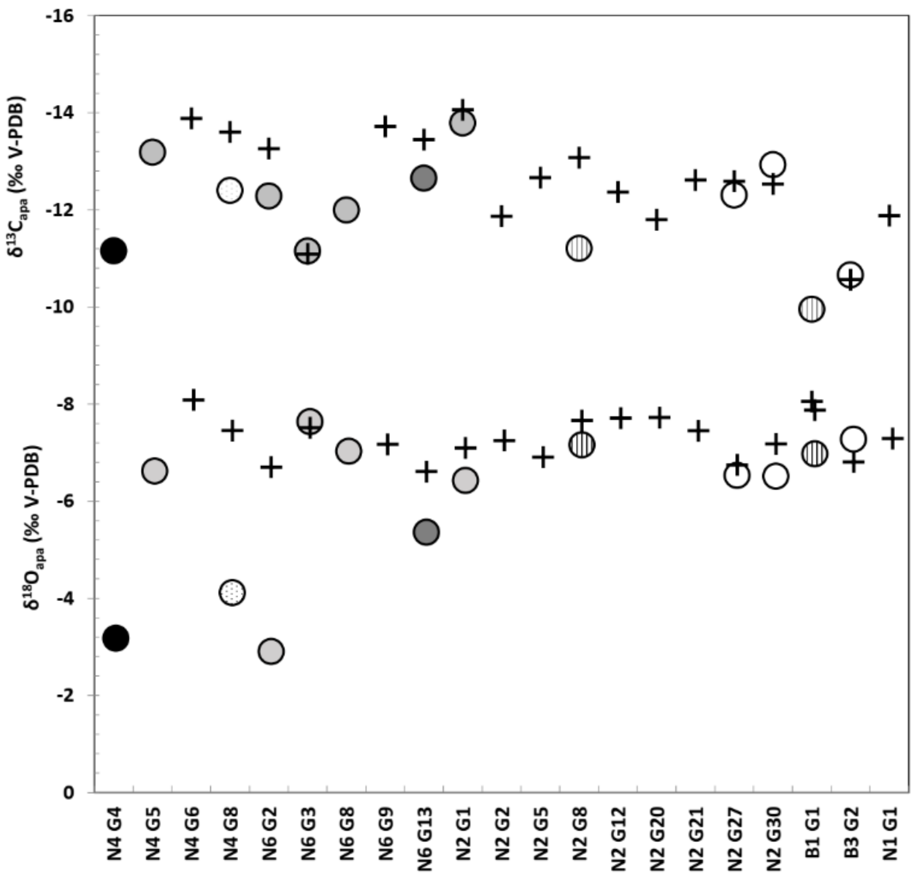


Fig. 8.3: Intra-individual variations of $\delta^{18}O_{apa}$ (left) and $\delta^{13}C_{apa}$ (right) of humans from Gelot, Darnaichi and Saridzhar. Plus correspond to bone samples, circles to tooth enamel (black M3, dark grey M2, light grey M1, empty M not determined, vertical stripes PM, horizontal stripes C, dots I). The symbols encompass the error margins at 1σ level for $\delta^{18}O_{apa}$ and $\delta^{13}C_{apa}$ ratios.

As this burial can be considered unique in richness and inventory among the burials from Gelot, several questions arise: Who was this woman? She was obviously a very important person with a high social status, today we would say she was a sophisticated woman with international connections. But what was the story behind? Where did she come from and what can isotope analyses tell us about her?

8.2. Isotopic results ($\delta^{18}O_{apa}$, $\delta^{13}C_{apa}$, $^{87}Sr/^{86}Sr$) from southern Tajikistan

The itemized results of Gelot, Darnaichi and Saridzhar are listed in the Appendix table 9. The human samples from the contemporaneous sites Gelot, Darnaichi and Sarizhar in southern Tajikistan mainly served as references for the present study, because not all isotopic analyses were performed on these samples, still some results can be evaluated. Analyses were performed on of $\delta^{18}O_{apa}$ and $\delta^{13}C_{apa}$ out of apatite of bones and tooth enamel of all individuals from Tajikistan, while $^{87}Sr/^{86}Sr$ analyses were done on each one from Gelot and Darnaichi, and three from Saridzhar. The preparation of structural carbonate was not sufficient for all individuals, collagen analyses have not been performed on these samples.

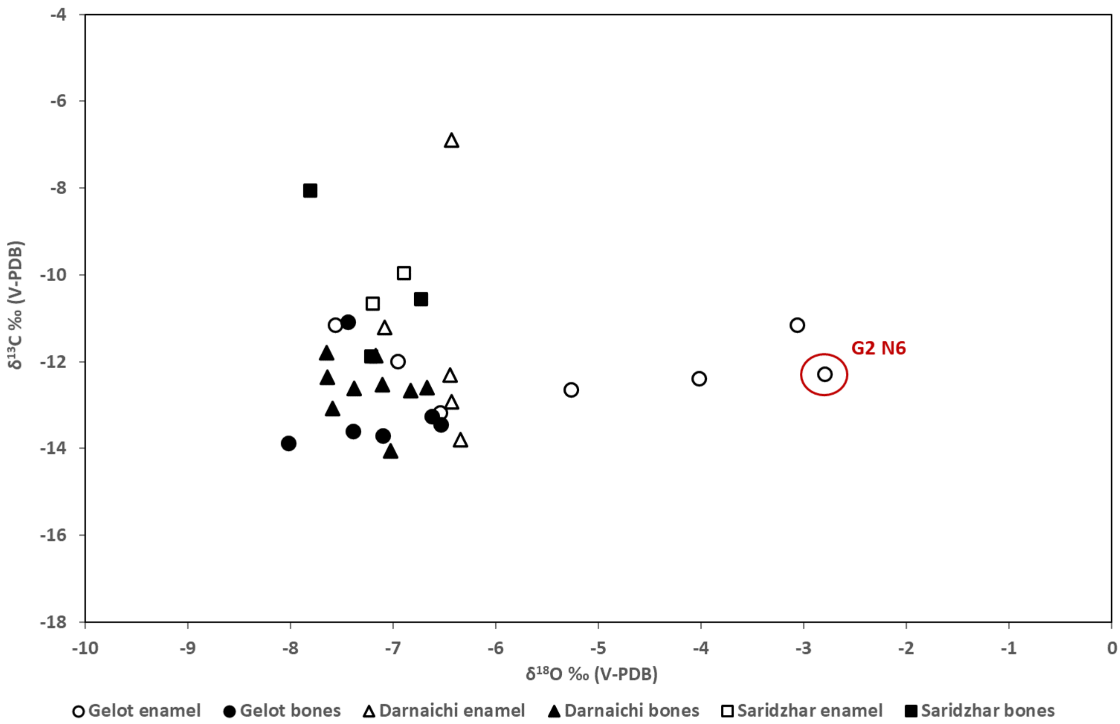


Fig. 8.4: Scatterplot of $\delta^{18}O_{apa}$ and $\delta^{13}C_{apa}$ of humans from Gelot, Darnaichi and Saridzhar. The symbols encompass the error margins at 1σ level for $\delta^{18}O_{apa}$ and $\delta^{13}C_{apa}$ ratios.

The $\delta^{18}O_{apa}$ ratios of all humans ranged between -2.8‰ and -8.0‰ with an average of -6.7‰ (± 1.2‰ n = 31), while $\delta^{13}C_{apa}$ ranged from -8.1‰ to -13.9‰ with an average of -12.2‰ (± 1.3‰ n = 31). The $\delta^{18}O_{apa}$ bone ratios ranged between -6.5‰ and -8.0‰ with an average of -7.2‰ (0.42‰ n = 18), while $\delta^{18}O_{apa}$ enamel ratios ranged between -2.8‰ and -7.6‰ with an average of -5.9‰ (1.4‰ n = 14). The measured $^{87}Sr/^{86}Sr$ ratios ranged between 0.708616 and 0.709374 (± 0.000241‰). All bone samples form a very homogeneous group in the $\delta^{18}O_{apa}$ ratios (fig. 8.3), similar to the correlation of $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ ratios, while the enamel ratios displayed a much wider variety. It is conspicuous, however, that all the analysed bone samples fell in a similar $^{87}Sr/^{86}Sr$ range but the tooth enamel samples contained several outliers (fig. 8.4). The results suggest that immigration also played an important role during the Bronze Age in Tajikistan.

8.3. The origin of N6 G2

Although isotope analyses on archaeological material from the Near East and Central Asia has caught up in the last years, the state of knowledge, especially of strontium and oxygen data, is still fragmentary. The apparent randomly selected sites used as references in the following discussion are chosen at the basis of the available data. The overlap of measurements reflects the problematic of strontium and oxygen isotopes, which depend on different natural factors and can be consistent in similar geological and climatic regions. The lack of data urges us to stay with the facts and rather exclude investigated sites than target possible origins. Therefore, the following discussion represents a first step as things can change instantly with more data.

The first insight delivered by isotope analyses consists of the fact, that the Lady from Gelot was not only buried in southern Tajikistan. Her $\delta^{18}O_{apa}$ ratio of the bone sample fell into the same range as the other four individuals from Gelot, Darnaichi and Saridzhar. All $^{87}Sr/^{86}Sr$ ratio range between 0.7091 and 0.7094, the $\delta^{18}O_{apa}$ ratios of bone compacta between -7.8‰ and -6.6‰. This indicates, that these five people, although the archaeological sites covered a chronological time period of around five hundred years, lived, at least the last years of their life, in the same geological habitat and shared a similar groundwater source. In contrary, the results of the isotopic ratios of her tooth enamel differed significantly from the rest of the group. The $^{87}Sr/^{86}Sr$ ratio was with 0.70874 ±0.000005 (1σ) in lower ranges, while the $\delta^{18}O_{apa}$ ratio out of tooth enamel of -2.8‰ (±0.046, $\delta^{18}O_{DW}$ -4.1‰[18]) is conspicuously higher, implying she was born in a hotter, lower, more arid region.

Several intensive studies were undertaken by colleagues in different regions of the Near East and Central Asia (cf. fig. 8.5 with references), and for the sake of completeness we will start the search with the already published data. Although some sites are far and not in relation to the archaeological evidence of southern Tajikistan they should not be disregarded. The following regions can be excluded as a potential places of origin: all investigated regions north and west of the Caspian Sea like the northern Caucasian Steppes, the Pontic Steppes, the Volga Region, and also the Andronovo sites Bestamak and Lisakovsk in the northern Kazakh steppes. All determined local signals are between 0.7090 and 0.7100 (after Gerling 2015; Ventresca Miller et al. 2017), significantly higher than those of the Lady from Gelot and therefore out of the question as a possible origin. Also, clearly eliminable is Harappa in the Indus Valley and Jirzankal on the eastern Pamir Plateau. Both local signals cover the upper range of the strontium scale (Harappa: 0.7158–0.7189 after Kenoyer et al. 2013; Jirzankal: 0.7102–0.7106 after Wang et al. 2016), caused by very diverse geological realities. On the other hand, the local strontium ranges of Balakot near Karachi in the Indus Delta, the Failaka Island off the coast of today Kuwait, as well as the northeastern coast of the United Arabic Emirates and Bahrain, all fall into the same range as the Lady from Gelot (0.7079–0.7095 after Gregoricka 2013). However, aridity and the proximity to

[18] After the equation for medium sized mammals of Chenery et al. 2012 $\delta^{18}O_{DW} = 1.59 \times \delta^{18}O_{apa}$ (V-SMOW) - 48.634 result in a $\delta^{18}O_{DW}$ of -4.1‰ for the Lady from Gelot.

the sea caused $\delta^{18}O_W$ values around zero and therefore significantly higher (-0.2‰ to -0.6‰ after the GNIP and OIPC) in UAE, Bahrain and Failaka Island. While Balakot is given a $\delta^{18}O_W$ ratio of -4.6‰ by the OIPC (after Bowen 2020), the same range as the Lady from Gelot. Hence, an origin in the Indus Delta is possible and Balakot represents the first potential place of origin for the Lady from Gelot (fig. 8.6). Another study investigated the isotopic composition of the Upper Khabur, Upper Tigris and Harran Plain, and the Pütürge Mountains. While the Khabur and Tigris plains showed $^{87}Sr/^{86}Sr$ ratios from 0.7086 to 0.7098, the Pütürge region ranged from 0.7123 to 0.7220 (after Kibaroğlu et al. 2017). The strontium signature of the Khabur-Tigris region would fit into the picture, but due to the mountainous, inner-continental location, the regions showed $\delta^{18}O_W$ values around -7‰ (after the GNIP and OIPC), significantly lower than the Lady from Gelot´s values and therefore excludable.

Fig. 8.5: Collected strontium data: Jirzankal after Wang et al. 2016; Harappa, Ur after Kenoyer et al. 2013; Bahrain, UAE, Failaka Island, Tepe Yahya, Allahdino after Gregoricka 2013; Upper Khabour and Pütürge Region after Kibaroğlu et al. 2017; Northern Pontic Steppe after Gerling 2015; Bestamak, Lisakovsk after Ventresca Miller et al. 2017. For Gelot-Darnaichi the ranges of the human bones are stated as the bioavailable strontium range. Pictures in the map after Lombardo et al. 2014: 10–11 fig. 8–10.

Let us now come to the new data and consider the adjoining regions in the west. The pottery being part of her grave inventory shows clear influences of the Surkhan Darya valley. Analyses from this region have been done on humans from Dzharkutan, Bustan, and Sapallitepa, and local signals were determined from Dzharkutan and Tilla Bulak. We do not have a determined local signal of Sapallitepa, but it can be assumed to be in similar ranges as Tilla Bulak. The lower Surkhan Darya valley is formed by two alluvial fans, Dzharkutan and Bustan were fed by the Sherabad River (Kaniuth 2021), while Tilla Bulak was fed by the Ulanbulaksaj River, which runs through the Pashkhurt Valley and continues to Sapallitepa (Askarov 1973; Kaniuth 2021). Dzharkutan is located only 25 km east of Tilla Bulak, but the two groundwater sources, respectively the strontium signatures are significantly different and well distinguishable. The results clearly prove that the Lady from Gelot does not fit into the determined local ranges of Dzharkutan or Tilla Bulak (fig. 8.6). The local signal of Tilla Bulak is characterized by a quite narrow range. The settlement is located in the sub-mountain plain west of Dzharkutan, a bit isolated behind a small mountain chain (Kaniuth 2016, 2021), whereas Sapallitepa was not far from the northern bank of the Amu Darya River, in the valley where Ulanbulaksaj and Amu Darya converge (Askarov 1973). It is therefore not excludable, that the strontium signature of Sapallitepa covers a wider range, but none of the analysed humans from Sapallitepa conforms with the Lady from Gelot. Hence, for now we have no evidence of an origin in southern Uzbekistan.

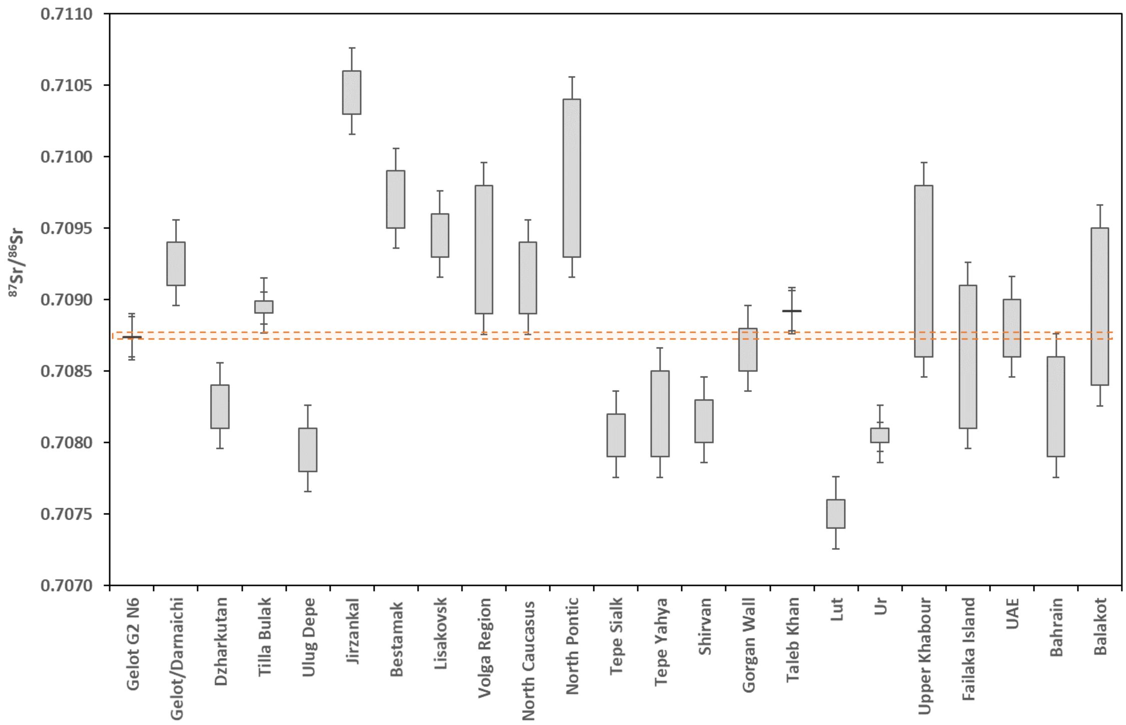


Fig. 8.6: Boxplot of $^{87}Sr/^{86}Sr$ ranges of the Lady from Gelot in correlation with the sites mentioned in the text. References: Jirzankal after Wang et al. 2016; Bestamak, Lisakovsk after Ventresca Miller et al. 2017; Volga Region, Northern Caucasus and Northern Pontic Steppe after Gerling 2015; Ur after Kenoyer et al. 2013; Upper Khabour after Kibaroğlu et al. 2017; Bahrain, UAE, Failaka Island, Tepe Yahya, Balakot after Gregoricka 2013. For Gelot-Darnaichi the ranges of the human bones are stated. Dotted orange box indicates the $^{87}Sr/^{86}Sr$ range of burial N6G2.

The same applies further west to southern Turkmenistan and sites like Gonur Depe or Altyn Depe. No data are available for both sites, and archaeological connections to Gonur Depe cannot be proven by isotopic results yet. But Altyn Depe is located on the northern foothills of the Kopet Dagh Mountains only 40 km east of Ulug Depe in the same geological surroundings (Masson 1981; Bendezu-Sarmiento 2013; Lecomte 2013). It can be assumed that the strontium signal of Altyn Depe does not differ much from the one of Ulug Depe. However, the results are in much lower ranges than the Lady from Gelot´s, thus an origin in Ulug Depe, respectively Altyn Depe can therefore be excluded. One interesting hint consists of the fact, that several individuals from Ulug Depe showed similar high oxygen ratios as the Lady from Gelot. Ulug Depe is located on the southern border of the Karakarum Desert in a sparse environment with a very hot and arid climate. Although Ulug Depe was not her place of birth, we can assume that she came from a region with similar conditions of temperature and aridity. The local signal of Tepe Sialk ranges between Ulug Depe and Dzharkutan and can therefore also be excluded. In the same range and therefore also excludable were the local strontium signals of Tepe Yahya in south-western Iran (0.7079–0.7085 after Gregoricka 2013) and two samples from Ur at the Euphrat River in southern Mesopotamia (0.7080–0.7081 after Kenoyer et al. 2013).

The iconographic attributes of the figurine strongly indicate analogues to elamite artifacts but also to eastern Iranian sites as Shahdad and Shahr-i Sokhta (Hakemi 1997; Salvatori, Vidale 1997). No data have been published until now from both sites, but an expedition under the direction of Hossein Akhani collected several plant samples at different stations in the Lut Desert (cf. chapter 4.5.5. and Trescher 2017: 37; Lyons et al. 2020; Rudov et al. 2020), ca. 120 km east of Shahdad, and enabled the performance of the first strontium analyses of the region. The determined signal of 0.7074–0.7076 clearly proved the different geological realities resulting in a lower range than all results obtained from Central Asia. The investigated area of more than 200 km^2 showed a quite homogeneous strontium signal, but settlements as Shahdad might alter in the signal due to varying groundwater sources like dwells or underground streams. Hence, an origin in Lut Desert can clearly be excluded, but Shahdad as place of birth is, due to the lack of data, not definitely excludable yet. Shahr-i Sokhta on the eastern border of Lut desert owed its existence the Helmand River, in whose northern delta it was located on the Ram Rud terrace (Tosi 1968). A single mouse from Tepe Taleb Khan, directly south of Shahr-i Sokhta, showed a strontium signal close to the one of the Lady from Gelot (cf. fig. 8.6). The databases provide a $\delta^{18}O_W$ range of -4.1‰, the exact same range as the $\delta^{18}O_{DW}$ of the Lady from Gelot. Of course, one analysed mouse is a far too little argument for a reliable statement, but the results prove a different bioavailable strontium signal of the area around Shahr-i Sokhta and indicate a possible origin of the Lady from Gelot in this region.

Another investigated region, which provided suitable $^{87}Sr/^{86}Sr$ and $\delta^{18}O_W$ signatures, are the Gorgan Plains in northeastern Iran. Kindly supported by Eberhard Sauer and Marjan Mashkour who collected charred plants on different excavations along the Gorgan Wall, it was possible to gain the first local strontium signature of the region (Sauer et al. 2013; Sauer 2017). The wall is located at the southeastern corner of the Caspian Sea in a geographic narrowing between the Elburz and Kopet Dagh Mountain ranges, which always connected the northern steppes and the Iranian heartland. The region is characterized by a hot and arid climate, and showed, due to a homogeneous environment, a precise strontium signal of 0.7085–0.7088. The OIPC provided $\delta^{18}O_W$ ratios for the region between -4‰ and -4.7‰, the GNIP around -6‰ (Teheran monitoring station), in a comparable range as the Lady from Gelot with $\delta^{18}O_{DW}$ -4.1‰. Of course, the Gorgan Wall was hardly her place of origin, as this Sassanian fortification system did not exist yet, but close and in the same geological environment was e.g., the site of Tureng Tepe. No isotopic data are available from Tureng Tepe itself, but the settlement was a powerful urban center during the Bronze Age, which played an important role in inter-regional systems. Tureng Tepe is characterized by another mix of cultures through connections to southern Central Asia and sites as Namazga Depe, as well as to the Iranian heartland and sites like Tepe Sialk or Shahr-i Sokhta (Olson, Thornton 2021). The tradition of figurines as grave goods was a common custom also in Tureng Tepe. Several human figurines with disparate iconographic attributes were discovered (cf. Olson, Thornton 2021: 14 fig. 11). The very diverse burial ensemble of the Lady from Gelot could indeed be explained by a cultural background from Tureng Tepe as a hub between Central Asia and Iran in combination with the traditions of the prevailing cultural communities in southern Tajikistan. Since the 4th mill. BCE, at least, a network of distribution and the frequent exchange of raw material, as lapis lazuli, gold, tin, or copper, from Central Asia, through Iran, and Caucasia, is evidenced (Thomalsky et al. 2013). Apparently, also people migrated along these overall connecting trade routes and certain social interactions really existed.

8.4. Conclusion

The discussion above quite clearly demonstrated the problems one encounters when trying to determine an individual´s origin through isotopic investigations. Although it seems, that more questions arose with the results of the isotope analyses, some facts can be delivered: The Lady from Gelot was a first-generation migrant. If she came to southern Tajikistan for marriage, trade, work, exploration, or just human behavior, is a question we cannot answer. But we know she stayed, and spent the last years of her life in the same region as the other people from Gelot and Darnaichi. She was well integrated in the local community, buried after the local burial traditions. And she was powerful. If she was powerful because she was a foreigner, or if it was an exchange of two powerful families is a question we can also only speculate about. The figurine found in her grave was probably made by Bactrian artisans using local material. We do not know if it was specifically made as a burial object or whether it belonged to her long before her death. But it reflects the empathy, knowledge, and skills of the local artisans to produce an artifact following the imaginations of a foreign woman, applying the iconographic attributes of a different cultural background. We cannot definitely name the place of her origin. But we could demonstrate, that up to now, within a respectable number of investigated regions the only isotopic signatures corresponding to her signature are regions in north- and eastern Iran. It does not matter if we consider Tureng Tepe or Shahr-i Sokhta as her potential origin, as both results prove excitingly archaeological analogues, and demonstrate not only that she was a woman, who travelled more than one thousand kilometers, passing harsh deserts and high mountains. Furthermore, the results substantiate active dynamics – people migrated during the 3rd mill. BCE within a wide area between eastern Iran and southern Central Asia.

Fig. 9.1: General view on the mounds of Tepe Sialk and the suburbs of Kashan city.[19]

9. Tepe Sialk

9.1. Preface

Tepe Sialk is one of the largest and most investigated archaeological sites on the Central Iranian Plateau. During the occupation from the 6th to the 1st millennia, the settlement experienced several changes and developments, influenced by different cultural communities and closely connected to the social structure of the populations. Many studies focusing on different aspects and archaeological questions about Tepe Sialk have been published (cf. Curtis 2019: 68 bibliography) while investigations on the subsistence of the people, the daily food supply, the composition of the respective populations and migratory impacts, are still rare in this region.

9.2. The site Tepe Sialk

Tepe Sialk (33°58'7.59"N 51°24'14.26"E) is located on the Central Iranian High Plateau in the province of Kashan in the southwestern suburbs of Kashan city. The Oasis of Kashan is situated between the Dasht-e Kavir to the east and the mountain range of Karkas to the west. The first mountain slope is in 8 km distance to the mounds of Sialk, only 70 km south of Sialk is the Kuh-e Karkas, the highest mountain of the Karkas Mountains with a height of 3.896 m a.s.l.

Modern research in Sialk started in 1933 when some painted vessels were stumbled upon in the Bazar of antiquities in Teheran (Curtis 2019: 1). After it became clear they came from Tepe Sialk, a French team under the direction of Roman Ghirshman and his wife Tania started the first field seasons (Ghirshman 1970). They carried out three excavation seasons in 1933, 1934 and 1937 in cooperation with the Iranian Cultural Heritage Organisation, the Musée du Louvre and the Institut Français de Recherche en Iran (cf. Ghirshman 1938, 1939). During the first excavations 1933/34 Ghirshman

[19] Image after Kashan.today https://www.destinationiran.com/sialk-mounds-kashan-iran-oldest-human-settlement.htm (last access 23.01.2021).

concentrated on the southern mound. He opened three trenches on the upper mound, additionally he undertook several sondages in the two graveyards. In the last campaign he opened three further trenches on the northern mound and had a special focus on the mud-brick platform of the south mound. After a long gap, work was resumed between 1999 and 2005 in the course of the Sialk Reconsideration Project by the Iranian Cultural Heritage Organisation under the direction of Sadegh Malek Shahmirzadi with international participation (cf. Shahmirzadi 2003, 2004, 2005, 2012). In 2009 and 2010 excavations were conducted under the direction of Hasan Fazeli Nashli. Among others he discovered Neolithic burial structures on the northern mound (Soltysiak and Fazeli 2010).

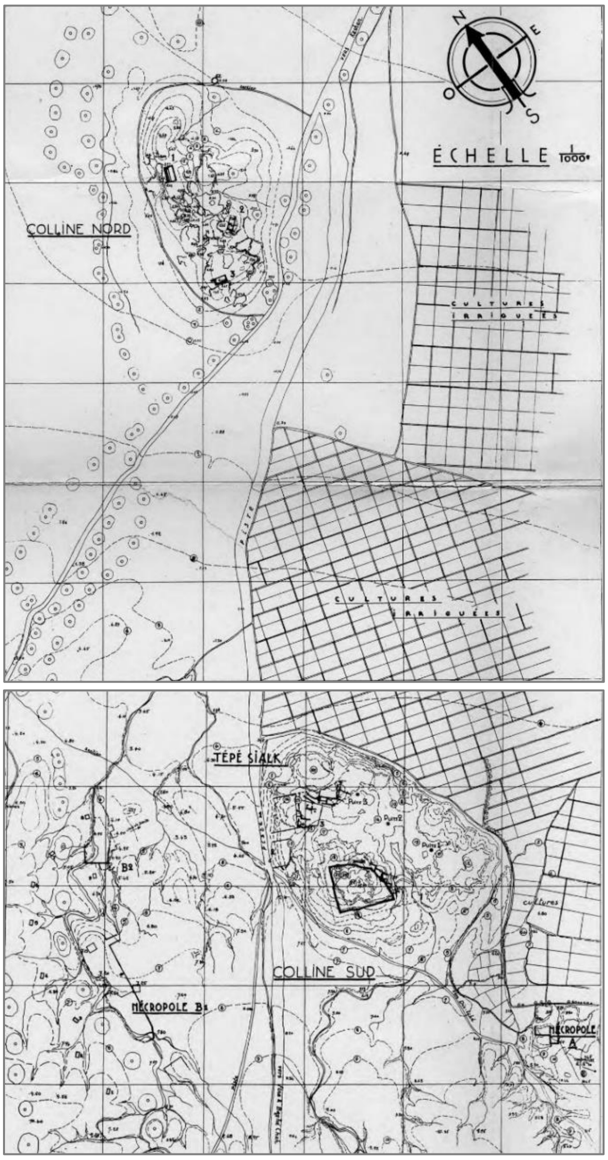


Fig. 9.2: Topographic plan of Tepe Sialk after Ghirshman 1938: 154–156 pl. XXXIII.

9.2.1. Archaeological Background

The two mounds in Sialk are comprised of a stratigraphic sequence from the Neolithic (6th mill. BCE) to the late Iron Age (1st mill. BCE) with a thickness of cultural layers of more than 16 m. The site of Tepe Sialk consists of two settlement mounds: the northern and the southern mound (fig. 9.2), in a distance of about 600 m to each other. Sialk A, the northern hill, was occupied between the 5th and 4th mill. BCE; Sialk B, the southern hill, between the 3rd and 1st mill. BCE. Especially in the south large graveyards (A and B) were uncovered, which provided a rich repertoire of grave goods (cf. Ghirshman 1939).

The first traces of Neolithic material on the Iranian plateau were found in Tepe Sialk by Ghirshman in 1933 (Ghirshman 1938: 10–24). Sialk A was founded at the end of the 6th mill. BCE (Sialk $I_{1–5}$, Late Neolithic period ca. 6000–5200 BCE) and abandoned at the very beginning of the 5th mill. BCE. During the earliest phases, populations lived in permanent villages with a mixed economy of plant cultivation of wheat, barley, lentils, and peas, and animal husbandry as well as exploitation of wild resources (Tengberg 2004; Shirazi and Tengberg 2012). The houses were made of packed mud, sometimes also made of reed, pottery was coarse and handmade (Fazeli and Nokandeh 2019). Tools for harvesting crops, butchering, working hides, as well as grinding stones, mortars, and pestles were numerous (Bernbeck 1995). The first evidence for treatment of native pure copper in forms of cold hammered pins, ales, and beads, were found in the Sialk I_3 period (Helwing 2010). The dead were buried in domestic spaces inside and next to the houses, normally placed under the floors of houses or in an open part of the settlement usually within the walls of an abandoned house. Bodies were put in flexed position; bones were often covered with red ochre. Children were mostly buried in jars, cremations were also detected (Soltysiak and Fazeli 2010), grave goods are in general rare.

During the transitional Chalcolithic (Sialk $II_{1–3}$, ca. 5200–4600 BCE) architectural developments show fundaments of floors and walls were now made of mudbricks, while the masonry stayed of pisé. Burial traditions continued without changes (Nokandeh 2010; Curtis 2019). Towards the end of the 4th mill. BCE (Sialk $III_{1–3}$) the settlement was relocated to the southern mound. Sialk III is characterized by the rise of the first proto-urban structures and significant developments concerning the architectural remains: houses now consist of several rooms, connected by courtyards, walls were made of systematically mass-produced mudbricks. Burial traditions of the chalcolithic period continued without significant changes; red ochre is visible till the Sialk III_4 period, grave goods are still rare (Nokandeh 2010; Curtis 2019). In the layers of Sialk III_6 first evidence of cultural influences from lowland Mesopotamia, such as the niche architecture and beveled-rim bowls, were documented. Additionally, trade goods from the east such as carnelian and lapis lazuli demonstrate long-distance interactions and the affiliation with further trade networks (Helwing 2013; Neuman forthcoming). During this period, Sialk inhabitants gained a high specialization in metal production and treatment of copper or silver (Pernicka 2004a, b). The first stamp seals with geometric pattern testify an established bureaucratic system. While in the earliest phases, I and II, the people in Sialk were living in small rectangular huts with thin mudbrick walls, sometimes also made of reed, the settlement structure of Sialk III changed fundamentally (Nokandeh 2010). The architecture gets more and more dense and typical chalcolithic achievements are visible, like pottery kilns, metal working and the first appearance of administrative tools, like stamp seals. Helwing summarized “Sialk III communities seem to have enjoyed relative stability and prosperity, as indicated by the prolonged occupation sequences that reach as much as 8 m” (Helwing 2013: 95).

With the Sialk IV period, the first proto-elamite phase is evidenced, representing the Early Bronze Age. It can roughly be divided in two phases: IV_a and IV_b. Sialk IV_a correspond to the proto urban phase with Uruk architecture, while Sialk IV_b represents the proto-elamite phase. In general architecture became more complex, mudbricks became big and rectangular, walls were structured with niches characteristic for the Mesopotamian lowlands (cf. Ghirshman 1938; Young 1969; Gopnik and Rothman 2011). The first clay tablets with proto-elamite characters were found in Sialk IV_2 (Helwing 2010), reflecting the complex administrative system, since Sialk was involved in the MAIS in this time period

(Possehl 2007). Burials are generally rare, unfortunately no samples of this period were available for the present study.

For the Late Bronze Age (ca. 2000–1500 BCE) no traces of occupation could be identified in Sialk. After this gap, a new occupation phase, Sialk V (Iron I, ca. 1200–800 BCE) started on the southern mound. Architectural structures are poorly preserved, but the period is well represented at Necropolis A, where several burials with rich inventories were excavated. Individuals were mostly single burials in flexed position, grave goods, among them pottery, weapons and other small metal objects could be documented. The typical Grey Ware was found in Sialk V, which is characteristic for the Early Iron Age (Iron I) (Curtis 2019; Fahimi 2019). Later in the Iron II period, Sialk VI (ca. 800–530 BCE), the necropolis was relocated to the western side of the settlement, called Necropolis B by Ghirshman (Ghirshman 1938: 8). Contemporary to Necropolis B was the big mud-brick construction on the southern top hill of Sialk´s south mound, which Ghirshman called "la grande construction". The discussion about the dating and purpose of this construction has not ended yet to everyone's satisfaction. Some scientists identified it as a proto-elamite ziggurat belonging to the Sialk III period (e.g., Shahmirzadi 2002), but recent studies and discussions, held during the two Sialk conferences in London,[20] argued for an Iron Age structure, attributed to the "Median Culture" (cf. chapter 5.2. and Roaf 2008; Kroll 2019; Naseri and Malekzadeh 2019). The insights of the conference proceedings and the present state of research is summarized in Curtis (2019: 1–4).

Fig. 9.3: Fields and natural vegetation on the Kashan Plains (bottom) and marginal zone of the Dasht-e Kavir (top).[21]

9.2.2. Landscape and subsistence

The plains of Kashan are divided by the mountains into two different climatic and vegetational regions: the arid eastern lowlands and the more moderate western highlands (fig. 9.3, e.g., Shirazi and

[20] The two conferences were organized by the Iranian Heritage Foundation in London in 2018 and 2019 entitled "Tappeh Sialk. The Glory of Ancient Kashan", cf. Nokandeh, Curtis, Pic (eds.) 2019.

[21] Top after https://www.tappersia.com/things-to-do-in-kashan/, bottom after https://commons.wikimedia.org/wiki/File:Iran,_Dasht-e-Kavir_desert_(9261278088).jpg (last access 16.03.2024).

Tengberg 2012; Zanjani 2012). Although this region is located at an altitude of 960 m a.s.l., it is characterized by a warm climate caused by the proximity to the desert. The western valley forms a natural pathway along the eastern foothills of Karakas Mountains, which follows from the northern plains of Qom to the Kerman province in the south (Zanjani 2012: 1–2). Botanical investigations showed that in prehistoric times the geological situation sculpted a climate and its depending vegetation similar to the one today (Shirazi and Tengberg 2012: 17). The vegetation in the Kashan plains consisted mainly of small shrubs and bushes (*Fabaceae, Chenopodia, Asteraceae*), adapted to a hot and arid climate. To the north, in the direction of Kashan plains, a sandy vegetation zone with mainly sand-binder plants (*Calligonum* and *Haloxylon*) was widespread. In the south- and southwestern located mountain foothills an open plant formation, consisting mainly of small shrubs, was predominant, while the mountains were covered by a steppe-forest (Shirazi and Tengberg 2012: 17–26). Around the natural water sources a high variety of flora and fauna was distinct. Species like willow, poplar, and tamarisks were frequent next to rare species as wild almonds, hackberry and pistachio. Today also fruit species like walnut, pistachio, almonds, and mulberries are cultivated (Shirazi and Tengberg 2012: 18).

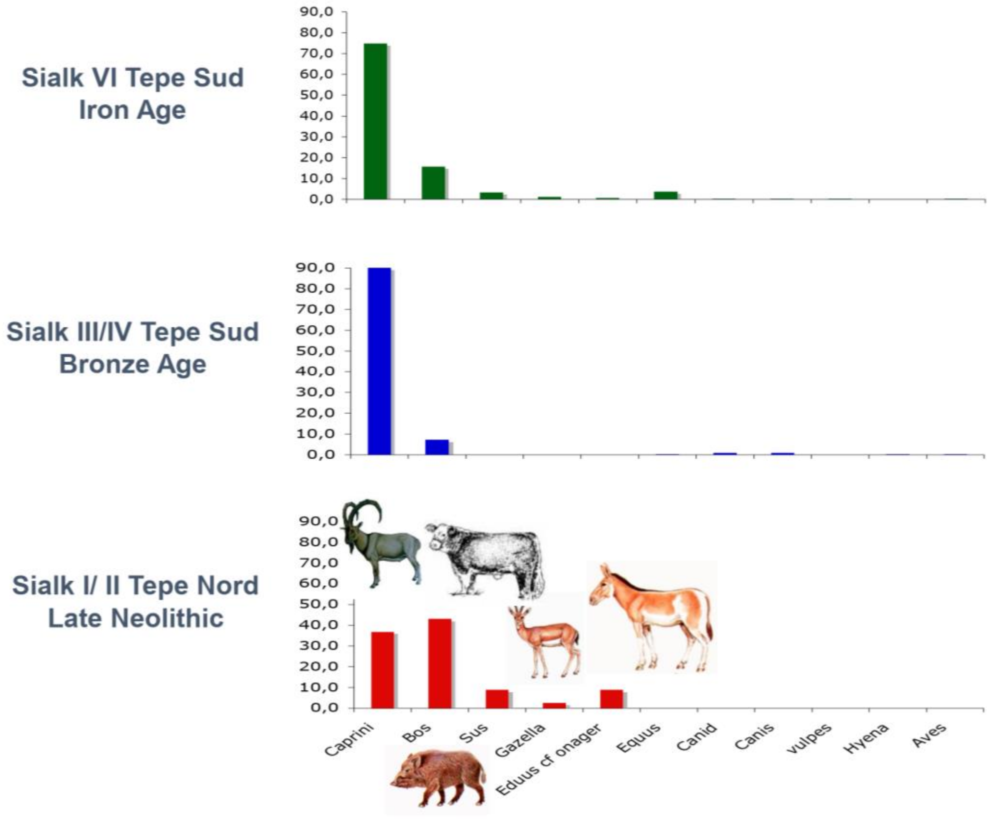


Fig. 9.4: Faunal spectra of Tepe Sialk (courtesy of Marjan Mashkour).

The archaeobotanical analyses brought remains of wheat and barley (*Triticum dicoccum, Triticum aestivum, Hordeum vulgare*) to light in high numbers. Moreover grapes (*Vitis vinifera*), and lentils (*Lens* sp.) could be determined, but in smaller numbers. The remains go back to the earliest layers and prove farming activities already in Neolithic periods in Tepe Sialk (Tengberg 2003, 2004). The faunal assemblage of Tepe Sialk consisted of domestic sheep and goats in a high number, wild forms were present in very low numbers, just as domestic cattle (cf. fig. 9.4 and Mashkour 2002, 2004a, b, et al. 2019). Gazelles seem to have been the main prey of hunting activities. Equids and suids were present, but contributed very little to the diet. Most equid remains were identified as hemione, at least for the earlier periods. Several other taxa could be identified during the excavation as dogs, fox, hyena, leopard and different bird taxa (Ghirshman 1939: 195–197; Mashkour 2002).

9.2.3. Burial customs

From the beginning of its discovery Sialk is an impressing case, especially because of the number of graves and immense variety of grave inventories. Especially the two graveyards revealed hundreds of well-preserved, and opulently equipped burials (cf. Ghirshman 1939: 113–192, pl. XXXVII–LXXIX). Necropolis A was located 250 m south of the Sialk B mound, 15 inhumations were excavated and documented (cf. Ghirshman 1939: 3–4). Necropolis B is located west of Sialk southern mound and comprises two graveyards (B1, B2) with 218 excavated graves (fig. 9.5 and Ghirshman 1939: 26–28).

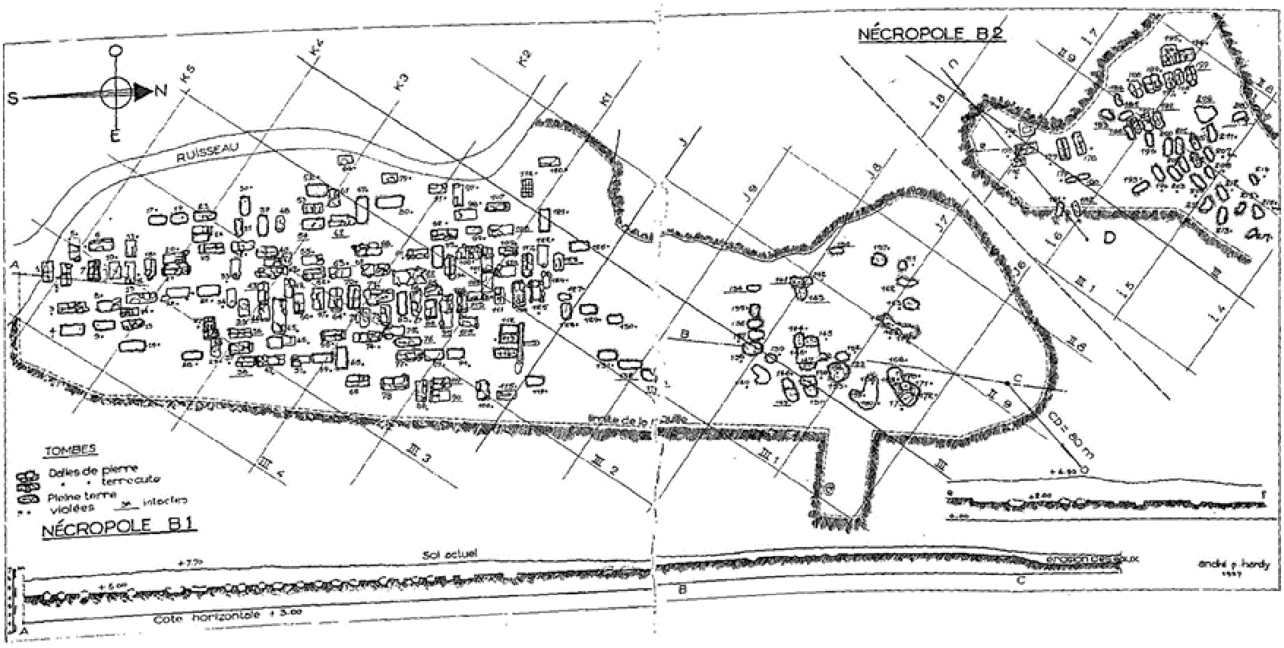


Fig. 9.5: Sialk Necropolis B after Ghirshman 1939: pl. XXXVI.

Ghirshman distinguished three main types of grave constructions: stone cist graves, graves with a fundament of rubbles, and simple earth-pit graves. The predominant burial custom were single inhumation graves, but also double and multiple burials were present. During the early periods (Neolithic/Chalcolithic) bones were often covered with red ochre and buried below the floors and walls in domestic contexts. Especially subadults were more often buried in intramural contexts. Grave goods are in general rare. Cremations are also documented in the earliest Tepe Sialk levels. The bodies of adults were also burnt, whereas the bodies of infants were buried without burning (Soltysiak and Fazeli 2010). Especially recognizable are mixed contexts of burnt adults buried together with unburnt subadults. “Although cremations are rare through all periods in the Near East […] obviously, cremation at Tepe Sialk was not accidental” (Soltysiak and Fazeli 2010: 10), indicating additional differing burial traditions in Tepe Sialk than at contemporaneous, adjacent sites. The later Iron Age burials from Necropolis A and B were mainly square and round pit constructions, sometimes with complex stone cists (Necropolis B, cf. Ghirshman 1939: Pl XLIX–LXXVIII) but also closing mud brick walls were common. Inhumation burials are known only from these time periods, where bodies were put in varying flexed positions. Grave inventories were partly extremely rich, including all types of objects of e.g., metal like weapons (daggers, swords, spears- and arrowheads), tools (needles, pins, knives, sickles, mirrors) made of copper, iron, as well as jewelry (finger-, food-, hair- and clothe-rings, bracelets, chains) with inlets of gold, semi-precious stones in a high variety (e.g., quartz, turquoise, lapis lazuli, carnelian). Moreover, many very diverse figurines (humans and animals), seals (stamp and cylinder), and miniature boxes, towers, phials, horse-gear, and a huge number of jars, vessels, plates, bowls, cans, goblets, or beakers. The most famous object is for sure the beak-spouted ewer. For discussion and information on the rich pottery ensemble cf. Ghirshman (1939), Boehmer (1965), Tourovetz (1989), Voigt and Dyson (1992), Helwing (2005). Ghirshman summarized the studied material from the earliest to the latest periods with technical analogues and cultural influences from Turkmenistan and sites like Anau or Namazga Dape (1938: 103), as well as to southern Mesopotamia with the Ubaid tradition and sites like Ur, Uruk or Tello (1938: 107), or Northern Mesopotamia and Samarra, Tell Halaf, and Nineveh (1938: 110–112).

Fig. 9.6: Sialk III burial 27276 bronze pin Ghirshman 1939: 120 pl. LXXXIV and pottery vessels from Necropolis B (pictures taken by the author in the National Museum in Teheran and Louvre).

9.2.4. The protagonists

To begin some issues concerning the investigated individuals from Tepe Sialk need to be clarified. The nomenclature of the Sialk graves used in this study was adopted by the collection of the Musée de l'Homme (MdH), because different scientists working on the material came to this agreement to ensure a certain uniformity of the results. The correlating denomination of Ghirshman will be defined in this chapter and can also be found in the Appendix table 3, but was not used in the following chapters and figures. As the anthropological description is very well presented by Ghirshman (1939: 116–125), the corresponding references can be found in the following text, but only a brief summary of the finding conditions will be given here.

The early graves from Tepe Sialk were all discovered at the northern mound without grave inventories or burial constructions. The burials from the Neolithic period (Sialk I) comprised three graves, burial 27281 (N°101, Sialk I_5, cf. Ghirshman 1939: 116) was a single burial of a 30–40-year-old man, buried in extreme crouched position on the right site, the bones were covered with red ochre. Burial 27282 (N°102, Sialk I_4, cf. Ghirshman 1939: 116) was an adult woman of 30–40 years, buried in extreme crouched position on the right side (fig. 9.7). On her bones traces of red ochre were found as well. Burial 27283 (N°103, Sialk I_4) was a double burial (cf. fig. 9.7), but only one individual was described by Ghirshman (1939: 116). It is a 30-year-old woman, buried in flexed position on the right side (cf. fig. 9.7). The second body was buried in spoons position, in a slightly flexed position. Here traces of red ochre were also documented.

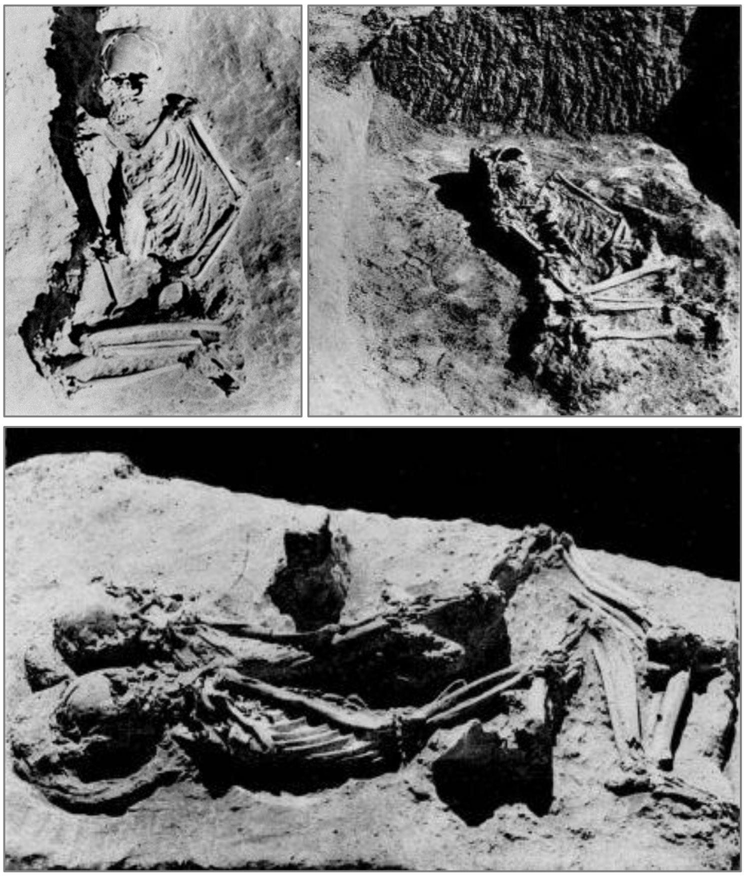


Fig. 9.7: Sialk I burials: top left burial 27281, top right burial 27282, bottom burial 27283 after Ghirshman 1939: pl. X 1–3.

The investigated individuals of the Sialk II period, the transitional Chalcolithic, comprise five burials. Burial 27268 (N°107, tomb 1, fouille II, Sialk II_3, cf. Ghirshman 1939: 118) was a 40–50 years old woman, buried in extreme flexed position on the right side. No funeral inventory has been found, but traces of red ochre. The grave was located next to burial 27269 (N°108) but ca. 2 m deeper (cf. fig. 9.8). Burial 27269 (N°108, tomb 2, fouille II, Sialk II_2, cf. Ghirshman 1939: 118) was a 25–30-year-old man, buried in crouched position on the right side (fig. 9.8), without grave goods, but traces of red ochre.

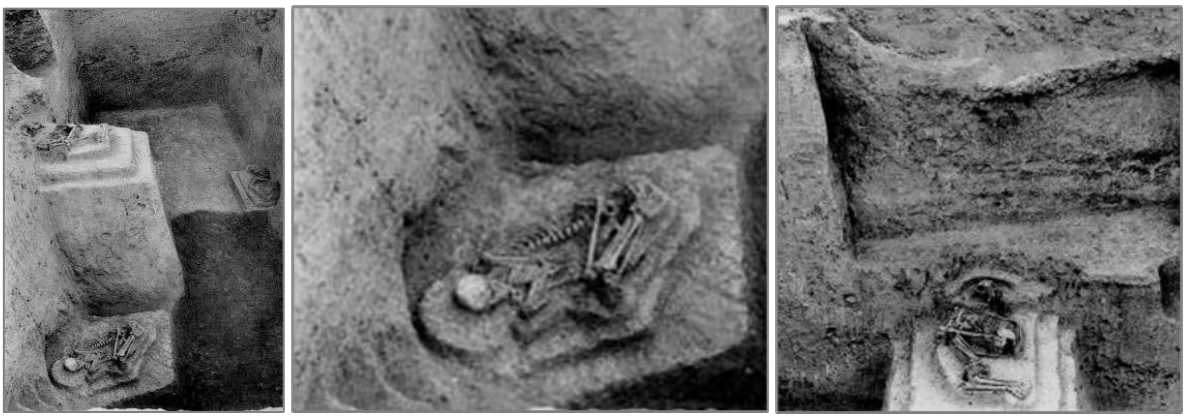


Fig. 9.8: Sialk II burials: left: overview of trench 2 with both burials; middle: burial 27268; right: burial 27269 after Ghirshman 1939: pl. XI 2–3.

Burial 27270 (N°109, tomb 1, fouille III, Sialk II_2, cf. Ghirshman 1939: 118) was a poorly preserved burial of an adult man (ca. 50 years), no further information was available. Burial 27271 (N°110, tomb 5, fouille II, Sialk II_1, cf. Ghirshman 1939: 119) was a young woman of ca. 15–18 years of age, where only the skull was preserved, on which traces of red ochre were found, too. Burial 27272 (N°111, tomb 6, fouille II, Sialk II_1, cf. Ghirshman 1939: 119) was a young woman (ca. 20–26 years of age) of the Sialk II period, only scattered bones were preserved, likewise two children of the Sialk III period. Burial 27273 (N°1, tomb 18, Sialk III_2, cf. Ghirshman 1939: 119) was an 8–10-year-old child, burial 27274 (N°2, tomb 17, Sialk III_2, cf. Ghirshman 1939: 119), was between 6 and 10 years old. Sialk III comprises the late Chalcolithic and EBA graves. Burial 27275 (N°3, tomb 12, Sialk III_3, cf. Ghirshman 1939: 119–120) was a 30–40-year-old man, which was as well poorly preserved, beside traces of ochre only scattered cranial bones were documented. Burial 27276 (N°112, Sialk III_5, cf. Ghirshman 1939: 120) was located in the substratum 5, where the graves described by Ghirshman are generally richer. Burial 27276 was an adult woman (25–30 years) buried under the wall of a house. Three vessels, a seal and a large pin with a conical head were found (fig. 9.6).

No material was provided from Sialk IV periods, in the next period, Sialk V, the dead were already buried on Necropolis A, but only one grave was investigated from this period. Burial 27305 (N°4, Necropolis A, tomb V, Sialk V, cf. Ghirshman 1939: 121) was a 30–40-year-old (most likely) man with an extraordinary rich funeral inventory (fig. 9.9). Next to several pottery vessels, a cylinder seal, several beads of carnelian, silver and copper, rings, as well as numerous small metal fragments were found with him.

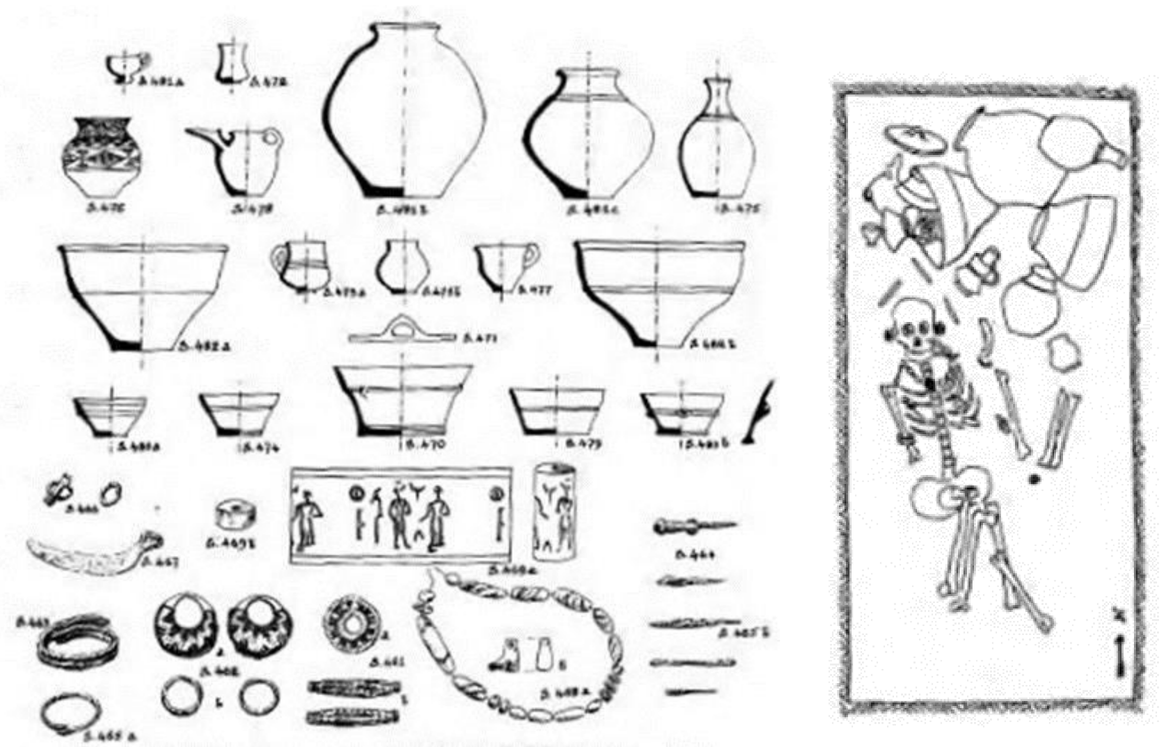


Fig. 9.9: Sialk V Necropolis A burial 27305 after Ghirshman 1939: pl. XL.

During Sialk VI, the Iron II period, the dead were buried in Necropolis B. All in all five individuals have been investigated from this period. Burial 27288 (N°7, Necropolis B, tomb 39, Sialk VI, cf. Ghirshman 1939: 122) was a mature woman (ca. 50–60 years) found without grave goods. No pictures are available from Ghirshman, but a picture of the MdH archive can be presented (cf. fig. 9.10).

Fig. 9.10: Sialk VI skull of burial 27288 (©Musee del´Homme).

Burial 27290 (N°9, Necropolis B, tomb 52, Sialk VI, cf. Ghirshman 1939: 122) was the burial of at least 3 individuals (fig. 9.11). According to Boehmer (1965) tomb 52 belongs to group B2, dating around 770–680 BCE, while group B1 is dated to around 820–740 BCE. Numerous finds were documented, as e.g., jewellery, as beads, a chain, several rings, a bronze mirror, daggers and a sickle, horse gear. Especially remarkable is the beautiful ensemble of pottery vessels, including forms of beak-spouted ewers, fig. 9.10, and bowls with the typical geometric paintings. One adult male individual (50–60 years) out of this burial was analysed.

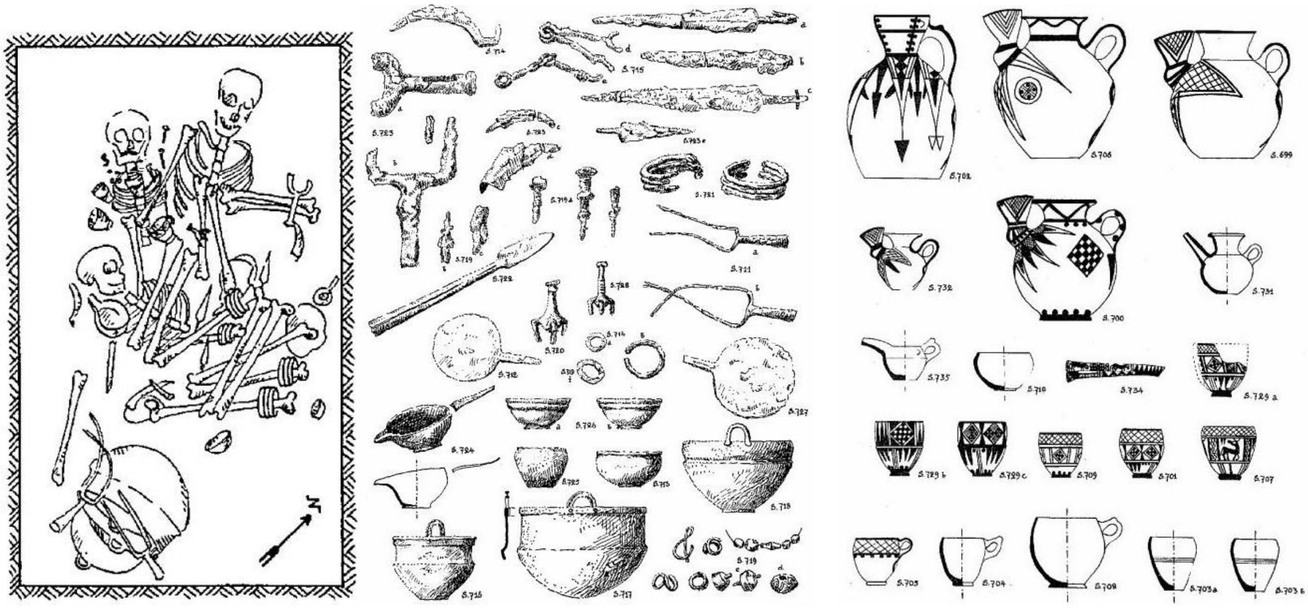


Fig. 9.11: Sialk VI Necropois B burial 27290 after Ghirshman 1939: pl. LXVI–LXVII.

