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DIETARY PRACTICES, CULTURAL AND SOCIAL IDENTITY IN THE EARLY BRONZE AGE SOUTHERN CAUCASUS: THE CASE OF THE KURA-ARAXES CULTURE

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Abstract. *Food and its interactions with the environmental, economic, social, and cultural spheres play an essential role in communities' cultural identity. This theory has been verified by an analysis of the Kura-Araxes (KA) culture, characterised by original cultural developments, which spread in the South Caucasus around the middle of the fourth millennium. This research aims to study the variability of dietary choices at the individual and population levels by analysing stable isotopes of carbon and nitrogen ($\delta^{13}\text{C}$, $\delta^{15}\text{N}$). To monitor regional and diachronic changes in dietary patterns, we performed analysis on human, animal, and plant materials ($n = 144$) from eight KA highland and lowland sites in Georgia, Azerbaijan and Armenia compared with data ($n = 39$) from Post-KA sites already published (Herrscher et al. 2016, 2018b). Isotopic data show no significant differences with altitude. The KA diet is characterised by higher consumption of herbivore meat than pork and higher barley consumption than wheat. No relationship with age at death, sex, and burial traits were observed, suggesting "equal" access to food among community members. Human low isotope variability shows persistence over KA's entire duration (3500-2500 BC), while it is significantly different between KA and Post-KA subjects. The results confirm the homogeneity of KA communities' food practices that reinforces the theory of a "strong cultural identity" of the KA populations.*

Résumé. *L'alimentation et l'ensemble des interactions qu'elle entretient avec les sphères environnementale, économique, sociale et culturelle jouent un rôle important dans l'identité culturelle des communautés. Cette théorie a été vérifiée par une analyse de la culture Kuro-Araxe (KA), caractérisée par des développements culturels originaux, qui s'est répandue dans le Caucase du Sud vers le milieu du quatrième millénaire. Cette recherche vise à étudier la variabilité des choix alimentaires, aux niveaux individuel et populationnel, par l'analyse des isotopes stables du carbone et de l'azote ($\delta^{13}\text{C}$, $\delta^{15}\text{N}$). Afin de suivre les changements régionaux et diachroniques des modes alimentaires, des analyses ont été réalisées sur des matériaux humains, animaux et végétaux ($n = 144$) provenant de sites d'altitudes différentes, 8 en Géorgie, 2 en Arménie et 1 en Azerbaïdjan et comparées à des données ($n = 39$) provenant de 4 sites Post KA de la région déjà publiées (Herrscher et al. 2016, 2018b) Les données isotopiques ne montrent aucun changement significatif avec l'altitude. L'alimentation KA se caractérise par une plus grande consommation de viande d'herbivore que de porc et une plus grande consommation d'orge que de blé. Aucune relation avec l'âge au décès, le sexe et les traits funéraires n'a été observée, ce qui suggère un accès « égal » à la nourriture entre les membres des communautés. La variabilité isotopique humaine montre une persistance sur toute la durée du KA (3500-2500 avant J.-C.), tandis qu'elle est significativement différente entre les sujets KA et Post KA. Les résultats convergent pour confirmer une homogénéité des pratiques alimentaires des communautés KA qui renforce la théorie d'une « forte identité culturelle » des communautés KA.*

Keywords. *Southern Caucasus, Early Bronze Age, Kura-Araxes, diet, bioarchaeology, carbon and nitrogen*

Mots-clés. *Caucase du Sud, début de l'âge du Bronze, Kuro-Araxe, régime alimentaire, bioarchéologie, carbone et azote*

INTRODUCTION

The differentiation of diets reflects the subsistence strategies resulting from the socio-economic systems' adaptation to the nutritional/edible resources available in specific environments. However, food cannot be considered exclusively as an ecofact (Parker Pearson 2003). Instead, food should preferably be evaluated as an interface between nature, society, and culture (Hastorf 2017: 17). The production, processing, preparation, and consumption of food are deeply entwined with economic and political "realities" (Twiss 2007: 2, 2012) and are thus actively operating in all societal processes (Hastorf 2017: 3). Food embodies significance as a means of reproduction and, at the same time, an expression of social and cultural realities. Also, food has the symbolic "power" to define cultural boundaries and different identity levels (Twiss 2007: 3-4, 2012; Hastorf 2017). The famous quote "Tell me what you eat, and I will tell you what you are," from the gastronome J. A. Brillat-Savarin, later echoed by the German philosopher Ludwig Feuerbach, emphasises the powerful symbolic role that dietary practices, as collective and ritualised performances, and food, as the nourishing material symbol that we incorporate daily, are actively participating in the construction and reproduction of both individual and collective identities, as well as in shaping group membership, differentiation, and exclusion (Twiss 2007: 1-2, 2012; Hastorf 2017: 3). With their well-codified material assemblage related to food preparation and consumption, the Kura-Araxes (hereafter KA) culture is an excellent case to test the hypothesis that cooking and food may unconsciously reveal the structure of a society (e.g. Levy-Strauss 1968) and potentially explain the structuring of a shared socio-cultural identity (Greenberg 2007: 266). This research aims to offer new insights to the discussions on KA life, socio-economic practices, and cultural identity using stable carbon and nitrogen isotope ratios analysis of human and faunal skeletal as well as botanical remains in the geographical context of the southern Caucasus.

The Caucasus, located between the Black Sea to the west and the Caspian Sea to the east, links Europe to Asia through the Great Caucasus mountain. This region is characterised by a mosaic of environments due to a strong climatic west-east gradient (humid subtropical to semi-arid continental) combined with an effect of the altitudinal gradient (sea level at over 5,000 m). In the middle part of the Kura River, the climate favors temperate grasslands, while eastward, in the Kura and Araxes valleys, the open steppes of the lowlands have a drier climate (Decaix 2012). In the middle Araxes River and

adjacent uplands, the climate leaves more wooded and humid vegetation. Paleoenvironmental data agree on a clear improvement of the climate between the Neolithic and the Bronze and Iron Ages, with different types of environment in different areas. The plain around the Kura and Araxes valleys appears to have retained its steppe character over time with the presence of Chenopodiaceae, Amaranthaceae, and Poaceae (Messenger et al. 2016, 2020). Several species of these steppe plants are C₄ plants that may have impacted the diet of the herds, leaving a C₄ footprint not necessarily due to millet consumption, which is only attested from the Middle Bronze Age in the South Caucasus (Herrschcher et al. 2018a, 2018b).

ON THE KURA-ARAXES CULTURAL TRADITION

CHRONOLOGICAL CONTEXT

The Kura-Araxes (ca. 3500-2500 BC) is one of the most durable and extensive cultural traditions in the Ancient Near East. Emerging and developing in the South Caucasus as early as the mid-4th millennium, the KA culture broke its pristine geographic boundaries and spread across wider areas towards the end of the fourth millennium. By the second quarter of the 3rd millennium BC, various elements of the Kura-Araxes repertoire are found throughout Anatolia, the South Caucasus, the Iranian plateau and the Levant (e.g. Sagona 1984, 2018; Palumbi 2008, 2016; Greenberg and Goren 2009; Chataigner and Palumbi 2014). This "expansion" has resulted from and involved complex dynamics and processes of cultural transmission in which human mobility and migration played a part (Greenberg and Goren 2009; Paz 2009; Batiuk 2013; Greenberg, Palumbi 2014; Rothman 2015). While the KA cultural phenomenon is highly distinctive, its expressions are not always uniform, and appear to represent multiple communities that shared many, but not all, material elements and traditions (Paz 2009; Palumbi and Chataigner 2014; Sagona 2018). Around the mid-third millennium, the KA communities disappear and their cultural traditions rapidly dissolve. The dynamics and factors behind this process are puzzling, but the changes that followed were sharp and radical in all terms. The conservatism of the Kura-Araxes ceramics gives way to new ceramic horizons (Martqopi and Bedeni). The stability of the Kura-Araxes villages is replaced by evanescent and flimsy traces of what appear short-lived and temporary occupations. In the frame of the generalised adoption of a new mobile

life-style, the, often very imposing, funerary mounds (kurgans) become new and more permanent landmarks of the landscape. Wooden wagons, as well as impressive concentrations of metals and golden jewelry contained in some of these kurgans (Makharadze et al. 2016) hint at the emergence of élites and hierarchised communities as well as at the new role that production, circulation and accumulation of metals played in constructing vertical inequalities among the so-called “Early-Kurgans” societies.

DAILY LIFE: SETTLEMENT PATTERNS AND AGRO-PASTORAL STRATEGIES

The KA communities were the first to live permanently in the mountains and highlands of the South Caucasus. It is still unclear if the process of sedentarisation in the mountains was the result of warmer and more stable climatic conditions (Connor and Kvavadze 2014) and/or to the adoption of new subsistence strategies. Both lowland and highland communities lived in small villages composed of small domestic units (with the exception of some small, and possibly communal, shrines). In spite of the large regional variability of architectural plans and building materials, the KA houses featured a recurrent set of principles related to the activities carried out in their interiors. Not only did KA houses host subsistence and production activities, but the spatial and symbolic centrality of the fire-places, trefoil-shaped hearths and anthropomorphic and zoomorphic andirons suggests that these fire-installations, were also the symbolic foci of ritual practices, beyond being the centre of cooking activities (Sagona 1998; Smith 2015). As to the “ingredients” that could have been consumed in the KA houses, archaeobotanical and archaeozoological data provide useful data to reconstruct diets and subsistence strategies. While in the past a strong pastoral and mobile connotation was suggested, both archaeobotanical and faunal data show that the KA communities were leading a settled type of lifestyle founded on an integrated agro-pastoral economy (Longford 2015; Sagona 2018; Decaix et al. 2019). The former data show that in comparison to the more diversified Chalcolithic and Neolithic agriculture recording a higher frequency of pulses (Hovsepian 2015; Longford 2015), the KA groups mainly practised cereal-focused agriculture, with barley, and wheat representing the most cultivated crops (Hovsepian 2015; Longford 2015; Messenger et al. 2015; Decaix et al. 2019). While barley often predominated in the upland settlements, wheat also played an important role at some sites (Longford 2015;

Decaix et al. 2019) and it has been suggested that this wheat-barley changing ratio could have been a strategy of the KA farmers aimed at minimising risks of crop failure (Hovsepian 2015; Sagona 2018). Conversely to agriculture, the KA animal husbandry strategies were more diversified and did not show a uniform regional trend (Decaix et al. 2019). In general, caprines were the most common reared species (with sheep usually outnumbering goats); however, a higher incidence of, and preference for, cattle can be observed at some sites, while pigs were rare and mainly reared in the plains (Badalyan et al. 2008; Badalyan et al. 2014; Sagona 2018; Decaix et al. 2019; Samei et al. 2019). These data point to an absence of specialised husbandry strategies among the KA communities which, by means of diversification of the reared species seem to aim at herd security management and risk minimisation strategies (Samei et al. 2019). Similar strategies were also deduced from kill-off patterns focused at once on the maintenance of herd security and on the exploitation of meat rather than on specific secondary products (Piro 2008; Badalyan et al. 2014; Samei et al. 2019).

