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HUMAN MOBILITY IN THE FINAL ENEOLITHIC POPULATION OF ŚWIĘTE, JAROSŁAW DISTRICT, SOUTH-EASTERN POLAND: EVIDENCE FROM STRONTIUM ISOTOPE DATA

ABSTRACT

Strontium isotope ratios ($^{87}Sr/^{86}Sr$) were applied to investigate provenance amongst the Final Eneolithic population at Święte (sites 11, 15 and 20) in the Subcarpathian region, south-eastern Poland. The study used 11 human enamel samples collected from the niche graves of the Corded Ware culture. To obtain base-line information on the local Sr isotope composition seven animal enamel samples were also examined. They were found in the adjacent archaeological sites of the Mierzanowice culture at Mirocin and Dobkowice, which have the same environmental and geological background as the sites at Święte. The investigated individuals from Święte display a wide spectrum of Sr isotope signatures, from 0.7094 to 0.7109. Because a comparison of human $^{87}Sr/^{86}Sr$ values from Święte with Sr animal signatures from Early Bronze Age sites in the area is not unambiguous the local range

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of $^{87}Sr/^{86}Sr$ values were based on published data for the Subcarpathian population of the Corded Ware culture. Strontium isotope ratios indicate that only three males with the most radiogenic $^{87}Sr/^{86}Sr$ values exhibit local signatures. Values below 0.7103 document individuals born outside of the Subcarpathian region. Among these are all women and children, two males and one individual with undetermined sex. The probable homeland of the non-local individuals were areas along the northern and eastern margins of the Carpathian Foredeep in Poland and Ukraine.

Key words: Final Eneolithic, Corded Ware culture, Święte, strontium isotopes, mobility

INTRODUCTION

Strontium isotopes are widely used in studies of migration and mobility of past populations [e.g., Grupe *et al.* 1997; Bentley *et al.* 2003; Price *et al.* 2004; Kusaka *et al.* 2009; Montgomery 2010; Frei, Price 2011]. This is because measurements of $^{87}Sr/^{86}Sr$ ratios in human or animal enamel offer unique opportunities for recognizing the geological substrate of an area in which individuals lived. The Sr isotope composition of enamel is derived from food and water ingested when the enamel was mineralizing during the early childhood years. This isotopic signal remains unchanged through life. It depends from the isotopic composition of local Sr reservoirs, i.e. geological substrate and surface water or groundwater. $^{87}Sr/^{86}Sr$ ratios of the host-rock and waters are transferred unfractionated into plants and animals [Poszwa *et al.* 2004; Montgomery *et al.* 2007], but because of mixing processes the Sr isotope composition of organic tissues evolve at each level of the food chain.

In this paper, we report the results of Sr isotope investigations of human remains from the Final Eneolithic graves of the Corded Ware culture (CWC) at Święte [Dobrakowska, Włodarczak 2018; Janczewski *et al.* 2018; Olszewski, Włodarczak 2018]. There were three cemeteries which belong to several Final Eneolithic communities discovered during excavations preceding motorway construction in the Subcarpathian region [Ligoda, Podgórska-Czopek 2011]. Previous isotopic studies at other archaeological sites in the Subcarpathian region revealed that at least one-quarter of the investigated individuals had moved from outside during their lifetime [Szczepanek *et al.* 2018; Belka *et al.* 2019]. The associated allochthonous grave inventories suggested that migrants came from areas of the present-day Belarus or Ukraine.

Fig. 1. Relief map of south-eastern Poland with the location of the Święte and other Final Eneolithic/Early Bronze Age sites mentioned in the paper. The map is constructed by using public domain data available under the Open Database License (https://www.openstreetmap.org/copyright/en). Insert shows location of the Subcarpathian region (black box) in Poland

1. GEOLOGICAL BACKGROUND

The Subcarpathian region of south-eastern Poland is situated within the Carpathian Foredeep Basin (CFB), a prominent geological structure which developed in the front of the Carpathian Orogenic Belt during Miocene time [Oszczypko 1998; Krzywiec 2001]. Forming originally a deep-water marine depression, the CFB is now filled with monotonous, very thick and predominantly argillaceous sequence. Its topmost part is composed of Miocene clays, a lithological unit which is usually called the Krakowiec Beds. These sediments crop out only locally in the front of the Carpathians (Fig. 2) but across the entire study area they form