Burial 27295 (N°118, tomb 136, Necropolis B, cf. Ghirshman 1939: 123) was a young woman between 15 and 18 years of age in a single burial, buried as well with a number of grave goods like e.g., a red slipped footed cup, a bronze pin with lion head, a bronze bracelet with silver beads, a bronze ring, earrings made of silver beads, and a pendant or button of bronze (fig. 9.12). Burial 27298 (N°121, tomb 186, Necropolis B, cf. Ghirshman 1939: 124) was a mature woman (50–60 years), the grave was disturbed and looted, only some traces of iron fragments were found (Tourovetz 1989). Burial 27300 (N°123, tomb 192, Necropolis B, cf. Ghirshman 1939: 124) was a young woman, where only the skull was preserved. No grave inventory was found.

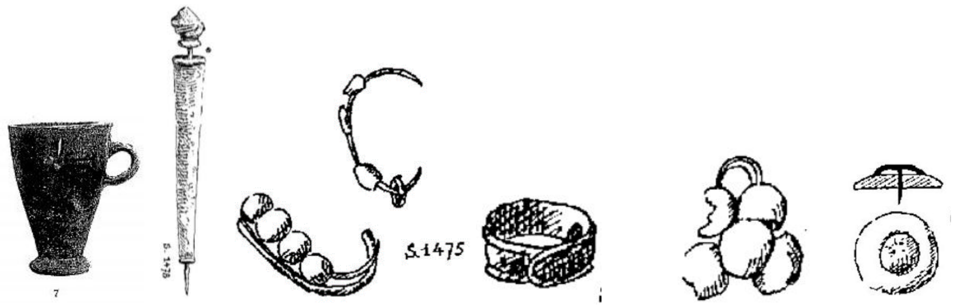


Fig. 9.12: Sialk VI grave goods of burial 27295. References after Ghirshman 1939 from left to right: red cup pl. XCIII. S. 1478 T. 136; bronze pin pl. XXIX,1; XCIII. S. 1478 T.; bracelet of silver beads pl. XCIV. S. 1475. T. 136; bronze ring S. 1476. T. 136; earrings of silver S. 1476 b; and bronze button S. 1476 a. T. 136.

9.3. Mobility and migration in Tepe Sialk

The migration issue in Tepe Sialk is compelling from several points of view. On the one hand Tepe Sialk was a powerful center of trade in the region, with networks in all directions, Ghirshman already stated for the earlier periods (Sialk III) close cultural relations to the east (Ghirshman 1938). Iconographic and technical features of pottery, as well as seals show strong relations with sites like e.g., Tepe Hissar (Pittman 2019), and Shahr-i Sokhte (Tosi 1968), but also Gonur Depe and the Oxus civilization (Khlopina 1981; Sarianidi 1998). Moreover, although on the periphery, Sialk was still part of the proto- and elamite realm (Sialk III/IV). Architectural remains were deeply influenced by southern Mesopotamia, with strong analogues to Godin Tepe, Susa, and Uruk (Ghirshman 1938; Young 1969). These different cultural influences through all periods, and additionally the geographic location between the natural pathway through the Karakas mountains and the entrance of Kavir desert, along one of the main roads for passing the desert towards the east, makes the composition of the population from Tepe Sialk very interesting for the determination of migration impacts, respectively provenience of the people. Many different opinions of scholars exist on the composition and subsistence of the people from Tepe Sialk, Fahimi e.g., summarized "for a long time, we thought that the Iron Age lifestyle on the Iranian Plateau was nomadic and we always referred to the high number of graveyards mentioned in relation to settlement. Now, because of the discovery of many Iron Age settlement sites on the Central Iranian Plateau, we have to be more cautious with this invalid opinion" (Fahimi 2019: 341). This statement perfectly mirrors the present state of research, respectively the ongoing discussions concerning the Iron Age periods. Not only the discoveries of new sites expand our knowledge every day, the here obtained isotopic data provide some more insights concerning the mobility and lifestyle of the communities that inhabited Tepe Sialk during millennia.

9.3.1. Results of strontium ($^{87}Sr/^{86}Sr$) and oxygen ($\delta^{18}O$)

The itemized results of all humans and animals from Iran are listed in the Appendix table 8, a summary of strontium and oxygen results is presented in table 9.1. The material from Tepe Sialk was in quite poor condition, implying that the error values (2σ level) measured for the $^{87}Sr/^{86}Sr$ ratios ranged from 0.000004 to 0.000010. The standard deviation of $\sigma\ \delta^{13}C = 0.03‰$ for carbon and $\sigma\ \delta^{18}O = 0.06‰$ for oxygen was fulfilled for 11 out of 18 samples of tooth enamel, and 9 samples out of bone compacta.

Strontium out of tooth enamel could be extracted for 13 individuals, out of bone compacta of 9 individuals, while samples only consisting of teeth were additionally analysed for tooth dentine (n = 6) and classified into the local range (cf. chapter 4.5.1.). A Levene test showed that there is no homogeneity of variances of the $^{87}Sr/^{86}Sr$ values between the Iranian and the Central Asian sites ($F(1.78) = 1.40$, $p < 0.001$). The one-way ANOVA showed that the differences between the periods in Sialk are statistically not significant ($F(2.51) = 0.47$, $p = 0.841$), just as the differences according to sex are statistically not significant. According to a Levene test, the $\delta^{18}O$ values of Iran and southern Central Asia showed a strong homogeneity of variance ($F(1.75) = 1.58$, $p = 0.091$). The one-way ANOVA proved no statistically significant differences in Sialk, neither between the periods ($F(2.47) = 1.02$, $p = 0.459$), nor between gender ($F(3.00) = 0.23$, $p = 0.872$). The deviations were negligible small, error bars are overlapped by the applied symbols in the figures. Hence, symbols encompass the error margins at 2σ level for the $^{87}Sr/^{86}Sr$ ratios and 1σ level for $\delta^{18}O$ ratios.

Table 9.1: Summary of human $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{apa}$ results from Tepe Sialk

	$^{87}Sr/^{86}Sr$					$\delta^{18}O_{apa}$ (‰ V-PDB)					
Period	**n**	**Min**	**Max**	**Mean**	**± 2б**	**n**	**Min**	**Max**	**Interval**	**Mean**	**± б**
Sialk I E	**3**	0.707980	0.708453	**0.708144**	± 0.000218	**3**	-6.6	-2.6	3.1	**-5.0**	± 1.73
Sialk I B/D	**3**	0.708062	0.708234	**0.708134**	± 0.000073	**3**	-5.4	-4.2	1.2	**-5.0**	± 0.59
Sialk II E	**4**	0.707964	0.708469	**0.708117**	± 0.000206	**3**	-6.3	-5.0	1.3	**-5.7**	± 0.55
Sialk II B/D	**4**	0.707998	0.708256	**0.708103**	± 0.000097	**4**	-5.8	-3.9	1.9	**-4.7**	± 0.71
Sialk III E	**3**	0.707969	0.708577	**0.708166**	± 0.000291	**3**	-6.4	-4.5	1.9	**-5.4**	± 0.77
Sialk III B	**4**	0.707957	0.708020	**0.707984**	± 0.000025	**4**	-6.2	-3.4	2.8	**-5.0**	± 1.02
Sialk V B	-	-	-	-	-	**1**	-4.7		-	-	-
Sialk VI E	**3**	0.708023	0.708367	**0.708138**	± 0.000162	**2**	-4.1	-2.5	1.6	**-3.3**	± 0.80
Sialk VI B	**4**	0.707997	0.708026	**0.708005**	± 0.000012	**5**	-5.3	-3.9	1.4	**-4.5**	± 0.53

The $^{87}Sr/^{86}Sr$ results of all Sialk humans ranged between 0.707952 and 0.708577 with a mean of 0.708085 (± 0.000186, n = 22, fig. 9.13), the enamel samples showed an $^{87}Sr/^{86}Sr$ mean of 0.708139 (± 0.000224, n = 13), bone samples of 0. 0.708007 (± 0.000041, n = 9). The $^{18}O/^{16}O$ ratio ($\delta^{18}O_{apa}$) of all samples ranged between -6.5‰ and -2.5‰ with an interval of 4‰ and an average of -4.9‰ (± 1.1‰, n = 25, fig. 9.14). The enamel samples displayed a $\delta^{18}O_{apa}$ average of -4.9‰ (± 1.3‰, n = 13), while bone samples had a $\delta^{18}O_{apa}$ average of -4.9‰ (± 0.8‰, n = 12). Concerning the three Sialk I (Neolithic) individuals, only one sample was provided with bone and tooth material, while only teeth were present for the other two individuals. The enamel $^{87}Sr/^{86}Sr$ ratios ranged between 0.707980 and 0.708453 with a mean of 0.708144 (± 0.000218, n = 3), the $\delta^{18}O_{apa}$ enamel ranged between-6.6‰ and -2.6‰ with an interval of 3.1‰ and a mean of -5.0‰ (± 1.7‰, n = 3). The one bone sample had a $^{87}Sr/^{86}Sr$ ratio of 0.708105 and a $\delta^{18}O_{apa}$ ratio of -5.4‰. Of the five Sialk II (transitional Chalcolithic) individuals, four only consisting of teeth samples, showed $^{87}Sr/^{86}Sr$ enamel results between 0.707964 and 0.708469 with a mean of 0.708117 (± 0.000206, n = 4), $\delta^{18}O_{apa}$ enamel ranged between -6.3‰ and -5.0‰ with an interval of 1.3‰ and a mean of -5.7‰ (± 0.6‰, n = 3). The one bone sample was not sufficient for strontium analyses, but displayed a $\delta^{18}O_{apa}$ result of -5.8‰. The four Sialk III (chalcolithic) individuals provided $^{87}Sr/^{86}Sr$ enamel ratios between 0.707969 and 0.708577 with a mean of 0.708166 (± 0.000291, n = 3), while the $\delta^{18}O_{apa}$ results ranged between -6.4‰ and -4.5‰ with an interval of 1.9‰ and a mean of -5.4‰ (± 0.8‰, n = 3). The bone $^{87}Sr/^{86}Sr$ results ranged between 0.707957 and

0.708020 with a mean of 0.707984 (± 0.000025, n = 4), $\delta^{18}O_{apa}$ ranged between -6.2‰ and -3.4‰ with an interval of 2.8‰ and a mean of -5.0‰ (± 1.2‰, n = 4).

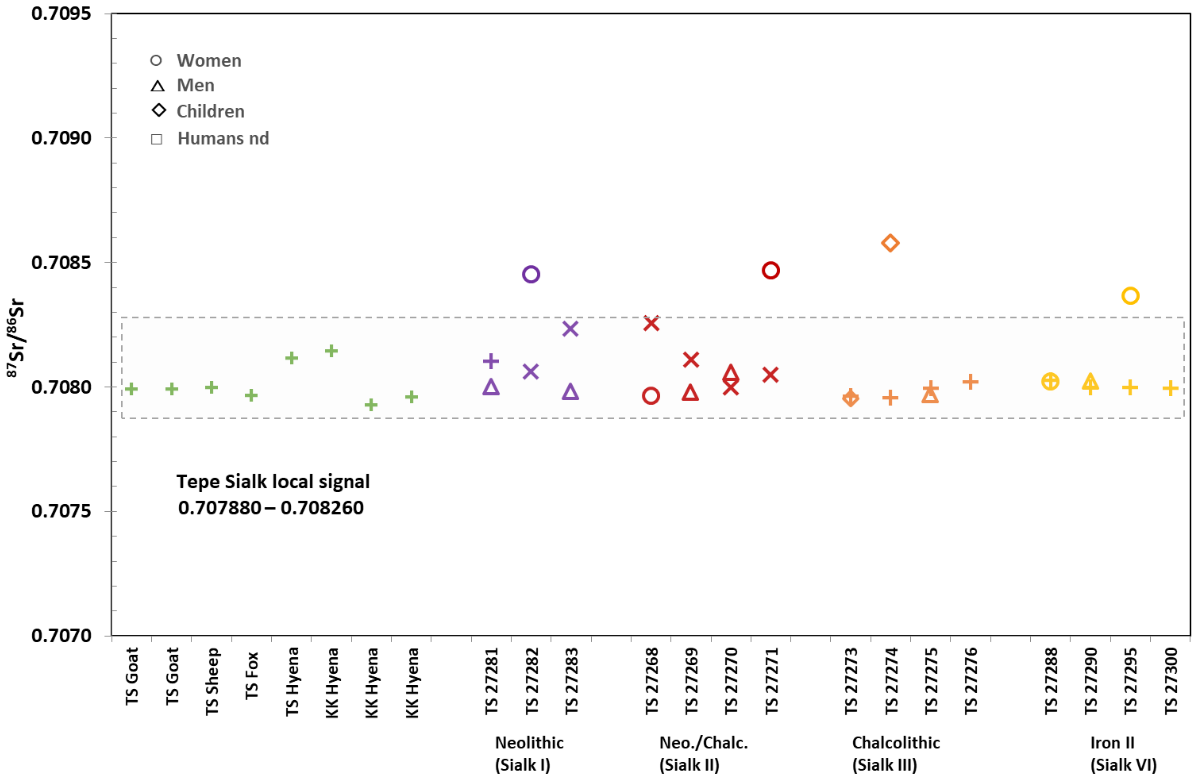


Fig. 9.13: Human intra-individual $^{87}Sr/^{86}Sr$ variations from Tepe Sialk (TS). Bone samples are marked with plus, X mark the dentine samples, tooth enamel samples are given with the particular gender. Dashed box marks the determined local range of Tepe Sialk. Symbols encompass the error margins at 2σ level.

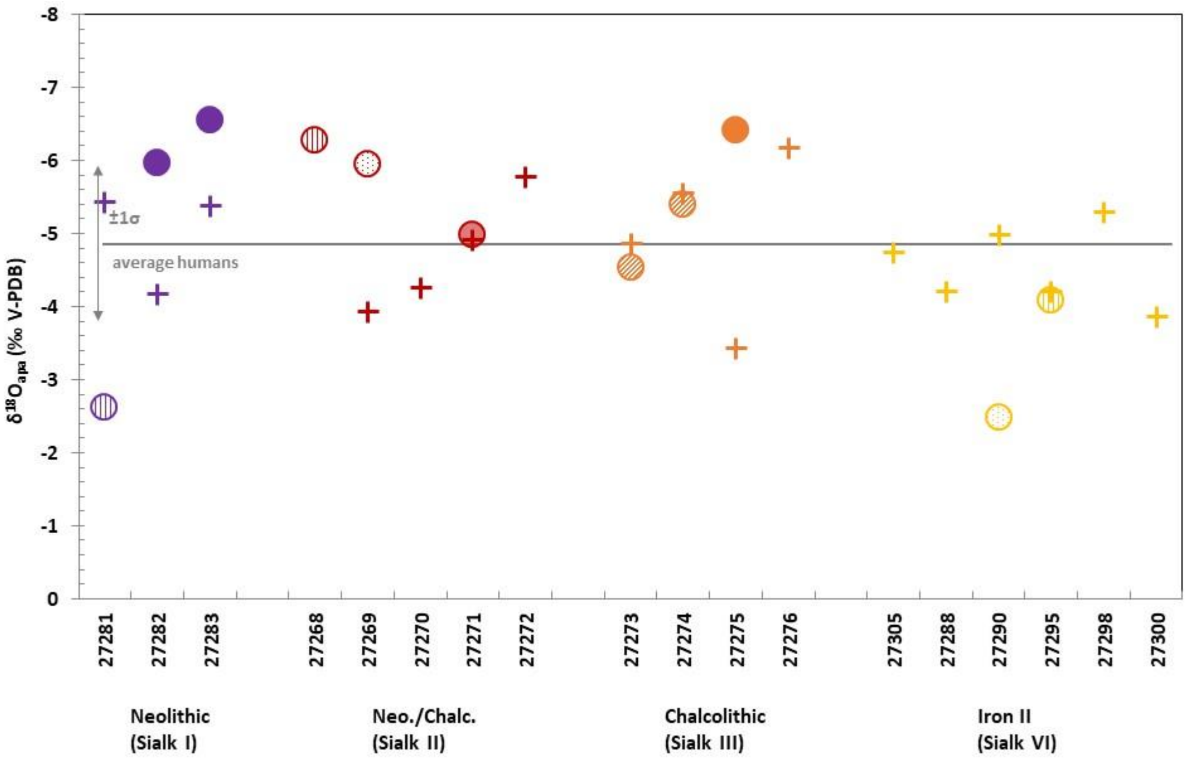


Fig. 9.14: Intra-individual variations of $\delta^{18}O_{apa}$ of humans from Tepe Sialk: plus correspond to bone samples, circles to tooth enamel (black M3, dark grey M2, light grey M1, empty M not determined, vertical stripes PM, horizontal stripes C, dots I). The symbols encompass the error margins at 1σ level for $\delta^{18}O$ ratios.

The material obtained from the remains of the male adult from the Sialk V (Iron I) period was not sufficiently preserved for strontium analyses, but a $\delta^{18}O_{apa}$ bone result of -4.7‰ could be measured. The five Sialk VI (Iron II) individuals displayed enamel $^{87}Sr/^{86}Sr$ results between 0.708023 and 0.708367 with a mean of 0.708138 (± 0.000162, n=3) and $\delta^{18}O_{apa}$ between -4.1‰ and -2.5‰ with an interval of 1.6‰ and a mean of -3.3‰ (± 0.8‰, n = 2). Their bone $^{87}Sr/^{86}Sr$ ratios ranged between 0.707997 and 0.708026 with a mean of 0.708005 (± 0.000012, n = 4), $\delta^{18}O_{apa}$ ranged between -5.3‰ and -4.2‰ with an interval of 1.1‰ and a mean of -4.5‰ (± 0.5‰, n = 5).

9.3.2. Reconstruction of human spatial movements

9.3.2.1. Migration according to strontium $^{87}Sr/^{86}Sr$

Of the 15 analysed individuals, 11 formed a rather homogeneous group in regard to the determined local $^{87}Sr/^{86}Sr$ range (cf. chapter 4.5.1.). Although the number of samples was so small, every period features one individual who did not fall within the local range (fig. 9.13). In the Sialk I, just as Sialk III and Sialk VI, one out of three individuals differs from the local range (Sialk I: 27282, Sialk III: 27274, Sialk VI: 27295). While in the Sialk II period the ratio is one (27271) out of four individuals who vary from the local range. The results indicate a constant immigration rate through all periods, although this hypothesis has not been statically substantiated yet due to the low number of samples. Interestingly three of the four “non-locals” were young women, one, was a 6–10 years old child from the Sialk III period. Until more data are available, it can only be assumed whether this mere coincidence or if there is a hidden pattern yet to be unveiled. All foreign women feature a similar strontium ratio, which could argue for a common place of birth, but with intervals of 3000 years in between. Still, it could indicate, the former existence of an affiliated place, which was in close contact to the population of Tepe Sialk and between which a frequent gene flow existed. Two individuals from the early periods (Sialk I: 27283; Sialk II: 27268) differ slightly in bone oxygen and strontium results. But these two repatriates were born in Sialk and were buried in Sialk, what might be an indication for a mobile lifestyle centred in Tepe Sialk during Neolithic and Chalcolithic periods. One individual was male the other female, giving, as expected, no hint of any gender differences concerning their lifestyle ordained by traditional role models.

9.3.2.2. Mobility according to oxygen $\delta^{18}O$

It should be mentioned first, that, due to the provided material, the number of obtained results from tooth enamel (n = 12) does not conform to the numbers of obtained bone results (n = 17). The $\delta^{18}O_{apa}$ ratios of all human samples from Tepe Sialk ranged between -6.5‰ and -2.5‰ with an average of -4.9‰ (± 1.1‰ n = 28). The results are, similar to Ulug Depe, in the upper range of the oxygen scale, indicating a hot and arid climate for Tepe Sialk as well. The tooth enamel samples provided an $\delta^{18}O_{apa}$ average of -4.9 (± 1.4‰ n = 12) and an interval of 4.1‰, while bone samples displayed a $\delta^{18}O_{apa}$ average of -4.8 (± 0.7‰ n = 17) and an interval of 2.8‰. The results showed an accumulation around -4‰, but several individuals spread to significant lower and higher values (cf. fig. 9.15) indicating that the people who lived in Sialk ingested water from some main water sources. While the teeth enamel results, respectively the origin of the people, contained traces of different water sources (Lightfoot et al. 2016; White et al. 2004).

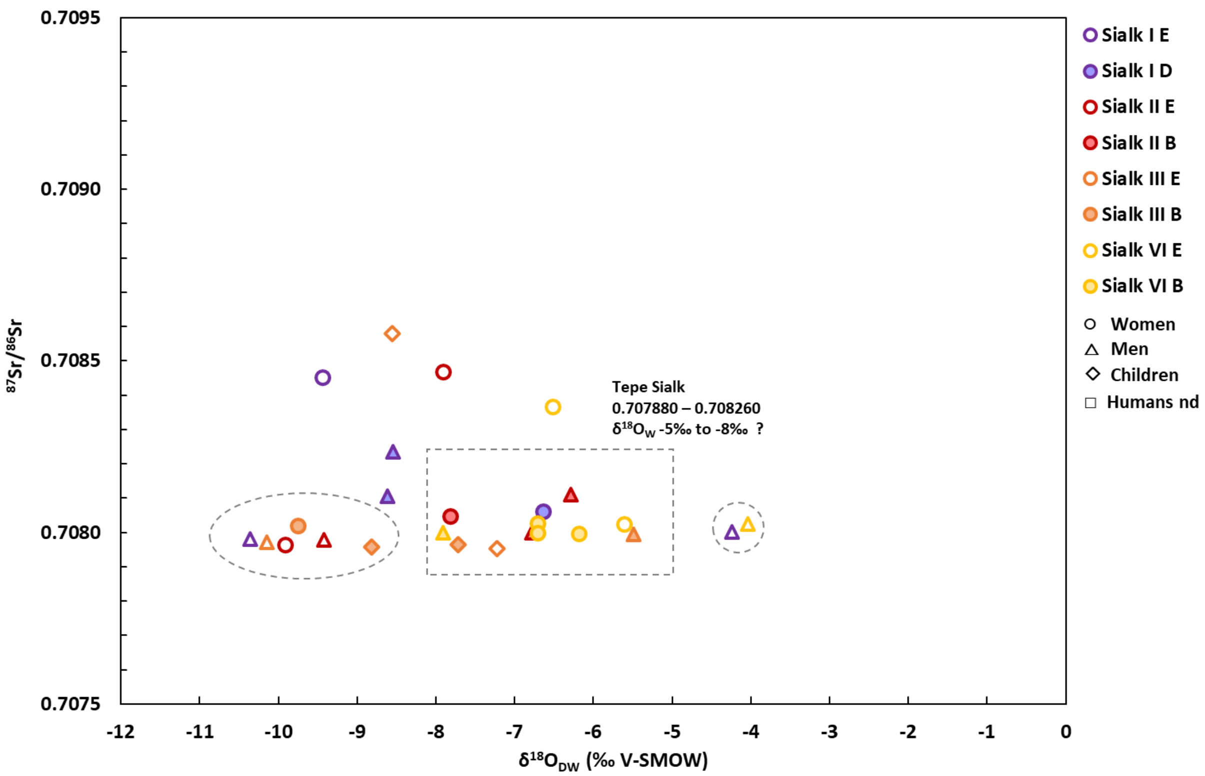


Fig. 9.15: Scatterplot $^{87}Sr/^{86}Sr$ versus $\delta^{18}O_{DW}$ ratios of Tepe Sialk humans. The symbols encompass the error margins at 2σ level for the $^{87}Sr/^{86}Sr$ ratios and 1σ level for $\delta^{18}O$ ratio. The dashed box marks the approximate local $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{DW}$ range of Tepe Sialk including the error margins at 1σ ($\delta^{18}O_{DW}$) and 2σ ($^{87}Sr/^{86}Sr$) levels, dashed circles indicate the coexisting accumulations.

Calculating the drinking water ranges (after Coplen et al. 1988, Iacumin et al. 1996, Daux et al. 2008) for the tooth enamel samples one yields $\delta^{18}O_{DW}$ ratios between -4.2‰ and -10.4‰ with an average of -8‰ (2.2‰ n = 11), and for bone samples $\delta^{18}O_{DW}$ ratios from -9.8‰ to -5.5‰ with an average of -7.6‰ (1.2‰ n = 17). Tooth enamel samples displayed a $\delta^{18}O_{DW}$ interval of 6.2‰, bone samples of 4.3‰. According to the OIPC the calculated annual averaged $\delta^{18}O_{W}$ of Tepe Sialk is -6.0‰, the GNIP names a value of -6.29‰. The $\delta^{18}O_{DW}$ results indicate three accumulations through all periods, especially of male enamel signatures. One accumulation is between -8‰ to -10‰, but the transition is close, and the second accumulation is around the $\delta^{18}O_{W}$ value of Sialk, while the third "accumulation", again two men (Sialk I and VI), fall within conspicuously higher ranges around -4‰. The higher oxygen results indicate an origin in a lower, hotter and more arid region. In the surroundings of Sialk this can only mean more east towards the desert or the Caspian Sea shore, which are both according to the OIPC range around -3‰. The accumulation in the lower ranges indicates an origin in a higher, colder region, but with a similar strontium signal. The valley where Tepe Sialk is located is surrounded by high mountains to the north and west and the Kavir desert to the east. Regarding this, it is most likely that next to Sialk other small settlements existed in the valley, hence within the same geological environment of strontium isotopes but with different groundwater sources.

When itemizing the results in chronological order, the enamel samples in the lower ranges belong to individuals of Sialk I to Sialk III. These periods cover the Neolithic, the transition, and the

Chalcolithic phases. While the individuals from the Iron Age all displayed higher $\delta^{18}O_{apa}$ ratios. It is difficult to assume a similar decrease of mobility towards the later periods, as it was indicated for Ulug Depe. No Bronze Age individuals from Sialk were available, and the Iron Age individuals in Ulug Depe showed a higher mobility again, while in Sialk the Iron II people (beside one man) displayed homogeneous results within the expected local signal, indicating rather little mobility.

The intra-individual $\delta^{18}O_{apa}$ variations of the individuals from Sialk ranged between 0.1‰ and 2.8‰ with an average of 1.4‰ (±1.12‰ n = 10). The intervals remain somehow constant over time, as no significant changes were definable between the periods, and all display high as well as very small variations (fig. 9.14, 9.15). Furthermore, the correlation between altitude and $\delta^{18}O_W$ according to the OIPC (Bowen 2010) resulted in an average of 0.3‰ per 100 m difference in altitude for Tepe Sialk (fig. 9.16). The highest intra-individual $\delta^{18}O_{apa}$ variation of 2.8‰ of a Neolithic man (27281), who was not standing out concerning his strontium values, indicates a difference in altitude of around 1000 m. Although the variation of 2.8‰ compared to the ovicaprids is not much, Sialk displayed the highest intervals compared to Ulug Depe and Dzharkutan, and therefore the highest degree of mobility among the individuals.

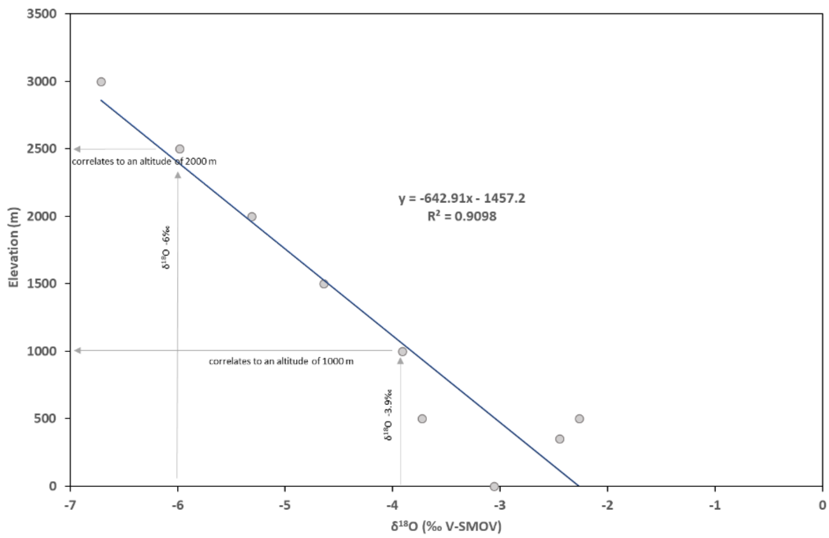


Fig. 9.16: Tepe Sialk differences in altitude correlating to the annual averaged $\delta^{18}O_W$ values of the OIPC (www.waterisotopes.org, last access 21.12.2020).

9.3.2.3. Gender and social differences

Compared to Ulug and Dzharkutan at Tepe Sialk a special pattern of migration seems to have been at work. It looks like, that in Sialk, where the proportion of male and female burials was most equalized, only women were identified as non-locals. Through all periods this pattern can be observed. But the number of samples is too small to utter more than an indication, whether Tepe Sialk can serve as an example for maternal migration where mainly women moved to new places. As we cannot attribute this to a special period, it is rather a coincidence of the selected samples than a distinct pattern. Concerning the oxygen results of men, they indicate a higher mobility, especially the early periods, but strontium results stayed quite homogeneous through all times.

Concerning the social rank of the individuals, respectively the funerary inventories no real distinction can be drawn yet, as the very rich graves from Sialk V and VI (272305, 27295, 27290) do not differ distinctly from the rest. Studies revealed a correlation between provenience and a higher social status (Münster et al. 2018), which can be adopted in Sialk for one grave, the young woman from burial 27295 (cf. chapter 9.2.4.). Whereas the three non-locals of the early periods were single burials in simple pit-constructions without any grave-goods. Hence, no statements on their social position can be drawn, and it is therefore not wise to proclaim a reliable correlation to mobility at the present state of research.

9.4. Subsistence in Tepe Sialk

Since Neolithic times people in Tepe Sialk cultivated crops as barley, wheat, and lentils, the natural food offer around springs and rivers were rich and the water supply enabled agricultural activities at least for some month of the year. Due to the location of Tepe Sialk on the southern border of modern Kashan city, and the resulting destruction of archaeological remains (e.g., irrigation systems), we do not have detailed information, on how the agricultural provision of Sialk´s inhabitants looked like. Fields around springs and along rivers seem reasonable, as the valley itself was dry and dominated by a steppe-, semi-desertic vegetation. We have evidence for animal breeding with a dominance of sheep, and goats, cattle rather less. Moreover, hunting of wild animals, mainly gazelles are documented for all periods (Mashkour 2002, 2004a, b).

Although Sialk was not part of the core area, the influence of the Uruk empire during the 4th mill. BCE and an ongoing urbanization are obvious in the archaeological remains. Urbanization is not only tightly connected to structural changes of the society and an increasing population, but also to the development of subsistence technologies and changes of strategies for a higher production. The question of millet as cultural and climatic indicator does not rise directly, because no traces have been found in Tepe Sialk. Although botanical studies documented millet in Iron Age layers in Bastam and Hasanlu in north-western Iran (cf. fig. 10.6; Miller et al. 2016), proving the presence of millet on the Central Plateau, but it is not the case for Tepe Sialk.

9.4.1. Results of nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C_{col}$, $\delta^{13}C_{apa}$) isotopes

The minimum of %C = 13% and %N = 5% content of Nitrogen and CO_2 needed for a sufficient quality of the collagen were fulfilled for 14 out of 18 individuals (Ambrose 1990). The calculated atomic ratio of Carbon to Nitrogen C/N did not result in the optimum range between 2.8 and 3.2 (DeNiro 1985) for all individuals, hence those with a ratio up to 3.5 were included in the present study. The itemized results from Tepe Sialk are listed in the Appendix table 8, a summary of collagen and carbonate results is presented in table 9.2. Error bars were not added to the graphs, as they are negligible and smaller than the plotted symbols. As already mentioned, the Kruskal-Wallis test proved that differences among Sialk, Ulug and Dzharkutan were not significant for both $\delta^{13}C_{col}$ and $\delta^{15}N$ ($\delta^{15}N$: $H(3) = -137.475$, $p = 0.728$; $\delta^{13}C_{col}$: $H(3) = -137{,}209$, $p = 1.383$). The one-way ANOVA analysis did attest no significantly different $\delta^{13}C_{col}$ values ($F(3.63) = 2.45$, $p = 0.143$), whereas the $\delta^{15}N$ values of Sialk individuals differed substantially between the periods ($F(3.63) = 7.48$, $p = 0.006$). The evaluation concerning gender did also not provide statistically relevant differences ($\delta^{15}N$: F(3.58) = 0.88, p = 0.481; $\delta^{13}C_{col}$: F(3.58) = 0.70; p = 0.569).

The $^{15}N/^{14}N$ ratio out of collagen ($\delta^{15}N$) of all human samples from Tepe Sialk through all periods showed the lowest $\delta^{15}N$ ratio at 12.5‰, the highest at 15.0‰, and an average of 13.7‰ (± ‰, n = 14), while carbon isotopes out of collagen ($\delta^{13}C_{col}$) ranged between -21.4‰ and -18.6‰ with an average of -19.6‰ (± ‰, n = 14). The three Sialk I individuals showed the lowest $\delta^{15}N$ result at 14.6‰, the highest at 15.0‰, and an average of 14.8‰ (± 0.2‰, n = 3). The $\delta^{13}C_{col}$ ranged between -20.1‰ and -19.8‰ with an average of -19.9‰ (± 0.2‰, n = 3). The four Sialk II individuals displayed the lowest $\delta^{15}N$ value at 11.9‰, the highest at 15.8‰, and an average of 13.3‰ (± 1.5‰, n = 4), while $\delta^{13}C_{col}$ ranged between -22.5‰ and -18.7‰ with a mean of -20.8‰ (± 1.3‰, n = 4). The $\delta^{15}N$ ratio of the three individuals of the Sialk III period ranged between 11.3‰ and 14.3‰ with an average of 13.9‰ (± 0.4‰, n = 3). $\delta^{13}C_{col}$ results were between -20.7‰ and -18.9‰ with a mean of -19.1‰ (± 0.2‰, n = 3). The one Sialk V individual, an adult man, showed a $\delta^{15}N$ results of 12.5‰ and a $\delta^{13}C_{col}$ result of -18.6‰. The five Sialk VI individuals displayed the lowest $\delta^{15}N$ value at 12.8‰, the highest at 14.8‰, and an average of 13.8‰ (± 0.6‰, n = 5), while the $\delta^{13}C_{col}$ results ranged between -20.0‰ and -19.0‰ with an average of -19.5‰ (± 0.4‰, n = 5).

Table 9.2: Summary of human and animal collagen results from Tepe Sialk

Trophic group	Species	n	$\delta^{15}N$ Collagen (‰ AIR) Min	Max	Mean	± б	Average	$\delta^{13}C$ Collagen (‰ V-PDB) Min	Max	Mean	± б	Average
Plants	C3 plants*	4	2.2	9.9	**5.7**	± 2.8	**5**	-28.3	-26.9	**-27.6**	± 0.7	
	C4 plant*	1	4.4		-	-		-12.6		-	-	
Herbivores	Gazelles*	5	6.9	9.4	**8.4**	± 0.9	**8.0**	-18.5	-16.6	**-17.7**	± 0.7	**-17.8**
	Sheep/goats	6	7.1	9.5	**8.2**	± 1.0		-19.2	-16.2	**-17.4**	± 1.0	
	Cattle	7	8.0	11.2	**9.5**	± 1.0		-19.0	-17.2	**-18.2**	± 0.6	
	Buffalo	1	6.9		-	-		-12.7		-	-	
Omnivores	Dogs	13	7.2	14.5	**10.6**	± 1.8	**11.0**	-19.2	-15.8	**-17.8**	± 1.1	**-18.3**
	Pig	1	5.6		-	-		-18.4		-	-	
	Wild boars*	4	9.7	12.2	**10.9**	± 1.0		-19.7	-18.4	**-19.1**	± 0.5	
Carnivores	Cat	1	16.4		-	-	**15.5**	-17.1		-	-	**-15.9**
	Fox	1	14.6		-	-		-15		-	-	
	Wolf*	1	15.5		-	-		-15.5		-	-	
Humans	Sialk I	3	14.6	15.0	**14.8**	± 0.18	**13.5**	-20.1	-19.8	**-19.9**	± 0.15	**-19.5**
	Sialk II	3	11.9	12.8	**12.5**	± 0.39		-21.4	-19.4	**-20.2**	± 0.86	
	Sialk III	2	13.6	14.3	**13.9**	± 0.37		-19.3	-18.9	**-19.1**	± 0.22	
	Sialk V	1	12.5		-	-		-18.6		-	-	
	Sialk VI	5	12.8	14.8	**13.8**	± 0.63		-20.0	-19.3	**-19.5**	± 0.53	

*after Bocherens et al. 2000

The ratio of $^{13}C/^{12}C$ carbon isotopes out of structural carbonate ($\delta^{13}C_{apa}$) of all human samples from Tepe Sialk shows the highest $\delta^{13}C_{apa}$ ratio at -10.3‰, the lowest at -14.9‰, and an average of -12.5‰ (± ‰, n = 28). The three Sialk I individuals showed the lowest $\delta^{13}C_{apa}$ enamel value at -12.9‰, the highest at -12.3‰ and a mean of -12.6‰ (± 0.2‰, n = 3), while $\delta^{13}C_{apa}$ dentine results ranged between -13.4‰ and -11.4‰ with an average of -12.7‰ (± 0.9‰, n = 3). The enamel $\delta^{13}C_{apa}$ results of the Sialk II individuals ranged between -13.0‰ and 11.3‰ with a mean of -12.2‰ (± 0.7‰, n = 3), bone and dentine $\delta^{13}C_{apa}$ results ranged between -13.0‰ and -10.3‰ with a mean of -12.0‰ (± 1.1‰, n = 4). The individuals of the Sialk III period showed $\delta^{13}C_{apa}$ enamel values between -12.9‰ and -12.0‰ with a mean of -12.5‰ (± 0.4‰, n = 3), bone $\delta^{13}C_{apa}$ results ranged between -14.9‰ and -12.4‰ with an average of -13.5‰ (± 1.0‰, n = 4). The one adult man of the Sialk V period showed a $\delta^{13}C_{apa}$ bone ratio of -11.0‰. The Sialk VI enamel $\delta^{13}C_{apa}$ results ranged between -13.7‰ and -12.9‰, bone $\delta^{13}C_{apa}$ ranged between -13.7‰ and -10.4‰. Enamel results displayed a $\delta^{13}C_{apa}$ mean of -13.3‰ (± 0.4‰, n = 2), while bone samples had a mean of -12.2‰ (± 1.3‰, n = 5).

9.4.2. The isotopic baseline of Tepe Sialk

For the determination of the isotopic baseline of Tepe Sialk, herbivores, omnivores and carnivores have been analysed. The group of herbivores consists of six ovicaprids, respectively five goats (*Capra aegagrus*) and one sheep (*Ovis vignei*). The omnivores are represented by one pig (*Sus scrofa*), and the carnivores by one fox (*Canis vulpes*). The data set from Tepe Sialk did not provide enough material for a general determination of the isotopic distribution of the different species. Therefore, the following calculations and discussion will be supplemented by studies from neighboured regions. Several intensive studies about animals were carried out in regions around the Caspian Sea (cf. Bocherens et al. 2000, 2006; Shishlina et al. 2009; Hollund et al. 2010; Rameroli et al. 2010; Gerling et al. 2015; Messager et al. 2015; Herrscher et al. 2018; Soltysiak et al. submitted). Comparative analyses revealed significant differences in the signatures of nitrogen isotopes (cf. chapter 2.2.4.2.), therefore the choice for a comparable ensemble was made on the basis of the $\delta^{15}N$ ratios of ovicaprids.[22] Sialk´s ovicaprids were in similar ranges with the ovicaprids from the Qazvin Plains, hence the analysed animal collection from the Qazvin Plains after Bocherens et al. 2000 was employed to complement the following calculations.

To establish the trophic steps (cf. fig. 9.17), plants as the basis of the nutrition pyramid, are necessary. The C3 plants (*Astragalus, Centaurea, Lagochilus, Onopordum*) from the Qazvin Plains provided $\delta^{13}C_{col}$ ratios between -26.8‰ and -28.3‰ with an average of -27.6‰ (± 0.7‰, n = 4) and $\delta^{15}N$ ratios between 2.2‰ and 9.9‰ with an average of 5.7‰ (± 2.8‰, n = 4). The only C4 plant (*Salsola*) showed a $\delta^{13}C_{col}$ ratio of -12.6‰ and a $\delta^{15}N$ ratio of 4.4‰. The first consumer step included ovicaprids, whose $\delta^{13}C_{col}$ ratios range from -16.2‰ to -19.2‰ in Sialk (average -17.4‰ ± 1.0‰, n = 6) and their $\delta^{15}N$ ratios falling between 7.1‰ and 9.5‰ (average 8.2‰ ± 1.0‰, n = 6). Next to sheep and goats, cattle were the main domestic animals, which were important for the human food supply. No cattle were available from Sialk, but two individuals were analysed from Tepe Naderi, close to the modern city of Shirvan in north-eastern Iran. The animals revealed $\delta^{13}C_{col}$ values of -18.7‰ and -18.5‰ (average -18.6‰ ±0.6‰, n = 2), and $\delta^{15}N$ values of 8.7‰ and 10.1‰ with an average 9.4‰ (±0.7‰, n = 2). The results fell within the results of the cattle from the Qazvin Plains with $\delta^{13}C_{col}$ ratios between -17.2‰ and –19.0‰ (average -18.0‰ ±0.2‰, n = 5) and $\delta^{15}N$ ratios between 8‰ and 11.2‰ (average 9.6‰ ±1.0‰, n = 5). All individuals´ values were therefore combined resulting in a range of $\delta^{13}C_{col}$ ratios between -17.2‰ and –19.0‰ (average -18.2‰ ±0.6‰, n = 7) and $\delta^{15}N$ ratios between 8‰ and 11.2‰ (average 9.5‰ ±1.0‰, n = 7). The same applies to gazelles, the one gazelle from Tepe Naderi with a $\delta^{15}N$ ratio of 8.2‰ fell within the results of the gazelles from the Qazvin plains with ratios between 6.9‰ and 9.4‰ (average 8.4‰ ±0.9‰, n = 4).

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[22] The ovicaprids from Sialk range between 7.1‰ and 9.5‰ with an average of 8.2‰ (± 1.0‰, n = 6). In comparison, the ovicaprids from the Qazvin Plains range between 8.1‰ and 12.0‰ (average 9.2‰ ± 1.2‰, n = 11), whereas ovicaprids from southern Central Asia and north-eastern Iran revealed an average around 11‰ (Ulug 10.9‰ ± 1.2‰, n = 9; Dzharkutan 10.6‰ ± 0.9‰, n = 5; Tepe Chalow 11.6‰ ± 2.9‰, n = 6). Another study from Mentesh Tepe in the southern Caucasus provided much lower ovicaprids $\delta^{15}N$ results between 5.7‰ and 8.6‰ with a mean of 6.6‰ (± 1.0‰, n = 8).

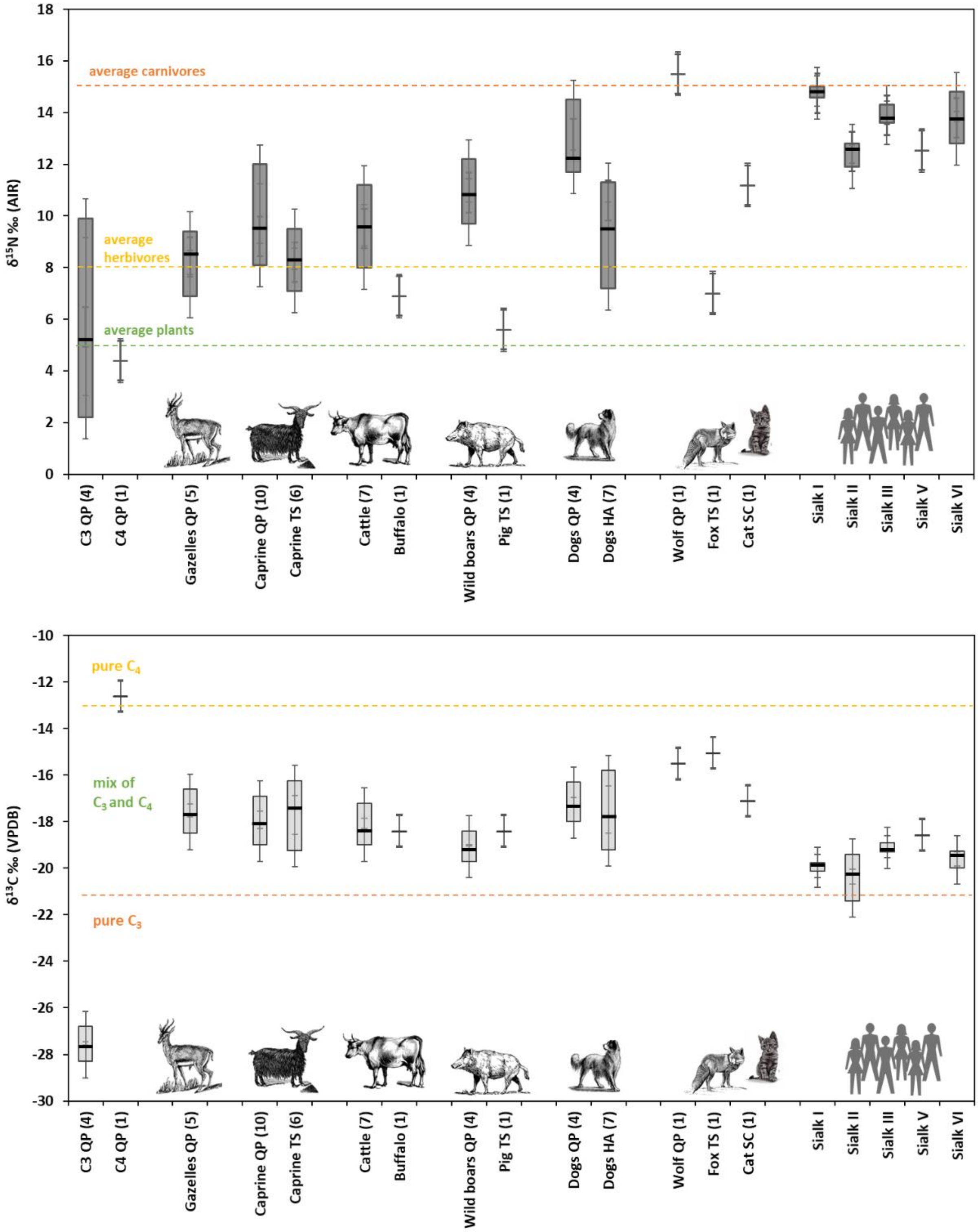

Fig. 9.17: Boxplot of $\delta^{15}N$ (top) and $\delta^{13}C_{apa}$ (bottom) results from Tepe Sialk with references from the Qazvin plains after Bocherens et al. 2000, black bars mark the averages.

All gazelles provided $\delta^{13}C_{col}$ ratios between -16.6‰ and -18.5‰ (average -17.7‰ ±0.7‰, n = 5). Pigs and dogs are representatives of omnivores, and the one pig from Sialk showed a $\delta^{13}C_{col}$ value of -18.4‰ and a $\delta^{15}N$ value of 5.6‰. In contrast, the wild boars from Qazvin range in the $\delta^{13}C_{col}$ values between -18.4‰ and -19.7‰ (average -19.1‰ ±0,5‰) while $\delta^{15}N$ results range from 9.7‰ to 12.2‰ (average 10.9‰ ±1.0‰, n = 3). Hence, the $\delta^{15}N$ ratio of the Sialk pig is comparably low, but the nitrogen content was low during the measurements as well and is most likely the reason for these low $\delta^{15}N$

results. Nevertheless, all suids fall within a general range of $\delta^{13}C_{col}$ from -18.4‰ to -19.7‰ (average -18.9 ±0.6‰, n = 4) and $\delta^{15}N$ from 5.6‰ to 12.2‰ (average 9.6‰ ±2.5‰, n = 4). Dogs are also considered to be omnivores, or an intermediate step between omnivores and carnivores. Several dogs from different Iranian sites were examined during this study, including single animals from Tepe Naderi, Nishapur, and Qoli Darvish, as well as six dogs from Hasanlu (dogs will be discussed in detail in chapter 10.5.).

The six Hasanlu dogs ranged in $\delta^{13}C_{col}$ from -15.8‰ to -19.2‰ (average -17.1‰ ± 1.1‰, n = 6) and in $\delta^{15}N$ from 7.2‰ to 11.3‰ (average of 9.3‰ ± 1.2‰, n = 6). The dogs from Qazvin ranged in $\delta^{13}C_{col}$ from -16.3‰ to -18.0‰ (average -17.0‰ ± 0.7‰, n = 3) and in $\delta^{15}N$ between 11.7‰ and 14.5‰ (average 12.6‰ ±1.3‰, n = 3), the single samples from Tepe Naderi, Nishapur, and Qoli Darvish fall within the same ranges (Naderi $\delta^{13}C_{col}$ -18.9‰ $\delta^{15}N$ 10.3‰, Nishapur $\delta^{13}C_{col}$ -18.0‰ $\delta^{15}N$ 12.5‰, Qoli Darvish $\delta^{13}C_{col}$ -18.9‰ $\delta^{15}N$ 11.8‰). All together they provide a $\delta^{13}C_{col}$ range between -15.8‰ and -19.2‰ with an average of -17.6‰ (± 1.1‰, n = 13) and a $\delta^{15}N$ range between 7.2‰ and 14.5‰ with an average of 10.6‰ (± 1.8‰, n = 13). As a representative of carnivores, a cat (*Felix sylvestris*) from Neolithic Tepe Sang-e Chakhmaq provided a $\delta^{13}C_{col}$ ratio of -17.1‰ and a $\delta^{15}N$ ratio of 11.2‰, the fox from Sialk showed a $\delta^{13}C_{col}$ -15.0‰ and a $\delta^{15}N$ ratio of 7‰. A wolf (*Canis lupus*) from the Qazvin Plains displayed a $\delta^{13}C_{col}$ value of -15.5‰ and a $\delta^{15}N$ value of 15.5‰, together with the cat from Geoktchik Depe ($\delta^{15}N$ 16.4‰, $\delta^{13}C_{Col}$ -16.5‰ after Bocherens et al. 2006: 257) they represent the highest $\delta^{15}N$ values measured of a carnivore species in this region.

The averages of the $\delta^{15}N$ and $\delta^{13}C_{col}$ ratios of all species within the respective trophic groups are summarized in table 9.2, whereas fig. 9.17 presents a compilation of all evaluated results. Concerning the $\delta^{13}C_{col}$ ratios, wild animals (except carnivores) show values between -12.7‰ (buffalo) and -19.7‰ (wild boar) (average -17.5‰ ± 1.9‰). Domestic animals range a bit higher between -16.2‰ and -19.2‰ (average -17.9‰ ± 1.0‰). In the case of Tepe Sialk, especially domestic ovicaprids provided a wide range of $\delta^{13}C_{col}$ values, which includes the ranges of wild gazelles as well as cattle, indicating a certain percentage of wild C4 plants in the diet. The carnivores displayed rather high $\delta^{13}C_{col}$ ratios which is also the case for Ulug Depe (fig. 9.17). By averaging the $\delta^{15}N$ ratios of the trophic groups, we receive the following steps: the basis (plants) at 5‰, the first step (herbivores) around 8‰, the second (omnivores) around 11‰, and the last (carnivores) around 13.5‰. This results in $\delta^{15}N$ intervals of 3‰ from the plants to herbivores, as well as from herbivores to omnivores, and 2.5‰ from omnivores to carnivores.

9.4.3. Reconstruction of human dietary habits

Summarizing all human individuals (cf. fig. 9.18), the $\delta^{13}C_{col}$ values range between -22.5‰ and -18.6‰ with an average of -19.6‰ (± 0.7‰, n = 14), while the $\delta^{15}N$ ratios range from 11.9‰ to 15.8‰ with an average of 13.7‰ (± 0.9‰, n = 14). The $\delta^{13}C_{col}$ averages show almost no differences concerning the chronological periods and biological criteria. The averages of all periods fell in a very narrow range between -19.1‰ (± 0.2‰ n = 2, Sialk III) and -20.2‰ (± 0.9‰, n = 3, Sialk II), indicating a stable subsistence with little changes (cf. fig. 9.19). Whereas the $\delta^{15}N$ ratios varied a bit more: the Neolithic Sialk I humans showed the highest results and an average of 14.8‰ (± 0.2‰, n = 3), in Sialk II results decreased slightly to 12.5‰ (± 0.4‰, n = 3), while Sialk III, the chalcolithic period, and Sialk VI, the MIA, showed averages around 13.9‰ (± 0.4‰, n = 7). The one man from Sialk V, the EIA period (Iron I), fell within the lower $\delta^{15}N$ ranges (12.5‰). In general, the isotopic results and averages did not show a certain pattern, differences between the periods are visible, but are due to the small number of samples difficult to generalize.

The $\delta^{13}C_{col}$ values of the ovicaprids range between -16.2‰ and -19.2‰ with an average of -18.1‰ (± 1.0‰, n = 6). The difference between humans (average -19.6‰ ± 0.7‰, n = 14) and ovicaprids is negligible small with a spacing of 1.5‰. All humans and four out of six ovicaprids fall within the typical range of a diet mainly based on C3 plants (fig. 9.18). The $\delta^{15}N$ average of the Sialk humans of all periods of 13.7‰ (± 0.9‰, n = 14) show an interval of 5.5‰ to the ovicaprids average of 8.2‰ (± 1.0‰, n = 6), gazelles displayed an interval of 5.3‰. Fluctuating differences are visible in the averages between the humans of the early Neolithic periods and the later urban periods (fig. 9.19). While intervals between humans and ovicaprids fall within a high range through all times: Sialk I (n = 3): 6.6‰ (gazelles 6.4‰); Sialk II (n = 3): 4.3‰ (gazelles 4.1‰); Sialk III (n = 2): 5.7‰ (gazelles 5.5‰); Sialk V (n = 1): 4.3‰ (gazelles 4.1‰); Sialk VI (n = 5): 5.6‰ (gazelles 5.4‰). The results all score in high ranges, compared to the usually calculated $\delta^{15}N$ interval of 3–5‰ per level, caused by the trophic level effect (Bocherens, Drucker 2003; Hedges, Reynard 2007). The average of the ovicaprids from Tepe Sialk of 8.2‰ (n = 6) or gazelles from the Qazvin plains (average 8.4‰, n = 4, Bocherens et al. 2000), resulted in the lowest human value of 12.5‰ of an adult man (272305, Sialk V) with an interval of 4.1‰ (gazelles 3.9‰); the highest human value of 15.0‰ of a young woman (27271, Sialk II) resulted in an interval of 6.8‰ (gazelles 6.6‰). Hence, the humans from Tepe Sialk from all periods revealed intervals between 4.1‰ and 6.8‰ to sheep and goats (fig. 9.19). The high variety of the $\delta^{15}N$ values of Sialk ovicaprids had the effect that cattle and gazelles also fell within this interval rendering a distinction difficult. In any case the intervals and the high $\delta^{15}N$ results suggest a diet rich in animal protein secondary products as milk, or yoghurt.

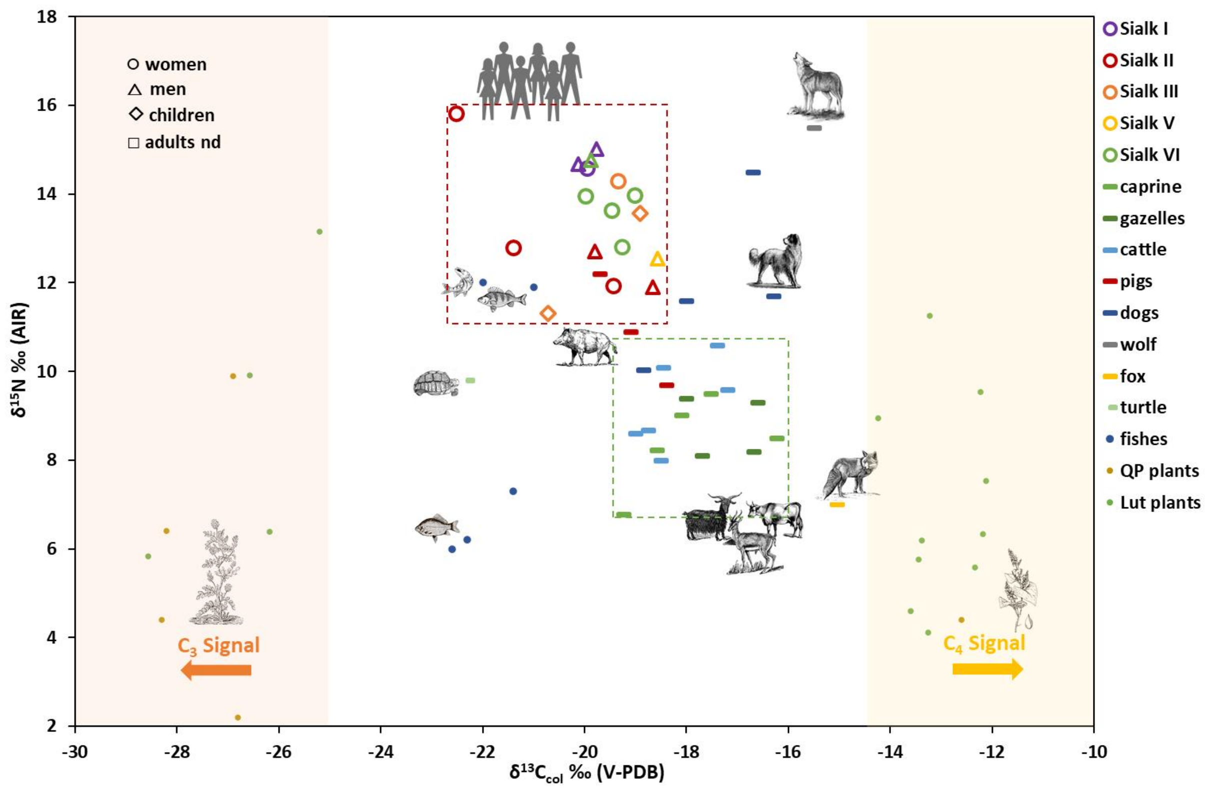

Fig. 9.18: Scatterplot of $\delta^{15}N$ versus $\delta^{13}C_{col}$ results out of collagen of all samples from Tepe Sialk with plants from Lut and Qazvin (QP), together with the wolf, gazelles, and cattle after Bocherens et al. 2000; fish from Mentesh Tepe after Herrscher et al. 2018. The symbols encompass the error margins at 1σ level for $\delta^{15}N$ and $\delta^{13}C_{col}$ ratios.

The generally high $\delta^{15}N$ ratios of Sialk humans might have also been caused by the consumption of water animals like fish, shells, crabs, maybe water plants, but also birds as ducks or goose, whose diet consists of water animals and plants (Katzenberg 2008; Göhring et al. 2016). It would be a good explanation for the high $\delta^{15}N$ ratios, but considering that all rivers were seasonal and water was rather rare in the region, water animals probably did not represent a high percentage in the diet. If hunting played an important role in the food supply is, according to the isotopic results, difficult to distinguish, but a particular content of hunted animals in the diet is not excludable. The archeozoological analyses evidenced a high percentage of ovicaprids through all periods, gazelles were present in the late periods but minor during the earlier periods (Mashkour 2004a, b, cf. fig. 9.4). The humans of the earliest, Neolithic period showed the highest $\delta^{15}N$ ratios, while the people from Sialk II, the transition to the chalcolithic period, showed the lowest (fig. 9.19). The notion that this is referable to higher hunting activities in the early periods and the increase of farming and crop cultivation, coming up towards end of the 6th mill. BCE would be a beautiful result, but needs to be proven by more results.

