Abhandlung

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Migration Period in Central Europe: New Multi-Isotopic Evidence from Tyniec upon Ślęża Cemetery (4th–5th Century AD, SW Poland)

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Zusammenfassung: Die Völkerwanderungszeit (4.–5. Jahrhundert n. Chr.) in Mitteleuropa war von tiefgreifenden demografischen und kulturellen Umbrüchen geprägt; dennoch sind bioarchäologische Daten aus dieser Epoche in der Region weiterhin selten. Der neu ausgegrabene Friedhof von Tyniec am Ślęża in Südpolen bietet eine einzigartige Gelegenheit, Lebensweisen in dieser Übergangsphase zu erforschen. An Kollagenproben von zehn Individuen wurden stabile Isotope ($\delta^{13}C$, $\delta^{15}N$) analysiert, um Ernährungsgewohnheiten zu rekonstruieren. Die Mobilität wurde anhand von zwanzig $^{87}Sr/^{86}Sr$-Messungen an Zahnschmelzproben untersucht. Eine lokale Umweltbasis wurde aus 27 Umweltproben aus prähistorischen Siedlungsgebieten im Raum Wrocław ermittelt. Ergänzend wurden Spurenelementkonzentrationen für acht Elemente im Zahnschmelz bestimmt, um Ernährungs- und Diageneseinterpretationen abzusichern. Die Studie verdeutlicht die Herausforderungen, individuelle Mobilität in hochdynamischen demografischen Kontexten wie der Völkerwanderungszeit zu interpretieren, in denen stabile lokale Bevölkerungen fehlen. Die Ergebnisse weisen auf eine ausgeprägte Ernährungsdiversität unter Einbezug terrestrischer und aquatischer Ressourcen sowie auf komplexe Mobilitätssignaturen hin, die vielfältige geographische Ursprünge und Lebensgeschichten widerspiegeln. Die Untersuchung liefert neue Erkenntnisse zur kulturellen Hybridisierung germanischer Gruppen in Schlesien sowie zu deren Anpassungsstrategien und Reaktionen auf Kontakte mit nomadischen Gruppen und die geopolitischen Umbrüche infolge des Zerfalls des Römischen Reiches.

Schlüsselworte: Völkerwanderungszeit, Polen, Friedhof, stabile Isotope, Strontiumisotope, Isoscape, Radiokarbondatierung, Ernährung.

Abstract: The Migration Period (4th–5th centuries AD) in Central Europe was marked by profound demographic and cultural transformations. Nevertheless, bioarchaeological data from this period remain scarce across the region. Tyniec upon Ślęża constitutes the only newly excavated Migration Period cemetery in southern Poland, providing a rare opportunity to explore lifeways during this transformative epoch. Stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope analyses were conducted on samples from ten individuals to reconstruct dietary patterns, while mobility was investigated through high-resolution strontium isotope ($^{87}Sr/^{86}Sr$) measurements of dental enamel from selected individuals,

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yielding a total of twenty determinations. A local environmental baseline was established, encompassing the principal prehistoric settlement zones surrounding Wrocław. To complement the isotopic dataset, trace element concentrations from dental enamel were examined to aid dietary reconstructions and assess potential diagenetic alterations. The findings highlight the interpretative challenges posed by the highly dynamic demographic landscape of the Migration Period, in which the absence of stable local populations complicates the identification of non-local individuals. Nevertheless, the results reveal pronounced dietary variability, including substantial consumption of aquatic resources, and complex mobility signatures, reflecting diverse geographic origins and life histories. Our paper provides new insights into the processes of cultural hybridization among Germanic populations inhabiting Silesia during this turbulent era. It further explores their adaptive strategies and cultural responses to interactions-both direct and indirect-with nomadic groups and the broader geopolitical transformations precipitated by the disintegration of the Roman Empire.

Keywords: Migration Period, Poland, cemetery, stable isotopes, strontium isotopes, isoscape, radiocarbon dating, diet.

1 Introduction

1.1 Historical background

The Migration Period in Central Europe was catalyzed by the arrival of nomadic groups from Central Asia, notably the Huns, who appeared in the Pontic Steppe around 375 AD and subjugated the Ostrogoths[1]. These incursions triggered a cascade of population movements, including the Visigoths from Transylvania and the Alans from the Caucasus[2]. Following the refusal of tribute by Roman Emperors Marcian and Valentinian III, the Huns invaded Gaul. Their defeat at the Battle of the Catalaunian Plains in 451 AD by Aetius, allied with the Visigoths, marked the beginning of the decline of Hunnic power. After Attila's death, a coalition led by the Gepid king Ardaric defeated the Huns. The Gepids subsequently occupied former Hunnic territories in the Carpathian Basin, while other Germanic groups such as the Herules established political rulership in Moravia[3]. The Przeworsk culture, closely linked with the Vandals and possibly also the Lugians, a powerful ethnic group active earlier in the 1st millennium BC, underwent significant transformation[4]. The impact of Hunnic activity contributed to a marked decline in archaeological evidence across the territory of present-day Poland, including Lower Silesia[5]. This phenomenon is likely attributable to continued depopulation[6]. Within this context, the cemetery at Tyniec upon Ślęża holds exceptional significance.

1.2 Local context

From the 1st to the late 3rd century AD, Central Europe experienced relative economic and political stability. The prosperity of local elites in non-Roman territories is evidenced by numerous Roman imports, such as coins, weapons, medallions, and jewelry. Although the Amber Road had declined in significance by the end of the 2nd century AD, economic exchange with the Roman Empire persisted through alternate trade routes, notably those connecting the Black Sea and the Baltic via the Danish islands[7]. Trade across the limes was often accompanied by low-intensity warfare. Central European warriors may have participated in Roman conflicts and gained spoils of war. Roman weaponry is notably present in Polish grave assemblages, suggesting either participation in military campaigns or illicit trade[8]. Notably, approximately half of all swords from Polish Roman-period graves are of Roman origin. Despite the importance of such finds, skeletal material from the Migration Period is extremely scarce. No large cemeteries from this time have been uncovered in Silesia since the 1930s, and even isolated burials are rare[9].

This study presents and interprets new bioarchaeological data derived from human skeletal remains excavated at the recently discovered Migration Period cemetery of Tyniec upon Ślęża, dated to the 4th–6th centuries AD. The primary aim is to investigate the chronology and subsistence strategies of populations inhabiting southwestern Poland during this transitional epoch, situating the results within their broader context. Particular attention is given to the distinctive characteristics and atypical burial practices documented at the site. A further objective is to construct a strontium isoscape for Lower Silesia to enhance recon-

1 Fouracre 2005, 35–55; Halsall 2005, 165–180.
2 Ausenda 1995, 146, 150–157.
3 Bona 1991, 15–16; Kim 2016, 110–165.
4 Heather 1991, 84–157; Mączyńska 1996;1998; Kokowski 2010.
5 Rudnicki 2017; Bursche 2020.
6 Gralak 2010; Pędziszewska *et al.* 2020.
7 Hedeager 2007.
8 Ferrill 1986; Chapman/Hamerow 1997; see also Rankov 1999.
9 see also Niebylski *et al.* 2024.

