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THE CATACOMB CULTURES OF THE NORTH-WEST CASPIAN STEPPE: ^{14}C CHRONOLOGY, RESERVOIR EFFECT, AND PALEODIET

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ABSTRACT. For the Bronze Age Catacomb cultures of the North-West Caspian steppe area in Russia, there is a conflict between the traditional relative archaeological chronology and the chronology based on radiocarbon dates. We show that this conflict can be explained largely by the fact that most dates have been obtained on human bone material and are subject to ^{14}C reservoir effects. This was demonstrated by comparing paired ^{14}C dates derived from human and terrestrial herbivore bone collagen. In addition, values of stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) and analysis of food remains from vessels and the stomach contents of buried individuals indicate that a large part of the diet of these cultures consisted of fish and mollusks, and we conclude that this is the source of the reservoir effect.

INTRODUCTION

In this paper, we discuss the radiocarbon database of the East Manych Catacomb culture of the North-West Caspian steppe area in terms of chronological problems. Under the field and research program of the Steppe Archaeological Expedition of the State Historical Museum, many kurgans (burial mounds) from the Bronze Age have been excavated in the area. The kurgans contain stratigraphical information showing cultural sequences for the region. Over a primary burial, a roof was constructed and covered by a mound. The population of the same culture as well as subsequent cultures used the same burial mound. The vertical stratigraphy, horizontal planigraphy, and prehistoric classification of funeral rituals and goods yield relative chronologies for the various Bronze Age cultures of the area under investigation during the 3rd millennium BC: the Yamnaya culture, the Early Catacomb culture, and the East Manych Catacomb culture (Alexandrovsky et al. 1997; Shishlina 2001; Shishlina et al. 2000, 2001).

Calibrated ^{14}C dates obtained for samples associated with the Yamnaya culture result in a time interval of 3200–2350 cal BC (based on 33 dates for human bones, wood, and textiles). The historical duration for the Early Catacomb culture, 3300/2900–2500 cal BC, is based on ^{14}C dates from 15 graves from 6 Early Catacomb culture burial grounds (22 dates on human bones, 1 on wood, and 1 bone pin). Calibrated ^{14}C dates obtained for samples associated with the East Manych Catacomb culture (61 dates on human bones, wood, charcoal, textile mats, and seeds) yield a cultural time span of 2900/2800–2000 cal BC (Alexandrovsky et al. 1997; Shishlina et al. 2000, 2001).

Comparison of the ^{14}C-based time ranges with those obtained from traditional relative archaeological chronologies for the 3 cultures reveals significant problems:

1. Wood and human bone samples from the same grave show that the bones have older ^{14}C dates than the contemporaneous wood.
2. Series of ^{14}C dates on human bone from the Early Catacomb culture are unexpectedly old: 3300–2900 cal BC. This would imply that the Early Catacomb culture population occupied the region during the same period as the Yamnaya cultural groups.

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3. ^{14}C dates of human bones from the East Manych Catacomb culture show that at some locations, evidence for this culture appears much earlier than the Early Catacomb and Yamnaya populations, ~2800 cal BC.

Thus, there are inconsistencies between the relative chronology and absolute time intervals based on ^{14}C dates. We believe that this can be explained by the so-called "reservoir effect" in human bone samples, which causes increased ages. The reservoir effect is caused by diets largely based on marine or freshwater sources, such as fish, mollusks, and water plants (Olsson 1983; Lanting and van der Plicht 1998; Kohn 1999; Yoneda et al. 2004). In this paper, we discuss these apparent ages and show supporting evidence for a reservoir effect based on the stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) measured on the same bone collagen, and on food residue analysis.

RESERVOIR EFFECTS AND STABLE ISOTOPES FOR HUMAN BONE COLLAGEN

^{14}C Dating of Archaeological Fish Bones

To investigate local reservoir effects during the Bronze Age, bones of pike fish and terrestrial seeds of *Lithospermum officinale* taken from the same grave (Shakchaevskaya, grave 32, kurgan 4) were dated. This grave dates to the West Manych Catacomb culture, which is contemporaneous with the East Manych Catacomb culture. The results are shown in Table 1. The ^{14}C dates are calibrated using the CALIB program by Stuiver and Reimer (1993), using the IntCal04 calibration curve (Reimer et al. 2004).

Table 1 Reservoir effect in fish bones from the Shakchaevskaya burial ground, kurgan 4, grave 32, West Manych Catacomb culture.

Sample	Lab nr	^{14}C age (BP)	Calibrated age range (68.2%, cal BC) [start: end] relative probability	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
Seeds (*Lithospermum officinale*)	Ua-21407	3745 ± 45	[2268: 2260] 0.04 [2206: 2124] 0.65 [2091: 2043] 0.31	–20.70	n/a
Pike bones	GrA-26902	4390 ± 40	[3084: 3065] 0.14 [3028: 2924] 0.86	–16.54	+15.0

The difference in the ^{14}C ages obtained enables us to establish the local reservoir effect (for the West Manych river basin) during the Catacomb culture period to be 640 ± 60 ^{14}C yr. This is simply the difference between the 2 dates. However, this correction cannot be used as a general correction valid for the region as it changes through time and appears to be different for different regions (Savinetsky and Khasanov 2004).

Stable Isotopes in Human and Animal Bone Collagen

We investigated the stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) in human bones taken from the Early Catacomb and East Manych Catacomb cultures. They are compared with isotope data obtained for animal bones taken from the same kurgans and graves. Some samples were also ^{14}C dated (see Table 2).

