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RECONSTRUCTION OF MOBILITY: COMPARISON BETWEEN THE ANALYSIS OF Sr ISOTOPES IN A SET OF NEOLITHIC SKELETONS FROM THE VEDROVICE CEMETERY, AND THE PETROGRAPHICAL ANALYSIS OF POTTERY IN GRAVES

ABSTRACT: From the analyses of strontium isotopes in the dental enamel of M1 and in the compact bone of the middle part of the femurs in a set of 17 skeletons from the Neolithic cemetery at Vedrovice resulted that the individuals from five graves (45/77 female 35–45 yrs, 67/78 female 35–45 yrs, 69/78 male 20–30 yrs, 70/79 female 45–50 yrs, and 81a/79 female 20–30 yrs, i.e. 29% migration) are non-locals coming from the north-western direction. The individual from Grave 67/78, a female aged 35–45 yrs (with Sr ratio >0.712), comes from the north-western direction, most probably from the Bohemian Massif. All the readings of isotopic ratios were higher than 0.710 and the sea basin sediments from the Viennese Basin, south-east of Vedrovice, show the isotopic ratio of biologically available Sr below 0.709.
Biological migration found out by the analysis of Sr in dental enamel and in the bones of the skeletons was compared with the migration found out by means of petrographical analysis of Neolithic pottery, and by distinguishing the non-local pottery from local production. By means of petrographical method, 6 imports were determined in the set of 27 samples from graves containing ceramic vessels – possible non-locals (27/76, 37/76, 66/78, 70/79, 79/79, 83/80, i.e. 22% migration). Seven graves were analysed at the same time (18/75, 19/75, 27/76, 36/76, 69/78, 70/79, 81a/79) by means of both the methods, by Sr analysis from skeletons and by petrographical analysis of pottery. The non-locals were determined, mutually independently, by means of Sr analysis in five graves (45/77, 67/78, 69/78, 70/79, 81a/79), and by petrographical analysis of pottery in two graves (69/78, 70/79). The young female in Grave 27/76 was determined as a non-local only petrographically. On determining the pottery of local origin it is still impossible to exclude a non-local in 50% of the graves. According to our comparison, the efficiency of the method of petrographical analyses of pottery could be 50%.

KEY WORDS: Bone – Trace elements – Neolithic – Neolithic pottery – Neolithic society – Population mobility

INTRODUCTION

Isotopes of strontium were analysed within the set of skeletons from the Neolithic cemetery at Vedrovice with the purpose to determine mobility in 17 selected individuals.

The Neolithic cemetery at Vedrovice is situated in South Moravia in the south-eastern part of the Czech Republic, near Moravský Krumlov (Ondruš 2002). Between 1961 and 1974 V. Ondruš (1961–1974) investigated in total 85 burials in the tract of land "Široká u lesa" at a burial ground

of the Linear Pottery culture (LBK) – the results were used by Whittle (1996), Gronenborn (1999), and Richards *et al.* (2003).

A newly originating research field of isotopic archaeology (Pollard 1998) appears within archaeological reconstruction. It is based on isotopic geology (Faure 1986).

The following isotopes can be used in archaeology: 1st: isotopes of hydrogen, deuterium, carbon and oxygen in palaeoecology and palaeoclimatology, 2nd: isotopes of carbon and nitrogen in interpretation of diet from human bone collagen, bone minerals and dental enamel, 3rd: isotopes of strontium for reconstruction of migration of people and animals from bone minerals and dental enamel, 4th: isotopes of lead for determination of the sources of civilisational influences (Smrčka *et al.* 2004, Smrčka 2005, Smrčka *et al.* 2005).

Stable isotopes of strontium were employed in the study of a set of seventeen skeletons from the Neolithic cemetery at Vedrovice (grant AHRB) for determination of migrations. 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 their origin. Dental enamel is forming at the tender age and it is not renewed later on whilst the bone tissue is renewed in the course of the whole life span. Hence, if the dental enamel and the compact bone have different values of the ratio of strontium isotopes, it can be supposed that the examined person spent his/her tender years and the years before his/her death in different geochemical ambients (Hillson 1997, Price *et al.* 2002).