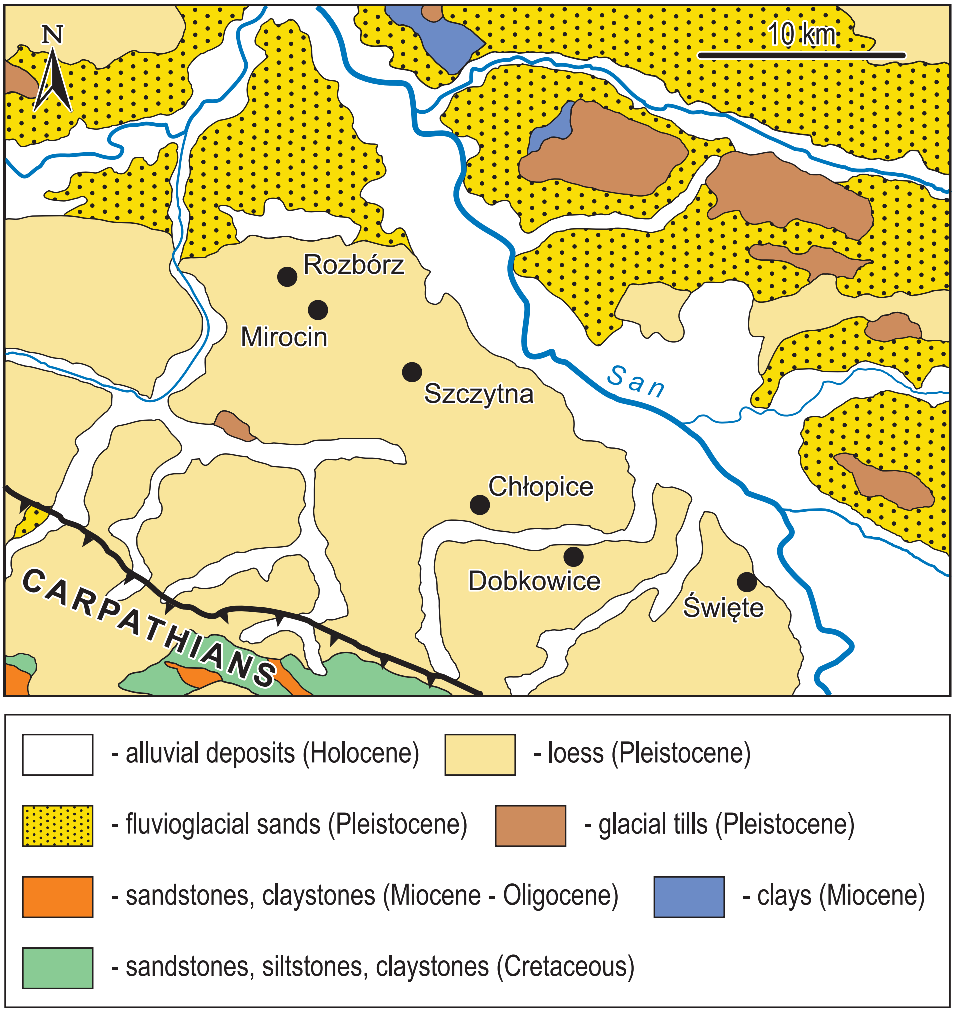

Fig. 2. Detailed geological map of the Subcarpathian region with the location of the Final Eneolithic/Early Bronze Age sites. The geological information taken from the Geological Map of Poland [Marks *et al.* 2006] is simplified

a uniform geological substrate. In the foothills of the Carpathians, the Miocene claystones are overlain by the Pleistocene loess deposits. More to the north, the Pleistocene cover consists of glaciogenic deposits (glacial tills and fluvioglacial sands). West of the San River (Fig. 2), the loess deposits are generally only a few metres thick and form a typical plateau landscape. The loess plateau is cut by rivers and streams. Their valleys are filled with Holocene alluvial sediments, mostly clays with intercalations of sands, muds and peats. The Święte sites are located on