The data presented in Table 2 show that for the Early Catacomb culture human bone collagen, the values of $\delta^{13}C$ range from –21.54 to –15.29‰, and $\delta^{15}N$ values range from +10.7 to +18.1‰. For herbivorous animal bones, the values of $\delta^{13}C$ range from –21.16 to –18.65‰, while the $\delta^{15}N$ values range from +4.7 to +9.9‰. There appear to be differences in human bone collagen obtained for several burial mounds (see Table 2).

Table 2 ^{14}C dating and stable isotope ratio measurements for human and animal bones from the Early Catacomb and East Manych Catacomb cultures.

Kurgan/grave	Sample material	Lab nr	^{14}C age (BP)	Calibrated age range (68.2%, cal BC) [start: end] relative probability	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
EARLY CATACOMB CULTURE						
	Peschany V burial ground, 46°33′21.7″N, 43°40′36.8″E					
k.1, g.1	Woman age 25–30	—	—	—	–18.25	+14.1
k.3, g.1	Man age 45–50	Bln-5616	4073 ± 35	[2834: 2817] 0.13 [2664: 2645] 0.11 [2638: 2569] 0.64 [2516: 2500] 0.11	–17.02	+17.2
k.3, g.2	Man age 40–45	IGAN-2946	3788 ± 57	[2335: 2324] 0.03 [2301: 2135] 0.94 [2069: 2064] 0.01	–21.54	+15.2
k.2, g.3	Man age 40–45	IGAN-2878	3908 ± 117	[2567: 2522] 0.11 [2498: 2265] 0.74 [2261: 2205] 0.14	–18.15	+15.8
k.1, sacrificial place 1	Horse	—	—	—	–21.16	+4.7
	Temrta III burial ground, 46°33′03.0″N, 43°39′53.7″E					
k.1, g.1	Man age 40–45	IGAN-2945	3987 ± 42	[2569: 2516] 0.62 [2500: 2469] 0.37	–18.34	+14.9
k.1, g.4	Man age 40–45	IGAN-2947	4100 ± 50	[2855: 2812] 0.23 [2746: 2725] 0.09 [2697: 2577] 0.67	–18.15	+14.7
k.1, g.4	Man age 40–45	OxA-15209	4169 ± 31	—	–17.3	n/a
k.2, g.1	Man age 45–50	—	—	—	–17.85	+14.1
k.1, sacrificial place 7	Sheep	—	—	—	–19.47	+9.6
	Temrta V burial ground, 46°32′52.1″N, 43°40′15.2″E					
k.1, g.2	Woman age 17–20	—	—	—	–17.97	+12.5
k.1, g.2	Man age 20–25	—	—	—	–20.60	n/a
k.1, g.3	Woman age 40–50	—	—	—	–17.98	+10.7
k.1, g.3	Man age 40–45	—	—	—	–17.74	+12.8
	Baga-Burul burial ground, 46°23′38.4″N, 42°13′46.8″E					
k.5, g.6	Human age 15–16	—	—	—	–18.79	+12.6
k.5, g.19	Cow	—	—	—	–18.5	+9.9
	Mandjikiny-2 burial ground, 45°41′28.2″N, 44°40′49.4″E					
k.37, g.3	Man age 15–16	Bln-5615	4095 ± 58	[2857: 2811] 0.22 [2749: 2723] 0.10 [2699: 2573] 0.64 [2510: 2506] 0.01	–17.9	+16.5
k.42, g.1	Woman age 40–45	—	—	—	–17.16	+17.3
k.42, g.4	Human age 3–4	—	—	—	–15.29	+18.1
k.45, g.2	Man age 17–20	—	—	—	–17.10	+17.5
k.54, g.6	Woman age 25–35	IGAN-2277	4319 ± 41	[3010: 2980] 0.28 [2957: 2952] 0.03 [2940: 2891] 0.68	–17.59	+15.0

Table 2 ^{14}C dating and stable isotope ratio measurements for human and animal bones from the Early Catacomb and East Manych Catacomb cultures. *(Continued)*