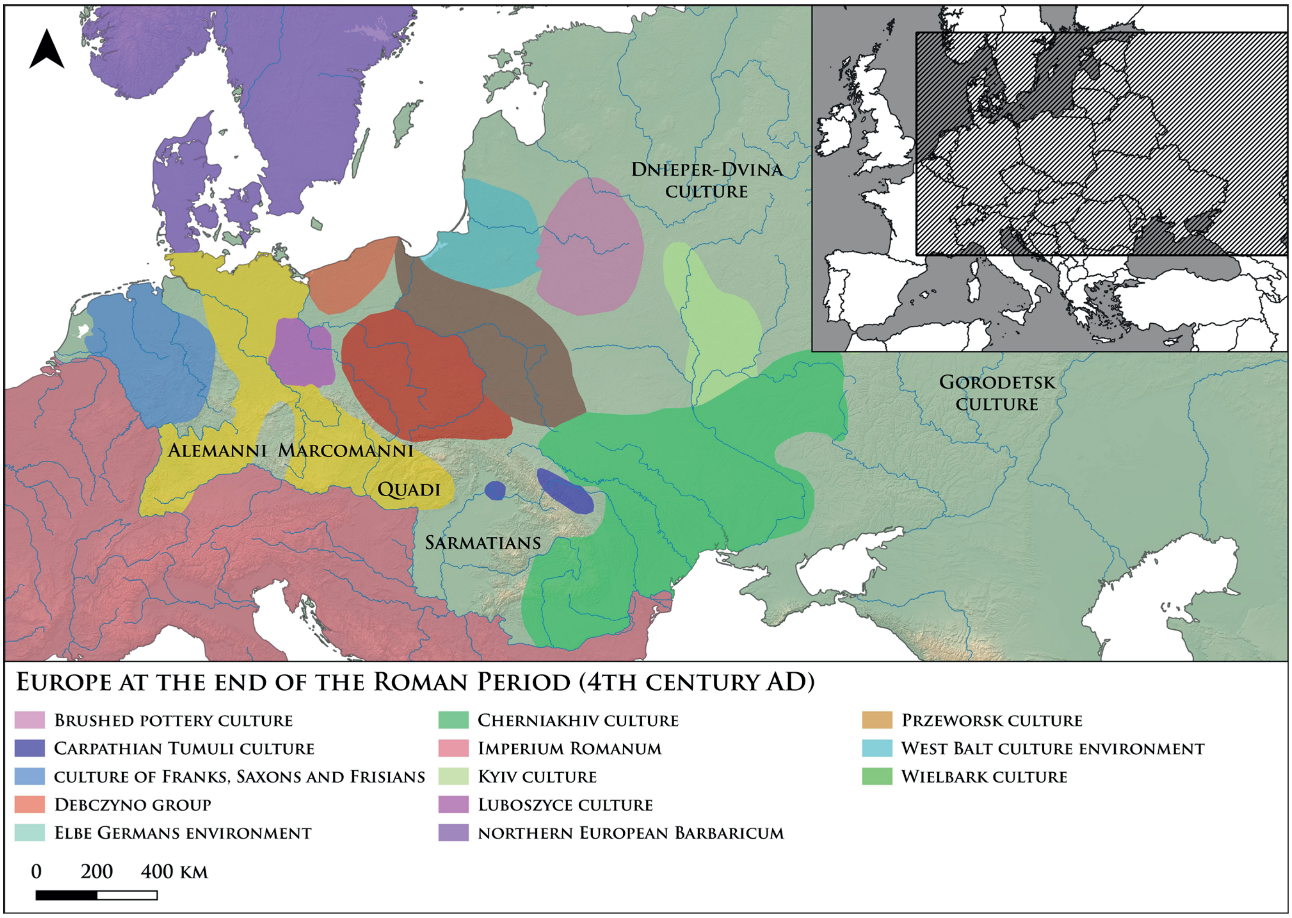

Fig. 1: Map of Central European Barbaricum by the end of 4th century AD- archaeological overview. Graphic by P. Tóth.

structions of prehistoric population mobility during the Migration Period. To this end, background strontium isotope ratios ($^{87}Sr/^{86}Sr$) were measured across nearly thirty major prehistoric settlement zones to evaluate regional variability.

1.3 The site

The cemetery is located on the terrace of the Ślęża River, a tributary of the Oder River, 29 km south of Wrocław (50.9508 ° N, 16.9330 ° E). Excavations at the site were conducted in 2011[10]. The chronology of the site is clearly and exclusively associated with the Migration Period. The burials represent the first discoveries from the Migration Period in Lower Silesia since the 1930s. At that time, the cemetery in Żerniki Wielkie (Wrocław district) was excavated[11]. Other sites investigated during the same period, such as those at Ługi, Czeladź, Grodzieszowice, and Wiklina, typically consisted of single graves and were mostly located along the northwestern margins of Lower Silesia[12]. In many cases, including almost all finds from Żerniki Wielkie, the materials were lost during World War II[13]. Consequently, the discovery of skeletal inhumations from the Migration Period at Tyniec is considered particularly significant, valuable, and, thus far, unique.

The Tyniec skeletal assemblage comprises both adults and juveniles, with identified individuals including two females and seven males (Tab. 1; Fig. 2)[14]. One grave (TYN1) contained only a fragment of a human skull, suggesting an adult of unknown sex (Tab. 1). Two inhumations were identified as re-burials or partial depositions, containing commingled human remains (Fig. 3C), and were marked by stone steles on the surface. The burial ground exhibited a clear spatial organization, with the majority of inhumations arranged in parallel rows along a WSW-ENE axis. Most in-

10 see Figs. 2–3.
11 Zotz 1935; Gralak 2008; Mączyńska/Jakubczyk 2017.
12 Błażejewski 1998, 117–118.
13 Zotz 1935; Mączyńska 1993; Gralak 2008.
14 Gralak/Waniek 2021; Dąbrowski/Gronkiewicz 2021.

Tab. 1: Tyniec upon Ślęża burial ground: archaeological overview.

Grave ID	Lab ID	^{14}C dating (BP)	Age/Sex	Element	Grave depth (m)	Body alignment	Grave furnishing
TYN 1	Ua-58739	1529±32	Adultus X	Long bone	0.55	WSS-ENN	Grave was marked with stone stele
TYN 2	–	Insufficient collagen content	Adultus F	Long bone	0.85	WSS-ENN	Iron knife, buckle, iron bar, glass beads, chain armour
TYN 4	Ua-58740	1541±31	Adultus M	Long bone	1.00	WSS-ENN	Iron knife, iron wire, fibula, comb, buckle and a mug
TYN 5	Ua-58742	1558±29	Adultus M	Long bone	0.58	WSS-ENN	Iron knife, iron and bronze buckles, bronze buckle, nails
TYN 6	Ua-58743	1583±29	Juvenis (F?)	Long bone	0.9	WSS-ENN	Bronze buckles (2), iron buckle, decorative iron plates (5), iron knife, loom weight, glass beads, amber beads (4) and mollusc shell decorative item.
TYN 7	Ua-58744	1623±29	Adultus M	Long bone	0.9	WSS-ENN	Iron knife, bronze tweezers, ceramic vessel
TYN 8	Ua-58745	1633±30	Adultus M	Long bone	0.75	WS-EN	Iron knife, bronze tweezers
TYN 9	Ua-58746	1667±32	Adultus M	Long bone	0.9	WSS-ENN	Iron knife, iron bars (2)
TYN 11	–	Insufficient collagen content	Maturus M	Long bone	0.9	WSS-ENN	Iron knife, iron bars (2), buckle
TYN 12	–	Insufficient collagen content	Juvenis M		0.5	WSS-ENN	Grave was marked with stone stele, traces of burning/hearth

