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CARBON, NITROGEN AND STRONTIUM ISOTOPES IN THE SET OF SKELETONS FROM THE NEOLITHIC SETTLEMENT AT VEDROVICE (CZECH REPUBLIC)

ABSTRACT: Isotopes C, N, Sr were employed in the study of eleven skeletons from the Neolithic settlements of the Linear Pottery Culture at Vedrovice. Samples of ribs were used for the analysis of ^{13}C, ^{12}C and ^{15}N, ^{14}N from organic part of the bone collagen.

The scope of stable isotopes in the bone collagen is + 8.8 to 12‰ for $\delta^{15}N$ and between –20.5 and –21.9 ‰ for $\delta^{13}C$ in the skeletons. This indicates a population dependent on the inland plants of the type C_3 of the photosynthetic cycle (wheat). The ratio of the isotopes of strontium ^{87}Sr and ^{86}Sr from the tooth tissue M1 and from compact bone of the middle part of the femur was used for distinction of the migrants. In the settlement at Vedrovice children in the grave 3/1966 (6–7 years) and in grave 4/1969 (child 7–8 years) most probably were from non-local population. Individuals from grave 5/1971 (child 5–6 years) and male in grave 10/1974 (40–50 years) may have moved more than once.

KEY WORDS: Diet – Migration – Bone – Teeth – Geochemistry – Neolithic

INTRODUCTION

A newly introduced field of archaeological research employing isotopes has been constituted within the archaeological reconstruction (Pollard 1998). It is based on isotope geology (Faure 1986).

The following isotopes can be employed in archaeology:

1. Isotopes of hydrogen, deuterium, carbon and oxygen in paleontology and paleoclimatology;
2. Isotopes of carbon and nitrogen for interpretation of diet from the human bone collagen, bone mineral and tooth enamel (Richards *et al.* 2003, Tauber 1981);
3. Isotopes of strontium for reconstruction of the migration of people and animals from the bone material and tooth enamel (Price *et al.* 2004);
4. Isotopes of lead for finding out the sources of civilisation influences (Smrčka 2005).

Isotopes C, N, Sr were employed in the study of the skeletons from the Neolithic settlement at Vedrovice in 2003 (grant No. 404/03/0741 coordinated by Dr. Alena Humpolová) with the aim to reconstruct the diet and migration from the collagen of the organic component of the bone. Collagen contains both the amino acids produced in the body and the essential acids obtained from food, based mainly on meat consumption. Consequently it is the most suitable organic bone material showing up the diet of the subjects under research.

Between 1961 and 1974, V. Ondruš investigated in total 11 graves within the settlement of Linear Pottery Culture in the tract of land "Široká u lesa" (Ondruš 1961–1974). From the time point of view they all can be classified into phase IIa according to R. Tichý (1962) for the Linear Pottery Culture (in German: *Linienbandkeramische Kultur*). The acronym LBK, used by Whittle (1996:146) and Gronenborn (1999: 124), follows the Central European tradition.

TABLE 1.

Grave No. /year of research	Grave character	Dimensions (in m)	Sex and age	Orientation of grave pit	Orientation of the individual		Position of the individual	Position of skull	View	Position of extremities		Situation of the find	Grave goods/ earth filling
					Head	Feet				Upper	Lower		
1/1963	in dwelling structure	–	child 6–8 months	–	SW	NE	left side	left temple	SSW	–	situated in parallel, bent at sharp angle, femurs forming right angle with body axis	depression of irregular oval shape in NE part of structure 25A, dimensions 2.00×1.70×0.75 m, oriented NW–SE; the individual situated in E part, 0.10 m above bottom	fragments of 2 ceramic bowls with retracted rim over the chest and behind the feet / –
2/1963	sunk into loess substratum by 0.25 m, grave pit not found	–	child 5–6 years	–	NW	SE	left side	left temple, unnaturally bent backwards – rear of the skull touching the spine	E	sharp bend in the elbow, palms in front of the face	only one extremity documented, bent at sharp angle, femur forming right angle with body axis	loosely laid among objects in cultural layer	bone awl behind the back of the skull / from the stratum under the individual, Ondruš mentions 11 pcs of pottery, 2 fragments of animal bones, 4 pcs of loam
3/1966	level of loess substratum, grave pit not found	–	child 6–7 years	E–W	W	E	left side	right temple, bent to the breast	E	sharp bend in the elbow, palms in front of the face	left extremity sharply bent, knee joint situated in front of the chest, right extremity bent to the extreme and at right angle to body axis	loosely laid among objects	– / 2 pcs of products of flaking
4/1969	grave pit	0.70×0.35×0.50	child 7–8 years	NW–SE	NW	SE	right side	rear side of skull	upward	right one bent to the extreme in the elbow, its palm situated under mandible, left one considerably bent in the elbow, with the palm under right elbow	situated in parallel, maximally drawn each to the other, knee joints in front of the chest, feet at the pelvis	in superposition with the construction pit and groove belonging to building complex D3	– / –