Kurgan/grave	Sample material	Lab nr	^{14}C age (BP)	Calibrated age range (68.2%, cal BC) [start: end] relative probability	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
	Zunda-Tolga-2 burial ground, 45°35′37″N, 44°16′19″E					
k.1, g.1	Man adultus	IGAN-2406	4531 ± 104	[3484: 3476] 0.01 [3370: 3089] 0.94 [3051: 3031] 0.05	–17.46	+16.1
k.2, g.3	Man age 35	IGAN-2547	4363 ± 123	[3326: 3232] 0.21 [3224: 3219] 0.01 [3174: 3160] 0.02 [3119: 2883] 0.74	–18.62	+13.9
	Zunda-Tolga-5 burial ground, 45°38′7.0″N, 44°14′20.6″E					
k.1, g.5	Man age 50–60	IGAN-3116	4102 ± 114	[2871: 2802] 0.23 [2779: 2568] 0.71 [2519: 2499] 0.06	–18.65	+14.0
EAST MANYCH CATACOMB CULTURE						
	Baga-Burul burial ground, 46°23′38.4″N, 42°13′46.8″E					
k.5, g.11	Woman age 25–35	IGAN-2765	5079 ± 341	[4325: 4286] 0.03 [4269: 3623] 0.87 [3604: 3523] 0.08	–16.94	+15.8
k.5, g.21	Man age ≥45	—	—	—	–17.86	+14.2
k.5, sacrifice 4	Cow	—	—	—	–20.65	+6.2
k.5, sacrifice 15	Sheep	—	—	—	–19.35	+8.3
	Ostrovnoy burial ground, 45°44′44.6″N, 44°0.6′53.0″E					
k.3, g.10	Man age 35	IGAN-2130	3977 ± 67	[2579: 2433] 0.82 [2422: 2403] 0.07 [2380: 2349] 0.11	–17.69	+12.8
k.3, g.39	Woman age 20–30	IGAN-3234	4824 ± 66	[3693: 3681] 0.1 [3664: 3623] 0.33 [3604: 3523] 0.61	–17.30	+16.1
k.3, g.38	Sheep	IGAN-3115	3743 ± 67	[2277: 2252] 0.11 [2228: 2222] 0.03 [2210: 2109] 0.53 [2105: 2035] 0.33	–19.21	+6.6
k.3, g.9	Sheep	—	—	—	–17.77	+6.4
k.3, g.9	Sheep	—	—	—	–18.11	+7.6
	Zunda-Tolga-1 burial ground, 45°34′36″N, 44°19′16″E					
k.9, g.1	Man age 50	IGAN-1792	3709 ± 44	[2193: 2178] 0.10 [2143: 2034] 0.90	–16.98	+14.2
k.9, g.1	Sheep	IGAN-3117	3922 ± 104	[2569: 2516] 0.15 [2500: 2280] 0.78 [2250: 2230] 0.05 [2219: 2212] 0.02	–17.38	+9.7
k.10, g.2	Woman age 50–60	IGAN-2421	4256 ± 75	[3008: 2986] 0.06 [2933: 2849] 0.47 [2813: 2741] 0.32 [2729: 2694] 0.13 [2687: 2679] 0.02	–16.58	+17.2
k.10, g.3	Man age 35	Bln-5529	3858 ± 32	[2454: 2419] 0.19 [2405: 2377] 0.19 [2350: 2285] 0.54 [2247: 2234] 0.07	–18.20	+14.2
k.10, g.3	Sheep	IGAN-3118	3809 ± 150	[2468: 2113] 0.87 [2101: 2037] 0.19	–18.83	+5.1
	Chilgir burial ground, 45°34′36″N, 44°19′16″E					
k.1, g.4	Woman age >45	IGAN-2652	4295 ± 41	[3003: 2992] 0.07 [2929: 2880] 0.92	–17. 24	+15.7

Table 2 ^{14}C dating and stable isotope ratio measurements for human and animal bones from the Early Catacomb and East Manych Catacomb cultures. *(Continued)*

Kurgan/grave	Sample material	Lab nr	^{14}C age (BP)	Calibrated age range (68.2%, cal BC) [start: end] relative probability	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
	Mandjikiny-1 burial ground, 45°42′32.5″N, 44°42′32.5″E					
k.10, g.2	Woman age 40–45	IGAN-2279	4092 ± 48	[2852: 2812] 0.21 [2744: 2726] 0.08 [2696: 2573] 0.71	–16.78	+17.2
k.14, g.1	Man age 30–35	IGAN-2493	4025 ± 113	[2859: 2809] 0.12 [2752: 2721] 0.07 [2701: 2457] 0.76 [2418: 2407] 0.02 [2375: 2367] 0.01 [2361: 2352] 0.02	–16.59	+17.7
k.14, g.1	Sheep	—	—	—	–16.37	+10.3

These differences in the isotope ratios could be explained by the fact that small pastoral family groups lived in different ecological contexts. They were mobile and occupied valleys of small steppe rivers or watershed plateaus during warm seasons, and during cold seasons moved to the Don or Volga delta regions, Caspian Sea or Black Sea coastline steppe areas, desert areas of the Black Lands (east part of the Caspian steppe), or the mountainous North Caucasus region. Differences in domesticated animal samples may be caused by the use of pastures with different vegetation. Another possible explanation of the unusually high $\delta^{15}N$ value range for one of the domesticated animals (sheep) dating back to the East Manych Catacomb culture is the ecological downturn that began in the area around 2400 cal BC (Shishlina 2001). The most severe droughts led to changes of annual precipitation, resulting in quantitative and qualitative changes of morphological and chemical properties of the soils, local vegetation, and water resources available. This phenomenon is also observed in ancient Egypt; an arid climate can result in high $\delta^{15}N$ values (Thompson et al. 2005).

The seasonal cycle of grassland use developed by the Early Catacomb and the East Manych Catacomb cultures population was characterized by small- and large-scale movements across the vast area of the North-West Caspian steppe. The area is characterized by a variety of ecological niches including numerous small steppe rivers, small and large steppe lakes, large valleys of the Low Don and Volga rivers, and large tributaries such as the Sal, East and West Manych rivers. The North Caucasus Piedmont region was also crossed by pastoral seasonal migrational routes favored by the steppe population. The region contains large rivers such as the Cuban, Kuma, Kalaus, and Egorlyk. The aquatic resources of this large area must have been used by the steppe population. Development of this large trade and exchange network dating back to the 3rd millennium BC led to the appearance of exotic imported items. Metal objects (tools, weapons, and ornaments) including silver and gold, textiles, luxury decorations made of precious stones (turquoise and carnelian) and faience, prestigious hammers, and a mace head made of North Caucasus stones appeared in the steppe. The steppe population traded their stock, i.e. domesticated animals and their craft products, for the aforesaid items. This may explain why they had to exploit all the food resources of their territory, including aquatic resources.