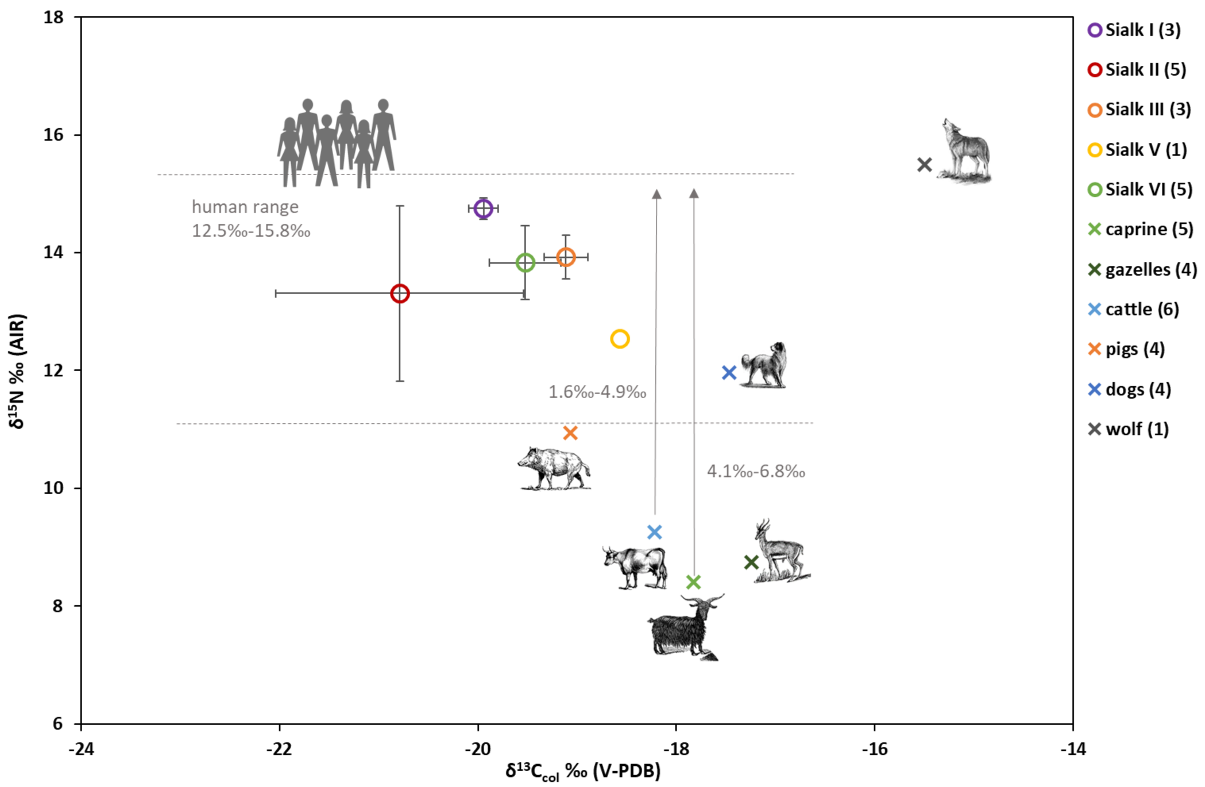

Fig. 9.19: Scatterplot of $\delta^{15}N$ and $\delta^{13}C_{col}$ averages (numbers in parenthesis) of all samples with intervals between the species, wolf, gazelles, cattle from Qazvin after Bocherens et al. 2000.

9.4.3.1. Trophic level shifts ($\delta^{13}C_{carb\text{-}col}$)

The $\delta^{13}C_{apa\text{-}col}$ results of Sialk humans range from 5.4‰ to 9.5‰ with an interval of 4.1‰, providing a distribution between Ulug (interval 2.5‰) and Dzharkutan (7.4‰). Hence, a more diverse dietary intake of faunal resources than Ulug Depe inhabitants but less than in Dzharkutan. The individuals from Tepe Sialk can be divided into two groups (fig. 9.20): one group included 7 individuals (3 men, 3 women, 1 child) and fell below 7‰, respectively on the trophic level of omnivores/carnivores; the second group included 9 individuals (3 men, 5 women, 1 child) ranged higher than 7‰, hence in the range of herbivores (Codron et al. 2018). No pattern of a distinct gender distribution or correlation between periods were determinable, but the results in general indicate a high variety of plants and terrestrial resources. This high variety on the one hand mirrors the fertile surroundings and the rich natural food offer in the valley. But in contrast to Dzharkutan, they might also be impacted by a higher degree of mobility and movements through different habitats (Lösch et al. 2006; Herrscher et al. 2018). At least during the early Neolithic and Chalcolithic periods, $\delta^{18}O$ analyses displayed an expanded catchment area of Sialk´s inhabitants towards higher, colder regions (lower ratios cf. fig. 9.15). Taking all results together, they can be considered as true indications for movements through different spaces.

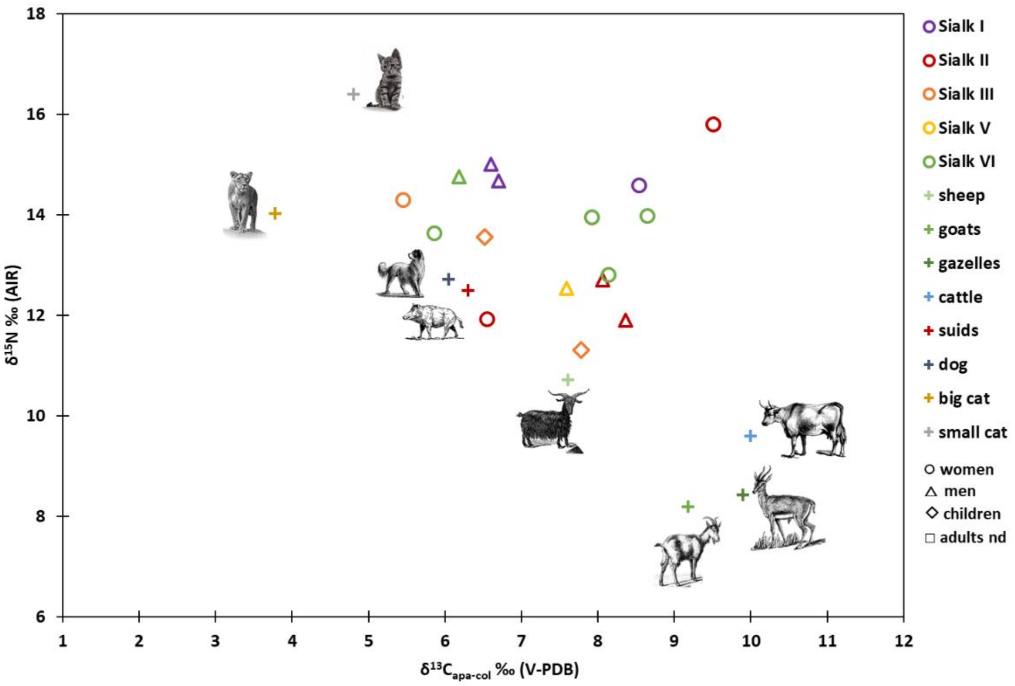

Fig. 9.20: Scatterplot of $\delta^{15}N$ versus $\delta^{13}C_{apa\text{-}col}$ of humans and animals from Tepe Sialk. $\delta^{13}C_{apa\text{-}col}$ of fox, gazelles and cattle after Codron et al. 2018: 3985–3986. The symbols encompass the error margins at 1σ level for $\delta^{15}N$ and $\delta^{13}C_{col}$ ratios.

9.4.3.2. Gender and social differences

Categorized after gender and age, the differences in the $\delta^{13}C_{col}$ averages become even smaller: men range between -18.4‰ and -20.1‰ with an average of -19.4‰ (± 0.7‰, n = 6); women a bit higher with ranges from -19.0‰ to -21.4‰ and an average of -19.7‰ (± 0.8‰, n = 6); the one child (Sialk III, 27273) revealed the lowest $\delta^{13}C_{col}$ value of -18.9‰. Furthermore, no differences are visible in the $\delta^{15}N$ results: the nine women had a mean of 13.5‰ ± 0.8‰, the six men 13.5‰ ± 1.4‰, the two children (both between 6–10 years old) provided $\delta^{15}N$ results of 13.6‰ and 11.3‰ and $\delta^{13}C_{col}$ ratios of -20.7‰ and -18.9‰, indicating a similar diet as the adults. Hence, concerning biological criteria, no pattern of gender distribution can be drawn. Interestingly, the three non-local women all fall within the uppermost range of the $\delta^{15}N$ scale (15.8‰, 14.6‰, 14.0‰) and within the lowest range of the $\delta^{13}C_{col}$ scale (-22.5‰, -20.0‰, -19.0‰), indicating a diet with a high content of animal protein and pure C3 plants. A higher social status is often not only associated with a richly furnished burial, but also with a different nutrition, especially concerning the content of meat in the diet (Mittnik et al. 2019; Mutin 2020). But the small sample number does not deliver more than an indication whether this can be considered as a richer diet caused by the social position of non-locals.

9.4.4. Feeding and herding practices

Although no time series of Sialk ovicaprids has been performed yet, some conclusions about the herding and feeding practices in Tepe Sialk can be drawn, at least for the Sialk III period as all ovicaprids date in this time. They provided a wide range of $\delta^{13}C_{col}$ values (between -19‰ and -16.2‰), which includes the ranges of wild gazelles as well as cattle, and indicate a high variety of plants in the diet just as a certain percentage of C4 plants. The same ovicaprids, which were used for the determination of the local $^{87}Sr/^{86}Sr$ range and the baseline of the nutrition, were additionally analysed for bone carbonate ($\delta^{13}C_{apa}$). The resulting $\delta^{13}C_{apa\text{-}col}$ ratios between 6‰ and 12‰ (n = 6) confirm a high variety of plants in the diet. This high variety is caused by different foddering methods, usually connected to environmental changes effecting the animals. Whereas the strontium signal was quite homogeneous and similar to one of the humans, the oxygen results differed significantly. We do not know the intervals of $\delta^{18}O$ and $\delta^{13}C$ during the life-span of the animals, but the $\delta^{18}O$ results out of bone apatite ranged between -0.9‰ and +2.5‰ strongly indicating the use of different water sources than the humans. While some human $\delta^{18}O$ results of this time period tend more towards lower signals, corresponding to colder, higher regions, the ovicaprids displayed higher signals, corresponding to a hotter, more arid climate. Summarized, to the present state of our knowledge, the results indicate that during the chalcolithic period the ovicaprids moved between different habitats, pastures, and groundwater sources in the plains and the surrounding steppe.

9.5. Discussion and summary

Comparative analyses of the humans from Tepe Sialk revealed no distinct pattern between the isotopic results and the particular time period, respectively the ongoing political and social events. But the small number of samples makes a generalization difficult. The humans of the earliest, Neolithic period Sialk I, showed the highest $\delta^{15}N$ ratios, and a distinct degree of mobility, while the people from Sialk II, the Transitional Chalcolithic, showed the lowest $\delta^{15}N$ results and decreased $\delta^{13}C$ ratios. If this is referable to a higher consumption of meat and milk products, correlated to a rather mobile way of life in the Late Neolithic period, and a reduction of hunting and herding activities through the intensification of farming and crop cultivation, coming up towards the end of the 6th mill. BCE needs to be proven by more samples.

The results of all humans through all periods demonstrate that no C4 plants were consumed in Tepe Sialk. Hence, the presence of millet in Hasanlu and Bastam cannot be stated for Tepe Sialk and confirms the botanical analyses (Tengberg 2003; Miller et al. 2016). Sialk´s inhabitants had a consistent diet of C3 plants like barley, wheat, lentils, fruits, and nuts. The consumption of millet can be negated for the humans and also most animals did not display a high content of C4 plants in the nutrition.

In general, Sialk inhabitants revealed the highest content of animal protein in the diet through all periods, as well as a high variety of plants and terrestrial resources. The data conform with the consumption of meat, milk, or dairy products from domesticated herbivores. Here especially, according to the faunal remains, sheep and goats contributed substantially to human diet (Mashkour 2004a, b, et al. 2019). The dietary variation concerning biological criteria like age, sex or even the archaeologically indicated social position, is only weakly reflected due to the small sample number. There is, however, an indication for a gender specific pattern in the migratory dynamics in Tepe Sialk. Only women were identified as non-locals, reoccurring through all periods (Sialk I: 27282, Sialk II: 27271, Sialk VI: 27295, cf. fig. 9.13). If Tepe Sialk is the first scientifically proven example for maternal migration in prehistoric Iran remains open until more results can be added. The isotopic results of Tepe Sialk in general indicate a comparably high rate of immigration just as the inter-individual variation displayed the highest degree of mobility among the populations. The distribution of isotopes in correlation to the periods does not show distinguishable patterns, but movements through different spaces can be observed through all periods. Interestingly, the cluster visible in the $^{87}Sr/^{86}Sr/\delta^{18}O$ results is reoccurring in the trophic level distribution, respectively the content of plant intake ($\delta^{15}N/\delta^{13}C_{apa\text{-}col}$), including the same individuals (cf. fig. 9.15 and 9.20). The spread to lower values indicates that these people ingested water from different water sources. Moreover, a correlation to a higher intake of animal protein can be drawn. Since the higher consumption of meat and dairy products is often applied to a pastoral way of life, this correlation might be a true indication that some individuals, buried in Tepe Sialk, followed a more mobile lifestyle. The oxygen isotopic results of the ovicaprids, which all date to Sialk III, confirm environmental changes and movements to different pastures during the late 4th and early 3rd mill. BCE.

It is not yet possible, to draw reliable conclusions on questions like e.g., was the immigration rate higher during the proto-urban phase? Or did the development of long-distance trade, respectively the urbanization process impact the diet of humans and animals? It can be surely assumed that the emerge of urban centers and a certain population growth during the 4th and 3rd mill. BCE had a deep impact on the subsistence strategies of Sialk inhabitants, coming along with developments in the agricultural provision or animal husbandry. But the isotopic results do not show any differences, which could be interpreted as e.g., a higher or lower intake of animal protein, or an increase of manuring through enhancements of farming activities. There is one distinct difference in the nutrition pattern, not concerning the general distribution of the results, but the averages and especially their standard deviations. The early periods (Sialk I and II) display a high standard deviation, resulting from variable dietary patterns of the single individuals. Whereas Sialk III individuals, the urbanization phase, and Sialk VI, the Iron II phase, displayed not only almost the same averages, but are also characterized by negligibly small deviations (cf. fig. 9.19). Sialk III and Sialk VI, both belong in a way to a more organized and centralized system and time period, the variations within the individuals are extremely small and can be interpreted as being caused by a constant nutrition, possibly being the result of a regular provision of food through systematic agriculture and a more complex organization system. But the general economic strategies like the consumption and cultivation of mainly C3 plants as wheat and barley, and movements between pastures for an adequate food supply of animals were a certain part of the economic strategies of Sialk´s inhabitants in these periods as well.

With the beginning of the Iron Age, after abandonment and reoccupation, new societies arose on the southern mound of Tepe Sialk. The burials discovered in the two graveyards revealed huge ensembles of rich inventories, indicating cultural influences with various places in the Near East. The mud-brick platform on the northern mound is attributed to the Medes (Roaf 2008; Lecomte 2011;

Curtis 2019) and demonstrates certain impacts on the societies in Sialk.[23] Concerning the isotopic results in general, with regard to the lack of samples from Sialk IV (and V), no differences between the previous chalcolithic Sialk III individuals, and the Sialk VI "Medes"/pre-Achaemenids are visible. Hence, the cultural changes, implicated by the archaeological remains, did not impact the dietary intake of animal proteins distinctly, nor the content and variety of plants and terrestrial resources, respectively the degree of mobility of the inhabitants of Sialk. The results implicate a stronger, endurable influence of natural offers in the surrounding vegetation and climatic conditions, than of occurring cultural phenomena. One interesting point is comprised by the fact, that the three non-local women, who all displayed similar $^{87}Sr/^{86}Sr$ ratios, fell within the range of Dzharkutan bones (cf. fig. 10.4). It seems rather attractive to assume a frequent exchange between southern Uzbekistan and central Iran (to remark, since the Neolithic, when Dzharkutan itself did not exist). But paleogenetic analyses revealed common ancestors of the Iron Age individuals from Sialk in north-western Iran. Comparisons with individuals from Hasanlu suggest a frequent gene-flow between the two regions (personal communication from Celine Bon, cf. also Narashiman et al. 2019).

[23] The knowledge about the Medes is up to today quite limited, and not only their origin, core areas and disappearance are unanswered questions. Economical strategies, like farming activities, or animal husbandry techniques also remain unknown. Several specialists have dedicated their research to this issue (cf. Roaf 2008; Lecomte 2011; Boucharlatet al. 2015, 2020; Kroll 2019), the author will not contribute to the discussion of existence and definition, hence the results are to be considered in the light of the inhabitants of Tepe Sialk and not in a greater view of a cultural affiliation.

10. Going beyond

This chapter includes some comparative approaches interpreting isotopic results of humans and animals to gain a broader view on the general situation in Central Asia and Iran. Different observations reoccurred during this study and evolved continuative ideas. Hence the single chapters try to catch different research approaches and are not related to each other.

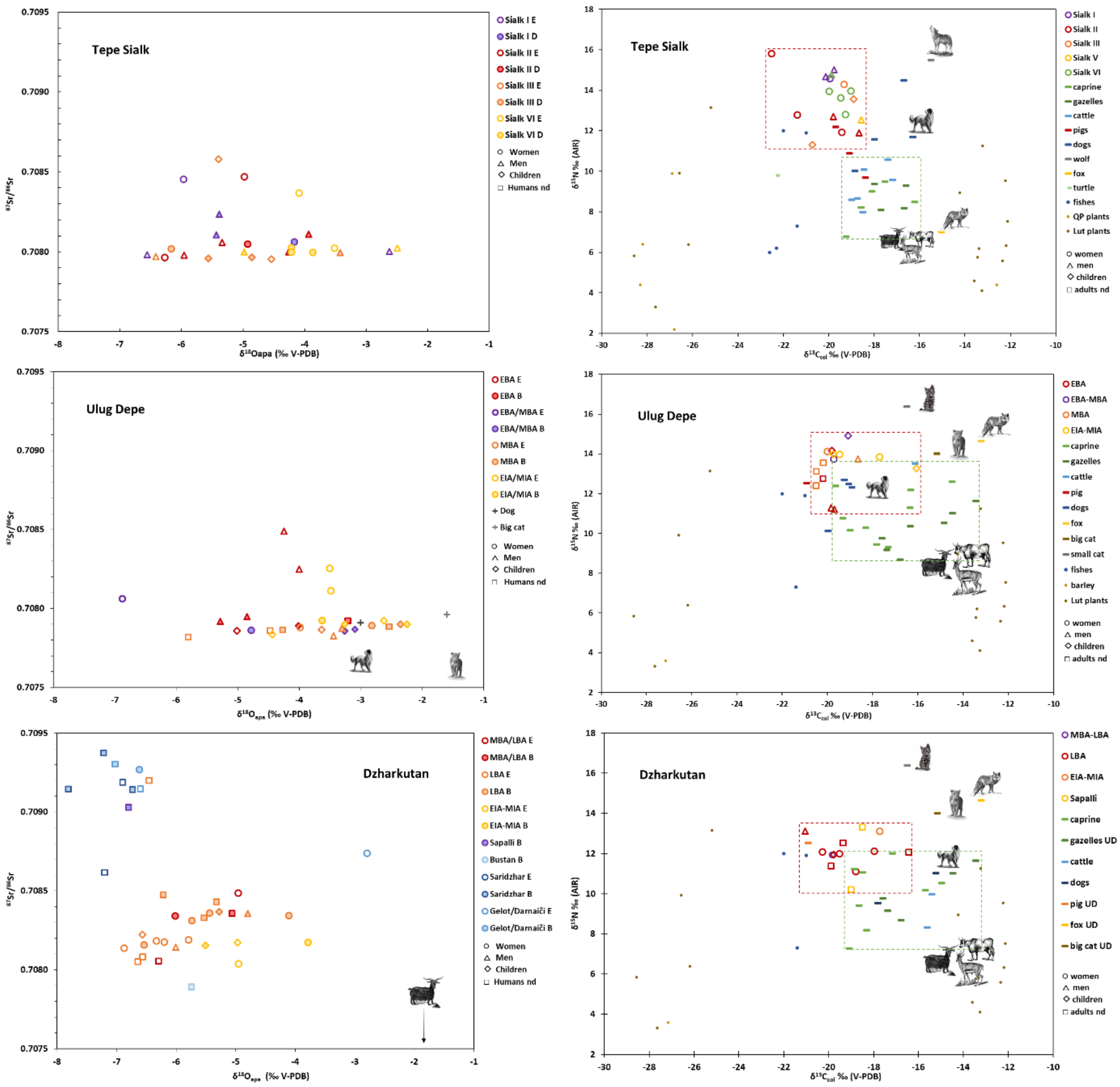

Fig. 10.1: Compilation of isotopic result of all human samples, left column $^{87}Sr/^{86}Sr$ versus $\delta^{18}O_{apa}$, right column $\delta^{15}N$ versus $\delta^{13}C_{col}$.

The general comparison of the patterns between the humans from Tepe Sialk, Ulug Depe, and Dzharkutan revealed that the mobility pattern of Ulug Depe seems almost identical to the pattern of Tepe Sialk, while Dzharkutan is different (fig. 10.1 left column). Whereas the broader view on the nutrition analyses ($\delta^{15}N$, $\delta^{13}C_{col}$) reveals similarities between Ulug and Dzharkutan, while Sialk differs (fig. 10.1 right column). Detailed analyses found Sialk´s inhabitants to feature the highest percentage of animal protein as meat and dairy products in their diet through all periods. Dzharkutan inhabitants displayed the highest variety of plants resources. Covering all periods Ulug Depe´s population showed a very limited variety in both, the content of animal protein and the diversity of plants in the diet. Moreover, Ulug Depe displayed the highest rate of immigration and Dzharkutan the most unusual mobility pattern.

Hence, based on the amplitude of $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{apa}$ (fig. 10.1 left column) the question arises what similarities can be drawn between Tepe Sialk and Ulug Depe but not with Dzharkutan? Sialk and Ulug are both located on mountain foothills in steppe surroundings with seasonal water supply through rivers at the border of the desert. Both surrounding landscapes highlight the necessity of seasonal movements to more fertile pastures for an adequate food supply. Dzharkutan is located in a more moderate climatic region with several streams enabling perennial irrigation. More samples, and especially populations need to be analysed to evaluate if the pattern of Sialk and Ulug (early periods) can be considered as the model of a sedentary population with seasonal movements while Dzharkutan rather represents the situation of surrounding settlements where people changed their residence during adulthood.

10.1. Pastoralists and agriculturalists

Transhumant animal husbandry or pastoral movements to fertile pastures have always been assumed as a substantial part of the economic strategies of the societies in southern Central Asia and Iran. Intensive studies on the mobile and sedentary pastoralists in the northern steppes, revealed that due to life conditions and availability, they had a higher amount of meat and dairy products in their nutrition, often with a high content of hunted animals in order to preserve their flocks (Ventresca Miller et al. 2014; Makarevizc 2018, Knipper et al. 2020). Although the earlier periods in Ulug Depe feature people with a higher degree of mobility, and this time period, respectively the life conditions through the EBA propose pastoral movements to the mountains, the results of these individuals did not deliver indication for a different composition of the diet. The LBA individuals from Ulug Depe and Dzharkutan were part of the specialized agriculturalists of the Oxus Civilisation. The Oxus people are famous for their technological developments concerning agricultural innovations in arid, unfruitful regions, implicating a rather sedentary lifestyle. In comparison, the Andronovo population from Bestamak and Lisakovsk in northern Kazakhstan (Ventresca Miller et al. 2014), who are assumed to have followed a more mobile way of life, had a diet mainly based on terrestrial animal protein and a high variety of individual dietary plant intake. Humans from Bestamak showed a $\delta^{15}N$ average of 12.0‰ (Lisakovsk 11.8‰), while sheep/goats had a $\delta^{15}N$ average of 8.1‰ (Lisakovsk 7.2‰), resulting in intervals of 3.9‰ (Lisakovsk 4.6‰) (cf. Ventresca Miller et al. 2014). Lightfood and colleagues performed intensive studies on several pastoral LBA populations throughout Kazakhstan documenting human $\delta^{15}N$ results between 9.7‰ and 14.7‰ with a mean of 13.0‰ (n = 15) while herbivores $\delta^{15}N$ averages ranged between 6.1‰ and 8.1‰ (Lightfood et al. 2016; Motuzaite Matuzeviciute et al. 2015). The resulting intervals between 4.9‰ and 6.9‰ are significantly higher than in Ulug Depe and Dzharkutan (cf. fig. 10.2). Recent isotopic studies of the BMAC/GKC population from Tepe Chalow in the Jajarm plains in north-eastern Iran were performed by Soltysiak et al. (submitted). The obtained results suggest a combination of intensive agriculture and household animal husbandry. The human individuals show a $\delta^{15}N$ average of 14.7‰ (n = 9), while domestic ovicaprids showed a $\delta^{15}N$ average of 11.6‰ (n = 6), resulting in intervals between 2.5‰ and 3.1‰, in the same range as the Ulug and Dzharkutan people. The relations clearly indicate a higher meat/animal protein consumption of the northern steppe communities, and a diet more based on vegetarian components of the mainly sedentary, highly specialized LBA agriculturalist in southern Central Asia.

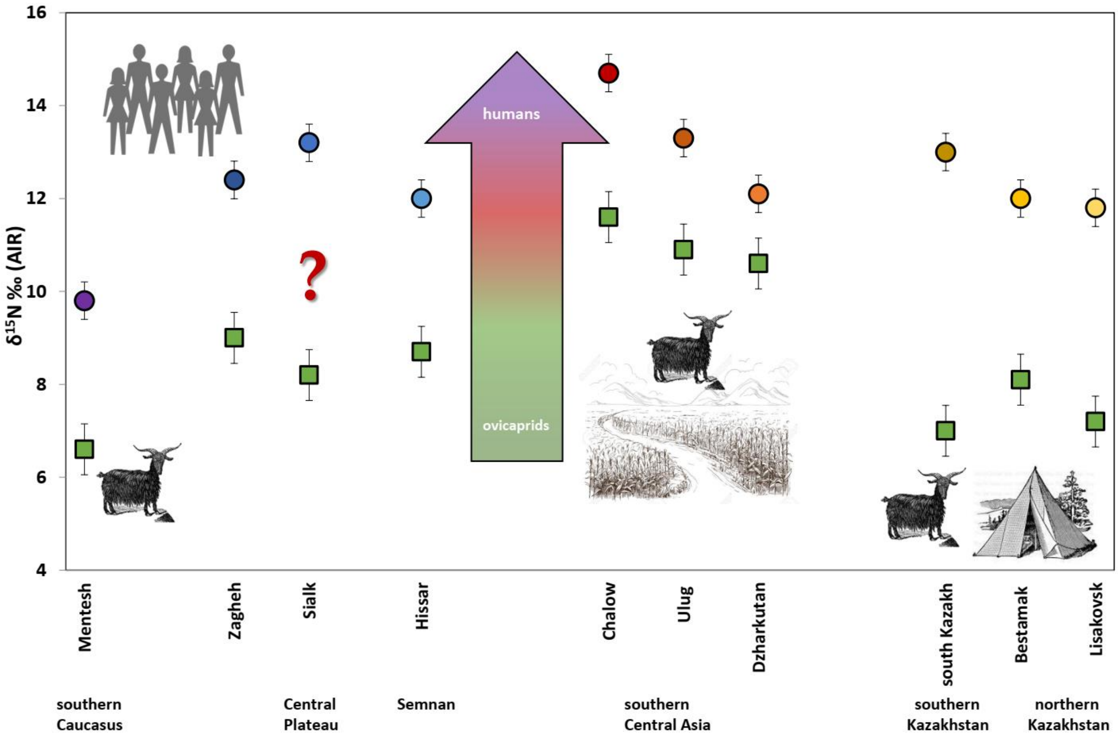

Fig. 10.2: Comparisons of averaged $\delta^{15}N$ ratios of humans (circles) and ovicaprids (squares) from southwest to north-east: Mentesh Tepe after Herrscher et al. 2018; Zagheh after Bocherens et al. 2000; Tepe Hissar after Afshar 2014; Tepe Chalow after Soltysiak et al. submitted, southern Kazakh sites after Motuzaite Matuzeviciute et al. 2015; Bestamak, Lisakovsk after Ventresca Miller et al. 2014.

The results obtained in Tepe Sialk fit better into the pattern of a pastoral lifestyle concerning the nutrition of the inhabitants. The results scored in high ranges through all periods, displaying averaged $\delta^{15}N$ intervals from humans and ovicaprids that are between 4.3‰ and 6.6‰. Comparative studies from nearby regions examined e.g., the late Neolithic/early Chalcolithic humans from Zagheh resulting in ranges between 11.0‰ and 13.6‰ (average 12.4‰, n = 4). The $\delta^{15}N$ average of the ovicaprids of 9.0‰ (n = 4) and resulting intervals of 3.4‰ indicate a distinct lower content of dairy products in their diet than Sialk inhabitants but still higher than Ulug and Dzharkutan. Studies about communities from Mentesh Tepe contains samples from the Neolithic and Bronze Age period, and fit well to the Sialk material (cf. Messager et al. 2015; Herrscher et al. 2018). The adult individuals $\delta^{15}N$ ranged from 8.2‰ to 11.9‰ (average 9.8‰ n = 23). The ovicaprids average was 6.6‰ resulting in $\delta^{15}N$ intervals around 3.2‰ (Herrscher et al. 2018). The intervals also propose a comparable content of meat and animal products for the agro-pastoral communities in southern Caucasus similar to the the agriculturalists from Ulug and Dzharkutan (cf. fig. 10.2). Another intensive anthropological study was performed by Afshar (2014) on the Chalcolithic and EBA populations from Tepe Hissar. Among 68 individuals from Hissar I–III the lowest $\delta^{15}N$ value was 8.8‰, the highest 14.1‰ (Hissar I: 11.8‰ (n = 8), Hissar II 12.2‰ (n = 11), Hissar III 12.2‰ (n = 49)). No reference animals from Hissar are available, but calculated with the reference herbivores collected in this study from north-eastern Iran (average 8.7‰, n = 7), they display approximate intervals between 3.1‰ and 3.5‰. The intervals are in similar ranges as Zagheh, Mentesh, but are distinctly lower than Sialk. The data conform with the consumption of meat, milk, or dairy products from domesticated herbivores, which contributed substantially to human diet at all Iranian sites. Still, Sialk´s inhabitants surpass them all. They in particular conform with the parameters attributed to a mobile lifestyle and a nutrition mainly based on animal products.

10.2. Correlation of provenience and nutrition

Nutrition strongly depends on the availability, but also on cultural imprints. It is observable till today, that people with a different cultural background and therefore diverse nutrition habits often have problems with the adaptation of another diet, even if the offer is more variable. Not only taste, also the digestion (cf. for example Ségurel and Bon 2017; Ségurel et al. 2020), hence metabolic predisposition is an important reason for different nutrition patterns.

In Ulug Depe the two non-local men from the EBA differed in terms of a lower content of protein in the diet and slightly enriched $\delta^{13}C$ ratios, hence a diet with a higher content of C4 plants. In correlation with low nitrogen ratios the results indicate a diet with a low content of animal protein, rather consisting of wild animals and plants, hence a subsistence based on hunting and gathering (cf. fig. 10.3). Moreover, the two non-local Iron Age women differed compared to the former period, but no further samples from the Iron Age are available for a reliable comparison. Nevertheless, they displayed enriched $\delta^{15}N$ ratios and enriched $\delta^{13}C$ ratios, and differed distinctly from the group. If this is referable to the status as non-locals or rather to the general developments and changes of this time period needs to be proved by further contemporary samples. In Dzharkutan the only real foreigner DZH 1019 also differed significantly from the rest of the group concerning extremely enriched $\delta^{13}C$ ratios (cf. fig. 10.3). This LBA person, who fits perfectly into the local $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ signals from southern Tajikistan, had a diet mainly consisting of C4 plants. The individuals from Tepe Sialk reflect this pattern as well, two of the non-local women were on the uppermost range of the $\delta^{15}N$ ratios (cf. fig. 10.3). Furthermore, burial 27295 (Sialk VI) had a beautiful grave inventory (cf. chapter 9.2.4.) and the individual buried within can be considered to have enjoyed a higher social status during lifetime. Hence, several foreigners displayed differing nutrition habits than the locals. The pattern is reoccurring at all the three sites through all periods. Accordingly, it can be considered to be more than an indication, but rather the isotopic manifestation of a real pattern. Moreover, the different nutrition habits of the foreigners, who were well integrated in the prevailing local traditions (e.g., funeral inventories) substantiate the fact that the cultural influences went in both directions and people kept their native customs.

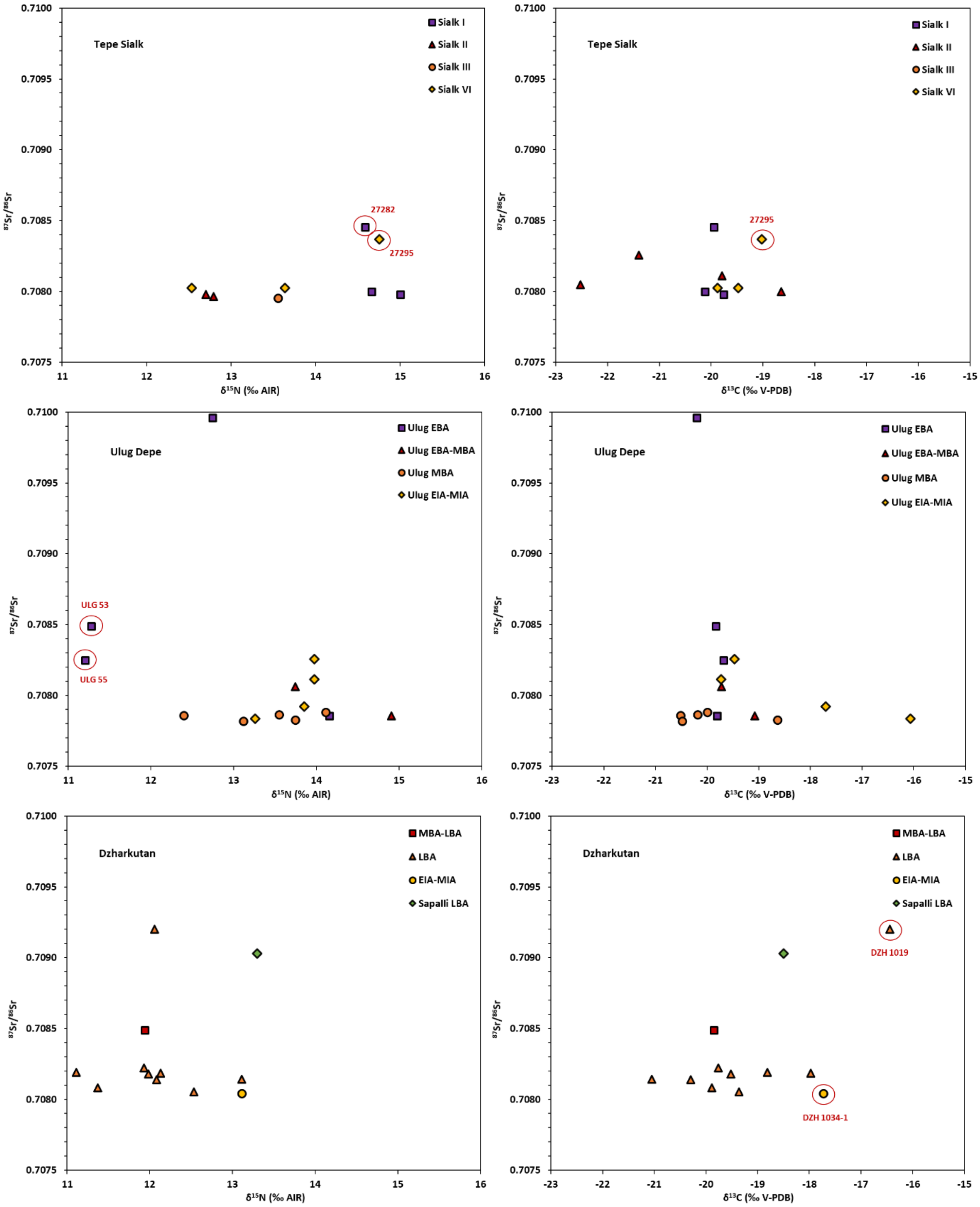

Fig. 10.3: Scatterplot $^{87}Sr/^{86}Sr$ ratios out of tooth enamel of human samples from Ulug, Dzharkutan, and Sialk: left column versus $\delta^{15}N$ ratios out of collagen, right column versus $\delta^{13}C$ out of collagen.

10.3. Tracking connections

The 3rd millennium BCE in southern Central Asia is characterized by the coexistence of different phenomena, closely related to each other and with fluent boundaries. Towards the transition of the 3rd to the 2nd mill. BCE an increasing influence of the Surkhan Darya region is noticeable, which led to the development of a specific eastern variation of the Sapalli-Dzharkutan culture (Teufer 2021). The search for connections between southern Uzbekistan and south Tajikistan using isotopic investigation is therefore inherently predetermined. Moreover, the correlation of $^{87}Sr/^{86}Sr$ and oxygen seems to point to the fact that the origins of some of our non-locals are quite clear and that extra-territorial connections really existed. The enamel $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results of Burial no. 1019 from Dzharkutan and Burial no. 8 from Sapallitepa fit within the accumulation of the Gelot, Darnaichi, and Saridzhar people (cf. fig. 10.4 and chapter 7.3.2. and 8.2.). It seems likely, that these individuals spent their childhood where the people who were buried in Gelot and Darnaichi had lived, but moved to Dzharkutan and Sapallitepa during their lifetime. The enamel $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ ratios of Burial no. 92 from Ulug Depe fit within the clusters of the Dzharkutan tooth enamel ratios (fig. 10.4), so perhaps this group of people shared the same birth/childhood locality. Several individuals from different sites fall within the local $^{87}Sr/^{86}Sr$ range of Ulug Depe, and the presence of mitochondrial haplogroups shared between Dzharkutan and Ulug Depe suggest the migration of women between the different localities. The sites in the Surkhan Darya valley (Dzharkutan, Tilla Bulak, Sapallitepa, Bustan cf. chapter 7.3.2.) show highly diverse $^{87}Sr/^{86}Sr$ results. The two samples from Sapallitepa showed two distinct different $^{87}Sr/^{86}Sr$ ratios (fig. 10.5): the enamel $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ ratio of Burial no. 8 is within Gelot and Darnaichi ratios; the $^{87}Sr/^{86}Sr$ bone ratio of Burial no. 20 is at the upper limit of Dzharkutan. The bone $^{87}Sr/^{86}Sr$ ratio from Bustan (Burial no. 23) fell within the local $^{87}Sr/^{86}Sr$ range of Ulug Depe. If this is a coincidence, or whether constant, dynamic interactions really existed, will remain contested until a larger sample is available. Nevertheless, the high variation in the results prove an active mobility among the inhabitants of the Surkhan Darya valley.

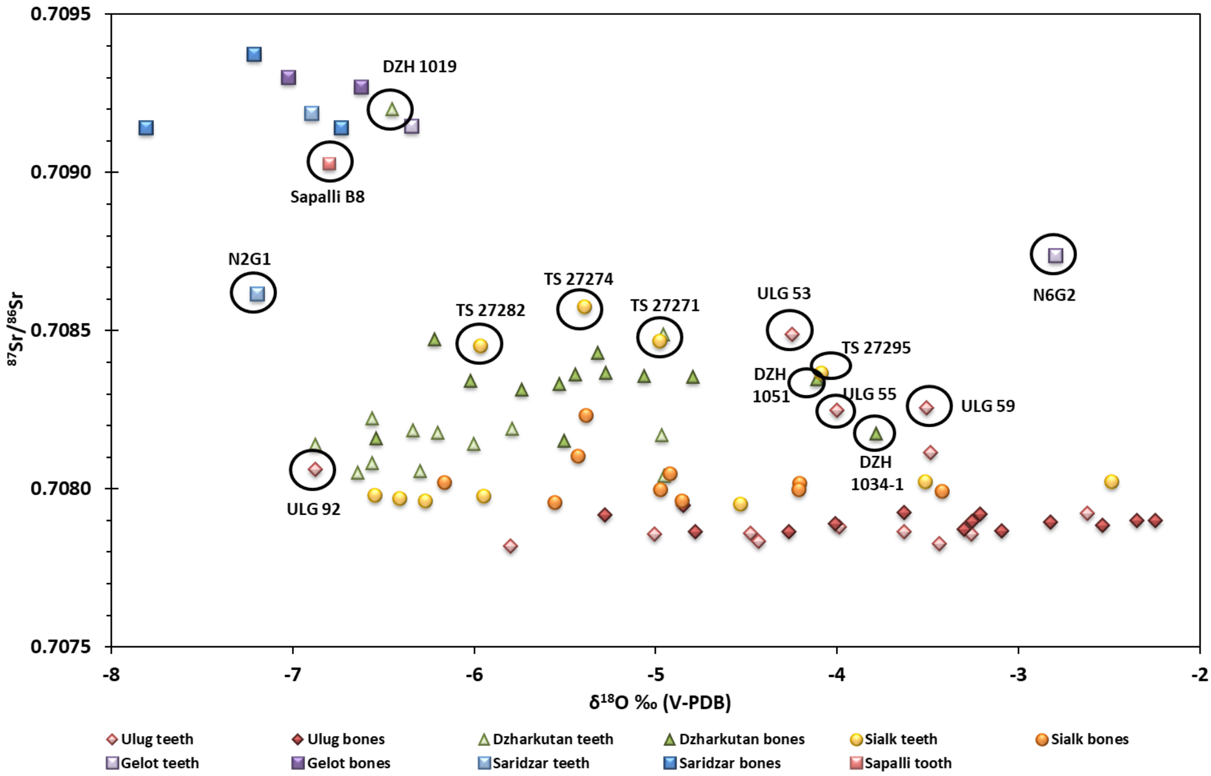

Fig. 10.4: Scatterplot $^{87}Sr/^{86}Sr$ versus $\delta^{18}O_{apa}$ ratios of humans from Tepe Sialk (TS), Ulug Depe (ULG) and Dzharkutan (DZH). The symbols encompass the error margins at 2σ level for the $^{87}Sr/^{86}Sr$ ratios and 1σ level for $\delta^{18}O$ ratios.

The remarkable rate of immigration during the EBA in Ulug Depe is not only represented by ULG 56, who migrated from the far north (cf. chapter 6). The other two men of this period (burial 53 and 55) were conspicuous as well concerning their tooth enamel $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{apa}$. Both fell together with the enamel ratio of burial 27295 from Tepe Sialk, the bone ratios of burial 1051 and 1034-1 from Dzharkutan and the enamel ratio of the Iron Age woman from Ulug Depe (ULG 59), in a different $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{apa}$ range (cf. fig. 10.4). The results indicate strong relations not only between the culturally closely related Central Asian sites. Evidence for connections to north-eastern and central Iran are demonstrated and proved through the results of burial N6G2 from Gelot (cf. chapter 8).

The two analysed individuals from Bashman 1 provided two distinct different enamel $^{87}Sr/^{86}Sr$ ratios. The child´s place of birth/childhood fell within the same range as the determined local $^{87}Sr/^{86}Sr$ range from Bashman 1 (cf. chapter 4.4.4. and fig. 4.7). The adult is noticeable, as this person was, together with ULG 56, distinctly different to all the results measured during this study, suggesting that a non-local person was buried at Bashman 1 (fig. 10.5). The site is located south of the Syr Darya which marks the northern border of the Oxus civilization, and an area inhabited by both groups – Oxus and Andronovo – in the first half of the 2nd mill. BCE. The results of isotope analyses from the northern communities, where nomadic pastoralism is argued to be a reason for the spread of the Andronovo culture, excluded long distance migration and a deeper influence on these societies (Ventresca Miller et al. 2017). However, insofar the mobility of Andronovo communities is suggested by an increased number of sites and material related to these populations in the southern territories during the first half of the 2nd mill. BCE (Vinogradova, Kuz'mina 1996; Cattani et al. 2008; Luneau 2017; Rouse, Cerasetti 2018).

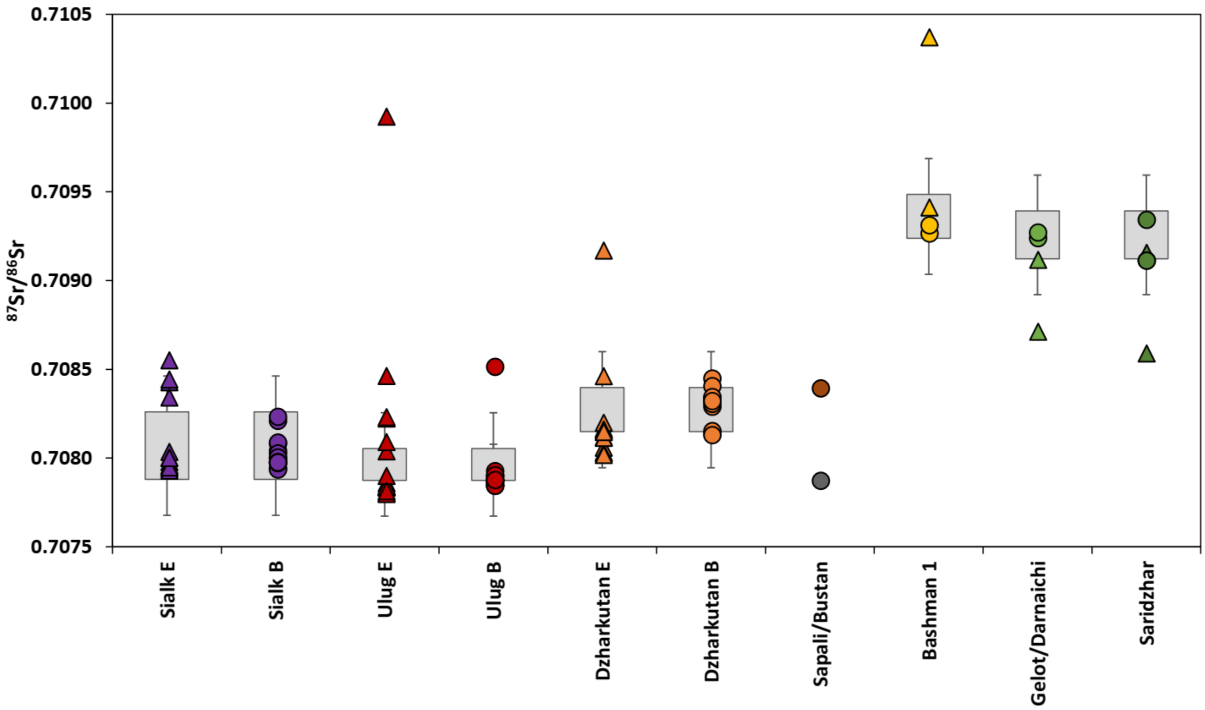

Fig. 10.5: $^{87}Sr/^{86}Sr$ results of all analysed human individuals in correlation to the bio-available local signals, grey boxes mark the local ranges, triangles correspond to enamel samples, circles to bone samples. Symbols encompass the error margins at 2σ level for the $^{87}Sr/^{86}Sr$ ratios.

10.4. Following the path of millet

Millet is therefore discussed here separately, because it is an important indicator for rising multi-crop agriculture and settled farming societies. Cultivated millet (broomcorn and foxtail) has its origin in

China and came to Central Asia during the 3rd and 2nd mill. BCE (Jones et al. 2011; Hunt et al. 2011; Miller et al. 2016). In the Balkans, Turkey and Central Asia, till today people drink a low-alcohol drink called Boza, which is based on millet malt. Compared to wheat and barley, millet grains are smaller and yields are correspondingly lower, but it grows unpretentious, is more resistant to water deficiency and aridity and has a short growing season. When the climate is very hot and dry, plants like wheat or barley might have a complete crop failure, while millet is always growing and producing at least something (Jones et al. 2011; Miller et al. 2016).

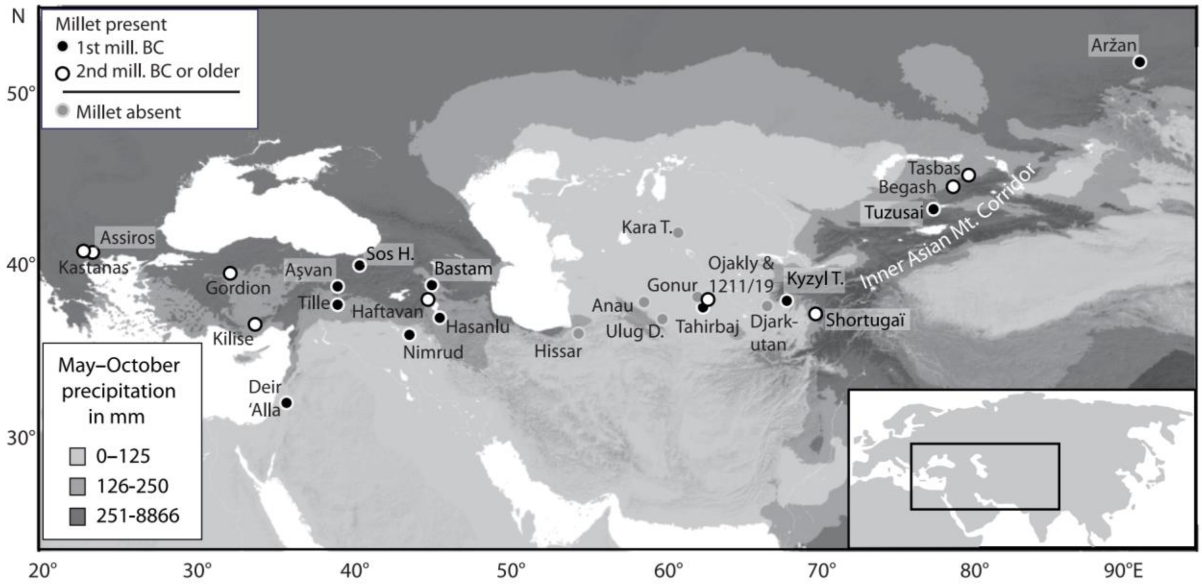

Fig. 10.6: Map of millet distribution in southern Central Asia after Miller et al. 2016: 1569 fig. 1a.

An increase in the millet cultivation is therefore often seen as an indication for climatic changes and increasing temperature and aridity. Millet has a special importance in isotopic science since it belongs to the C4 plants, and the consumption of millet is visible through enriched $\delta^{13}C$ ratios in the collagen of humans and animals. Several studies on carbon isotopes are available, especially on the Kazakh and Russian steppes (cf. fig. 10.6 and Miller et al. 2016). In the most detailed study Svyatko et al. (2013) presented more than 350 human and animal remains of numerous sites across the Minusinsk Basin, in Russia. The insight was an increase in the $\delta^{13}C$ values after 1500 BCE, indicating the beginnings of millet cultivation in the region. Further studies from the Andronovo sites in Bestamak and Lisakovsk along the Tobol River in northern Kazakhstan found no enrichment in the $\delta^{13}C$ results (Ventresca Miller et al. 2014), providing a temporal as well as geographic boundary for the westward spread of this trend (Miller et al. 2016). Another intensive study was conducted by Motuzaite-Matuzeviciute et al. (2015) revealing the beginning of millet distribution through an enrichment of $\delta^{13}C$ values from the early 2nd mill. BCE along the mountains of inner Central Asia and a spread southward. Furthermore, studies from pastoral communities in the southern Kazakh steppes might indicate the cultivation of millet as foddering material for the animals already in the LBA (Hermes et al. 2019). The systematic cultivation of fodder for animals implies a change in the production management of humans and developments in the subsistence strategies. A selective production of fodder for the animals demands a higher effort for the humans. This in return implies a higher value of the animals and their products. But the correlation between enriched $\delta^{13}C$ ratios and the consumption of millet with concomitant changes of economic strategies cannot always be considered as applicable, especially in regions with extreme climatic conditions and an adapted vegetation as it is often the case in the steppes of Central Asia. The appearance of millet in Dzharkutan (in Ulug and Sialk no millet was found) is only evidenced in the botanic remains in the Iron Age layers (Tengberg ongoing study). The isotopic analyses will provide further information on the question of millet consumption respectively a systematic cultivation as a part of the human and animal nutrition. Concerning the consumption of millet, the results from Ulug Depe, but especially Dzharkutan are ambiguous (Tepe Sialk is excluded as the isotopic results on humans did not provide any indication for the consumption of C4 plants cf. chapter 9.4.). The humans from Dzharkutan revealed distinct enriched $\delta^{13}C_{col}$ up to -16.4‰, which argue for a substantial intake of C4 plants in the diet through all periods. But millet was found only in traces in the Iron Age layers, the archaeological evidence for the consumption, respectively the cultivation of millet in the Bronze Age layers of Dzharkutan and Ulug Depe are totally absent (Tengberg et al. 2020). Studies from southern Kazakhstan showed $\delta^{13}C_{col}$ results between -13.3‰ and -19.0‰ of LBA steppe people, who consumed a substantial part of C4 plants (Motuzaite Matuzeviciute et al. 2015), according to botanical analyses domesticated millet (Spengler et al. 2013, 2014a, b). This territory represents a crossroad for the movement of crops traded and shared by mobile pastoralists (Frachetti 2012; Spengler et al. 2014a, b). While studies from northern Kazakhstan provided a temporal and geographic boundary for the westward spread of millet (Miller et al. 2016). Following a diachronic and regional development (cf. fig. 10.7), the Dzharkutan Oxus occupation already displayed increased $\delta^{13}C_{col}$, but the cultivation is not documented in these layers.

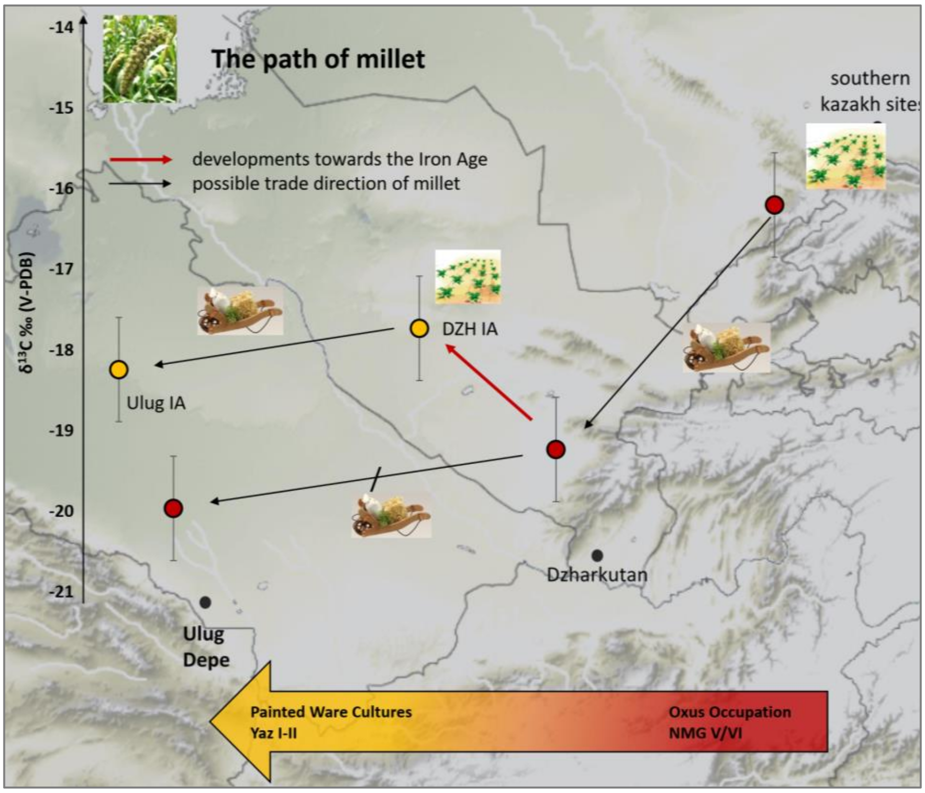

Fig. 10.7: Reconstruction of the possible distribution of millet during LBA and EIA according to the $\delta^{13}C_{col}$ results from Ulug Depe and Dzharkutan. Southern Kazakh sites after Motuzaite Matuzeviciute et al. 2015.

We might assume that trade brought millet into the settlement already during the LBA and people consumed a certain quantity but did not grow it. Not before the developments during the Iron Age established a wider cultivation, while in Ulug Depe the Oxus inhabitants do not display increased $\delta^{13}C_{col}$ ratios, implicating no substantial consumption of C4 plants. But the Iron Age individuals do, although millet was obviously not cultivated. It is always difficult to assume such a shift only on one side within the same cultural appearance like Ulug Depe and Dzharkutan. But there must have been other reasons why Ulug inhabitants did not consume and cultivated millet, although it was obviously available in neighboured regions (cf. Spengler et al. 2014, Miller et al. 2016, Tengberg et al. 2020). Especially around Ulug Depe the floral biome is dominated by facultative C4 plants (Tengberg et al. 2020), arguing for a high impact of the surrounding vegetation representing most likely the more substantial argument for the enriched $\delta^{13}C_{col}$ ratios of Ulug humans and animals.

10.5. Does dogs' diet mirror human diet?

This chapter arose through personal interest and a certain family tradition, but more due to the lucky coincidence of available material, funding, and the gratitude of Marjan Mashkour as a passionate collector. The relationship between predators and prey, respectively the nutrition of carnivores has rarely been studied using isotopic approaches and only single examples are available in the literature. Next to some rare wild predators as cats and foxes, dogs represent the most frequent species in archaeological material. Dogs are humans' best friend and longest partner concerning the domestication history (e.g., Davis and Valla 1978; Larson et al. 2012; Clutton-Brock 2016, Bergström et al. 2020).

Fig. 10.8: Dog burial Op V 22; Fd. Nr. 14 from Hasanlu III period (courtesy of the Hasanlu Project).

Dogs and humans not only share a similar nutrition, but their social behaviour and hunting techniques display many parallels as well, substantiating the relationship between dogs and humans. The presence of domesticated dogs is evidenced already in Mesolithic times or even earlier. The probably most famous discovery representing the special relationship between humans and dogs is the grave of a woman with a puppy in her arms from Ain Mallaha in Israel, dating to 11.500 BCE (e.g., Valla et al. 2017). It is therefore not surprising that the remains of dogs are found in almost every site in the Near East (e.g., fig. 10.8). Recent paleogenetic studies of Ollivier, Arendt and colleagues (2016) followed the question if domestication may have been accompanied by changes in the diet, using the adaptation of the *Amy2B* gene coding for pancreatic amylase, the enzyme that breaks starch into maltose. It is not clear whether these changes can be associated with the initial domestication, or if they represent a secondary shift related to the subsequent development of agriculture. But the results suggest that the increased selection of *Amy2B* genes started latest around 7000 years cal. BP as a biocultural coevolution of dog genes and human culture. Local adaptation within early farming societies allowed dogs to thrive on a starch rich diet (Ollivier et al. 2016; Arendt et al. 2016). Nutrition analyses out of collagen of dogs from different time periods from Iran and Central Asia performed during this study may deliver further insights on the development of dogs' nutrition in human coexistence.

To establish their trophic levels 17 dogs, dating from Chalcolithic to early Islamic periods, were analysed within this study: six dogs from Hasanlu dating to Hasanlu V–II (cf. Appendix table 3), one each from Nishapur, Tepe Naderi, and Qoli Darvish. From southern Central Asia four dogs from Ulug Depe, and each one from Sangir-tepe and Erkurgan were analysed (see chapter 3.1., 4.4. and 4.5. for site information). Central Asian dogs all date to Bronze Age periods, the dog from Tepe Naderi also dates to the LBA, and the one from Qoli Darvish between LBA and EIA, while the dog from Nishapur lived its life in the 3rd cent. AD. To get a broader picture obtained results of further predators were added from the literature to complement our dataset. These are summarized in table 10.1 with references and fig. 10.9–10.10.

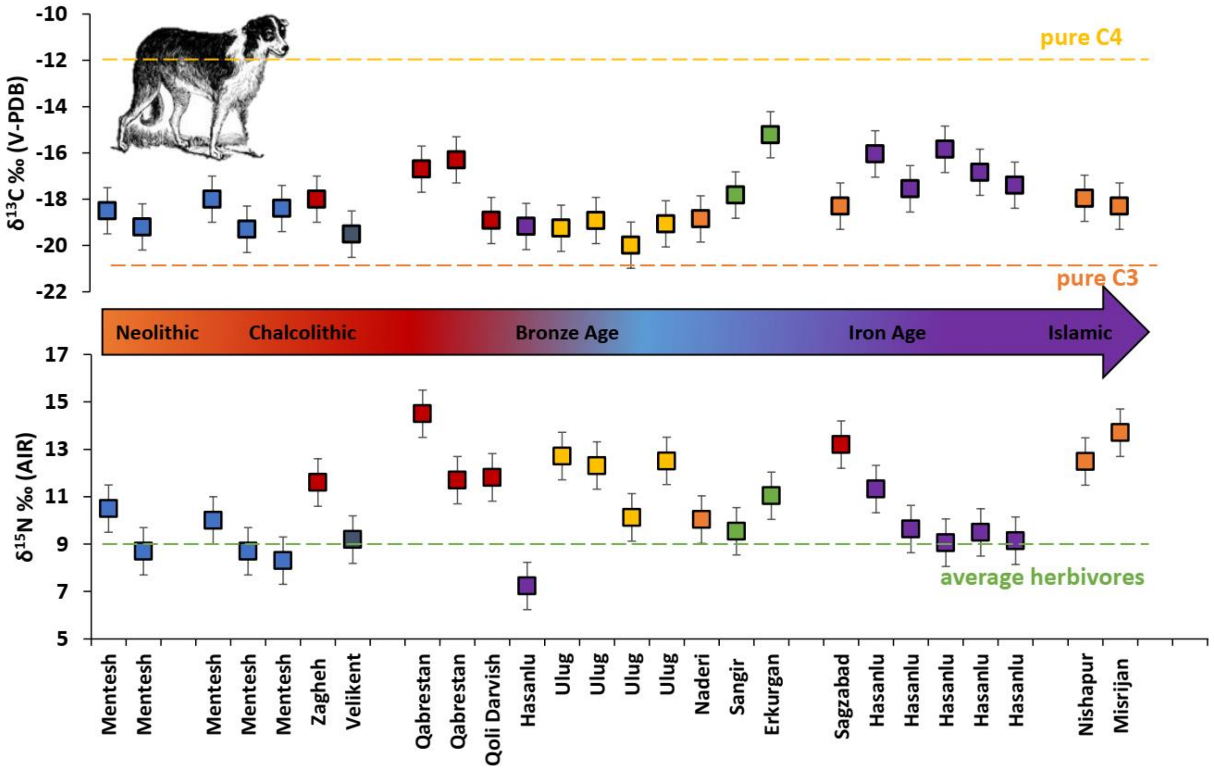

Fig. 10.9: Collected $\delta^{15}N$ and $\delta^{13}C$ results out of collagen from dogs around the Caspian Sea in chronological order. References: Velikent after Hollund et al. 2010; Mentesh Tepe after Herrscher et al. 2018; Zagheh, Qabrestan, Sagzabad after Bocherens et al. 2000; Geokchik Depe, Misrijan after Bocherens et al. 2006. Given average of the herbivores (green dashed line) was calculated using the mean value of all analysed ovicaprids from Iran and Central Asia.