Determination of the isotopic Sr ratio typical of local population is the key question. The isotopic ratio $^{87}Sr/^{86}Sr$ in the tissues reflects the isotopic composition of the local

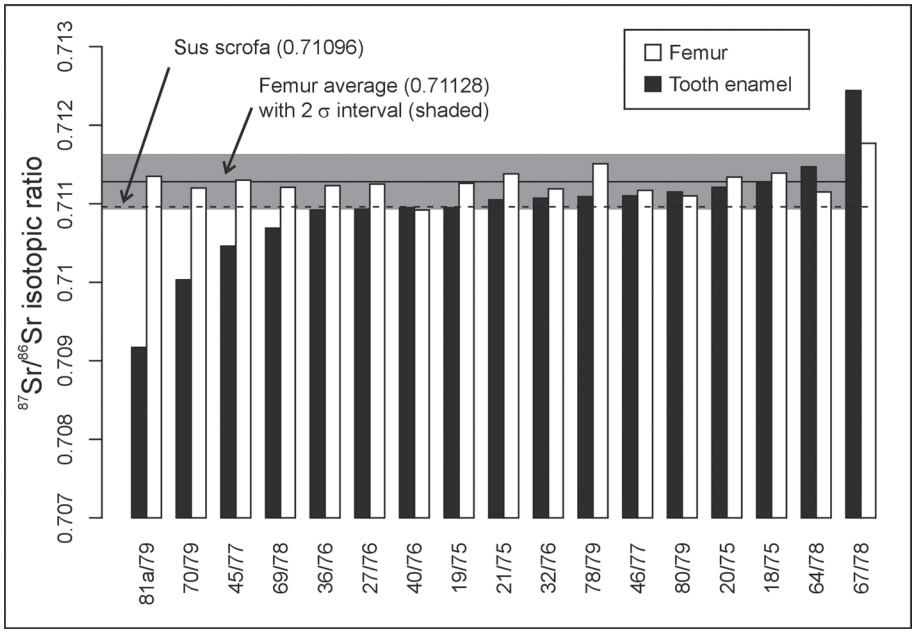

FIGURE 1A. $^{87}Sr/^{86}Sr$ in enamel and compact bone in 17 skeletons from graves of the Neolithic cemetery at Vedrovice (domestic pig *Sus scrofa f. domestica* as an indicator of local biologically available Sr).

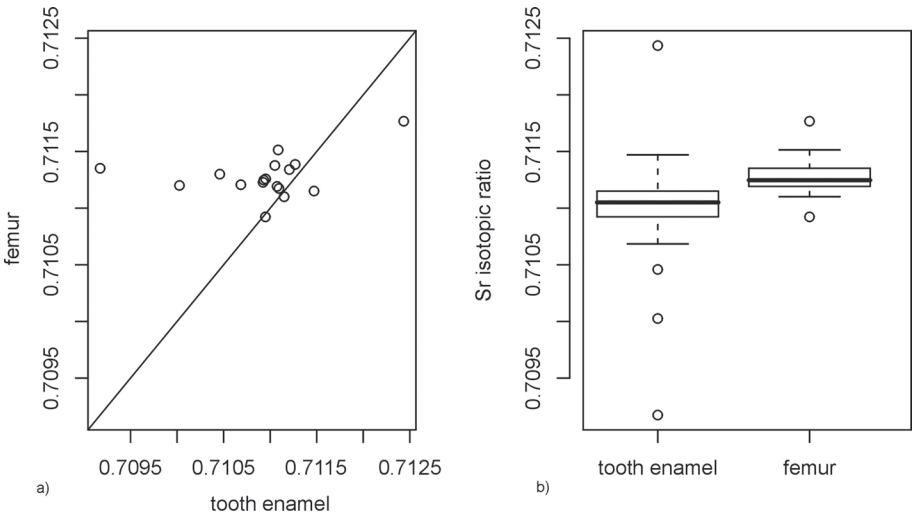

FIGURE 1B. a) Relation of the value of isotopic ratio in bones and dental enamel. Diagonal axis represents an ideal situation of equality of the isotopic ratio in both the tissues. Projection points of the individuals considerably to the left from the axis document higher values of the ratio in the femur. b) Similar information is given by the "box-and-whiskers" diagram in which the individual horizontal lines represent the minimum, the first quartile, median, the third quartile and the maximum. The rings represent outlying values.