The stable isotope ratio of human bone can potentially be used as an indication for the reservoir effect, which makes ^{14}C dates too old. The ^{14}C dates obtained for these bones are shown in Table 2. The stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) clearly show that all individuals apparently had a diet based largely on river and lake food, such as fish, mollusks, and water plants. Bones of pike, sturgeon, and carp (Shilov 1975), as well as remains of microplates of lake and river fish scales preserved in clay pots, confirm this observation. The ^{14}C dates would therefore require correction for a local reservoir effect.

The $\delta^{15}N$ value, averaged for the human bones that were ^{14}C dated, is +15.4‰. We can estimate a reservoir correction by assuming $\delta^{15}N$ values of +18‰ for a 100% terrestrial diet. Then, our data are consistent with an approximately 70% aquatic diet (i.e. aquatic to total protein). Based on these numbers, we estimate the ^{14}C reservoir effect as 400 ± 100 ^{14}C yr (Cook et al. 2001).

Parallel Dating Using Different Contemporaneous Materials

The size of the reservoir effect can be estimated by parallel ^{14}C dating of wood and animal bones from the same or similar Early and East Manych Catacomb graves. The combination of carbon and nitrogen stable isotope ratios provides a direct measure of the diet of an individual.

Unfortunately, no well-preserved wood, textiles, or animal bones have been found in the graves for which we dated human bones. Such terrestrial samples are needed to properly identify reservoir effects and their correction (see e.g. Arneborg et al. 1999; Cook et al. 2001).

For the Early Catacomb culture, estimates of the reservoir correction can be made by comparative analyses of ^{14}C dates of human bones and wood from graves of the Khar-Zukha burial ground. Graves of this site are characterized by very similar funerary rituals and were made by a small independent group of Early Catacomb culture pastoralists. The data are shown in Table 3 and are from 1 burial ground only. Comparison of the ^{14}C date of wood with the ^{14}C dates of human bones shows that the dates obtained for human bones have apparent ages. The data shown in Table 3 are consistent with a reservoir effect of about 400 ± 100 ^{14}C yr, as discussed above. A precise determination is not possible because of the large measurement errors, in particular for the wood sample. This conclusion should be confirmed by additional parallel dating of Early Catacomb culture samples for which we already have measured $\delta^{13}C$ and $\delta^{15}N$ (see Table 2).

Table 3 Results of ^{14}C dating of wood and human bone samples from the Khar-Zukha-I burial ground.

Kurgan/ grave	Sample material	Lab nr	^{14}C age (BP)	Calibrated age range (68.2%, cal BC) [start: end] relative probability	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
k.4, g.1	Wood	IGAN-1273	3561 ± 308	[2336: 2323] 0.01 [2308: 1519] 0.98	n/a	n/a
k.5, g.3	Woman old age	OxA-4734	3940 ± 70	[2565: 2532] 0.15 [2528: 2525] 0.09 [2496: 2338] 0.79 [2322: 2309] 0.04	–15.42	+18.1
k.1, g.5	Man age 45–50	IGAN-1420	4059 ± 152	[2874: 2465] 1.00	–17.62	+15.7

Parallel dating was performed on human bone and a piece of a (non-human, presumably terrestrial herbivore) bone pin taken from the Zunda-Tolga-5 burial ground: kurgan 1, grave 7 (see Table 4). This grave dates to the Yamnaya-Catacomb cultural group, which is contemporaneous with the Early Catacomb culture. A woman 50–55 yr old was buried in this grave. Isotope data indicate that she consumed primarily fish.

Table 4 Parallel ^{14}C dating of human bone and (non-human) bone pin.

Sample material	Lab nr	^{14}C age (BP)	Calibrated age range (68.2%, cal BC) [start: end] relative probability	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
Zunda-Tolga-5 burial ground, kurgan 1, grave 7, 45°38′7.0″N, 44°14′20.6″E					
Woman age 50–55	IGAN-2494	4866 ± 57	[3708: 3632] 0.86 [3558: 3538] 0.13	–17.77	+14.9
Bone pin (probably herbivore)	GrA -29135	4110 ± 45	[2856: 2812] 0.25 [2747: 2725] 0.12 [2698: 2617] 0.48 [2610: 2581] 0.15	–21.01	+5.4

The ^{14}C date of the human bone shows an exceptionally large, apparently discrepant age. Based on the difference in age between the human bone and the bone pin, the reservoir correction would be about 750 yr. Clearly, this needs to be confirmed, and more work is needed for the reliable dating of this particular burial.

Parallel dating of different materials was conducted on human and animal bones taken from synchronous graves of the Ostrovnoy and Zunda-Tolga-1 East Manych Catacomb culture burial grounds (see Table 5). According to the relative stratigraphy of the kurgans, all graves belong to the same stratum.

Table 5 Parallel ^{14}C dating of human and animal bone and wood samples from the East Manych Catacomb graves.

Kurgan/ grave	Sample material	Lab nr	^{14}C age (BP)	Calibrated age range (68.2%, cal BC) [start: end] relative probability	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
Ostrovnoy burial ground, 45°44′44.6″N, 44°0.6′53.0″E						
k.3, g.10	Human	IGAN-2130	3977 ± 67	[2458: 2416] 0.21 [2410: 2283] 0.70 [2248: 2232] 0.08 [2217: 2215] 0.02	–17.69	+12.8
k.3, g.38	Sheep	IGAN-3115	3743 ± 67	[2277: 2252] 0.11 [2228: 2222] 0.03 [2210: 2109] 0.53 [2105: 2035] 0.33	–19.21	+6.6
Mandjikiny-1 burial ground, 45°42′32.5″N, 44°42′32.5″E						
k.14, g.1	Man age 30–35	IGAN-2493	4025 ± 113	[2859: 2809] 0.12 [2752: 2721] 0.07 [2701: 2457] 0.76 [2418: 2407] 0.02 [2375: 2367] 0.01 [2361: 2352] 0.02	–16.59	+17.7
k.14, g.1	Wood (*Fraxinus*)	IGAN-3229	3760 ± 90	[2289: 2131] 0.87 [2085: 2054] 0.13	n/a	n/a