All analysed dogs displayed $\delta^{15}N$ results between 7.2‰ and 14.5‰ and $\delta^{13}C_{col}$ results between -15.8‰ and -20.0‰. The results revealed a variety, but more in the lower ranges of the nitrogen scale. The Hasanlu dogs provided $\delta^{15}N$ results between 7.2‰ and 11.3‰ and $\delta^{13}C_{col}$ ratios between -15.8‰ and -19.2‰ (averages: $\delta^{15}N$ 9.3‰ ± 1.2; $\delta^{13}C_{col}$ -17.1‰ ±1.1). The dogs from Mentesh showed $\delta^{15}N$ results between 8.3‰ and 10.5‰ and $\delta^{13}C_{col}$ ratios between -18.0‰ and -19.3‰ (averages: $\delta^{15}N$ 9.2‰ ±0.9; $\delta^{13}C_{col}$ -18.7‰ ±0.5). Ulug dogs yielded $\delta^{15}N$ results between 10.1‰ and 12.7‰ and $\delta^{13}C_{col}$ ratios between -18.9‰ and 20.0‰ (averages: $\delta^{15}N$ 11.9‰ ±1.0; $\delta^{13}C_{col}$ -19.3‰ ±0.4). The single dogs from Naderi and Velikent fall within the same ranges as the Mentesh animals, whereas results of the dogs from Nishapur and Qoli Darvish are in slightly higher ranges, like Qazvin with $\delta^{15}N$ results between 11.6‰ and 14.5‰ and $\delta^{13}C_{col}$ ratios between -16.3‰ and -18.3‰ (averages: $\delta^{15}N$ 12.8‰ ±1.2; $\delta^{13}C_{col}$ -17.3‰ ±0.8). Especially the dogs from Mentesh and Hasanlu fall within low $\delta^{15}N$ ranges, more towards herbivores than carnivores. The Mentesh dogs (Neolithic) occupy a normal C3 range in the $\delta^{13}C_{col}$ ratios, while Hasanlu dogs displayed enriched $\delta^{13}C_{col}$ ratios (fig 10.9). Interestingly most dogs revealed low $\delta^{13}C_{col}$ ratios, especially compared to the wild carnivores. Considering the diachronic development, it can be pointed out that the early (Neolithic/Chalcolithic) and late (Iron II–III) dogs all display low $\delta^{15}N$ ratios, and the Bronze Age animals are all found in higher ranges. All dogs displayed rather low $\delta^{13}C_{col}$ ratios, in the range of a diet mainly consisting of C3 plants or animals who consumed C3 plants. It is difficult to distinguish a general pattern since the early and late periods are also connected to the respective geographic location (cf. fig. 10.9 and fig. 10.10). In the light of this regional comparison the $\delta^{15}N$ and $\delta^{13}C_{col}$ ratios of the Neolithic and Chalcolithic dogs from Mentesh seem rather depleted. This is also the case for the dogs from Hasanlu dating from the 3rd mill. BCE to the Achaemenid period. Whereas the dogs from the Qazvin Plains showed enriched $\delta^{15}N$ and $\delta^{13}C_{col}$ ratios, Ulug dogs are enriched in $\delta^{15}N$ but have depleted $\delta^{13}C_{col}$ ratios, and the dogs from central Uzbekistan are low in $\delta^{15}N$ and distinctly enriched in $\delta^{13}C_{col}$. Hence, the correlation between the geographic surroundings and the isotopic ratios are distinct. The climatic conditions and therefore the predominant ecosystem of the particular sites had a deeper impact on the results than the chronological distribution. The Hasanlu dogs can be evaluated diachronically, the oldest animal, dates back to the 3rd mill. BCE (Hasanlu VII, EBA), revealing depleted $\delta^{15}N$ and $\delta^{13}C_{col}$ ratios. The second oldest dog dates to the Early Iron Age (Hasanlu V–VI) and provided the highest $\delta^{15}N$ ratio and a distinct enriched $\delta^{13}C_{col}$ ratio. The remaining four canines date back to the Iron II (burnt city, Hasanlu IV, fig. 10.8) and Urartian/Achaemenid period (Hasanlu III/II), revealing rather low $\delta^{15}N$ and high $\delta^{13}C_{col}$ ratios.

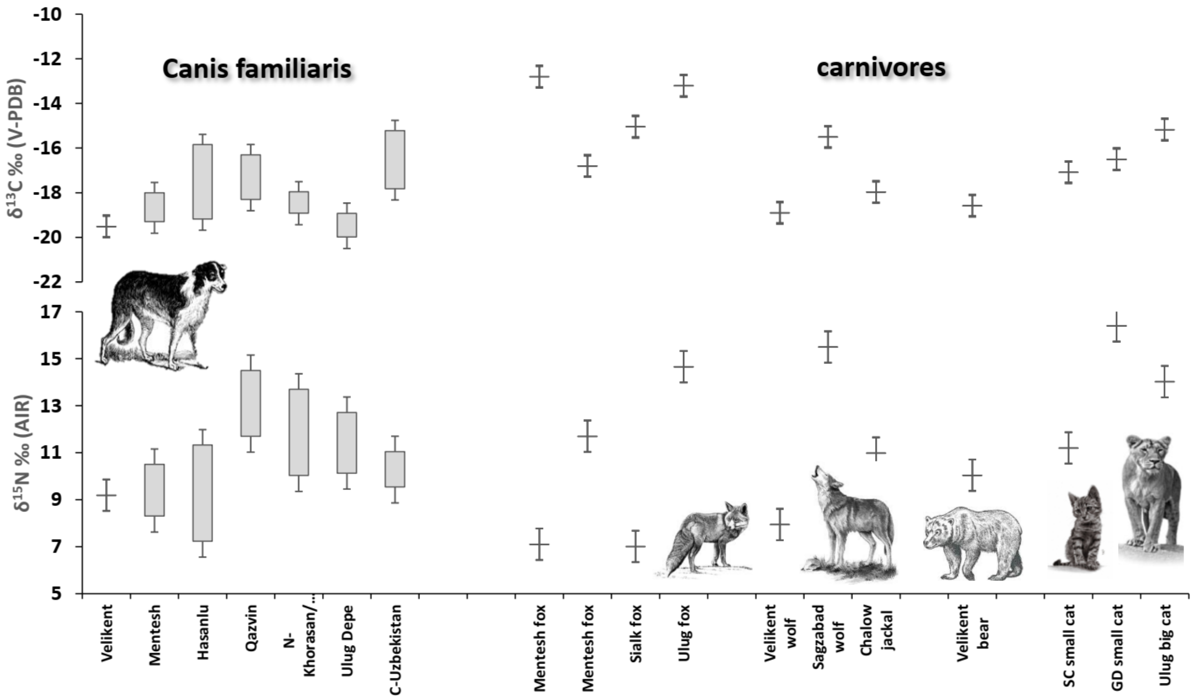

Fig. 10.10: Collected $\delta^{15}N$ and $\delta^{13}C$ results out of collagen from dogs and carnivores around the Caspian Sea in geographical order. References: Velikent after Hollund et al. 2010; Mentesh Tepe after Herrscher et al. 2018; Zagheh, Qabrestan, Sagzabad after Bocherens et al. 2000; Tepe Chalow after Soltysiak et al. submitted, Geokchik Depe (GD), Misrijan after Bocherens et al. 2006. "N-Khorasan" includes the dogs from Tepe Naderi, Nishapur, Qoli Darvish and Misrijan; "C-Uzbekistan" the dogs from Erkurgan and Sangir-tepe.

The enrichment in $\delta^{13}C_{col}$ can be referred to a nutrition consisting of wild animals and plants, whereas the dog from the EBA had a diet mainly consisting of C3 plants and animals with a diet of C3 plants. Hence the EBA dog was most likely fed by humans, whereas the later dogs added a certain amount of wild mammals to their menu. Summarized already the Neolithic/chalcolithic dogs display an adaptation to the human diet and fall within distinctly lower $\delta^{15}N$ and $\delta^{13}C_{col}$ ranges than their wild ancestors. Especially the early dogs (Mentesh, Zagheh, Ulug) revealed high $\delta^{13}C_{col}$ and rather low $\delta^{15}N$, in similar ranges as the humans, indicating the same nutrition and therefore a supply with food by humans. The later dogs (Iron Age) on the other hand revealed enriched $\delta^{13}C_{col}$ ratios, caused by a certain quantity of wild animals in the diet. The minimal enriched $\delta^{13}C_{col}$ ratios are possibly caused by the additional consumption of small wild mammals, birds or whatever passed their snouts. The results indicate that the early dogs were fed and shepherded by humans, whereas the late dogs seem to have been more self-reliant with less support of humans in terms of food supply.

The dog´s wild ancestor, the wolf is preferable carnivore and a predator of medium to large mammals as deer, gazelles, or boar, if available comprising up to 96% of their diet. In regions where such animals do not live, fruits, carrion, birds and small mammals can also be part of the diet (e.g., Lingen 2003: 131). Wolfs are very adaptable in terms of food consumption, and so are dogs. When living in human company a dog's menu mainly consisted of kitchen waste, maybe supplemented by hunting small mammals or searching for carrion. Hence, dogs who lived next to humans comprise the trophic levels of omnivores and carnivores. The classification of carnivores in the studied region turned out to be quite diverse. Single individuals of different species displayed highly variable isotopic results (fig. 10.10). The collected results with references are summarized in table 10.1. All in all, four foxes were available revealing $\delta^{15}N$ results between 7.0‰ and 14.7‰ and $\delta^{13}C_{col}$ ratios between -12.8‰ and -16.8‰. Foxes being opportunistic feeder consume, depending on season and availability small mammals, birds, insects, eggs, fruits, and herbs. Another close relative, a jackal from Tepe Chalow had a $\delta^{15}N$ ratio of 11.0‰ and $\delta^{13}C_{col}$ -18.0‰. Two wolfs were available, one from Velikent, one from Sagzabad, also revealing very diverse results of 7.9‰ and 15.5‰ in $\delta^{15}N$, -18.9‰ and -15.5‰ in $\delta^{13}C_{col}$ respectively. The in general highest results were found in cats (*Felidae*). Cats are hypercarnivores, with a diet of up to 80–90% of meat, and a low content of non-animal nutrients such as fungi, fruits or other plant material. Every species in the family Felidae, including the domesticated cat, is a hypercarnivore in its natural state. Therefore, they perfectly represent the topmost step of the nutrition pyramid.

Several individuals who biologically belong to the carnivores as the wolf from Velikent, the cat from Sang-e Chakhmaq, the jackal from Chalow, as well as two foxes, one from Mentesh, one from Sialk displayed significant low $\delta^{15}N$ ratios. The reasons are not clear, the authors assumed different reasons like diseases, metabolism and climatic impact (cf. Hollund et al. 2010; Herrscher et al. 2018; Soltysiak at al. submitted). Moreover, an impact of availability can be considered. Especially in hot and arid regions, and possibly intensive by hot seasons when food and water were scarce for both predators and preys. And when maybe the larger prey animals such as gazelles were rare as well, even large predators as wolfs started eating small mammals, birds, reptiles or fish. Only few results are available of small mammals or in general small prey animals. Results were available of two hares, one from Mentesh, one from Qabrestan, three turtles (from Mentesh and Zagheh), one pheasant from Mentesh and a snake from Aygurskiy. All revealing $\delta^{15}N$ ratios between 2.5‰ and 9.8‰ (the snake being a carnivore showed 11.4‰, cf. table 10.1).

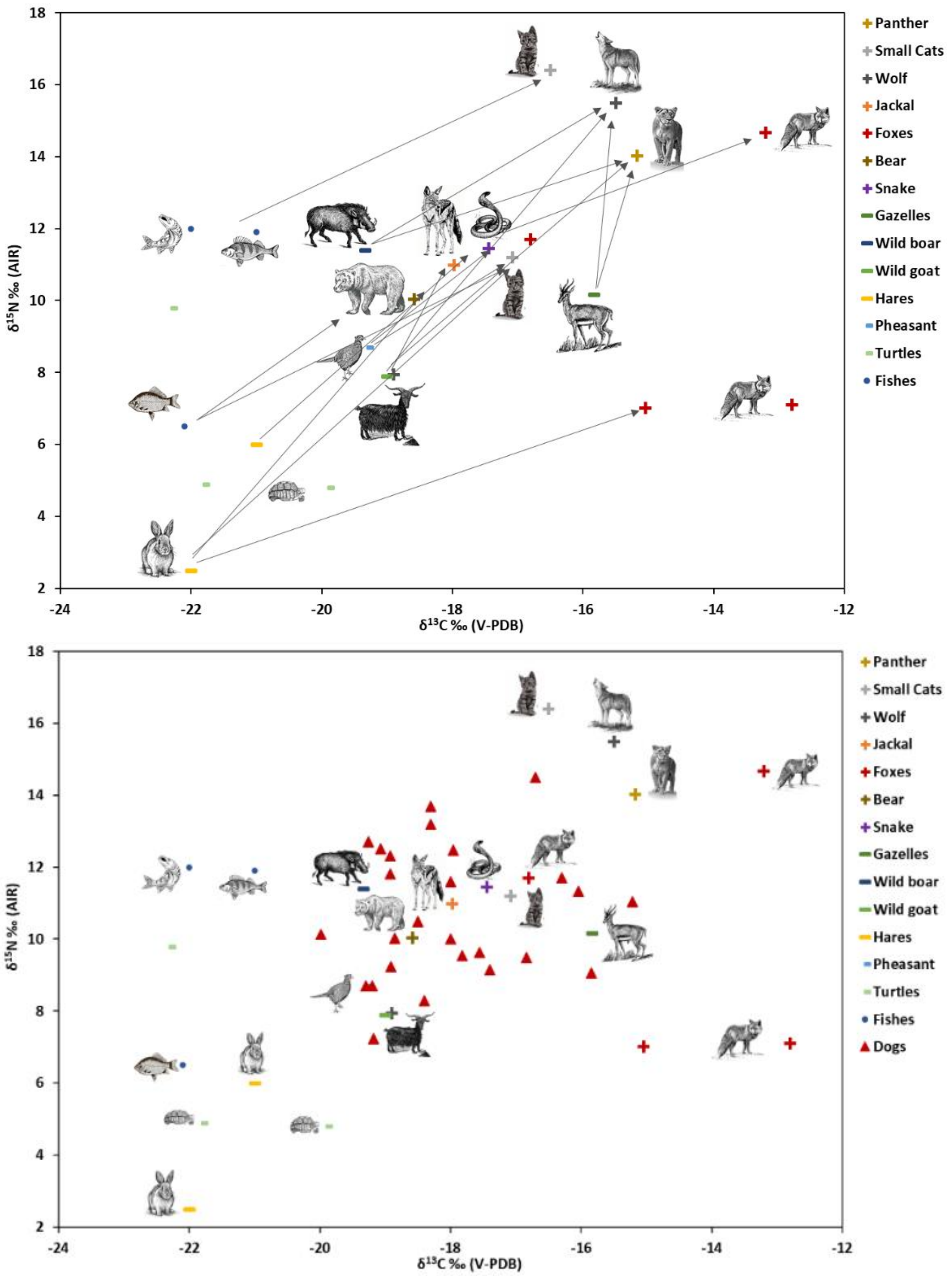

Fig. 10.11: Collected results of $\delta^{15}N$ and $\delta^{13}C_{col}$ out of collagen of wild animals. Top: predators and their prey. Bottom: dogs within the predators and the prey. References cf. table 10.1.

Hence, considering the small number available samples, small animals like mice, birds, hares, or turtles, as prey, comparative analyses showed intervals up to 4.5‰. Analyses of hares and e.g., turtles provided $\delta^{15}N$ results between 2.5‰ and 6‰ (after Herrscher et al. 2018, Bocherens et al. 2000). The trophic shift, which increases the $\delta^{15}N$ values between 3–5‰ per level from predator to prey (Bocherens, Drucker 2003; Hedges, Reynard 2007) was however also fulfilled for the low ranging predators (cf. fig. 10.11 top). Just as remarkable is an enrichment in $\delta^{13}C_{col}$ with an increasing trophic level. The small prey animals like hear, pheasants and also fish display distinct low $\delta^{13}C_{col}$ ratios, caused by a strict diet of C3 plants. Whereas the next step of prey animals, the larger herbivores as gazelles and sheep/goats, but also omnivores as bears, snakes and pigs already displayed an enrichment in $\delta^{13}C_{col}$. The uppermost trophic step, the higher predators, all revealed distinct enriched $\delta^{13}C_{col}$ ratios.

Table 10.1: Collection of $\delta^{15}N$ and $\delta^{13}C$ data out of collagen from dogs, predators and small prey animals

	Site	Species	approximate dating/additional information	$\delta^{15}N$ ‰ (AIR)	$\delta^{13}C$ ‰ (PDB)	Reference
dogs	Mentesh Tepe	Canis sp.	Neolithic	10.5	-18.5	after Herrscher et al. 2018
		Canis sp.	Neolithic	8.7	-19.2	
		Canis sp.	CH	10.0	-18.0	
		Canis sp.	CH	8.7	-19.3	
		Canis sp.	KA	8.3	-18.4	
	Ulug Depe	Canis fam.	EBA	12.7	-19.3	
		Canis fam.	EBA-MBA	12.3	-18.9	
		Canis fam.	MBA	10.1	-20.0	
		Canis fam.	MBA	12.5	-19.1	
	Hasanlu	Canis fam.	Period VII 3rd Mill	7.2	-19.2	
		Canis fam.	Period V-IV (?)	11.3	-16.0	
		Canis fam.	Has III or II	9.5	-16.8	
		Canis fam.	Has III or II	9.1	-17.4	
		Canis fam.	probably Has IV	9.6	-17.6	
		Canis fam.	probably Has IV	9.1	-15.8	
	Qabrestan	Canis fam.	Bronze Age	14.5	-16.7	after Bocherens et al. 2000
		Canis fam.	Bronze Age	11.7	-16.3	
	Zagheh	Canis fam.	Chalcolithic	11.6	-18.0	
	Sagzabad	Canis fam.	Iron Age	13.2	-18.3	
	Velikent	Canis fam.	Chalcolithic	9.2	-19.5	after Hollund et al. 2010
	Sangir Tepe	Canis fam.	LBA	9.5	-17.8	
	Erkurgan	Canis fam.	LBA	11.0	-15.2	
	Tepe Naderi	Canis fam.	LBA	10.0	-18.9	
	Qoli Darvish	Canis fam.	LBA	11.8	-18.9	
	Nishapur	Canis fam.	3rd cent. AD/islm.	12.5	-18.0	
	Misrijan	Canis fam.	Islamic	13.7	-18.3	after Bocherens et al. 2006
predators	Chalow	Canis aureus	LBA	11.0	-18.0	after Soltysiak et al. forthc.
	Sagzabad	Canis lupus	Iron Age	15.5	-15.5	after Bocherens et al. 2000
	Velikent	Canis lupus	Late Chalcolithic	7.9	-18.9	after Hollund et al. 2010
	Mentesh	Vulpes vulpes	Chalcolithic	7.1	-12.8	after Herrscher et al. 2018
		Vulpes vulpes	Chalcolithic	11.7	-16.8	
	Sialk	Vulpes vulpes	KA	7.0	-15.0	
	Ulug Depe	Vulpes vulpes	EIA-MIA	14.7	-13.2	
	Ulug Depe	Panthera sp.	EBA-MBA	14.0	-15.2	
	Sang-e Chakhmaq	Felix sylvestris	Neolithic	11.2	-17.1	
	Geoktchik	Felidae indet.	Iron Age	16.4	-16.5	after Bocherens et al. 2006
	Velikent	Urs sp.	Late Chalcolithic	10.0	-18.6	after Hollund et al. 2010
small prey	Qabrestan	Lepus sp.	hare - herbivore	2.5	-22.0	after Bocherens 2000
	Mentesh	Lepus sp.	hare - herbivore	6.0	-21.0	after Herrscher et al. 2018
		Phasianidae	pheasant - herbi-/insectivore	8.7	-19.3	
		Testudines sp.	turtle - herbivore	4.8	-19.9	
		Testudines sp.	turtle - herbivore	4.9	-21.8	
	Zagheh	Testudines sp.	turtle - herbivore	9.8	-22.3	after Bocherens et al. 2000
	Aygurskiy	Serpentes sp.	snake - omni-/carnivore	11.4	-17.4	after Hollund et al. 2010
	Lake Baikal	Cypriniformes	carp - detritivore	7.3	-21.4	after Katzenberg 1999
		Cypriniformes	carp - detritivore	6.5	-22.1	
		Perciformes	perch - omnivore	11.9	-21.0	
		Esociformes	pike - piscivore	12.0	-22.0	
	Qabrestan/Sagzabad	Sus scrofa	boar - omnivore	10.9	-19.1	after Bocherens et al. 2000
		Sus scrofa	boar - omnivore	9.7	-18.4	
		Sus scrofa	boar - omnivore	12.2	-19.7	
		Sus scrofa	boar - omnivore	12.1	-19.4	
		Sus scrofa	boar - omnivore	12.1	-20.1	

Hence, at least for the animals around the Caspian Sea, the trophic steps are not only following the $\delta^{15}N$ scale towards higher ratios, but also the $\delta^{13}C_{col}$ scale towards lower ratios. Adding the dogs into the picture (cf. fig 10.11 bottom), it is evident, that they occupy a wide area between herbivores and carnivores, respectively between predator and prey. Moreover, they are limited to the range of omnivores and herbivores, but are not present in between the large predators or pure carnivores. Hence, already the oldest analysed dogs display a significant adaptation to human farming societies, continuing through all periods.

11. Synthesis and conclusion

This thesis investigated two main aspects through isotopic applications: on the one hand the subsistence, respectively the nutrition and economic strategies of the Bronze and Iron Age communities in southern Central Asia, and the Neolithic/Chalcolithic, respectively the Iron Age population from Tepe Sialk on the Central Iranian Plateau. On the other hand, the level of migratory impact reflecting cultural influences was investigated in the different geographic regions through times.

The communities of the Oxus Civilization were long assumed to follow an agro-pastoral lifestyle, specialized in agricultural development, famous for their irrigation systems making sparse land livable and seasonal movements for herding and breeding sheep/goat flocks. The obtained results argue that people from Ulug Depe and Dzharkutan followed a sedentary lifestyle, with nutrition based little on animal protein as meat, fat or milk, but with a higher intake of terrestrial resources. Comparative diachronic analyses indicate that the social and cultural changes coming along with the appearance of the Oxus Civilization did not have a direct or significant impact on the nutrition of the humans from Ulug Depe, but on the animals. Changes in feeding and herding management can be reconstructed, certainly coming along with changes of the daily life organization of the humans in terms of agricultural management and daily food supply. The dietary variation concerning biological criteria like age, sex or even the archaeologically indicated social position, is only weakly reflected through the small sample number. But none of the isotopic characteristics of pastoralists applied to the results, instead an extensive use of the direct surroundings is evidenced. Moreover, the results indicate a high impact of hunting activities, while the own flocks were rather kept for secondary production. The results merge perfectly in standing theories implying that a high degree of specialization was distinct for this time period and several different lifestyles, practiced by separated groups of people, existed within these societies. Next to pastoralists, who moved for herding and breeding of animals possibly living in nearby villages or seasonal campsites in the mountains, existed the inhabitants of Ulug Depe and Dzharkutan, representing sedentary urbanites, most likely specialized agriculturalists responsible for the agrarian provision. Broader comparative analyses in general proved a nutrition mainly based on terrestrial resources produced by sedentary farming communities in southern Central Asia. Whereas a higher intake of animal protein, like meat, milk, and yoghurt is described of the northern steppe tribes. The analysed remains of the EBA periods from Ulug Depe indicate the use of different groundwater sources, hence a higher mobility during times when organization units consisted rather of self-sustaining families or clans. The results of sheep/goats argue for a more natural way of feeding and herding, supporting the image of a basic lifestyle of the humans impacted by the collection of natural resources, while tracking seasonal food and water reservoirs together with the animals. The Iron Age individuals from Ulug Depe and Dzharkutan displayed different nutrition habbits as well as mobility patterns. Enrichments in $\delta^{13}C$ could be observed in all individuals indicating a higher consumption of C4 plants, maintaining the fact that millet was common in the 1^{st} mill. BCE. Even if not cultivated locally, the distribution through trade can be assumed. Furthermore, the migratory impact increased again: in Ulug Depe both Iron Age women, and in Dzharkutan the one adult woman were identified as non-local, suggesting recurrent increasing migratory movements.

For the inhabitants of Tepe Sialk the use of different groundwater sources is now documented through all periods, accompanied by a distinct high content of animal protein in the diet as well as a high variety of plants and terrestrial resources. The data conform with the consumption of meat, milk, or dairy products from domesticated herbivores. Strontium analyses only identified women as non-locals indicating a gender specific pattern in Sialk. Comparative investigations suggest a frequent gene-flow and dynamic interactions throughout millennia between north-western Iran and the Central Plateau.

Migration studies delivered fundamental insights concerning the cultural relations and mutual impacts, as well as migration routes, directions, and distances. Ulug Depe is characterized by an exceptional high rate of immigration long before the appearance of Oxus and Andronovo. Furthermore, burial ULG 56 is an evidence for long-distance migration: isotopic and paleogenetic analyses attest ancestries with Swedish Sami and therefore migration from the far north. The idea of the distance this person covered over a lifetime in 2800 BCE is breathtaking, just as the implication of how far the cultural connections and influences of the EBA people really went. Towards the end of the 3rd and the beginning of the 2nd mill. BCE the sites in southern Uzbekistan (Dzharkutan, Tilla Bulak, Sapallitepa, and Bustan) show highly diverse $^{87}Sr/^{86}Sr$ results, proving an active mobility among the inhabitants of the newly founded settlements. The people buried in Dzharkutan suggest a complex pattern of mobility or subsistence, where movements between a person's place of birth and residence in a limited area were a regular feature, observable throughout the centuries. In the same way evidence of movements between southern Uzbekistan and the neighboring communities in southern Tajikistan can be drawn from the material. Moreover, the Lady from Gelot delivered shed some light on the migration routes during the Bronze Age between regions which are commonly not considered to belong to a common cultural horizon. The results substantiate active dynamics within a wide area between Iran and southern Central Asia.

12. Summary in English German and French

The aim of this interdisciplinary approach of natural sciences and archaeology was to investigate the mobility and subsistence of prehistoric communities settled in southern Central Asia and Iran using isotopic applications. This thesis is divided into two main aspects, on the one hand the isotopic description of Bronze and Iron Age populations in southern Central Asia. The concept arose as a sub-project of a larger scientific project consisting of the disciplines of archaeozoology, archaeobotany, isotope chemistry, paleogenetic, anthropology and morphology. The project is based at the Institute for Archéozoologie, Archéobotanique, Sociétés, Pratiques et Environnements (AASPE), and the Laboratoire Eco-anthropologie (UMR 7206) of the Muséum National d´Histoire Naturelle (MNHN, CNRS) in Paris, in cooperation with the Mission archéologique Franco-Ouzbèke Protohistoire (MAFOuz-P), the Mission archéologique franco-turkmène (MAFTur), and the French Archaeological Delegation in Afghanistan (DAFA). Focus are the sites Ulug Depe in southern Turkmenistan and Dzharkutan in southern Uzbekistan. Thanks to colleagues from the German Archaeological Institute (DAI) and the Ludwig Maximilian University in Munich who kindly provided further samples, it was possible to gain cross-regional results from the sites Tilla Bulak, Sapallitepa and Bustan in southern Uzbekistan, Bashman 1 in central Uzbekistan, and Gelot, Darnaichi, and Saridzhar in southern Tajikistan. Tepe Sialk on the central Iranian plateau represents the second sub-project, which includes the processing of the Ghirshman collection of the Louvre Museum and the Musée de l´Homme in Paris. Since the samples from Tepe Sialk did not coincide in time with the samples from Central Asia, covering only the Neolithic/Chalcolithic and Iron Age periods, Sialk was treated separately in this thesis. The selection of the sites and samples, in which the author was not involved, was made long before the work on this thesis started. The selection was determined by the state of preservation of the graves and very limited by the prevailing political situation in the particular countries. For this reason, it was unfortunately not possible to obtain a representative cross-section of space and time, or a uniform distribution of age and gender as well as the chronological periods, what significantly impacted the evaluation of the results and their relevance for further interpretations.

The research area includes the Bronze and Iron Ages in Central Asia and the Neolithic, Chalcolithic and the late Iron Age on the Iranian Plateau. Towards the end of the 3rd mill. BCE two main cultural entities coexisted in Central Asia: The northern steppe territories were occupied by the Andronovo Cultural Community, while the south, present-day southern Uzbekistan, Turkmenistan, Tajikistan, northern Afghanistan, and northeastern Iran was the zone occupied by the Oxus Civilization (GKC, BMAC). Recent excavations in southern Tajikistan also evidenced the co-existence and merge of both traditions. The appearance of the Oxus Civilization is still not fully understood, but archaeological remains evidence urbanism and population growth, which caused major changes in southern Central Asian societies affecting also different aspects of the local subsistence economies. Larger settlements acted as structuring units for the surrounding land and main localities, where trade and distribution of food took place. Sophisticated irrigation systems opened up new territories and enabled them to settle also in hot and arid regions. Huge fortification systems argue for territorial boundaries, as well as the existence of property and its bureaucratic organisation. The large number of exotic artifacts indicated widespread connections and a certain role in the interregional trade network between Indus and Euphrates. The fall of the Oxus civilization is just as unclear as its appearance, but after a short, gradual transition period an economic and ideological shift took place. Southern Central Asia was then occupied by a mosaic of smaller cultures, known as the "Yaz I Cultures" or *Handmade Painted Ware Cultures*. The settlement pattern changed, the territory expanded further to the east, moreover surveys evidenced a pattern back to smaller villages, and de-centralized organisations units. Archaeological remains indicated luxury goods were replaced by utilitarian objects and agrarian tools. Adaptations of livestock husbandry and farming practices have been suggested, as well as a certain social homogenization of the societies since neither the material culture nor the architectural simplicity give any indication concerning the social organization or hierarchy. The questions that arise in Ulug Depe and Dzharkutan concerning nutrition habits and mobility are based on the general theories of pastoralism or seasonal movements to more fertile pastures, as well as possible changes in nutrition and mobility due to the rise and fall of the Oxus civilization. Whether the archaeologically documented developments regarding a hierarchically structured society or a centrally organized system had a direct influence on the diet of the people and their way of life. The case is similar in Sialk, where the research focus was on possible changes due to the intensification of agricultural land use in the Neolithic and Chalcolithic periods, as well as ongoing urbanization processes in the proto-elamite period, or the external cultural influences during the Iron Age.

The application of multi-isotopic investigations, here the combination of $^{87}Sr/^{86}Sr$, $\delta^{18}O$, $\delta^{15}N$, and $\delta^{13}C$, represents in the meanwhile well-established methods to follow questions on mobility, possible migrations and dietary patterns of humans and animals. Strontium and oxygen isotopes ($^{87}Sr/^{86}Sr$, $\delta^{18}O$) out of tooth enamel and bones, enable the description of geological regions and groundwater sources, hence movements between different regions can be reconstructed, as well as migration rates. The characterization of strontium and oxygen isotopes, which depend on various factors, resulted in an iso-chemical differentiation of the particular regions and enabled despite some overlapping the identification of locals and non-locals. The reconstruction of the diet on the basis of nitrogen and carbon isotope analyses ($\delta^{15}N$, $\delta^{13}C$) was carried out on the same individuals. Nutrition analyses based on collagen out of bones provide information about the content of animal protein in the diet and the general proportion of meat, milk or other animal products. Moreover, insights into the content and type of plant resources are given, which can be used to reconstruct agricultural techniques, land use and climatic impacts. The evaluation included the results of 74 humans, 102 animals and 55 plants, respectively 167 strontium analyses, 133 collagen and 136 bioapatite analyses. A main part of this study was the determination of the isotopic background. Through the analyses of different local animal and plant species a picture of the regional geological conditions and the surrounding floral biome is given, with the aim is to classify the humans most reliably. The focus was on the one hand on the determination of numerous biologically available local strontium signals in the research area, ideally by means of sedentary animals such as rodents and different plant species. In addition to the three main sites Ulug Depe, Dzharkutan and Tepe Sialk, biologically available strontium signals were also determined from Tilla Bulak near Dzharkutan, from Bashman 1 south of the Nuratau Mountains, along the Gorgan Wall in Golestan, from North-Khorasan region, and the southern part of the Lut desert. In addition, numerous single rodents were analysed in order to create a cross-regional basis. Hence, individual strontium isotopic results from Geokchik Depe on the Turkmen Caspian Sea coast, as well as from Sangirtepe and Erkurgan in central Uzbekistan, Kalateh Khan in the Shahroud plain, Tepe Damghani in Semnan, Tepe Taleb Khan near Shahr-i Sokhte, Tepe Pahlavan and Sarvestan in Fars, and from Hasanlu and Tepe Zagheh in north-western Iran, can be presented. To determine the local oxygen signal and due to the lack of more suitable reference material than the animals, the available results of the databases were included. The basis of the nutrition analyses was laid using the highest possible variation of different animal species reflecting a broad spectrum of herbivores and carnivores, wild and domesticated, to characterize the trophic levels.

The results displayed a positive correlation of $\delta^{15}N$ and $\delta^{13}C$ isotopes, as well as a strong influence of the climatic conditions in the investigated regions. The individuals of the early periods in Ulug

Depe indicate the use of different water sources, hence a higher mobility. The results of domesticated sheep and goats show a diet similar to that of the wild gazelle, and therefore a more natural way of feeding and herding, in which humans and animals were more dependent on natural resources and water reservoirs. Whereas the people of the Oxus phases limited their use to a few water sources in the direct surroundings, indicating a more intensive land use and a rather sedentary way of life. All individuals from Ulug and Dzharkutan showed a diet that was little based on animal protein such as meat, fat or milk, but had a high proportion of vegetable components. In addition, the results indicate the consumption of wild animals rather than that of domesticated ones. The zoological investigations of the animal bones already indicated their own herds were kept for secondary production or trade rather than as primary food source, which has now been proved by the isotope analyses. The dietary variation concerning biological criteria like age, sex or the archaeologically indicated social position of the individuals, is only weakly reflected through the small sample number throughout all periods. Comparative diachronic evaluations showed the social and cultural changes coming along with the appearance of the Oxus civilization had no direct or significant impact on the diet of the humans in Ulug Depe, but on the animals. The results of the domesticated herbivores suggest changes in dietary habits, most likely due to developments in the livestock organisation. The Iron Age individuals from Ulug Depe and Dzharkutan again showed a different diet and mobility pattern. An enrichment in carbon can be observed for all human individuals, indicating a higher content of C4 plants in the diet, possibly caused by the consumption of millet, which was common in the 1st mill. BCE. Even if not grown locally, as in Ulug Depe, large-scaled trade connections are assumed by several colleagues. Additionally, increasing migratory impact can be observed, in Ulug both women, in Dzharkutan the one adult woman, were identified as non-locals. Despite the small number of samples, a general increase of mobility can be assumed.

The residents of Tepe Sialk used different water sources through all times and had a comparatively high content of animal protein in their diet. The data conform with the consumption of meat, milk and dairy products of domesticated herbivores, but could also result from the consumption of freshwater fish, mussels or snails. However, the natural conditions in the surrounding region do not substantiate this. Throughout all periods the human diet displayed a high variety of different plant species, but no consumption of C4 plants or millet could be documented. Migration studies only identified women as non-natives, which might indicate a gender-specific pattern in Sialk but needs to be confirmed by further results. Paleogenetic studies have shown gene flow between northwest Iran and the Central Plateau over millennia.

Migration studies delivered fundamental insights concerning the cultural relations and mutual impacts, as well as migration routes, directions, and distances. Ulug Depe demonstrate an exceptional high rate of immigration long before the appearance of Oxus and Andronovo. Burial ULG 56 delivered true evidence for long-distance migration, the combination of isotope and paleogenetic analyses displayed a genetic ancestry from the Swedish indigenous people (Sami) and an immigration from the north. The results demonstrate what distance a person can cover over a lifetime at the beginning of the 3rd millennium BCE, and how far the cultural connections and influences really went already in the early phases. Towards the end of the 3rd and beginning the 2nd mill. BCE the sites in southern Uzbekistan (Dzharkutan, Tilla Bulak, Sapallitepa, and Bustan) show highly diverse $^{87}Sr/^{86}Sr$ results, proving an active mobility among the inhabitants of the newly founded settlements. The people buried in Dzharkutan followed a complex mobility pattern, where movements between a person's place of birth and residence in a limited area were a regular feature, observable throughout the centuries. In the same way movements are demonstrated between southern Uzbekistan and the neighboring communities in southern Tajikistan. Moreover, the Lady from Gelot delivered fundamental insights on the migration routes during the Bronze Age between regions which officially did not belong to a common cultural horizon. The results substantiate not only active exchanges between eastern Iran and southern Tajikistan, but also confirm the migration of people along routes known through trade of raw materials since the Neolithic times.

The applications of multi-isotope approaches deliver meaningful and reliable results, if a statistically relevant sample number of human individuals, but also a wide range of reference material is available. The example of Ulug Depe clearly demonstrate how different results can be correlated to an overall picture if, in addition to humans, a broad spectrum of animals and plants is available in the sample pool. In addition, the results showed that detailed analyses of animals provide indispensable results for the elucidation of human ways of life. However, the problem of availability arose when working on old excavations. Nevertheless, the present data set showed that the study area is isotopically distinguishable, and even if only provisional statements can be made or tendencies shown due to the small sample number, this study presents the first detailed and cross-regional isotopic data from southern Central Asia and provide an excellent basis for future studies.

Das Ziel dieser interdisziplinär angelegten Studie der Naturwissenschaften und der Archäologie war mittels Isotopenanalysen die Mobilität und Wirtschaftsweise prähistorischer Gesellschaften im südlichen Zentralasien und Iran zu untersuchen. Die Arbeit gliedert sich in zwei Teilprojekte. Bei dem ersten handelt es sich um die isotopenchemische Beschreibung bronze- und eisenzeitlicher Populationen im südlichen Zentralasien. Das Konzept entstand als Teilstudie eines größer angelegten naturwissenschaftlichen Projekts bestehend aus den Disziplinen der Archäozoologie, Archäobotanik, Isotopenchemie, Paläogenetik, sowie der Anthropologie und Morphologie. Das Projekt ist angesiedelt am Institut für Archéozoologie, Archéobotanique, Sociétés, Pratiques et Environnements (AASPE), und dem Laboratoire Eco-anthropologie (UMR 7206), des Muséum National d´Histoire Naturelle (MNHN, CNRS) in Paris in Kooperation mit der Mission archéologique franco-turkmène (MAFTur), der Mission archéologique Franco-Ouzbèke Protohistoire (MAFOuz-P) und der Französischen Archäologischen Delegation in Afghanistan (DAFA). Der Schwerpunkt liegt auf den Fundorten Ulug Depe in Süd Turkmenistan und Dzharkutan im südlichen Usbekistan. Freundlicherweise wurden von Kollegen des Deutschen Archäologischen Instituts (DAI) und der Ludwig-Maximilian-Universität München weitere Proben zur Verfügung gestellt; dies ermöglichte regional übergreifende Ergebnisse aus den Fundorten Tilla Bulak, Sapallitepa und Bustan in Südusbekistan, Bashman 1 in Zentralusbekistan, sowie Gelot, Darnaichi und Saridzhar in Süd Tadschikistan. Tepe Sialk auf dem Zentral-Iranischen Plateau stellt das zweite Teilprojekt dar, bei dem es sich um die Aufarbeitung der Ghirshman Kollektion des Louvre Museums, bzw. des Musée de l´Homme in Paris handelt. Nachdem die Proben aus Tepe Sialk zeitlich nicht mit den Proben aus Zentralasien übereinstimmen, sondern das Neolithikum, Chalkolithikum und die Eisenzeit abdecken, wurde Tepe Sialk in dieser Arbeit gesondert behandelt. Die Selektion der Proben sowie der Fundorte, die nicht in den Händen der Verfasserin lag, wurde lange bevor die Arbeit an diesem Projekt startete vorgenommen. Die Auswahl wurde durch den Erhaltungszustand der Gräber bestimmt sowie durch die vorherrschende politische Situation der jeweiligen Länder sehr beschränkt. Aus diesem Grund war es leider nicht möglich einen repräsentativen Querschnitt durch Raum und Zeit zu erhalten, bzw. eine einheitliche Verteilung von Alters- und Geschlechtsgruppen sowie der chronologischen Perioden, was die Evaluation der Ergebnisse bzw. deren Relevanz für weiterführende Interpretationen erheblich beeinträchtigte.

Das Forschungsgebiet umfasst die Bronze- und Eisenzeit in Zentralasien, sowie das Neolithikum, Chalkolithikum und die späte Eisenzeit auf dem Iranischen Hochplateau. Gegen Ende des 3. Jahrtausend v. Chr. wurde Zentralasien von zwei unterschiedlichen kulturellen Erscheinungen dominiert: Im Norden befand sich das Steppengebiet, das von den Andronovo Stämmen besiedelt wurde, der Süden, das heutige südliche Usbekistan, Turkmenistan, Tadschikistan, Nordafghanistan und der nordöstliche Iran, wurde von der Oxus Zivilisation (GKC, BMAC) besiedelt. Jüngste Erkenntnisse aus Süd Tadschikistan belegen anhand von Grabfunden eine zeitgleiche Existenz beider Traditionen, bzw. auch ihre Verschmelzung. Das Aufkommen der Oxus Zivilisation ist bis heute nicht geklärt, archäologische Funde belegen ein rasches Wachstum und die Neugründung von Siedlungen, wobei ein ansteigendes Bevölkerungswachstum gewisse urbane Strukturen begünstigt und zu Veränderungen der lokalen Subsistenzwirtschaft führten. Größere Siedlungen fungierten als zentrale Organisationssysteme für das umliegende Land, in denen Handel und Verteilung von Nahrung und Gütern stattfanden. Die Oxus Zivilisation war berühmt für ihre ausgeklügelten Bewässerungssysteme, die es ihnen ermöglichten auch in trockenen und heißen Regionen zu siedeln. Architektonisch zeugen große Verteidigungs- bzw. Begrenzungsmauern von einer gewissen territorialen Abgrenzung bzw. der Existenz von Besitz und deren Verwaltung. Besonders die große Anzahl exotischer Artefakte zeugte von weitreichenden Verbindungen und einem dynamischen Netzwerk, das die Regionen zwischen Indus und Euphrat miteinander verband. Der Untergang der Oxus Zivilisation ist genauso wenig geklärt wie ihr Erscheinen, nach einer kurzen Übergangszeit fand um 1500 v. Chr. ein wirtschaftlicher und ideologischer Wandel statt. Ein Mosaik kleinerer Kulturen, die als „Yaz I-Kulturen“ oder *Handmade Painted Ware Cultures* bezeichnet werden, überzog das südliche Zentralasien. Das Siedlungsmuster ändert sich, das Territorium erstreckt sich weiter in den Osten, außerdem zeigten Oberflächenbegehungen einen Rückgang zu kleineren Dörfern und einem dezentralisierten Organisationsystem. Archäologische Funde belegen das Verschwinden von Luxusgütern, die durch Gebrauchsgegenstände und Werkzeuge ersetzt wurden. Grundlegende Veränderungen in der Agrar- bzw. Weidewirtschaft und Landnutzung werden angenommen, sowie eine gewisse soziale Homogenisierung der Gesellschaft, nachdem weder die materiellen Hinterlassenschaften noch die architektonische Einfachheit einen Hinweis auf eine soziale Organisation oder Hierarchie geben.

Die Erforschung des Ernährungsverhalten und der Mobilität in Ulug Depe und Dzharkutan bedient sich der grundlegenden Theorien zum Pastoralismus. Saisonale Wanderungen zu ertragreichen Weidegründen, sowie mögliche Veränderungen von Ernährung und Mobilität durch das Aufkommen und den Untergang der Oxus Zivilisation stehen im Mittelpunkt. Weiterhin stellt sich die Frage, ob die archäologisch belegten Entwicklungen hinsichtlich einer hierarchisch gegliederten Gesellschaft bzw. einem zentralorganisierten System einen direkten Einfluss auf die Ernährung und Lebensweise der Menschen hatten. Ähnlich ist der Fall in Sialk, hier lag der Forschungsschwerpunkt auf eventuellen Veränderungen der Lebensweise durch die Intensivierung der agrarwirtschaftlichen Landnutzung im Neolithikum und Chalkolithikum, bzw. der Urbanisierung durch die proto-elamische Zeit sowie äußere kulturelle Einflüsse während der Eisenzeit.

Die Methodik der Multi-Isotopenanalysen, in diesem Fall eine Kombination aus $^{87}Sr/^{86}Sr$, $\delta^{18}O$, $\delta^{15}N$, und $\delta^{13}C$, ist ein mittlerweile lang etabliertes Mittel zu Erforschung von Mobilität, Migration und Ernährungsverhalten von Menschen und Tieren. Anhand von Strontium- und Sauerstoffisotopen ($^{87}Sr/^{86}Sr$, $\delta^{18}O$) aus Zahnschmelz und Knochen können Herkunftsgebiete analysiert und eingeschränkt werden, bzw. Grundwasserquellen charakterisiert werden, und damit Rückschlüsse auf die Lebensweise der Menschen und ihr Mobilitätsverhalten sowie Migrationsraten gezogen werden. Die Charakterisierung der Strontium- und Sauerstoffisotopen, welche von verschiedenen Faktoren abhängen, ergab trotz einiger Überlappungen eine isotopenchemische Differenzierung der einzelnen Regionen und ermöglichte so die Identifizierung von lokal und nicht lokal. Die Rekonstruktion der Ernährung anhand von Stickstoff- und Kohlenstoffisotopenanalysen ($\delta^{15}N$, $\delta^{13}C$) wurde an den gleichen Individuen durchgeführt. Ernährungsanalysen anhand von Kollagen aus Knochen geben einerseits Informationen über den Gehalt von tierischem Protein in der Nahrung und den generellen Anteil von Fleisch, Milch oder anderen tierischen Produkten. Andererseits werden Einblicke in den Gehalt und die Art der pflanzlichen Ressourcen gegeben, anhand derer man landwirtschaftliche Techniken, Landnutzung, sowie Klimafaktoren rekonstruieren kann. Die Auswertung beinhaltet die Ergebnisse von 74 Menschen, 102 Tieren und 55 Pflanzen, bzw. 167 Strontium Analysen, 133 Kollagen- und 136 Bioapatit-Analysen. Ein erheblicher Teil dieser Arbeit beschäftigt sich mit der Hintergrundbestimmung, bei der mittels lokaler Tier- und Pflanzenarten ein möglichst präzises Bild der regionalen geologischen Bedingungen und des umgebenden floralen Bioms bestimmt wird. Ziel ist eine realitätsnahe Einordnung der Menschen. Der Fokus lag einerseits auf der Bestimmung zahlreicher biologisch verfügbarer lokaler Strontium Signale aus dem Forschungsgebiet, im Optimalfall mittels sesshafter Tiere wie Nager und unterschiedlicher Pflanzenarten. Neben den drei Hauptfundorten Ulug Depe, Dzharkutan und Tepe Sialk wurden auch biologisch verfügbare Strontium Signale aus Tilla Bulak nahe Dzharkutan, Bashman 1 südlich des Nuratau Gebirges, sowie entlang der Gorgan Mauer in Golestan, der nördlichen Khorasan Region, und dem südlichen Teil der Wüste Lut bestimmt. Darüber hinaus wurden zahlreiche einzelne Kleinnager analysiert, um eine überregionale Basis zu schaffen. Unter anderem liegen jetzt einzelne Strontium Isotopien aus Geokchik Depe an der turkmenischen Kaspischen Meer Küste vor, sowie aus Sangirtepe und Erkurgan in Zentralusbekistan, Kalateh Khan in der Shahroud Ebene, Tepe Damghani in Semnan, Tepe Taleb Khan nahe Shahr-i Sokhte, Tepe Pahlavan und Sarvestan in Fars, und aus Hasanlu und Tepe Zagheh im Nordwesten Irans. Für die Bestimmung des lokalen Sauerstoffsignals wurden aus Mangel an geeigneterem Referenzmaterial zu den Tieren noch die vorliegenden Ergebnisse der Datenbanken hinzugezogen. Die Basis der Ernährungsanalysen wurde mittels einer möglichst großen Bandbreite an unterschiedlichen Tierarten gelegt, die ein breites Spektrum an Pflanzen- und Fleischfressern aus wilden und domestizierten Arten zur Charakterisierung der trophischen Stufen wieder spiegeln.

Die Ergebnisse belegen einerseits eine positive Korrelation von $\delta^{15}N$ und $\delta^{13}C$ Isotopen, sowie einen starken Einfluss der klimatischen Bedingungen der untersuchten Regionen. Die Individuen der frühen Perioden in Ulug Depe deuten auf die Nutzung unterschiedlicher Wasserquellen hin, folglich einer höheren Mobilität. Die Ergebnisse der domestizierten Schafe und Ziegen zeigen eine Ernährung ähnlich der wilden Gazellen, also eine naturverbundene Art der Fütterung und Haltung, bei der Mensch und Tier stärker auf natürliche Ressourcen und Wasservorkommen angewiesen waren. Die Menschen der Oxus Phasen hingegen beschränkten die Nutzung auf wenige Wasserquellen, was für eine intensivere Landnutzung der direkten Umgebung spricht und damit für eine sesshaftere Lebensweise. Alle Individuen aus Ulug und Dzharkutan zeigten eine Ernährung, die wenig auf tierischem Eiweiß wie Fleisch, Fett oder Milch basiert, aber einen hohen Anteil von pflanzlichen Bestandteilen aufweist. Darüber hinaus deuten die Ergebnisse eher auf den Verzehr von Wildtieren hin, und weniger auf den der domestizierten Tiere. Schon die zoologischen Untersuchungen der Tierknochen deuteten an, dass die eigenen Herden eher für die Sekundärproduktion oder den Verkauf gehalten wurden und weniger als primäre Nahrungsquelle, was jetzt durch die Isotopenanalysen bestätigt werden konnte. Die Variation der Nahrungsbestandteile bezüglich biologischer Kriterien wie Alter und Geschlecht, aber auch der durch die archäologischen Funde angezeigten sozialen Stellung der Individuen, spiegelt sich durch alle Perioden nur schwach in der geringen Stichprobenzahl wider. Vergleichende diachrone Auswertungen zeigten, dass die sozialen und kulturellen Veränderungen, die mit dem Erscheinen der Oxus Zivilisation einhergingen, keinen direkten oder signifikanten Einfluss auf die Ernährung der Menschen in Ulug Depe hatten, aber sehr wohl auf die der Tiere. Die Ergebnisse der domestizierten Herbivoren deuten auf Veränderungen in der Ernährung hin, die höchstwahrscheinlich auf Entwicklungen in der Viehwirtschaft zurückzuführen sind. Die eisenzeitlichen Individuen aus Ulug Depe und Dzharkutan zeigten wiederum ein unterschiedliches Ernährungs- und Mobilitätsmuster. Eine Anreicherung an Kohlenstoff kann bei allen Individuen beobachtet werden, was einen höheren Anteil an C4-Pflanzen in der Nahrung bedeutet und auf den Verzehr von der im 1. Jahrtausend aufkommenden Hirse zurückzuführen ist. Auch wenn sie wie in Ulug Depe nicht lokal angebaut wurde, wird ein weitreichender Handel von vielen Kollegen angenommen. Darüber hinaus nimmt der Anteil an Migranten erneut zu; in Ulug wurden beide Frauen, in Dzharkutan die eine Frau, als nicht lokal identifiziert. Trotz der geringen Probenzahl kann von einem erneuten Aufkommen von Mobilität ausgegangen werden.

Die Bewohner von Tepe Sialk nutzten zu allen Zeiten unterschiedliche Wasserquellen, und hatten einen vergleichsweise hohen Gehalt an tierischem Eiweiß in der Nahrung. Die Ergebnisse zeigten in erster Linie den Verzehr von Fleisch, Milch oder Milchprodukten von domestizierten Pflanzenfressern, könnten aber auch durch den vermehrten Verzehr von Süßwasserfischen, Muscheln oder Schnecken zustande kommen. Allerdings sprechen die natürlichen Gegebenheiten der Umgebung eher dagegen. Durch alle Perioden wurde eine große Vielfalt an unterschiedlichen Pflanzenarten in der Nahrung festgestellt, aber grundsätzlich kaum Verzehr von C4 Pflanzen bzw. Hirse. Migrationsstudien identifizierten nur Frauen als Nicht-Einheimische, was auf ein geschlechtsspezifisches Muster in Sialk hinweisen könnte, jedoch durch weitere Ergebnisse bestätigt werden muss. Paläogenetische Studien zeigten einen genetischen Austausch zwischen dem Nordwesten des Iran und dem Zentralplateau über Jahrtausende hinweg.

Die Migrationsanalysen dieser Studie lieferten fundamentale Erkenntnisse über die kulturellen Beziehungen und gegenseitigen Einflüsse sowie Wanderungsrouten, -richtungen und -entfernungen. Lange vor dem Erscheinen von Oxus und Andronovo weist Ulug Depe nicht nur eine außergewöhnlich hohe Einwanderungsrate auf, auch liefert ULG 56 einen echten Beweis für Einwanderung aus sehr weit entfernten Gebieten. Die Kombination aus isotopen- und paläogenetischen Analysen zeigte eine genetische Abstammung von den schwedischen Ureinwohnern (Sami) und eine Einwanderung aus dem Norden. Das Ergebnis verdeutlicht, welche Distanz eine Person Anfang des 3. Jahrtausend v. Chr. zurücklegen konnte, bzw. wie weit die Verbindungen und kulturellen Einflüsse schon in den frühen Phasen wirklich gingen. Darüber hinaus zeigten gegen Ende des 3. und Anfang des 2. Jahrtausend die Menschen aus Süd-Usbekistan (Dzharkutan, Tilla Bulak, Sapallitepa und Bustan) sehr unterschiedliche $^{87}Sr/^{86}Sr$ Isotopien, was auf eine aktive Mobilität der Bewohner dieser „neu“ gegründeten Siedlungen zurückzuführen ist. Die in Dzharkutan bestatteten Menschen folgten einem äußerst komplexen Mobilitätsmuster über Jahrhunderte, das mit einem Wechsel zwischen dem Geburtsort und dem nahegelegenen Wohnort einhergeht. Ebenfalls konnten die Daten Wanderungen zwischen Süd-Usbekistan und den benachbarten Gemeinden in Süd-Tadschikistan nachweisen. Ferner lieferte die Dame aus Gelot grundlegende Einblicke in die Migrationsrouten während der späten Bronzezeit zwischen Regionen, die offiziell nicht zu einem gemeinsamen kulturellen Horizont gehörten. Die Ergebnisse belegen nicht nur den aktiven Austausch zwischen dem Ost Iran und dem südlichen Tadschikistan, sondern bestätigen auch die Wanderung von Menschen entlang von Routen, die durch Rohstoffhandel bereits seit dem Neolithikum bekannt waren.

Viele Studien haben gezeigt, dass die Anwendung von Multi-Isotopenanalysen mit einer statistisch relevanten Probenmenge menschlicher Individuen, aber auch einer breitgefächerten Selektion von Referenzmaterial sinnvolle und verlässliche Ergebnisse liefern. Das Beispiel Ulug Depe zeigt deutlich wie viele unterschiedliche Ergebnisse zu einem Gesamtbild korreliert werden können, wenn neben Menschen ein breites Spektrum an Tieren und Pflanzen im Probenfundus zur Verfügung steht. Darüber hinaus zeigen die Ergebnisse, dass detaillierte Analysen der Tiere unverzichtbare Ergebnisse zur

Aufklärung menschlicher Lebensweisen geben. Allerdings stellte sich gerade bei der Aufarbeitung von alten Grabungen das Problem des Vorhandenseins. Ungeachtet dessen konnte mit dem vorliegenden Datenkorpus gezeigt werden, dass das Forschungsgebiet isotopenchemisch differenzierbar ist. Auch wenn aufgrund der geringen Anzahl an Probenmaterial nur vorläufige Aussagen gemacht werden können, bzw. Tendenzen aufgezeigt werden, präsentiert diese Arbeit die ersten detaillierten und regional übergreifenden Isotopendaten aus dem südlichen Zentralasien und liefert eine sehr fundierte Basis für zukünftige Studien.

L'objectif de l'approche multidisciplinaire utilisée dans cette thèse est d'examiner la mobilité et la subsistance des communautés préhistoriques installées dans le sud de l'Asie centrale et de l'Iran à l'aide des analyses isotopiques.

Cette thèse est divisée en deux chapitres, la description isotopique des populations de bronze et de fer vivant dans le sud de l'Asie centrale est décrite dans le premier chapitre. Le concept de base était de mettre en place un semi-projet qui se base sur une étude multidisciplinaire ; archéozoologie, archéobotanique, chimie isotopique, paléogénétique, l'anthropologie et la morphologie. Le projet est domicilié à l'institut d'Archéozoologie, Archéobotanique, Sociétés, Pratiques et Environnements (AASPE), et le laboratoire Eco-anthropologie (UMR 7206) du musée national d'histoire naturelle (MNHN, CNRS) en coopération avec la mission archéologique de protohistoire Franco-Ouzbèque (MAFOuz-P), et la délégation archéologique française en Afghanistan (DAFA). Durant ce premier chapitre nous nous intéresserons en particulier au site d'Ulug Depe au sud du Turkménistan et au site de Dzharkutan au sud de l'Ouzbékistan. Dans ces provinces, quelques échantillons ont étés fournis par les collègues de l'institut archéologique Allemand (DAI) et l'université de Ludwig-Maximilienne de Munich. Il y avait aussi d'autres échantillons qui permettaient d'obtenir des résultats globaux à partir des sites de Tilla Bulak, Sapallitepa et Bustan au sud d'Ouzbékistan, Bashman 1 a Ouzbékistan central et Gelot, Darnaichi et Saridzhar au sud du Tadjikistan.

Le traitement de la collection de Ghirshman du musée du Louvre et le musée de l'homme à Paris représentent le deuxième chapitre de cette thèse. Cette collection fait partie du site de Tepe Sialk dans le plateau iranien central. Étant donné que les échantillons de Tepe Sialk ne coïncident pas en matière de temps avec ceux de l'Asie centrale, couvrant seulement le Néologique/chalcolithique et l'âge du fer; Tepe Sialk a été traité séparément dans cette thèse. Le choix des sites et des échantillons, a été longuement débattue et proposés par des auteurs avant l'élaboration de ce travail. En outre, le choix a été déterminée par l'état de conservation des tombes ainsi que les contraintes de frontières en vigueur des pays respectifs. C'est pour cela qu'il n'était malheureusement pas possible d'obtenir des cross-sections représentatives dans l'espace et dans le temps, ou une distribution uniforme d'âge et de groupe ainsi que les périodes chronologiques. Ceci a considérablement affecté l'évaluation des résultats pour d'autres interprétations. Notre domaine de recherche comprend l'ère de bronze et de fer en Asie centrale et le néolithique, chalcolithique et l'âge du fer tardif dans le plateau Iranien. Dans la partie centrale de l'Asie vers la fin des 3éme millénaire, deux phénomènes culturels ont été connus. Dans les territoires nord, la région de Steppe était occupée par la communauté des Andronovo, tandis que la partie sud, le sud d'Ouzbékistan d'aujourd'hui, le Turkménistan, le Tadjikistan, le Nord de l'Afghanistan et le nord-est de l'Iran ont étés occupé par la civilisation d'Oxus (GKC, BMAC. Récemment dans le sud du Tadjikistan, des excavations récentes ont montrées des évidences de coexistences et de fusion des deux traditions culturelles. La civilisation d'Oxus n'est pas si bien connus jusqu'au jour d'aujourd'hui mais les avancés archéologiques montrent des évidences de croissance rapide et de refondation de colonies ce qui a causé des changements majeurs dans l'économie de subsistance locale. Des colonies plus grandes ont agi en tant d'unités structurées dans des localités principales ou le commerce et la distribution de nourriture ont eu lieu. En outre, des systèmes d'irrigation sophistiqués ont aussi aidé pour s'installer dans des régions chaudes et arides. Leurs énormes systèmes de fortifications témoignent d'une délimitation territoriale ainsi que l'existence d'une administration. Le grand nombre d'artefacts exotiques met en évidence un réseau assez dynamique qui combinait la région d'Indus à celle d'Euphrate. La chute de la civilisation d'Oxus est aussi floue que son apparence, mais après une courte période de transition progressive, un changement économique et idéologique s'est produit.