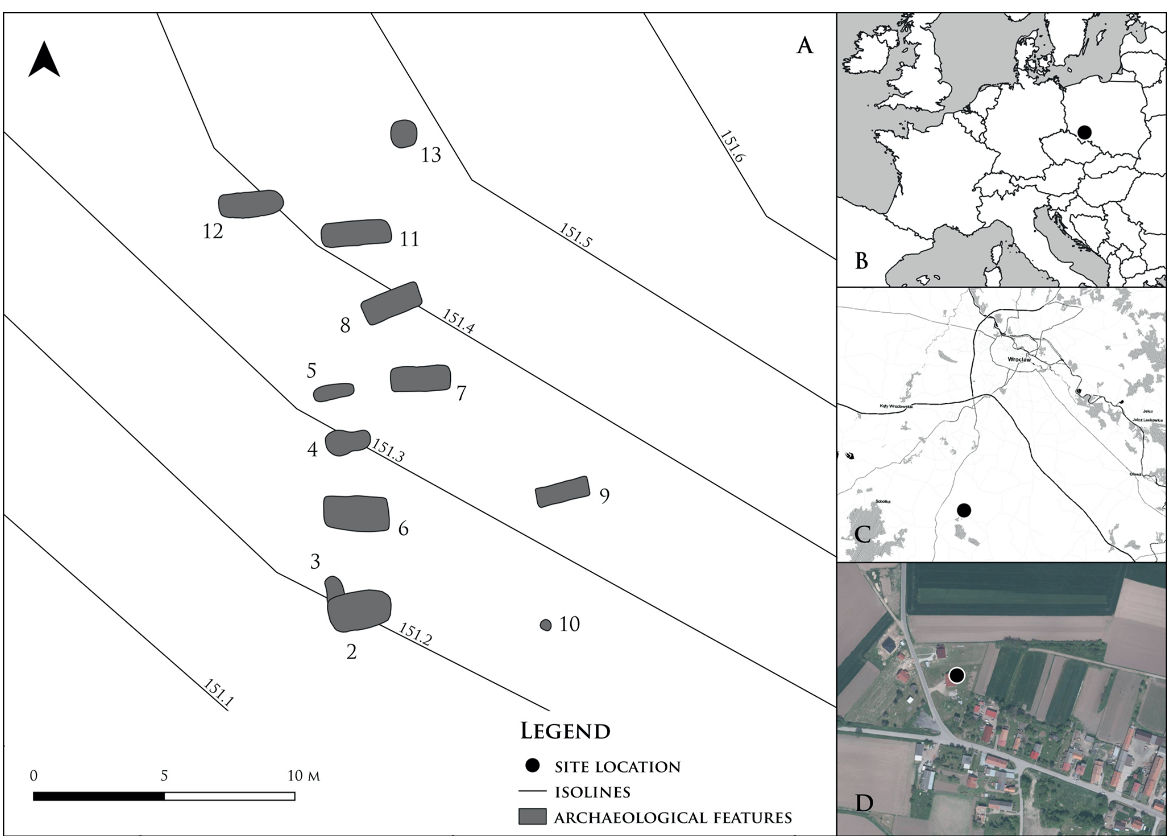

Fig. 2: Tyniec upon Ślęża- site location. Map based on Gralak/Waniek 2021. Graphic by P. Tóth.

Fig. 3: Tyniec upon Ślęża- inhumations; A) grave no.6, juvenile female; B) grave no.8, adult male; c) grave no.9, adult male. For description: see Tab. 1. Photo W. Waniek.

terments contained articulated skeletons lying supine, with skulls oriented towards the WSW direction. Certain aspects of the Tyniec inhumations resembled nomadic burial practices observed among neighboring populations, such as those of the Chernyakhov culture. In several graves (nos. 2, 6, 9, and 11), large, elongated human-shaped and size concavities were found at the bottom of graves[15]. These concavities, likely covered with wooden laths, are typical of Sarmatian burial practices[16]. Metal fasteners found in several graves were likely used to secure laths forming coffins. Similar funerary structures have been identified in nearby Żerniki Wielkie[17], and at the Tiszadob-Sziget cemetery in Hungary[18]. Additionally, several inhumations at Tyniec contained disarticulated human remains, deposited without truncation, appearing orderly and anatomically aligned (Fig. 3). Notably, the use of primitive masonry was evident, with grave 1 marked by a large boulder and grave 12 covered by a stela (these graves are chronologically the youngest and the oldest on site; see Fig. 5). A third stela was found without stratigraphic context. Otherwise, grave furnishings were relatively sparse and uniform (Tab. 1).

15 Gralak/Waniek 2021.
16 Magomedov 2001.
17 Zotz 1935; Gralak 2008.
18 Istvánovits 1993.

2 Materials and Methods

In this study, we analyzed the remains of ten adult individuals buried at the Tyniec cemetery (Tab. 1). For the isotopic dietary analyses, we used first molars, which form during early childhood[19]. The preservation of the dental material was rated as moderate to poor according to the Brabant index[20]. Radiocarbon dating was performed on long bones (skulls and femurs) at the Tandem Laboratory, University of Uppsala (Tab. 1, Fig. 5). Owing to the burial conditions, the dental surfaces exhibited localized erosion and vertical enamel cracking. Consequently, $^{87}Sr/^{86}Sr$ LA-ICP-MS analyses were limited to well-preserved molar samples from selected individuals, resulting in 21 measurements (Tab. 6). Additionally, local referential isotopic points (Sr baselines, including local soils and waters) were collected and analyzed from major prehistoric settlement zones in the Wrocław area (TIMS; Tabs. 4–5).

2.1 Sampling and Decontamination

Obtaining high-quality $^{87}Sr/^{86}Sr$ measurements required thorough sample decontamination, which involved the complete removal of dental calculus, necrotic tissue,

19 Hillson 1996.
20 Brabant/Sally 1962; Hillson 1996.

organic impurities, and soil. One objective was to expose the perikymata lines to better identify chronological indicators for each individual. For in-depth decontamination, a clinical irrigation procedure was applied using NaOCl (5.25 %) and EDTA (17 %, Merck) at a temperature of 60 °C, following the method outlined by Castagnola *et al.*[21] During ablation scanning, any fragments of the enamel surface affected by pathological changes were omitted.

2.2 Dietary analyses

The site yielded very few faunal remains. The isotopic reconstruction of the local ecology was based on isotopic data published by Pokutta (2013; n=49), with additional new specimens (n=18) collected for the purpose of this study. The faunal remains originated from earlier periods, ranging from the Neolithic to the early Iron Age. Bone collagen in human samples was extracted following the method by Brown *et al.*[22] The decalcified material was dissolved in 0.01 N HCl and gelatinized at 58 °C for 18 hours. The gelatin was filtered to remove any remaining solids, then ultrafiltered to eliminate the <30-kD fraction, and finally lyophilized. Isotopic measurements were conducted using a continuous flow mass spectrometer, the Finnigan Elemental Analyzer Delta V Advantage[23]. Approximately 0.5 mg of collagen was weighed for combustion. The precision of the measurements was ±0.15 ‰ or better for both $\delta^{13}C$ and $\delta^{15}N$ (Tab. 2, Tab. 3; Fig. 6).

Tab. 2: Tyniec upon Ślęża: human bone collagen $\delta^{13}C$ and $\delta^{15}N$ data.

Grave ID	Age/Sex	$\delta^{13}C$ vs PDB (‰)	% C	$\delta^{15}N$ vs AIR(‰)	% N	C/N
TYN 1	Adultus X	−19.62	31.67	10.57	11.14	3.3
TYN 2	Adultus F	−20.46	44.64	10.51	14.68	3.5
TYN 4	Adultus M	−18.98	41.73	10.32	14.98	3.2
TYN 5	Adultus M	−18.08	42.69	10.11	15.33	3.2
TYN 6	Juvenis (F?)	−20.69	39.71	10.55	14.11	3.2
TYN 7	Adultus M	−18.94	38.15	10.58	13.52	3.2
TYN 8	Adultus M	−20.72	34.65	9.84	12.42	3.2
TYN 9	Adultus M	−17.92	46.13	10.89	16.66	3.2
TYN 11	Maturus M	−21.06	47.19	10.79	14.07	3.6
TYN 12	Juvenis M	−19.69	45.53	10.24	16.31	3.2

2.3 Lower Silesia isoscape: $^{87}Sr/^{86}Sr$ data from soils and water (TIMS)

The territory of Wrocław has been densely populated since the Neolithic, with evidence of settlement throughout prehistory. In this study, we analyzed soil samples from carefully selected locations in the vicinity of Wrocław (Tab. 4). The samples were collected according to a targeted strategy designed to provide a comprehensive representation of all known major prehistoric settlement zones in the area (Fig. 4). Additionally, at the prehistoric site of Siechnice, we carried out intensive soil sampling by collecting samples at approximately 300-meter intervals and a depth of 0.5 meters. This approach was designed to investigate local-scale variability in strontium baseline values within a single locality (Tab. 4). Previous studies have analyzed and published $^{87}Sr/^{86}Sr$ water values from an Oder River aquifer[24]. For this study, we analyzed a single water sample from the Olza River (a tributary of the Oder; Fig. 4, Fig. 8) to complement these prior analyses. Soil samples were dried at room temperature for five days, then sieved and pulverized (mesh 0.125/0.063 mm). The sieved samples were sterilized with UV light and heated in an oven (900 °C for 3 hours) to remove organic content and water. The chemical separation of Sr and the measurement of Sr isotope ratios were conducted at the Isotope Laboratory, University of Poznań. Chromatography was performed using the method outlined by Pin *et al.*[25], with modifications by Dopieralska[26]. Strontium was loaded with a $TaCl_5$ activator onto a single rhenium filament and analyzed in dynamic collection mode on a Finnigan MAT 261 mass spectrometer. Total procedure blanks were less than 80 pg.