From the stable isotope ratios, we conclude that also here, humans consumed river food. Based on the 2 ^{14}C dates for human and sheep, we calculate the reservoir correction for the Ostrovnoy burial ground to be 230 ± 100 ^{14}C yr. This is consistent with the $\delta^{15}N$ values for these samples. From the

^{14}C dates of the wood and human bone, the reservoir correction for the Mandjikiny burial ground is 260 ± 140 ^{14}C yr.

We also used a ^{14}C database available for different materials such as seeds, textiles, charcoal, wood, and sheep bone, obtained for the East Manych Catacomb culture, in order to compare the data with ^{14}C data of human bones (Table 6). All graves are characterized by similar funerary rituals and goods and must have been left by synchronous population groups.

Table 6 ^{14}C dates for plant and wood remains and human bone samples from the East Manych Catacomb culture graves.

Sample	Lab nr	Burial ground: kurgan, grave	^{14}C age (BP)	Calibrated age range (68.2%, cal BC) [start: end] relative probability
Charcoal	GrA-10694	Zunda-Tolga-1: k.5, g.1	3700 ± 80	[2202: 2007] 0.89 [2004: 1975] 0.11
Burned branches	GrA-10051	Zunda-Tolga-1: k.7, g.1	3880 ± 40	[2457: 2417] 0.30 [2409: 2334] 0.55 [2324: 2300] 0.16
Cane from the grave	GrA-10043	Zunda-Tolga-1: k.8, g.1	3975 ± 40	[2568: 2518] 0.57 [2499: 2465] 0.43
Wood branches	GrA-10575	Zunda-Tolga-1: k.8, g.1	3840 ± 60	[2452: 2445] 0.02 [2437: 2420] 0.07 [2405: 2378] 0.13 [2350: 2204] 0.77
Textile from the grave	GrA-10046	Zunda-Tolga-1: k.8, g.1	3870 ± 40	[2456: 2418] 0.27 [2408: 2374] 0.24 [2368: 2361] 0.04 [2356: 2292] 0.46
Charcoal	GrA-10045	Zunda-Tolga-1: k.9, g.1	3910 ± 40	[2468: 2390] 0.66 [2385: 2345] 0.34
Sheep bone	IGAN-5529	Zunda-Tolga-1: k.9, g.1	3922 ± 104	[2569: 2516] 0.15 [2500: 2280] 0.78 [2250: 2230] 0.05 [2219: 2212] 0.02
Textile mat	GrA-10696	East Manych, Left bank, III, 1966: k.16, g.3	3880 ± 80	[2469: 2279] 0.89 [2250: 2230] 0.08 [2220: 2211] 0.03
Seeds of *Lithospermum officinale*	Ua-21406	Kermen-Tolga: k.26, g.1	3855 ± 75	[2458: 2416] 0.19 [2411: 2277] 0.64 [2252: 2228] 0.11 [2223: 2209] 0.06
Man age 60–65	IGAN-1723	Zunda-Tolga-1: k.4, g.1	4064 ± 93	[2853: 2812] 0.14 [2745: 2726] 0.06 [2696: 2481] 0.80
Woman age 50–60	IGAN-2281	Mandjikiny-1: k.15, g.1	4060 ± 50	[2835: 2817] 0.10 [2665: 2644] 0.10 [2639: 2557] 0.52 [2555: 2550] 0.02 [2537: 2491] 0.30
Woman age >45	IGAN-2652	Chilgir: k.1, g.4	4295 ± 41	[3003: 2992] 0.08 [2929: 2880] 0.92
Woman age 40–45	IGAN-2279	Mandjikiny: k.10, g.2	4092 ± 48	[2852: 2812] 0.21 [2744: 2726] 0.08 [2696: 2573] 0.71
Man age 30–35	IGAN-2493	Mandjikiny: k.14, g.1	4025 ± 113	[2859: 2809] 0.12 [2752: 2721] 0.07 [2701: 2457] 0.76 [2418: 2407] 0.02 [2375: 2367] 0.01 [2361: 2352] 0.02

The ^{14}C dates given in Table 6 are obtained for different types of materials and show a significant variation in ages. However, we have to emphasize again that analyses of archaeological data (type of grave, grave goods, stratigraphic position) strongly suggest that graves from which all samples were taken were contemporaneous. Comparing ^{14}C dates from terrestrial bone samples, the ^{14}C dates of human bones are clearly older. This is confirmed by stable isotope data for 1 individual buried in the Chilgir burial ground (Table 2). This is a woman older than 45 yr whose stable isotopic composition indicates she consumed mainly river and lake food, showing an apparent ^{14}C age caused by the reservoir effect.

From the data in Table 6, we calculate the (non-weighted) average ^{14}C dates for human bone as 4110 ± 50 BP; the other associated samples have an average value of 3870 ± 25 BP. The difference is a determination of the reservoir correction for the East Manych Catacomb graves: 240 ± 60 ^{14}C yr. The data in Table 6 yield an approximate correction of 250–400 yr for the reservoir effect during the East Manych Catacomb culture. However, the size of this correction needs further verification. In addition, the correction value may be different for different local ecological systems of the North-West Caspian steppe.