water sources for which the dominant source of strontium is the bedrock. Since most of the rocks are composed from more minerals of various isotopic composition, and, which is more, are weathering out and releasing their components into water at various rate, in many cases the information about composition of rocks cannot be used for the needs of determination of mobility. Due to the variability of hydrological and hydrogeological conditions also direct measuring of water sources is problematic. Skeletons of minor rodents or domestic animals, especially those of pigs, which are very near to humans in the trophic chain (Bentley 2002, Bentley, Knipper 2005, Price *et al.* 2002), prove to be the best indicator of the local isotopic signal.

METHOD AND MATERIAL

Human skeletons

Skeletal material comes from the graves: 18/75 (child 6–7 yrs), 19/75 (male 25–35 yrs), 20/75 (child 3–4 yrs), 21/75 (female 30–40 yrs), 27/76 (female 20–25 yrs), 32/76 (child 12–14 yrs), 36/76 (male 45–50 yrs), 40/76 (child 8–10 yrs), 45/77 (female 35–45 yrs), 46/77 (male 20–35 yrs), 64/78 (female 18–25 yrs), 67/78 (female 35–45 yrs), 69/78 (male 20–30 yrs), 70/79 (female 45–50 yrs), 78/79 (child 7–8 yrs), 80/79 (male 35–45 yrs), 81a/79 (female 20–30 yrs), at the Vedrovice cemetery, deposited in the Anthropos Institute in Brno. Samples were taken from 17 individuals for the attempt to distinguish local members of population from the non-locals.

The ratios of strontium isotopes ^{87}Sr and ^{86}Sr from dental tissue of M1 (enamel) and from the compact bone of the middle part of the right femur were used to distinguish the non-locals.

Sample processing for determination of mobility by means of Sr isotopes

Pairs of bone samples and samples of enamel from the graves intended for determination of the ratio of Sr isotopes were, after their cleaning, decomposed in HCl. Chromatographic column with cation exchanger BIORAD AG-WX8 was used for separation of Sr.

The ratio $^{87}Sr/^{86}Sr$ was determined by mass spectrometer Finnigan MAT 262 with ionisation from the solid phase, in the static mode and in double filament assembly. Thermal fractionation was corrected by normalisation to the supposed value of the ratio $^{87}Sr/^{86}Sr=8.375209$. Reproducibility was checked up by measuring the isotopic ratio of $^{87}Sr/^{86}Sr$ standard NBS 987, whose long-time average is 0.710250±0.000024 (2δ), n=21.

Bone and tooth enamel samples were mechanically abraded to remove the visible dirt and underlying dentine, cleaned using dilute ultrapure acetic acid and deionised water, and incinerated in a muffle furnace. Ash samples were dissolved in nitric acid. Strontium was isolated using cation-exchange chromatography columns filled with Eichrom's Sr Spec Resin.

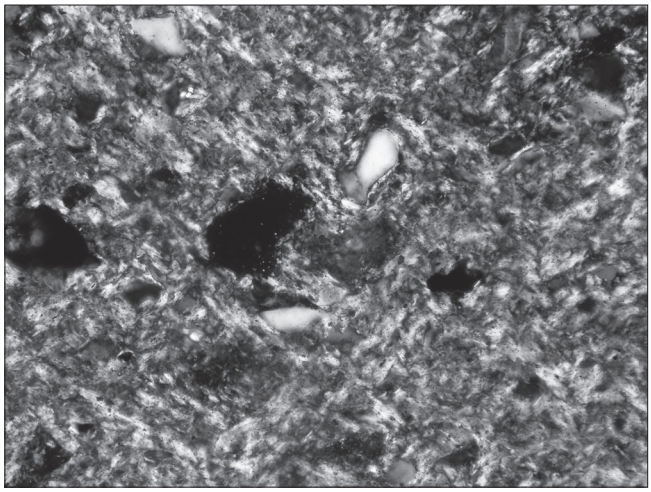

FIGURE 2. Microstructure of grave pottery fabricated from the local subsoil. Grave 66/78 – carbonate shells of microfossils in the ceramic mass. XPL.