2.4 Human dental enamel $^{87}Sr/^{86}Sr$ measurements (LA-ICP-MS)

Strontium isotope analysis of dental enamel was performed at the Microgeochemistry Laboratory, University of Gothenburg. Unlike traditional *in situ* $^{87}Sr/^{86}Sr$ determinations of dental enamel[27], the mass spectrometer used features a reaction cell sandwiched between two quadrupoles[28]. This design results in slightly lower precision (ca. ±0.0006) but allows similarly accurate measurements while enabling simultaneous analysis. Interferences, such as $^{87}Rb^+$, dimers, and ridges[29], can be efficiently eliminated by reacting Sr

21 Castagnola *et al.* 2014.
22 Brown *et al.* 1988.
23 Department of Geology and Geochemistry, University of Stockholm.

24 Pokutta 2013; Zielinski *et al.* 2018.
25 Pin *et al.* 1994.
26 Dopieralska 2003.
27 see also Le Roux *et al.* 2014.
28 Agilent 8800 QQQ.
29 Willmes *et al.* 2016.

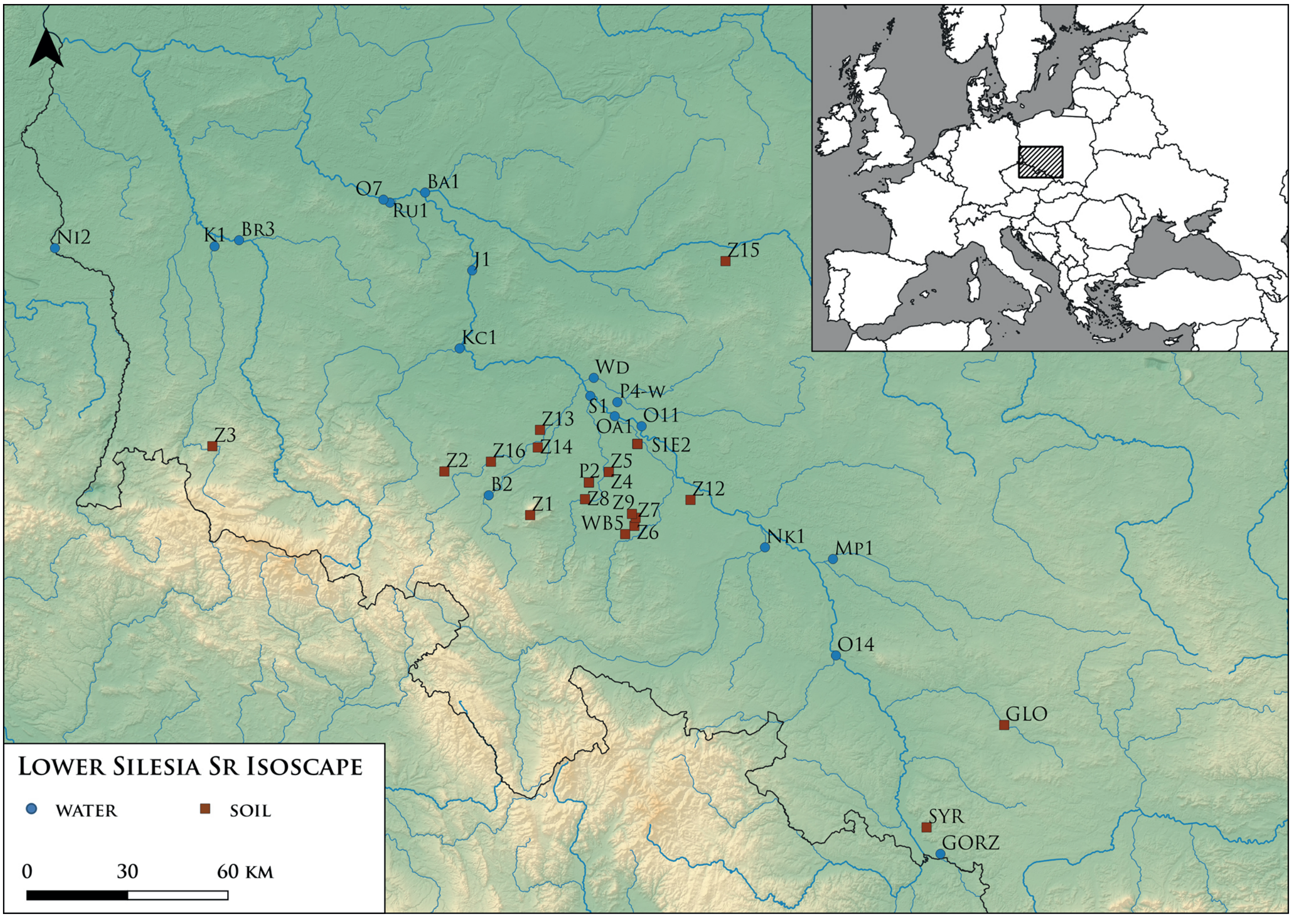

Fig. 4: Strontium isoscape in Lower Silesia: map with the location of sampling sites (see also Tab. 4; Tab. 5). In blue: the $^{87}Sr/^{86}Sr$ signatures of the Oder river, after: Zieliński *et al*. 2018.

ions with N_2O and measuring them as SrO+, following the protocol outlined by Hogmalm *et al.*[30] Additionally, the use of quadrupoles allows for the simultaneous determination of major and trace elements along with $^{87}Sr/^{86}Sr$ ratios, which can be useful for detecting diagenetic alterations[31]. Measurements were conducted using a series of line scans on fresh surfaces of tooth enamel, employing a 110 µm beam from a 213 nm Nd:YAG laser with a fluence of 6.4 J/cm², along a 500 µm profile. In total, 11 line scans were performed for tooth TYN5, and 10 line scans for tooth TYN8. Quantification of Sr isotopes was achieved using a sample bracketing approach, with every five line scans of the samples bracketed by one line scan each for the primary standards used. The primary reference materials were NIST SRM 610[32] and two natural idiomorphic crystals of Durango apatite[33]. The difference between the measured Sr isotope ratios and the expected ratios for NIST SRM 610 and the two Durango apatites were 1.02888±0.00042, 1.0288±0.00056, and 1.0284±0.00064, respectively, contributing to an overall uncertainty of ±0.00030 (all errors reported as 2σ). No drift or excess error beyond counting statistics was encountered.

3 Results

3.1 Chronology and spatial development of the cemetery

The graves at Tyniec were generally furnished modestly and uniformly, with notable exceptions in two female interments (burials 2 and 6). Iron knives and buckles, although typical for the period, cannot serve as reliable chronological

30 Hogmalm *et al.* 2017

31 Willmes *et al.* 2016.

32 $^{87}Sr/^{86}Sr$ ratio of 0.709699±0.000018; Woodhead/Hergt 2001.

33 $^{87}Sr/^{86}Sr$ ratio of 0.706328±0.000023; Yang *et al.* 2014.

Tab. 3: Tyniec upon Ślęża: local isotopic ecology and faunal $\delta^{13}C$ and $\delta^{15}N$ data.