Finally, we show a plot for the stable isotope ratios $\delta^{13}C$ and $\delta^{15}N$ for the bone samples discussed in this article (Figure 1). The figure presents an overview of these stable isotope values for humans, herbivore animals, a single fish, and the bone pin.

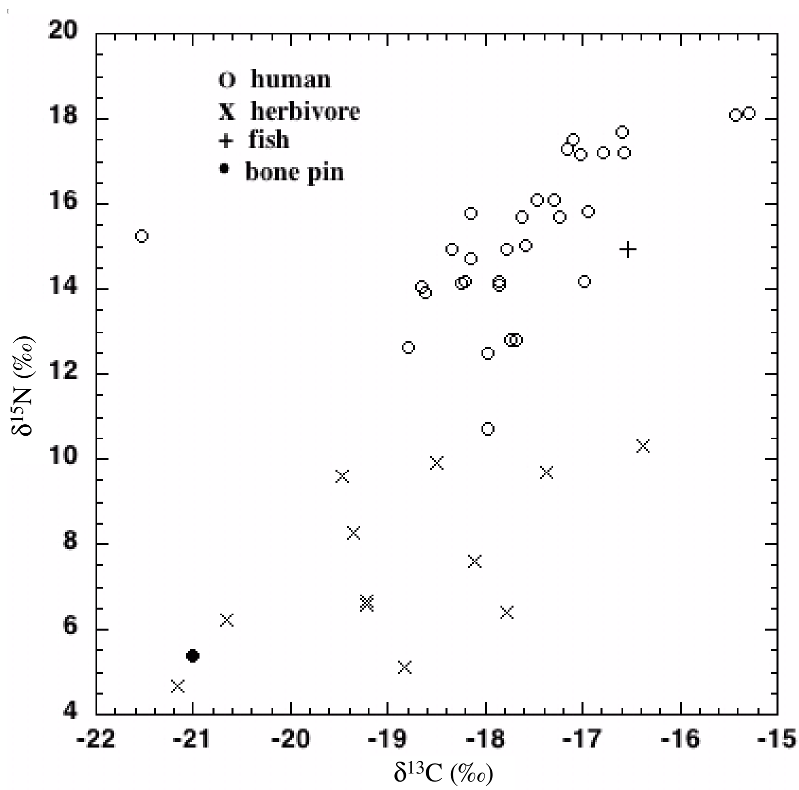

Figure 1 Stable isotope ratios $\delta^{13}C$ (horizontal) and $\delta^{15}N$ (vertical) for the bone samples discussed in this article. It shows an overview of these stable isotope values for humans, herbivore animals, a single fish, and a bone pin found in the Zunda-Tolga burial ground.

ADDITIONAL DIETARY COMPONENTS

Plant material has been identified for the Early Catacomb and East Manych Catacomb cultures. The data are shown in Tables 7 and 8. Soil samples were taken from the contents of pots, from the area of the human stomach, and from between the teeth of human skeletons. These samples were analyzed for both pollen and phytoliths. After death, residue of the "last meal" could remain in the stomach cavity of the human skeleton. Such work has been done before for other archaeological sites (Shishlina 2001; Berg 2002). Pollen and phytoliths could remain in the tooth stones and between teeth. In addition, cooking vessels are also known to show reservoir effects (Fischer and Heinemeier 2003).

(i) Early Catacomb Culture

Table 7 Plant material from vessels and the stomachs of the buried individuals (Early Catacomb).

Kurgan, grave, sex, age	Pollen	Phytoliths
Baga-Burul burial ground, 46°23′38.4″N, 42°13′46.8″E		
k.5, g.6 Man age 30–35	Pot: very little pollen: *Poaceae*, *Asteraceae*, *Artemisia*, *Chenopodiacea*; remains of plant lice (*Rhopalosiphoninus*); gramineous plants (*Hordeum*) Stomach area: spores of mushrooms; pollen of *Asteraceae*, *Poaceae*, *Chenopodiaceae*; pollen of water plant *Sparganium*; seldom pollen of *Alnus*, *Ulnus*	—
Mandjikiny-2 burial ground, 45°41′28.2″N, 44°40′49.4″E		
k.37, g.3 Man age 15–16	Stomach area: a lot of pollen of *Varia*, including: *Chenopodiaceae*, *Asteraceae*, *Liliaceae*, *Iridaceae*, *Typha*; *Betula* and *Pinus*	—
k.54, g.6 Woman age 25–35	Stomach area: pollen of *Liliaceae*, *Iridaceae*; *Chenopodiaceae*, *Poaceae*, *Asteraceae*, *Silenaceae*, *Cichoriaceae*, *Geraniaceae*; *Pinus*, *Betula*; siliceous remains of scales of grains of gramineous plants (*Hordeum*)	Stomach area: stick-like phytoliths
Peschany V burial ground, 46°33′21.7″N, 43°40′36.8″E		
k2, g.3 Man age 40–45	Stomach area: a few pollen of *Varia*	Tooth: dark-brown scrap pieces of plant origin, stick-like phytoliths, light-brown scrap pieces of animal origin
k.2, g.1 Human age 8–9	Stomach area: a few pollen of *Asteraceae*, *Chenopodiaceae*, *Cichriaceae*; seldom *Alnus*	Tooth: a lot of plant remains, dark-brown scrap pieces of plant origin, stick-like phytoliths, phytoliths of gramineous plants, freshwater spicula
k.1, g.1 Woman age 25–30	Stomach area: pollen of *Cichriaceae*, *Artemisia, Silenaceae*, *Asteraceae*, *Varia*	—
k.1, g.5 Man age 50–55	Stomach area: pollen of *Rosaceae*, *Fabaceae*, *Betula*	Stomach area: gray-brown plant material, rectangular phytoliths of gramineous plants, phytoliths of *Poaceae*, dark-brown scrap pieces of plant origin