Par la suite, l'Asie centrale a été occupé par une mosaïque de petites cultures connues sous le nom de Yaz ou Handman Painted Ware Cultures. Par conséquent, le modèle de règlement a changé et les territoires s'étendent donc plus loin à l'Est. Aussi, il y a eu des évidences de retour aux petits villages ainsi qu'aux unités d'organisations décentralisées. Les vestiges archéologiques indiquent que les produits de luxe ont été remplacés par des objets utilitaires et des outils agraires. Des adaptations de l'élevage et des pratiques agricoles ont été suggérées, ainsi que qu'une homogénéisation sociale des sociétés puisque ni la culture ni la simplicité architecturale ne donnent d'indication sur l'organisation sociale ou la hiérarchie. Les questions que l'on pose aujourd'hui à Ulug Depe et au Dzharkutan concernant les habitudes alimentaires et la mobilité sont basées sur les théories du pastoralisme ou des mouvements saisonniers vers des pâturages plus fertiles, ainsi que des changements possibles de nutrition et de mobilité dus à l'essor et à la chute de la civilisation Oxus. La question de savoir si les développements archéologiques documentés concernant une société hiérarchiquement structurée ou un système centralisé ont eu une influence directe sur le régime alimentaire des gens et leur mode de vie. C'est exactement le même cas à Sialk, où les recherches se sont concentrées sur les changements possibles dus à l'intensification de l'utilisation des terres agricole dans les périodes néolithique et chalcolithique, ainsi que sur les processus d'urbanisation en cours dans la période proto-élamite, ou les influences culturelles externes.

Dans ce cas, pour répondre à ces questions de mobilité, migrations et le comportement nutritionnel des humains et des animaux, l'application des investigations multi isotopique en combinant le 87Sr/86Sr, δ18O, δ15N, and δ13C est la méthode la plus adaptée. Les isotopes du strontium et de l'oxygène (87Sr/86Sr, δ18O) des dents et des os permettent de décrire des régions géologiques et des sources d'eau souterraine. Ceci permet d'éventuellement reconstruire les mouvements entre les différentes régions ainsi que le taux de migration. La caractérisation des isotopes du strontium et de l'oxygène, qui dépendent de divers facteurs, a abouti à une différenciation isochimique des régions particulières et a permis l'identification des locaux et des non locaux. La reconstitution du régime alimentaire à partir d'analyses isotopiques de l'azote et du carbone (δ15N, δ13C) a été réalisée sur les mêmes individus. Les analyses nutritionnelles basées sur le collagène des os fournissent des informations sur la teneur en protéines animales de l'alimentation et la proportion générale de viande, de lait ou d'autres produits animaux. En outre, des informations sur le contenu et le type de ressources végétales sont données qui peuvent être utilisées pour reconstruire les techniques agricoles, l'utilisation des terres et les impacts climatiques. L'évaluation comprenait des résultats de 74 humains, 102 animaux et 55 plantes, respectivement 167 analyses de strontium, 133 analyses de collagène et 136 analyses de bioapatite. Une partie principale de cette étude était la détermination du fond isotopique. À travers les analyses de différentes espèces animales et végétales locales, une image des conditions géologiques régionales et du biome floral environnant est donnée, dans le but de classer les humains de la manière la plus fiable. L'intérêt a été mis d'une part sur la détermination de nombreux signaux de strontium locaux biologiquement disponibles dans la zone de recherche, idéalement au moyen d'animaux sédentaires tels que les rongeurs et différentes espèces végétales. En plus des trois sites principaux Ulug Depe, Dzharkutan et Tepe Sialk, des traces de strontium biologiquement disponibles ont également été déterminés de Tilla Bulak près de Dzharkutan, de Bashman 1 au sud des montagnes de Nuratau, le long du mur de Gorgan au Golestan, dans la région du Nord-Khorasan et dans la partie sud du désert de Lut. De plus, de nombreux rongeurs isolés ont été analysés afin de créer une base interrégionale. Par conséquent, les résultats isotopiques individuels du strontium de Geokchik Depe sur la côte turkmène de la mer Caspienne, ainsi que de Sangir-tepe et Erkurgan dans le centre de l'Ouzbékistan, Kalateh Khan dans la plaine de Shahroud, Tepe Damghani dans le Semnan, Tepe Taleb Khan près de Shahr-i Sokhte, Tepe Pahlavan et Sarvestan dans le Fars, et de Hasanlu et Tepe Zagheh dans le nord-ouest de l'Iran, peuvent être présentés. Pour déterminer le signal local d'oxygène et en raison du manque de matériel de référence plus approprié pour les animaux, les résultats disponibles des bases de données ont été inclus. La base des analyses nutritionnelles a été réalisée en utilisant la plus grande variation possible de différentes espèces animales reflétant un large spectre d'herbivores et de carnivores, sauvages et domestiqués, pour caractériser les niveaux trophiques. Les résultats démontrent une corrélation positive des isotopes δ15N et δ13C, déjà connue de la littérature, ainsi qu'une forte influence des conditions climatiques dans les régions étudiées. Les individus des premières périodes à Ulug Depe indiquent l'utilisation de différentes sources d'eau, d'où une mobilité plus élevée. Les résultats des ovins et caprins domestiqués montrent une alimentation similaire à celle de la gazelle sauvage, et donc un mode d'alimentation et d'élevage plus naturel, dans lequel les humains et les animaux étaient plus dépendants des ressources naturelles et des réservoirs d'eau. Alors que les habitants des phases Oxus ont limité leur utilisation à quelques sources d'eau dans les environs directs, indiquant une utilisation des terres plus intensive et un mode de vie plutôt sédentaire. Tous les individus d'Ulug et du Dzharkutan ont montrés un régime peu basé sur les protéines animales telles que la viande, la graisse ou le lait, mais qui contenait une forte proportion de composants végétaux. De plus, les résultats indiquent la consommation d'animaux sauvages plutôt que celle d'animaux domestiques. Les recherches zoologiques sur les os d'animaux ont déjà indiqué que leurs propres troupeaux étaient destinés à la production secondaire ou au commerce plutôt qu'à la principale source de nourriture, ce qui a maintenant été prouvé par les analyses isotopiques. La variation alimentaire concernant des critères biologiques comme l'âge, le sexe ou le statut sociale archéologique des individus, n'est que faiblement reflétée par le petit nombre d'échantillons à toutes les périodes. Des évaluations diachroniques comparatives ont montré que les changements sociaux et culturels accompagnant l'apparition de la civilisation Oxus n'avaient pas d'impact direct ou significatif sur le régime alimentaire des humains à Ulug Depe, mais sur les animaux. Les résultats des herbivores domestiqués suggèrent des changements dans les habitudes alimentaires, probablement dus à l'évolution de l'organisation de l'élevage. Les individus de l'âge du fer d'Ulug Depe et du Dzharkutan ont de nouveau montré un régime alimentaire et un modèle de mobilité différents. Un enrichissement en carbone peut être observé pour tous les individus humains, indiquant une teneur plus élevée en plantes C4 dans l'alimentation, probablement due à la consommation de mil, qui était courante dans le 1er moulin. Les individus de l'âge du fer d'Ulug Depe et du Dzharkutan ont de nouveau montré un régime alimentaire et un modèle de mobilité différents. 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Pendant toutes les périodes, le régime alimentaire humain a présenté une grande variété d'espèces végétales différentes, mais aucune consommation de plantes C4 ou de mil n'a pu être documentée. Les études sur la migration n'ont identifié que les femmes comme étant des non-autochtones, ce qui pourrait indiquer un modèle spécifique au sexe à Sialk, mais doit être confirmé par d'autres résultats. Des études paléogénétique ont montré un flux de gènes entre le nord-ouest de l'Iran et le plateau central pendant des millénaires. Les analyses isotopiques confirment des interactions dynamiques et un échange constant entre ces deux régions. Les études sur la migration ont fourni des informations fondamentales sur les relations culturelles et les impacts mutuels, ainsi que sur les itinéraires, les directions et les distances de migration. Ulug Depe démontre un taux d'immigration élevé et exceptionnel bien avant l'apparition d'Oxus et d'Andronovo. L'inhumation ULG 56 a fourni de véritables preuves de migration à longue distance, la combinaison d'analyses isotopiques et paléogénétique a montré une ascendance génétique du peuple indigène suédois (Sami) et une immigration du nord.

Les résultats démontrent la distance qu'une personne peut parcourir au cours de sa vie au début du 3ème millénaire avant notre ère, et jusqu'où les connexions et influences culturelles allaient réellement déjà dans les premières phases. Vers la fin du 3ème et début du 2ème moulin. Avant JC, les sites du sud de l'Ouzbékistan (Dzharkutan, Tilla Bulak, Sapallitepa et Bustan) affichent des résultats de 87Sr / 86Sr très divers, prouvant une mobilité active parmi les habitants des nouvelles colonies. Les personnes enterrées au Dzharkutan ont suivi un schéma de mobilité complexe, où les mouvements entre le lieu de naissance et de résidence d’une personne dans une zone limitée étaient une caractéristique régulière, observable à travers les siècles. De la même manière, des mouvements sont démontrés entre le sud de l'Ouzbékistan et les communautés voisines du sud du Tadjikistan. De plus, la Dame de Gelot a livré des aperçus fondamentaux sur les routes migratoires à l'âge du bronze entre des régions qui n'appartenaient officiellement pas à un horizon culturel commun. Les résultats attestent non seulement des échanges actifs entre l'est de l'Iran et le sud du Tadjikistan, mais confirment également la migration de personnes le long des itinéraires connus grâce au commerce des matières premières depuis le néolithique. Les applications des approches multi-isotopiques fournissent des résultats significatifs et fiables, si un nombre d'échantillons statistiquement pertinent d'individus humains, mais aussi un large éventail de matériaux de référence sont disponibles. L'exemple d'Ulug Depe démontre clairement comment différents résultats peuvent être corrélés à une image globale si, en plus des humains, un large spectre d'animaux et de plantes est disponible dans le pool d'échantillons. De plus, les résultats ont montré que des analyses détaillées des animaux fournissent des résultats indispensables pour l'élucidation des modes de vie humains. Cependant, le problème de la disponibilité s'est posé lors de travaux sur d'anciennes fouilles. Néanmoins, le présent ensemble de données a montré que la zone d'étude est isotopiquement distinguable, et même si seules des déclarations provisoires peuvent être faites ou des tendances montrées en raison du petit nombre d'échantillons, cette étude présente les premières données isotopiques détaillées et interrégionales du sud de l'Asie centrale et fournir une excellente base pour les études futures.

13. Bibliography

A

Afshar, S. (**2014**) Mobility and economic transition in the 5th to the 2nd millennium B.C. in the population of the Central Iranian Plateau, Tepe Hissar, Durham theses, Durham University. http://etheses.dur.ac.uk/11064/

Ambrose, S.H. (**1990**) Preparation and characterization of bone and tooth collagen for isotopic analysis. Journal of Archeological Science 17, 431–451.

Ambrose, S.H. (**1986**) Stable carbon and nitrogen isotope analysis of human diet in Africa. Journal of Human Evolution 15, 707–731.

Ambrose, S.H., DeNiro, M.J. (**1987**) Bone nitrogen isotope composition and climate. Nature 325(6101), 201. doi.org/10.1038/325201a0

Ambrose, S.H., DeNiro, M.J. (**1986**) Reconstruction of African human diet using bone collagen carbon and nitrogen isotope ratios. Nature 319(6051), 321–324.

Ambrose, S.H., Norr, L. (**1993**) Experimental Evidence for the Relationship of the Carbon Isotope Ratios of Whole Diet and Dietary Protein to those of Bone Collagen and Carbonate. In: J.B. Lambert, G. Grupe (eds.) Prehistoric Human Bone. Springer, Berlin, Heidelberg. doi.org/10.1007/978-3-662-02894-0_1

Ambrose, S.H., Sikes, N.E. (**1991**) Soil carbon isotope evidence for Holocene habitat change in the Kenya Rift Valley. Science 253, 1402–1405.

Amiet, P. (**1986**) L'âge des échanges inter-iraniens: 3500-1700 avant J.-C. Notes et documents des musées de France.

Anthony, D.W. (**2000**) Comment on: S. Burmeister, Archaeology and migration. Approaches to an archaeological proof of migration. Current Anthropology 41/4, 554–555.

Anthony, D.W. (**1997**) Prehistoric migration as social process, in: J. Chapman, H. Hamerow (eds.), Migrations and invasions in archaeological explanation. BAR International Series 664, Oxford, 21–32.

Anthony, D.W. (**1992**) The bath refilled: Migration in archeology again. American Anthropologist 94, 174–176.

Anthony, D.W. (**1990**) Migration in Archaeology: The baby and the bathwater. American Anthropologist 92, 895–914.

Arendt, M.L., Cairns, K.M., Ballard, J.W.O., Savolainen, P. & Axelsson, E. (**2016**) Diet adaptation in dog reflects spread of prehistoric agriculture. Heredity 117(5), 301–306.

Askarov, A.A., Shirinov, T.Š. (**1994**) The "Palace," Temple, and Necropolis of Jarkutan. Bulletin of the Asia Institute 8, New Series, 13–25. http://www.jstor.org/stable/24048762

Askarov, A.A., Širinov, T.Š. (**1993**) Ranââ gorodskaâ kul'tura epohi bronzy ûga Srednej Azii. [L'ancienne culture urbaine de l'âge du bronze en Asie centrale méridionale], Samarkand, Uzbekistan Respublikasinig Arheologiâ Institut.

Askarov, A.A., Abdullaev, B.N. (**1983**) Džarkutan [Dzharkutan], Taškent, FAN.

Askarov, A.A. (**1977**) Drevnezemledel'cheskaja kul'tura epokhi bronzy juzhnogo Uzbekistana, Tashkent, FAN.

Askarov, A.A. (**1973**) Sapallitepa, Taškent, FAN.

Avanesova, N.A. (**2016**) Bustan VI – The necropolis of fireworshippers of pre-urban Bactria, International Institute for Central Asian Studies, Samarkand.

Atamuradov, H.I., Fet, G.N., Fet, V., Valdez, R. & Feldman, W.R. (**1999**) Biodiversity, genetic diversity, and protected areas in Turkmenistan. Journal of Sustainable Forestry 9(1-2), 73–88.

Azizipour, T., Mirfattah, A., Sabzi, M. (**2010**) Evaluation of subsistence pattern of Valiran Damavand based on the amount of strontium in ancient teeth. Payem-e Bastanshenash 13, 101–106.

B

Babae, A.G. (**1994**) Landscapes of Turkmenistan, in: Fet, V., Atamuradov K.I. Biogeography and Ecology of Turkmenistan. Springer-Science + Business Media, B.V, 5–23.

Balasse, M. (**2003**) Potential biases in sampling. Design and interpretation of intra-tooth isotope analysis. International Journal of Osteoarchaeology 13, 3–10.

Balasse, M., Obein, G., Ughetto-Monfrin, J., Mainland, I. (**2012**) Investigating seasonality and season of birth in past herds: a reference set of sheep enamel stable oxygen isotope ratios. Archaeometry 54(2), 349–368.

Balasse M., Tresset A. (**2009**) A key to the adaptation of Neolithic husbandry in the Orkneys: contribution of seaweed to the sheep diet at the Holm of Papa Westray, revealed through stable isotope analysis (δ13C and δ18O) of teeth. In: A. Ritchie (ed.) On the fringe of Neolithic Europe. Excavation of a chambered cairn on the Holm of Papa Westray, Orkney, Society of Antiquaries of Scotland, Edinburgh, 74–82.

Balasse, M., Tresset, A. (**2007**) Environmental constraints on the reproductive activity of domestic sheep and cattle:

What latitude for what herder? Anthropozoologica 42, 71–87.

Balasse, M., Tresset, Ambrose, S.H. (**2006**) Stable isotope evidence (13C, 18O) for winter feeding on seaweed by Neolithic sheep of Scotland. Journal of Zoology 270, 170–176.

Balasse, M., Tresset, A. & Dobney, K., Ambrose, S.H. (**2005**) The use of isotope ratios to test for seaweed eating in sheep. Journal of Zoology 266, 283–91. doi.org/10.1017/S0952836905006916

Balasse, M., Smith, A. B., Ambrose, S. H., Leigh, S. R. (**2003**) Determining sheep birth seasonality by analysis of tooth enamel oxygen isotope ratios: the Late Stone Age site of Kasteelberg (South Africa). Journal of Archaeological Science 30(2), 205–215.

Balasse, M., Tresset, A. (**2002**) Early weaning of Neolithic domestic cattle (Bercy, France) revealed by intra-tooth variation in nitrogen isotope ratios. Journal of Archaeological Science 29, 853–859.

Balasse, M., Ambrose, S. H., Smith, A. B., Price, T. D. (**2002**) The seasonal mobility model for prehistoric herders in the south-western Cape of South Africa assessed by isotopic analysis of sheep tooth enamel. Journal of Archaeological Science 29(9), 917–932.

Balasse, M., Bocherens, H., Mariotti, A. (**1999**) Intra-bone variability of collagen and apatite isotopic composition used as evidence of a change of diet. Journal of Archaeological Science 26(6), 593–598.

Barnard, H. (**2008**) The archaeology of mobility: old world and new world nomadism. Cotsen Advanced Seminars 4, Los Angeles.

Barbieria, M., Kuznetsovab, T.V., Nikolaevc, V.I., Palombo, M.R. (**2008**) Strontium isotopic composition in late Pleistocene mammal bones from the Yakutian region (North-Eastern Siberia). Quaternary International 179, 72–78.

Behrensmeyer, A. K. (**1978**) Taphonomic and ecologic information from bone weathering. Paleobiology 4, 150–162.

Bellwood, P.S. (**2005**) First farmers: The origins of agricultural societies. Malden, MA, Blackwell Pub, 360.

Bendezu-Sarmiento, J. (**2020**) Ulug dépé. Royaume oublié du Tukménistan. Archéologia 588, 52–61.

Bendezu-Sarmiento, J. (**2013**) Archéologie funéraire et bioanthropologie à Ulug dépé et Dzharkutan. Âge du bronze au Turkménistan et en Ouzbékistan. In: J. Bendezu-Sarmiento (ed.) L'archéologie française en Asie centrale. Nouvelles recherches et enjeux socioculturels, 501–532.

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), Urban Cultures of Central Asia from the Bronze Age to the Karakhanids, Harrassowitz Verlag Wiesbaden & Harrassowitz.

Bendezu-Sarmiento, J., Lhuillier, J. (**2016**) Some more exceptional discoveries at Ulug-depe. In: N.A. Dubova, E.V. Antonova, P.M. Kozhin, M.F. Kosarev, R.G. Muradov, R.M. Sataev, A.A. Tishkin (eds.) Transactions of Margiana Archaeological Expedition 6, Moscou, 522–528.

Bendezu-Sarmiento, J., Lhuillier, J. (**2015**) Sine Sepulchro Cultural Complex of Transoxiana (Between 1500 and the Middle of the 1st Millennium BC): Funerary Practices of the Iron Age in Southern Central Asia: Recent Work, Old Data, and New Hypotheses. Archäologische Mitteilungen aus Iran und Turan 45 (2013), 283–317.

Bendezu-Sarmiento, J., Lhuillier, J. (**2014**) Les "silos funéraires" de l'âge du Fer en Asie centrale: dépotoir, ossuaire ou monument de mémoire? In: Le funéraire: mémoire, protocoles, monuments, 11 e colloque annuel de la MAE, 18–20.

Bendezu-Sarmiento, J., Mustafakulov, S. (**2013**) Le site proto-urbain de Dzharkutan durant les âges du bronze et du fer. Recherches de la Mission archéologique franco-ouzbèke-Protohistoire. In: J. Bendezu-Sarmiento (ed.) L'archéologie française en Asie centrale. Nouvelles recherches et enjeux socioculturels, 207–236.

Bendezu-Sarmiento, J., Mustafakulov, S. (**2009**) "Arkheo-antropologicheskie issledovanija na mogil'nike Dzharkutan", I.M.K.U. 36, 56–60.

Bendezu-Sarmiento, J., Mamedow, M., Khalmuradow, A., Lecomte, O. (**forthcoming**) Ulug Depe, a Cradle of Central Asiatic Civilization: Twenty-six Years of Fieldwork by the Franco-Turkmen Archaeological Expedition (MAFTUR). In: M. Mamedow (ed.) Historical and Cultural sites of Turkmenistan, Ashgabat.

Bendezu-Sarmiento, J., Bajpakov, K., Ismagulova, A., Samashev, Z. (**2007**) De l'âge du Bronze à l'âge du Fer au Kazakhstan. Gestes funéraires et paramètres biologiques, MMAFAC 12, De Boccard, Paris, 11–599.

Bentley, R.A. (**2006**) Strontium isotopes from the earth to the archaeological skeleton: a review. Journal of archaeological method and theory 13(3), 135–187.

Bentley, R.A., Knipper, C. (**2005**) Geographical patterns in biologically available strontium, carbon and oxygen isotope signatures in prehistoric SW Germany. Archaeometry 47, 629–644.

Bentley, R.A., Price, T.D., Stephan, E. (**2004**) Determining the 'local' 87Sr/86Sr range for archaeological skeletons: a case study from Neolithic Europe. Journal of Archaeological Science 31, 365–375.

Bergström, A., Frantz, L., Schmidt, R., Ersmark, E., Lebrasseur, O., Girdland-Flink, L., ... Skoglund, P. (**2020**) Origins and genetic legacy of prehistoric dogs. Science 370(6516), 557–564.

Berking, J., Beckers, B., Reimann, T., Pollock, S., Bernbeck, R. (**2017**) Modern impacts on an ancient landscape, the piedmont plain in southwest Turkmenistan. Wiley Interdisciplinary Reviews: Water 4(2), e1202.

Bernbeck, R. (**2001**) Forschungsperspektiven für das Iranische Neolithikum. Archäologische Miteilungen aus Iran und Turan 33, 1–18.

Bernbeck, R. (**1999**) The Ancient Mesopotamian City.

Bernbeck, R. (**1995**) Lasting alliances and emerging competition: economic developments in early Mesopotamia. Journal of Anthropological Archaeology 14(1), 1–25.

Besenval, R. (**1987**) Découvertes récentes à Sarazm (RSS Tadjikistan): attestations des relations au IIIè millénaire entre l'Asie centrale, l'Iran du nord-est et le Balouchistan. Comptes rendus des séances de l'Académie des Inscriptions et Belles-Lettres 131(2), 441–456.

Beyzaei Doust, S., Mashkour, M., Azizi, H. (**2017**) The faunal remains of Tepe Pahlavan. Unpublished report.

Biglari, F., Jahani, A., Mashkour, M., Argant, A., Shidrang, S., Taheri, K. (**2007**) Darband cave a lower palaeolithic cave site at western Alborz range, Gilan (in Persian). Proceedings of the 11th Symposium of the Geological Society of Iran, Pp.1687–1694, Ferdowsi University of Mashhad, Mashhad. *Bastanshenasi & Tarikh* (Iranian Journal of Archaeology and History) 41, 30–37.

Biglari, F., Shidrang, S. (**2006**) The Lower Paleolithic Occupation of Iran, Near Eastern Archaeology 69(3-4), 160–168. doi.org/10.1086/NEA25067668

Biscione, R., Vahdati, A.A. (**2021**) The BMAC presence in eastern Iran: state of affairs in December 2018 – towards the Greater Khorasan Civilization?

Biscione, R. (**1976**) The crisis of Central Asia urbanization in II millennium BC and villages as an alternative system. In Deshayes J (ed) Le Plateau Iranien et l´Asie Centrale des Origines à la Conquête Islamique. Paris, CNRS, 113–127.

Bista, D. (**2019**) Reconstructing the Pleistocene connectivity history of the Black Sea and the Caspian Sea using strontium isotopes (PhD thesis University of Bristol).

Bleicher, F., Richard, B., Thivichon-Prince, B., Farges, J.C., Carrouel, F. (**2015**) Odontoblasts and dentin formation, Stem Cell Biology and Tissue Engineering in Dental Sciences, Academic Press, 379–395.

Bobomulloev, S., Vinogradova, N., Bobomulloev, B. with contributions by M. Teufer and G. Lombardo (**2017**) Preliminary Results of Research of the Burial Ground of Farkhor, a Middle Bronze Age Monument in the South of Tajikistan. In: S. Bobomulloev (ed.) Materialy Farkhorskoj ekspeditsii, Vol. I, Dushanbe, Institute of History, Archaeology and Ethnography of Academy of Sciences of Republic of Tajikistan, 78–127.

Bocherens, H., Cotte, M., Bonini, R. A., Straccia, P., Scian, D., Soibelzon, L., Prevosti, F. J. (**2017**) Isotopic insight on paleodiet of extinct Pleistocene megafaunal Xenarthrans from Argentina. Gondwana Research 48, 7–14. doi.org/10.1016/j.gr.2017.04.003

Bocherens, H., Mashkour, M., Drucker, D.G., Moussa, I., Billiou, D. (**2006**) Stable isotope evidence for paleodiets in southern Turkmenistan during Historical period and Iron Age, Journal of Archeological Science 33, 253–264.

Bocherens, H., Drucker, D., (**2003**) Trophic level isotopic enrichment of carbon and nitrogen in bone collagen: case studies from recent and ancient terrestrial ecosystems. International Journal of Osteoarchaeology 13(1-2), 46–53.

Bocherens, H., Mashkour, M., Billiou, D. (**2000**) Paleo-environmental and archaeological implications of isotopic analyses (13C, 15N) from Neolithic to Present in Qazvin Plain (Iran). Environmental Archaeology 5(1), 1–19.

Bocherens, H., Fizet, M., Mariotti, A., (**1994**) Diet, physiology and ecology of fossil mammals as inferred from stable carbon and nitrogen isotope biogeochemistry: implications for Pleistocene bears. Palaeogeography, Palaeoclimatology, Palaeoecology 107(3-4), 213–225.

Bocherens, H., Fizet, M., Mariotti, A., Lange-Badré, B., Vandermeersch, B., Borel, J., Bellon, G. (**1991**) Isotopic biogeochemistry (13C, 15N) of fossil vertebrate collagen: Implications for the study of fossil food web including Neandertal man. Journal of Human Evolution 20, 481–492.

Böhlke, J., Horan, M. (**2000**) Strontium isotope geochemistry of groundwaters and streams affected by agriculture, Locust Grove, MD. Applied Geochemistry 15, 599–609.

Boehmer, R.M. (**1965**) Zur Datierung der Nekropole B von Tepe Sialk, Archäologischer Anzeiger: 802–822.

Bogaard, A., Hodgson, J., Nitsch, E., Jones, G., Styring, A., Diffey, C., ... Fraser, R. (**2016**) Combining functional weed ecology and crop stable isotope ratios to identify cultivation intensity: a comparison of cereal production regimes in Haute Provence, France and Asturias, Spain. Vegetation History and Archaeobotany 25(1), 57–73. doi.org/10.1007/s00334-015-0524-0

Bogaard, A., Fraser, R., Heaton, T.H., Wallace, M., Vaiglova, P., Charles, M., Stephan, E. (**2013**) Crop manuring and intensive land management by Europe's first farmers. Proceedings of the National Academy of Sciences 110(31), 12589–12594.

Bokovenko, N.A. (**2013**) Migration of Early Nomads of the Eurasian Steppe in Context of Climatic changes. In: M. Scott, A. Yu, A.G. Zaitseva (eds.) Impact of the Environment on Human Migration in Eurasia. Kluwer Academic Publishers, New-York, Boston, 21–33.

Bonora, G.L. (**2021**) The Oxus Civilization and the Northern Steppes. In: B. Lyonnet, N. Dubova (eds.) The World of the Oxus Civilization. Routledge, London, 734–777.

Bosch, D., Mechati, M., Hammor, D., Fernandez, L., Bruguier, O., Caby, R., Verdoux, P. (**2014**) Geochemical study (major, trace elements and Pb-Sr-Nd isotopes) of mantle material obducted onto the North African margin (Edough Massif, N.E. Algeria): Tethys fragments or lost remnants of the Liguro-Provençal basin? Tectonophysics 626, 53–68.

Boucharlat, R. (**2020**) The Citadel of Ulug Depe and the "Median Forts" in Western Iran. In: Archaeology of Iran in the Historical Period, Springer, Cham, 141–156.

Boucharlat, R. (**2006**) Architectural remains of Sialk VI period (Iron Age III). The south mound of Sialk (Excavation Report of Trench R19). In: S.M. Shahmirzadi (ed.) The Potters of Sialk. Sialk Reconsideration Project Report n° 3. Tehran, 2004, 21–22. (Archaeological Report Monograph Series 5). Abstracta Iranica. Revue bibliographique pour le domaine irano-aryen, Volume 27.

Boucharlat, R., Francfort, H.-P., Lecomte, O. (**2005**) "The Citadel of Ulug Depe and the Iron Age Archaeological Sequence in Southern Central Asia", Iranica Antiqua 40, 479–513.

Bowen, G.J. (**2012**) The Online Isotopes in Precipitation Calculator, Version 2.2. http://www.waterisotopes.org

Bowen, G.J., West, J.B., Vaughn, B.H., Dawson, T.E., Ehleringer, J.R., Fogel, M.L., Hobson, K., Hoogewerff, J., Kendall, C., Lai, C.T., Miller, C.C., Noone, D., Schwarcz, H., Still, C.J. (**2009**) Isoscapes to address large-scale earth science challenges. EOS, Transactions American Geophysical Union 90(13), 109–110.

Bowen, G. J., Wassenaar, L. I., Hobson, K. A. (**2005**) Global application of stable hydrogen and oxygen isotopes to wildlife forensics. Oecologia 143(3), 337–348.

Bowen, G. J., Revenaugh, J. (**2003**) Interpolating the isotopic composition of modern meteoric precipitation. Water Resources Research 39(10), 1299.

Brettell, R., Montgomery, J., Evans, J. (**2012**) Brewing and stewing: The effect of culturally mediated behaviour on the oxygen isotope composition of ingested fluids and the implications for human provenance studies. Journal of Analytical Atomic Spectrometry 27, 778–785.
doi.org/10.1039/C2JA10335D

Britton, K., Müldner, G., Bell, M. (**2008**) Stable isotope evidence for salt-marsh grazing in the Bronze Age Severn Estuary, UK: implications for palaeodietary analysis at coastal sites. Journal of Archaeological Science 35, 2111e2118.

Broushaki, F., Thomas, M.G., Link, V., López, S., van Dorp, L., Kirsanow, K., ... Burger, J. (**2016**) Early Neolithic genomes from the eastern Fertile Crescent. Science 353(6298), 499–503.

Budd, P., Millard, A., Chenery, C., Lucy, S., Roberts, C. (**2004**) Investigating population movement by stable isotope analysis: a report from Britain. Antiquity 78(299), 127–141.

Budd, P., Montgomery, J., Barreiro, B., Thomas, R. (**2000**) Differential diagenesis of strontium in archaeological human dental tissues. Applied Geochemistry 15(5), 687–694.

Budd, P., Montgomery, B.L.J., Rainbird, P., Thomas, R.G., Young, S.M. (**1999**) Pb and Sr isotope composition of human dental enamel: an indicator of Pacific Islander population dynamics. In: J.-C. Galipaud, I. Lilley (eds.) The Pacific from 5000 to 2000 BP: Colonization and Transformations. Institut de Recherche pour le Développement, Paris, 301–311.

Burmeister, S. (**2017**) One Step Beyond. Migration als kulturelle Praxis. Distant Worlds Journal 3, 3–18.

Burmeister, S. (**2000**) Archaeology and Migration. Approaches to an archaeological proof of migration. Current Anthropology 41/4, 539–553.

Burmeister, S. (**1998**) Ursachen und Verlauf von Migrationen – Anregungen für die Untersuchung prähistorischer Wanderungen. Studien zur Sachsenforschung 11, 19–41.

Burton, J.H., Price, T.D., (**2013**) Seeking the local 87Sr/86Sr ratio to determine geographic origins of humans. In: R.A. Armitage, J.H. Burton (eds.) Archaeological chemistry VIII, American Chemical Society, 309–320.

Burton, J.H., Price, T.D., Cahue, L., Wright, L.E. (**2003**) The Use of Barium and Strontium Abundances in Human Skeletal Tissues to Determine their Geographical Origins. International Journal of Osteoarchaeology 13, 88–95.

C

Campbell, N.A., Markl, J. (**1997**) Biology. Spektrum Akademischer Verlag GmbH.

Cantrell, D.O., Finkelstein, I. (**2006**) A kingdom for a horse: the Megiddo stables and eighth century Israel. In: I. Finkelstein, D. Ussishkin, B. Halpern (eds.) Megiddo IV, 643–665.

Cattani, M., Salvatori, S., Tosi, M. (**2008**) The final phase of the Bronze Age and the 'Andronovo Question' in Margiana. In: S. Salvatori, M. Tosi (eds.) The Bronze Age and early Iron Age in the Margiana lowlands. Facts and methodological proposals for a redefinition of the research strategies, the archaeological map of the Murghab delta studies and Reports, 133–151.

Champion, T. (**1990**) Migration revived. Journal of Danish Anthropology 9, 214–218.

Chapman, J., Hamerow, H. (**1997**) Migrations and invasions in archaeological explanation. British Archaeological Reports International Series, BAR Publishing, Oxford.

Chapman, J., Dolukhanov, P.M. (**1992**) The baby and the bathwater. Pulling the plug on migrations. American Anthropologist 94, 169–174.

Chase, B., Meiggs, D., Ajithprasad, P., Slater, P.A. (**2014**) Pastoral land-use of the Indus Civilization in Gujarat: faunal analyses and biogenic isotopes at Bagasra. Journal of Archaeological Science 50, 1–15.
doi.org/10.1016/j.jas.2014.06.013

Chenery, C.A., Pashley, V., Lamb, A. L., Sloane, H.J., Evans, J.A. (**2012**) The oxygen isotope relationship between the phosphate and structural carbonate fractions of human bioapatite. Rapid Communications in Mass Spectrometry 26(3), 309–319. doi.org/10.1002/rcm.5331

Chieruzzi, M., Pagano, S., Moretti, S., Pinna, R., Milia, E., Torre, L., Eramo, S. (**2016**) Nanomaterials for tissue engineering in dentistry. Nanomaterials 6(7), 134.
doi.org/10.3390/nano6070134

Childe, V.G. (**1958**) The prehistory of European society (London).

Childe, V.G. (**1950**) The urban revolution. The town planning review 21(1), 3–17.

Childe, V.G. (**1930**) The Bronze Age (London).

Childe, V.G. (**1925**) The dawn of European civilization (London).

Chisholm, B. S. (**1989**) Variation in diet reconstructions based on stable carbon isotopic. The chemistry of prehistoric human bone, 10.

Clutton-Brock, J. (**2016**) Origins of the dog: the archaeological evidence. The Domestic Dog: Its Evolution, Behavior and Interactions with People, 5–7.

Codron, D., Clauss, M., Codron, J., Tütken, T. (**2018**) Within trophic level shifts in collagen–carbonate stable carbon isotope spacing are propagated by diet and digestive physiology in large mammal herbivores. Ecology and evolution 8(8), 3983–3995. doi.org/10.1002/ece3.3786

Collective (**2015**) Ulug Depe a forgotten city in Central Asia. MAFTUR, Mission Archéologique Franco-Turkmène. MAE, CNRS, Ginkgo éditeur.

Conard, N.J., Ghasidian, E., Heydari-Guran, S. (**2013**) The Paleolithic of Iran. In: D.T. Potts (ed.) The Oxford Handbook of Ancient Iran, Oxford, New York, 29–48.

Coon, C. S. (**1951**) Cave explorations in Iran 1949.

Coplen, T. B. (**1988**) Normalization of oxygen and hydrogen isotope data. Chemical Geology: Isotope Geoscience Section 72, 293–297.

Cucchi, T., Papayianni, K., Cersoy, S. et al. (**2020**) Tracking the Near Eastern origins and European dispersal of the western house mouse. scientific reports 10, 8276.
doi.org/10.1038/s41598-020-64939-9

Curtis, J. (**2019**) An introduction to Tappeh Sialk. In: J. Nokandeh, J. Curtis, M. Pic (eds.) Tappeh Sialk. The Glory of Ancient Kashan. Iran Heritage Foundation Special Studies 1, 1–5.

D

D’Angela, D., Longinelli, A. (**1990**) Oxygen isotopes in living mammal’s bone phosphate: further results. Chemical Geology 86, 75–82.

Damgaard, P.d.B., Marchi, N., Rasmussen, S. et al. (**2018a**) 137 ancient human genomes from across the Eurasian steppes. Nature 557, 369–374.
doi.org/10.1038/s41586-018-0094-2

Damgaard, P.d.B., Martiniano, R., Kamm, J. et al. (**2018b**) The First Horse Herders and the Impact of Bronze Age Steppe Expansion into Asia. Science, Vol. 360/6396.
science.org/doi/10.1126/science.aar7711

Danti, M.D. (**2013**) Hasanlu V: The Late Bronze and Iron I Periods. University of Pennsylvania Press.

Daux, V., Lécuyer, C., Héran, M.A., Amiot, R., Simon, L., Fourel, F., Martineau, F., Lynnerup, N., Reychler, H., Escarguel, G. (**2008**) Oxygen isotope fractionation between human phosphate and water revisited. Journal of human evolution 55(6), 1138–1147.

Davis, S.J., Valla, F.R. (**1978**) Evidence for domestication of the dog 12,000 years ago in the Natufian of Israel. Nature 276(5688), 608–610.

Davoudi, H. (**2017**) Subsistence economy of the Iron Age societies in north-western Iran based on archaeozoological studies, the case of Tepe Hasanlu. PhD thesis in Archaeology, Tarbiat Modares University, Tehran, Iran.

De la Vaissière, E. (**2002**) Central Asia and the Silk Road. In: S. Fitzgerald Johnson (Ed.) The Oxford Handbook of Late Antiquity, Oxford University Press, Oxford.
doi.org/10.1093/oxfordhb/9780195336931.013.0005

DeNiro, M.J. (**1985**) Postmortem preservation and alteration of in vivo bone collagen isotope ratios in relation to paleodietary reconstruction. Nature 317, 806–809.
doi.org/10.1038/317806a0

DeNiro, M.J., Epstein, S. (**1981**) Influence of diet on the distribution of nitrogen isotopes in animals. Geochimica et cosmochimica acta 45(3), 341–351.

DeNiro, M.J., Epstein S. (**1978**) Influence of diet on the distribution of carbon isotopes in animals. Geochimica et Cosmochimica Acta 42(5), 495–506.
doi.org/10.1016/0016-7037(78)90199-0

Denys, C. (**2002**) Taphonomy and experimentation. Archaeometry 44, 469–484.

Der Sarkissian, C., Allentoft, M.E., Avila-Arcos, M.C., Barnett, R., Campos, P.F., Cappellini, E. et al. (**2015**) Ancient genomics. Philos Trans R Soc Lond B Biol Sci 370(1660).
www.ncbi.nlm.nih.gov/pubmed/25487338

Derenko, M. et al (**2013**) Complete mitochondrial DNA diversity in Iranians. PloS one 8(11), e80673.
doi.org/10.1371/journal.pone.0080673

Djamali, M., Mashkour, M., Akhani, H., Belkacem, D., Gambin, B., Leydet, M., Samadi, N., Tengberg, M., Gandoin, E. (**2020**) Pollen analysis of present-day striped hyaena (Hyaena hyaena) scats from central Iran: implications for dryland palaeoecology and animal palaeoethology. Review of Palaeobotany and Palynology. sciencedirect.com/science/article/abs/pii/S0034666720301627?via%3Dihub

Dolgopolova, A., Seltmann, R., Konopelko, D., Biske, Y.S., Shatov, V., Armstrong, R., Belousova, E., Pankhurst, R., Koneev, R., Divaev, F. (**2017**) Geodynamic evolution of the western Tien Shan, Uzbekistan: insights from U-Pb SHRIMP geochronology and Sr-Nd-Pb-Hf isotope mapping of granitoids. Gondwana Research 47, 76–109.

Dubova, N.A. (**2019**) Gonur Depe – City of Kings and Gods, and the Capital of Margush Country (Modern Turkmenistan). In: Christoph Baumer and Mirko Novák (Edt.) Urban Cultures of Central Asia from the Bronze Age to the Karakhanids. Learnings and conclusions from new archaeological investigations and discoveries. Proceedings of the First International Congress on Central Asian Archaeology held at the University of Bern, 4–6 February 2016, Harrassowitz Verlag Wiesbaden, 30–53.

Dubova, N.A., Grushin, S.P., Sataev, R.M., Fribus, A.V. (**2018**) Evidence of Funeral Rituals from the Bactria Margiana Archaeological Complex in Turkmenistan: The Case of Gonur Depe. In: Proceedings of the 10th International Congress on the Archaeology of the Ancient Near East, Vol. 1, Harrassowitz Verlag Wiesbaden.

Drucker, D.G., Bridault, A., Hobson, K.A., Szuma, E., Bocherens, H. (**2008**) Can carbon-13 in large herbivores reflect the canopy effect in temperate and boreal ecosystems? Evidence from modern and ancient ungulates. Palaeogeography, Palaeoclimatology, Palaeoecology 266(1-2), 69–82.

Dvorak, S., Langenegger, K.E., Novak, M. (**2020**) Gonur Depe: Ein zentraler Fundort in der Margiana (Turkmenistan). SLSA Jahresbericht 2019, 181–196.

E

Ericson, J.E. (**1985**) Strontium isotope characterization in the study of prehistoric human ecology. Journal of Human Evolution 14, 503–514.

Ericson, J.E. (**1981**) Residence patterns by isotopic characterization. Paper presented at the Society for American Archaeology, San Diego.

Evans, J.A., Montgomery, J., Wildman, G., Boulton, N. (**2010**) Spatial variations in biosphere 87Sr/86Sr in Britain. Journal of the Geological Society 167(1), 1–4.

F

Fahimi, H. (**2019**) The Bronze Age and the Iron Age on the Central Iranian Plateau. Two successive cultures or the appearance of a new culture? In: J.W. Meyer, E. Vila, M. Mashkour, M. Casanova, R. Vallet (eds.) The Iranian Plateau during the Bronze Age: Development of urbanisation, production and trade. MOM éditions.

Fahimi, H. (**2011**) Studien zur Eisenzeit im zentraliranischen Hochland unter besonderer Berücksichtigung der neuen Ausgrabungen von Tepe Sialk. Dissertation zur Erlangung des Doktorgrads an der Freien Universität Berlin.

Fathi, H., Mashkour, M. (**2018**) Unpublished report. The study of the faunal remains of Taleb Khan, ICHHTO.

Faure, G. (**1986**) Principles of Isotope Geology. John Wiley & Sons, New York.

Faure, G. (**1977**) Principles of isotope geology.

Faure, G., Mensing, T.M. (**2005**) Isotopes: Principles and Applications. Wiley, Hoboken, N.J.

Fazeli H.N., Nokandeh, J. (**2019**) The Chronology of Tappeh Sialk: from Local Development to Globalisation. In: J. Nokandeh, J. Curtis, M. Pic (edts) Tappeh Sialk The Glory of Ancient Kashan. Iran Heritage Foundation Special Studies 1, 1–5.

Fazeli, N.H., Valipour, H.R., Azizi Kharanaghi, M.H. (**2013**) The late chalcolithic and early bronze age in the Qazvin and Tehran plains: a chronological perspective. In: C.A. Petrie (ed.) Ancient Iran and Its Neighbours, Local developments and Long-range interactions in the fourth Millenium BC, 107–131.

Fazeli H.N., Beshkani, A., Markosian, A., Ilkani, H., Seresty, R.A., Young, R. (**2009**) The Neolithic to Chalcolithic transition in the Qazvin Plain, Iran: chronology and subsistence strategies. Archäologische Mitteilungen aus Iran und Turan 41, 1–21.

Fet, V. (**2020**) Central Asia: Northern Afghanistan, southern Turkmenistan, southern Uzbekistan, extending into Iran and Tajikistan. www.worldwildlife.org/ecoregions/pa1306

Fet, V., Atamuradov K.I. (**1994**) Biogeography and Ecology of Turkmenistan. Springer-Science + Business Media, B.V.

Fet, V. (**1994**) Biogeographic position of Khorassan-Kopetdagh. In: V. Fet, K.I. Atamuradov (eds.) Biogeography and Ecology of Turkmenistan, Springer-Science + Business Media, B.V, 197–204.

Fernandez, R.A., Anderson, J.B., Wellner, J.S., Minzoni, R.L., Hallet, B., Smith, R.T. (**2016**) Latitudinal variation in glacial erosion rates from Patagonia and the Antarctic Peninsula (46°S–65°S). Geological Society of America Bulletin 128, 1000–1023. doi.org/10.1130/B31321.1

Fernandez, L., Bosch, D., Bruguier, O., Hammor, D., Caby, R., Monié, P., Arnaud, N., Toubal, A., Galland, B., Douchet, C. (**2016**) Permo-Carboniferous and early Miocene geological evolution of the internal zones of the Maghrebides – New insights on the western Mediterranean evolution. Journal of Geodynamics 96, 146–173.
doi.org/10.1016/j.jog.2015.10.001

Fiorentino, G., Ferrio, J.P., Bogaard, A., Araus, J.L., Riehl, S. (**2015**) Stable isotopes in archaeobotanical research. Vegetation History and Archaeobotany 24(1), 215–227.

Fouache, E., Cez, L., Andrieu-Ponel, V., Rante, R. (**2020**) Environmental changes in Bactria and Sogdiana (Central Asia, Afghanistan, and Uzbekistan) from the Neolithic to the Late Bronze Age: interaction with human occupation. In: B. Lyonnet, N. Dubova (eds.) The world of the Oxus Civilisation, Routledge, London, 82–110.

Frachetti, M.D. (**2013**) Bronze Age Pastoralism and Differentiated Landscape along the Inner Asian Mountain Corridor. In: S. Abraham, P. Gullapalli, T. Raczek (eds.) Connections and Complexity: New Approaches to the Archaeology of South Asia Ch 15, Left Coast Press, 279–298.

Frachetti, M.D. (**2012**) Multiregional emergence of mobile pastoralism and nonuniform institutional complexity across Eurasia. Current Anthropology 53. doi.org/10.1086/663692

Frachetti, M.D. (**2011**) Migration Concepts in Central Eurasien Archaeology. Annual Review of Anthropology 40, 195–212. doi.org/10.1146/annurev-anthro-081309-145939

Frachetti, M.D., Rouse, L.M. (**2012**) Central Asia, the Steppe, and the Near East, 2500–1500 BC. In: D. Potts (ed.) A Companion to the Archaeology of the Ancient Near East, Blackwell Publishing, Oxford, 688–705.
doi.org/10.1002/9781444360790

Francfort, H.P. (**2016**) How the Twins Met: Indus and Oxus Bronze Age Civilizations in Eastern Bactria. Shortughai Revisited Forty Years Later. In: N. Dubova (ed.) Trudy Margianskoj Arkheologicheskoj Ekspeditsii, Vol. 6, Moscow, Staryj Sad, 461–475.

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. (**1989**) Fouilles de Shortughaï: recherches sur l'Asie centrale protohistorique, Éditions De Boccard, Paris.

Francfort, H.P., Lecomte, O. (**2002**) Irrigation et société en Asie centrale des origines à l'époque achéménide. In: Annales. Histoire, Sciences Sociales 57(3), Éditions de l'EHESS, 625–663.

Fraser, R.A., Bogaard, A., Heaton, T., Charles, M., Jones, G., Christensen, B.T., Styring, A.K. (**2011**) Manuring and stable nitrogen isotope ratios in cereals and pulses: towards a new archaeobotanical approach to the inference of land use and dietary practices. Journal of Archaeological Science 38(10), 2790–2804.

G

Gentelle, P. (**1989**) Prospections archéologiques en Bactriane Orientale (1974–1978), Volume 1 : Données paléographiques et fondements de l'irrigation, M.M.A.F.A.C., Tome III, Paris, De Boccard.

Gerling, C. (**2015**) Prehistoric Mobility and Diet in the West Eurasian Steppes 3500 to 300 BC: An Isotopic Approach. Walter de Gruyter, Berlin.

Gerling, C. (**2013**) A multi-isotopic approach to the reconstruction of prehistoric mobility and economic patterns in the West Eurasian steppes 3500 to 300 BC.

Gerling, C., Bánffy, E., Dani, J., Köhler, K., Kulcsár, G., Pike, A.W., Szeverenyi, V., Heyd, V. (**2012**) Immigration and transhumance in the Early Bronze Age Carpathian Basin: the occupants of a kurgan. Antiquity 86(334), 1097–1111.
doi.org/10.1017/S0003598X00048274

Ghirshman, R. (**1939**) Fouilles de Sialk/2. Fouilles de Sialk près de Kashan, 1933, 1934, 1937.

Ghirshman, R. (**1938**) Fouilles de Sialk, Série archéologique / Musée du Louvre, Departement des Antiquités Orientáles 5, Paris.

Ghirshman, T. (**1970**) Archéologue malgré moi. Vie quotidienne d'une mission archéologique en Iran. 42 planches, et & carte, Neuchâtel et Paris, 431.

Gillmore, G.K., Coningham, R.AE., Fazeli, H.N., Young, R.L., Magshoudi, M., Batt, C.M., Rushworth, G. (**2009**) Irrigation on the Tehran Plain, Iran: Tepe Pardis—The site of a possible Neolithic irrigation feature? Catena 78(3), 285–300.

Göhring, A., Mauder, M., Kröger, P., Gruppe, G. (**2016**) Using Gaussian Mixture Model clustering for multi-isotope analysis of archaeological fish bones for paleo-biodiversity studies. Rapid Communications in Mass Spectrometry.
doi.org/10.1002/rcm.7573

Goldberg, M. (**2014**) Pulp anatomy and characterization of pulp cells. In The Dental Pulp. Springer, Berlin, Heidelberg, 13–33.

Goldstein, S.J., Jacobson, S.B. (**1988**) Rare earth elements in river waters. Earth and Planetary Science Letters, Vol. 89/1: 35–47.

Gopnik, H., Rothman, M.S. (**2011**) On the high road: the history of Godin Tepe, Iran. Mazda Publ.

Graebner, F. (**1911**) Methode der Ethnologie (Vol. 1). C. Winter.

Gregoricka, L.A. (**2013**) Residential mobility and social identity in the periphery: strontium isotope analysis of archaeological tooth enamel from southeastern Arabia. Journal of Archaeological Science 40(1), 452–464.
doi.org/10.1016/j.jas.2012.07.017

Grupe, G., Grigat, A., McGlynn, G.C. (**2017**) Across the Alps in Prehistory. Isotopic Mapping of the Brenner Passage by Bioarchaeology. Springer, 27–48.
doi.org/10.1007/978-3-319-41550-5

Grupe, G., Hölzl, S., Kocsis, B., Kröger, P., Mauder, M., Mayr, C., Ntoutsi, E., Schmahl, W., Söllner, W., Toncala, A., Wycisk, D. (**2017**) Isotopic Mapping and Migration Research Based on Bioarchaeological Finds. The Interdisciplinary Project 'Transalpine Mobility and Culture Transfer'. In: A.K. Scholz, M. Bartelheim, R. Hardenberg, J. Staecker (eds.) Resource Cultures. Sociocultural Dynamics and the Use of Resources – Theories, Methods, Perspectives (Bd. 5), Tübingen: Eberhard Karls Universität Tübingen, 195–208.

Grupe, G., Peters, J. (**2006**) Molecular biological methods applied to Neolithic bioarchaeological remains: Research potential, problems, and pitfalls. In: Innovation and Continuity: Non-Megalithic Mortuary Practices in the Baltic. Workshop Schwerin, 24–25.

Grupe, G., Price, T., Schroter, P., Söllner, F., Johnson, C., Beard, B. (**1997**) Mobility of the Bell Beaker people revealed by strontium isotope ratios of tooth and bone: a study of southern Bavarian skeletal remains. Applied Geochemistry 12, 517–525. doi.org/10.1016/S0883-2927(97)00030-9

Guichard, M. (**2021**) The Oxus Civilization and Mesopotamia. A philologist's point of view. In: B. Lyonnet and N. Dubova (eds.) The World of the Oxus Civilization, Routledge, London, 66–81.

H

Haak, W., Lazaridis, I., Patterson, N. et al. (**2015**) Massive migration from the steppe was a source for Indo-European languages in Europe. Nature 522, 207–211. doi.org/10.1038/nature14317

Haghipour, A., Saidi, A., Aganabati, A., Moosavi, A., Mohebi, A., Sadeghi, M., Zarei, M. (**2009**) International geological map of the Middle East. Commission for the Geological Map of the World (Subcommission for the Middle East).

Hakemi, A. (**1997**) Shahdad. Archaeological Excavations of a Bronze Age Center in Iran, Rome.

Haverkort, C.M., Weber, A., Katzenberg, M.A., Goriunova, O.I., Simonetti, A., Creaser, R.A. (**2008**) Hunter-gatherer mobility strategies and resource use based on strontium isotope (87Sr/86Sr) analysis: a case study from Middle Holocene Lake Baikal, Siberia. Journal of Archaeological Science 35(5), 1265–1280.

Heaton, T.H. (**1987**) The 15 N/14 N ratios of plants in South Africa and Namibia: relationship to climate and coastal/saline environments. Oecologia 74, 236e246.

Hedges, R.E.M. (**2002**) Bone Diagenesis: An Overview of Processes. Archaeometry 44/3, 319–328.

Hedges. R.E.M., Reynard, L.M. (**2007**) Nitrogen isotopes and the trophic level of humans in archaeology. Journal of Archaeological Science 34, 1240–1251.

Heidari, S. (**2012**) Excavation report at Trench A and geomorphology in the region of Kashan. In: M. Shahmirzadi (ed.) The Ziggurat of Sialk. ICTHO, Teheran, 93–111.

Helwing, B. (**2013**) Some thoughts on the mode of culture change in the fourth millennium BC Iranian highlands. Ancient Iran and its neighbors, local developments and long-range interactions in the fourth millennium BC. The British Institute of Persian Studies, Archaeological Monograph Series III, OXBOW Books, 93–107.

Helwing, B. (**2010**) Tepe Sialk. 3G/09 Reallexikon der Assyriologie Bd. XII Lfg. 5/6.

Helwing, B. (**2006**) The rise and fall of Bronze Age centers around the Central Iranian Desert – a comparison of Tappe Hesar II and Arisman. Archäologische Mitteilungen aus Iran und Turan 38, 35–48.

Helwing, B. (**2005**) Tappeh Sialk south mound: operation 3. The Fishermen of Sialk; Sialk Reconsideration Project Report 4, 27–66.

Hermes, T.R., Frachetti, M.D., Doumani Dupuy, P. 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(1910), 20191273.

Hermes, T.R., Frachetti, M.D., Bullion, E.A., Maksudov, F., Mustafokulov, S., Makarewicz, C.A. (**2018**) Urban and nomadic isotopic niches reveal dietary connectivities along Central Asia's Silk Roads. Scientific reports 8(1), 1–11.

Herrscher, E., Poulmarc'h, M., Pecqueur, L., Jovenet, E., Benecke, N., Decaix, A., ... André, G. (**2018**) Dietary inferences through stable isotope analysis at the Neolithic and Bronze Age in the southern Caucasus (sixth to first millenium BC, Azerbaijan): From environmental adaptation to social impacts. American journal of physical anthropology 167(4), 856–875.

Heydari-Guran, S. (**2014**) Paleolithic landscapes of Iran, Vol. 2568, Archaeopress.

Heyer, E., Chaix, R., Pavard, S., Austerlitz, F. (**2012**) Sex-specific demographic behaviours that shape human genomic variation. Molecular ecology 21(3), 597–612.

Heyer, E., Balaresque, P., Jobling, M.A. et al. (**2009**) Genetic diversity and the emergence of ethnic groups in Central Asia. BMC Genet 10(49). doi.org/10.1186/1471-2156-10-49

Hiebert, F.T. (**2004**) Origins of the Bronze Age Oasis Civilization in Central Asia. American School of Prehistoric Research Bulletins 42, Peabody Museum Press, American School of Prehistoric Research Bulletins.

Hiebert, F.T. (**1994**) Origins of the Bronze Age oasis civilization in Central Asia. Peabody Museum of Archaeology and Ethnology, Cambridge.

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: M.F. Kosarev, P.M. Kozhin, N.A. Dubova (eds.) U istokov tsivilizatsii: Sbornik statey k 75-letiyu Viktora Ivanovicha Sarianidi, Moscow: Staryj sad, 294–302.

Hiebert, F.T., Lamberg-Karlovsky, C.C. (**1992**) Central Asia and the Indo-Iranian Borderlands. Iran Journal of the British Institute of Persian Studies 30, 1–15.

Hillson, S. (**2005**) Teeth. (Cambridge).

Hillson, S. (**1996**) Dental Anthropology. Cambridge University Press, Cambridge, 373.

Hillson, S. (**1986**) Teeth. Cambridge University Press, Cambridge, 376.

Hole, F. (**2004**) Neolithic Age in Iran. Encyclopædia Iranica. iranicaonline.org/articles/neolithic-age-in-iran

Hole, F. (**1987**) The archaeology of western Iran: settlement and society from prehistory to the Islamic conquest. Washington DC, Smithsonian Institution Press.

Hollund, H.I., Higham, T., Belinskij, A., Korenevskij, S. (**2010**) Investigation of palaeodiet in the North Caucasus (South Russia) Bronze Age using stable isotope analysis and AMS dating of human and animal bones. Journal of archaeological Science 37(12), 2971–2983.

Hoppe, K.A., Koch, P.L., Furutani, T.T. (**2003**) Assessing the preservation of biogenic strontium in fossil bones and tooth enamel. International Journal of Osteoarchaeology 13(1-2), 20–28.

Hübner, C., Novak, M., Winkelmann, S. (**2019**) The Swiss IAW-EurAsia Project on Urban Development and land Use in Konus Deep (Turkmenistan).

Huertas, A.D., Iacumin, P., Stenni, B., Chillón, B.S., Longinelli, A. (**1995**) Oxygen isotope variations of phosphate in mammalian bone and tooth enamel. Geochimica et Cosmochimica Acta 59(20), 4299-4305.

Huff, D., Teufer, M. (**2010**) Dzharkutan, Uzbekistan. Archäologische Forschungen in Kasachstan, Tadschikistan, Turkmenistan und Usbekistan, 22–27.

Huff, D., Pidaev, Š., Šaydullaev, Š. (**2001**) Uzbek-German archaeological researches in the Surkhan Darya region. In: P. Leriche, Š. Pidaev, M. Gelin, K. Abdoullaev (eds.) La Bactriane au carrefour des routes et des civilisations de l'Asie centrale. Termez et les villes de Bactriane-Tokharestan. Actes du colloque de Termez 1997, Paris, Maisonneuve et Larose – IFEAC, 219–233.

Huff, D. (**2000a**) Djarkutan Archaeological Research on Tepe VI, Istoriâ material'noj kul'tury Uzbekistana 31, 58–69.

Huff, D. (**2000b**) Tempel oder Palast? Dscharkutan – Monumentalbauten und Siedlung im bronzezeitlichen Baktrien. In: K. Rheidt, A. Schöne-Denkinger, A. Nünnerich-Asmus (eds.) Archäologische Entdeckungen. Die Forschungen des Deutschen Archäologischen Instituts im 20. Jahrhundert, 115–118.

Hunt, H.V., Campana, M.G., Lawes, M.C., Park, Y.J., Bower, M.A., Howe, C.J., Jones M.K. (**2011**) Genetic diversity and phylogeography of broomcorn millet (Panicum miliaceum L.) across Eurasia. Molecular ecology 20(22), 4756–4771. doi.org/10.1111/j.1365–294X.2011.05318.x.

I

Iacumin, P., Bocherens, H., Mariotti, A., Longinelli, A. (**1996**) An isotopic palaeoenvironmental study of human skeletal remains from the Nile Valley. Palaeogeography, Palaeoclimatology, Palaeoecology 126(1-2), 15–30.

Ingman, M., Gyllensten, U. (**2007**) A recent genetic link between Sami and the Volga-Ural region of Russia. European Journal of Human Genetics 15(1), 115–120.

Irvine, B., Erdal, Y.S. (**2020**) Analysis of dietary habits in a prehistoric coastal population from İkiztepe, North Turkey, using stable isotopes of Carbon, Nitrogen, and sulphur. Journal of Archaeological Science: Reports 29, 102067.

J

Jamali, F., Hessami, K., Ghorashi, M. (**2011**) Active tectonics and strain partitioning along dextral fault system in Central Iran: Analysis of geomorphological observations and geophysical data in the Kashan region. Journal of Asian Earth Sciences 40, 1015–1025.
doi.org/10.1016/j.jseaes.2010.05.013

Jarrige, J.F. (**2013**) Les relations archéologiques entre les régions au sud et au nord de l'Hindu Kush du Vè millénaire jusqu'au milieu du IIIè millénaire avant notre ère à la lumière des données fournies par les sites de la région de Kashi-Bolan au Baloutchistan pakistanais. In: J. Bendezu-Sarmiento (ed.) L'archéologie française en Asie centrale. Nouvelles recherches et enjeux socioculturels, Cahiers d'Asie Centrale 21/22, 41–68.