TABLE 1. (continued).

Grave No. /year of research	Grave character	Dimensions (in m)	Sex and age	Orientation of grave pit	Orientation of the individual		Position of the individual	Position of skull	View	Position of extremities		Situation of the find	Grave goods/ earth filling
					Head	Feet				Upper	Lower		
5/1971	little hole in construction pit	0.70×0.50×?	child 5–6 years	N–S	NW	SE	upper part of the body prone, lower extremities on right side	right temple, unnaturally bent backwards – rear of the skull touching the spine	NW	only left ulna and finger bones; possibility of crouching below the chest with palms under mandible	crouched in parallel at sharp angle, femoral bones forming right angle with body axis	at W rim of S part of structure O89, ashy layer, small hole of regular oval groundplan and concave profile dug into the bottom	skull placed on a fragment of trituration stone of triangular shape; at E rim of the pit ca 0.15 m from the scapula and 0.03 m above the bottom a chip of hornstone; in the W part in front of the humerus transversally placed bottle-like vessel with 3 protrusions on the maximum chamber and little boulder / 12 pcs of products of flaking
6/1972	level of loess substratum, grave pit not found	–	child 3–4 years	–	NE	SW	left side	left temple, unnaturally bent backwards – rear of the skull touching the spine	E	–	strong crouching, knee joints in front of the chest	besides the skull only fragments of chest, pelvis and lower extremities preserved	– / in the surroundings of the grave – 3 pcs of quarry stones, red-deer antler, animal bones and 6 pcs of products of flaking, pottery, 5 pcs of loam
7/1972	grave pit	–	neonate	E–W	E	W	left side	left temple	N	–	situated in parallel, maximally drawn each to the other, knee joints in front of the chest, feet at the pelvis	hole of regular oval shape, W from the grave accumulation of quarry stones and medium sized fragments of triturating stones, arranged to form regular oval groundplan, orientation E–W	– / 2 pcs of products of flaking, pottery, 1 pc of loam, 1 pc of trituration stone, animal bones

TABLE 1. (continued).

Grave No. /year of research	Grave character	Dimensions (in m)	Sex and age	Orientation of grave pit	Orientation of the individual		Position of the individual	Position of skull	View	Position of extremities		Situation of the find	Grave goods/ earth filling
					Head	Feet				Upper	Lower		
8/1974	?	–	neonate	–	–	–	–	–	–	–	–	remains of a baby not found until laboratory processing, only the position O 120 is known – sector 21/1974	– / –
9/1974	not standard position	–	female 50–60 years	–	W	R	prone	right temple	S	left arm along the body, right one under the body with elbow touching other elbow	situated in parallel, turned left from body axis, knees slightly bent, crossed above the ankles	in an unevenness of the terrain that came into existence at covering the structure with sediments	–/4 pcs of products of flaking, pottery, animal bones, 1 pc of loam
10/1974	grave pit	1.20×0.65×?	male 40–50 years	E–W	E	W	right side	right temple, unnaturally bent backwards – rear of the skull touching the spine	NE	left humerus along the body, forming right angle with forearm, palm in front of mandible, thumb and index in stretched position, other fingers crouched; right hand stretched along the body, the palm touches left knee joint	"semi-crouched" position; left femur perpendicular to the body axis; right knee joint in NW corner of grave pit, tibia crossed with left tibia; right foot covering the left one	pit situated in S part of structure O122, flat bottom by 0.30 m below level of irregular concave profile of the dwelling structure	hoof-shaped wedge in the area of chest / 2 pcs of products of flaking, pottery, animal bones, pottery fragment under mandible, lump of graphite under the skull

TABLE 1. (continued).