A NEW CERAMIC TRADITION FOR NEW FOOD-WAYS?

Ceramics are among the most “diagnostic” components of the KA culture (fig. 1A). In comparison to the Chalcolithic pottery, the “new” KA ceramics embodied a radically different *chaîne opératoire* and morphological repertoires (Sagona 2014). A significant investment in terms of time and labour for an accurate burnishing and polishing of the surfaces, conferred a very distinctive shiny appearance to the Kura-Araxes ceramic containers thus enhancing their aesthetic impact (Iserlis 2009; Iserlis et al. 2015). Simultaneously, the contrastive red-black pattern between the exterior (black) and interior (red) surfaces which became an aesthetic “hallmark” of the KA ceramics, might have strengthened, as proposed by Greenberg (2007), symbolic connections between colour codes and vessels functions. All this could have aimed at “structuring the cultural attitudes to food and cooking” (Greenberg 2007) which reinforced the KA cultural identity throughout the large geographical area (Iran, East Anatolia and the Levant) involved in the expanse of this tradition. As a whole, the new aesthetics may stress a new role and meaning that the KA ceramics acquired in the frame of food-related practices. As to the latter, the KA containers also featured a very original morphological repertoire. Tall-necked jars with ovoid bodies, large S-shaped bowls



Fig. 1 – A. Kura-Araxes ceramics of the second half of the fourth millennium (Phase KA I). a. Kharnut; b, e. Elar; c. Mentesh Tepe (after Lyonnet and Guliyev 2012; b, c, e at the same scale); d. Gegharot (photo © R. Badalyan). **B.** Individual #669 excavated in the KA collective burial at Gegharot (T2E.662; photo © R. Badalyan).

and circular lids are among the most common shapes to appear from the earliest stages of the KA tradition and represented a very distinctive and quite standard cooking-assembly. The latter was significantly different from those of the Chalcolithic period and points to the emergence of new (and possibly different) practices related to the preparation, cooking and consumption of food. On this note, T. Wilkinson has suggested that the appearance of lids and the frequent occurrence of jars in the KA repertoires point to a shift in the alimentary practices, possibly more focused on boiling, stewing or steaming of foods than they were in the Chalcolithic period (Wilkinson 2014). Notwithstanding the diachronic regionalisation of the repertoires and decorative styles, a series of aesthetic, morphological and functional traits remained basically stable throughout the whole duration of this tradition (Badalyan 2014). Did this conservatism mirror a precise set of codified food-related functions that the KA vessels performed over time?

FUNERARY TRADITIONS

The funerary contexts, from which all the anthropological materials analysed in this paper derive, provide insightful data on both cultural variability and on the organisational principles of the KA society. Different types of structures, such as pit burials, stone-cists, stone constructed, horse-shoe shaped, kurgans and catacomb tombs express highly diversified

funerary traditions (Sagona 2004; Poulmarc'h et al. 2014). Similarly, the presence of both single and multiple inhumations (sometimes in the same cemetery), as well as primary and secondary burials (sometimes in the same tomb) testify to very diversified practices and choices related to both funerary recruitment and treatment of the bodies (fig. 1B; Poulmarc'h et al. 2014). In spite of this high variability two main “structuring” concepts were observed. First, there is a narrow range of not abundant grave-goods, usually including ceramic vessels, spindle-whorls, lithic tools and metal artefacts. The latter is usually limited to few body ornaments (double-spiral headed pins and hair-spirals are among the most common ones) but large concentrations of metals in the same tomb are usually very rare. As already pointed out (Palumbi 2007, 2008; Smith 2015), the restricted variability and the small quantities of the grave goods communicate a strong sense of repetitiveness and standardisation of the funerary practices that, altogether with the lack of concentrations of prestige items, emphasise a highly prescriptive and egalitarian funerary ideology.

Second, though single burials were a common practice, multiple burials are also found, possibly enlightening on another important concept structuring the social organisation of these communities. The number of people buried in the same funerary structure is highly variable, ranging from a few to several dozens of individuals as in the case of the kurgans in Western Azerbaijan (Poulmarc'h et al. 2014; Laneri et al.

2020). Moreover, these multiple tombs hosted people of both sexes and of different classes of age (Poulmarc'h 2014; Erdal et al. 2019) thus highlighting an inclusive funerary ideology pointing probably to a kinship-based organisation.¹

In conclusion, the KA cultural package includes red-black and monochrome burnished ceramics produced through a unique traditional *chaîne opératoire*, typical houses with central hearths and decorated andirons, burials, symbolic artefacts, and specific forms of metal. Recent archaeobotanical and archaeozoological research also highlighted distinctive farming and animal husbandry practices (e.g. Berger 2013, 2018; Hovespyan 2015; Longford 2015; Samei et al. 2019) that established a mixed agro-pastoral based economy (Sagona 2018: 273-279; Decaix et al. 2019) of the KA groups that mostly appear as sedentary communities. Lack of evidence for socio-economic differentiation in the various components of the KA repertoire, suggests an egalitarian model for Kura-Araxes populations (Palumbi 2008; Poulmarc'h 2014; Sagona 2018).

Within this archaeological framework, the goal of this archaeometric study is to explore the evolution of KA dietary habits through time, at various scales. What were their dietary preferences, were they similar for all members of a community, and how were they related to their environment considering the various ecological niches of the southern Caucasus? To disentangle these issues, this research explores the isotopic variability of human dietary choices at the individual and populational levels using data from a sample of sites spanning the KA and Post-KA periods and located across the highland and lowland of the southern Caucasus in Georgia (8 sites), Armenia (3 sites), and Azerbaijan (1 site).

PALAEODIETARY RECONSTRUCTION IN THE SOUTHERN CAUCASUS: AN ISOTOPIC APPROACH

Stable carbon and nitrogen isotope ratios measured on collagen are one of the most suitable proxies to accurately identify dietary characteristics and provide metabolic information on the nature of dietary proteins (terrestrial, marine) and their trophic levels (plants, meat) corresponding to the last diets (10-15 years) of the individual's life (Katzenberg 2008).

This isotopic analysis documents food items' dietary contribution with high trophic levels, such as animal proteins (domestic and wild animals, meat/milk) and freshwater fish, in the southern Caucasus. Consumer tissues are systematically enriched in heavy isotopes in comparison to diet. Isotopic fractionation between two consecutive (prey-predator) trophic levels is between 0 and 1‰ for carbon, between 3 and 5‰ for nitrogen (Bocherens and Drucker 2003; Hedges and Reynard 2007).

C₃-plants and terrestrial organisms are depleted in the heavier stable carbon isotope (¹³C) compared to C₄-plants and marine organisms (Smith and Epstein 1971; Schoeninger and DeNiro 1984; Fischer et al. 2007). Considering the location of archaeological sites far from the Black and Caspian seas and their position mostly above 1,100 m of altitude, marine resource consumption is not of significant interest. Conversely, the detection of C₄-plant consumers in contrast to wheat or barley consumers (C₃-plants) can be of interest since wild C₄-plants are documented across the southern Caucasus (Decaix 2012). Following a predictable stepwise enrichment in ¹⁵N between each successive trophic level (3-5‰; Bocherens and Drucker 2003), nitrogen stable isotope ratios are expected to be lower for plant protein consumers than for animal protein consumers, and for aquatic protein consumers (O'Connell et al. 1999). Marine protein consumption can be recognised thanks to the positive correlation between carbon and isotope values (Valentin et al. 2014). Nevertheless, it is harder to identify freshwater fish consumption because of their wide isotopic variability (Dufour et al. 1999; Katzenberg and Weber 1999). The possible detection of legume consumers from perceptible low δ¹⁵N collagen values can also be of great interest in the southern Caucasus as it was hypothesised for the Neolithic Mentesh Tepe population (Herrscher et al. 2018a).

Even though most of the mechanisms involved in isotope transfers along the food chains are understood, it is also well-demonstrated they rely on complex physiological processes involving numerous factors such as the environment, climate, or anthropic pressure. Altering plants' carbon and isotope ratios at the base of the food chain can consequently modify isotope ratios at the tissue consumer level (Heaton 1999; Schwarcz et al. 1999; van Klinken et al. 2000; Bogaard et al. 2007). Besides, isotope ratios recorded at bone tissue level may also be affected by particular physiological, pathological, or chronic conditions, such as osteomyelitis, fractures, metabolic disorders, as well as transitory states, like pregnancy or anorexia (Katzenberg and Lovell 1999; Fuller et al. 2004; Mekota et al. 2006). Thus, to reliably interpret human isotope ratios, controlling for local environmental and anthropic

1. Systematic aDNA analyses on Kura-Araxes collective tombs need to verify this assumption.

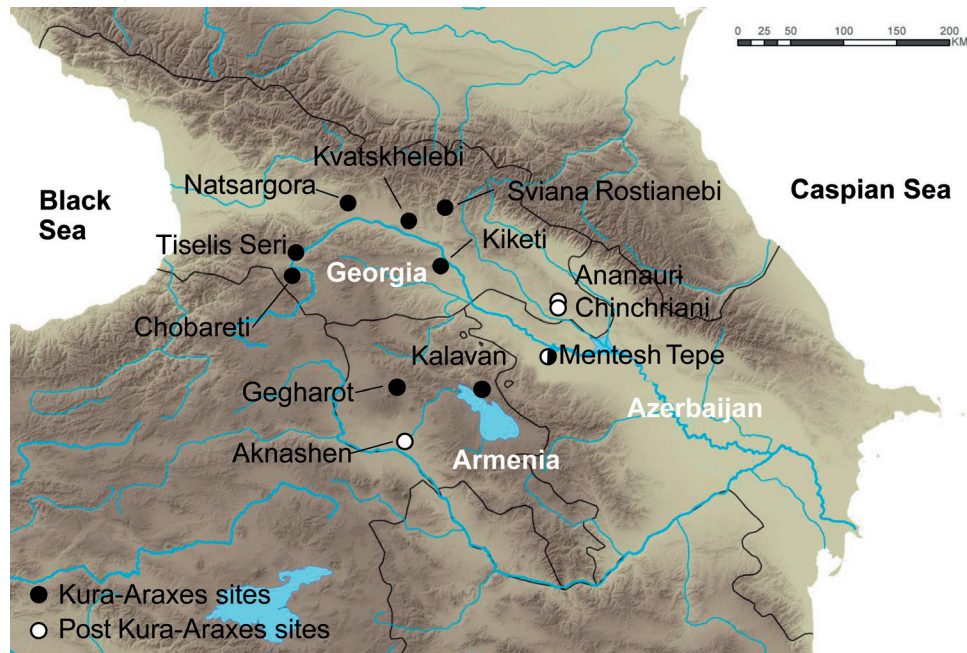


Fig. 2 – Location of Kura-Araxes and Post Kura-Araxes archaeological sites across the Southern Caucasus.

factors, as well as biological variables, is required (Herrscher and Le Bras-Goude 2010). Consequently, one of the first step to improve palaeodietary reconstruction is to provide a detailed description of local isotopic variability, including animal and plant dietary resources, in conjunction with anthropological criteria, such as age at death, sex, and pathologies. However, even in a detailed isotopic context, it is important to keep in mind that several combinations of food resources (mixtures) may lead up to similar isotopic records in consumer tissues, so the proposed reconstructions should always be considered with caution.