Jones, M., Hunt, H., Lightfoot, E., Lister, D., Liu, X., Motuzaite-Matuzeviciute, G. (**2011**) Food globalization in prehistory. World Archaeology 43(4), 665–675.

K

Kaniuth, K. (**2021**) Life in the countryside. The rural archaeology of the Sapalli culture. In: B. Lyonnet, N. Dubova (eds.) The World of the Oxus Civilization, Routledge, London, 457–486.

Kaniuth, K. (**2016**) The Late Bronze Age Settlement of Tilla Bulak (Uzbekistan) – a summary of four years´ work. In: V. Lefèvre, A. Didier, B. Mutin (eds.) South Asian Archaeology and Art 2012. Man and environment in Prehistoric and Protohistoric South Asia: New Perspectives. Indicopleustoi, Brepols, Turnhout, 117–127.

Kaniuth, K. (**2010**) Long distance imports in the Bronze Age of Southern Central Asia. Recent finds and their implications for chronology and trade. Archäologische Mitteilungen aus Iran und Turan 42, 3–22.

Kaniuth, K. (**2009**) Analyse pflanzlicher Makroreste von Bodenproben von Michael Peters. In: Tilla Bulak 2008 - Vorbericht zur zweiten Kampagne. Archäologische Mitteilungen aus Iran und Turan 41, 89–91.

Kaniuth, K. (**2006**) Metallobjekte der Bronzezeit aus Nordbaktrien. Philipp von Zabern.

Kaniuth, K., Teufer, M., Iljasov, J., Daszkiewicz, M., Schneider, G. (**2007**) Tilla Bulak 2007 – Vorbericht zur ersten Kampagne. Archäologische Mitteilungen aus Iran und Turan 39, 31–47.

Kaniuth, K., Teufer, M., Vinogradova, N.M. (**2006**) Neue bronzezeitliche Funde aus Südwest-Tadžikistan. Archäologische Mitteilungen aus Iran und Turan 38, 81–102.

Kasiri, M.B., Abedi, A. (**2020**) Application of Strontium Isotope Analysis of Bone and Tooth in the Study of Ancient Immigrations. Journal of Research on Archaeometry 6(1), 17–31.

Kasiri, M.B., Karimi, H.Z. (**2017**) Study of skeletons of the Iron Age cemetery of Tabriz by strontium isotopes Analysis. Journal of Archeological Science: Reports 16, 359–364. doi.org/10.1016/j.jasrep.2017.10.030

Katzenberg, M.A. (**2008)** Stable Isotope Analysis: A Tool for Studying Past Diet, Demography, and Life History. In: M.A. Katzenberg, S.R. Saunders (eds.) Biological Anthropology of the Human Skeleton, Wiley, John & Sons, Incorporated, Hoboken, 411–441.

Katzenberg, M.A., Goriunova, O.I., Weber, A. (**2009**) Paleodiet reconstruction of Early Bronze Age Siberians from the site of Khuzhir-Nuge XIV, Lake Baikal. Journal of Archaeological Science 36, 663–674.

Katzenberg, M.A., Weber, A. (**1999**) Stable isotope ecology and palaeodiet in the Lake Baikal region of Siberia. Journal of Archaeological Science 26, 651–659.

Kavosh, H.A., Shirazi, Z., Naseri, R. (**2020**) The Archaeobotanical Studies of Tepe Taleb Khan, Sistan, Southeast of Iran (2500–2300 BCE). Journal of research on Archaeometry 6(1), 137–154.

Kempe U., Belyatsky R.S., Kremenetsky A.A., Ivanov P.A., **2001**. Sm-Nd and Sr isotope systematics of scheelite from the giant Au(-W) deposit Muruntau (Uzbekistan): implications for the age and sources of Au mineralization. Mineralium Deposita 36, 379–392.

Kenoyer J.M., Price T.D., Burton J.H. (**2013**) A new approach to tracking connections between the Indus Valley and Mesopotamia: Initial results of strontium isotope analyses from Harappa and Ur. Journal of Archaeological Science 40(5), 2286–2297.

Khazaeli, R. (**2014**) The subsistence economy of the ancient city of Nishapur from its rise to the Mongol era. University of Tehran. MA thesis.

Khazaeli R., Fathi, H., Amiri, S., Beyzaei Doust, S., Sarlak, S., Mashkour, M. (**2016**) Faunal remains of Qoli Darvish (Qom) (dir. Sarlak S.). ICAR- ICHHTO, 20.

Khazanov, A.M. (**1994**) Nomads and the Outside World, The University of Wisconsin Press, Wisconsin.

Khlopina, L.I. (**1981**) Namazga-Depe and the Late Bronze Age of Southern Turkmenia. In: P. Kohl (ed.) The Bronze Age Civilization of Central Asia. Recent Soviet Discoveries, Sharpe, New York, 35–62.

Kibaroğlu, M., Kozal, E., Klügel, A., Hartmann, G., Monien, P. (**2019**) New evidence on the provenance of Red Lustrous Wheel-made Ware (RLW): Petrographic, elemental and Sr-Nd isotope analysis. Journal of Archeological Science: Reports 24, 412–433.

Kibaroğlu, M., Falb, C., Hartmann, G. (**2017**) Application of strontium isotope analysis to provenance studies of Early Bronze Age North-Mesopotamian Metallic Ware. Journal of Archeological Science: Reports 16, 573–588. doi.org/10.1016/j.jasrep.2017.09.024

Kirčo, L.B. (**2021**) The rise of the early urban civilization in southwestern Central Asia: from the Middle Chalcolithic to the Middle Bronze Age in southern Turkmenistan. In: B. Lyonnet, N. Dubova (eds.) The World of the Oxus Civilization, Routledge, New York/London, 110–142.

Kircho, L.B. (**2014**) The Problem of the Origin of the Early Bronze Age Culture of Southern Turkmenia. Soviet Anthropology and Archeology 19(1-2), 1981 (published online 20. 12.2014), 96–106.

Knipper, C., Reinhold, S., Gresky, J., Berezina, N., Gerling, C., Pichler, S.L., ... Alt, K.W. (**2020**) Diet and subsistence in Bronze Age pastoral communities from the southern Russian steppes and the North Caucasus. Plos one 15(10), e0239861.

Knipper, C. (**2004**) Die Strontiumisotopenanalyse: eine naturwissenschaftliche Methode zur Erfassung von Mobilität in der Ur-und Frühgeschichte. Jahrbuch des Römisch-Germanischen Zentralmuseums Mainz 51(2), 589–686.

Kohl, P.L. (**2007**) The making of Bronze Age Eurasia, Cambridge University Press, Cambridge.

Kohl, P.L. (**1984**) Central Asia: Paleolithic beginnings to the Iron age, Paris, Editions Recherche sur les civilisations.

Kohl, P.L. (**1981**) The Bronze Age Civilization of Central Asia. Recent Soviet Discoveries, New York.

Kohn, M.J. (**1999**) You are what you eat. Science 283(5400), 335–336.

Kroll, S.E. (**2019**) A Note on Late Iron Double-Handled Tankards from Sialk. In: J. Nokandeh, J. Curtis, M. Pic (eds.) Tappeh Sialk. The Glory of Ancient Kashan. Iran Heritage Foundation Special Studies 1, 38–40.

Kroll, S.E. (**2018**) Horse Stables in Urartu. In: B. Gökce, P. Pinarcik, E. Yakındoğu'da Ulaşım Üzerine Yazılar, Articles on Transportation in Ancient Near East, Ankara, 133–146.

Kroll, S.E. (**2012**) On the Road(s) to Nowhere: A Re-Analysis of the Hasanlu "Tripartite Road System" in Light of the Excavated Evidence. In: H.D. Baker, K. Kaniuth, and A. Otto (eds.) Stories of Long Ago. Festschrift für Michael D. Roaf, AOAT 397, Ugarit Verlag Münster, 277–284.

Krueger, H.W., Sullivan, C.H. (**1984**) Models for Carbon Isotope Fractionation Between Diet and Bone. Stable Isotopes in Nutrition, 205–220. doi.org/10.1021/bk-1984-0258.ch014.

Krzewinska M., Kjellström A., Günther T., Hedenstierna-Jonson C., Zachrisson T., Omrak A., Yaka R. Kılınc G.M., Somel M., Sobrado V., Evans J., Knipper C., Jakobsson M., Stora J., Götherström A. (**2018**) Genomic and Strontium Isotope

Variation Reveal Immigration Patterns in a Viking Age Town. Current Biology 28, 2730–2738.

Kurbanov, D. (**1994**) Flora of Kopetdag. In: V. Fet, K.I. Atamuradov (eds.) Biogeography and Ecology of Turkmenistan, Springer-Science + Business Media, B.V, 105–129.

Kutimov, Y.G. (**2014**) K voprosu o kul'turnykh kontaktakh stepnogo i zemledel'cheskogo naseleniya v pozdnem bronzovom veke na territorii Turkmenistana. In: V.A. Alokshin, L.B. Kircho, M.T. Kashuba, V.Y. Stogantseva (eds.) Arkheologiya drevnikh obshchestv Yevrazii: khronologiya, kul'turogenez, religioznyye vozzreniya – Pamyati Vadima Mikhaylovicha Massona (03.05.1929–19.02.2010), St. Petersburg: Institut istorii material'noy kul'tury RAN; "Art-Xpress", 86–96.

Kuz´mina, E.E. (**2007**) The Origin of the Indo-Iranians, Indo-European Etymological Dictionary Series III, Leiden-Boston, Brill Leiden.

L

Lam, Y.M. (**1994**) Isotopic evidence for change in dietary patterns during the Baikal Neolithic. Current Anthropology 35, 185–190.

Lamberg-Karlovsky, C.C. (**2013**) The Oxus Civilisation. La Civilización del Oxus. Cuadernos de Prehistoria y Arqueología Universidad Autónoma de Madrid 39, 21–63.

Lamberg-Karlovsky, C.C. (**1974**) Urban interaction on the Iranian Plateau: excavations at Tepe Yahya 1967–1973, London: Oxford University Press.

Larson, G., Karlsson, E.K., Perri, A., Webster, M.T., Ho, S.Y., Peters, J., ... Lindblad-Toh, K. (**2012**) Rethinking dog domestication by integrating genetics, archeology, and biogeography. Proceedings of the National Academy of Sciences 109(23), 8878–8883.

Lazaridis, I. et al. (**2016**) Genomic insights into the origin of farming in the ancient Near East. Nature 536, 419–424.

Lécolle, P. (**1985**) The oxygen isotope composition of landsnail shells as a climatic indicator: Applications to hydrogeology and palaeoclimatology. Chemical Geology 58, 157–181.

Lecomte, O. (**2015**) Ulug Depe a forgotten city in Central Asia. MAFTUR, Mission Archéologique Franco-Turkmène. MAE. CNRS.

Lecomte, O. (**2013**) Activités archéologiques françaises au Turkménistan. In: J. Bendezu-Sarmiento (ed.) Archéologie française en Asie centrale. Nouvelles recherches et enjeux socioculturels. Cahiers d'Asie Centrale 21/22, 165–190.

Lecomte, O. (**2011**) Ulug-depe: 4000 years of evolution between plain and desert. In: Historical and Cultural Sites of Turkmenistan. Monuments of History and Culture of Turkmenistan (Discoveries, Researches and Restoration for 20 years of Independence), Turkmen state publishing service, 221–238.

Lecomte, O. (**2007a**) An Iron Age Urban Settlement Revealed by Magnetic Survey: The Case of Ulug Depe (Turkmenistan). In: M. Posselt, B. Zickgraf, C. Dobiat (eds.) Geophysics and excavation. Deployment and utilization of non-destructive methods in Archaeology, 99–111.

Lecomte, O. (**2007b**) Gorgân and Dehistan: The North-East Frontier of the Iranian Empire. In: J. Cribb and G. Hermann (eds.) After Alexander. Central Asia before Islam, British Academy Scholarship Online.
doi.org/10.5871/bacad/9780197263846.001.0001

Lecomte, O. (**2005**) The Iron Age of Northern Hyrcania. Iranica Antiqua 40, 461–478. doi.org/10.2143/IA.40.0.583222

Lee-Thorp J., Sponheimer, M., van der Merwe, A.E. (**1989**) Stable carbon isotope ratio differences between bone-collagen and bone apatite, and their relationship to diet. Journal of Archaeological Science 16, 585–599.

Lengfelder, F., Grupe, G., Stallauer, A., Huth, R., Söllner, F. (**2019**) Modelling strontium isotopes in past biospheres – Assessment of bioavailable 87Sr/86Sr ratios in local archaeological vertebrates based on environmental signatures. Science of the Total Environment 648, 236–252.

Lhuillier, J. (**2019**) The settlement pattern in Central Asia during the Early Iron Age. In: C. Baumer, M. Novák (eds.), Urban cultures of Central Asia from the Bronze Age to the Karakhanids. Learnings and conclusions from new archaeological investigations and discoveries, Proceedings of the First International Congress on Central Asian Archaeology held at the University of Bern, 4–6 February *2016*, Schriften zur Vorderasiatischen Archäologie 12, Harrassowitz Verlag, Wiesbaden, 115–128.

Lhuillier, J. (**2016**) Ulug-depe and the transition period from Bronze Age to Iron Age in Central Asia. A tribute to V.I. Sarianidi. In: N.A. Dubova, E.V. Antonova, P.M. Kozhin, M.F. Kosarev, R.G. Muradov, R.M. Sataev, A.A. Tishkin (eds.) Transactions of Margiana Archaeological Expedition vol. 6, To the memory of Professor Viktor Sarianidi, Moscou, Staryj Sad, 509–521.

Lhuillier, J. (**2013**) Les Cultures à céramique modelées peinte en Asie Centrale Méridionale : Dynamiques socio-culturelles à l'Âge du Fer ancien (1500–1000 av. n.è), MMAFAC XIII, De Boccard, Paris.

Lhuillier, J. (**2010**) Le phénomène des " cultures à céramique modelée peinte " en Asie centrale dans l'évolution et la transformation des sociétés de la fn de l'âge du Bronze et du début de l'âge du Fer (IIe-Ier millénaire avant n.è.). Une synthèse comparative et régionale de la culture matérielle. Archéologie et Préhistoire. Université Panthéon-Sorbonne - Paris I, Français.

Lhuillier, J., Mashkour, M. (**2017**) Animal exploitation in the oases: an archaeozoological review of Iron Age sites in southern Central Asia. Antiquity 91/357, 655–673.

Li, H., Durbin, R. (**2009**) Fast and accurate short read alignment with Burrows-Wheeler Transform. Bioinformatics 25, 1754–1760. doi.org/10.1093/bioinformatics/btp324

Lightfoot, E., O’Connell, T.C. (**2016**) On the use of biomineral oxygen isotope data to identify human migrants in the archaeological record: intra-sample variation, statistical methods and geographical considerations. PloS one 11(4), e0153850.

Lightfoot, E., Liu, X., Jones, M.K. (**2013**) Why move starchy cereals? A review of the isotopic evidence for prehistoric millet consumption across Eurasia. World Archaeology 45(4), 574–623.

Lingen (**2003**) Enzyklopädie der Tiere. Lingen Verlag, Köln, 131.

Lisitsina, G.N. (**1969**) The earliest irrigation in Turkmenia. Antiquity 43(172), 279–288.

Litvinskij, B.A. (**1998**) La civilisation de l'Asie centrale antique. Archäologie in Iran und Turan 3, Verlag Marie Leidorf.

Lösch, S., Gruppe, G., Peters, J. (**2006**) Stable isotopes and dietary adaptations in humans and animals at pre-pottery Neolithic Nevalı Çori, Southeast Anatolia. American Journal of Physical Anthropology 131, 181–193.
doi.org/10.1002/ajpa.20395

Lombardo, G., Vinogradova, N., Kutimov, J., Teufer, M., Filimonova, T. (**2014**). Excavations of the burial ground of Gelot in 2007–2010. Bollettino di Archeologia ON LINE, Direzione Generale per le Antichita´ Vol. 2014/1, 1–26.

Longin, R. (**1971**) New method of collagen extraction for radiocarbon dating. Nature 230, 241–242.

Longinelli, A., Anglesio, E., Flora, O., Iacumin, P., Selmo, E. (**2006**) Isotopic composition of precipitation in Northern Italy: reverse effect of anomalous climatic events. Journal of Hydrology 329(3-4), 471–476.

Longinelli, A. (**1984**) Oxygen isotopes in mammal bone phosphate: a new tool for palaeoclimatological and palaeoenvironmental research? Geochimica et Cosmochimica Acta 48, 385–390.

Luneau, É. (**2021**) The End of the Oxus Civilization. In: B. Lyonnet, N. Dubova (eds.) The World of the Oxus Civilization, Routledge, 496–524.

Luneau, É. (**2019**) Climate Change and the Rise and Fall of the Oxus Civilization in Southern Central Asia. In: Socio-Environmental Dynamics along the Historical Silk Road, Cham Springer International Publishing, 275–99.
doi.org/10.1007/978-3-030-00728-7_14

Luneau, É. (**2017**) Transfers and Interactions between North and South in Central Asia during the Bronze Age. In: E. Allinger, F. Grenet, C. Jahoda, M.K. Lang, A. Vergati (eds.) Interaction in the Himalayas and Central Asia, Vienna, Austrian Academy of Sciences Press, 13–27.
doi.org/10.2307/j.ctt1pv891n.5

Luneau, É. (**2016**) The Fall of the Oxus Civilisation and the Role of Exchanges with Neighbouring Societies during the First Half of the Second Millennium BC. In: V. Lefèvre, A. Didier, B. Mutin (eds.) South Asian Archaeology and Art 2012. Volume I. Man and Environment in Prehistoric and Protohistoric South Asia: New Perspectives, Turnhout, Belgium, Brepols Publishers, 169–183.

Luneau, É. (**2014**) La fin de la civilisation de l'Oxus. Transformations et recompositions des sociétés de l'âge du bronze final en Asie centrale méridionale (1800–1500–1400 avant n. è). Mémoires des Missions Archéologiques Françaises en Asie Centrale et en Asie Moyenne, Tome XVI, Paris, Éditions de Boccard.

Luneau, É. (**2010**) L’âge du Bronze final en Asie centrale méridionale (1750–1500/1450 avant n.è.): la fin de la civilisation de l’Oxus. Archéologie et Préhistoire, Université Panthéon-Sorbonne - Paris I, Français.

Luneau, É., Bendezu-Sarmiento, J., Mustafakulov, S. (**2013**) Вахшская культура на Джаркутане (Узбекистан, бронзовый век): Новое освоение ? [The Vakhsh culture at Dzharkutan (Uzbekistan, Bronze Age): a new occupancy?]. In: G.J. Kolganova, A.A. Petrova, S.V. Kullanda (eds.) Последний энциклопедист. К юбилею со дня рождения Б.А. Литвинского [The last encyclopedist. The Issue in Honor of the 90-Anniversary of Boris Litvinsky], Moscow, Institut of Oriental Studies, 253–263.

Luz, B., Kolodny, Y., Horowitz, M. (**1984**) Fractionation of oxygen isotopes between mammalian bone-phosphate and environmental drinking water. Geochimica et Cosmochimica Acta 48, 1689–1693.

Lyonnet, B. Dubova, N. (eds.) (**2021**) The World of the Oxus Civilization., Routledge, London.

Lyonnet, B. (**1996**) Sarazm (Tadjikistan). Céramiques (Chalcolithique et Bronze ancien), De Boccard, Paris.

Lyons, W.B., Welch, S.A., Gardner, C.B., Sharifi, A., AghaKouchak, A., Mashkour, M., Djamali, M., Matinzadeh, Z., Palacio, S., Akhani, H. (**2020**) The hydrogeochemistry of shallow groundwater from Lut Desert, Iran: The hottest place on Earth. Journal of Arid Environments 178, 104143.

M

Madgwick, R., Lamb, A.L., Sloane, H., Nederbragt, A.J., Albarella, U., Pearson, M.P., Evans, J.A. (**2019**) Multi-isotope analysis reveals that feasts in the Stonehenge environs and across Wessex drew people and animals from throughout Britain. Science Advances 5(3), eaau6078.

Makarewicz, C.A. (**2018**) Stable isotopes in pastoralist archaeology as indicators of diet, mobility, and animal husbandry practices. In: A. Miller A, C.A. Makarewicz (eds.) Isotopic investigations of pastoralism in prehistory, Routledge, London, 142–158.

Makarewicz, C.A., Pederzani, S. (**2017**) Oxygen (δ18O) and carbon (δ13C) isotopic distinction in sequentially sampled tooth enamel of co-localized wild and domesticated caprines: Complications to establishing seasonality and mobility in herbivores. Palaeogeography, Palaeoclimatology, Palaeoecology 485, 1–15.
doi.org/10.1016/j.palaeo.2017.01.010

Mashkour, M., Khazaeli, R., Amiri, S., Fathi, H., Beyzaei Doust, S., Mohaseb, A., Davoudi, H., Debue, K., Antoine Ruchonnet, A., Radu, V., Laleh, H., Nokandeh, J., Omrani Rekavandi, H., Nemati, M.R., Sauer, E.W. (**in press**) Archaeozoology of Sasanian and Islamic sites from the Gorgan Wall to the Tehran Plain. In: E. Sauer, J. Nokandeh, H. Omrani Rekavandi (eds.) Ancient Arms Race: Antiquity's Largest Fortresses and Sasanian Military Networks of Northern Iran: A joint fieldwork project by the Iranian Cultural Heritage, Handcraft and Tourism Organisation and the Universities of Edinburgh and Durham (2014–2016), Oxbow Books, Oxford.

Mashkour, M., Bon, C., Demeter, F., Friess, M., Sheikhi, S., Huet, L., Thomas, L. (**2019**) Tappeh Sialk Human and Animal Osteological Collections at the National Museum of Natural History. In: J. Nokandeh, J. Curtis, M. Pic (eds.) Tappeh Sialk the Glory of Ancient Kashan, Iranian Heritage Foundation, Louvre, Richt, National Museum of Iran, 45–55.

Mashkour, M., Fathi, H. (**2019**) The faunal remains of Tepe Naderi. Unpublished report.

Mashkour, M., Askari, A.R. (**2017**) The faunal remains of Sarvestan. Unpublished report.

Mashkour M., Amiri S., Fathi H. (**2016a**) Rapport préliminaire sur l'étude archéozoologique des sites de Dzarkutan, de Kok Tepe de Sangir Tepe et Padayatak en Uzbekistan. Soumis à l'IFA.

Mashkour, M., Mohaseb, F.A., Rezvani, H. (**2016b**) Faunal remains of Deh Kheir and Kalāteh Khan, two late Neolithic sites of the Shahroud and Bastam plains (North East Iran). The Neolithic of the Iranian Plateau. Recent Research and Prospects. Studies in Early Near Eastern Production, Subsistence, and Environment (SENEPSE series), ex oriente, Berlin, 85–100.

Mashkour, M. (**2015**.) In Ulug Depe a forgotten city in Central Asia. MAFTUR, Mission Archéologique Franco-Turkmène. MAE, CNRS, Ginkgo éditeur.

Mashkour, M., Vigne, J.-D., Mohaseb, A.F., Bréhard, S., Bemili, C., Reynolds, W., Daujat, J., Debue, K., Tsuneki, A. (**2014**) Neolithisation of Eastern Iran: New insights through the study of the faunal remains of Tappeh Sang-e Chakhmaq. In: The First Farming Village in Northeast Iran and Turan, Tsukuba University, 29–35.

Mashkour, M. (**2013a**) Sociétés pastorales et économies de subsistance au Nord Est de l'Iran et au Sud du Turkménistan. In: J. Bendezu-Sarmiento (ed.) L'archéologie française en Asie centrale. Nouvelles recherches et enjeux socioculturels, Cahiers d'Asie Centrale 21/22, 533–544.

Mashkour, M. (**2013b**) Section C. Specialist contributions, Chp. Animal Bones 20.3 Animal exploitation during the Iron Age to Achaemenid, Sasanian and Early Islamic periods along the Gorgan Wall. In: E. Sauer, H. Omrani Rekavandi, T. Wilkinson, J. Nokandeh (eds.) Persia's Imperial Power in Late Antiquity: The Great Gorgan Wall and the Frontier Landscapes of Sasanian Iran. British Institute of Persian Studies monograph, British Academy, Oxbow Books, 548−580.

Mashkour, M., (**2008**) Faunal remains of Tepe Damghani (dir. A. Vahdati, H.P. Francfort). ICHHTO.

Mashkour, M., Mohaseb, A. (**2007**) Archaeozoological report of Kalateh Khan, Semnan – Iran (dir. H. Rezvani). ICHHTO.

Mashkour, M. (**2006**) Faunal Remains from Tol-e Nurabad and Tol-e Spid. In: D.T. Potts, R. Roustaei (eds.) The Mamasani Archaeological Project Stage One: A report on the first two seasons of the ICAR - University of Sydney expedition to the Mamasani District, Fars Province, Iran, ICAR, Tehran, 135–146.

Mashkour, M. (**2004a**) (1382). Paleo-environmental studies in Sialk (Kashan). In: M. Shahmirzadi (ed.) The Silver Smith of Sialk, Report N°2, ICHTO, 189–194.

Mashkour, M. (**2004b**) (1383). Preliminary report of archaeozoological studies of the third season of the Sialk Reconsideration Project. In: M. Shahmirzadi (ed.) The potters of Sialk, Report N°3. Archaeological Report Monograph Series 5, ICHTO, 95–108.

Mashkour, M. (**2002**) Preliminary report of the faunal assemblage of 1999 excavation. In: K. Abdi (ed.) Archaeological Fieldwork Resumed at Malyan, Bastanshenasi et Tarikh (Iranian Journal of Archaeology) 29-30, 47–67.

Mashkour, M. (**2001**) Chasse et élevage du Néolithique à l'Âge du Fer dans la plaine de Qazvin (Iran). Etude archéozoologique des sites de Zagheh, Qabrestan et Sagzabad. PhD thesis, Université de Paris I-Sorbonne.

Mashkour, M., Fontugne, M., Hatte, C. (**1999**) Investigations on the evolution of subsistence economy in the Qazvin Plain (Iran) from the Neolithic to the Iron Age. Antiquity 73(279), 65.

Mashkour, M. (**1998**) The subsistence Economy in the Rural Community of Geoktchik Depe in Southern Turkmenistan; Preliminary Results of the Faunal Analysis. In: H. Buitenhuis, H. Bartosiewicz, A.M. Choyke (eds.) Archaeozoology of the Near East III, ARC Publication, Groningen, 200–220.

Masson, V.M. (**2006**) Kul'turogenez drevneĭ Tsentral'noĭ Azii. St. Petersburg: Filologicheskiĭ fakul'tet Sankt-Peterburgskogo gosudarstvennogo universiteta.

Masson, V.M. (**1981**) Altyn-depe, Nauka, Leningrad.

Masuda, S., Goto, T., Iwasaki, T., Kamuro, H., Furusato, N., Ikeda, J., Tsuneki, A. (**2013**) Tappeh Sang-e Chakhmaq: investigations of a Neolithic site in Northeastern Iran. The Neolithisation of Iran: the formation of new societies, 201–241.

Matthews, R., Matthews, W., Mohammadifar, Y. (**2013**) The earliest Neolithic of Iran: 2008 excavations at Sheikh-e Abad and Jani (Vol. 1). Oxbow Books.

Matthews, R., Fazeli Nashli, H. (**2022**) The archaeology of Iran from the Palaeolithic to the Achaemenid empire. Routledge.

Matthews, R., Nashli, H.F. (**2013**) The Neolithisation of Iran: the formation of new societies. British Association for Near Eastern Archaeology and Oxbow Books, Oxford, 272.

Maurer, A.F., Galer, S.J.G., Knipper, C., Beierlein, L., Nunn, E.V., Peters, D., Tütken, T., Alt, K.W., Schöne, B.R. (**2012**) Bioavailable 87Sr/86Sr in different environmental samples — Effects of anthropogenic contamination and implications for isoscapes in past migration studies. Science of the Total Environment 433, 216–229.

McArthur, J.M., Donovan, D.T., Thirlwall, M.F., Fouke, B.W., Mattey, D. (**2000**) Strontium isotope profile of the early Toarcian (Jurassic) oceanic anoxic event, the duration of ammonite biozones, and belemnite palaeotemperatures. Earth and Planetary Science Letters 179(2), 269–285.

Mehrjoo, Z., Fattahi, Z., Beheshtian, M., Mohseni, M., Poustchi, H., Ardalani, F., ... Nothnagel, M. (**2019**) Distinct genetic variation and heterogeneity of the Iranian population. PLoS genetics 15(9), e1008385.
doi.org/10.1371/journal.pgen.1008385

Meisel, T., Krahenbuhl, U., Nazarov, M.A. (**1995**) Combined osmium and strontium isotopic study of the Cretaceous-Tertiary boundary at Sumbar, Turkmenistan: A test for an impact vs. a volcanic hypothesis. Geology 23(4), 313–316.

Messager, E., Herrscher, E., Martin, L., Kvavadze, E., Martkoplishvili, I., Delhon, C., ... Lordkipanidze, D. (**2015**) Archaeobotanical and isotopic evidence of Early Bronze Age farming activities and diet in the mountainous environment of the South Caucasus: a pilot study of Chobareti site (Samtskhe–Javakheti region). Journal of archaeological Science 53, 214–226.

van der Merwe, N.J, Vogel, J.C. (**1978**) 13C content of human collagen as a measure of prehistoric diet in the Woodland North America. Nature 276, 815–816.

Meyer, J.W., Vila, E., Mashkour, M., Casanova, M., Vallet, R. (eds.) (**2020**) The Iranian Plateau during the Bronze Age: Development of urbanisation, production and trade. Coll. Archéologie(s) 1, MOM Éditions, Lyon.

Millard, A., Lucy, S., Roberts, C. (**2004**) Direct evaluation of archaeological immigration, population dynamics and lead exposure by isotope biogeochemistry. AnNERC project at the University of Durham. http://www.dur.ac.uk

Miller, N.F., Spengler, R.N., Frachetti, M. (**2016**) Millet cultivation across Eurasia: Origins, spread, and the influence of seasonal climate. The Holocene 26(10), 1566–1575.

Miller, N.F. (**2003**) The use of plants at Anau North. In: F.T. Hiebert, K. Kurdansakhatov (eds.) A Central Asian village at the dawn of civilization, excavations at Anau, Turkmenistan. University of Pennsylvania Museum, Philadelphia.

Miller, N.F. (**1999**) Agricultural development in western Central Asia in the Chalcolithic and Bronze Ages. Vegetation history and Archaeobotany 8, 13–19.

Mittnik, A., Massy, K., Knipper, C., Wittenborn, F., Friedrich, R., Pfrengle, S., ... Krause, J. (**2019**) Kinship-based social inequality in Bronze Age Europe. Science 366(6466), 731–734. doi.org/10.1126/science.aax6219

Monchot, H., Mashkour, M. (**2010**) Hyenas around the city (Kashan, Iran). Journal of Taphonomy 8(1), 17–32.

Moore, K., Miller, N.F., Hiebert, F.T., Meadow R.H. (**1994**) Agriculture and herding in early oasis settlements of the Oxus civilization. Antiquity 68, 418–427.

Motuzaite-Matuzeviciute, G., Lightfoot, E., O'Connell, T.C., Kukushkin, I.A., Loman, V., Varfolomeev, V., Liu, X., Jones, M.K. (**2015**) How 'Pastoral' is Pastoralism? Dietary Diversity in Bronze Age Communities in the Central Kazakhstan Steppes. Archaeometry 57, 232–249.

Münster, A., Knipper, C., Oelze, V.M., Nicklisch, N., Stecher, M., Schlenker, B., ... Alt, K.W. (**2018**) 4000 years of human dietary evolution in central Germany, from the first farmers to the first elites. PloS one 13(3), e0194862.
doi.org/ 10.1371/journal.pone.0194862

Mukin, P. in Moore, E.M., Fairbridge, R.W. (**1997**) Encyclopedia of European and Asian regional Geology. "Uzbekistan". Chapman & Hall, Springer, Dordrecht, 766–773.

Muradov, R.G. (**2021**) The architecture of the Bactria-Margiana Archaeological Culture. In: B. Lyonnet, N. Dubova (eds.) The World of the Oxus Civilization, Routledge, London, 145–177.

Murphy, E.M., Schulting, R., Beer, N., Chistov, Y., Kasparov, A., Pshenitsyna, M. (**2013**) Iron Age pastoral nomadism and agriculture in the eastern Eurasian steppe: implications from dental palaeopathology and stable carbon and nitrogen isotopes, Journal of Archaeological Science 40(5), 2547–2560.

Mutin, B. (**2020**) Exploring Gender Inequality Between Makran and Turan During the Bronze Age. In: D. Usai, S. Tuzzato, M. Vidale (eds.) Tales of Three Worlds. Archaeology and beyond: Asia, Italy, Africa. A tribute to Sandro Salvatori, Archaeopress, 85–97.

Mutin, B., Lamberg-Karlovsky, C.C. (**2013**) The proto-elamite settlement and its neighbors: Tepe Yahya period IVC. Oxbow books.

N

Naseri, R., Malekzadeh, M. (**2019**) Decorative bricks of the Late Iron Age in Eastern Media: some pieces from Sialk. In: J. Nokandeh, J. Curtis, M. Pic (eds.) Tappeh Sialk. The Glory of Ancient Kashan. Iran Heritage Foundation Special Studies 1, 32–38.

Narasimhan, V.M., Patterson, N., Moorjani, P., Rohland, N., Bernardos, R., Mallick, S., ... Reich, D. (**2019**) The formation of human populations in South and Central Asia. Science 365(6457), eaat7487.
science.org/doi/10.1126/science.aat7487

Narasimhan, V.M., Patterson, N.J., Moorjani, P., Lazaridis, I., Mark, L., Mallick, S., ... Reich, D. (**2018**) The genomic formation of South and Central Asia.

Nesbitt, M., O'Hara, S. (**2000**) Irrigation agriculture in Central Asia: a long-term perspective from Turkmenistan. In: G. Baker, D. Gilbertsom (eds.) The archaeology of drylands. Living at the margin, London-New York, Routledge, 103–122.

Neumann, G. (**forthcoming**) The Iranian Plateau from the Palaeolithic to the Beginning of the Bronze Age. In: Touraj Daryaee and Robert Rollinger (eds.) Iran from the beginnings to the Achaemenid-Persian empire, Proceedings of the First and Second Payravi Conference on Ancient Iranian History, Classica et Orientalia, Wiesbaden: Harrasowitz, in preparation.

Neustupny, E. (**1981**) Mobilität der äneolithischen Populationen. Slovenská Archeológia 29/1, 111–119.

Neustupny, E. (**1983**) The demography of prehistoric cemeteries. Památky Archeologické 74, 7–34.

Nobari, A., Davoudi, H., Kouhpar, S.M., Mashkour, M. (**2018**) Studying the subsistence economy of northwestern Iran during the Iron Age through the bioarchaeological researches at Tepe Hasanlu. Pazhohesh-ha-ye Bastanshenasi Iran, Vol. 16, 165–182 (in Persian).
doi.org/10.22084/NBSH.2017.13690.1603

Nokandeh, J. (**2010**) Neue Untersuchungen zur Sialk III-Periode im zentraliranischen Hochland auf der Grundlage der Ergebnisse des „Sialk Reconsideration Project". Berlin.

Nuscheler, F. (**1995**) Historische Verortung von Flucht und Migration. In: Internationale Migration. Flucht und Asyl. VS Verlag für Sozialwissenschaften, 44–53.

O

O'Connell, T.C., Levine, M.A., Hedges, R.E.M. (**2003**) The importance of fish in the diet of central Eurasian peoples from the Mesolithic to the Early Iron Age. In: M.A. Levine, A.C. Renfrew, K. Boyle (eds.) Prehistoric steppe adaptation and the horse, McDonald Institute for Archaeological Research, Cambridge, 253–268.

O'Leary, M.H. (**1988**) Carbon isotopes in photosynthesis. Bioscience 38/5, 328–336.

Ollivier, M., Tresset, A., Bastian, F., Lagoutte, L., Axelsson, E., Arendt, M.L., ... Hänni, C. (**2016**) Amy2B copy number variation reveals starch diet adaptations in ancient European dogs. Royal Society open science 3(11), 160449.
http://dx.doi.org/10.1098/rsos.160449

Olson, K.G., Thornton, C.P. (**2021**) Tureng Tepe, a Bronze Age Centre in Northeastern Iran Revisited. Iran. Journal of the British Institute of Persian Studies 59, 1–32.
doi.org/10.1080/05786967.2019.1679034

van Oven, M., Kayser, M. (**2009**) Updated comprehensive phylogenetic tree of global human mitochondrial DNA variation. Human mutation 30(2), E386–E394.
doi.org/10.1002/humu.20921

Orlovsky, N.S. (**1994**) Climate of Turkmenistan. In: V. Fet, K.I. Atamuradov (eds.) Biogeography and Ecology of Turkmenistan, Springer Science+Busines Media Dordrech, 23–49.

P

Pakendorf, B., Stoneking, M. (**2005**) Mitochondrial DNA and human evolution. Annu. Rev. Genomics Hum. Genet. 6, 165–183.

Pearson, J.A., Bogaard, A., Charles, M., Hillson, S.W., Larsen, C.S., Russell, N., Twiss, K. (**2015**) Stable carbon and nitrogen isotope analysis at Neolithic Çatalhöyük: evidence for human and animal diet and their relationship to households. Journal of Archaeological Science 57, 69–79.

Peng, M.S. et al. (**2018**) Mitochondrial genomes uncover the maternal history of the Pamir populations. European Journal of Human Genetics 26(1), 124–136.
doi.org/10.1038/s41431-017-0028-8

Pernicka, E. (**2004a**) Kupfer und Silber in Arisman und Tappeh Sialk und die frühe Metallurgie in Iran. In: T. Stöllner, R. Slotta, A. Vatandoust (eds.) Persiens Antike Pracht. Bergbau, Handwerk, Archäologie. Katalog der Ausstellung des Deutschen Bergbau-Museums Bochum vom 28. November 2004 bis 29. Mai 2005, Veröffentlichungen aus dem Deutschen Bergbau-Museum, Bochum, 232–239.

Pernicka, E. (**2004b**) Silver production by cupellation in the fourth millennium BC at Tepe Sialk. In: S.M. Shahmirzadi (ed.) The Potters of Sialk, Archaeological Report Monograph Series 5, Tehran, 69–71.

Petrie, C.A. (ed.) (**2013**) Ancient Iran and Its Neighbours: Local Developments and Long-range Interactions in the 4th Millennium BC. Oxbow Books.

Pin, C., Briot, D., Bassin, C., Poitrasson, F. (**1994**) Concomitant separation of strontium and samarium–neodymium for isotopic analysis in silicate samples, based on specific extraction chromatography. Analytica Chimica Acta 298, 209–217.

Pittman, H. (**2019**) Bronze Age Interaction on the Iranian Plateau: From Kerman to the Oxus Through Seals. The Iranian Plateau During the Bronze Age. Development of Urbanisation, Production and Trade, 267–288.

Poage, M.A., Chamberlain, C.P. (**2001**) Empirical relationships between elevation and the stable isotope composition of precipitation and surface waters: Considerations for studies of paleoelevation change. American Journal of Science 301, 1–15.

Pollard, A.M., Nashli, H.F., Davoudi, H., Sarlak, S., Helwing, B., Saeidi, F. (**2013**) A new radiocarbon chronology for the North Central Plateau of Iran from the Late Neolithic to the Iron Age. Archäologische Mitteilungen aus Iran und Turan 45, 27–50.

Possehl, G.L. (**2002**) The Indus Civilization: a contemporary perspective. Rowman Alt.

Potts, D.T. (**2016**) The archaeology of Elam. Formation and transformation of an ancient Iranian state, Cambridge World Archaeology.

Potts, D.T. (**2009**) Bevel-rim bowls and bakeries: evidence and explanations from Iran and the Indo-Iranian borderlands, JCS 61(2), 1–23.

Potts, D.T. (**2001**) Excavations at Tepe Yahya, Iran, 1967–1975: The Third Millennium, Bulletin of the American School of Prehistoric research 45, Peabody Museum of Archaeology and Ethnology, Harvard university, Cambridge MA.

Potts, D.T., Roustaei, K. (eds.) (**2006**) The Mamasani Archaeological Project Stage One: A report on the first two seasons of the ICAR - University of Sydney expedition to the Mamasani District, Fars Province, Iran, ICAR.

Price, T.D., Knipper, C., Grupe, G., Smrcka, V. (**2004**) Strontium isotopes and prehistoric human migration: the Bell Beaker period in central Europe. European journal of archaeology 7(1), 9–40.

Price, T.D., Burton, J.H., Bentley, R.A. (**2002**) Characterization of biologically available strontium isotope ratios for the study of prehistoric migration. Archaeometry 44, 117–135.

Price, T.D., Bentley, R.A., Luening, J., Gronenborn, D., Wahl, J. (**2001**) Prehistoric human migration in the Linearbandkeramik of Central Europe. Antiquity 75, 593–603.

Price, T.D., Manzanilla, L., Middleton, W. (**2000**) Immigration and the ancient city of Teotihuacan in Mexico: a study using strontium isotope ratios in human bone and teeth. Journal of Archaeological Science 27, 903–913.

Price, T.D., Johnson, C.M., Ezzo, J.A., Ericson, J., Burton, J.H. (**1994a**) Residential mobility in the Prehistoric Southwest United States: A preliminary study using strontium isotope analysis. Journal of Archaeological Science 21, 315–330.

Price, T.D., Grupe, G., Schröter, P. (**1994b**) Reconstruction of migration patterns in the Bell Beaker period by stable strontium isotope analysis. Applied Geochemistry 9, 413–417.

Prien, R. (**2005**) Archäologie und Migration: vergleichende Studien zur archäologischen Nachweisbarkeit von Wanderungsbewegungen. Bonn, Habelt.

P'yankova, L. T. (**2002**) South Tajikistan: Synthesis of Settled and Steppe Cultures at the End of the Bronze Age. In: K. Jones-Bley, D.G. Zdanovich (eds.) Complex Societies of Central Eurasia from the 3rd to the 1st Millennium BC: Regional Specifics in Light of Global Models, Washington, DC, Institute for the Study of Man, 558–573.

Q

Quintana-Murci, L., Chaix, R., Wells, R.S., Behar, D.M., Sayar, H., Scozzari, R., ... McElreavey, K. (**2004**) Where west meets east: the complex mtDNA landscape of the southwest and Central Asian corridor. The American Journal of Human Genetics 74(5), 827–845. doi.org/10.1086/383236

R

Ravenstein, E.G. (**1889**) The laws of migration. Journal of the royal statistical society 52(2), 241–305.

Ravenstein, E.G. (**1885**) The laws of migration. Journal of the statistical society of London 48(2), 167–235.

Ramaroli, V., Hamilton, J., Ditchfield, P., Fazeli, H., Aali, A., Coningham, R.A.E., Pollard, A.M. (**2010**) The Chehr Abad "Salt men" and the isotopic ecology of humans in ancient Iran. American journal of physical anthropology 143(3), 343–354. doi.org/10.1002/ajpa.21314

Reynard, L.M., Tuross, N. (**2015**) The known, the unknown and the unknowable: weaning times from archaeological bones using nitrogen isotope ratios. Journal of Archaeological Science 53, 618–625.

Roaf, M. (**2008**) Medes beyond the borders of modern Iran, Bāstānpazhuhi Persian Journal of Iranian Studies (Archaeology) 3(6), 9–11.

Roaf, M. (**1990**) Cultural Atlas of Mesopotamia and the Ancient Near East. Oxford - New York, Fact On File.

Rosenbaum, G., Lister, G. (**2002**) Reconstruction of the evolution of the Alpine-Himalayan orogen - an introduction. In: (Ed.) Gideon Rosenbaum, and Gordon Lister, Reconstruction of the evolution of the Alpine-Himalayan orogen, Journal of the Virtual Explorer 8(1), Electronic Edition. https://api.semanticscholar.org/CorpusID:140618040

Rossi-Osmida, G., Cengia, A.R., Bonora, G.L. (**2020**) Grave ADJ1F from the farmhouse of Adji Kui 1 (Margiana, Turkmenistan): Description and preliminary analyses of an Oxus Civilisation funerary context.

Rouse, L.M., Cerasetti, B. (**2018**) Mixing metaphors: sedentary-mobile interactions and local-global connections in prehistoric Turkmenistan. Antiquity 92(363), 674–689. doi.org/10.15184/aqy.2018.88

Roustaei K., Mashkour M. (eds.) (**2016**) The Neolithic of the Iranian Plateau. Recent Research and Prospects. Studies in Early Near Eastern Production, Subsistence, and Environment (SENEPSE series), ex oriente, Berlin.

Roustaei, K. (**2016**) Kalāteh Khān: a sixth-millennium BC site in the Shāhroud Plain, north-east Iran. In: K. Roustaei, M. Mashkour (eds.) The Neolithic of the Iranian Plateau: recent research, ex oriente, Berlin, 53–84.

Roustaei K., Mashkour, M., Tengberg M. (**2015**) Tappeh Sang-e Chakhmaq and Beginning of the Neolithic Period in Northeastern Iran. Antiquity 89(345), 573–595.

Royer, A., Daux, V., Fourel, F., Lecuyer, C. (**2017**) Carbon, nitrogen and oxygen isotope fractionation during food cooking: Implications for the interpretation of the fossil human record. American journal of physical anthropology 163(4), 759–771.

Rozanski, K., Araguás-Araguás, L., Gonfiantini, R. (**1993**) Isotopic patterns in modern global precipitation. Climate change in continental isotopic records, Geophysical Monographs 78, Washington, DC, 1–36.

Rudnick R.L., Goldstein S.L. (**1990**) The Pb isotopic compositions of lower crustal xenoliths and the evolution of lower crustal Pb. Earth and Planetary Science Letters 98/2, 192–207.

Rudov, A., Mashkour, M., Djamali, M., Akhani, H. (**2020**) A Review of C4 Plants in Southwest Asia: An Ecological, Geographical and Taxonomical Analysis of a Region with High Diversity of C4 Eudicots. Frontiers in plant science, 11.

Rustamov A.K., Sopye, O. (**1994**) Vertebrates in the Red Data Book of Turkmenistan. In: V. Fet, K.I. Atamuradov (eds.) Biogeography and Ecology of Turkmenistan, Springer-Science + Business Media, B.V, 205–230.

Ruslan, G., Muradov, R.G. (**2021**) The Architecture of the Bactria-Margiana Archaeological Complex. In: B. Lyonnet, N. Dubova (eds.) The World of the Oxus Civilization, Routledge.

S

Salvatori, S. (**2016**) Bactria-Margiana Archaeological Complex: how terminology hides historical processes. Trudy Margianskoj Arkheologicheskoj Ekspeditsii (Transactions of Margiana Archaeological Expedition) Vol. 6, to the memory of Professor Viktor Sarianidi, Moscow, 449–460.

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: S. Salvatori, M. Tosi, B. Cerasetti (eds.) The Bronze Age and Early Iron Age in the Margiana Lowlands. Facts and Methodological Proposals for a Redefinition of the Research Strategies, Oxford UK BAR International Series 1806, Oxford, 57–74.

Salvatori, S. (**2008b**) Cultural Variability in the Bronze Age Oxus Civilization and Its Relations with the Surrounding Regions of Central Asia and Iran. In: S. Salvatori, M. Tosi, B. Cerasetti (eds.) The Bronze Age and Early Iron Age in the Margiana Lowlands. Facts and Methodological Proposals for a Redefinition of the Research Strategies, Oxford UK BAR International Series 1806, Oxford, 75–98.

Salvatori, S., Tosi, M. (**1997**) Postscriptum. Some Reflections on Shahdad and Its Place in the Bronze Age of Middle Asia. Shahdad. Archaeological Excavations of a Bronze Age Center in Iran, 121–138.

Salvatori, S., Vidale, M. (**1997**) Shahr - i Sokhta 1975–1978: Central Quarter Excavations, IsIAO, Reports and Memoirs I, Roma.

Sarianidi, V.I. (**2007**) Necropolis of Gonur. Kapon Editions.

Sarianidi, V.I. (**2005**) Gonurdepe. City of Kings and Gods. Ashgabat.

Sarianidi, V.I. (**1998**) Margiana and protozoroastrism. Athens, Kapon, 88–89.

Sarianidi, V.I. (**1990**) Drevnosti strany Margush. Ashgabat.

Sarianidi, V.I. (**1976**) Issledovanija pamjatnikov Dashlinskogo oazisa. Research of settlements in the Dashly oasis]. In: I.T. Kruglikova (ed.) Drevnjaja Baktrija, Moscow: Nauka, 21–86.

Sauer, E. (ed.) (**2017**) Sasanian Persia: Between Rome and the Steppes of Eurasia. Edinburgh University Press.

Sauer, E., Rekavandi, H.O., Wilkinson, T.J., Nokandeh J. (**2013**) Perisa´s Imperial Power in Late Antiquity. The Great Wall of Gorgan and frontier landscape of Sasanian Iran. The British Institute of Persian Studies, Archaeological Monographs Series II.

Schoeninger, M.J., Moore, K. (**1992**) Bone stable isotope studies in archaeology. Journal of World Prehistory 6(2), 247–296.

Schoeninger, M.J., DeNiro, M.J. (**1984**) Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals. Geochimica et Cosmochimica acta 48(4), 625–639.

Schwarcz, H.P., Schoeninger, M.J. (**2012**) Stable isotopes of carbon and nitrogen as tracers for paleo-diet reconstruction. Handbook of environmental isotope geochemistry, Springer, Berlin, Heidelberg, 725–742.

Sealy, J., Armstrong, R. (**1995**) Beyond lifetime averages: tracing life histories through isotopic analysis of different calcified tissues from archaeological human skeletons. Antiquity 69, 290–300.

Ségurel, L., Guarino-Vignon, P., Marchi, N., Lafosse, S., Laurent, R., Bon, C., Heyer, E. (**2020**) Why and when was lactase persistence selected for? Insights from Central Asian herders and ancient DNA. PLoS Biology 18(6), e3000742.

Ségurel, L., Bon, C. (**2017**) On the evolution of lactase persistence in humans. Annual review of genomics and human genetics, 18.

Shahmirzadi, S.M. (**2012**) The Villagers of Sialk.

Shahmirzadi, S.M. (**2005**) The fishermen of Sialk.

Shahmirzadi, S.M. (**2004**) The Potters of Sialk. Sialk Reconsideration Project Report n° 3, Tehran.

Shahmirzadi, S.M. (**2003**) The Silversmiths of Sialk. Sialk Reconsideration Project Report n° 2, Tehran.

Sharp, (**2007**) Z. Sharp, Principles of stable isotope geochemistry. Upper Saddle River, NJ.

Shchetenko, A., Kutimov, J.G. (**1999**) Keramika stepnogo oblika epokhi pozdnej bronzy Tekkem Depe (juznij Turkmenistan). Arkheologicheskie Vesti 6, 114–123.

Sheikhshoaee, F., Niknami, K.A. (**2018**) Strontium Isotope Ratio (87Sr/86Sr) To Determine Human Skeletons Origins from The Ancient Cemeteries, Case study: An Iron Age Cemetery of Gohar Tepe. Journal of Archaeological Studies 10(2), 159–170. doi.org/10.22059/jarcs.2019.68536

Sheikhshoaee, F., Mousavi Kohpar, S.M. (**2017**) Fresh Water Fish, Food Resource Used by the Inhabitants of the Gowhar Tepe Site, Mazandaran. pazhoheshha-ye Bastan shenasi Iran 7(13), 243–257. doi.org/10.22084/nbsh.2018.15386.1691

Sheikhshoaee, F., Niknami, K.A. (**2016**) Stable Isotope Analysis to Determining Gender Differences in Ancient Dietary Systems. Journal of Archaeological Studies 8(1), 77–89.

Sheikhshoaee, F. (**2009**) Paleodietary of Gohar Tepeh site of Iron age on the bases of their discovered bones. parseh.modares.ac.ir/thesis/1174688

Shishlina, N.I., Bobrov, A.A., Simakova, A.M., Troshina, A.A., Sevastyanov, V.S., van der Plicht, J. (**2018**) Plant food subsistence in the human diet of the Bronze Age Caspian and Low Don steppe pastoralists: archaeobotanical, isotope and 14 C data. Vegetation History and Archaeobotany 27(6), 833–842.

Shishlina, N.I., Sevastyanov, V., Kuznetsova, O. (**2017**) Seasonal practices of prehistoric pastoralists from the south of the Russian plain based on the isotope data of modern and archaeological animal bones and plants. Journal of Archaeological Science: Reports 21, 1247–1258.

Shishlina, N.I., Sevastyanov, V., Hedges, R.E.M. (**2012**) Isotope ratio study of Bronze Age samples from the Eurasian Caspian Steppes. Population dynamics in prehistory and early history: new approaches by using stable isotopes and genetics, 177–97.

Shishlina, N.I., Zazovskaya, E.P., Van Der Plicht, J., Hedges, R.E.M., Sevastyanov, V.S., Chichagova, O.A. (**2009**) Paleoecology, subsistence, and 14C chronology of the Eurasian Caspian steppe Bronze Age. Radiocarbon 51(2), 481–499.

Shirazi, Z., Tengberg, M. (**2012**) Vegetation and Wood Exploitation at Tepe Sialk from the Neolithic to the Iron Age from Sialk contexts SRP 82/N/P300032 and SRP_NP F.322a. In: M. Shahmirzadi (ed.) The Villagers of Sialk, ICTHO, Teheran, 17–26.

Shirinov, T.S. (**2002**) Die frühurbane Kultur der Bronzezeit im südlichen Mittelasien. Die vorgeschichtliche Siedlung von Dzharkutan. Archäologische Mitteilungen aus Iran und Turan 34, 1–170.

Siegenthaler, U., Oeschger, H. (**1980**) Correlation of 18 O in precipitation with temperature and altitude. Nature 285(5763), 314–317.

Sjögren, K.G., Price, T.D. (**2012**) A complex Neolithic economy: isotope evidence for the circulation of cattle and sheep in the TRB of western Sweden. Journal of Archaeological Science 40(1), 690–704.

Slovak, N.M., Paytan, A. (**2011**) Applications of Sr isotopes in archaeology. In: M. Baskaran (ed.) Handbook of Environmental Isotope Geochemistry. Advances in Isotope Geochemistry, Springer-Verlag, Berlin, 743–768.

Smith, B.N., Epstein, S. (**1971**) Two categories of 13C/12C ratios for higher plants. Plant physiology 47(3), 380–384.

Smith, P.E. (**1974**) Ganj Dareh Tepe. Paléorient 2(1), 207–209.

Soltysiak, A., Fetner, R.A., Vahdati, A.A., Biscione, R., (**submitted**) Between the mountains and the desert: isotopic evidence of oasis-like subsistence at Tepe Chalow, an early urban center in NE Iran.

Sołtysiak and H. Fazeli Nashli, (**2010**) Short Fieldwork Report: Tepe Sialk (Iran), seasons 2008–2009, Bioarchaeology of the Near East 4, 69–73.

Spengler, R.N., Ryabogina, N., Tarasov, P.E., Wagner, M. (**2016a**) The spread of agriculture into northern Central Asia: Timing, pathways, and environmental feedbacks. The Holocene 26(10), 1527–1540. doi.org/10.1177/0959683616641739

Spengler, R.N., De Nigris, I., Cerasetti, B., Carra, M., Rouse, L.M. (**2016b**) 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. doi.org/10.1016/j.jasrep.2016.03.029

Spengler, R.N., Cerasetti, B., Tengberg, M., Cattani, M., Rouse, L.M. (**2014a**) Agriculturalists and pastoralists: Bronze Age economy of the Murghab alluvial fan, southern Central Asia. Vegetation history and archaeobotany 23, 805. doi.org/10.1007/s00334-014-0448-0

Spengler, R.N., Frachetti, M., Doumani, P., Rouse, L., Cerasetti, B., Bullion, E., Mar'yashev, A. (**2014b**) Early agriculture and crop transmission among Bronze Age mobile pastoralists of Central Eurasia. Proceedings of the Royal Society B: Biological Sciences 281(1783), 20133382. doi.org/10.1098/rspb.2013.3382

Spengler, R.N. (**2013**) Botanical resource use in the Bronze and Iron Age of the Central Eurasian mountain/steppe interface: decision making in multiresource pastoral economies.

Stančo, L., Pažout, A. (**2020**) Which way to Roxane: Mobility networks in the heartland of Central Asia. Journal of Archaeological Science: Reports 32, 102391. doi.org/10.1016/j.jasrep.2020.102391

Stančo, L. (**2020**) Sherabad Oasis. Tracing Historical Landscape in Southern Uzbekistan. Karolinum Books.

Stanley, K.O., Faure, G. (**1979**) Isotopic composition and sources of strontium in sandstone cements; the High Plains sequence of Wyoming and Nebraska. Journal of Sedimentary Research 49(1), 45–53.

Styring, A.K., Evans, J.A., Nitsch, E.K., Lee-Thorp, J.A., Bogaard, A. (**2019**) Revisiting the Potential of carbonized grain to preserve biogenic 87Sr/86Sr signatures within the burial environment. Archaeometry 61(1), 179–193.

Styring, A.K., Charles, M., Fantone, F., Hald, M.M., McMahon, A., Meadow, R.H., Nicholls, G.K., Patel, A.K., Pitre, M.C., Smith, A., Sołtysiak, A., Stein, G., Weber, J.A., Weiss, H., Bogaard A. (**2017**) Isotope evidence for agricultural extensification reveals how the world's first cities were fed. Nature Plants 3, 1–11.

Sullivan, C.H., Krueger, H.W. (**1981**) Carbon isotope analysis of separate chemical phases in modern and fossil bone. Nature 292, 333–335. doi.org/10.1038/292333a0

Svyatko, S.V., Schulting, R.J., Mallory, J., Murphy, E.M., Reimer, P.J., Khartanovich, V.I., Chistov, Y.K., and Sablin, M.V. (**2013**) Stable isotope dietary analysis of prehistoric populations from the Minusinsk Basin, southern Siberia, Russia: a new chronological framework for the introduction of millet to the eastern Eurasian steppe. Journal of Archaeological Science 40, 3936–3945.

Sumner, W.M. (**2003**) Early urban life in the land of Anshan: excavations at Tal-e Malyan in the highlands of Iran (Vol. 3). UPenn Museum of Archaeology.

T

Tengberg, M., Daujat, J., Mashkour, M., Decaix, A., Amiri, S., Sheikhi, S., Debue, K., Berthon, R., Lhuillier, J., Bendezu-Sarmiento, J. (**2020**) Environment and Subsistence Economies at Iron Age Ulug-depe, South-eastern Turkmenistan: First Results from the Archaeozoological and Archaeobotanical Studies. In: J. Lhuillier (ed.) Archaeology of Central Asia during the first millennium BC, from the beginning of the Iron Age to the Hellenistic period. Proceedings of the workshop held at 10th International Congress on the Archaeology of the Ancient Near East, OREA series, Vienna, Austrian Academy of Sciences press.

Tengberg, M. (**2013**) Économies végétales et environnements en Asie centrale du Néolithique à l'époque sassanide : la contribution des disciplines archéobotaniques. In: J. Bendezu-Sarmiento (ed.) Archéologie française en Asie centrale. Nouvelles recherches et enjeux socioculturels, Cahiers d'Asie Centrale 21/22, 545–558.

Tengberg, M. (**2004**) Archaeobotanical analysis at Tepe Sialk. Results from the 2003/04 season. The potters of Sialk. Sialk Reconsideration Project Report 3, 25–32.

Tengberg, M. (**2003**) The archaeobotanical project at Tape Sialk; A preliminary report. The Silversmiths of Sialk, Tehran, ICHO, Archaeological Research Center, 9–11.

Teufer, M. (**2021**) The "Classical Vakhsh Culture", a Bronze Age Culture of the 3rd and early 2nd Millennium BC in Southern Tajikistan. In: B. Lyonnet, N. Dubova (eds.) The World of the Oxus Civilization, Routledge, New York/London, 698–733.

Teufer, M. (**2018a**) Der Baktro-Margianische Archäologische Komplex und die Oxus-Zivilisation. In: W. Wemhoff, M. Nawroth, R.M. Weiss, A. Wieczorek (eds.) Margiana. Ein Königreich der Bronzezeit in Turkmenistan, Michael Imhof Verlag, Petersberg, 75–81.

Teufer, M. (**2018b**) Saridzar – ein spätbronzezeitlicher befestigter Siedlungsplatz und Ort des Soma-Opfers in Südwest-Tadzikistan. Das Altertum 63, 161–222.

Teufer, M. (**2015**) Spätbronzezeitliche Grabfunde aus Nordbaktrien und benachbarten Regionen. Studien zur Chronologie zwischen Aralsee und Persischem Golf. Archäologische Mitteilungen aus Iran und Turan 13, Berlin.