Table 7 Plant material from vessels and the stomachs of the buried individuals (Early Catacomb). *(Continued)*

Kurgan, grave, sex, age	Pollen	Phytoliths
Temrta III burial ground, 46°33′3.0″N, 43°39′53.7″E		
k.1, g.1 Woman age 35–45	Tooth: 30 pollen grains: 60–65% tree pollen; the rest is pollen of *Varia* and spores: *Betula* (1), *Picea* (2), *Pinus* (5), *Alnus* (3), *Corylus* (1), coniferous (4), grass *Asteraceae* (1), *Geraniaceae* (1), *Liliaceae* (2), *Plantaginaceae* (1), *Cannabis* (1), *Polygonaceae* (1), *Cichoriacea*e (1), *Polypodiaceae* (2) Stomach area: a few unidentified pollen	Tooth: unidentified phytoliths
k.1, g.4 Man age 40–45	Stomach area: pollen of *Dipsacaceae* (*Scabiosa*), *Allium* (wild onion), *Chenopodiaceae*, *Alnus*; siliceous remains of scales of grains of wild gramineous plants (3–4 variations)	Tooth: unidentified phytoliths

(ii) East Manych Catacomb Culture

Table 8 Plant material from vessels found in graves (East Manych Catacomb).

Kurgan, grave, sex, age	Pollen identification	Phytolith
Ostrovnoy burial ground, 45°44′44.6″N, 44°0.6′53.0″E		
k.3, g.8 Cenotaph	Pot: concentration of goosefoot (*Chenopodium*), wormwood, plantain plants (*Plantaginaceae*), mixed grass; very rarely pollen of pine and spruce; 1 spore of wood fern (*Dryopteris*); abundance of siliceous remains of non-thrashed grains of gramineous plants (*Hordeum*)	—
k.3, g.10 Child	—	Pot: phytoliths of different shape, unidentified plant remains with large pores
k.3, g.32 Woman age 40–45	Jar: pollen of goosefoot (*Chenopodium*), *Ephedra*, chicory, wormwood, asters, catchfly (*Silene*); legumes; in rare cases, spores of fern, pollen of pine; a lot of siliceous remains of scales of wild gramineous plants (*Hordeum*)	Jar: rare phytoliths within the background
k.6, g.6 Woman age 30–35	Pot: very little pollen of *Liliaceae*, *Silenaceae*; in rare cases, *Chenopodiaceae* as well as *Betula*, *Alnus*; siliceous remains of scales of grains of gramineous plants (*Hordeum*)	Pot: background residues of phytoliths
Mu-Sharet 4 burial ground, 45°41′46″N, 44°32′04″E		
k.12, g.4 Man age 50–60	Pot: very little of pollen of *Chenopodiaceae, Artemisia, Asteraceae, Varia*; in rare cases, pollen of trees: *Alnus, Pinus, Betula*; chitinous remains of microscopic *Arthropoda*; microscopic cilia of grains of gramineous plants (*Hordeum*)	—

Table 8 Plant material from vessels found in graves (East Manych Catacomb). *(Continued)*

Kurgan, grave, sex, age	Pollen identification	Phytolith
Zunda-Tolga-2 burial ground, 45°35′37″N, 44°16′19″E		
k.1, g.4 Human adult	Pot: abundance of pollen, predominance of bits of stamen with undecomposed and underdeveloped pollen; a few pollen of *Artemisia*, *Chenopodiaceae*; in one case, *Polypodiaceae*	Pot: phytoliths of gramineous plants, wormwood, hemp
k.1, g.5 Man, age matures-senilis; Woman, age adultus	Pot 1: abundance siliceous remains of scales of grains of gramineous plants (*Hordeum*, *Helictotrichon*); a few pollen of *Poaceae*, *Chenopodiaceae*; chitinous remains of insects	Pot 1: phytoliths of gramineous plants
k.1, g.5 Man, age matures-senilis; Woman, age adultus	Pot 2: A few pollen of *Varia*, *Chenopodiaceae*, *Artemisia, Ephedra*, *Asteraceae*, *Poaceae*; remains of microplates of fish scales, which are morphologically different	Pot 2: no phytoliths
Zunda-Tolga-3 burial mound, 45°42′17.5″N, 44°08′15.5″E		
k.1, g.1 Human age 10	Pot: very little pollen of *Chenopodiaceae*, *Ephedra*; in one case, *Carpinus*, *Corylus*; golden color organics, maybe of animal origin; siliceous remains of scales of grains of gramineous plants (*Hordeum*, *Helictotrichon*)	Pot: phytoliths of gramineous plants, fossil conductive tissue, concentration of fossil ball-like phytoliths
k.1, g.5 Human age 16	Pot: pollen of *Chenopodiaceae*, *Asteraceae*, *Fabaseae*, *Varia*; siliceous remains of scales of grains of gramineous plants (*Hordeum*)	Pot: phytolith of *Cannabis*, gramineous plants
Baga-Burul burial ground, 46°23′38.4″N, 42°13′46.8″E		
k.5, g.5 Man age 45–55	Pot 5: pollen of *Varia* (from buds); in very rare cases, pollen of *Malva*	Pot 5: few phytoliths
k.5, g.5 Man age 45–55	Turnip-shaped large pot: concentration spots of pollen of *Asteraceae*, *Silenaceae*, *Artemisia*	Turnip-shaped large pot: a large number of brown stick-shaped unidentified phytoliths
k.5, g.7 Cenotaph	Bowl: very little pollen of *Plumbaginaceae*, *Silenaceae*, *Artemisia*, *Asteracea*, *Poaceae*, *Cichoriaceae*, *Ehpedra*; very seldom *Chenopodiaceae*, *Polipodiacea*, *Alnus*, *Pinus*; seldom remains of grains of gramineous plants	Bowl: few phytoliths
k.5, g.11 Woman age 25–35	Pot: practically no pollen (in rare cases, *Chenopodiaceae*, *Poaceae*); chitinous limbs, maybe of plant lice; siliceous cilia of grains of gramineous plants (*Hordeum*, *Helictotrichon*)	Pot: phytoliths from the upper part of the horizon A1
Chilgir burial ground, 45°34′36″N, 44°19′16″E		
k.5, g.1 Human adult	Pot: very little pollen of *Chenopodiaceae*; very seldom *Apiaceae*, *Ephedra*, *Asteraceae*	Pot: few phytoliths
k.3, g.2 Human age 9	Pot: abundance of pollen of *Poceae*, *Chenopodiaceae*; very seldom *Artemisia*, *Liliaceae*, *Alnus*, *Pinus*	Pot: few phytoliths