MATERIALS: ARCHAEOLOGICAL CONTEXT, SAMPLE PREPARATION AND ISOTOPIC MEASUREMENTS

ARCHAEOLOGICAL SAMPLING STRATEGY

To increase the isotopic reference base of archaeological food resources in Georgia and explore isotopic variability between highland and lowland KA communities, new analyses were performed on faunal remains recently excavated at Natsargora site near the Kura valley at 770 m asl, in the Shida-Kartli province (Puturidze and Rova 2012; Rova et al. 2017; n = 9) and at Sviana-Rostianebi site located in the south

foothills at 1550 m asl of the Great Caucasus in Dusheti area (Ramishvili et al. 2004; Gogochuri 2010; n = 13). In addition, analyses were also conducted on the bioarchaeological material excavated from Kvatskhelebi (humans, fauna and cereals, n = 42), located on the Kura river at 635 m asl, in Georgia in the Shida Kartli (Javakhishvili and Glonti 1962; Sagona 1984; Palumbi 2008). These new data were compared to isotopic sets of data already published for highland communities, located between 1,200 and 1,600 m asl in Georgia, respectively from the site of Kiketi site in Kvemo-Kartli, nearby Tbilisi and the sites of Chobareti and Tiselis Seri in the southern part of the territory overlooking the Turkish border (Messenger et al. 2015; Herrscher et al. in press; n = 59; fig. 2).

For synchronic comparisons across the southern Caucasus, additional previously published data from Mentesh Tepe in the Middle Kura valley in Azerbaijan were also considered (Herrscher et al. 2018b) and new data from two KA sites located in Armenia, Kalavan-1 (n = 5) north of Lake Sevan and Gegharot (n = 3) in the Tsaghkahovit plain. In total, the research presented here is based on 144 KA isotopic samples from the three South Causasian countries, with a total of 34 human, 85 animal and 25 botanical remains. For diachronic comparisons across the southern Caucasus, 39 isotopic samples either already published (Ananauri, Chinchriani in Georgia; Herrscher et al. 2016) or unpublished (Aknashen in the Ararat plain; n = 1) corresponding to the Post KA period (the so-called “Early Kurgans” cultures) were also considered (fig. 2; table 1).

Table 1 – Description of samples used in this isotopic study according to sites, territories, and chronological attribution.

*: New isotopic data are published in this study for one barley seed.

	Kura Araxes				Post Kura Araxes/Early Kurgan				Total	Isotopic references
	Humans	Animals	Plants	Total KA	Humans	Animals	Plants	Total P-KA		
Georgia										
Chobareti	10	21	8*	39					39	Messenger, Herrscher et al. 2015
Tiselis Seri	6			6					6	Herrscher et al. in press, In: Marro Stoëllner
Kiketi	7	7		14					14	Herrscher et al. in press, In: Marro Stoëllner
Kvatskhelebi	3	30	9	42					42	This study
Natsargora		9		9					9	This study
Sviana-Rostiaanebi		13		13					13	This study
Ananaouri					20	5		25	25	Herrscher et al. 2016
Chinchriani						3		3	3	Herrscher et al. 2016
Armenia										
Kalavan1	4	1		5					5	This study
Gegharot	3			3					3	This study
Aknashen					1			1	1	This study
Azerbaijan										
Mentesh Tepe	1	4	8	13	4		6	10	23	Herrscher et al. 2018
Grand total	34	85	25	144	25	8	6	39	183	

THE ARCHAEOLOGICAL SITES INCLUDED IN THE STUDY

Natsargora: located in the Kashuri district in Shida Kartli, 7 km from the Kura river, at 770 m asl. Excavations were first directed by a Georgian team between 1984 and 1992 and later by a Georgian-Italian team in 2011-2012 (Puturidze and Rova 2012; Rova et al. 2017). The site consists of a small mound and the most recent excavations suggest a KA settlement that was abandoned and then a re-occupation of the site during the Early Kurgan period. Based on archaeological data and radiocarbon dates, the settlement is dated to the KA II (Rova 2014). Although twenty-six Early Bronze Age pit burials were excavated by the Georgian expedition (Puturidze et al. 2012), bone samples were not available for any of them. In contrast, a sampling of ten animal bone remains from the KA settlement was done thanks to the 2011 Georgian-Italian excavation (Rova et al. 2017). According to archaeological data, all bones are dated from the KA period and the sample consists of three cattle, three sheep or goats and three pigs as well as one *Cervus* sp. specimen (tables 2, 3).

Sviana-Rostianebi: is a settlement located in the territory of Dusheti municipality, near to the area of Mtiuleti Aragvi river-head in the Khada gorge on the left bank of Khadis Tskali. The site is near the village of Sviana-Rostianebi at the altitude of 1,554-1,561 m asl and was discovered in 1988 during the construction of a gas pipeline. Ceramics are typologically compatible with those of the late stages of the KA culture (Ramishvili et al. 2004), as confirmed by one radiocarbon date on an animal bone (table 2). The sampling of animal bone remains was conducted at Dusheti Museum by a specialist to ensure the selection of different individuals. It consists of thirteen remains of domestic animals including four cattle, two sheep or goat, four goats and three wild animals, that is two *Capra caucasica* and one *Cervus* sp. (tables 2, 3).

Kvatskhelebi: Located in the Shida Kartli region in Georgia, it is one of the best-preserved and thoroughly excavated Kura-Araxes sites. Excavations at the site were conducted between 1954-1964 as part of the Urnisi Archaeological Project, and directed by A. Javakhishvili and L. Glonti, but only partly published (Javakhishvili and Glonti 1962; Sagona 1984; Palumbi 2008). The new Kvatskhelebi Research and Publication Project, headed by Sarit Paz, in collaboration with

Table 2 – AMS radiocarbon dates from KA and Post-KA human and animal individuals.
 *: ^{14}C dates were run on a different collagen samples than those used for isotopic analysis (this study).

Sites	#Lab code	^{14}C -Lab Code	Burial	Nature	^{14}C dates results	Calibrated dates cal. BC (95.4% probability)		Bibliography
					Cal. BP	min.	max.	
Kura-Araxes sites								
Kiketi	CG01	Poz-60845	Burial 6, Skull 1	human	4195 ± 35	2895	2666	Herrscher et al. in press
	CG04	Poz-56572	Burial 5,	human	4120 ± 35	3325	2920	Herrscher et al. in press
	CG07	Poz-60846	Burial 4, Skull 3	human	4330 ± 30	3019	2894	Herrscher et al. in press
	GKF02	Poz-60847	Burial 4	Ovis sp.	4315 ± 30	3013	2888	Herrscher et al. in press
	GKF06	Poz-60848	--	Bos sp.	4300 ± 30	3011	2880	Herrscher et al. in press
Chobareti	CHOH05	Poz-56370	Burial 5	human	4460 ± 30	3346	2944	Messenger et al. 2015
	CHOH08	Poz-56371	Burial 9	human	4380 ± 40	3264	2902	Messenger et al. 2015
Sviana-Rostianebi	SVIA F07	Poz-43670		<i>Bos taurus</i>	4195 ± 35	2895	2666	This study
Post-Kura-Araxes sites								
Ananaouri	ANA H02	Sac-43658	Kurgan 3	human	3970 ± 30	2574	2350	Herrscher et al. 2016
	ANAH03	Sac-43659	Kurgan 3	human	3965 ± 30	2573	2348	Herrscher et al. 2016
	ANAH04	Sac-43660	Kurgan 3	human	4020 ± 30	2620	2471	Herrscher et al. 2016
	ANAH08	Sac-43661	Kurgan 3	human	3980 ± 35	2580	2349	Herrscher et al. 2016
	ANAH10	Sac-43663	Kurgan 3	human	3945 ± 30	2567	2341	Herrscher et al. 2016
	ANAH100	Sac-43664	Kurgan 3	human	4010 ± 30	2617	2480	Herrscher et al. 2016
Aknashen	(CAR 06)*	Ly-6992	TR7 UF 5 F2	human	3860 ± 35	2464	2203	Poulmarc'h et al. in press
	(CAR 06)*	UGAMS-6460	TR7 UF 5 F2	human	3830 ± 30	2351	2198	Poulmarc'h et al. in press
Kalavan-1	(CAR 05)*	Lyon-9705	UF 8	human	4020 ± 35	2620	2471	Poulmarc'h et al. 2016
	(CAR 08)*	Poz-2234	UF 9	human	3990 ± 35	2619	2410	Poulmarc'h et al. 2016
Mentesh Tepe	CAZ 103	Poz-63143	ST54 1	human	3920 ± 30	2480	2299	Herrscher et al. 2018
	CAZ 104	Poz-63144	ST54 2	human	3970 ± 30	2575	2350	Herrscher et al. 2018
	AZH400	Poz-82220	ST 54 3	human	3935 ± 35	2558	2295	Herrscher et al. 2018
	AZH228	Poz-68643	ST 54 Ind 5	human	3785 ± 30	2300	2133	Herrscher et al. 2018

Mindia Jalabadze, has been working since 2014 to study and publish the material from the old excavations, with the aid of a research grant from the White-Levy Foundation (Paz forthcoming). The site is located on the north bank of the Kura river, on a flat extension (ca. 635 m asl) rising over 30 m above the river. Several phases of the small village (ca. 3,500 m²) were discovered, among which Stratum C1 was destroyed by conflagration, and yielded remains of 25 structures with hundreds of complete vessels *in situ* in domestic contexts. Several graves from a slightly earlier phase (C3-2) were excavated at the edge of the settlement. The site is dated to the KA II period, with new calibrated dates at ca. 2,900-2,800 BC. Due to the good preservation, Kvatskhelebi provides a unique contribution to the isotopic study, with material from both funerary and

domestic contexts, including human, faunal and botanical remains. The latter two allow us to describe the local environment isotopically. The sampled material included human skeletal remains of three individuals from Tomb #3 and Tomb #2 (Stratum C3-2). Thirty animal bones from Stratum C and B were sampled, including domestic and wild herbivore, carnivores as well as suids. Finally, ten botanical samples of barley and wheat grains from Strata C1 and C3 were analysed (table 4).

Gegharot: is located near Aragats mountains at 2,124 m asl, in the Tsaghkahovit plain. It was excavated by Ruben Badalyan and Adam Smith from 2002 to 2018, in the frame of the Archaeology and Geography of ancient Transcaucasian societies (ArAGATS) project. The Early Bronze Age village,

Table 3 – Elemental and stable isotope data of animals from KA Natsargora (NATS) and Sviana-Rotianebi (SVIA) sites in Georgia. *: Samples radiocarbon dated.