No.	Lab ID	Site	Species	Element	$\delta^{13}C$ vs PDB (‰)	$\delta^{15}N$ vs AIR (‰)	C/N ratio	Source
1.	A3/WOJ/43	Wojkowice	*Bos taurus*	Bone	−22.51	8.79	3.3	Pokutta 2013
2.	BO1	Borów	*Bos taurus*	Bone	−21.14	8.49	3.3	Pokutta 2013
3.	CH2a	Chociwel	*Bos taurus*	Bone	−21.85	7.08	3.3	Pokutta 2013
4.	KW 7A	Kąty Wrocławskie	*Bos taurus*	Bone	−20.70	11.55	3.3	Pokutta 2013
5.	MIL102A	Milejowice	*Bos taurus*	PM	−17.56	8.18	3.2	Pokutta 2013
6.	MIL19/882/K	Milejowice	*Bos taurus*	Bone	−20.64	8.33	3.3	Pokutta 2013
7.	PR8 A	Przecławice	*Bos taurus*	Bone	−18.42	6.99	3.3	Pokutta 2013
8.	ST4	Strzelin	*Bos taurus*	Bone	−20.50	7.21	3.2	Pokutta 2013
9.	WOJ 123 A	Wojkowice	*Bos taurus*	Bone	−21.74	8.47	3.2	Pokutta 2013
10.	WOJ 1021	Wojkowice	*Bufo bufo*	Bone	−21.00	7.28	3.3	Pokutta 2013
11.	WOJ/1021m	Wojkowice	*Buteo buteo*	Bone	−19.99	9.53	3.2	Pokutta 2013
12.	MIL 150/P	Milejowice	*Canis familiaris*	Bone	−18.23	11.90	3.2	Pokutta 2013
13.	MIL 287	Milejowice	*Canis familiaris*	M1	−17.87	12.08	3.2	Pokutta 2013
14.	MIL A 117	Milejowice	*Canis familiaris*	M3	−19.79	13.70	3.2	Pokutta 2013
15.	WOJ A 115	Wojkowice	*Canis familiaris*	PM	−19.77	13.35	3.2	Pokutta 2013
16.	ST2X	Strzelin	*Capreolus capreolus*	Antler	−23.41	4.50	3.3	Pokutta 2013
17.	ST16/5	Strzelin	*Cervus elaphus*	Antler	−22.43	4.64	3.2	Pokutta 2013
18.	ST16/96	Strzelin	*Cervus elaphus*	Antler	−22.67	4.38	3.1	Pokutta 2013
19.	WOJ (15) 482	Wojkowice	*Cervus elaphus*	Antler	−22.76	4.35	3.2	Pokutta 2013
20.	WILK8/118	Wilkowice	*Corvus monedula*	Bone	−20.17	8.93	3.3	Pokutta 2013
21.	SZCZA1	Szczepankowice	*Cricetus cricetus*	Bone	−21.73	7.15	3.3	Pokutta 2013
22.	MIL 1506 K	Milejowice	*Equus caballus*	Bone	−20.65	7.67	3.3	Pokutta 2013
23.	MIL A 103	Milejowice	*Equus caballus*	PM	−22.00	5.04	3.3	Pokutta 2013
24.	MIL19/882	Milejowice	*Equus caballus*	Bone	−21.31	5.19	3.4	Pokutta 2013
25.	WID17/1049	Widawa	*Equus caballus*	Bone	−21.02	5.16	3.2	Pokutta 2013
26.	WR9K	Wrocław Pl. Uniwersytecki	*Equus caballus*	Canine	−22.19	6.97	3.2	Pokutta 2013
27.	WILK8/118/b	Wilkowice	*g. Stratopelia*	Bone	−19.61	7.39	3.2	Pokutta 2013
28.	CH5b	Chociwel	*Lepus Europaeus*	Bone	−24.10	7.57	3.2	Pokutta 2013
29.	MIL 1506	Milejowice	*Lepus Europaeus*	Bone	−21.14	5.74	3.2	Pokutta 2013
30.	WILK8/118/c	Wilkowice	*Lururus tetrix*	Bone	−19.74	9.44	3.2	Pokutta 2013
31.	WILK8/118/c	Wilkowice	*Lururus tetrix*	Bone	−19.24	9.31	3.1	Pokutta 2013
32.	WR9	Wrocław Pl. Uniwersytecki	*Lururus tetrix*	Bone	−19.88	10.28	3.3	Pokutta 2013
33.	MIL A 106	Milejowice	*Ovis aries*	M1	−20.59	8.75	3.2	Pokutta 2013
34.	MIL882	Milejowice	*Ovis aries*	M1	−21.14	6.94	3.2	Pokutta 2013
35.	WOJ A 116	Wojkowice	*Ovis aries*	M2	−20.76	11.73	3.2	Pokutta 2013
36.	WOJ 1017	Wojkowice	*Sciurus vulgaris*	I1	−21.65	9.62	3.3	Pokutta 2013
37.	MAR 629	Marszowice	*Sus scrofa dom.*	M3	−21.85	6.56	3.2	Pokutta 2013
38.	MIL 150/S	Milejowice	*Sus scrofa dom.*	Bone	−21.66	7.50	3.3	Pokutta 2013
39.	MIL 1506/S	Milejowice	*Sus scrofa dom.*	Canine	−21.56	8.40	3.2	Pokutta 2013
40.	MIL A 104	Milejowice	*Sus scrofa dom.*	PM/M1?	−21.28	6.16	3.2	Pokutta 2013
41.	MIL A 105	Milejowice	*Sus scrofa dom.*	M3	−22.18	8.99	3.1	Pokutta 2013
42.	MIL A 108A	Milejowice	*Sus scrofa dom.*	PM	−21.86	10.96	3.3	Pokutta 2013
43.	MIL A 110	Milejowice	*Sus scrofa dom.*	I1	−20.21	12.34	3.3	Pokutta 2013
44.	MIL A 112	Milejowice	*Sus scrofa dom.*	M3	−21.57	6.81	3.4	Pokutta 2013
45.	WOJ15/1017	Wojkowice	*Sus scrofa dom.*	Bone	−22.04	8.38	3.3	Pokutta 2013
46.	WOJ15/1021S	Wojkowice	*Sus scrofa dom.*	Bone	−23.02	8.89	3.5	Pokutta 2013
47.	MIL855	Milejowice	*Vulpes vulpes*	Bone	−19.27	9.98	3.2	Pokutta 2013
48.	WILK8/118/e	Wilkowice	*Vulpes vulpes*	Bone	−20.18	9.49	3.4	Pokutta 2013
49.	WOT 129	Wroclaw Ostrow Tumski	*Salmo salar*	Fish bone	−16.40	9.54	3.2	In this study
50.	WOT 262	Wroclaw Ostrow Tumski	*Silurius glanis*	Fish bone	−23.37	12.46	3.2	In this study
51.	WOT40	Wroclaw Ostrow Tumski	*Acipenser sturio*	Fish bone	−16.34	10.51	3.1	In this study
52.	WOT43	Wroclaw Ostrow Tumski	*Sander lucioperca*	Fish bone	−25.70	10.69	3.2	In this study
53.	WOT44	Wroclaw Ostrow Tumski	*Acipenser sturio*	Fish bone	−17.29	10.25	3.2	In this study

Tab. 3: (continued)