Grave No. /year of research	Grave character	Dimensions (in m)	Sex and age	Orientation of grave pit	Orientation of the individual		Position of the individual	Position of skull	View	Position of extremities		Situation of the find	Grave goods/ earth filling
					Head	Feet				Upper	Lower		
11/1974	not standard position	–	male 35–40 years	–	–	–	–	–	–	–	–	parts of skeleton in non-anatomic position dispersed over the area of 3.0 m^2, on the surface of filled up dwelling structure O123, 0.35 m under level of arable soil, traces of purposeful splitting	– / human bones mixed with animal bones, pottery fragments, products of flaking and loam
2/1985	grave pit	1.80×0.80×0.10	male 25–30 years	NW – SE	SE	NW	left side	left temple	SW	both arms bent at sharp angle in front of the chest one after the other, palms in front of the face	situated in parallel, maximum crouching, knee joints at obtuse angle from the body axis, feet at the pelvis	lay-out disturbed by excavation of the palisade of roundel MMK (Moravian Painted Ware Culture)	in the area of abdominal cavity a stone hoe with a drilled hole, at W rim of the pit spike of bone awl; spondyle bracelet on left forearm, 10 pcs of beads around cervical vertebrae / fragment of stone material

TABLE 2.

Sample	Sample place	δ^{13}C (‰)	δ^{15}N (‰)
Sus scrofa f. domestica (A 1)	pig-maxilla	–18.0	7.7
Bos primigenius (A 2)	aurochs	–20.7	10.5
Bos primigenius f. taurus (A 3)	cow-femur	–20.9	7.2
Ovis ammon f. aries/ Capra aegagrus f. hircus (A 11)	sheep/goat-mandible	–21.6	9.2
Cervus elaphus (*A 12)*	hart-maxilla (tooth)	–20.8	7.3
Sus scrofa f. domestica (A 18)	pig-maxilla	–19.7	7.5
Canis lupus f. familiaris (A19)	dog	–19.6	7.4
Grave 2/63 *(B 1)*	rib	–20.6	9.5
Grave 2/85 *(B 2)*	rib	–20.7	9.7
Grave 3/66 *(B 3)*	rib	–21.4	9.0
Grave 4/69 *(B 4)*	rib	–21.6	9.8
Grave 5/71 *(B 5*)	rib	–20.7	8.8
Grave 6/72 *(B6)*	rib	–20.9	10.7
Grave 7/63 *(B7)*	rib	–21.2	12.0
Grave 8/74 *(B 8)*	rib	–20.5	11.3
Grave 9/74 *(B 9)*	rib	–21.9	10.7
Grave 11/74 *(B 10)*	rib	–20.7	10.0

Funerals H1/1963–H11/1974 and H2/1985 have been found in an area enclosed by a ditch ("Erdwerk"). North from this densely populated place there is a regular burial ground where the dead had been continually buried already since the phase Ib_1 of the Linear Pottery Culture (Podborský 2002).

Besides classical reverent funerals into separate grave pits (H4, H7 and H10), into a settlement pit (H1) or the funeral into a construction pit (H5) also cases of discarding (H9) and anthropophagy (H11) were recorded. Ritual position was recorded in individuals H2, H3 and H6. In them, however, it was impossible to identify a grave pit, if any, because they were buried on the level of the loess substratum (*Table 1*).