Teufer, M. (**2014**) Bronzezeitliche und früheisenzeitliche Fundplätze im Jach-Su-Tal, Tadžikistan. In: S. Hansen (ed.) Aktuelle Forschungen in Eurasien. Deutsches Archäologisches Institut, Eurasien-Abteilung, Berlin, 92–93.

Teufer, M., Vinogradova, N., Kutimov, J. (**2014**) Der Übergang von der Spätbronze- zur Früheisenzeit in Mittelasien. Das Altertum 59, 109–148.

Teufer, M., Vinogradova, N. (**2010**) Das Gräberfeld von Gelot. In: N. Boroffka, S. Hansen (eds.) Archäologische Forschungen in Kasachstan, Tadschikistan und Usbekistan, Berlin, 28–31.

Thomalsky, J. (**2014**) Ganj Dareh: New emphasis on an old-fashioned "villagers site". Proceedings of the International Conference of Young Archaeologists, University of Tehran, October 2013.

Thomalsky, J., Bräutigam, B., Karaucak, M., Kraus, S. (**2013**) Early Mining and metal production in Afghanistan: The first year of investigations. Archäologische Mitteilungen aus Iran und Turan 45, 199–230.

Thornton, C. P. (**2013a**) The Bronze Age in Northeastern Iran. The Oxford Handbook of Ancient Iran.

Thornton, C.P. (**2013b**) Tappeh Sang-e Chakhmaq: a new look. The Neolithisation of Iran, 241–257.

Tosi, M. (**1988**) The origins of early Bactrian Civilization. In: G. Ligabue, S. Salvatori (eds.) Bactria, an ancient oasis civilization from sands of Afghansitan, Erizzo, Venezia, 43–72.

Tosi, M. (**1977**) The archaeological evidence for protostate structures in Eastern Iran and Central Asia at the End of the 3rd millenium B.C. In: J. Deshayes (ed.) Le plateau iranien et l'Asie centrale des origines à la conquête islamique. Leurs relations à la lumière des documents archéologiques (Actes du Colloque international no 567 du CNRS, Paris, 22– 24 mars 1976), Paris, Éditions du CNRS, 1977, 45–66.

Tosi, M. (**1972**) Iran, l'alba della civiltà. Milan, Provinciali Spotorno.

Tosi, M. (**1968**) Excavations at Shahr-i Sokhta, a Chalcolithic Settlement in the Iranian Sistan. Preliminary Report on the First Campaign, October-December 1967. East and West 18.

Tourovetz, A. (**1989**) Observations concernant le materiel archéologique des Nécropoles A et B de Sialk. Iranica Antiqua 24, 209.

Trescher, T. (**2017**) Am Hitzepol der Erde. Geo 11, 28–52.

Tütken, T., Vennemann, T.W., Pfretzschner, H.U. (**2011**) Nd and Sr isotope compositions in modern and fossil bones – Proxies for vertebrate provenance and taphonomy. Geochimica et Cosmochimica Acta 75, 5951–5970.

Tütken, T. (**2010**) Die Isotopenanalyse fossiler Skelettreste – Bestimmung der Herkunft und Mobilität von Menschen und Tieren. Tagungsband des 2. Mitteldeutschen Archäologentages in Halle (Saale): Anthropologie, Isotopie und DNA – biographische Annäherung an namenlose vorgeschichtliche Skelette? Tagungen des Landesmuseums für Vorgeschichte Halle (Saale) 3, 33–51.

Tütken, T., Vennemann, T.W., Pfretzschner, H.U. (**2004**) Analyse stabiler und radiogener Isotope in archäologischem Skelettmaterial: Herkunftsbestimmung des karolingischen Maultiers von Frankenthal und Vergleich mit spätpleistozänen Großsäugerknochen aus den Rheinablagerungen. Prähistorische Zeitschrift 79(1), 89–110.

Tütken, T. (**2003**) Die Bedeutung der Knochenfrühdiagenese für die Erhaltungsfähigkeit in vivo erworbener Element- und Isotopenzusammensetzungen in fossilen Knochen. Dissertation zur Erlangung des Grades eines Doktors der Naturwissenschaften der Geowissenschaftlichen Fakultät der Eberhard-Karls-Universität Tübingen.

V

Vahdati, A.A., Biscione, R. (**2021**) Distribution of BMAC material culture across Khorasan and Sistan. Research seminars on “Early Urbanization in Iran: Development of the Urban Centers in the Iranian Plateau”. Talk available at youtube.com/channel/UCqigQxA0FW7HDNrhF4Px4Qw

Vahdati, A.A., Biscione, R., La Farina, R., Mashkour, M., Tengberg, M., Fathi, H., Mohaseb, A.F. (**2020**) Preliminary report on the first season of excavations at Tepe Chalow: New GKC (BMAC) finds in the plain of Jajarm, NE Iran.

Vahdati, A.A., Biscione, R., Tengberg, M., Mashkour, M. (**2019**) Excavation at Tepe Chalow: Some Evidence of “Bactria-Margiana Archaeological Complex” (BMAC) in the Plain of Jajarm, Northeastern Iran. Archaeology Journal 3(1), 63–74.

Vahdati, A.A. (**2010**) Tepe Pahlavan: a Neolithic-Chalcolithic site in the Jajarm Plain, north-eastern Iran. Iranica Antiqua 45, 7–30.

Vahdati Nasab, H. (**2011**) A Review of Bio-anthropological studies in Iranian Archaeology (Paleolothic and Neolithic) Iranian Journal of Anthropology Research 1(1), 101–119.

Valentine, B., Kamenov, G.D., Kenoyer, J.M., Shinde, V., Mushrif-Tripathy, V., Otarola-Castillo, E. (**2015**) Evidence for Patterns of Selective Urban Migration in the Greater Indus Valley (2600-1900 BC): A Lead and Strontium Isotope Mortuary Analysis. PLoS ONE 10(4), e0123103. doi.org/10.1371/journal.pone.0123103

Valla, F., Khalaily, H., Samuelian, N., Bocquentin, F., Bridault, A., Rabinovich, R. (**2017**) Eynan (Ain Mallaha).

Ventresca Miller, A.R., Haruda, A., Varfolomeev, V., Goryachev, A., Makarewicz, C.A. (**2020**) Close management of sheep in ancient Central Asia: evidence for foddering, transhumance, and extended lambing seasons during the Bronze and Iron Ages. STAR: Science & Technology of Archaeological Research 6(1), 41–60. doi.org/10.1080/20548923.2020.1759316

Ventresca Miller, A.V., Bragina, T.M., Abil, Y.A., Rulyova, M.M., Makarewicz, C.A. (**2019a**) Pasture usage by ancient pastoralists in the northern Kazakh steppe informed by carbon and nitrogen isoscapes of contemporary floral biomes. Archaeological and Anthropological Sciences 11(5), 2151–2166.

Ventresca Miller, A.V., Makarewicz, C.A. (**2019b**) Intensification in pastoralist cereal use coincides with the expansion of trans-regional networks in the Eurasian Steppe. Scientific reports 9(1), 1–12.

Ventresca Miller, A.V., Makarewicz, C.A. (**2018**) Isotopic investigations of pastoralism in prehistory. Themes in Contemporary Archaeology 4, European Association of Archaeology, Routledge.

Ventresca Miller, A.R., Winter-Schuh, C., Usmanova, E.R., Logvin, A., Shevnina, I., Makarewicz, C.A. (**2017**) Pastoralist mobility in bronze age landscapes of northern Kazakhstan: 87Sr/86Sr and δ18O analyses of human dentition from Bestamak and Lisakovsk. Environmental Archaeology 23(4), 352–366. doi.org/10.1080/14614103.2017.1390031

Ventresca Miller, A.V., Usmanova, E., Logvin, V., Kalieva, S., Shevnina, I., Logvin, A., ... Rosenmeier, M. (**2014**) Subsistence and social change in central Eurasia: stable isotope analysis of populations spanning the Bronze Age transition. Journal of Archaeological Science 42, 525–538.

Vogel, J.C., van der Merwe, N.J. (**1977**) Isotopic evidence for early maize cultivation in New York State. American Antiquity 42(2), 238–242.

Vidale, M. (**2017**) Treasures from the Oxus. The art and civilization of Central Asia, Bloomsbury Publishing, London.

Vinogradova, N.M. (**2021**) The formation of the Oxus Civilization/BMAC in southwestern Tajikistan. In: B. Lyonnet, N. Dubova (eds.) The World of the Oxus Civilization, Routledge, New York/London, 635–664.

Vinogradova, N.M., Winkelmann S. (**2016**) The Rich Grave in the Burial Ground of Gelot (South Tajikistan)-Contextualizing Material Culture in South and Central Asia in Pre-Modern Times. In Papers from the 20th Conference of the European Association for South Asian Archaeology and Art held in Vienna from 4th to 9th July 2010. South Asian Archaeology and Art 2, 361–377.

Vinogradova, N.M., Kutimov, Y.G. (**2018**) Погребальные памятники эпохи бронзы в Южном Таджикистане (могильники Гелота и Дарнайчи) / Институт востоковедения (Burial Sites of the Bronze Age in Southern Tajikistan - Gelot and Darnay Chi necropolises -). Russian Academy of Sciences; Institute for the History of Material Culture, Institute of Oriental Studies.

doi.org/10.31600/978-5-89282-843-7

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(4), 29–54. doi.org/10.2753/AAE1061-1959340429

Vohberger, M. (**2011**) Lokal oder eingewandert? Interpretationsmöglichkeiten und Grenzen lokaler Strontium-und Sauerstoffisotopensignaturen am Beispiel einer Altgrabung in Wenigumstadt (Doctoral dissertation, LMU).

Voigt, M.-M., Dyson, R.H. Jr. (**1992**) The Chronology of Iran, ca. 8000-2000 B.C. In: R.W. Ehrich (ed.) Chronologies in Old World Archaeology: Third Edition, University of Chicago Press, Volume 1: 122–178; Volume 2: 125.

W

Wang, X., Tang, Z. (**2020**) The first large-scale bioavailable Sr isotope map of China and its implication for provenance studies. Earth-Science Reviews, 103353.

Wang, X., Shen, H., Wei, D., Hu, X., Xu, B., Qin, X., Tang, Z. (**2020**) Human mobility in the Lop Nur region during the Han-Jin Dynasties: a multi-approach study. Archaeological and Anthropological Sciences 12(1), 20.

Wang, X., Tang, Z., Wu, J., Wu, X., Wu, Y., Zhou, X. (**2016**) Strontium isotope evidence for a highly mobile population on the Pamir Plateau 2500 years ago. Scientific reports 6(1), 1–7. doi.org/10.1038/srep35162

Weeks, L.R. (**2013**) The development and expansion of a Neolithic way of life, in: D. T. Potts (ed.), The Oxford Handbook of Ancient Iran, Oxford, New York, 49–75.

Weeks, L.R., Alizadeh, K.S., Niakan, L., Alamdari, K., Khosrowzadeh, A., Zeidi, M. (**2006**) Excavations at Tol-e Nurabad. The Mamasani Archaeological Project Stage One: A report on the first two seasons of the ICAR—University of Sydney expedition to the Mamasani District, Fars Province, Iran, Tehran, 31–88.

Wendrich, W., Barnard, H. (**2008**) The archaeology of mobility: Definitions and research approaches. In: H. Barnard, W. Wendrich (eds.) The archaeology of mobility. Old World and New World nomadism, Cotsen Advanced Seminars 4, Los Angeles, CA, 1–21.

White, C.D., Longstaffe, F.J., Law, K.R. (**2004**) Exploring the Effects of Environment, Physiology and Diet on Oxygen Isotope Ratios in Ancient Nubian Bones and Teeth. Journal of Archeological Science 31(2), 233–250. doi.org/10.1016/j.jas.2003.08.007

White, C.D., Spence, M.W., Stuart-Williams, H.L.Q., Schwarcz, H.P. (**1998**) Oxygen isotopes and the identification of geographical origins: the Valley of Oaxaca versus the Valley of Teotihuacan. Journal of Archaeological Science 25(7), 643–655.

Whitlam, J., Bogaard, A., Matthews, R., Matthews, W., Mohammadifar, Y., Ilkhani, H., Charles, M. (**2018**) Pre-agricultural plant management in the uplands of the central Zagros: the archaeobotanical evidence from Sheikh-e Abad. Vegetation History and Archaeobotany 27(6), 817–831.

Willcox, G. (**1978**) Charcoal remains from Tepe Abdul Hosein. Tepe Abdul Hosein: a Neolithic Site in Western Iran: Excavations, 223–227.

Willerslev, E., Cooper, A. (**2005**) Ancient DNA. Proceedings: Biological sciences 272(1558), 3–16. pubmedcentral.nih.gov/articlerender.fcgi?artid=1634942&tool=pmcentrez&rendertype=abstract

Willmes, M. (**2015**) Strontium isotope tracing of prehistoric human mobility in France. Dissertation to obtain the doctoral degree at the Australian National University.

Wilkins, J.F. (**2006**) Unraveling male and female histories from human genetic data. Current opinion in genetics & development 16(6), 611–617.

Wilkinson, T.C. (**2014**) Tying the Threads of Eurasia. Transregional Routes and Material Flows in Transcaucasia, Eastern Anatolia and Western Central Asia, c. 3000–1500 BC. Sidestone Press, Leiden.

Weiss, H., Young, T.C. (**1975**) The merchants of Susa: Godin V and plateau-lowland relations in the late fourth millennium BC. Iran 13(1), 1–17.

Y

Young, T.C. (**1967**) The Iranian migration into the Zagros. Iran, 5(1), 11–34.

Young, T.C. (**1969**) Excavations at Godin Tepe: first progress report. Occasional paper.

Young, T.C., Levine, L.D. (**1974**) Excavations of the Godin project: 2, progress report.

Z

Zanjani H. (**2012**) “KASHAN i. GEOGRAPHY,” Encyclopaedia Iranica XVI/1, 1–2. http://www.iranicaonline.org/articles/kashan-i-geography

Zazzo, A., Balasse, M., Passey, B.H., Moloney, A.P., Monahan, F.J., Schmidt, O. (**2010**) The isotope record of short- and long-term dietary changes in sheep tooth enamel: implications for quantitative reconstruction of paleodiets. Geochimica et Cosmochimica Acta 74(12), 3571–3586.

van Zeist, W., Smith, P.E., Palfenier-Vegter, R.M., Suwijn, M., Casparie, W.A. (**1984**) An archaeobotanical study of Ganj Dareh Tepe, Iran. Palaeohistoria, 201–224.

Zhang, Q., Li, S. (**2006**) Xinjiang Nileke Xian Kongkeke yihao mudi gudai jumin de shiwu jiegou fenxi (Analysis on paleodiet of ancient inhabitants in no. 1 cemetery of Qiongkeke at Nika County, Xinjiang), Xiyu Yanjiu, The Western Regions Studies 4, 78–82.

Zhang, Q., Zhu, H. (**2011**) Xinjiang Gumugou mudi rengu de wending tongweisu fenxi: zaoqi Luobubo xianmin yinshi jiegou chutan (Stable isotopic analysis on human bones from Gumugou cemetery, Xinjiang: paleodietary reconstruction on Luobubo population), Xiyu Yanjiu (The Western Regions Studies) 3, 91–96.

Zhang, Q., Chang, X., Liu, G. (**2009**) Xinjiang Balikun xian Heigouliang mudi chutu rengu de shixing fenxi (Stable isotopic analysis on human bones from Heigouliang cemetery in Barkol, Xinjiang), Xiyu Yanjiu (The Western Regions Studies) 3, 45–49.

Zhang, Q., Chang, X., Liu, G. (**2010**) Xinjiang Hami Tianshanbeilu mudi chutu rengu de wending tongweisu fenxi (Stable isotopic analysis of human bones unearthed from Tianshan Beilu cemetery in Hami, Xinjiang), Xiyu Yanjiu (The Western Regions Studies) 2, 38–43.

14. List of figures and tables

List of tables

Chapter 1: Introduction

Chapter 2: Archaeological Background

Chapter 3: Material and Methods

Fig. 3.9: Bar chart of humans from Tepe Sialk after periods and gender.
Fig. 3.10: Pie charts of the composition of all samples from Iran.
Fig. 3.11: Bar chart of humans from Tajikistan after periods and gender.
Fig. 3.12: Cleaning and leaching from left to right: cleaning and crushing of bones with mortar and pistil; fractions of bone compacta; diamond drill for taking samples (pictures taken by the author during the lab work).
Fig. 3.13: Preparation of charred plants from left to right: charred grain samples; Volca V50 Oven for burning samples; remains of burnt plant samples (pictures taken by the author during the lab work).
Fig. 3.14: Cleaning and leaching of dried plants from left to right: sample before preparation; dried plants rinsing with H_2O MilliQ in the ultrasonic bath; leaching procedure of all samples in the ultrasonic bath; 8. (pictures taken by the author during the lab work).
Fig. 3.15: Strontium extraction from left to right: samples drying on the hot plate; chemical extraction of strontium; MC-ICP MS in the laboratory of the Geoscience in Montpellier (pictures taken by the author during the lab work).
Fig. 3.16: Collagen extraction from left to right: leaching with HCl; samples before gelatinization; freezing in fluent nitrogen; freeze dryer loaded with samples; final product of pure collagen (pictures taken by the author during the lab work).
Fig. 3.17: Equipment in the Mass Spectrometry Service of the National Museum of Natural History in Paris from left to right: Mettler Toledo special accuracy weighing machine; Thermo Scientific MS DeltaV-Advantage for collagen; DeltaV-Advantage MS with Kiel IV device for apatite (pictures taken by the author during the lab work).

Chapter 4: Determination of local ranges

Fig. 4.1: The Alpine-Himalayan orogen stretches from Spain to New Zealand. Manipulated after Rosenbaum, Lister 2002: 1 fig. 2.
Fig. 4.2: Map of mean annual rainfall (left) and mean annual temperature (right) of the Near East and southern Central Asia after Roaf 1998: 22–23.
Fig. 4.3: Geological map of southern Central Asia after Haghipour et al. 2009, red stars mark the investigated regions.
Fig. 4.4: Possibilities of interpretation of tooth and bone strontium results after Knipper 2004: 631 fig. 19.
Fig. 4.5: Local $^{87}Sr/^{86}Sr$ signals from southern Central Asia (sites are in geographical order from west to east): orange circles correspond to animals, blue triangles to human dentine, green rhombs to plants, yellow squares to rodents. Grey boxes mark the measured results of the references, dashed boxes mark the calculated local $^{87}Sr/^{86}Sr$ signals including the error margins at 2σ level, yellow box marks the calculated regional range (dark ± 1σ, light ± 2σ).
Fig. 4.6: Local $^{87}Sr/^{86}Sr$ signals from Iran: orange circles correspond to animals, blue triangles to human dentine, green rhombs to plants, yellow squares to rodents. Grey boxes mark the measured results of the references, dashed boxes mark the calculated local $^{87}Sr/^{86}Sr$ signals including the error margins at 2σ level, yellow box marks the calculated regional ranges (dark ± 1σ, light ± 2σ).
Fig. 4.7: Geographic locations of the sites in the Gorgan Plains (©Google Earth maps).
Fig. 4.8: Geographic location of the sites in north-eastern Iran (©Google Earth maps).
Fig. 4.9: Geographic location of the sites in southern Iran (©Google Earth maps).
Fig. 4.10: Map of the different stations in Lut Desert after Lyons et al. 2020: 2 fig. 1.
Fig. 4.11: Geographic location of the sites in north-western Iran (©Google Earth maps).
Fig. 4.12: Weighted annual $d^{18}O_{Water}$ averages with monitoring stations after IAEA/WMO (2015). Global Network of Isotopes in Precipitation (GNIP) accessible at: https://nucleus.iaea.org/wiser and right after the OIPC accessible at www.wateriso-topes.org (last access 21.12.2020).
Fig. 4.13: Model of the local $\delta^{18}O_{DW}$ ranges of Ulug Depe, Dzharkutan and Tepe Sialk.
Fig. 4.14: Collected $^{87}Sr/^{86}Sr$ data: Jirzankal after Wang et al. 2016; Harappa, Ur after Kenoyer et al. 2013; Bahrain, UAE, Failaka Island, Tepe Yahya, Allahdino after Gregoricka 2013; Upper Khabour and Pütürge Region after Kibaroğlu et al. 2017; Tabriz after Kasiri et al. 2017; Northern Pontic Steppe (including signals of Babina Mogila, Drana Kokhta, Ordzhonikidze, Alexandro-pol', Zolotaya Balka), Olennii, Sukhaya Termista II, Politotdel'skoe, and Volga Region (including Kalinovka I, Nikolaevka III, Podlesnyi) after Gerling 2015; Bestamak, Lisakovsk after Ventresca Miller et al. 2017. For Gelot-Darnaichi the ranges of the human bones are stated as the bioavailable strontium range.
Fig. 4.15: Map of $\delta^{18}O$ (V-SMOW) in groundwaters of the British Isles (left) and Strontium ($^{87}Sr/^{86}Sr$) biosphere map of Great Britain after Madgwick 2019: 6 fig. 4.
Fig. 4.16: $^{87}Sr/^{86}Sr$ isotope values of the geological units. Blue stars denote the isotopic values of Caspian Sea water. Values in red and green denote the local mean values obtained on rodents (*Mus sp.*) and barley (*Hordeum vulg.*) respectively (cour-tesy of Arash Sharifi).

Chapter 5: Ulug Depe

Fig. 5.1: View from the north on the mound of Ulug Depe with the Kopet Dagh Mountains in the background (©MAFTur).
Fig. 5.2: Top: topographic plan of Ulug Depe after Bendezu-Sarmiento et al. 2019: 6 fig.2 and reconstruction of the Iron Age settlement after Lecomte 2013: 172 fig. 5. Bottom: distribution of the excavated areas (unpublished excavation report).
Fig. 5.3: The citadel from Ulug Depe after Lecomte 2013: 170 fig. 3.
Fig. 5.4: Top: Kopet Dagh mountain vegetation (©UNESCO/Kopet Dag Biosphere Reserve, Islamic Republic of Iran). Bottom: View from Ulug Depe to the west in the desertic-steppe surrounding (taken by the author during the campaign 2019).

Fig. 5.5: Model of the location of Ulug Depe in foothills of Kopet Dagh and the course of Kelet River after Lecomte 2011: 225 fig. bottom.
Fig. 5.6: Preliminary results of identified animal bones from Ulug Depe (courtesy of Marjan Mashkour).
Fig. 5.7: Intramural EBA burial in Ulug Depe (ULG 55) after Bendezu-Sarmiento 2013: 507 fig. 3F.
Fig. 5.8: Alabaster vessels and beads of the rich funeral found during the campaign 2014 after Bendezu-Sarmiento, Lhuillier 2016: 526–527 fig 4, 6.
Fig. 5.9: EBA burials in Ulug Depe (left to right: ULG 53, 54, 55) after Bendezu-Sarmiento 2013: 506 fig. 3 A, C, 508 fig. 4B (©MAFTur).
Fig. 5.10: MBA burials from Ulug Depe (top: ULG 61, 66, bottom ULG 62, 76) after Bendezu-Sarmiento 2013: 507–510 fig. 3 D, E, fig. 4 I, fig. 5 B (© MAFTur).
Fig. 5.11: EIA-MIA burials from Ulug Depe (from left to right: ULG 59, 100, 80) after Bendezu-Sarmiento, Lhuillier 2015: 284–287 fig 5, 9, 10 (© MAFTur).
Fig. 5.12: $^{87}Sr/^{86}Sr$ results of Ulug humans and references with human intra-individual variations. Plus correspond to bone samples, enamel samples are plotted with the sign of the particular gender. Symbols encompass the error margins at 2σ level, dashed box marks the local $^{87}Sr/^{86}Sr$ signals including the error margins at 2σ level.
Fig. 5.13: Intra-individual variations of $\delta^{18}O_{apa}$ of humans and carnivores from Ulug Depe: plus correspond to bone samples, circles to tooth enamel (black M3, dark grey M2, light grey M1, empty M not determined, vertical stripes PM, horizontal stripes C, dots I). The symbols encompass the error margins at 1σ level for $\delta^{18}O$ ratios.
Fig. 5.14: Scatterplot $^{87}Sr/^{86}Sr$ versus $\delta^{18}O_{DW}$ ratios of Ulug Depe humans. The symbols encompass the error margins at 2σ level for the $^{87}Sr/^{86}Sr$ ratios and 1σ level for $\delta^{18}O$ ratio, dashed box marks the approximate local $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{DW}$ range of Ulug Depe including the error margins at 1σ ($\delta^{18}O_{DW}$) and 2σ ($^{87}Sr/^{86}Sr$) levels.
Fig. 5.15: Ulug Depe differences in altitude correlating to the annual averaged $\delta^{18}O_{W}$ values of the OIPC (www.wateriso-topes.org, last access 21.12.2020).
Fig. 5.16: Intra-tooth sequential sampling applied to the caprine molar (courtesy of Marie Balasse and Denis Fiorillo ©SSMIM).
Fig. 5.17: Intra-tooth variation in carbon $\delta^{13}C_{apa}$ and $\delta^{18}O_{apa}$ (PDB) isotope ratios of enamel bioapatite of MBA (NMG V) gazelles (top) and caprine (bottom).
Fig. 5.18 Boxplot of $\delta^{15}N$ (top) and $\delta^{13}C_{apa}$ (bottom) results from Ulug Depe with references from Geokchik Depe after Bocherens et al. 2006. Black bars mark the averages.
Fig. 5.19: Map of the investigated region with the sites mentioned in the graphic. Graphic: distribution of collected data of $\delta^{15}N$ averages from herbivores (numbers in parenthesis) around the Caspian Sea. References: Yergueni (Y) Zund-Tolga 1 after Shishlina et al. 2009; Velikent (V), Aygurskiy (A) after Hollund et al. 2010; Mentesh Tepe (MT) after Herrscher et al. 2018; Qabrestan (Q), Zagheh (Z), Sagzabad (S) after Bocherens et al. 2000; Tepe Chalow (TC) after Soltysiak at al. submitted, Geokchik Depe (GD), Misrijan (M) after Bocherens et al. 2006; Tashik, Temirkash after Motuzaite Matuzeviciute et al. 2015; Bestamak, Lisakovsk after Ventresca Miller et al. 2014.
Fig. 5.20: Scatterplot of $\delta^{15}N$ versus $\delta^{13}C_{col}$ results out of collagen of all samples from Ulug Depe with plants from Lut, fish from Lake Baikal (LB) after Katzenberg et al. 1999, small cat from Geokchik Depe (GD) after Bocherens et al. 2006. The symbols encompass the error margins at 1σ level for $\delta^{15}N$ and $\delta^{13}C_{col}$ ratios.
Fig. 5.21: Scatterplot of $\delta^{15}N$ and $\delta^{13}C_{col}$ averages (numbers in parenthesis) of all samples with intervals between the species, small cat from Geokchik Depe (GD) after Bocherens et al. 2006.
Fig. 5.22: Scatterplot of $\delta^{15}N$ versus $\delta^{13}C_{apa\text{-}col}$ of humans and animals. $\delta^{13}C_{apa\text{-}col}$ of fox, gazelles, and cattle after Codron et al. 2017: 3985–3986. The symbols encompass the error margins at 1σ level for $\delta^{15}N$ and $\delta^{13}C_{col}$ ratios.
Fig. 5.23: Reconstruction of the foothill environment manipulated after Hiebert 1994 fig. 8.2.
Fig. 5.24: Distribution of the groups of the caprine from Ulug Depe. The symbols encompass the error margins at 1σ level for $\delta^{15}N$ and $\delta^{13}C_{col}$ ratios.
Fig. 5.25: Intra-tooth variation in carbon $\delta^{13}C_{apa}$ and $\delta^{18}O_{apa}$ (PDB) isotope ratios of enamel bioapatite of caprine and gazelles from Ulug Depe sorted after periods.

Chapter 6: A case study: the stranger from Ulug Depe

Fig. 6.1.: Remains of burial ULG 56 after Bendezu-Sarmiento et al. 2013: 510.
Fig. 6.2: Scatterplot of $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{carb}$ results of ULG 56. The symbols encompass the error margins at 2σ level for the $^{87}Sr/^{86}Sr$ ratios and 1σ level for $\delta^{18}O$ ratio.
Fig. 6.3: Distribution of the V haplogroups in Central Asia and Europe (courtesy of Celine Bon).

Chapter 7: Dzharkutan

Fig. 7.1: View from the east to the hill of Dzharkutan with the Kugitang Mountains in the background (©MAFOuz-Protohistoire).
Fig. 7.2: Topographic plan after Bendezu-Sarmiento, Lhuillier 2019: 107 fig. 10.
Fig. 7.3: Impression of the Surkhan Darya valley landscape after https://www.people-travels.com/about-uzbekistan/uzbekistan-nature-reserves/surkhan-state-nature-reserve.html and http://explorers.uz/en/sights/surhanskiy_gosudarstvennii_zapovednik.html (last access 01.02.2021).

Fig. 7.4: Topographic map of southern Uzbekistan manipulated after Stančo, Pažout 2020: 2 fig. 1.
Fig. 7.5: Preliminary results of identified animal bones from Dzharkutan (courtesy of Marjan Mashkour).
Fig. 7.6: MBA-LBA burials from Dzharkutan trench 1: left and middle burial 1001B after Bendezu-Sarmiento, Mustafakulov 2009: 58–59 fig. 2, 4; right burial 1028 after Bendezu-Sarmiento, Grizeaud 2010: 39 fig. 5.
Fig. 7.7: LBA burials from Dzharkutan: top left burial 1051 after Bendezu-Sarmiento 2013: 525 fig. 16A; top right burial 999 after Bendezu-Sarmiento, Mustafakulov 2009: 59 fig. 3; bottom burial 1001A after Bendezu-Sarmiento, Mustafakulov 2009: 58 fig. 1.
Fig. 7.8: EIA-MIA burial stage 1, 3, and 4 of the multiple burial 1034 from Dzharkutan. After Bendezu-Sarmiento, Lhuillier 2015: 287–289: fig. 13, 14, 16.
Fig. 7.9: $^{87}Sr/^{86}Sr$ results from Uzbekistan with human intra-individual variations. Bone samples are marked with plus, X marks the dentine samples, tooth enamel samples are given with the particular gender. Symbols encompass the error margins at 2σ level, dashed boxes mark the local $^{87}Sr/^{86}Sr$ signals including the error margins at 2σ level.
Fig. 7.10: Intra-individual variations of $\delta^{18}O_{apa}$ of humans and sheep from Dzharkutan: plus correspond to bone samples, circles to tooth enamel (black M3, dark grey M2, light grey M1, empty M not determined, vertical stripes PM, horizontal stripes C, dots I). The symbols encompass the error margins at 1σ level for $\delta^{18}O$ ratios.
Fig. 7.11: Scatterplot of $^{87}Sr/^{86}Sr$ vs $\delta^{18}O_{DW}$ ratios of humans from Dzharkutan, Sapalli, Bustan, Gelot/Darnaichi. The symbols encompass the error margins at 2σ level for the $^{87}Sr/^{86}Sr$ ratios and 1σ level for $\delta^{18}O$ ratio, dashed box marks the approximate local $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{DW}$ range of Dzharkutan including the error margins at 1σ ($\delta^{18}O_{DW}$) and 2σ ($^{87}Sr/^{86}Sr$) levels.
Fig. 7.12: Dzharkutan differences in altitude correlating to the annual averaged $\delta^{18}O_W$ values after the OIPC (www.waterisotopes.org, last access 21.12.2020).
Fig. 7.13: Box plot of $\delta^{15}N$ (top) and $\delta^{13}C$ (bottom) results from Dzharkutan (DZH) with references from Ulug Depe (UD) and Geokchik Depe (GD) after Bocherens et al. 2006. Black bars mark the averages.
Fig. 7.14: Scatterplot of $\delta^{15}N$ versus $\delta^{13}C_{col}$ results out of collagen of all samples with references from Lut, Ulug Depe (UD), fish from Lake Baikal (LB) after Katzenberg et al. 1999, small cat from Geokchik Depe (GD) after Bocherens et al. 2006. The symbols encompass the error margins at 1σ level for $\delta^{15}N$ and $\delta^{13}C_{col}$ ratios.
Fig. 7.15: Scatterplot of $\delta^{15}N$ and $\delta^{13}C_{col}$ averages (numbers in parenthesis) with intervals between the species of samples from Dzharkutan. References from Ulug Depe, small cat from Geokchik Depe (GD) after Bocherens et al. 2006.
Fig. 7.16: Scatterplot of $\delta^{15}N$ versus $\delta^{13}C_{apa\text{-}col}$ of humans from Dzharkutan, including animals from Ulug, and $\delta^{13}C_{apa\text{-}col}$ of fox, gazelles, and cattle after Codron et al. 2017: 3985–3986. The symbols encompass the error margins at 1σ level for $\delta^{15}N$ and $\delta^{13}C_{col}$ ratios.

Chapter 8: Another case study: The Lady from Gelot

Fig. 8.1: Left: Burial 2 Excavation 6 from Gelot (Archaeological Expedition in Southern Tajikistan of the Academies of Science of Russia and Tajikistan). Right: Graphic reconstruction of the Lady from Gelot (courtesy of Aleksey Nechvaloda).
Fig. 8.2: Plan of burial 2 excavation 6 after Vinogradova, Winkelmann 2016: 364 fig. 3, 6.
Fig. 8.3: Intra-individual variations of $\delta^{18}O_{apa}$ (left) and $\delta^{13}C_{apa}$ (right) of humans from Gelot, Darnaichi and Saridzhar. Plus correspond to bone samples, circles to tooth enamel (black M3, dark grey M2, light grey M1, empty M not determined, vertical stripes PM, horizontal stripes C, dots I). The symbols encompass the error margins at 1σ level for $\delta^{18}O_{apa}$ and $\delta^{13}C_{apa}$ ratios.
Fig. 8.4: Scatterplot of $\delta^{18}O_{apa}$ and $\delta^{13}C_{apa}$ of humans from Gelot, Darnaichi and Saridzhar. The symbols encompass the error margins at 1σ level for $\delta^{18}O_{apa}$ and $\delta^{13}C_{apa}$ ratios.
Fig. 8.5: Collected strontium data: Jirzankal after Wang et al. 2016; Harappa, Ur after Kenoyer et al. 2013; Bahrain, UAE, Failaka Island, Tepe Yahya, Allahdino after Gregoricka 2013; Upper Khabour and Pütürge Region after Kibaroğlu et al. 2017; Tabriz after Kasiri et al. 2017; Northern Pontic Steppe (including signals of Babina Mogila, Drana Kokhta, Ordzhonikidze, Alexandropol', Zolotaya Balka), Olennii, Sukhaya Termista II, Politotdel'skoe, and Volga Region (including Kalinovka I, Nikolaevka III, Podlesnyi) after Gerling 2015; Bestamak, Lisakovsk after Ventresca Miller et al. 2017; Tilla Bulak after Kroll et al. submitted; Gorgan Wall, Lut Desert after Kroll PhD in preparation. For Gelot-Darnaichi the ranges of the human bones are stated as the bioavailable strontium range. Pictures in the map after Lombardo et al. 2014: 10–11 fig. 8–10.
Fig. 8.6: Boxplot of $^{87}Sr/^{86}Sr$ ranges of the Lady from Gelot in correlation with the sites mentioned in the text. References: Jirzankal after Wang et al. 2016; Bestamak, Lisakovsk after Ventresca Miller et al. 2017; Volga Region, Northern Caucasus and Northern Pontic Steppe after Gerling 2015; Ur after Kenoyer et al. 2013; Upper Khabour after Kibaroğlu et al. 2017; Bahrain, UAE, Failaka Island, Tepe Yahya, Balakot after Gregoricka 2013. For Gelot-Darnaichi the ranges of the human bones are stated as the bioavailable strontium range.

Chapter 9: Tepe Sialk

Fig. 9.1: General view on the mounds of Tepe Sialk and the suburbs of Kashan city (image after Kashan.today https://www.destinationiran.com/sialk-mounds-kashan-iran-oldest-human-settlement.htm).
Fig. 9.2: Topographic plan of Tepe Sialk after Ghirshman 1938: 154–156 Pl. XXXIII.
Fig. 9.3: Fields and natural vegetation on the Kashan Plains (bottom) after https://www.tappersia.com/things-to-do-in-kashan/ and marginal zone of the Dasht-e Kavir (top) after https://commons.wikimedia.org/wiki/File:Iran,_Dasht-e-Kavir_desert_(9261278088).jpg (last access 16.03.2024).

Fig. 9.4: Faunal spectra of Tepe Sialk (courtesy of Marjan Mashkour).
Fig. 9.5: Sialk Necropolis B after Ghirshman 1939: Pl. XXXVI.
Fig. 9.6: Sialk III burial 27276 bronze pin Ghirshman 1939: 120 Pl. LXXXIV, S. 1774 and pottery vessels from Necropolis B (pictures taken by the author in the National Museum in Teheran).
Fig. 9.7: Sialk I burials: top left burial 27281, top right burial 27282, bottom burial 27283 after Ghirshman 1939: pl. X 1–3.
Fig. 9.8: Sialk II burials: left: overview of trench 2 with both funerals; middle: burial 27268; right: burial 27269 after Ghirshman 1939: pl. XI 2–3.
Fig. 9.9: Sialk V Necropolis A burial 27305 after Ghirshman 1939: pl. XL.
Fig. 9.10: Sialk VI skull of burial 27288 (©Musee del´Homme).
Fig. 9.11: Sialk VI burial 27290 after Ghirshman 1939: pl. LXVI–LXVII.
Fig. 9.12: Sialk VI grave goods of burial 27295. References after Ghirshman 1939 from left to right: red cup Pl. XCIII. S. 1478 T. 136; bronze pin Pl. XXIX,1; XCIII. S. 1478 T.; bracelet of silver beads Pl- XCIV. S. 1475. T. 136; bronze ring S. 1476. T. 136; earrings of silver S. 1476 b; and bronze button S. 1476 a. T. 136.
Fig. 9.13: Human intra-individual $^{87}Sr/^{86}Sr$ variations from Tepe Sialk (TS). Bone samples are marked with plus, X mark the dentine samples, tooth enamel samples are given with the particular gender. Dashed box marks the determined local range of Tepe Sialk. Symbols encompass the error margins at 2σ level.
Fig. 9.14: Intra-individual variations of $\delta^{18}O_{apa}$ results of humans from Tepe Sialk: plus correspond to bone samples, circles to tooth enamel (black M3, dark grey M2, light grey M1, empty M not determined, vertical stripes PM, horizontal stripes C, dots I). The symbols encompass the error margins at 1σ level for $\delta^{18}O$ ratios.
Fig. 9.15: Scatterplot $^{87}Sr/^{86}Sr$ versus $\delta^{18}O_{DW}$ ratios of Tepe Sialk humans. The symbols encompass the error margins at 2σ level for the $^{87}Sr/^{86}Sr$ ratios and 1σ level for $\delta^{18}O$ ratio. The dashed box marks the approximate local $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{DW}$ range of Tepe Sialk including the error margins at 1σ ($\delta^{18}O_{DW}$) and 2σ ($^{87}Sr/^{86}Sr$) levels, dashed circles indicate the coexisting accumulations.
Fig. 9.16: Tepe Sialk differences in altitude correlating to the annual averaged $\delta^{18}O_W$ values of the OIPC (www.wateriso-topes.org, last access 21.12.2020).
Fig. 9.17: Boxplot of $\delta^{15}N$ (top) and $\delta^{13}C_{apa}$ (bottom) results from Tepe Sialk with references from the Qasvin plains after Bocherens et al. 2000. Black bars mark the averages.
Fig. 9.18: Scatterplot of $\delta^{15}N$ versus $\delta^{13}C_{col}$ results out of collagen of all samples from Tepe Sialk with plants from Lut, fish from Mentesh Tepe after Herrscher et al. 2018, wolf, gazelles, and cattle from Qasvin after Bocherens et al. 2000. The symbols encompass the error margins at 1σ level for $\delta^{15}N$ and $\delta^{13}C_{col}$ ratios.
Fig. 9.19: Scatterplot of $\delta^{15}N$ and $\delta^{13}C_{col}$ averages (numbers in parenthesis) of all samples with intervals between the species, wolf, gazelles, cattle from Qasvin after Bocherens et al. 2000.
Fig. 9.20: Scatterplot of $\delta^{15}N$ versus $\delta^{13}C_{apa-col}$ of humans and animals. $\delta^{13}C_{apa-col}$ of fox, gazelles and cattle after Codron et al. 2017: 3985–3986. The symbols encompass the error margins at 1σ level for $\delta^{15}N$ and $\delta^{13}C_{col}$ ratios.

Chapter 10: Going beyond

Fig. 10.1: Compilation of isotopic result of all human samples, left column $^{87}Sr/^{86}Sr$ versus $\delta^{18}O_{apa}$, right column $\delta^{15}N$ versus $\delta^{13}C_{col}$.
Fig. 10.2: Comparisons of averaged $\delta^{15}N$ ratios of humans (circles) and ovicaprids (squares) from southwest to northeast: Mentesh after Herrscher et al. 2018; Zagheh after Bocherens et al. 2000; Tepe Hissar after Afshar 2014; Tepe Chalow after Soltysiak et al. submitted, southern Kazakh sites after Motuzaite Matuzeviciute et al. 2015; Bestamak, Lisakovsk after Ventresca Miller et al. 2014.
Fig. 10.3: Scatterplot $^{87}Sr/^{86}Sr$ ratios of the tooth enamel samples of human samples from Ulug, Dzharkutan, and Sialk: left column versus $\delta^{15}N$ ratios out of collagen, right column versus $\delta^{13}C$ out of collagen.
Fig. 10.4: Scatterplot $^{87}Sr/^{86}Sr$ versus $\delta^{18}O_{apa}$ ratios of humans from Tepe Sialk (TS), Ulug Depe (ULG) and Dzharkutan (DZH). The symbols encompass the error margins at 2σ level for the $^{87}Sr/^{86}Sr$ ratios and 1σ level for $\delta^{18}O$ ratios.
Fig. 10.5: $^{87}Sr/^{86}Sr$ results of all analysed human individuals in correlation to the bio-available local signals, grey boxes mark the local ranges, triangles correspond to enamel samples, circles to bone samples. Symbols encompass the error margins at 2σ level for the $^{87}Sr/^{86}Sr$ ratios.
Fig. 10.6: Map of millet distribution in southern Central Asia after Miller et al. 2016: 1569 fig. 1a.
Fig. 10.7: Reconstruction of the possible distribution of millet during LBA and EIA according to the $\delta^{13}C_{col}$ results from Ulug Depe and Dzharkutan. Southern Kazakh sites after Motuzaite Matuzeviciute et al. 2015.
Fig. 10.8: Dog funeral Op V 22; Fd. Nr. 14 from Hasanlu III period (courtesy of the Hasanlu Project).
Fig. 10.9: Collected $\delta^{15}N$ and $\delta^{13}C$ results out of collagen from dogs around the Caspian Sea in chronological order. References: Velikent after Hollund et al. 2010; Mentesh Tepe after Herrscher et al. 2018; Zagheh, Qabrestan, Sagzabad after Bocherens et al. 2000; Geokchik Depe, Misrijan after Bocherens et al. 2006.
Fig. 10.10: Collected $\delta^{15}N$ and $\delta^{13}C$ results out of collagen from dogs and carnivores around the Caspian Sea in geographical order. References: Velikent after Hollund et al. 2010; Mentesh Tepe after Herrscher et al. 2018; Zagheh, Qabrestan, Sagzabad after Bocherens et al. 2000; Tepe Chalow after Soltysiak at al. submitted, Geokchik Depe, Misrijan after Bocherens et al. 2006. “N-Khorasan” includes the dogs from Tepe Naderi, Nishapur, Qoli Darvish and Misrijan; “C-Uzbekistan” the dogs from Erkurgan and Sangir-tepe.

List of tables

In the text:

In the Appendix:

15. Appendix

Table 1: Compilation of all samples from Turkmenistan

Site	Species	Name of sample	#Ref	Period	Dating cal. BC	Age (in years)	Sex	Material
Ulug Depe	Homo sap.	ULG 53	ULG01-Sep53	EBA	2864–2506	>40	male	Phalanx; M3
Ulug Depe	Homo sap.	ULG 54	ULG01-Sep54	EBA		1–3	n.d.	Costa; M3
Ulug Depe	Homo sap.	ULG 55	ULG05-Sep55	EBA	2836–2481	>40	male	Costa, M3
Ulug Depe	Homo sap.	ULG 56	ULG01-Sep56	EBA		adult	n.d.	Costa; C
Ulug Depe	Homo sap.	ULG 90	ULG06-CH17-Sep90	EBA/MBA		ca. 3	n.d.	Costa; M3
Ulug Depe	Homo sap.	ULG 92	ULG05-CH17-Sep92	EBA/MBA		>40	female	Os fragm.; M3
Ulug Depe	Homo sap.	ULG 61	ULG04-Sep61	MBA		21–28	male	Os fragm.; M
Ulug Depe	Homo sap.	ULG 62	ULG04-Sep62	MBA		adult	n.d.	Phalanx; M3
Ulug Depe	Homo sap.	ULG 66	ULG04-CH1Est-Sep66	MBA		>40	female	Os fragm.; M3
Ulug Depe	Homo sap.	ULG 76-1	ULG04-Sep76Ind1	MBA		4–6	n.d.	Vertebra; M3
Ulug Depe	Homo sap.	ULG 83	ULG05-CH17-Sep83	MBA		adult	n.d.	Vertebra; C, M3
Ulug Depe	Homo sap.	ULG 59	ULG02-Sep59	EIA–MIA	976–822	adult	female	Costa; M3, I
Ulug Depe	Homo sap.	ULG 80	ULG06-CH3-Sep80	EIA–MIA	913–810	2–4	n.d.	Costa; M3
Ulug Depe	Homo sap.	ULG 82	ULG05-CH1Est-Sep82	EIA–MIA		adult	female	Os fragm.; PM
Ulug Depe	Homo sap.	ULG 100	Ulg10-CH16-Sep100	EIA–MIA	1011–846	4–5	n.d.	Os fragm.; M3
Geokchik Depe	Homo sap.	SK16-56	GD 95; 433; C 13; (21)	IA		adult	n.d.	Talus
Ulug Depe	Gazella sub.	SK18-33	Ch. 1; U 558	MBA				Mandible
Ulug Depe	Gazella sub.	SK18-34	Ch. 1; U 573	MBA				Mandible
Ulug Depe	Gazella sub.	SK16-82	Ch. 1 est; U572/Ind.5	MBA				Mandible
Ulug Depe	Gazella sub.	SK16-83	Ch. 1 est; U570/Ind.2	MBA				Mandible
Ulug Depe	Gazella sub.	SK16-84	Ch. 1 est; U571/Ind.3	MBA				Mandible
Ulug Depe	Gazella sub.	SK16-85	Ch. 16; U441/Ind.3	EIA–MIA				Mandible
Ulug Depe	Gazella sub.	SK16-86	Ch. 16; U442/Ind.1	EIA–MIA				Mandible
Ulug Depe	Capra aeg.	SK18-35	Ch. 5; Ind. 27	EBA				Mandible
Ulug Depe	Capra aeg.	SK18-36	Ch. 5; Ind. 51	EBA				Mandible
Ulug Depe	Ovis aries	SK18-37	Ch. 5; Ind. 32	EBA				Mandible
Ulug Depe	Ovis aries	SK18-38	Ch. 5; Ind. 58	EBA				Mandible
Ulug Depe	Ovis aries	SK18-39	Ch. 5; Ind. 66	EBA				Petrosa
Ulug Depe	Ovicaprid	SK16-87	Ch. 1 est; Ind. 16	MBA				Mandible
Ulug Depe	Ovicaprid	SK16-88	Ch. 1 est; Ind. 24	MBA				Mandible
Ulug Depe	Ovicaprid	SK16-89	Ch. 1 est; Ind. 29	MBA				Mandible
Ulug Depe	Ovicaprid	SK16-90	Ch. 1 est; Ind. 1	EIA–MIA				Mandible
Ulug Depe	Bos taurus	SK17-40	Ch. 1	MBA				Os fragm.
Ulug Depe	Sus scrofa	SK16-58	Ch. 1	MBA				Os fragm.
Ulug Depe	Canis fam.	SK16-24	Ch. 5	EBA				Mandible
Ulug Depe	Canis fam.	SK16-18	Ch. 1; 2007	EBA/MBA				Mandible
Ulug Depe	Canis fam.	SK16-20	Phase A	MBA				Mandible
Ulug Depe	Canis fam.	SK16-23	Ch. 1	MBA				Mandible
Ulug Depe	Vulpes vulpes	SK16-22	Ch. 8/10	EIA–MIA				Humerus
Ulug Depe	Panthera sp.	SK16-25	Ch. 5; 2004	EBA–MBA				Ulna
Ulug Depe	Mus sp.	R-CH. 1	Ch. 1	MBA				Os fragm.
Ulug Depe	Mus sp.	R-CH. 5	Ch. 5	MBA				Os fragm.
Ulug Depe	Mus sp.	R-CH. 16	Ch. 16	MIA				Os fragm.
Ulug Depe	Tamaris sp.	SK18-01	Ch. 1 Est	MBA				charcoal
Ulug Depe	Juniperus sp.	SK18-02	Ch. 8, US 8350	MIA				charcoal
Ulug Depe	Hordeum vulg.	SK18-03-1	Ch. 5, US 5012	EBA				charred grains
Ulug Depe	Hordeum vulg.	SK18-03-2	Ch. 5, US 5012	EBA				charred grains
Ulug Depe	Hordeum vulg.	SK18-04	Ch. 1 est, US 1579	MBA				charred grains
Ulug Depe	Hordeum vulg.	SK18-05	Ch. 8, US 8305	MIA				charred grains
Geokchik Depe	Mus sp.	SK18-28		IA				long bone
Geokchik Depe	Mus sp.	SK18-115		IA				long bone

Table 2: Compilation of all samples from Uzbekistan

Site	Species	Name of sample	#Ref	Period	Dating cal. BCE	Age (in years)	Sex	Material
Dzharkutan	Homo sap.	DZH 1001B	DZH-2007 Sep1001B	MBA/LBA	2040–1880	20–29	female	Os fragm.; C
Dzharkutan	Homo sap.	DZH 1028-1	DZH-2009 Sep1028-1	MBA/LBA	2131–1912	adult	n.d.	Phalanx; PM
Dzharkutan	Homo sap.	DZH 999	DZH-2007 Sep999	LBA		20–39	male	Phalanx; C
Dzharkutan	Homo sap.	DZH 1001A	DZH-2007 Sep1001A	LBA		20–29	female	Carpal; PM
Dzharkutan	Homo sap.	DZH 1006	DZH-2008 Sep1006	LBA		adult	n.d.	
Dzharkutan	Homo sap.	DZH 1019	DZH-2008 Sep1019	LBA	1890–1693	adult	n.d.	Phalanx; M3
Dzharkutan	Homo sap.	DZH 1022	DZH-2009 Sep1022	LBA		adult	n.d.	Costa; PM
Dzharkutan	Homo sap.	DZH 1025	DZH-2009 Sep1025	LBA		17–40	female	Os fragm.; I
Dzharkutan	Homo sap.	DZH 1028-2	DZH-2009 Sep1028-2	LBA		child	n.d.	Humerus; M3
Dzharkutan	Homo sap.	DZH 1033	DZH-2009 Sep1033	LBA	1950–1774	>40	female	Costa; PM
Dzharkutan	Homo sap.	DZH 1049	DZH-2011 Sep1049	LBA		adult	n.d.	M3
Dzharkutan	Homo sap.	DZH 1051	DZH-2011 Sep1051	LBA		15–20	female	M3
Dzharkutan	Homo sap.	DZH 1034-1	DZH-2009 Sep1034 Ind 1	EIA–MIA	1263–1052	adult	female	Costa; M3
Dzharkutan	Homo sap.	DZH 1034-4	DZH-2009 Sep1034 Ind 4	EIA–MIA	1262–1016	3–4	n.d.	Femur dist.; M3
Sapallitepa	Homo sap.	SK17-24	Sep 8 (2) 00-149	LBA	20./19. cent.	n.d.	n.d.	M3
Sapallitepa	Homo sap.	SAP2	Sapalli 1971 20 0027	LBA	20./19. cent.	n.d.	n.d.	Os fragm.
Bustan	Homo sap.	SK17-23	Sep 23 59-30	LBA	18.-16. cent.	n.d.	n.d.	Os fragm.; M
Bashman1	Homo sap.	SK18-119	2018; GPS 150	LBA		adult	n.d.	M3
Bashman1	Homo sap.	SK18-120	2018; GPS 150	LBA		child	n.d.	M
Dzharkutan	Ovis aries	SK18-43	DZH 09/04, 14, US4084	LBA				Petrosa
Dzharkutan	Ovis aries	SK18-44	DZH 13, 15, 9079	LBA				Petrosa
Dzharkutan	Ovicaprid	SK18-45	DZH 2009, Ch. 19, Sep 1023	LBA				Petrosa
Dzharkutan	Ovicaprid	SK18-46	Ch. 7, 18, US7128	LBA				Petrosa
Dzharkutan	Ovicaprid	SK18-47	DZH09-4, US4122	LBA				Petrosa
Dzharkutan	Mus sp.	R-DZH 1066	Sep. 1066	LBA				Os fragm.
Dzharkutan	Mus sp.	R-DZH 2012		LBA				Os fragm.
Dzharkutan	Tamaris sp.	SK18-86	Ch. 7, US 7018	EIA				Charcoal
Dzharkutan	Salix sp.	SK18-07	Ch. 7, US 7034	LBA				Charcoal
Dzharkutan	Hordeum vulg.	SK18-09-1	Ch. 7, US 7034	LBA				charred grains
Dzharkutan	Hordeum vulg.	SK18-09-2	Ch. 7, US 7034	LBA				charred grains
Dzharkutan	Hordeum vulg.	SK18-10	Ch. 7, US 7018	EIA				charred grains
Sangir-tepe	Ovis aries	SK18-40	10/3/2003; IIIB V-IV AC					Os fragm.
Sangir-tepe	Ovis aries	SK18-52	KD254	2nd/1st mill.				Os fragm.
Sangir-tepe	Canis fam.	SK16-44	Kopak					Mandible
Sangir-tepe	Mus sp.	SK18-32	ST-04 -03 delta 3 pit, ST/28/04					Os fragm.
Padayatak	Ovis aries	SK18-51	PDK2011, 5, Ch. 5, US5024					Os fragm.
Koktepe	Ovicaprid	SK18-50	6, KT04/12/500	2nd/1st mill.				Os fragm.
Koktepe	Bos taurus	SK18-53	K806, 7, NISP-1	2nd/1st mill.				Os fragm.
Erkurgan	Bos taurus	SK18-54	23; 29, 30; NISP-1	1st cent. BC				Os fragm.
Erkurgan	Canis fam.	SK16-43	Kopak; Level 20					Mandible
Erkurgan	Mus sp.	SK18-31						Os fragm.
Tilla Bulak	Triticum aest.	SK18-76	TB10-KF-541	LBA				charred grains
Tilla Bulak	Triticum aest.	SK18-77	TB10-KF-701	LBA				charred grains
Tilla Bulak	Triticum aest.	SK18-80	TB10-KF-935	LBA				charred grains
Tilla Bulak	Hordeum vulg.	SK18-75	TB09-KF-626	LBA				charred grains
Tilla Bulak	Hordeum vulg.	SK18-78	TB10-KF-890	LBA				charred grains
Tilla Bulak	Hordeum vulg.	SK18-79	TB10-KF-919	LBA				charred grains
Tilla Bulak	Hordeum vulg.	SK18-81	TB10-KF-937	LBA				charred grains

Table 3: Compilation of all samples from Iran

Site	Species	Name of sample	#Ref	Period	Age (in years)	Sex	Material
Tepe Sialk	Homo sap.	27281	N°101 N-mount, Sialk I-5	Sialk I	30–40	male	Phalanx; PM
Tepe Sialk	Homo sap.	27282	N°102 N-mount, Sialk I-4	Sialk I	ca. 30	female	M3
Tepe Sialk	Homo sap.	27283	N°103 N-mount, Sialk I-4	Sialk I	ca. 40	male	M3
Tepe Sialk	Homo sap.	27268	N°107 tomb 1, foulle II, Sialk II-3	Sialk II	40–50	female	PM
Tepe Sialk	Homo sap.	27269	N°108 tomb 2, foulle II, Sialk II-2	Sialk II	25–30	male	I
Tepe Sialk	Homo sap.	27270	N°109 tomb 1, fouille III, Sialk II-2	Sialk II	ca. 50	male	M3
Tepe Sialk	Homo sap.	27271	N°110 tomb 5, fouille II, Sialk II-1	Sialk II	20–25	female (?)	M3
Tepe Sialk	Homo sap.	27272	N°111 tomb 6, fouille II, Sialk II-1	Sialk II	20–26	female	Petrosa
Tepe Sialk	Homo sap.	27273	N°1 tomb 18, Sialk III-2	Sialk III	8–10	n.d.	Maxialla, M
Tepe Sialk	Homo sap.	27274	N°2 tomb 17, Sialk III-2	Sialk III	6–10	n.d.	Petrosa, M
Tepe Sialk	Homo sap.	27275	N°3 tomb 12, Sialk III-3	Sialk III	30–40	male	M3
Tepe Sialk	Homo sap.	27276	N°112 under a wall, Sialk III-5	Sialk III	25–30	female	Sternum
Tepe Sialk	Homo sap.	27305	N°4 tomb V, Necropole A, Sialk V	Sialk V	30–40	male (?)	Vertebra
Tepe Sialk	Homo sap.	27288	N°7 tomb 39, Necropole B, Sialk VI	Sialk VI	50–60	female	Os fragm., I
Tepe Sialk	Homo sap.	27290	N°9 tomb 52, Necropole B, Sialk VI	Sialk VI	50–60	male	Os fragm., I
Tepe Sialk	Homo sap.	27295	N°118 tomb 136, Necropole B, Sialk VI	Sialk VI	15–18	female	Vertebra, PM
Tepe Sialk	Homo sap.	27298	N°121 tomb 186, Necropole B, Sialk VI	Sialk VI	50–60	female	Vertebra
Tepe Sialk	Homo sap.	27300	N°123 tomb 192, Necropole B, Sialk VI	Sialk VI	20–25	female	Petrosa
Tepe Sialk	Capra aeg.	SK18-87	OC-IR/SI6, Prof 110, Sialk III-1, No1; CH1420	Sialk III			Os fragm.
Tepe Sialk	Capra aeg.	SK18-88	OC-IR/SI2, Prof. 110 Sialk III-1 No3; CH1380	Sialk III			Os fragm.
Tepe Sialk	Ovis aries	SK18-89	SN mound, L86; 403, CH899, No41				Os fragm.
Tepe Sialk	Capra aeg.	SK19-01	A(2), Sialk III-1; 100-105; OC-IR/Si3; CP8	Sialk III			Petrosa
Tepe Sialk	Capra aeg.	SK19-03	1380; trench A(2), Sialk III-1; 110; OC-IR/SI7	Sialk III			Petrosa
Tepe Sialk	Capra aeg.	SK19-07	A(2), Sialk III-1; prof. 110; OC-IR/SI1	Sialk III			Petrosa
Tepe Sialk	Sus scrofa	SK16-81	F 4188				Molar
Tepe Sialk	Vulpes vulpes	SK18-90	Sialk LIS 408				Mandible
Tepe Sialk	Hyena sp.	SK18-91	KKH, F99, NW, 5-7				Coprolites
Kaftar Khoun	Hyena sp.	SK18-92	F101/3, group 1,	modern			Coprolites
Kaftar Khoun	Hyena sp.	SK18-100	F100/2, group 2,	modern			Coprolites
Kaftar Khoun	Hyena sp.	SK18-101	F100, D1	modern			Coprolites
Hasanlu	Canis fam.	SK 16-26	Op U 22; P V II; Layer 19; Has. 1974	Period VII 3rd Mill			Mandible
Hasanlu	Canis fam.	SK 16-28	Op R 23; Locus 4 a. 3; Layer 7; Has. 1972	Period V-IV (?)			Mandible
Hasanlu	Canis fam.	SK 16-29	Op Y 33; Fd.Nr. 2; Layer 3; Has. 1974	Has III or II			Mandible
Hasanlu	Canis fam.	SK 16-30	Op Y 33; Fd.Nr. 2; Layer 3; Has. 1974	Has III or II			Mandible
Hasanlu	Canis fam.	SK 16-32	Op X 32; Locus 17; Layer 4 a. 5; Has. 1974	probably Has IV			Mandible
Hasanlu	Canis fam.	SK 16-33	Op X 32; Fd.Nr. 17; Layer 5; Has. 1974	probably Has IV			Mandible
Hasanlu	Canis fam.	SK 16-34	Op V 22; Fd.Nr. 14; Has. 1974	Has III or II			Mandible
Hasanlu	Canis fam.	SK 16-35	Op V 22 W; pit D; Has. 1974	Has III or II			Mandible
Nishapur	Canis fam.	SK 16-42	Tr. D-1; Depth: R X	3rd cent. AD/islm.			Mandible
Qoli Darvish	Canis fam.	SK 16-45	BA 40; D: 420-440 cm	LBA or EIA			Mandible
Tepe Naderi	Gazella sub.	SK19-08	Naderi 2016; Tr. 2, disturbed	BA			Mandible
Tepe Naderi	Bos taurus	SK19-09	Naderi 2016; Tr. 1 F7; depth 190-245	BA			Cranium
Tepe Naderi	Bos taurus	SK19-10	Naderi 2018; Tr. 1 sect. 7; surface	BA			Cranium
Tepe Naderi	Canis fam.	SK18-99	Tr.2; Naderi 2016; #107	BA			Ulna
Shirvan	Hyena sp.	SK18-98		modern			Mandible
Shirvan	Tamaris sp.	SK18-97		modern			dried wood
Tepe Pahlavan	Capra aeg.	SK18-41	TP96; Tr. D, C.4003; R.N. 4032; 96,05,25	neolith./chalc.			Petrosa
Gorgan Wall	Bubalo sp.	SK16-76	Trench S; Context 32; 24.8.2008	sassanain			Vertebra
Sang-e Chakhmaq	Felix sylv.	SK19-11		neolithic			Mandible
Gholjogh	Asteraceae sp.	SK18-93		modern			dried wood
Gholjogh	Alhagi sp.	SK18-95		modern			dried leaves
Gholjogh	n.d.	SK18-96		modern			Coproliths
Hasanlu	Mus sp.	SK18-117	Hasanlu 1974, Operation W32, 4. 13 L.23	probably Has IV			Femur
Tepe Taleb Khan	Mus sp.	SK18-17	Tr IV Cont 4033 RN 4230; RN4410 N:38	BA			Cranium
Tepe Pahlavan	Mus sp.	SK18-18		neolith./chalc.			Femur
Sarvestan Palace	Mus sp.	SK18-19		sassanian			Cranium
Kalateh Khan	Mus sp.	SK18-27	Khorasan Reference: Tr 2L. 222 date 1384/11/25	neolithic			Cranium
Tepe Zagheh	Mus sp.	SK18-29	ST (CT) Level 125 (-450 to-468	neolithic			Femur
Tepe Damghani	Mus sp.	SK18-30		BA			Femur