#Lab code	Archaeol. Data	Species	Skeletal Element	Yld (mg/g)	%C	%N	C/N	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)
NATS F10	2011- NTS 0077-E2	<i>Bos</i> sp.	phalanx	180,9	40,5	14,7	3,2	-19,0	5,3
NATS F11	2011- NTS 0077-E2	<i>Bos</i> sp.	skull	127,0	40,6	14,8	3,2	-18,7	5,8
NATS F12	2011 - NTS 0048 E8	<i>Bos</i> sp.	radius	2,9	--	--	--	--	--
NATS F13	2011- NTS 0077-E2	<i>Cervus</i> sp.	teeth	154,0	40,9	14,8	3,2	-20,3	8,9
NATS F14	2011- NTS 0077-E2	<i>Ovis/Capra</i>	teeth	141,4	38,1	13,7	3,2	-20,2	8,7
NATS F15	2011- NTS 0077-E2	<i>Ovis/Capra</i>	scapula	124,1	40,5	14,8	3,2	-20,3	4,8
NATS F16	2011 - NTS 0048 E8	<i>Bos</i> sp.	long bones	36,1	37,2	13,3	3,2	-19,7	7,8
NATS F17	2011- NTS 0077-E2	<i>Sus</i> sp.	phalanx	173,7	41,7	15,1	3,2	-20,3	5,3
NATS F18	2011- NTS 0077-E2	<i>Sus</i> sp.	maxilla	131,6	41,3	14,8	3,2	-15,8	8,2
NATS F19	2011 - NTS 0048 E8	<i>Sus</i> sp.	phalanx	179,5	41,5	15,0	3,2	-20,4	5,3
SVIA F07*	--	<i>Bos taurus</i>	skull	68,3	39,2	14,3	3,2	-18,1	6,4
SVIA F08	--	<i>Bos</i> sp.	mandibula	89,7	38,7	13,8	3,3	-20,1	6,1
SVIA F09	355-10	<i>Bos</i> sp.	maxilla	51,5	35,8	12,6	3,3	-19,6	5,8
SVIA F10	bag 21	<i>Bos</i> sp.	molar	46,2	37,8	13,5	3,3	-20,2	5,9
SVIA F01	--	<i>Ovis/Capra</i>	calcaneum	119,9	40,6	14,6	3,2	-19,8	4,0
SVIA F02	bag 21	<i>Ovis/Capra</i>	calcaneum	134,8	39,6	14,0	3,3	-20,0	4,3
SVIA F03	493-10	<i>Capra hircus</i>	corn	115,4	38,8	13,9	3,2	-19,0	4,0
SVIA F04	363-10	<i>Capra hircus</i>	corn	137,4	41,1	14,7	3,2	-19,9	4,5
SVIA F05	361-10	<i>Capra hircus</i>	corn	109,6	40,3	14,4	3,2	-19,7	4,2
SVIA F06	--	<i>Capra hircus</i>	corn	107,9	40,3	14,4	3,3	-19,4	4,3
SVIA F12	bag 21	<i>Capra caucasicus</i>	skull	108,6	38,1	13,6	3,3	-19,6	4,5
SVIA F13	--	<i>Capra caucasicus</i>	corn	117,5	39,5	14,0	3,3	-19,6	4,0
SVIA F11	bag 21	<i>Cervus</i> sp.	maxilla	67,6	39,1	13,9	3,3	-19,3	3,3

established on a hill, has been occupied during two phases of the KA horizon. The early phase (ca. 3500/3350-2900 BC) yielded a collective funerary deposit including two to three adult individuals and one child buried in a square constructed tomb (fig. 1C; Badalyan et al. 2008; Poulmarc'h 2014; Poulmarc'h et al. in press). The isotopic analyses from Gegharot were carried out on three human remains of the collective tomb (tables 2, 5).

Kalavan-1: is an open-air site situated 1,640 m asl on the south-west-facing slopes of the Aregunyats Range north of Lake Sevan. Archaeological and geological investigations were conducted between 2005 and 2009 as part of a collaborative Armenian and French project "Mission Caucas" (French Ministry for Foreign Affairs, dir. C. Chataigner; Montoya et al. 2013). The excavation revealed two main levels of occupation dated to the Terminal Palaeolithic, overlaid by a KA burial ground. Due to the steep topography above Kalavan-1, only a limited exposure of the archaeological remains could be made.

Five burial pits were uncovered, four of which contained single primary burials; the fifth held the remains of at least three individuals. Six consistent ^{14}C dates on human skeletal material bracket the use of the burial site between ca. 2850 and 2490 cal BC (Poulmarc'h et al. 2016). The isotopic analyses from Kalavan 1 were carried out on four human bones from four single burials (tables 2, 5).

Aknashen-Khatunarkh: is located in the Ararat Plain, at 838 m asl m. The settlement mound was excavated by Ruben Badalyan and Armine Harutyunyan from 2004 to 2019, in the frame of the "Mission Caucas". Neolithic and Chalcolithic levels were uncovered, as well as many burials ranging from the 6th millennium to the contemporary period. One of the burials (TR7 UF5 F2), cut into the Neolithic levels, is dated to the second half of the third millennium, that is from the Post KA period (Badalyan et al. 2010). This subadult was sampled for isotopic analyses (tables 2, 5).

Table 4 – Elemental and stable isotope data of humans, animals and cereals from KA Kvatskhelebi site (KVAT) in Georgia.
VS: variable shape.

#Lab code							Yld (mg/g)	%C	%N	C/N	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)
Humans	Archaeol. Data	Age	Sex	Skeletal Element	Burial type	Funerary type						
KVAT H01	C3; Burial 1	Adult	M	coxal	VS	Double	101,8	40,2	15,0	3,1	-18,2	10,6
KVAT H02	C3; Burial 1	Adult	F	coxal	VS	Double	183,3	39,4	14,7	3,1	-18,9	10,4
KVAT H03	C3; Burial 3	Adult	I	humerus	VS	Single	27,2	35,4	13,0	3,2	-18,8	9,8
Animal	Archaeol. Data	#Collection	Species									
KVAT F01		Burial 1	<i>Bos taurus</i>	radius			168,8	41,4	15,5	3,1	-19,3	7,6
KVAT F02	C	Settlement	<i>Bos taurus</i>	skull			25,6	34,7	12,6	3,2	-18,0	5,8
KVAT F03	B; Ex. 1964'?	#15-55:531	<i>Bos sp.</i>	maxilla			60,5	40,0	14,9	3,1	-18,9	6,5
KVAT F04	C2N1	#214	<i>Bos sp.</i>	scapula			148,5	41,6	15,6	3,1	-19,2	6,2
KVAT F05	C2	#215	<i>Bos sp.</i>	scapula			120,5	41,4	15,2	3,2	-19,4	5,7
KVAT F06	C2N1 ; 1958'	#219	<i>Bos sp.</i>	scapula			128,9	42,4	15,6	3,2	-19,4	6,2
KVAT F07	B; Excavated area 1958'	#248	<i>Bos sp.</i>	metacarpal			84,7	41,5	15,5	3,1	-19,9	7,4
KVAT F08	B; from squares; 1958'	#260	<i>Bos sp.</i>	calcaneus			75,2	35,6	13,4	3,1	-19,7	7,1
KVAT F09	B; from squares; 1959'	#272	<i>Bos sp.</i>	calcaneus R			69,6	43,0	14,5	3,4	-21,5	5,0
KVAT F11	B; 1958'	#275	Bison	calcaneus			109,9	41,7	15,4	3,1	-18,9	5,3
KVAT F12	C		<i>Ovis aries</i>	skull			71,8	35,3	12,9	3,2	-19,7	6,1
KVAT F13	B; Trench 1; 1958'	#94	<i>Ovis/ Capra</i>	scapula			139,6	41,0	15,2	3,1	-18,3	6,9
KVAT F14	B; 2nd; 3rd Building	#98	<i>Ovis/ Capra</i>	scapula			124,5	41,2	15,3	3,1	-19,4	4,5
KVAT F15	B1	#561	<i>Ovis/ Capra</i>	mandibula			113,2	41,6	15,3	3,1	-18,5	6,7
KVAT F16	B1	#570	<i>Ovis/ Capra</i>	mandibula			93,1	41,0	15,3	3,1	-19,2	6,2
KVAT F17	B1	#575	<i>Ovis/ Capra</i>	mandibula			58,2	40,9	15,2	3,1	-16,4	5,8
KVAT F18	B1	#586	<i>Ovis/ Capra</i>	maxilla			117,2	41,1	15,2	3,1	-18,8	5,8
KVAT F19	B; Trench 2; 1958'	#57	<i>Capra sp.</i>	horn			112,2	40,6	15,1	3,1	-18,6	6,0
KVAT F20	B1	#584	<i>Capra sp.</i>	skull			111,4	40,6	14,9	3,1	-19,3	6,5
KVAT F21	C1N1; 1958'	#301	<i>Sus scrofa</i>	femur			30,6	32,6	12,0	3,1	-16,1	5,4
KVAT F22	C1N2; 1958'	#355	<i>Sus scrofa</i>	skull			48,7	40,7	14,9	3,2	-14,7	5,6

#Lab code	Archaeol. Data	#Collection	Species			Yld (mg/g)	%C	%N	C/N	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)
Animal	Archaeol. Data	#Collection	Species								
KVAT F23	C1N2; 1964'	#15-55:268	<i>Canis familiaris</i>	skull		27,4	39,4	14,7	3,1	-18,3	10,0
KVAT F24	C1N1; 1958'	#306	<i>Canis familiaris</i>	mandibula		127,0	40,8	15,2	3,1	-18,0	10,0
KVAT F25	C1N1; 1958'	#307	<i>Canis familiaris</i>	mandibula		170,1	42,1	15,8	3,1	-17,9	8,2
KVAT F26	BN1 & N2; 1958'	#313	<i>Equus</i> sp.	pubis		156,1	42,2	15,7	3,1	-20,3	4,5
KVAT F27	C	#218	<i>Equus caballus</i>	scapula		37,4	19,4	6,9	3,3	-18,9	6,8
KVAT F29	B; Trench 1; 1958'	#60	<i>Cervus elaphus</i>	antler		116,2	41,6	15,4	3,1	-20,2	3,1
KVAT F30	B; from squares; 1968'	#314	<i>Cervus elaphus</i>	antler		143,3	40,8	15,2	3,1	-20,8	3,8
KVAT F31	B; N1 & N2; 1958'	#316	<i>Cervus elaphus</i>	antler		10,3	35,7	12,8	3,2	-21,1	3,6
KVAT F32	C; N1; 1959'	#435	<i>Cervus elaphus</i>	metacarpal		65,3	40,5	14,9	3,1	-20,3	5,4
Plant	Archaeol. Data	#Sample	Species	Tissue							
KVAT P01	C1N1	Sample 1	<i>Hordeum vulgare</i>	seed		93,1	61,4	4,6	15,3	-24,0	7,9
KVAT P02	C1N1	Sample 1	<i>Hordeum vulgare</i>	seed		6,9	--	--	--	--	--
KVAT P03	C1N1	Sample 1	<i>Hordeum vulgare</i>	seed		87,8	60,9	6,0	11,7	-23,6	5,1
KVAT P04	C1N1	Sample 1	<i>Hordeum vulgare</i>	seed		87,4	59,5	5,3	13,0	-25,1	7,3
KVAT P05	C1N1	Sample 1	<i>Hordeum vulgare</i>	seed		72,3	66,3	6,0	12,9	-23,4	8,6
KVAT P06	C3N3	Sample 8	<i>Triticum aestivum</i>	seed		67,6	60,1	4,1	17,0	-21,8	5,4
KVAT P07	C3N3	Sample 8	<i>Triticum aestivum</i>	seed		79,5	61,3	4,7	15,1	-21,7	6,3
KVAT P08	C3N3	Sample 8	<i>Triticum aestivum</i>	seed		35,1	60,6	4,8	14,6	-21,5	4,4
KVAT P09	C3N3	Sample 8	<i>Triticum aestivum</i>	seed		67,2	59,1	5,6	12,3	-21,5	6,2
KVAT P10	C3N3	Sample 8	<i>Triticum aestivum</i>	seed		67,0	60,8	4,3	16,4	-22,4	6,1

METHODOLOGICAL ASPECTS

PROTOCOLS, ISOTOPIC MEASUREMENTS

The collagen extraction was performed at the Laboratoire méditerranéen de Préhistoire Europe-Afrique, Aix Marseille University. Collagen extraction was performed according to the protocol of Longin (1971) modified by Bocherens et al.