No.	Lab ID	Site	Species	Element	δ¹³C vs PDB (‰)	δ¹⁵N vs AIR (‰)	C/N ratio	Source
54.	WOTRZM	Wroclaw Ostrow Tumski	*Sander lucioperca*	Fish bone	−23.71	11.90	3.2	In this study
55.	UN34	Wroclaw Ostrow Tumski	*Abramis brama*	Fish bone	−29.36	7.23	3.2	In this study
56.	UN27	Wroclaw Ostrow Tumski	*Abramis brama*	Fish bone	−25.09	11.4	3.2	In this study
57.	UN17	Wroclaw Ostrow Tumski	*Perca fluviatilis*	Fish bone	−25.64	10.69	3.1	In this study
58.	UN29	Wroclaw Ostrow Tumski	*Esox lucius*	Fish bone	−24.35	10.97	3.2	In this study
59.	UN31	Wroclaw Ostrow Tumski	*Barbus sclateri*	Fish bone	−25.33	11.5	3.2	In this study
60.	UN26	Wroclaw Ostrow Tumski	*Vimba vimba*	Fish bone	−28.72	9.68	3.2	In this study
61.	UN32	Wroclaw Ostrow Tumski	*Esox lucius*	Fish bone	−25.86	11.49	3.2	In this study
62.	UN33	Wroclaw Ostrow Tumski	*Barbus sclateri*	Fish bone	−28.5	9.88	3.2	In this study
63.	UN30	Wroclaw Ostrow Tumski	*Abramis brama*	Fish bone	−23.87	10.15	3.0	In this study
64.	UN23	Wroclaw Ostrow Tumski	*Leuciscus idus*	Fish bone	−27.53	9.17	3.2	In this study
65.	UN24	Wroclaw Ostrow Tumski	*Esox lucius*	Fish bone	−24.47	12.05	3.2	In this study
66.	UN28	Wroclaw Ostrow Tumski	*Esox lucius*	Fish bone	−24.69	10.68	3.2	In this study
67.	UN25	Wroclaw Ostrow Tumski	*Acipenser sturio*	Fish bone	−18.31	11.33	3.2	In this study

Tab. 4: Strontium isotope ratios (TIMS) from prehistoric settlement zones in Wroclaw area, with location of sampling sites.

No.	Sample ID	Site	County/ province	GPS sample coordinates	$^{87}Sr/^{86}Sr$ Norm*	Ext. prec. 2σ
1	Z1	Tąpadła Pass	Świdnica/Lower Silesia	50 °50′48″N 16 °42′01″E	0.733706	0.000015
2	Z2	Strzegom	Świdnica/Lower Silesia	50 °57′40″N 16 °20′40″E	0.740846	0.000016
3	Z3	Karłowice	Lubań/Lower Silesia	51 °01′38″N15 °22′54″E	0.739376	0.000015
4	Z4	Żerniki Wielkie (1)	Wrocław/Lower Silesia	50 °57′35″N 17 °01′36″E	0.735767	0.000009
5	Z5	Żerniki Wielkie (2)	Wrocław/Lower Silesia	50 °57′35″N 17 °01′36″E	0.726089	0.000010
6	Z6	Brożec	Strzelin/Lower Silesia	50 °49′06″N 17 °07′59″E	0.729196	0.000011
7	Z7	Wawrzęcice	Strzelin/Lower Silesia	50 °50′23″N 17 °08′17″E	0.737082	0.000010
8	Z8	Tyniec nad Ślężą	Wrocław/Lower Silesia	50 °53′18″N 16 °55′41″E	0.735820	0.000010
9	Z9	Grodziszowice	Oława/Lower Silesia	50 °50′59″N 17 °07′22″E	0.731667	0.000010
10	Z10	Szczepankowice (1)	Wrocław/Lower Silesia	50 °55′56″N 16 °56′39″E	0.732769	0.000010
11	P1	Szczepankowice (2)*	Wrocław/Lower Silesia	50 °55′56″N 16 °56′39″E	0.712860	0.000010
12	P2	Szczepankowice (3)*	Wrocław/Lower Silesia	50 °55′56″N 16 °56′39″E	0.713140	0.000010
13	WB5	Chociwel	Strzelin/Lower Silesia	50 °47′48″N 17 °05′41″E	0.714430	0.000010
14	Z12	Gać	Oława/Lower Silesia	50 °53′12″N 17 °21′57″E	0.729039	0.000011
15	Z13	Chmielów	Środa Śląska/Lower Silesia	51 °04′11″N 16 °44′28″E	0.725230	0.000015
16	Z14	Nowa Wieś Kącka	Wrocław/Lower Silesia	51 °01′26″N 16 °43′55″E	0.739556	0.000016
17	Z15	Wrocław-Jagodno	Wrocław/Lower Silesia	51 °30′31″N 17 °30′40″E	0.727558	0.000010
18	Z16	Pyszczyn	Świdnica/Lower Silesia	50 °59′12″N 16 °32′16″E	0.715424	0.000013
19	GLO	Gliwice	Gliwice/ Silesia	50 °17′32″N 18 °40′03″E	0.731644	0.000010
20	SYR	Syrynia	Wodzisław Śląski/Silesia	50 °01′10″N 18 °20′44″E	0.721565	0.000014
21	SIE1	Siechnice (1)	Wrocław/Lower Silesia	51 °01′59″N 17 °08′44″E	0.723388	0.000016
22	SIE2	Siechnice (2)	Wrocław/Lower Silesia	51 °01′59″N 17 °08′44″E	0.725369	0.000013
23	SIE3	Siechnice (3)	Wrocław/Lower Silesia	51 °01′59″N 17 °08′44″E	0.717581	0.000013
24	SIE4	Siechnice (4)	Wrocław/Lower Silesia	51 °01′59″N 17 °08′44″E	0.731595	0.000012
25	SIE5	Siechnice (5)	Wrocław/Lower Silesia	51 °01′59″N 17 °08′44″E	0.726142	0.000012
26	SIE6	Siechnice (6)	Wrocław/Lower Silesia	51 °01′59″N 17 °08′44″E	0.729395	0.000014

* $^{87}Sr/^{86}Sr$ from local soil measurements after: Pokutta 2013

Tab. 5: Strontium isotope ratios (TIMS) from Oder river aquafier used in this study.

No.	Sample ID	River/ Oder aquafier	Location/GPS sample coordinates	$^{87}Sr/^{86}Sr$ Norm*	Ext. prec. 2σ	Study
27	Oa1	Oława	Wrocław/51 °06′20″N 17 °03′05″E	0.711583	0.000010	Zieliński *et al.* 2018
28	B2	Bystrzyca	Panków/50 °53′55″N 16 °31′43″E	0.712282	0.000009	Zieliński *et al.* 2018
29	Wd	Widawa	Szewce/51 °12′20″N 16 °57′52″E	0.710847	0.000009	Zieliński *et al.* 2018
30	S1	Ślęża	Wrocław/51 °09′30″ N 16 °57′00″E	0.711948	0.000009	Zieliński *et al.* 2018
31	Kc1	Kaczawa	Kwiatkowice/51 °16′56″ N 16 °24′28″E	0.711316	0.000015	Zieliński *et al.* 2018
32	Ru1	Rudna	Głogów/51 °39′35″N 16 °07′07″E	0.710975	0.000010	Zieliński *et al.* 2018
33	K1	Kwisa	Trzebów/51 °32′49″N 15 °23′27″E	0.712660	0.000009	Zieliński *et al.* 2018
34	Ni2	Nysa Łużycka	Łęknica/51 °32′32″N 14 °43′42″E	0.711261	0.000016	Zieliński *et al.* 2018
35	Ba1	Barycz	Wyszanów/51 °41′09″N 16 °15′52″E	0.711375	0.000010	Zieliński *et al.* 2018
36	Nk1	Nysa Kłodzka	Skorogoszcz/50 °45′43″N 17 °40′30″E	0.712020	0.000009	Zieliński *et al.* 2018
37	J1	Jezierzyca	Budków/51 °29′05″N 16 °27′36″E	0.710824	0.000012	Zieliński *et al.* 2018
38	Mp1	Mała Panew	Luboszyce/50 °43′52″N 17 °57′25″E	0.709714	0.000010	Zieliński *et al.* 2018
39	Br3	Bóbr	Szprotawa/51 °33′46″N 15 °29′33″E	0.711671	0.000010	Zieliński *et al.* 2018
40	P4-w	Oder (main stream)	Wrocław Koszarowa St./51 °08′32″N 17 °03′44″E	0.710770	0.000010	Pokutta 2013
41	O7	Oder (main stream)	Głogów/51 °40′03″N 16 °05′30″E	0.710291	0.000010	Zieliński *et al.* 2018
42	O11	Oder (main stream)	Kamieniec Wrocławski/51 °04′46″N 17 °09′47″E	0.710460	0.000009	Zieliński *et al.* 2018
43	O14	Oder (main stream)	Krapkowice/50 °28′36″N 17 °58′10″E	0.710639	0.000009	Zieliński *et al.* 2018
44	GORZ	Olza	Gorzyczki/49 °56′55″N 18 °24′11″E	0.710087	0.000011	This study

markers[34]. The burial record from Tyniec upon Ślęża does not reflect a complete population profile; notably, infants and small children, are entirely absent from the assemblage. Grave 6, attributed to young adult female, contained imported items of significant value, including bronze and iron buckles, decorated iron plates, an iron knife, a loom weight, glass beads, amber beads, and jewelry made from mollusk shells. Grave 2 also contained high-status items, such as an iron bar, glass beads, and fragments of chain armor, which may be indicative of a female warrior. Alternatively, fragments of chain mail found in female graves may represent apotropaic or symbolic items rather than indicators of marital status, as suggested by prior research on the reuse of Roman military equipment in barbarian funerary contexts[35].