Table 1

Strontium isotope composition of human enamel samples from the Final Eneolithic sites at Święte

Site	Individual	Tooth	Age (years)	Sex	$^{87}Sr/^{86}Sr$
Święte, 20	40A	UM1	6-7	M?	0.709889 ± 10
	43_I	UM1	40-45	M	0.709818 ± 15
	43_III	UM1	7-14	?	0.709803 ± 13
Święte, 15	173	UM1	30-40	K	0.709365 ± 14
	408a	LM1	30-40	K	0.710060 ± 10
	408b	UP1	30-40	M	0.710706 ± 12
	431	LM1	20-50	?	0.710106 ± 10
	427	LM1	6-7	?	0.710004 ± 10
Święte, 11	876	LP1	40-50	M	0.709804 ± 08
	1149	UM1	50-60	M	0.710891 ± 11
	1290D	UM1	20-30	M	0.710431 ± 10

Sex: M = Male; F = Female; ? = Unknown;
Teeth types: LM1 = lower first molar; UM1 = upper first molar; LP1 = lower first premolar; UP1 = upper first premolar

the loess plateau, close to its margin, in exposed position above the adjacent wide valley of the San River (Fig. 2).

Strontium isotope data from the CFB are scarce and only available from the Miocene gypsum deposits occurring along the northern margin of the basin [Peryt *et al.* 2010; Peryt, Anczkiewicz 2015]. Very recently, Szczepanek *et al.* [2018] published results of the first Sr isotope investigations in the Subcarpathian region. They showed that the claystones of the Krakowiec Beds have a relatively uniform composition with $^{87}Sr/^{86}Sr$ ratios from 0.7144 to 0.7150, whereas the overlying loess deposits are much more radiogenic with $^{87}Sr/^{86}Sr$ values between 0.7200 and 0.7235. The Sr isotope composition of Holocene alluvial sediments is unknown. Considering that the rivers and streams draining the eastern Carpathians erode various Cretaceous and Paleogene clastic rocks, it is very likely that the Holocene alluvial sediments have radiogenic Sr isotope signatures, certainly higher than 0.7120.

2. SAMPLES AND PROCEDURES

Basic information on the samples used in this study, including site names, age and sex of individuals, tooth type and isotope values is presented in Table 1. In overall, the Sr isotope analyses included human enamel samples obtained from 11 individuals who were excavated from three sites: Święte 20, Święte 15 and Święte 11 [Szczepanek 2018]. The individuals were selected for sampling based on preserved dental enamel and availability of contextual information. Among them were females and males, which represent predominantly adult and mature individuals, and also three children. Enamel was taken from first molars (M1) whenever possible and occasionally from first premolars (P1).

The Sr isotope analyses were carried out in the Isotope Laboratory of the Adam Mickiewicz University at Poznań, Poland. The procedure included chemical separation of Sr and measurements of Sr isotope ratios. Prior to analysis, the mechanically isolated enamel was cleaned in an ultrasonic bath in ultrapure water to remove the sediment particles. Afterwards, about 10 mg of powdered enamel was treated sequentially with 0.1 ultrapure acetic acid (5 times) to eliminate the diagenetic Sr contamination, according to the procedure described by Dufour *et al.* [2007]. Subsequently the samples were dissolved on a hot plate (~100°C, overnight) in closed PFA vials using 1 N HNO_3. The miniaturized chromatographic technique described by Pin *et al.* [1994] was applied for Sr separation. Some modifications in the column size and concentration of reagents were introduced by Dopieralska [2003]. Strontium was loaded with a $TaCl_5$ activator on a single Re filament and analysed in dynamic collection mode on a Finnigan MAT 261 mass spectrometer. During this study, the NBS 987 Sr standard yielded $^{87}Sr/^{86}Sr = 0.710236 \pm 12$ (2σ mean on ten analyses). Total procedure blanks were less than 80 pg. The $^{87}Sr/^{86}Sr$ values were corrected to $^{86}Sr/^{88}Sr = 0.1194$. The Sr results for samples were normalized to certified value of NIST-987 = 0.710240.