(1991). After cleaning the bone specimens (~ 250 mg) with distilled water, each sample was ground into a powder (> 700 μm for collagen and < 700 μm for apatite). One in-house lab standard of archaeological bovine bone powder is included in all batches to ensure the quality of the extraction procedure. The protocol calls for an acidic soak on stirrer (HCl 1M, 20') for demineralisation, following by a soak in a basic solution (NaOH 0.125M, < 18 hours) to remove humic contaminants.

Then, collagen was solubilised in a weakly acidic solution (HCl pH = 2, 17 hours, 100°C), and the purified “collagen” was lyophilised for 48 hours.

Pre-weighted bone collagen samples were analysed by a Europa Scientific elemental analyser connected to a Europa Scientific 20-20 (IRMS) at Iso-Analytical Limited (Cheshire, UK). Stable isotopes were measured relative to standards (V-PDB for carbon, AIR for nitrogen) and expressed in parts per mil (‰). The reference material for collagen is IA-R068 (soy protein, $\delta^{13}\text{C}_{\text{V-PDB}} = -25.22 \pm 0.02\text{‰}$, $\delta^{15}\text{N}_{\text{AIR}} = 0.99 \pm 0.07\text{‰}$), and for seed, IA-R001 (wheat flour, $\delta^{13}\text{C}_{\text{V-PDB}} = -26.43 \pm 0.02\text{‰}$, $\delta^{15}\text{N}_{\text{AIR}} = 2.55 \pm 0.02\text{‰}$). For collagen samples, measurements uncertainty was monitored using check samples with well characterised isotopic compositions: IA-R038 (L-alanine, $\delta^{13}\text{C}_{\text{V-PDB}} = 24.99 \pm 0.06\text{‰}$, $\delta^{15}\text{N}_{\text{AIR}} = -0.65 \pm 0.04\text{‰}$), IA-R069 (tuna protein, $\delta^{13}\text{C}_{\text{V-PDB}} = -18.88 \pm 0.05\text{‰}$, $\delta^{15}\text{N}_{\text{AIR}} = 11.60 \pm 0.09\text{‰}$) and a mixture of ammonium sulfate and IA-R046/IAEA-C7 (oxalic acid, $\delta^{13}\text{C}_{\text{V-PDB}} = -14.48 \pm 0.21\text{‰}$, $\delta^{15}\text{N}_{\text{AIR}} = 22.04 \pm 0.06\text{‰}$). Quality control check samples are calibrated and traceable to the international standards IAEA-CH-6 and IAEA-N-1.

For seeds measurements, measurements uncertainty was monitored using check samples with well characterised isotopic compositions: IA-R045/IA-R005 (mixture of ammonium sulfate and beet sugar, $\delta^{13}\text{C}_{\text{V-PDB}} = -26.03 \pm 0.11\text{‰}$, $\delta^{15}\text{N}_{\text{AIR}} = -4.71 \pm 0.07\text{‰}$), IA-R046/IA-R006 (mixture of ammonium sulfate and cane sugar, $\delta^{13}\text{C}_{\text{V-PDB}} = -11.64 \pm 0.03\text{‰}$, $\delta^{15}\text{N}_{\text{AIR}} = 22.04 \pm 0.06\text{‰}$). Quality control check samples are calibrated and traceable to the international standard IAEA-CH-6 and IAEA-N-1. Using calculation provided by Szpak et al. (2017) based on repeated measurements of calibration standards, check standards and sample replicates, precision ($u(R_w)$) was determined to be $\pm 0.19\text{‰}$ and $\pm 0.15\text{‰}$ respectively for collagen and seed $\delta^{13}\text{C}$, and $\pm 0.04\text{‰}$ for collagen $\delta^{15}\text{N}$ and $\pm 0.07\text{‰}$ seed $\delta^{15}\text{N}$. The total analytical uncertainty is estimated, for collagen, to be $\pm 0.18\text{‰}$ for both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$, and for seed, to be $\pm 0.19\text{‰}$ for $\delta^{13}\text{C}$ and $\pm 0.15\text{‰}$ for $\delta^{15}\text{N}$.

Collagen preservation was checked according to several criteria, such as the yield of extraction ($\geq 10 \text{ mg.g}^{-1}$), the percentages of C and N ($\%C \geq 30 \%$ and $\%N \geq 11 \%$) and the atomic C/N ratio (between 2.9 and 3.6; DeNiro 1985; Ambrose 1990; van Klinken 1999).

STATISTICAL ANALYSIS

Statistical analyses were performed using the statistical program R (version 3.6.1) and RStudio (version 1.2.5033; R Development Core Team 2005; R Core Team 2018). The non-parametric tests, Mann-Whitney-Wilcoxon and Kruskal-Wallis with FDR correction, were used to compare between series. The dependence of variables was tested using the Spearman rank correlation.

PRESERVATION OF NEW SAMPLES OF THIS STUDY

The new samples from Georgia and Armenia produced collagen with a yield above 10.3 mg.g^{-1} for animals and 21.5 mg.g^{-1} for humans (tables 3-5). Carbon and nitrogen percentage yields in the animal and human collagen samples range from 19.4 to 43.1 % for carbon and from 6.9 to 15.8 % for nitrogen. Atomic C:N ratios range between 3.1 and 3.2. Based on the classical criteria used to check the preservation of collagen samples (DeNiro 1985; Ambrose 1990; van Klinken 1999), one animal sample (KVAT_F27) exhibits percentage yields in carbon and nitrogen under the limit mentioned above, nevertheless its atomic C:N ratio confirmed a non-altered collagen. The cereals (wheat and barley; table 3) from Kvatskhelebi exhibit carbon and nitrogen percentages ranging from 59.1 to 61.3 and 4.1 to 6.0, respectively. These values are in line with previous data recorded in southern Caucasus, as well as with the new barley data from Chobareti ($\delta^{13}\text{C}_{\text{V-PDB}} = -22.8\text{‰}$, $\delta^{15}\text{N}_{\text{AIR}} = 6.8\text{‰}$; $\%C = 61\%$ and $\%N = 3.1\%$).

RESULTS AND DISCUSSION

DIVERSITY OF SOUTH CAUCASUS ENVIRONMENTS AND ISOTOPIC VARIABILITY OF DIETARY RESOURCES

All animal species from Georgian sites (Kiketi, Tiselis Seri, Natsargora, Sviana-Rostianebe, and Kvatskhelebi) exhibit $\delta^{13}\text{C}$ values from -21.5 to -12.3‰ ($-18.9 \pm 1.8\text{‰}$, $n = 85$) and $\delta^{15}\text{N}$ values from 3.1 to 11.7‰ ($5.9 \pm 1.6\text{‰}$, $n = 85$; tables 3, 4; Messenger et al. 2015, Herrscher et al. in press). Most animal $\delta^{13}\text{C}$ values (median -19.1‰ and -18.9‰ for lowland and highland respectively) agree with the presence of a C_3 -environment consistent with the type of vegetation coverage in the South

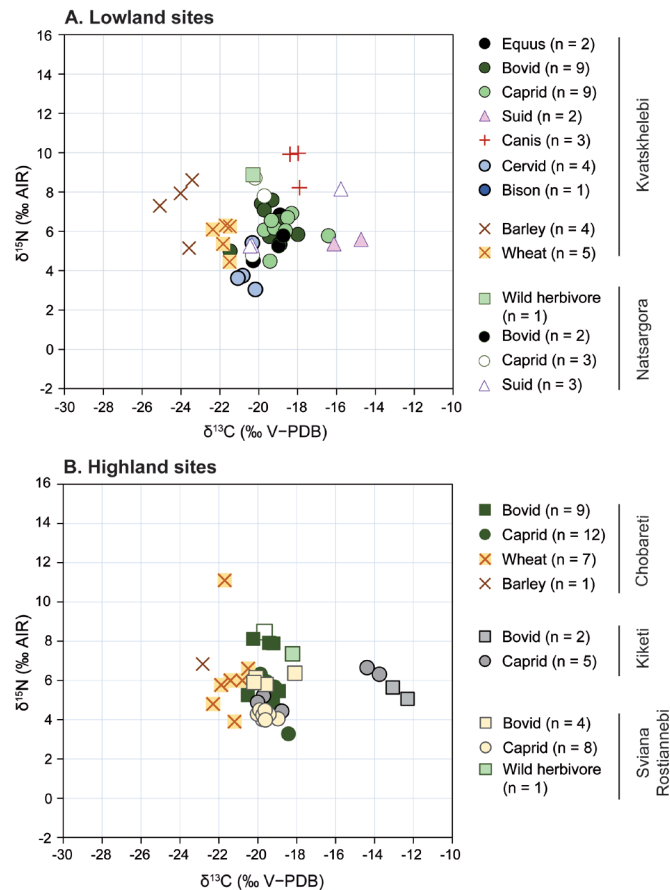


Fig. 3 – Animal and cereal carbon and nitrogen isotope ratios for Georgian archaeological sites. **A.** Sites below 770 m asl, Natsargora, and Kvatskhelebi sites (this study); **B.** Sites above 1,300 m asl, Sviana-Rostianebe (this study) and Kiketi, Tselis Seri, Chobareti sites. After Messager et al. 2015; Herrscher et al. in press.