MATERIAL

Human skeletons: Samples were taken from the skeletons in graves 1/1963, 2/1963, 2/1985, 3/1966, 4/1969, 5/1971, 6/1972, 8/1974, 9/1974, 11/1974 from the settlement at Vedrovice, deposited at Anthropos Institute in Brno (*Table 1*), to be used for diet reconstruction and to distinguish local members of the population from migrants. Samples of ribs were used for analysis of stable isotopes from the organic part of bone collagen ^{13}C, ^{12}C and ^{15}N, ^{14}N.

The ratio of the isotopes of strontium ^{87}Sr and ^{86}Sr from the tooth tissue M1 and from the compact bone of the middle part of the femur was used for distinction of migrants.

Malacofauna: Shells of molluscs served for reconstruction of diet and determination of migrations as geological niveau. They were represented by three types, i.e. by *Cepaea vindobonensis* Férussac, 1821; *Unio crassus* Retzius, 1788; *Unio pictorum* Linné, 1758.

According to the condition of the shells, these were in no case recent finds. Any of the three species are not found currently in the given locality and it is very probable that they occurred in the region at the given time only. Since there is a water stream (Šumice creek) in the vicinity of the site, the possibility that the shells might get to the site in fluvial deposits should be taken in consideration.

METHODS

Processing of the samples: For credible isotope analyses it is substantial to maintain the composition of isotope of the original organic carbon and nitrogen and to remove alien and inorganic material. A well-proved methodology was employed, used also for radiocarbon dating (Stafford

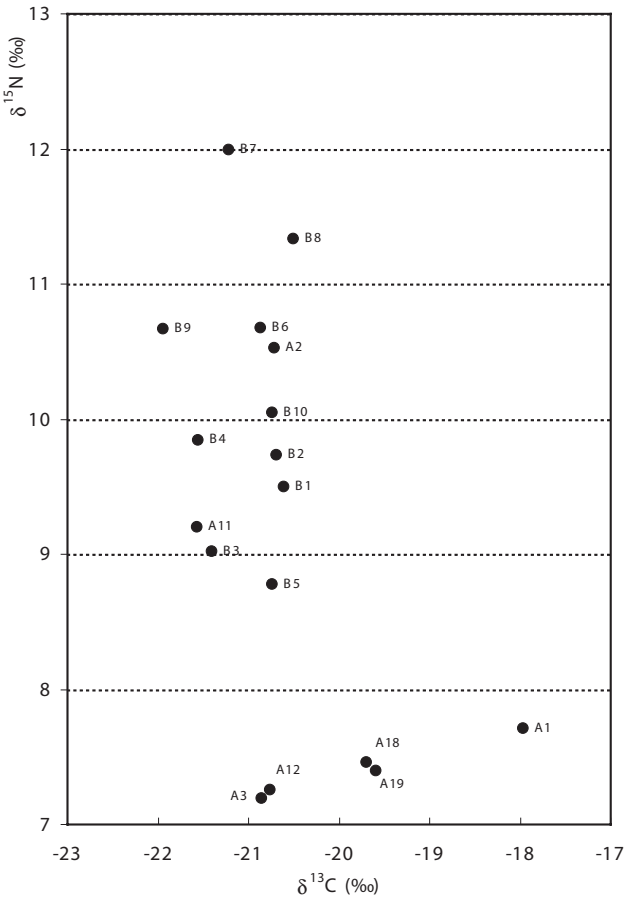

FIGURE 1. Stable isotopes of nitrogen (δ^{15}N) and carbon (δ^{13}C) from the analyses of 10 human and 7 animal skeletal remains at Vedrovice settlement /S/.