3. RESULTS

The investigated individuals from Święte display a wide spectrum of Sr isotope signatures, from 0.7094 to 0.7109. There are some differences in the Sr isotope composition related to sex The three most radiogenic signatures were recognized among males. Thus, females and children yield less radiogenic Sr composition than males in average. Fig. 3 illustrates the distribution of human $^{87}Sr/^{86}Sr$ values relative to composition of the local fauna. Since no animals were buried in the cemeteries at Święte, published $^{87}Sr/^{86}Sr$ values of archaeofauna from adjacent Early Bronze Age sites in the Subcarpathian region [Szczepanek *et al.* 2018; Belka *et al.* 2018] were taken for comparison.

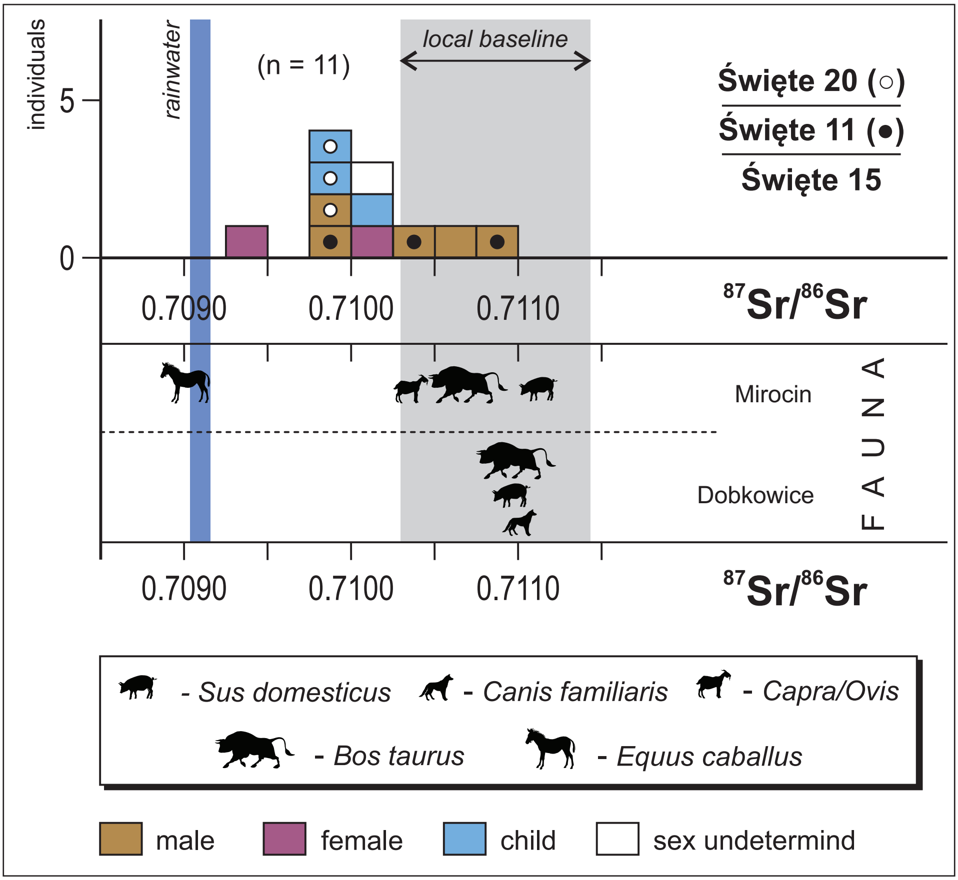

Fig. 3. Strontium isotope composition of the Final Eneolithic human enamel samples from the Święte cemeteries in comparison to the composition of the Early Bronze Age archaeofauna from Mirocin and Dobkowice. Each faunal silhouette indicates a single sample. The Sr isotope composition of rainwater, the most non-radiogenic element of the local environment, is indicated. The shaded area indicates the range of Sr isotope signatures characteristic for the local Final Enolithic populations in the Subcarpathian region [after Szczepanek *et al.* 2018]