Caucasus. Several animals show $\delta^{13}\text{C}$ values above -15.8‰ much higher than all other animal carbon isotope values, suggesting the consumption of C_4 -plants (figs. 3A, 3B). These animals are two *Bos Taurus* and two *Ovis/Capra* from Kiketi for highland sites, three *Sus* sp., and one *Ovis/Capra* from Natsargora and Kvatskhelebi for lowland sites. C_4 plants, such as Chenopodiaceae or Poaceae, are widespread in southern Caucasus and preferentially around the Kura Valley (Decaix 2012). This distribution could explain the values recorded for animals from Natsargora and Kvatskhelebi. These high carbon values, only observed for some specimens, could also support different herd management strategies related to a different human social group/family or the animal's age. For the Chobareti specimens, one hypothesis could be a different geographical origin linked either to human or animal mobility through market trade. On the other hand, the latter domestic

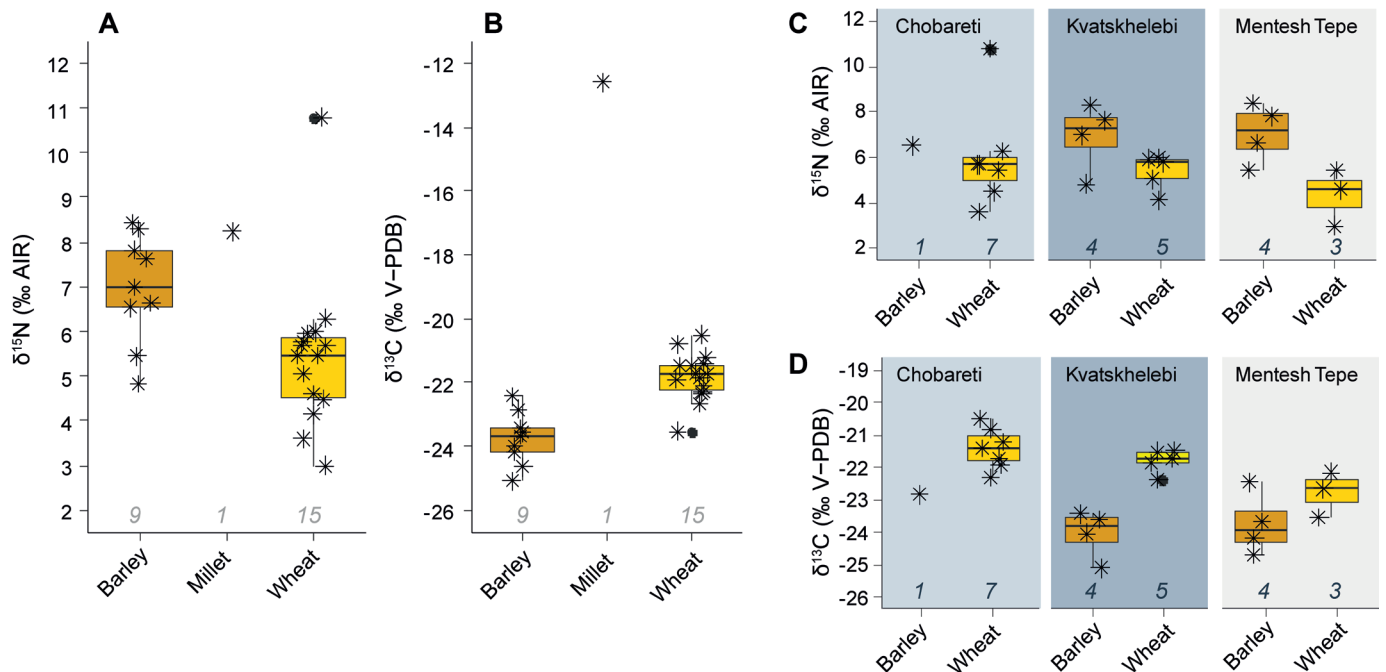
animals' high isotopic values were discovered in association with human skeletons and were used as grave goods. These burial deposits raise a question regarding animals' status and the use of animal remains (as "grave goods") to establish an isotopic baseline of past dietary resources. Kruskal-Wallis tests performed between Georgian sites did not significantly differ in stable isotope ratios of carbon and nitrogen. However, a trend could be noted with the highest nitrogen values for carnivores compatible with their ethology (fig. 3) and the lowest isotopic values for carbon and nitrogen for Kvatskhelebi deer, consistent with the use of a more closed environment than domestic species. Mann-Whitney tests were conducted to identify the differences between animals more precisely, between archaeological sites according to the most represented species: cattle and sheep/goat. Only caprids from Sviana-Rostianebe showed significantly lower values compared to the other sites, while cattle showed similar carbon and nitrogen ratios for all sites. Concerning suids, despite the limited data available only for lowland sites (fig. 3A), $\delta^{15}\text{N}$ values, from 5.3 to 8.2‰ , are similar to those of herbivores, which could indicate a specific herding strategy with foraging based mainly on plants rather than on the usual human waste. Suid $\delta^{13}\text{C}$ values exhibit a wide dispersion from -20.4 to -14.7‰ defining two clusters, one with a median value around -20‰ and a second around -15‰ . These suid specimens from settlement excavations would therefore be more representative of food resources actually consumed by humans. Thus, without rejecting a possible different geographical origin, a herding practice in a free pasture (wild environment with C_4 -plants) could explain the cluster with the highest $\delta^{13}\text{C}$ values. Outside Georgia, only two KA sheep/goat individuals from Kalavan and Mentesh Tepe are available, presenting similar isotopic values with the values of Georgian herbivores (table 5; fig. 6; Herrscher et al. 2018b).

At Kvatskhelebi and Chobareti, cereals $\delta^{13}\text{C}$ values are between -25.1 and -20.5‰ ($-22.8 \pm 0.8\text{‰}$, $n = 24$), and $\delta^{15}\text{N}$ values range between 3.3 and 8.1‰ ($6.5 \pm 1.5\text{‰}$, $n = 24$). For both sites, wheat values appear higher for $\delta^{13}\text{C}$ and lower for $\delta^{15}\text{N}$ compared to barley values. The same significant pattern is observed at Mentesh Tepe (figs. 4C, 4D). Mann-Whitney tests confirm a significant difference for both isotopic ratios between the two types of cereal when sites are pooled ($p\text{-}\delta^{13}\text{C}$ and $p\text{-}\delta^{15}\text{N} < 0.014$; figs. 4A, 4B).

Modification of $\delta^{13}\text{C}$ values with altitude is mentioned for different organisms with an increase of around $1.0\text{-}1.5\text{‰}$ per $1,000$ m (Heaton 1999; Hobson et al. 2003). No such strong effect has been reported for nitrogen stable isotope ratios (Ambrose 2000; Hobson et al. 2003). Other local environmental conditions, such as aridity, densification of vegetation

Table 5 – Elemental and stable isotope data of humans and animals from KA Armenian sites. VS: variable shape; BPM: presence of a box in perishable material

#Lab	Site	Archaeo. data	Grave type	Funerary type	Age/ Species	Sex	Skeletal Element	Yld (mg/g)	%C	%N	C/N	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)
CAR 11	Gegharot	Ind 669	VS	Collective	Adult	M	hand phalanx	197,3	41,7	15,1	3,2	-18,7	9,4
CAR 12	Gegharot	Ind 670-1	VS	Collective	Adult	M	metacarpal 2	152,6	43,1	15,5	3,2	-18,9	10,8
CAR 13	Gegharot	Ind 670-2	VS	Collective	Subadult	I	hand phalanx	192,8	40,4	14,6	3,2	-18,8	9,2
CAR 03	Kalavan-1	2006-UF1	BPM	Single	Adult	F	radius	121,9	40,5	15,1	3,1	-19,3	9,7
CAR 04	Kalavan-1	2006-UF2	BPM	Single	Adult	I	tibia	65,8	39,2	14,4	3,2	-18,8	9,6
CAR 05	Kalavan-1	2006-UF8	Pit	Single	Subadult	I	tibia	21,5	39,6	14,7	3,1	-18,8	10,9
CAR 08	Kalavan-1	2006-UF9	BPM	Single	Adult	I	hand phalanx	60,1	41,2	14,9	3,2	-19,1	9,6
CAR F03	Kalavan-1	2007 - UF5			Ovis/ Capra		tarsal	74,3	36,1	13,0	3,2	-19,6	6,9
CAR 06	Aknashen	Tr7 UF5 F2	Pit	Single	Subadult	I	tibia	69,8	44,2	15,5	3,2	-18,0	11,8

**Fig. 4** – Carbon and nitrogen isotope ratios for cereals from Caucasian archaeological sites. Chobareti and Mentesh Tepe sites data from Messager et al. 2015; Herrscher et al. 2018. Box-plot corresponds to median, Q1, Q3, with min, max, and outliers.

cover, and soil composition, may have impacted plants' stable isotope ratios and, consequently, those of consumers. For instance, aridity and the use of manure are known to increase plant nitrogen stable isotope ratios (Schwarcz et al. 1999; Bogaard et al. 2007), whereas forested cover can decrease both carbon and nitrogen stable isotope ratios (van der Merwe and Medina 1991; Rodière et al. 1996; Bonafini et al. 2013). Considering the distribution of these sites across the Caucasus, with the low altitude of Natsargora, Kvatskhelebi, and Mentesh Tepe below 800 m asl, in contrast to all the other sites above

1,200 m, we can ask if environmental factors might influence the isotope ratios recorded at different archaeological sites. To evaluate this hypothesis, we tested the correlation between isotopic data and altitude (fig. 5). Despite a wide dispersion of human and animal (grouped per species) isotopic values, results show no correlation over 0.38 between the two variables (fig. 5A, 5D). For cereals, wheat $\delta^{13}\text{C}$ values show an intermediate correlation of 0.64 (fig. 5E, 5F); however, the analysis is not robust enough to conclude a relationship between isotope ratios and altitude. These results were unexpected since

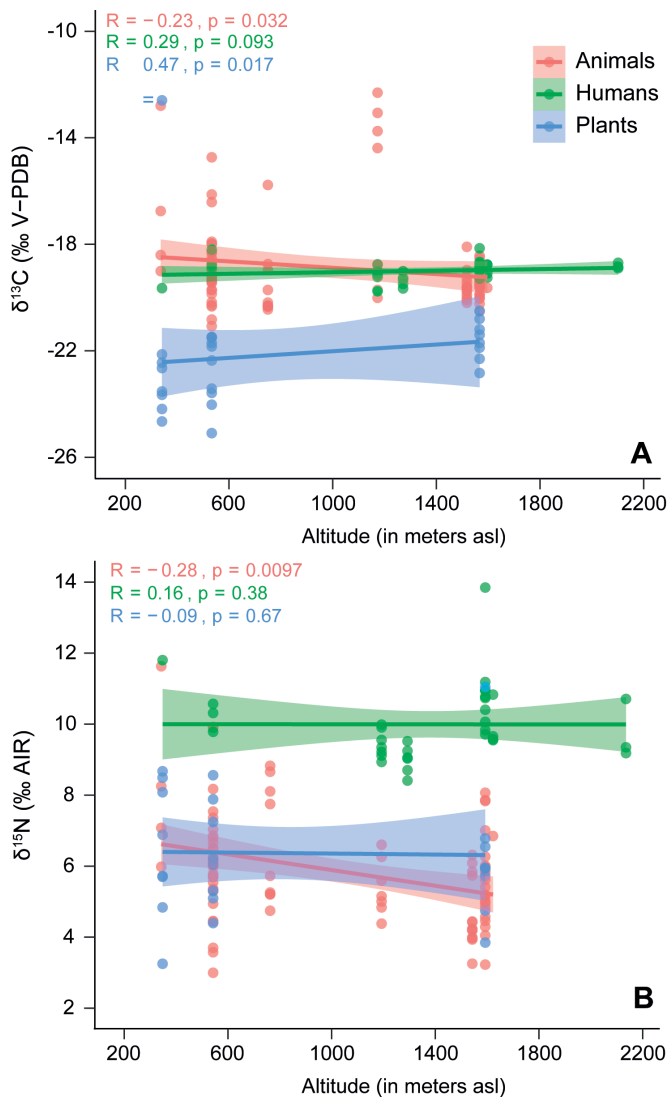


Fig. 5 – Carbon and nitrogen stable isotopic ratios according to the altitude of archaeological sites for Kura-Araxes humans (A, B), fauna (C, D) and cereals (E, F) across the southern Caucasus ($n = 144$).

samples were numerically well represented and accounted for a significant altitudinal gradient from 335 m asl for Mentesh Tepe in Azerbaijan to 2,124 m asl for Gegharot in Armenia, and raises the question of geographical specificity. The diverse ecological niches (Messenger et al. 2020), combined with temperature and precipitation changes in the highlands during the 4th millennium BC (Connor and Kvakadze 2014), may have masked an altitudinal gradient effect on isotopic data. On the other hand, barley and wheat show consistent isotopic trends in all the sampled archaeological sites, regardless of their altitude (fig. 4), confirming their independence from the altitudinal

gradient, which raises the question of a “universal” difference between both types of cereals that needs to be tested further in other geographical contexts and periods.