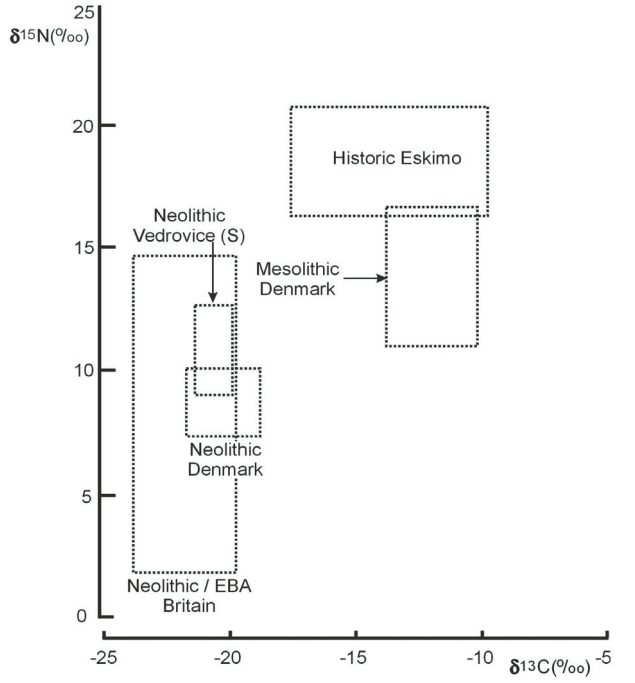

FIGURE 2. Stable isotopes of nitrogen (δ^{15}N) and carbon (δ^{13}C) from the analyses of 10 skeletons at Vedrovice settlement /S/ in the context of European populations (Tauber 1981, Pollard 1998).

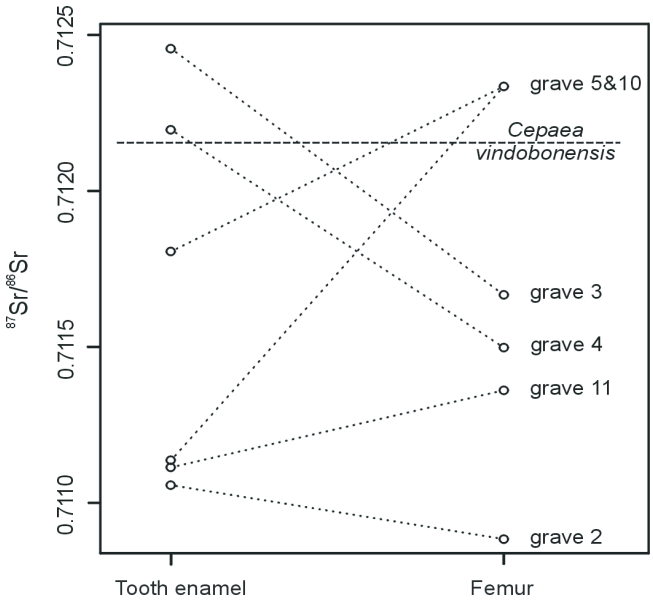

FIGURE 3. ^{87}Sr/ ^{86}Sr in tooth enamel and in skeletons of children in graves 2, 3, 4, 5, and of adults in graves 10 and 11 at Vedrovice settlement.

et al. 1988). Samples of bones were broken to pieces less than 1 cm in size and only then cleaned up ultrasonically in distilled water. After that the fragments were dried up at 50° C, homogenized to the size of <63 μm and extracted by methanol and water. The rest was mineralised (to remove carbonate compounds) at 4° C with 0.5N HCl under constant pH, washed with distilled water and re-dried at 50° C. In order to minimise the losses of collagen, alkaline leaching of the samples was not used.

Elemental composition was determined in the samples, i.e. the contents of carbon and nitrogen as well as analyses of δ^{13}C and δ^{15}N. Analyses were carried out by means of the procedure standard for this type of material – after combustion of the collagen in the elemental analyser (Fisons 1108) the products were chromatographically separated to nitrogen and carbon dioxide and analysed in mass spectrometer Mat 251 by comparison with reference gases of known isotopic composition. The whole procedure was controlled by means of international reference materials NBS 22 (NIST USA, δ^{13}C –29,75 ‰) and NZ1, NZ2 (IAEA Vienna δ^{15}N 0 and 20 ‰). The size of the sample was optimised so that the measurement error could not exceed 0.15 ‰.

Determination of mobility: The method is based on the principle that the ratio of Sr isotopes in the tissues reflects the isotopic ratio in the diet at the time of its origin. If the tooth enamel and the compact bone give different values of strontium isotopes, it can be supposed that the examined person passed the early years of life and pre-mortal years in different geochemical types of environments.