4. DISCUSSION AND CONCLUSIONS

The environmental isotopic data collected in the Subcarpathian region [Szczepanek *et al.* 2018] showed that the natural Sr reservoirs of the local environment exhibit a radically different isotopic composition. While rainwater, with its signature around 0.7092 (if not contaminated by dust), constitutes a source of non-radiogenic strontium, the geological substrate is the most radiogenic element in the environment. This implies that all element of the biosphere (plants, animals, humans) in the Subcarpathian region should have Sr isotope signatures higher than 0.7092 but lower than those of the geological substrate (<0.7140). Although $^{87}Sr/^{86}Sr$ values of all investigated individuals meet this basic criterion, it does not mean that all persons were of local origin.

A comparison of human $^{87}Sr/^{86}Sr$ values from Święte with Sr animal signatures from Early Bronze Age sites in the area is not unambiguous (Fig. 3). At Dobkowice, the $^{87}Sr/^{86}Sr$ ratios of the fauna are very uniform. In contrast, at Mirocin, the faunal signatures vary within a wide range, even if we exclude the value of the horse because of its non-local provenance [*see* Szczepanek *et al.* 2018]. If the signatures of the prehistoric animals at Dobkowice would really reflect an accurate estimate of local $^{87}Sr/^{86}Sr$ values, all individuals from Święte, except of a single male, would be identified as non-locals. On the other hand, the faunal data from Mirocin would lead to a completely different interpretation. This example confirms earlier suggestions that Sr isotope signatures of prehistoric and modern fauna do not provide a reliable $^{87}Sr/^{86}Sr$ baseline for investigating past human provenance and migration [Maurer *et al.* 2012; Zieliński *et al.* 2016; Szczepanek *et al.* 2018].

In the Subcarpathian region, Sr isotope signatures of human enamel are already available from several archaeological sites: Rozbórz, Mirocin, Szczytna, Chłopice and Dobkowice [Szczepanek *et al.* 2018; Belka *et al.* 2018; 2019]. They reveal a clearly defined range of $^{87}Sr/^{86}Sr$ values characteristic for the local population, from ~0.7103 to ~0.7114. Since the environmental background at Święte is identical to that of other sites mentioned above, it can be assumed that the same variation in $^{87}Sr/^{86}Sr$ ratios represent the local baseline at Święte. Thus, the wide range of values of the investigated individuals is unexpected. In consequence, it appears that only three males with the most radiogenic $^{87}Sr/^{86}Sr$ ratios exhibit local signatures. All $^{87}Sr/^{86}Sr$ ratios below the value of 0.7103 document individuals born outside of the Subcarpathian region. Among these are all women and children, two males and one individual with undetermined sex.

The non-local Sr signatures below 0.7103 imply the presence of an unradiogenic bedrock component in the local environment, with $^{87}Sr/^{86}Sr$ values lower than that of rainwater. Therefore, we suspect that an area in which Miocene carbonate rocks occur in the bedrock was the probable homeland of the non-local individuals. This points to areas along the northern and eastern margins of the Carpathian Foredeep in Poland and Ukraine. We speculate that non-local individuals came probably from the basins of Dnieper and Pripyat rivers. This is suggested by allochthonous grave inventories found in Mirocin, linked to the Middle Dnieper culture [Szczepanek *et al.* 2018].

In summary, isotopic data from the Final Eneolithic remains of Corded Ware culture inhabitants at Święte show a high proportion of non-local individuals in the population. This pattern has also been recognized in the site of Mirocin [Szczepanek *et al.* 2018] and confirms a substantial human mobility during this period in the Subcarpathian region. Since all investigated women and children came from outside, the groups had to be highly mobile and the mobility continued across the generations. These all are features observed also in the CWC societies of southern Germany [Sjögren *et al.* 2016]. Moreover, the fact that females were more mobile than males in the CWC suggests a predominant exogamic social system [Szczepanek 2008; Müller *et al.* 2009] in which males were largely stationary and women moved to their husband's settlements.

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