A warmer and more humid climate in the highland steppes during the 4th and 3rd millennium BC (Connor and Kavavadze 2014; Hovsepian 2015) could echo our isotopic results with a uniform isotopic trend from the middle Kura valley to the Samtskhe-Javakheti highlands, as evidenced in the isotopic pattern of cereals. Our results suggest that climate change could provide a reasonable explanation for the stability of isotope ratios of animal and plant resources in relation to altitude in the South Caucasus. In addition, the results could also support the presence of similar traits in the daily life and farming practices of KA communities throughout the South Caucasus, regardless of the various altitudes and ecological niches. The isotopic value recorded in bone tissue corresponds to an averaged signal from the last years of the individuals’ life; thus, the value’s lack of isotopic distinction between contrasting habitats does not strictly reject a seasonal, cyclical lifestyle between highland and lowland habitats.

- As no consistent difference appears with geographical location and altitude, the isotopic variability of the resources was calculated by grouping the individual animal and plant data throughout the KA period and in the South Caucasus region to increase the statistical robustness. Thus, the isotopic baseline of KA food resources for the South Caucasus includes: two plant resources (barley and wheat) to identify their relative contribution to the human diet with a higher enrichment in ^{15}N and lower enrichment in ^{13}C for barley consumers;
- “Herbivore meat” with typical $\delta^{13}\text{C}$ values of a C_3 -environment, combined with $\delta^{15}\text{N}$ ratios, may allow the identification of consumers of “cattle and sheep/goat meat” expected with higher values, and consumers of “wild herbivore meat/hunted meat” expected with lower values; the “suid meat” with higher carbon isotope values may identify pork meat consumers (fig. 6).

KURA-ARAXES DIETARY PRACTICES IN THE SOUTHERN CAUCASUS

The maximum dispersion of human $\delta^{15}\text{N}$ values from Georgia was identified for highland individuals ranging from 8.5 to 13.9‰, as already discussed elsewhere (Messenger et al. 2015; Herrscher et al. in press). Even if an overlap exists between each series, the mean value increases significantly

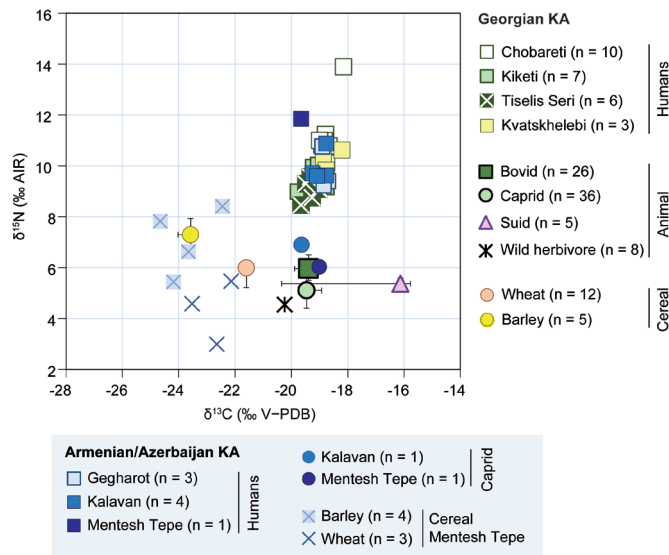


Fig. 6 – Human, animal and cereal carbon and nitrogen isotope ratios for Caucasian archaeological sites. Kiketi, Tiselis Seri, Chobareti and Mentesh Tepe sites data from Messenger et al. 2015; Herrscher et al. 2018, in press.

from Tiselis Seri and Kiketi to Chobareti without being explained by a significant difference in their dietary behaviour ($\text{Diff-}\delta^{15}\text{N} = 9.0/9.5$ to 10.9‰ ; $p\text{-}\delta^{15}\text{N} = 0.008$). Kvatskhelebi individuals are in the upper dispersion of human $\delta^{15}\text{N}$ values from Georgia, ranging from 9.8 to 10.5‰ , and overlap of Kiketi and Chobareti isotopic distribution (table 6; fig. 6). For carbon, a significant difference of 0.5‰ was observed only between humans of Tiselis Seri and Chobareti. Considering humans pooled into two groups (< 700 m asl and $> 1,200$ m asl), carbon isotope ratios exhibit a substantial overlap, with values ranging from -19.8 to -18.1‰ for the highland, and -18.9 to -18.2‰ for the lowland sites, in agreement with a lack of significant isotopic difference between both altitude groups ($p\text{-}\delta^{13}\text{C} = 0.13$).

The 8‰ carbon isotopic range of food resources (animal and cereal) is much greater than the 2‰ human range, indicating a low range of human dietary choice in contrast to the wide isotopic range of food resources (fig. 6). Bearing in mind the theoretical isotopic fractionation (= enrichment factor in heavy isotope) expected between two consecutive trophic levels (food-consumer: $0\text{-}2\text{‰}$ for carbon, and $3\text{-}5\text{‰}$ for nitrogen; Bocherens and Drucker 2003), preferential consumption of herbivore meat (such as cattle, sheep or goat) associated with an insignificant consumption of pig meat, might be proposed to explain KA human isotope variability (fig. 6). In addition, the narrow range of human carbon values could also be explained by a significant consumption of cereals, in the

form of bread and “porridge”, as a dietary staple. Therefore, the best candidate regarding the isotopic fractionation between food-consumers would be the barley. High-proportion consumption of barley will induce much higher nitrogen values and lower consumer tissues’ carbon values, fitting perfectly with the Kvatskhelebi and Chobareti isotopic data, whereas wheat consumption would have significantly increased the carbon values of consumer tissues.

At the broader regional scale of the southern Caucasus, the two Armenian and Azerbaijani caprid overlap the isotope variability of Georgian herbivores, as they do Armenian and Georgian human isotope data. The parsimonious interpretation to explain the comparable distribution between food-consumers would be similar dietary practices throughout the South Caucasus. As explained above, the subsistence strategies would reflect a selection of food products based on a preferential contribution of herbivore meat and barley grains to their diet. Pork consumption is still difficult to confirm due to the scarcity of isotope values for the Caucasian zone. For example, further analyses are needed to explain the two groups of pigs formed by the five specimens in our study (fig. 3A). Are they related to different husbandry strategies based on a biological criterion? Or could this indicate a species identification problem with a mixture of domestic pig and wild boar, as observed in other Neolithic and Late Bronze Age Caucasian sites (Herrscher et al. 2014, 2015)? The low contribution of pigs to the diet suggested by our isotopic results echoes the archaeological data, which suggests that the KA peoples’ interest in pigs was low compared to cattle and sheep/goat. Moreover, Decaix et al. (2019) reported the sole presence of pigs at Natsargora based on the comparison of eight KA sites’ faunal assemblages, which raises the question of the animal’s status in the KA economy. Furthermore, archaeological datasets reveal a low presence of wild animal remains in the KA sites, consistent with isotopic results not precise enough to identify the consumption of hunted resources by human consumers (Decaix et al. 2019).

Although evidence of fishing and fish consumption is scarce in the entire KA context, the geographical scale of this study with numerous waterways, freshwater resources could potentially be of great interest for protein intake in humans. Freshwater fish consumption could therefore be a possible explanation, especially for the KA individual from Mentesh Tepe, given the isotopic baseline established for this region and its highest nitrogen isotope value (fig. 6). The available modern isotope values of cyprinids from the Kura River (median values: $\delta^{13}\text{C} = -18\text{‰}$; $\delta^{15}\text{N} = 3,8\text{‰}$, $n = 2$) and the Khrami river around Tbilisi (median values: $\delta^{13}\text{C} = -22\text{‰}$; $\delta^{15}\text{N} = 10\text{‰}$,

n = 5), relevant for the Kvatskhelebi series, located on the Kura riverbank, show no overlap with the expected human isotope values for this type of consumption, suggesting that fish was not a preferred food for these people. This interpretation would also agree with recent archaeological results on fish consumption at Tel Bet Yerah/Khirbet el-Kerak in Israel, where KA migrants settled ca. 2850 BC (Lerneau et al. in press). In the context of the highland and lowland series, a more specific local baseline would be needed to specifically document freshwater fish and discuss its contribution to KA communities' diet.

Despite no consolidated local isotope baseline being available for Armenia and Azerbaijan, comparison of the Georgian, Armenian, and Azerbaijani sites shows an apparent homogeneity of isotope data that would suggest a uniform KA model, implying similar dietary intake among KA communities. The diet of KA communities in the southern Caucasus seems to be characterised by a low range of dietary practices both within and between groups, which raises the question: could this apparent isotope homogeneity result from a decrease in the availability of food resources (climate/environmental factor), or from a reduced human choice/preference for specific domestic resources (cultural factor)? Since the South Caucasus is characterised by diverse climatic and geographic environments, with a high food isotopic variability in contrast with humans, and no observable spatial food trends, the most parsimonious interpretation would be to advocate for deliberate cultural choices.

To further test the isotopic homogeneity of this dietary model at the intra-population level and over time, investigating additional factors (e.g. biological, social), as well as the diachronic evolution of the variables, would help consolidate this hypothesis.