Table 4: $^{87}Sr/^{86}Sr$ results of references from southern Central Asia

Site	Species	Name of sample	Material	#Ref	$^{87}Sr/^{86}Sr$		± 2σ
Ulug Depe	Rodent	R-CH. 1	bone	Ch. 1	**0.707922**	±	0.000006
Ulug Depe	Rodent	R-CH. 5	bone	Ch. 5	**0.707885**	±	0.000004
Ulug Depe	Rodent	R-CH. 16	bone	Ch. 16	**0.707972**	±	0.000007
Ulug Depe	Panthera	SK16-25	bone	Ch. 5; 2004	**0.707961**	±	0.000003
Ulug Depe	Dog	SK16-18	bone	Ch. 1; 2007	**0.707908**	±	0.000005
Ulug Depe	Tamarisk	SK18-01	charred grains	Ch. 1 Est	**0.708016**	±	0.000004
Ulug Depe	Juniper	SK18-02	charred grains	Ch. 8, US 8350	**0.708045**	±	0.000003
Ulug Depe	Barley	SK18-03-1	charred grains	Ch. 5, US 5012	**0.707955**	±	0.000005
Ulug Depe	Barley	SK18-03-2	charred grains	Ch. 5, US 5012	**0.70796**	±	0.000005
Ulug Depe	Barley	SK18-04	charred grains	Ch. 1 est, US 1579	**0.707963**	±	0.000006
Ulug Depe	Barley	SK18-05	charred grains	Ch. 8, US 8305	**0.707911**	±	0.000005
Geokchik Depe	Rodent	SK18-28	bone	-	**0.709237**	±	0.000004
Geokchik Depe	Rodent	SK18-115	bone	-	**0.708480**	±	0.000011
Dzharkutan	Rodent	R-DZH 1066	bone	Sep. 1066	**0.708201**	±	0.000005
Dzharkutan	Rodent	R-DZH 2012	bone	-	**0.708204**	±	0.000003
Dzharkutan	Tamarisk	SK18-86	charred grains	Ch. 7, US 7018	**0.708312**	±	0.000009
Dzharkutan	Willow	SK18-07	charred grains	Ch. 7, US 7034	**0.708191**	±	0.000004
Dzharkutan	Barley	SK18-09-1	charred grains	Ch. 7, US 7034	**0.708258**	±	0.000006
Dzharkutan	Barley	SK18-09-2	charred grains	Ch. 7, US 7034	**0.708359**	±	0.000006
Dzharkutan	Barley	SK18-10	charred grains	Ch. 7, US 7018	**0.708259**	±	0.000007
Tilla Bulak	Wheat	SK18-76	charred grains	TB10-KF-541	**0.708965**	±	0.000003
Tilla Bulak	Wheat	SK18-77	charred grains	TB10-KF-701	**0.708931**	±	0.000013
Tilla Bulak	Wheat	SK18-80	charred grains	TB10-KF-935	**0.708959**	±	0.000006
Tilla Bulak	Barley	SK18-75	charred grains	TB09-KF-626	**0.708968**	±	0.000008
Tilla Bulak	Barley	SK18-78	charred grains	TB10-KF-890	**0.708944**	±	0.000004
Tilla Bulak	Barley	SK18-79	charred grains	TB10-KF-919	**0.70893**	±	0.000011
Tilla Bulak	Barley	SK18-81	charred grains	TB10-KF-937	**0.708937**	±	0.000007
Sangir-tepe	Rodent	SK18-32	bone	ST-04 -03 delta 3 pit, ST/28/04	**0.709224**	±	0.000006
Erkurgan	Rodent	SK18-31	bone	-	**0.708273**	±	0.000003
Bashman1	Human	SK18-119	dentine	2018; GPS 150	**0.709297**	±	0.000005
Bashman1	Human	SK18-120	dentine	2018; GPS 150	**0.709343**	±	0.000005

Table 5: $^{87}Sr/^{86}Sr$ results of references from Iran

Site	Species	Name of sample	Material	#Ref	GPS	Date of collection	$^{87}Sr/^{86}Sr$		± 2σ	$\delta^{15}N$ ‰ (AIR)	$\delta^{13}C$ ‰ (PDB)	% N	% C	C/N
Tepe Sialk	Goat	SK18-87	bone	OC-IR/SI6, Prof 110, Sialk III-1, No1; CH1420			**0.707992**	±	0.000005	-	-	-	-	-
Tepe Sialk	Goat	SK18-88	bone	OC-IR/SI2 Prof. 110 Sialk III-1 No3; CH1380			**0.707993**	±	0.000010	-	-	-	-	-
Tepe Sialk	Sheep	SK18-89	bone	SN mound, L86; 403, CH899, No4:		-	**0.707998**	±	0.000006	-	-	-	-	-
Tepe Sialk	Fox	SK18-90 E	enamel	Sialk LIS 408	-	-	**0.707966**	±	0.000005	-	-	-	-	-
Tepe Sialk	Fox	SK18-90 B	bone	Sialk LIS 408	-	-	**0.707967**	±	0.000004	-	-	-	-	-
Tepe Sialk	Hyena	SK18-91	coproliths	KKH, F99, NW, 5-7	-	-	**0.708117**	±	0.000007	-	-	-	-	-
Kaftar Khoun	Hyena	SK18-92	coproliths	F101/3, group 1	-	-	**0.708145**	±	0.000005	-	-	-	-	-
Kaftar Khoun	Hyena	SK18-100	coproliths	F101/3, group 1	-	-	**0.707927**	±	0.000004	-	-	-	-	-
Kaftar Khoun	Hyena	SK18-101	coproliths	F101/3, group 1	-	-	**0.707961**	±	0.000005	-	-	-	-	-
Shirvan	Hyena	SK18-98	bone (modern)	F101/3, group 1	-	-	**0.708064**	±	0.000003	-	-	-	-	-
Shirvan	Tamarisk	SK18-97	dried leaves	F101/3, group 1	-	-	**0.708072**	±	0.000006	-	-	-	-	-
Gholjogh	plant n.d.	SK18-96	Coproliths	F101/3, group 1	-	-	**0.708385**	±	0.000007	-	-	-	-	-
Gholjogh	Asteraceae	SK18-93	dried wood	F101/3, group 1	-	-	**0.708094**	±	0.000002	-	-	-	-	-
Gholjogh	Alhagi	SK18-95	dried leaves	F101/3, group 1	-	-	**0.708177**	±	0.000008	-	-	-	-	-
Nurabad	Rodent	SK18-15	bone	F101/3, group 1	-	-	**0.708258**	±	0.000004	-	-	-	-	-
Nurabad	Pistacia	SK18-111	charred grains	F101/3, group 1	-	-	**0.708251**	±	0.000004	-	-	-	-	-
Nurabad	Amygdalus	SK18-112	charred grains	F101/3, group 1	-	-	**0.708244**	±	0.000003	-	-	-	-	-
Nurabad	Cereal	SK18-113	charred grains	F101/3, group 1	-	-	**0.708746**	±	0.000007	-	-	-	-	-
Tepe Zagheh	Rodent	SK18-29	Femur	F101/3, group 1	-	-	**0.707743**	±	0.000004	-	-	-	-	-
Hasanlu	Rodent	SK18-117	Femur	F101/3, group 1	-	-	**0.708033**	±	0.000010	-	-	-	-	-
Kalateh Khan	Rodent	SK18-27	Cranium	F101/3, group 1	-	-	**0.708538**	±	0.000003	-	-	-	-	-
Tepe Damghani	Rodent	SK18-30	Femur	F101/3, group 1	-	-	**0.707587**	±	0.000003	-	-	-	-	-
Taleb Khan	Rodent	SK18-17	Cranium	F101/3, group 1	-	-	**0.708923**	±	0.000005	-	-	-	-	-
Tepe Pahlavan	Rodent	SK18-18	Femur	F101/3, group 1	-	-	**0.708552**	±	0.000003	-	-	-	-	-
Sarvestan	Rodent	SK18-19	Cranium	F101/3, group 1	-	-	**0.707995**	±	0.000003	-	-	-	-	-
Dasht Qaleh	plant n.d.	SK19-20	charcoal	F101/3, grou	37°26.949 55°25.275	23/10/2015	**0.708769**	±	0.000004	-	-	-	-	-
Dasht Qaleh	plant n.d.	SK19-21	charcoal	F101/3, grou	37°26.949 55°25.275	23/10/2015	**0.708808**	±	0.000003	-	-	-	-	-
Dasht Qaleh	plant n.d.	SK19-22	charcoal	F101/3, grou	37°26.949 55°25.275	23/10/2015	**0.708778**	±	0.000006	-	-	-	-	-
Dasht Qaleh	plant n.d.	SK19-23	charcoal	F101/3, grou	37°26.949 55°25.275	23/10/2015	**0.708764**	±	0.000008	-	-	-	-	-
Dasht Qaleh	plant n.d.	SK19-24	charcoal	F101/3, grou	37°26.949 55°25.275	23/10/2015	**0.708573**	±	0.000004	-	-	-	-	-
Dasht Qaleh	plant n.d.	SK19-25	charcoal	F101/3, grou	37°26.949 55°25.275	23/10/2015	**0.708788**	±	0.000005	-	-	-	-	-
Qaleh Kharabch	plant n.d.	SK19-26	charcoal	F101/3, grou	37°05.974 54°25.515	23/10/2015	**0.708827**	±	0.000004	-	-	-	-	-
Malay Sheikh-Fort 4	plant n.d.	SK19-27	charcoal	F101/3, grou	37°26.949 55°25.275	23/10/2015	**0.708822**	±	0.000003	-	-	-	-	-
Malay Sheikh-Fort 4	plant n.d.	SK19-28	charcoal	F101/3, grou	37°26.949 55°25.275	23/10/2015	**0.708763**	±	0.000005	-	-	-	-	-
Ban Saran Fort	plant n.d.	SK19-29	charcoal	F101/3, grou	36°44.189 54°03.125	23/10/2015	**0.708777**	±	0.000004	-	-	-	-	-
Qelich Qoineh	plant n.d.	SK19-30	charcoal	F101/3, grou	37°08.485 54°29.208	23/10/2015	**0.708831**	±	0.000003	-	-	-	-	-
Qelich Qoineh	plant n.d.	SK19-31	charcoal	F101/3, grou	37°08.485 54°29.208	23/10/2015	**0.708792**	±	0.000009	-	-	-	-	-
Lut	Salsola	SK18-65	wood/leaves	F101/3, group 1	-	29/3/2017	**0.707498**	±	0.000003	**5.6**	**-12.3**	2.3	31.9	15.9
Lut	Salsola	SK18-55	wood/leaves	F101/3, group 1	-	30/3/2017	-		-	**7.5**	**-12.1**	1.7	30.2	20.8
Lut	Salsola	SK18-66	wood/leaves	F101/3, group 1	-	30/3/2017	-		-	**9.5**	**-12.2**	2.1	30.5	17.1
Lut	Salsola	SK18-70	wood/leaves	F101/3, group 1	-	30/3/2017	**0.707541**	±	0.000004	**11.3**	**-13.2**	1.8	26.9	17.3
Lut	Salsola	SK18-72	wood/leaves	F101/3, group 1	-	30/3/2017	-		-	**6.3**	**-12.2**	1.2	24.9	23.3
Lut	Salsola	SK18-57	wood/leaves	F101/3, group 1	-	-	-		-	**5.8**	**-13.4**	2.9	29.9	12.0
Lut	Calligonum	SK18-56	wood/leaves	F101/3, group 1	-	29/3/2017	**0.707611**	±	0.000011	**4.1**	**-13.3**	1.4	43.0	36.2
Lut	Calligonum	SK18-62	wood/leaves	F101/3, group 1	-	-	-		-	**1.7**	**-13.5**	1.6	28.9	21.1
Lut	Calligonum	SK18-69	wood/leaves	F101/3, group 1	-	-	-		-	**-1.7**	**-14.1**	1.9	42.6	25.9
Lut	Hammada	SK18-74	wood/leaves	F101/3, group 1	-	29/3/2017	-		-	**4.6**	**-13.6**	1.3	32.8	29.2
Lut	Hammada	SK18-61	wood/leaves	F101/3, group 1	-	29/3/2017	**0.707628**	±	0.000003	**2.0**	**-13.5**	1.6	29.1	21.2
Lut	Hammada	SK18-59	wood/leaves	F101/3, group 1	-	-	-		-	**6.2**	**-13.4**	2.3	34.1	17.2
Lut	Haloxylon	SK18-71	wood/leaves	F101/3, group 1	-	30/3/2017	-		-	**9.0**	**-14.2**	3.5	39.5	13.1
Lut	Tamarisk	SK18-64	wood/leaves	F101/3, group 1	-	29/3/2017	**0.707497**	±	0.000002	**0.1**	**-26.9**	0.8	43.3	63.4
Lut	Tamarisk	SK18-63	wood/leaves	F101/3, group 1	-	29/3/2017	-		-	**5.8**	**-28.6**	1.0	36.3	44.3
Lut	Tamarisk	SK18-58	wood/leaves	F101/3, group 1	-	30/3/2017	**0.707446**	±	0.000003	**3.3**	**-27.6**	0.7	36.9	58.0
Lut	Tamarisk	SK18-60	wood/leaves	F101/3, group 1	-	-	-		-	**6.4**	**-26.2**	1.8	37.3	23.8
Lut	Tamarisk	SK18-73	wood/leaves	F101/3, group 1	-	31/3/2017	**0.707418**	±	0.000005	**1.2**	**-25.5**	2.1	37.6	20.7
Lut	Tamarisk	SK18-67	wood/leaves	F101/3, group 1	-	1/4/2017	-		-	**13.1**	**-25.2**	1.5	31.3	24.9
Lut	Tamarisk	SK18-68	wood/leaves	F101/3, group 1	-	1/4/2017	-		-	**9.9**	**-26.6**	1.3	31.2	29.1

Table 6: Results of all human isotopic analyses and animal collagen from Ulug Depe

Sample			Collagen						Bioapatite out of bone compacta							Bioapatite out of tooth enamel						
Site	Species	Name of sample	$\delta^{15}N$ ‰ (AIR)	$\delta^{13}C$ ‰ (PDB)	% N	% C	C/N	$\delta^{13}C_{carb-col}$ (‰)	Material	$^{87}Sr/^{86}Sr$	± 2σ	$\delta^{18}O$ ‰ (PDB)	± σ	$\delta^{13}C$ ‰ (PDB)	± σ	Material	$^{87}Sr/^{86}Sr$	± 2σ	$\delta^{18}O$ ‰ (PDB)	± σ	$\delta^{13}C$ ‰ (PDB)	± σ
Ulug Depe	Human	**ULG 53**	**11.3**	**-19.8**	14.1	37.4	3.1	**5.4**	Phalanx	**0.707918**	± 0.000003	**-5.3**	± 0.013	**-14.4**	± 0.018	M3	**0.708488**	± 0.000008	**-4.3**	± 0.052	**-13.5**	± 0.019
Ulug Depe	Human	**ULG 54**	**14.2**	**-19.8**	15.3	40.7	3.1	**5.6**	Costa	**0.707890**	± 0.000006	**-4.0**	± 0.014	**-14.2**	± 0.008	M	**0.707856**	± 0.000004	**-5.0**	± 0.017	**-13.3**	± 0.032
Ulug Depe	Human	**ULG 55**	**11.2**	**-19.7**	15.5	41.5	3.1	**5.1**	Costa	**0.707948**	± 0.000004	**-4.9**	± 0.022	**-14.5**	± 0.018	M3	**0.708247**	± 0.000003	**-4.0**	± 0.036	**-13.9**	± 0.021
Ulug Depe	Human	**ULG 56**	**12.7**	**-20.2**	10.1	27.0	3.1	**6.9**	Costa	**0.707921**	± 0.000007	**-3.2**	± 0.029	**-13.3**	± 0.006	C	**0.709960**	± 0.000004	**-3.4**	± 0.047	**-13.6**	± 0.024
Ulug Depe	Human	**ULG 90**	**14.9**	**-19.1**	14.5	38.8	3.1	**6.1**	Costa	**0.707867**	± 0.000006	**-3.1**	± 0.023	**-13.0**	± 0.011	M	**0.707857**	± 0.000004	**-3.3**	± 0.020	**-12.4**	± 0.021
Ulug Depe	Human	**ULG 92**	**13.7**	**-19.7**	14.6	38.7	3.1	**5.7**	Os fragm.	**0.707864**	± 0.000005	**-4.8**	± 0.019	**-14.0**	± 0.010	M3	**0.708061**	± 0.000005	**-6.9**	± 0.022	**-12.9**	± 0.030
Ulug Depe	Human	**ULG 61**	**13.7**	**-18.6**	15.1	41.2	3.2	**5.5**	Os fragm.	**0.707873**	± 0.000004	**-3.3**	± 0.027	**-13.2**	± 0.008	I	**0.707826**	± 0.000008	**-3.4**	± 0.027	**-13.5**	± 0.026
Ulug Depe	Human	**ULG 62**	**12.4**	**-20.5**	13.4	36.5	3.2	**7.6**	Phalanx	**0.707886**	± 0.000006	**-2.5**	± 0.043	**-12.9**	± 0.021	M3	**0.707859**	± 0.000006	**-4.5**	± 0.023	**-13.0**	± 0.026
Ulug Depe	Human	**ULG 66**	**14.1**	**-20.0**	15.4	41.8	3.2	**6.7**	Os fragm.	**0.707894**	± 0.000005	**-2.8**	± 0.019	**-13.3**	± 0.012	M3	**0.707880**	± 0.000004	**-4.0**	± 0.040	**-13.1**	± 0.023
Ulug Depe	Human	**ULG 76-1**	**13.6**	**-20.2**	14.2	37.8	3.1	**7.2**	Vertebra	**0.707899**	± 0.000004	**-2.4**	± 0.014	**-13.0**	± 0.015	M	**0.707865**	± 0.000005	**-3.6**	± 0.029	**-12.6**	± 0.024
Ulug Depe	Human	**ULG 83**	**13.1**	**-20.5**	13.9	38.0	3.2	**6.5**	Vertebra	**0.707865**	± 0.000004	**-4.3**	± 0.019	**-14.0**	± 0.012	M3	**0.707819**	± 0.000006	**-5.8**	± 0.027	**-13.6**	± 0.025
Ulug Depe	Human	**ULG 59**	**14.0**	**-19.5**	14.6	39.3	3.1	-	Costa	**0.708540**	± 0.000032	-	-	-	-	M3	**0.708255**	± 0.000005	**-3.5**	± 0.033	**-9.1**	± 0.029
Ulug Depe	Human	**ULG 80**	**13.9**	**-17.7**	15.0	41.1	3.2	**6.8**	Costa	**0.707899**	± 0.000003	**-2.2**	± 0.020	**-10.9**	± 0.013	M	**0.707922**	± 0.000006	**-2.6**	± 0.031	**-11.6**	± 0.029
Ulug Depe	Human	**ULG 82**	**14.0**	**-19.7**	15.1	40.6	3.1	**7.1**	Os fragm.	**0.707926**	± 0.000004	**-3.6**	± 0.018	**-12.6**	± 0.018	M3	**0.708113**	± 0.000011	**-3.5**	± 0.057	**-13.6**	± 0.043
Ulug Depe	Human	**ULG 100**	**13.3**	**-16.1**	14.1	37.8	3.1	**7.7**	Os fragm.	**0.707898**	± 0.000004	**-3.3**	± 0.022	**-8.3**	± 0.017	M	**0.707835**	± 0.000006	**-4.4**	± 0.033	**-11.6**	± 0.040
Ulug Depe	Gazelle	**SK18-33**	**9.2**	**-17.4**	13.2	36.1	3.2	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Gazelle	**SK18-34**	**11.0**	**-14.5**	13.5	36.2	3.1	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Gazelle	**SK16-82**	**9.8**	**-17.6**	11.3	31.0	3.2	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Gazelle	**SK16-83**	**8.7**	**-16.8**	19.2	52.1	3.2	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Gazelle	**SK16-84**	**11.7**	**-13.5**	11.6	31.4	3.1	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Gazelle	**SK16-85**	**10.4**	**-16.3**	14.7	39.6	3.1	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Gazelle	**SK16-86**	**10.5**	**-14.8**	13.3	35.8	3.1	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Goat	**SK18-35**	**12.4**	**-19.6**	14.4	38.9	3.2	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Goat	**SK18-36**	**10.2**	**-19.0**	12.5	33.1	3.1	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Sheep	**SK18-37**	**9.5**	**-17.8**	12.6	33.0	3.1	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Sheep	**SK18-38**	**10.3**	**-18.3**	14.6	39.6	3.2	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Sheep	**SK18-39**	**9.3**	**-17.3**	14.7	40.0	3.2	-	Petrosa	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Ovicaprid	**SK16-87**	**12.6**	**-14.5**	11.1	29.9	3.2	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Ovicaprid	**SK16-88**	**11.3**	**-16.4**	14.1	38.6	3.2	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Ovicaprid	**SK16-89**	**12.2**	**-16.3**	18.5	50.5	3.2	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Ovicaprid	**SK16-90**	**10.8**	**-19.3**	15.7	42.0	3.1	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Cattle	**SK17-40**	**13.5**	**-16.1**	13.5	36.7	3.2	-	Os fragm.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Pig	**SK16-58**	**12.5**	**-20.9**	14.8	40.1	3.2	-	Os fragm.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Dog	**SK16-18**	**12.7**	**-19.3**	14.1	37.8	3.1	**6.0**	Mandible	**0.707908**	± 0.000005	**-3.0**	0.07	**-13.2**	0.03	-	-	-	-	-	-	-
Ulug Depe	Dog	**SK16-20**	**10.1**	**-20.0**	2.2	5.5	2.9	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Dog	**SK16-23**	**12.3**	**-18.9**	14.9	40.1	3.1	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Dog	**SK16-24**	**12.5**	**-19.1**	12.5	34.8	3.2	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Fox	**SK16-22**	**14.7**	**-13.2**	10.9	30.6	3.3	-	Humerus	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulug Depe	Panthera	**SK16-25**	**14.0**	**-15.2**	13.9	36.8	3.1	**3.8**	Ulna	**0.707961**	± 0.000003	**-1.6**	0.05	**-11.4**	0.021	-	-	-	-	-	-	-
Ulug Depe	Barley	**SK18-04**	**3.59**	**-27.15**	7.4	36.9	5.8	-	charcoal	**0.707963**	± 0.000006	-	-	-	-	-	-	-	-	-	-	-

Table 7: Results of all human isotopic analyses and animal collagen from Uzbekistan

Sample			Collagen						Bioapatite out of bone compacta/tooth dentine							Bioapatite out of tooth enamel						
Site	Species	Name of sample	$\delta^{15}N$ ‰ (AIR)	$\delta^{13}C$ ‰ (PDB)	% N	% C	C/N	$\delta^{13}C_{carb-col}$ (‰)	Material	$^{87}Sr/^{86}Sr$	± 2σ	$\delta^{18}O$ ‰ (PDB)	± σ	$\delta^{13}C$ ‰ (PDB)	± σ	Material	$^{87}Sr/^{86}Sr$	± 2σ	$\delta^{18}O$ ‰ (PDB)	± σ	$\delta^{13}C$ ‰ (PDB)	± σ
Dzharkutan	Human	DZH 1001B	11.9	-19.8	20.5	57.0	3.2	8.4	Os fragm.	0.708343	± 0.000005	-6.0	± 0.018	-11.5	± 0.017	C E	0.708487	± 0.000007	-5.0	± 0.041	-13.3	± 0.029
Dzharkutan	Human	DZH 1028-1	-	-	-	-	-	-	Phalanx	0.708358	± 0.000005	-5.1	± 0.032	-11.3	± 0.009	PM E	0.708055	± 0.000006	-6.3	± 0.026	-13.6	± 0.029
Dzharkutan	Human	DZH 999	13.1	-21.0	9.6	24.2	2.9	9.7	Phalanx	0.708355	± 0.000003	-4.8	± 0.023	-11.3	± 0.016	C E	0.708142	± 0.000007	-6.0	± 0.029	-11.9	± 0.013
Dzharkutan	Human	DZH 1001A	12.0	-19.5	14.2	38.9	3.2	7.2	Carpal	0.708314	± 0.000005	-5.7	± 0.012	-12.3	± 0.014	PM E	0.708178	± 0.000008	-6.2	± 0.008	-12.7	± 0.030
Dzharkutan	Human	DZH 1006	-	-	-	-	-	-	-	-	-	-5.5	± 0.02	-13.4	± 0.024	-	-	-	-	-	-	-
Dzharkutan	Human	DZH 1019	12.1	-16.4	15.7	42.8	3.2	3.3	Phalanx	0.708474	± 0.000003	-6.2	± 0.018	-13.1	± 0.024	M3 E	0.709200	± 0.000008	-6.5	± 0.070	-9.6	± 0.040
Dzharkutan	Human	DZH 1022	11.4	-19.9	11.2	28.3	3.0	6.5	Costa	0.708430	± 0.000004	-5.3	± 0.025	-13.4	± 0.030	PM E	0.708082	± 0.000008	-6.6	± 0.018	-13.3	± 0.032
Dzharkutan	Human	DZH 1025	11.1	-18.8	9.9	25.3	3.0	6.0	Os fragm.	0.708362	± 0.000006	-5.4	± 0.032	-12.9	± 0.017	I E	0.708190	± 0.000006	-5.8	± 0.081	-11.0	± 0.011
Dzharkutan	Human	DZH 1028-2	11.9	-19.8	13.3	36.6	3.2	6.8	Humerus	0.708368	± 0.000004	-5.3	± 0.020	-13.0	± 0.009	M E	0.708223	± 0.000006	-6.6	± 0.070	-13.0	± 0.038
Dzharkutan	Human	DZH 1033	12.1	-18.0	15.1	41.4	3.2	5.3	Costa	0.708160	± 0.000004	-6.5	± 0.027	-12.7	± 0.019	PM E	0.708185	± 0.000006	-6.3	± 0.031	-11.8	± 0.011
Dzharkutan	Human	DZH 1049	12.5	-19.4	11.9	32.9	3.2	8.1	M3 D	0.708330	± 0.000005	-5.5	± 0.066	-11.2	± 0.031	M3 E	0.708052	± 0.000004	-6.6	± 0.025	-12.5	± 0.022
Dzharkutan	Human	DZH 1051	12.1	-20.3	3.8	10.3	3.2	10.7	M3 D	0.708346	± 0.000005	-4.1	± 0.059	-9.6	± 0.029	M3 E	0.708138	± 0.000005	-6.9	± 0.071	-13.2	± 0.019
Dzharkutan	Human	DZH 1034-1	13.1	-17.7	16.0	41.8	3.1	6.8	Costa	0.708176	± 0.000005	-3.8	± 0.025	-11.0	± 0.008	M3 E	0.708040	± 0.000005	-5.0	± 0.033	-10.3	± 0.010
Dzharkutan	Human	DZH 1034-4	-	-	-	-	-	-	Femur	0.708153	± 0.000004	-5.5	± 0.033	-11.8	± 0.011	M E	0.708171	± 0.000004	-5.0	± 0.040	-9.6	± 0.034
Sapallitepa	Human	SK17-24	13.3	-18.5	12.9	35.2	3.2	-	-	-	-	-	-	-	-	M3 E	0.709030	± 0.000026	-6.8	± 0.026	-9.8	± 0.033
Sapallitepa	Human	SAP2	10.2	-19.0	13.2	36.2	3.2	-	Os fragm.	0.708418	± 0.000006	-	-	-	-	-	-	-	-	-	-	-
Bustan	Human	SK17-23	-	-	-	-	-	-	Os fragm.	0.707893	± 0.000007	-5.7	± 0.035	-11.6	0.013	M1 E	-	-	-6.9	± 0.043	-7.1	± 0.019
Bashman1	Human	SK18-119	-	-	-	-	-	-	M3 D	0.709297	± 0.000005	-	-	-	-	M3 E	0.710410	± 0.00004	-	-	-	-
Bashman1	Human	SK18-120	-	-	-	-	-	-	M D	0.709343	± 0.000005	-	-	-	-	M E	0.709445	± 0.000007	-	-	-	-
Dzharkutan	Sheep	SK18-43	12.0	-17.2	12.3	32.5	3.1	7.0	Petrosa	-	-	-1.9	± 0.038	-10.2	± 0.012	-	-	-	-	-	-	-
Dzharkutan	Sheep	SK18-44	9.4	-18.7	11.7	32.4	3.2	8.2	Petrosa	-	-	-1.7	± 0.031	-10.5	± 0.007	-	-	-	-	-	-	-
Dzharkutan	Sheep	SK18-45	9.9	-15.1	8.0	23.2	3.4	-	Petrosa	-	-	-	-	-	-	-	-	-	-	-	-	-
Dzharkutan	Caprine	SK18-46	10.2	-15.7	25.1	64.3	3.0	-	Petrosa	-	-	-	-	-	-	-	-	-	-	-	-	-
Dzharkutan	Caprine	SK18-47	11.2	-18.9	8.1	23.6	3.4	-	Petrosa	-	-	-	-	-	-	-	-	-	-	-	-	-
Sangir-tepe	Sheep	SK18-40	10.5	-15.0	14.0	37.8	3.1	-	Os fragm.	-	-	-	-	-	-	-	-	-	-	-	-	-
Sangir-tepe	Sheep	SK18-52	8.2	-18.3	13.0	35.8	3.2	-	Os fragm.	-	-	-	-	-	-	-	-	-	-	-	-	-
Padayatak	Sheep	SK18-51	7.3	-19.1	14.4	41.5	3.4	-	Os fragm.	-	-	-	-	-	-	-	-	-	-	-	-	-
Koktepe	Caprine	SK18-50	11.1	-18.8	13.4	37.2	3.3	-	Os fragm.	-	-	-	-	-	-	-	-	-	-	-	-	-
Koktepe	Cattle	SK18-53	8.3	-15.6	7.6	22.4	3.4	-	Os fragm.	-	-	-	-	-	-	-	-	-	-	-	-	-
Erkurgan	Cattle	SK18-54	10.0	-15.4	13.1	36.0	3.2	-	Os fragm.	-	-	-	-	-	-	-	-	-	-	-	-	-
Sangir-tepe	Dog	SK16-44	9.5	-17.8	16.1	44.0	3.2	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-
Erkurgan	Dog	SK16-43	11.0	-15.2	13.1	35.9	3.2	-	Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 8: Results of all human isotopic analyses and animal collagen from Iran

Sample			Collagen						Bioapatite out of bone compacta/tooth dentine										Bioapatite out of tooth enamel									
Site	Species	Name of sample	$\delta^{15}N$ ‰ (AIR)	$\delta^{13}C$ ‰ (PDB)	% N	% C	C/N	$\delta^{13}C_{carb-col}$ (‰)	Material	$^{87}Sr/^{86}Sr$		± 2σ	$\delta^{18}O$ ‰ (PDB)		± σ	$\delta^{13}C$ ‰ (PDB)		± σ	Material	$^{87}Sr/^{86}Sr$		± 2σ	$\delta^{18}O$ ‰ (PDB)		± σ	$\delta^{13}C$ ‰ (PDB)		± σ
Sialk I	Human	27281	14.7	-20.1	14.5	40.5	3.3	6.7	bone	0.708105	±	0.000001	-5.4	±	0.018	-13.4	±	0.017	PM	0.708000	±	0.000003	-2.6	±	0.021	-12.3	±	0.037
Sialk I	Human	27282	14.6	-20.0	14.9	41.5	3.2	8.5	dentine	0.708062	±	0.000005	-4.2	±	0.009	-11.4	±	0.018	M2	0.708453	±	0.000004	-6.0	±	0.033	-12.9	±	0.025
Sialk I	Human	27283	15.0	-19.8	13.5	38.3	3.3	6.6	dentine	0.708234	±	0.000006	-5.4	±	0.018	-13.2	±	0.016	M3	0.707980	±	0.000004	-6.6	±	0.041	-12.5	±	0.018
Sialk II	Human	27268	12.8	-21.4	14.9	38.2	3.0	-	dentine	0.708256	±	0.000010	-		-	-		-	PM	0.707964	±	0.000006	-6.3	±	0.027	-11.3	±	0.025
Sialk II	Human	27269	12.7	-19.8	13.9	39.3	3.3	8.1	dentine	0.708110	±	0.000001	-3.9	±	0.012	-11.7	±	0.028	I	0.707978	±	0.000003	-6.0	±	0.063	-13.0	±	0.035
Sialk II	Human	27270	11.9	-18.7	1.7	4.9	3.2	8.4	dentine	0.707998	±	0.000009	-4.3	±	0.022	-10.3	±	0.01	I	0.708058	±	0.000002	-5.3	±	0.108	-13.4	±	0.068
Sialk II	Human	27271	15.8	-22.5	12.6	38.3	3.6	9.5	dentine	0.708048	±	0.000004	-4.9	±	0.037	-13.0	±	0.015	M2	0.708469	±	0.000011	-5.0	±	0.027	-12.2	±	0.015
Sialk II	Human	27272	11.9	-19.4	2.6	7.0	3.1	6.6	bone	-		-	-5.8	±	0.009	-12.9	±	0.010	-	-		-	-		-	-		-
Sialk III	Human	27273	13.6	-18.9	25.4	65.6	3.0	6.5	bone	0.707964	±	0.000005	-4.9	±	0.016	-12.4	±	0.018	M1	0.707952	±	0.000008	-4.5	±	0.027	-12.9	±	0.036
Sialk III	Human	27274	11.3	-20.7	2.4	7.1	3.5	7.8	bone	0.707957	±	0.000003	-5.6	±	0.027	-12.9	±	0.020	M1	0.708577	±	0.000033	-5.4	±	0.015	-12.7	±	0.016
Sialk III	Human	27275	-	-	-	-	-	-	bone	0.707994	±	0.000009	-3.4	±	0.025	-14.9	±	0.014	M3	0.707969	±	0.000003	-6.4	±	0.018	-12.0	±	0.016
Sialk III	Human	27276	14.3	-19.3	13.6	38.2	3.3	5.4	bone	0.708020	±	0.000008	-6.2	±	0.010	-13.9	±	0.012	-	-		-	-		-	-		-
Sialk V	Human	27305	12.5	-18.6	14.0	40.5	3.4	7.6	bone	-		-	-4.7	±	0.017	-11.0	±	0.008	-	-		-	-		-	-		-
Sialk VI	Human	27288	13.6	-19.5	14.1	38.5	3.2	5.9	bone	0.708026	±	0.000005	-4.2	±	0.022	-13.6	±	0.023	I	0.708024	±	0.000006	-3.5	±	0.082	-12.6	±	0.057
Sialk VI	Human	27290	14.8	-19.9	14.3	40.9	3.3	6.2	bone	0.707998	±	0.000004	-5.0	±	0.031	-13.7	±	0.011	I	0.708023	±	0.000004	-2.5	±	0.031	-12.9	±	0.005
Sialk VI	Human	27295	14.0	-19.0	6.3	17.1	3.2	8.6	bone	0.707999	±	0.000003	-4.2	±	0.038	-10.4	±	0.022	PM	0.708367	±	0.000005	-4.1	±	0.049	-13.7	±	0.038
Sialk VI	Human	27298	14.0	-20.0	11.0	32.3	3.4	7.9	bone	-		-	-5.3	±	0.011	-12.1	±	0.009	-	-		-	-		-	-		-
Sialk VI	Human	27300	12.8	-19.3	5.7	15.9	3.3	8.1	bone	0.707997	±	0.000005	-3.9	±	0.031	-11.1	±	0.006	-	-		-	-		-	-		-
Tepe Sialk	Goat	SK18-87	8.2	-18.6	8.6	24.9	3.4	9.5	-	0.707992	±	0.000005	-0.9	±	0.011	-9.1	±	0.011	-	-		-	-		-	-		-
Tepe Sialk	Goat	SK18-88	7.1	-19.2	1.6	4.3	3.2	12.0	-	0.707993	±	0.000010	2.5	±	0.032	-7.2	±	0.012	-	-		-	-		-	-		-
Tepe Sialk	Sheep	SK18-89	9.5	-17.5	13.4	34.5	3.0	7.7	-	0.707998	±	0.000006	1.8	±	0.03	-9.8	±	0.015	-	-		-	-		-	-		-
Tepe Sialk	Goat	SK19-01	9.0	-18.1	12.8	36.2	3.3	10.2	-	-		-	1.0	±	0.033	-7.9	±	0.012	-	-		-	-		-	-		-
Tepe Sialk	Goat	SK19-03	6.8	-19.2	13.9	40.1	3.4	9.5	-	-		-	2.9	±	0.029	-9.8	±	0.019	-	-		-	-		-	-		-
Tepe Sialk	Goat	SK19-07	8.5	-16.2	13.9	38.1	3.2	6.2	-	-		-	1.3	±	0.026	-10.0	±	0.019	-	-		-	-		-	-		-
Tepe Pahlavan	Goat	SK18-41	9.6	-18.9	4.5	11.3	2.9	-	-	-		-	-		-	-		-	-	-		-	-		-	-		-
Tepe Naderi	Gazelle	SK19-08	8.2	-16.7	15.5	41.1	3.1	-	-	-		-	-		-	-		-	-	-		-	-		-	-		-
Tepe Naderi	Cattle	SK19-09	8.7	-18.7	13.1	33.5	3.0	-	-	-		-	-		-	-		-	-	-		-	-		-	-		-
Tepe Naderi	Cattle	SK19-10	10.1	-18.5	14.9	39.5	3.1	-	-	-		-	-		-	-		-	-	-		-	-		-	-		-
Gorgan Wall	Buffalo	SK16-76	6.9	-12.7	14.3	39.6	3.2	-	-	-		-	-		-	-		-	-	-		-	-		-	-		-
Tepe Sialk	Pig	SK16-81	5.6	-18.4	11.1	30.2	3.2	9.0	-	-		-	3.6	±	0.021	-9.4	±	0.023	-	-		-	-		-	-		-
Hasanlu	Dog	SK 16-26	7.2	-19.2	6.4	17.6	3.2	-	-	-		-	-		-	-		-	-	-		-	-		-	-		-
Hasanlu	Dog	SK 16-28	11.3	-16.0	3.7	9.9	3.1	-	-	-		-	-		-	-		-	-	-		-	-		-	-		-
Hasanlu	Dog	SK 16-29	9.5	-16.8	5.0	13.4	3.1	4.7	-	-		-	-3.6	±	0.068	-12.1	±	0.032	-	-		-	-		-	-		-
Hasanlu	Dog	SK 16-30	9.1	-17.4	4.0	10.9	3.2	-	-	-		-	-		-	-		-	-	-		-	-		-	-		-
Hasanlu	Dog	SK 16-32	9.6	-17.6	7.3	20.0	3.2	-	-	-		-	-		-	-		-	-	-		-	-		-	-		-
Hasanlu	Dog	SK 16-33	9.1	-15.8	5.0	13.7	3.2	-	-	-		-	-		-	-		-	-	-		-	-		-	-		-
Hasanlu	Dog	SK 16-34	-	-	-	-	-	-	-	-		-	-		-	-		-	-	-		-	-		-	-		-
Hasanlu	Dog	SK 16-35	-	-	-	-	-	-	-	-		-	-3.8	±	0.052	-11.5	±	0.02	-	-		-	-		-	-		-
Nishapur	Dog	SK 16-42	12.5	-18.0	9.1	24.2	3.1	-	-	-		-	-		-	-		-	-	-		-	-		-	-		-
Qoli Darvish	Dog	SK 16-45	11.8	-18.9	10.6	28.5	3.1	6.5	-	-		-	-2.4	±	0.053	-12.4	±	0.04	-	-		-	-		-	-		-
Ch. Az.	Dog	SK 16-51	9.2	-18.9	4.9	13.5	3.2	-	-	-		-	-		-	-		-	-	-		-	-		-	-		-
Tepe Naderi	Dog	SK18-99	10.0	-18.9	14.0	38.2	3.2	-	-	-		-	-		-	-		-	-	-		-	-		-	-		-
Gholjogh	Coproliths	SK18-96	-	-	-	-	-	-	-	0.708385	±	0.000007	-		-	-		-	-	-		-	-		-	-		-
Tepe Sialk	Fox	SK18-90	7.0	-15.0	5.3	16.5	3.6	-	-	0.707967	±	0.000004	-		-	-		-	-	0.707966	±	0.000005	-		-	-		-
Sang-e Chakhmaq	Cat	SK19-11	11.2	-17.1	10.8	30.9	3.3	-	-	-		-	-		-	-		-	-	-		-	-		-	-		-

Table 9: Results of 87Sr/86Sr and bio-apatite of human samples from southern Tajikistan

Sample					Bioapatite out of tooth enamel							Bioapatite out of bone compacta						
Site	**Species**	**Name of sample**	**#Ref**	**Period**	**Material**	**$^{87}Sr/^{86}Sr$**	**± 2σ**	**$\delta^{18}O$ ‰ (PDB)**	**± σ**	**$\delta^{13}C$ ‰ (PDB)**	**± σ**	**Material**	**$^{87}Sr/^{86}Sr$**	**± 2σ**	**$\delta^{18}O$ ‰ (PDB)**	**± σ**	**$\delta^{13}C$ ‰ (PDB)**	**± σ**
Gelot	Homo sap.	SK17-01	N4 grave 4	MBA-LBA	M3 E	-	-	**-3.1**	± 0.04	**-11.2**	± 0.01	-	-	-	-	-	-	-
Gelot	Homo sap.	SK17-02	N4 grave 5	MBA-LBA	M1 E	-	-	**-6.5**	± 0.03	**-13.2**	± 0.02	-	-	-	-	-	-	-
Gelot	Homo sap.	SK17-03	N4 grave 6	MBA-LBA	-	-	-	-	-	-	-	Tibia	-	-	**-8.0**	± 0.05	**-13.9**	± 0.02
Gelot	Homo sap.	SK17-04	N4 grave 8	MBA-LBA	I1 E	-	-	**-4.0**	± 0.02	**-12.4**	± 0.03	Tibia	-	-	**-7.4**	± 0.05	**-13.6**	± 0.02
Gelot	Homo sap.	SK17-05	N6 grave 2	MBA-LBA	M E	**0.70874**	± 0.000005	**-2.8**	± 0.05	**-12.3**	± 0.02	Os fragm.	**0.709270**	± 0.000003	**-6.6**	± 0.04	**-13.3**	± 0.01
Gelot	Homo sap.	SK17-06	N6 grave 3	MBA-LBA	M E	-	-	**-7.6**	± 0.01	**-11.2**	± 0.01	Costa	-	-	**-7.4**	± 0.05	**-11.1**	± 0.04
Gelot	Homo sap.	SK17-07	N6 grave 8	MBA-LBA	M E	-	-	**-7.0**	± 0.03	**-12.0**	± 0.02	-	-	-	-	-	-	-
Gelot	Homo sap.	SK17-08	N6 grave 9	MBA-LBA	-	-	-	-	-	-	-	Os fragm.	-	-	**-7.1**	± 0.02	**-13.7**	± 0.01
Gelot	Homo sap.	SK17-09	N6 grave 13	MBA-LBA	M E	-	-	**-5.3**	± 0.04	**-12.6**	± 0.03	Os fragm.	-	-	**-6.5**	± 0.04	**-13.4**	± 0.02
Darnaichi	Homo sap.	SK17-13	N2 grave 1	MBA	M E	**0.70915**	± 0.000004	**-6.3**	± 0.03	**-13.8**	± 0.03	Calotte	**0.709302**	± 0.000008	**-7.0**	± 0.04	**-14.1**	± 0.01
Darnaichi	Homo sap.	SK17-14	N2 grave 2	MBA	-	-	-	-	-	-	-	Os fragm.	-	-	**-7.2**	± 0.03	**-11.9**	± 0.02
Darnaichi	Homo sap.	SK17-15	N2 grave 5	MBA	-	-	-	-	-	-	-	Os fragm.	-	-	**-6.8**	± 0.03	**-12.7**	± 0.01
Darnaichi	Homo sap.	SK17-16	N2 grave 8	MBA	PM1 E	-	-	**-7.1**	± 0.02	**-11.2**	± 0.01	Os fragm.	-	-	**-7.6**	± 0.01	**-13.1**	± 0.02
Darnaichi	Homo sap.	SK17-17	N2 grave 12	MBA	-	-	-	-	-	-	-	Os fragm.	-	-	**-7.6**	± 0.02	**-12.4**	± 0.02
Darnaichi	Homo sap.	SK17-18	N2 grave 20	MBA	-	-	-	-	-	-	-	Os fragm.	-	-	**-7.7**	± 0.03	**-11.8**	± 0.01
Darnaichi	Homo sap.	SK17-19	N2 grave 21	MBA	-	-	-	-	-	-	-	Os fragm.	-	-	**-7.4**	± 0.03	**-12.6**	± 0.01
Darnaichi	Homo sap.	SK17-20	N2 grave 27	MBA	M E	-	-	**-6.4**	± 0.03	**-12.3**	± 0.01	Os fragm.	-	-	**-6.7**	± 0.04	**-12.6**	± 0.04
Darnaichi	Homo sap.	SK17-21	N2 grave 30	MBA	M E	-	-	**-6.4**	± 0.01	**-12.9**	± 0.04	Os fragm.	-	-	**-7.1**	± 0.02	**-12.5**	± 0.01
Saridzhar	Homo sap.	SK17-10	B1 grave 1	LBA	PM E	**0.70919**	± 0.000009	**-6.9**	± 0.03	**-10.0**	± 0.02	Calotte	**0.70914**	± 0.000005	**-7.8**	± 0.04	**-8.1**	± 0.02
Saridzhar	Homo sap.	SK17-11	B3 grave 2	LBA	M E	**0.70862**	± 0.000016	**-7.2**	± 0.04	**-10.7**	± 0.02	Os fragm.	**0.70914**	± 0.000010	**-6.7**	± 0.02	**-10.6**	± 0.02
Saridzhar	Homo sap.	SK17-12	N1 grave 1	LBA	-	-	-	-	-	-	-	Os fragm.	**0.70937**	± 0.000009	**-7.2**	± 0.01	**-11.9**	± 0.02

Table 10: Strontium isotope values of the geological units in Central Asia

Location Name*	Latitude	Longitude	$^{87}Sr/^{86}Sr$	Reference
Caspian Sea Water (Modern), *n=67*	-	-	0.70818	Clauer et al. 2000
Qara Boghaz Bay (Modern), *n=10*	41.36	53.57	0.70815	
Amu Darya Basin (Mid to Upper Jurassic), *n=3*	37.28–38.37	66.87–67.83	0.70848	Zheng et al. 2011
Western Tien Shan (Uzbekistan)	42.12	60.29	0.70585	Dolgopolova et al. 2017
	42.15	64.11	0.71115	
	42.67	63.39	0.70495	
	42.18	63.57	0.71672	
	41.65	64.33	0.70816	
	41.68	64.29	0.83899	
	41.20	63.54	0.71474	
	40.66	66.24	0.70940	
	40.64	66.23	0.71491	
	40.38	66.69	0.72017	
	39.30	66.92	0.72162	
	38.95	67.34	0.71164	
	38.95	67.35	0.72289	
	40.81	69.65	0.71399	
	40.81	69.65	0.72278	
	41.05	69.72	0.70457	
	40.78	69.78	0.71274	
	40.78	69.78	0.71024	
	40.97	70.16	0.71462	
	41.02	69.99	0.71922	
	41.02	69.98	0.71130	
	41.03	69.97	0.72917	
	41.02	69.94	0.70801	
	40.96	69.87	0.71793	
	41.05	69.95	0.72654	
	41.05	69.95	0.71502	
	40.97	70.16	0.72176	
	41.29	70.44	0.74356	
	41.29	70.44	0.74637	
	41.00	70.44	0.71214	
	40.93	70.14	0.70927	
	40.55	70.14	0.71277	
Muruntau Au Deposit (Uzbekistan), *n=11*	41.50	64.50	0.71512	Kempe et al. 2001
Kosmanachi Au Deposit (Uzbekistan)	41.45	64.37	0.71623	
Koksu (Kazakhstan), *n=39*	42.08	69.01	0.70909	Stammeier et al. 2019
Kyrshabakty (Kazakhstan), *n=17*	42.14	69.15	0.71043	
Sumbar K-T boundary (Tajikistan), *n=7*	38.44	56.29	0.70787	Meisel et al. 1995

*n refers to the number of samples used to calculate the average value

Table 11: Compilation of $\delta^{18}O_{apa}$ results and calculated $\delta^{18}O_{DW}$ ratios

Name of sample	δ^{18}OApa (‰ V-PDB)	δ^{18}OApa-E (‰ V-SMOW) after Coplen et al. 1988	δ^{18}OPhosp (‰ V-SMOW) after Iacumin et al. 1996	δ^{18}ODW (‰ V-SMOV) after Daux et al. 2008	δ^{18}ODW (‰ V-SMOV) after Chenery et al. 2012	Name of sample	δ^{18}OApa (‰ V-PDB)	δ^{18}OApa-E (‰ V-SMOW) after Coplen et al. 1988	δ^{18}OPhosp (‰ V-SMOW) after Iacumin et al. 1996	δ^{18}ODW (‰ V-SMOV) after Daux et al. 2008	δ^{18}ODW (‰ V-SMOV) after Chenery et al. 2012
Ulug Depe											
ULG 53 E	-4.3	26.5	17.4	**-6.9**	-6.5	**ULG 53 B**	-5.3	25.4	16.4	**-8.4**	-8.2
ULG 54 E	-5.0	25.8	16.7	**-7.9**	-7.7	**ULG 54 B**	-4.0	26.8	17.8	**-6.4**	-6.0
ULG 55 E	-4.0	26.8	17.8	**-6.4**	-6.0	**ULG 55 B**	-4.9	25.9	16.8	**-7.8**	-7.5
ULG 56 E	-3.4	27.4	18.4	**-5.5**	-5.1	**ULG 56 B**	-3.2	27.6	18.6	**-5.1**	-4.7
ULG 90 E	-3.3	27.5	18.5	**-5.3**	-4.9	**ULG 90 B**	-3.1	27.7	18.7	**-5.0**	-4.6
ULG 92 E	-6.9	23.8	14.8	**-10.9**	-10.8	**ULG 92 B**	-4.8	26.0	16.9	**-7.6**	-7.4
ULG 61 E	-3.4	27.4	18.4	**-5.5**	-5.1	**ULG 61 B**	-3.3	27.5	18.5	**-5.3**	-4.9
ULG 62 E	-4.5	26.3	17.2	**-7.2**	-6.9	**ULG 62 B**	-2.5	28.3	19.3	**-4.1**	-3.6
ULG 66 E	-4.0	26.8	17.8	**-6.4**	-6.0	**ULG 66 B**	-2.8	28.0	19.0	**-4.5**	-4.1
ULG 76-1 E	-3.6	27.2	18.2	**-5.8**	-5.4	**ULG 76-1 B**	-2.4	28.4	19.4	**-3.9**	-3.4
ULG 83 E	-5.8	24.9	15.9	**-9.2**	-9.0	**ULG 83 B**	-4.3	26.5	17.4	**-6.9**	-6.5
ULG 59 E	-3.5	27.3	18.3	**-5.6**	-5.2	**ULG 59 D**	-	-	-	**-**	-
ULG 80 E	-2.6	28.2	19.1	**-4.2**	-3.8	**ULG 82 B**	-2.2	28.6	19.5	**-3.7**	-3.2
ULG 82 E	-3.5	27.3	18.3	**-5.6**	-5.2	**ULG80 B**	-3.6	27.2	18.2	**-5.8**	-5.4
ULG 100 E	-4.4	26.3	17.3	**-7.1**	-6.8	**ULG100 B**	-3.3	27.6	18.5	**-5.2**	-4.8
Dzharkutan											
DZH 1001B E	-5.0	25.8	16.7	**-7.9**	-7.7	**DZH 1001B B**	-6.0	24.7	15.7	**-9.5**	-9.3
DZH 1028-1 E	-6.3	24.4	15.4	**-10.0**	-9.8	**DZH 1028-1 B**	-5.1	25.7	16.6	**-8.1**	-7.8
DZH 999 E	-6.0	24.7	15.7	**-9.5**	-9.3	**DZH 999 B**	-4.8	26.0	16.9	**-7.6**	-7.4
DZH 1001A E	-6.2	24.5	15.5	**-9.8**	-9.6	**DZH 1001A B**	-5.7	25.0	16.0	**-9.0**	-8.8
DZH 1019 E	-6.5	24.2	15.2	**-10.3**	-10.1	**DZH 1019 B**	-5.5	25.3	16.3	**-8.7**	-8.5
DZH 1022 E	-6.6	24.1	15.1	**-10.4**	-10.3	**DZH 1022 B**	-6.2	24.5	15.5	**-9.8**	-9.6
DZH 1025 E	-5.8	24.9	15.9	**-9.2**	-9.0	**DZH 1025 B**	-5.3	25.4	16.4	**-8.4**	-8.2
DZH 1028-2 E	-6.6	24.1	15.1	**-10.4**	-10.3	**DZH 1028-2 B**	-5.4	25.3	16.3	**-8.6**	-8.3
DZH 1033 E	-6.3	24.4	15.4	**-10.0**	-9.8	**DZH 1033 B**	-5.3	25.4	16.4	**-8.4**	-8.2
DZH 1049 E	-6.6	24.1	15.1	**-10.4**	-10.3	**DZH 1049 D**	-6.5	24.2	15.2	**-10.3**	-10.1
DZH 1051 E	-6.9	23.8	14.8	**-10.9**	-10.8	**DZH 1051 D**	-5.5	25.2	16.2	**-8.7**	-8.5
DZH1034-1 E	-5.0	25.8	16.8	**-7.9**	-7.6	**DZH 1034-1B**	-4.1	26.7	17.6	**-6.5**	-6.2
DZH1034-4 E	-5.0	25.8	16.8	**-7.9**	-7.6	**DZH 1034-4B**	-3.8	27.0	18.0	**-6.1**	-5.7
SK17-24	-6.8	23.9	14.9	**-10.7**	-10.6	**SK17-24**	-5.5	25.2	16.2	**-8.7**	-8.5
SK17-23	-6.9	23.8	14.8	**-10.9**	-10.9	**SK17-23**	-5.7	25.0	16.0	**-9.0**	-8.8
Tepe Sialk											
27281 E	-2.6	28.2	19.1	**-4.2**	-3.8	**27281 B**	-5.4	25.3	16.3	**-8.6**	-8.4
27282 E	-6.0	24.8	15.8	**-9.4**	-9.3	**27282 D**	-4.2	26.6	17.6	**-6.6**	-6.3
27283 E	-6.6	24.2	15.2	**-10.4**	-10.2	**27283 D**	-5.4	25.4	16.4	**-8.5**	-8.3
27268 E	-6.3	24.4	15.5	**-9.9**	-9.8	**-**	-	-	-	**-**	-
27269 E	-6.0	24.8	15.8	**-9.4**	-9.2	**27269 D**	-3.9	26.9	17.8	**-6.3**	-5.9
-	-	-	-	**-**	-	**27270 D**	-4.3	26.5	17.5	**-6.8**	-6.5
27271 E	-5.0	25.8	16.8	**-7.9**	-7.6	**27271 D**	-4.9	25.8	16.8	**-7.8**	-7.6
-	-	-	-	**-**	-	**27272 B**	-5.8	25.0	16.0	**-9.2**	-9.0
27273 E	-4.5	26.2	17.2	**-7.2**	-6.9	**27273 B**	-4.9	25.9	16.9	**-7.7**	-7.4
27274 E	-5.4	25.4	16.3	**-8.6**	-8.3	**27274 B**	-5.6	25.2	16.2	**-8.8**	-8.6
27275 E	-6.4	24.3	15.3	**-10.1**	-10.0	**27275 B**	-3.4	27.4	18.3	**-5.5**	-5.1
-	-	-	-	**-**	-	**27276 B**	-6.2	24.6	15.6	**-9.8**	-9.6
27288 E	-3.5	27.3	18.3	**-5.6**	-5.2	**27305 B**	-4.7	26.0	17.0	**-7.5**	-7.3
27290 E	-2.5	28.3	19.3	**-4.0**	-3.6	**27288 B**	-4.2	26.6	17.5	**-6.7**	-6.4
27295 E	-4.1	26.7	17.7	**-6.5**	-6.2	**27290 B**	-5.0	25.8	16.8	**-7.9**	-7.6
-	-	-	-	**-**	-	**27295 B**	-4.2	26.6	17.5	**-6.7**	-6.4
-	-	-	-	**-**	-	**27298 B**	-5.3	25.5	16.4	**-8.4**	-8.2
-	-	-	-	**-**	-	**27300 B**	-3.9	26.9	17.9	**-6.2**	-5.8
Gelot, Darnaichi, Saridzhar											
SK17-05T	-2.8	28.0	19.0	**-4.5**	-4.1	**SK17-05B**	-6.6	24.1	15.1	**-10.5**	-10.3
SK17-13T	-6.6	24.1	15.1	**-10.4**	-10.3	**SK17-13B**	-7.0	23.7	14.7	**-11.1**	-11.0
SK17-10 E	-6.9	23.8	14.8	**-10.9**	-10.8	**SK17-11 B**	-6.7	24.0	15.0	**-10.6**	-10.5
SK17-11 E	-7.2	23.5	14.5	**-11.4**	-11.3	**SK17-12 B**	-7.2	23.5	14.5	**-11.4**	-11.3
-	-	-	-	**-**	-	**SK17-10 B**	-7.8	22.9	13.9	**-12.3**	-12.3
Animals											
dog Ulug	-3	27.8	18.8	**-4.8**	-4.4	**ovicaprid Sialk**	-0.9	30.0	20.9	**-1.5**	-0.9
big cat Ulug	-1.6	29.3	20.2	**-2.6**	-2.1	**ovicaprid Sialk**	2.5	33.5	24.4	**3.8**	4.7
dog Hasanlu	-3.6	27.2	18.1	**-5.8**	-5.4	**ovicaprid Sialk**	1.8	32.7	23.6	**2.6**	3.4
dog Hasanlu	-3.8	27.0	18.0	**-6.1**	-5.7	**ovicaprid Sialk**	1.0	32.0	22.8	**1.4**	2.2
ovicarprid DZH	-1.9	29.0	19.9	**-3.1**	-2.6	**ovicaprid Sialk**	2.9	33.9	24.7	**4.3**	5.2
ovicarprid DZH	-1.7	29.1	20.0	**-2.9**	-2.3	**ovicaprid Sialk**	1.3	32.3	23.1	**1.9**	2.7

List of Aberrations

Ch.	Chantier
US	Stratigraphic Unit
LN	Late Neolithic
TC	Transitional Chalcolithic
BA	Bronze Age
EBA	Early Bronze Age
MBA	Middle Bronze Age
LBA	Late Bronze Age
IA	Iron Age
EIA	Early Iron Age
MIA	Middle Iron Age
ULG/UD	Ulug Depe
DZH	Dzharkutan
TS	Tepe Sialk
TB	Tilla Bulak
GD	Geokchik Depe
SC	Sang-e Chakhmaq
Sep.	Sepulture
n.d.	not determined
Os fragm.	not determined bone fragment
f	female
m	male
yrs.	years
E	enamel
B	bone
D	dentine
M	Molar
PM	Premolar
C	Caninus
I	Incisivi
n	number of individuals
SK	Lab initials of samples from this study