The site's relative chronology points to phases C3–D1/D2 of the Migration Period (360–430 AD[36], with most artifacts dating to phase D1 (late 4th to early 5th century AD). Radiocarbon dating results suggest the cemetery was in use between approximately 380/90 AD and 540/50 AD.[37] Two distinct phases of spatial development are evident at the site. The oldest burials were arranged in a SW-NW row[38], while later interments followed an intersecting N-S alignment[39]. A correlation between chronological phases and grave depth was also observed. Earlier burials were uniform in depth (approximately 0.9m) and size, possibly reflecting the work of skilled undertakers during the late 4th to mid–5th century AD. In contrast, later interments exhibit greater variability in both depth and size, suggesting a decline in expertise among those preparing the graves.

3.2 Dietary patterns

A broad isotopic baseline for Lower Silesia was previously reconstructed from animal remains by Pokutta (n= 49)[40]. In the present study, this baseline has been expanded through the addition of further prehistoric fish samples (n= 18). The new assemblage includes both predatory and herbivorous fish from Oder, such as Atlantic salmon, catfish, sturgeon, bream, perch, pike, Sclater's barbel, Vimba bream, and ide[41]. The aquatic food webs of the Oder River represent a very broad range of values from $\delta^{13}C$ – 29.36 ‰ with $\delta^{15}N$ 7.23 ‰ to $\delta^{13}C$ – 16.34 ‰ with $\delta^{15}N$ 10.51 ‰. The terrestrial environment (n=48) is also characterised by a broad range of isotopic values, ranging from $\delta^{13}C$ – 23.28 ‰/$\delta^{15}N$ 2.91 ‰ to $\delta^{13}C$ – 19.79 ‰ with $\delta^{15}N$ 13.7 ‰. For terrestrial wild herbivores the $\delta^{13}C$ values range from – 24.1 ‰ (*Lepus Europaeus*) to – 21.1 ‰. For deer (*Capreolus capreolus* and

34 typology of artefacts in Gralak/Waniek 2021.
35 Godłowski 1980, 63–106; Czarnecka 1994; 1995.
36 Gralak/Waniek 2021.
37 Tab. 1; Fig. 5.
38 graves 7, 8 and 9.
39 e. g. burials 2,4 or 5; Tab. 1.
40 Pokutta 2013.
41 Tab. 3, Fig. 6.

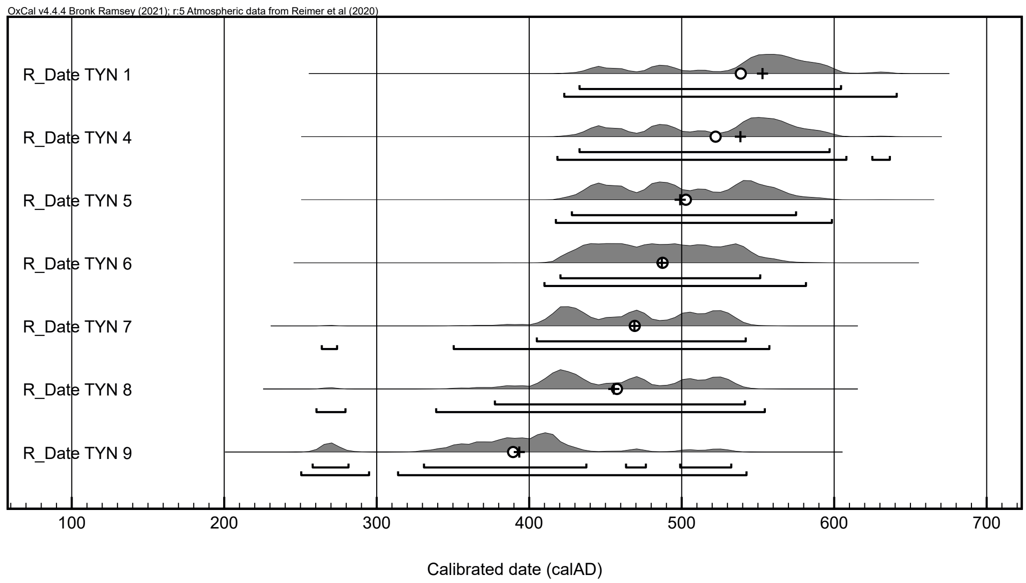

Fig. 5: Tyniec upon Ślęża: radiocarbon dating of inhumations; OxCal. For details: see Tab. 1.

Cervus elpahus) the average δ^{13}C value was – 22.8 ‰, while the cervine δ^{15}N value was ≤ 5 ‰ (average value of 4.5 ‰). The overall range of δ^{15}N variation for other wild herbivores was between 4.3 ‰ and 7.6 ‰ (*Lepus Europaeus*). Animals feeding of mixed resources with occasional episodes of carnivorism, included hamsters (*Cricetus cricetus*), toads (*Bufo bufo*) or squirrels (*Sciurus vulgaris*). This identified group represents the transitional step to mesopredators, with an average δ^{13}C value of – 21.5 ‰ and a mean δ^{15}N value of 8.0 ‰. The comparison between hamsters and squirrels shows some dichotomy in modes of food acquisition and biological adaptations: both species belong to the order of *Rodentia,* though hamsters area purely vegetarian, while occasional carnivorism is observed in squirrels (larva, insects, carrion etc.). The mesopredatory group for Silesian territory is represented by foxes (*Vulpes vulpes*), one of the most invasive predatory mammals of the canids (*Canidae*). The mean values for both δ^{13}C and δ^{15}N were values of – 19.3 ‰ and 9.7 ‰ respectively. Avifauna for prehistoric Lower Silesia is represented by both predatory and omnivorous birds. Avian herbivores are represented by the pigeon (g. *Stratopelia*) with a leading δ^{13}C signature of – 19.6 ‰ and δ^{15}N 7.4 ‰, while omnivorous birds, occasionally feeding on flesh or carrion, for example, jackdaw (*Corvus monedula)* and common pheasant (*Phasianus colchicus)*, display an average δ^{13}C value of – 19.8 ‰ and δ^{15}N value of 9.5 ‰. Typical predatory avifauna is isotopically characterised by the common buzzard (*Buteo buteo*) with a δ^{13}C signature of – 20.0 ‰ and δ^{15}N value of 9.5 ‰. The key domesticated animals, cows (n=15) and pigs (n=10) average values are: δ^{13}C – 20.88 ‰, δ^{15}N 7.42 ‰ (*Bos taurus*), and δ^{13}C – 21.72 ‰, δ^{15}N 8.49 ‰ (*Sus scrofa*)[42].