THE BIOLOGICAL AND TEMPORAL DIMENSION OF THE ISOTOPIC DATA

In order to identify the impact of demographic variables on dietary habits, age at death (adult/subadult) and sex (male/female) were determined for the human skeletons to evaluate the inter-individual isotope variability (Poulmarc'h 2014). The one-year-old child from Chobareti exhibits the highest nitrogen isotope values (13.9‰) consistent with breast milk consumption. Significantly higher carbon isotopic values were observed only for subadults in comparison to adults (fig. 3). Based on the coxal bone, the sex of seven individuals (four females and three males), out of 30 adults, could be diagnosed with the highest

probability (Bruzek 2002; Murail et al. 2005). This small sample size prevented any significant statistical test by sex; however, a substantial overlap of data between sexes was observed for both carbon and nitrogen ratios (figs. 7A1, 7B1). Similarly, the analysis of funerary practices in Shida Kartli and Kvemo Kartli (Poulmarc'h 2014), among others, shows a high variability of funerary architecture (pit, ceramic vessel, box in perishable material, variable shape in stone) and burial practices (single or collective). No isotopic clusters were identified in the KA communities based on these variables (figs. 7A3, 7B3). Furthermore, if we assume that the individuals buried in collective graves were linked together by some specific ties (such as kinship), the homogeneity of diets should apply to the members of the same social (possibly kinship-based) groups. According to our results, we can conclude that neither biological nor social factors influenced the homogeneity of the food practices among the KA communities. Conversely, the lack of diet distinctions could mirror the lack of social inequalities regarding access to food resources. Thus, the homogeneity of diets could be a consequence of the KA social organisation.

Based on the funerary practices, the social organisation does not seem structured according to individual status or hierarchical differences. Instead, groups appear to be structured on family and kinship ties which potentially reflects an egalitarian social model. There is also compelling evidence from settlements showing a household-based society with no socio-economic differentiation. The radiocarbon dates from seven KA sites with human remains examined in this paper cover the entire chronological span of the KA culture (from 3400 BC with Chobareti, then Gegharot 3100-2900 BC, Natsargora 3100-2850 BC, Kiketi 3000-2800 BC, Kvatskhelebi 2900-2700 BC, Tiseli Seri 2800-2600 BC, to 2500 BC with Mentesh Tepe and Kalavan). The minimal isotopic difference measured between the individuals from these sites over the entire period suggests a diachronic persistence of dietary practices more focused on a preferential consumption of herbivores meat than pig meat, and barley rather than wheat, consistent with a previous archeozoological and archaeobotanical study (Decaix et al. 2019). Regarding the low dispersion of human isotopic data in contrast to animal and vegetal local baselines, we propose that a cultural homogeneity of KA subsistence strategies may have been the norm, with the persistence of a long-term "conservative" diet over one millennium. This diachronic stability/homogeneity of subsistence strategies and diets could correspond to an unchanging set of dietary practices and food-consumption patterns over time.

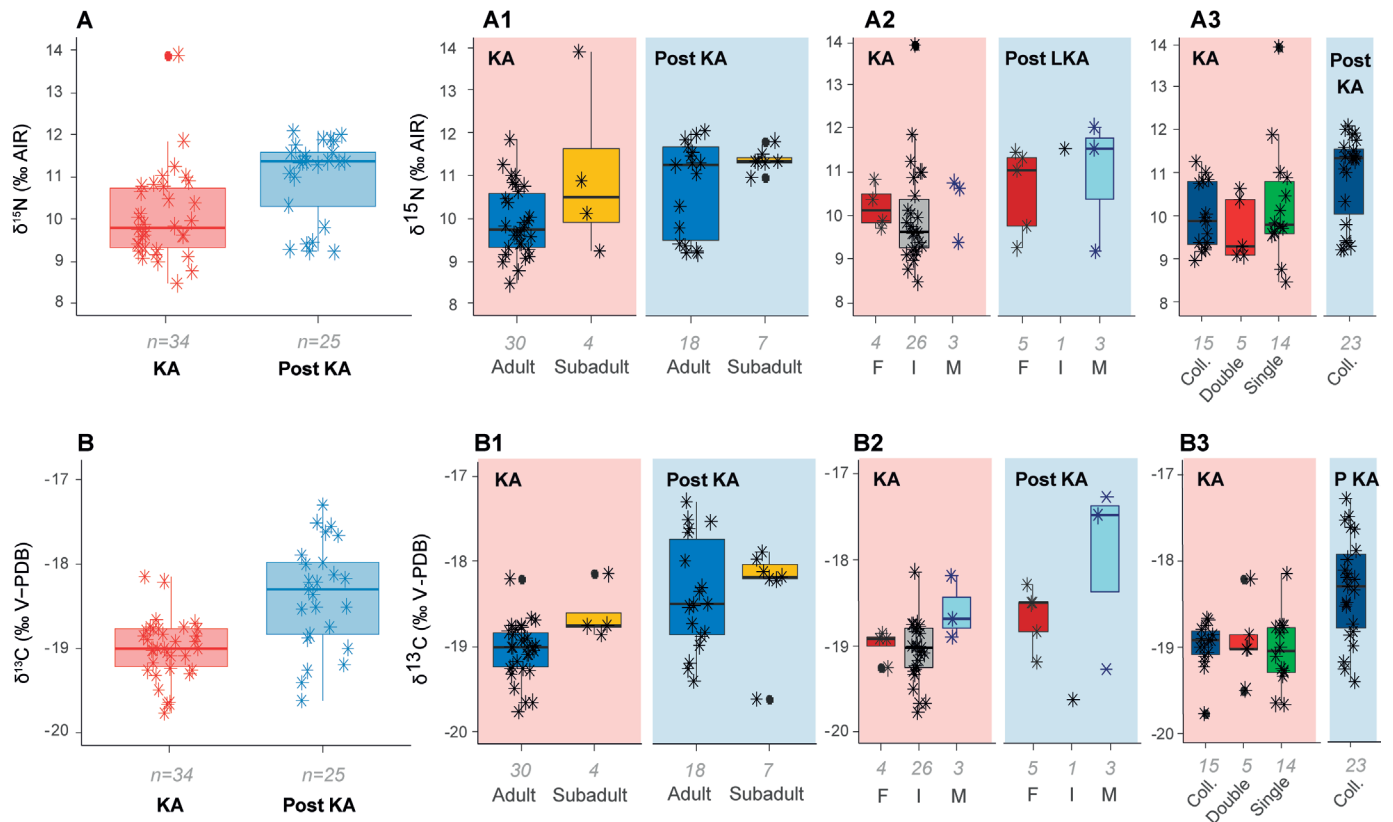


Fig. 7 – Human carbon and nitrogen isotope ratios for KA and Post-KA Caucasian archaeological sites according to several biological and funerary criteria. **A, B.** Isotopic distribution of pooled data. **A1, B1.** Isotopic distribution according to age groups. **A2, B2.** Isotopic distribution according to the sex. **A3, B3.** Isotopic distribution according to the type of burial. Coll. = collective, double, single; previously published data from Messager et al. 2015; Herrscher et al. 2015, 2018, in press; Box-plot corresponds to the median, Q1, Q3, with min, max, and outliers.

To explore the evolution of KA dietary homogeneity, comparative analyses were performed using published data on the post-KA/Early Kurgans period from Ananauri (Herrscher et al. 2016), Mentesh Tepe (Herrscher et al. 2018), and the subadult individual from Akanashen (Tr7 UF5 F2; Poulmarc'h 2014). In the data pooled by periods, the post-KA/Early Kurgans individuals exhibited higher carbon and nitrogen isotopic ratios than the KA individuals (p -values < 0.000; fig. 7A, 7B). In addition to different medians, the dispersion of data was also different, indicating a higher diversity of food resources consumed by post-KA/Early Kurgans individuals. Although there are no significant differences among age groups (figs. 7A1, 7B1), subadults are clustered and display low dispersion in the upper limit of adult variability for both carbon and nitrogen values. Finally, males show the highest dispersion of carbon and nitrogen values, which could be linked to greater human mobility of the post-KA/Early Kurgans individuals than observed among the KA people (figs. 7A2, 7B2). This

isotopic dispersion is clearly visible in the Ananauri and Mentesh Tepe examples. For the Akanashen individual, the isotopic baseline is not documented enough to confirm this pattern. In summary, the KA isotopic characteristics described in this study seem to end during the following period with the emergence of the Martqopi and Bedeni cultures, thus clearly distinguishing KA communities' dietary specificities.

CONCLUSION

Contrary to the previous Neolithic (Herrscher et al. 2018) and the following post-KA/Early Kurgans (Herrscher et al. 2016) cultures, the dietary practices of the KA populations show a low dietary breadth, with preferential consumption of herbivores meat instead of pig meat, and extensive consumption of cereals (mainly barley). The low inter- and intra-group

isotopic diversity has been interpreted as homogeneous dietary practices and a willingness to not discriminate between individuals within the group. This outcome would support normative dietary practices adopted by the KA communities that may reflect equal access to the same food resources regardless of biological, geographical, chronological, and social variables. Could these shared dietary traits have actively shaped the construction of the KA social and cultural identity?

Regarding the social sphere, the evidence for equal access to food corroborates the archaeological narrative suggesting no signs of socio-economic inequality in the funerary and residential contexts, as well as no political hierarchies. Thus, the KA communities appear to have been very cohesive and composed of undifferentiated, probably kin-based, social groups. Furthermore, the strong normative characterisation of the KA dietary habits is also reflected in food preparation and consumption practices and the associated material culture. Several authors have suggested (Sagona 2018) that some of the most conservative traits of the KA tradition is those expressed by a very distinctive “food-related” material culture such as pottery. Furthermore, the extensive geographical spread and diachronic persistence of the distinctive morpho-functional repertoires of the ceramic containers throughout the South Caucasus, coupled with the new aesthetics that could have enhanced the symbolic role of the containers, point to a strong link between ceramic traditions and daily practices of food processing and food consumption. Greenberg (2007) suggested that the KA ceramics’ functions and colour codes seem to have been aimed at “structuring the cultural attitudes to food and cooking” and eventually at strengthening a kind of KA cultural identity through dietary practices. Moreover, the centrality of fire installations in the domestic space, yet another distinctive feature of the KA culture, may have played an active role in entwining practical and symbolic activities attached to cooking and food consumption.

The isotopic data presented in this research strengthens this argument by demonstrating a precise set of dietary traits and normative food-ways adopted by the KA communities. This innovative study complements the picture emerging from archaeozoological and archaeobotanical results throughout the KA culture. The dietary habits outlined here could have acted as practical and symbolic means structuring and defining KA social and cultural identity. Food and related habits could have worked powerfully at the individual and collective levels, in the construction and persistence of a sense of group-membership across generations. Eventually, dietary practices actively shaped some of the most distinctive traits of the KA material culture. The continuity of traditional eating practices further

supports this interpretation, in the scattered contexts of the KA sphere in Iran or Anatolia communities (Greenberg 2007; Greenberg and Goren 2009; Paz 2009; Longford 2015). Future isotopic studies ($\delta^{34}\text{S}$, $\delta^{18}\text{O}$, $^{87}\text{Sr}/^{86}\text{Sr}$) in these areas will hopefully provide further insights into the substantial existing evidence. The case of the Kura-Araxes communities is thus an exceptional example of the ways food and cultural identity are mutually constituted and tightly entangled. This study also demonstrates the fundamental benefits of food and dietary practices studies in archaeology for revealing society’s operating principles.

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