Local sources such as skeletons of small animals or shells can serve for determination of local geochemical conditions (Bentley *et al.* 2002).

Samples from the M1 tooth enamel and from the compact bone of the middle part of the femur employed for determination of the ratio of Sr isotopes, were decomposed in HCl first. Chromatographic column with cation exchanger BIORAD AG-WX8 was used for separation of Sr.

The value of $^{87}Sr/^{86}Sr$ ratio was determined in mass spectrometer with ionisation from the solid phase MAT 262, mark Finnigan, in static mode and in two-fibre arrangement. Thermal fractionalisation was corrected by normalisation to supposed value of the ratio of $^{88}Sr/^{86}Sr=8.375209$.

Reproducibility was checked by measurement of ratio of $^{87}Sr/^{86}Sr$ isotopes of the standard NBS 987 whose long-time mean is 0.710252, with standard deviation 0.000022.

RESULTS

Reconstruction of diet: The scope of stable isotopes in the bone collagen is + 8.8 to 12‰ for $\delta^{15}N$ and between –20.5 and –21.9 ‰ for $\delta^{13}C$ in the skeletons at the settlement of Vedrovice (*Figure 1*). This indicates a population dependent on inland plants of the type C_3 of the photosynthetic cycle (wheat) and with various representations of proteins both of vegetal and biological origin. Similar type of diet was found in the Neolithic population from the region of Denmark (Tauber 1981) (*Figure 2*).

Determination of mobility: Skeletons from graves 2, 3, 4, 5, 10 and from grave 11 were analysed. The skeleton from grave 3/1966 (a child 6–7 years old) and grave 4/1969 (child 7–8 years) exhibit a high ratio of $^{87}Sr/^{86}Sr$ in the tooth enamel compared with the bone collagen of the femur and with the shell that represents the local background value. It is highly probable that these children (grave 3 and 4) were neither local nor from the surroundings of Vedrovice. Individuals from grave 5/1971 (child 5–6 years) and male in grave 10/1974 (40–50 years) exhibit a high ratio of $^{87}Sr/^{86}Sr$ in the bone collagen of the femur compared with the tooth enamel and with the shell. They may have moved more than once (*Figure 3*). The skeletons from graves 2 and 11 exhibit very similar values of isotopic ratio in the tooth enamel and in the femur, which does not indicate any significant migration.

DISCUSSION AND CONCLUSION

The diet of Mesolithic hunters and fishermen is clearly distinguishable by means of isotopes from the Neolithic populations (Tauber 1981, Richards *et al.* 2003). Children are predominant in the enumeration of burials presented above. The burials in the settlements in separate grave pits, settlement pits, construction pits or in non-standard positions are quite a current phenomenon in the settlements of the Linear Pottery Culture, for example at Mikulov (Unger 1974), Těšetice – Kyjovice (Dočkalová, Koštuřík 1996, Koštuřík, Lorencová 1989–1990), Žádovice (Čižmář, Geislerová 1997).

The Vedrovice population fits into the Neolithic diet (*Figure 2* – Vedrovice settlement /S/), it differs only in the newborn babies from graves 1/63 and 8/74.

Reconstructions of migration in Neolithic burial grounds show 65% of migrations for example in Dillingen (Bentley *et al.* 2002) especially in females, in settlement Vedrovice 36.3% migrations (three children and one male). Mobility of children was documented in the Bell Beaker Culture (Grupe *et al*. 1997, Price *et al.* 2004).

In the settlement at Vedrovice the children in graves Nos. 3 and 4 most probably were not from the local population. They came from another place. Bone values should be more representative of the place of residence during their last years of life. It is likely that individuals in grave 5/1971 (child 5–6 years) and male in grave 10/1974 (40–50 years) may have moved more that once. In these cases bone strontium isotope values will reflect a combination of the original places of residence, length of stay, and number of years of residence prior to death (Price *et al.* 2004).

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