FIGURE 3. Microstructure of imported pottery in the cemetery. Grave 69/78 – All-direction granular, anisotropic microstructure in the central part. PPL.

Isotopic analyses were performed at the Czech Geological Survey using a Finnigan MAT 262 TIMS system in dynamic mode with a double Re filament assembly. The $^{87}Sr/^{86}Sr$ ratios were corrected for mass fractionation assuming $^{86}Sr/^{88}Sr=0.1194$. External reproducibility is given by the results of repeated analyses of the NBS 987 ($^{87}Sr/^{86}Sr=0.710250\pm0.000024$ (2δ), n=21) isotopic standards.

Micropetrographical analyses for distinguishing the local and non-local pottery

The analyses were performed at 27 samples of intact or reconstructed vessels. 55 thin sections from the settlement pottery of the stages Ia, Ib, IIa of LBK and the raw material extracted from the subsoil of the LBK settlement at Vedrovice were used for comparison. The microscopic study of the thin sections should reveal the differences between the pottery from graves and from the settlement

of particular LBK stages, import of ceramic artefacts and local base of raw material.

27 pottery samples were taken from graves of the Neolithic cemetery "Široká u lesa" (15/75–2×, 18/75, 19/75, 27/76, 36/76–2×, 37/76, 50/77, 66/78, 69/78–4×, 70/79, 71/79, 72/79–2×, 77/79, 79/79, 81a/79–2×, 83/80, 86/80, 91/80, 99/81, 106/82) in such a way that the aesthetic aspect of the vessel should not be disturbed while the thin sections were prepared. Surface structure, sound returns, granularity, porosity, binding agent, microstructure, modal composition of temper, and the proper micropetrographical analysis were evaluated and the source raw material and firing were determined (Gregerová 1996: 139). The samples were studied by means of Olympus BX51 polarising microscope, which allows to microscope by both types of polarisation (*Figures 2, 3*).

Seven graves of the Vedrovice cemetery (18/75, 19/75, 27/76, 36/76, 69/78, 70/79, 81a/79) were analysed at the same time by both the methods, i.e. by the analysis of Sr from the skeletons, and by petrographical analysis of pottery.

RESULTS

Determination of mobility

From 17 graves from the cemetery "Široká u lesa" (with total number of graves N=85) pairs of samples of M1 enamel and of the middle part of the thigh bone were analysed. Skeletons from the graves feature a high ratio of $^{87}Sr/^{86}Sr$ in tooth enamel compared with the bone collagen of the femur and with the reference sample of a pig jaw, which is determined by the local biologically available isotopic ratio (0.711) (*Figure 1A, B*).

Individuals from five graves (45/77 female 35–45 yrs, 67/78 female 35–45 yrs, 69/78 male 20–30 yrs, 70/79 female 45–50 yrs, and 81a/79 female 20–30 yrs) feature a high ratio of $^{87}Sr/^{86}Sr$ in the femur compared with the enamel of M1. Hence, there is a high probability that these are not local people and not even from the surroundings of Vedrovice, they represent non-locals by 29%. If we suppose that the local Sr signal is represented by the sample of the pig bone in 2 sigma SD, then the bone samples of the femurs get within this interval. Isotopic ratios of enamel of the given individuals are out of the range hence these are possible non-locals. If the set is extended by the boundary values for the individuals 19/75 male 25–35 yrs, 27/76 female 20–25 yrs, and 36/76 female 45–50 yrs, the migration would be 41%.

The skeletons from the remaining nine graves have the values of the isotopic ratio in the enamel and in the femur above the value determined by the isotopic ratio of the reference sample of the pig, which does not suggest a considerable migration.

Biological migration found out by the Sr analysis in enamel and in bones of the skeletons was compared with potential migration found out by means of petrographical analysis of Neolithic pottery and by distinguishing non-local pottery from local production. Six imported vessels (6 potential non-locals: 27/76, 37/76, 66/78, 70/79, 79/79, 83/80, i.e. 22% migration) were determined from the set of 27 pottery samples from graves by means of petrographical analyses.