The data in Tables 7 and 8 show that Catacomb culture populations consumed a lot of C_3 plants, common drug plants like wormwood (*Artemisia*) and strong drug plants such as hemp (*Cannabis*). Phytoliths of *Cannabis* and gramineous plants (oats) and remains of grains of gramineous wild plants (*Hordeum*, *Helictotrichon*) were found in many vessels. The pot from kurgan 1, grave 5, of the Zunda-Tolga-2 burial ground contained a lot of fish scales (river or lake fish). It is clear that the vessel contained a fish soup, prepared using 2 or 3 species. Bones of pike, sturgeon, and carp (Shilov 1975) as well as shells of river mollusks (i.e. *Unio*, *Paludina* sp., and others) were found in the Early Catacomb and Manych Catacomb culture graves.

In addition, we analyzed the "last meal"—the residue of the stomach area—and the area between the teeth of the buried individuals. Thus, we can compare data obtained from the vessels and for the residue of the stomach and tooth area of the buried individuals from the same grave. Two examples are very interesting: kurgan 1, grave 1; and kurgan 5, grave 5. It is clear that both people (who were very old) consumed some herbal drink in the moments before death, possibly for medical reasons. There were 5 vessels in one of the graves, where a man 45–55 yr old was buried. The residue of one of the vessels was identified as herbs. There were abundant remains of wild cereals in the area of the stomach of a woman 25–35 yr old. She appeared to have died during childbirth; there was a skeleton of an unborn infant inside her skeleton. In the pot that was placed inside the grave, many very poorly processed wild steppe cereals were identified. Pollen and phytoliths of wild steppe plants and cereals were found in the area between the teeth of the individuals, as well as pollen of herbs.

The content of control samples taken from the bottom of the graves, as well as from under the skull of the skeletons, differed from the content of the samples discussed above. Soil samples from the bottom of the graves are characterized by phytoliths of reed, sedge, feather-grass, and cane (i.e. steppe plants that were used to make vegetable fibers and plant mats). Soil samples taken from under the skull sometimes showed traces of steppe flowers and plants such as *Chenopodiaceae*, *Tilia*, *Betula*, *Pinus*, *Liliaceae*, *Linaceae*, *Rumex*, *Asteraceae*, *Artemisia*, and *Varia.* Other samples did not contain pollen grains (Shishlina 2001).

No domesticated cereals or C_4 plants were found. Using a variety of food resources, the nomadic populations of the Catacomb cultures were able to prepare a variety of dishes: meat soup, fish soup, roast meat, porridge made of wild cereals (*Hordeum* and *Helictotrichon*), and strong drug teas.

CONCLUSION

Studies of the ^{14}C reservoir effect through identification of the paleodiet (using the stable isotopes $\delta^{13}C$ and $\delta^{15}N$) and parallel dating of different samples taken from the same archaeological context explain the difference between the relative and absolute chronology of Bronze Age cultures, which is mainly based on ^{14}C dates of human bones. Such dates show an "apparent age" due to a ^{14}C reservoir effect.

Most ^{14}C dates of human bones of the Early Catacomb and East Manych Catacomb culture are older than expected. The population of these cultures consumed a significant quantity of food from freshwater sources (rivers and lakes), such as sturgeon, pike, carp, mollusks, and water plants. Stable isotope ratios of the bone collagen reflect this type of diet, while fish bones in graves and the remains of microplates of fish scales preserved in clay pots confirm their presence in the diet. The consumption of river food is the basis of the reservoir effect in the collagen of human bone.

At present, our new data set can only be used to make an approximate regional reservoir effect correction. Additional studies are needed to verify the correction for the Early Catacomb culture, which is about 400–500 yr, and for the East Manych Catacomb culture, which is about 300–450 yr. Using these corrections, we conclude that the historical time interval for the Early Catacomb culture is 2600–2350 cal BC, instead of 3300/2900–2450 cal BC, and for the East Manych Catacomb culture is 2500–2000 cal BC, instead of 2900/2800–2300 cal BC.

Such reservoir effect corrections need to be identified for other Bronze Age cultures, which can resolve existing discrepancies between relative and absolute chronology in the North-West Caspian Sea steppe.

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