At the same time, mutually independently, the non-locals were determined by means of Sr analysis in five graves (45/77, 67/78, 69/78, 70/79, 81a/79), from these by means of petrographical analyses of pottery in two graves (69/78, 70/79), and only petrographically in the grave 27/76.

DISCUSSION

With regard to the fact that all the measured isotopic ratios, without exception, are higher than 0.710, it can be supposed that the individuals did not come from the region of the Viennese Basin spreading to the south-east from Vedrovice. The sea basin sediments of the Neogenous age have the isotopic ratio of bio-available Sr considerably lower (below 0.709) (De Paolo, Ingram 1985). On the contrary, in the region of the Bohemian Massif to the north-west from the settlement there is sufficient quantity of strontium sources with a considerably higher isotopic ratio. Migration in the individuals at the Vedrovice cemetery "Široká u lesa" was 41% when the set was extended (from 17 analysed individuals there are 8 non-locals, namely 6 females and 2 males), in the narrowed set it was 29% (from 17 analysed individuals there are 5 non-locals, namely 4 females and 1 male).

Reconstruction of migration at Neolithic burial grounds gives 65% migration, for example at Dillingen (Bentley *et al.* 2002), namely especially in females. Mobility of children was documented for the Bell Beaker culture in Grave 1 at Straubing (Grupe *et al.* 1997). At the Neolithic site of Vedrovice, at the settlement "Široká u lesa", the migration was 67% (Smrčka *et al.* 2005).

In 50% a non-local individual cannot be excluded even if local pottery is found in the grave. The possibilities of correct determination of mobility depend on a relative comparison with funerary goods, type of pottery and ceramic matter, and their origin. Micropetrographical analyses of pottery indicate that a part of ceramic imports were fabricated within the area of 20–50 km to the north and west from Vedrovice. With their composition two imported ceramic vessels are near to the LBK from the settlement of Těšetice-Kyjovice. The origin of the remaining pottery imports cannot be determined exactly. It cannot be always supposed that the imported vessel in a grave should indicate a non-local. Vessels of various composition in one and the same grave allow to suppose that these can be the vessels that the buried individual was using and gradually acquiring in the course of his/her life. Neither another possibility can be excluded, namely that a ceramic vessel from a remote place was put into the grave of a local inhabitant. According to our comparison, the efficiency of the method of petrographical analysis of the pottery could be 50%.

CONCLUSIONS

From the analysis of Sr isotopes in a set of 17 skeletons from the Neolithic cemetery at Vedrovice resulted that the individuals from five graves (45/77 female 35–45 yrs, 67/78 female 35–45 yrs, 69/78 male 20–30 yrs, 70/79 female 45–50 yrs, and 81a/79 female 20–30 yrs, i.e. 29% migration) are non-locals. If the set was extended by boundary values in the individuals 19/75 male 25–35 yrs, 27/76 female 20–25 yrs, and 36/76 female 45–50 yrs, the migration would be 41%. The individual from Grave 67/78 (with Sr ratio >0.712) comes from the north-western direction, probably from the Bohemian Massif.

Biological migration found out by the analysis of Sr in enamel and in the bones of the skeletons was compared with the migration found out by means of petrographical analysis of the Neolithic pottery and by distinguishing non-local pottery from local production. From the set of 27 pottery samples from graves 6 possible non-locals were determined by means of petrographical analyses of pottery (27/76, 37/76, 66/78, 70/79, 79/79, 83/80, i.e. 22% migration).

At the same time seven graves (18/75, 19/75, 27/76, 36/76, 69/78, 70/79, 81a/79) were tested by means of both the methods, i.e. by the analyses of Sr from the skeletons and by petrographical analysis of pottery. At the same time, mutually independently, the non-locals were determined by means of Sr analysis in five graves (45/77, 67/78, 69/78, 70/79, 81a/79), from these by means of petrographical analyses of pottery the non-locals were determined in two graves (69/78, 70/79), and the non-local from the grave 27/76 was determined only petrographically.

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