The results of human bone δ^{13}C and δ^{15}N analysis are shown in Tab. 2 (Fig. 6). The average of δ^{13}C values is – 19.61 ±1.11 ‰, ranging between – 17.92 ‰ and – 21.06 ‰, while the average of δ^{15}N values is 10.44 ±1.43 ‰, ranging between 9.84 ‰ and 10.89 ‰. This analysis indicates a stable long-term dietary trend based primarily on C3 plants, supplemented with domestic animals as a source of protein. There are no observable differences between males and females, or age groups. The relatively elevated δ^{13}C values observed in individuals TYN 9 (-17.92 ‰) and TYN 12 (-18.08 ‰) may reflect, theoretically, a limited dietary contribution of C_4 plants such as millet[43]. However, freshwater fish from eutrophic environments or ecological variation in C_3 sources cannot be ruled out as alternative explanations. In one case (grave no. 8, adult male, δ^{13}C – 20.72 ‰, δ^{15}N 9.84 ‰) the measured isotopic values appear to signify the effect of disease. Anthropological assessment of this skeleton revealed advanced periodontal changes in dentition, carries and extra-large supragingival calculus forming mineral overhangs within the oral cavity[44]. It is plausible that this

42 isotopic values of local herbivores adapted from Pokutta 2013, 351–354.

43 The consumption of millet during the Migration Period remains problematic; according to recent studies, increased millet consumption in Central Europe appears in later centuries and is associated with the expansion of Slavic populations: see also Macháček *et al.* 2025.

44 Dąbrowski/Gronkiewicz 2021.

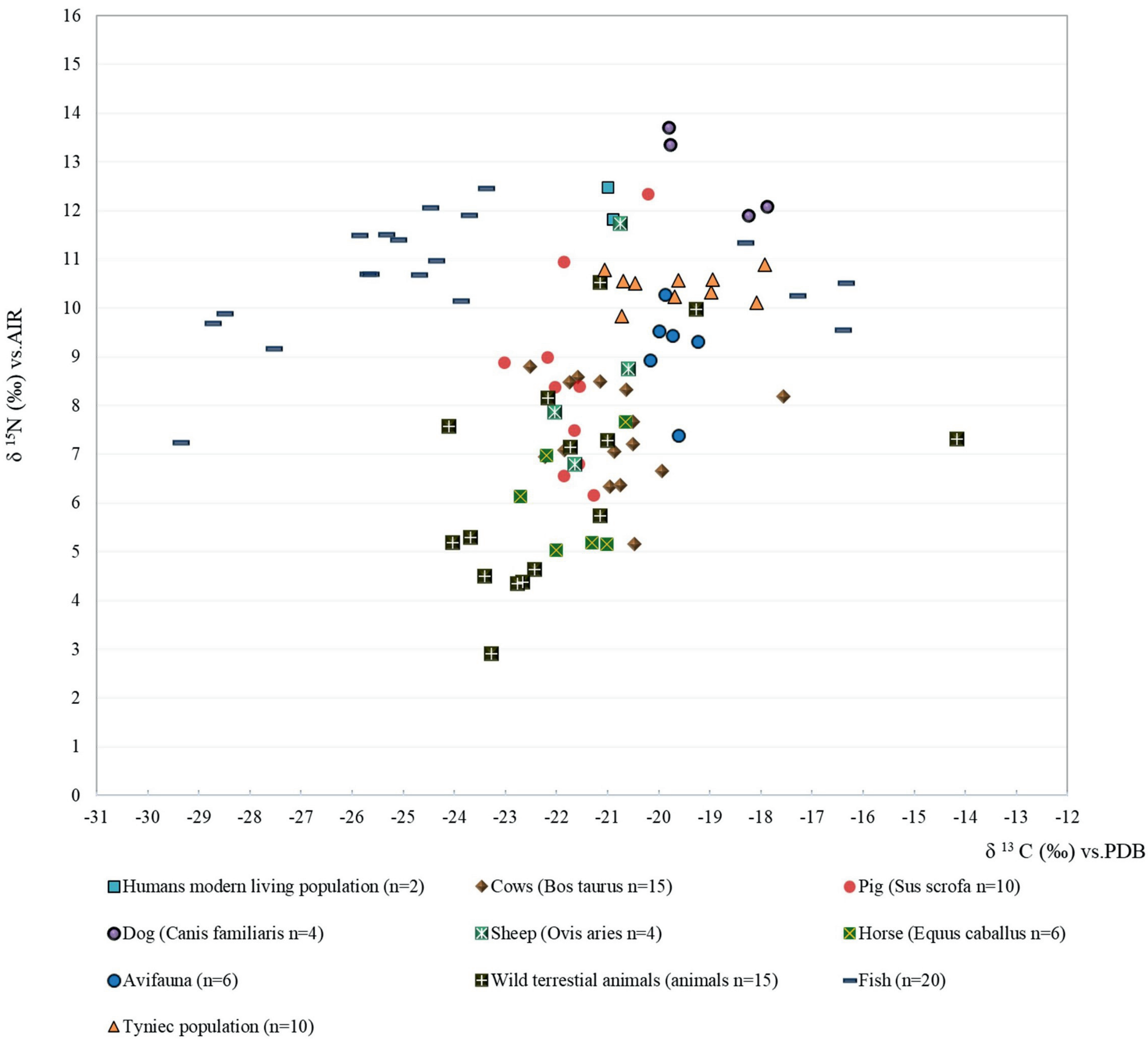

Fig. 6: Human bone collagen $\delta^{13}C$ and $\delta^{15}N$ from Tyniec upon Ślęża (n=10; Tab. 2), plotted against global reconstruction of isotopic ecology of prehistoric Lower Silesia (n=67; Tab. 3).

pathology directly impacted the diet and consumption practices of the individual.

Anthropological assessment indicated a generalised fragility in the health status of all analysed individuals. The volume of skeletal pathologies is substantial ranging from the lack of teeth (frontal, partial or nearly complete), enamel hypoplasia and molar abrasion 5th–6th degree, deep carries, dental calculus, peri-mortem healed/unhealed trauma, and one case of possible body dismemberment resulting from high-velocity impact with a blunt-edged object[45].

Several individuals exhibit notably elevated $\delta^{15}N$ values, particularly TYN 9 (16.66 ‰) and TYN 12 (16.31 ‰). These levels exceed the local herbivore baseline for Lower Silesia by approximately 8–9 ‰[46], suggesting the consumption of high-trophic-level protein sources. Such values are consistent with the intake of freshwater fish from eutrophic water bodies, which are known to elevate isotopic signatures within aquatic food webs. $\delta^{15}N$ values above 15.5 ‰ in adult individuals are rare in communities dependent exclusively on terrestrial mammals and are more typically

45 grave no. 12; for details see Dąbrowski/Gronkiewicz 2021.

46 see Pokutta 2013.

Tab. 6: Tyniec upon Ślęża: LA-ICP-MS elemental (ppm) and $^{87}Sr/^{86}Sr$ isotopic data from analysed individuals.

Sample ID	Line	Na	Mg	Ti	Mn	Fe	Cu	Zn	Rb	Sr	$^{87}Sr/^{86}Sr$	2s
TYN5	1	5116	2735	1.3	113	593	0.78	189	0.05	91	0.7114	0.0017
TYN5	2	4810	2707	1.3	76	443	0.49	347	0.04	83	0.7114	0.0013
TYN5	3	4503	2437	1.2	67	379	0.51	555	0.34	84	0.7124	0.0019
TYN5	4	4233	2204	1.4	52	256	0.26	670	<0.051	81	0.7109	0.0019
TYN5	5	4105	2024	1.1	52	267	0.44	671	0.10	80	0.7109	0.0019
TYN5	6	4005	1919	1.2	54	297	0.78	700	<0.057	80	0.7119	0.0016
TYN5	7	3950	1591	1.6	16	152	18.4	787	0.71	78	0.7111	0.0019
TYN5	8	4023	1533	1.8	17	131	18.0	846	0.17	79	0.7114	0.0021
TYN5	9	3710	1464	1.8	49	306	1.82	938	<0.054	82	0.7114	0.0017
TYN5	10	3525	1318	1.8	40	263	1.68	841	<0.065	83	0.7117	0.0015
TYN8	1	5280	2231	1.1	5.6	39	0.09	110	0.06	62	0.7093	0.0017
TYN8	2	4178	1810	1.0	3.3	19	0.08	292	<0.071	56	0.7101	0.0020
TYN8	3	4178	1783	1.2	3.3	22	0.16	364	<0.062	55	0.7132	0.0019
TYN8	4	4197	1890	1.1	3.5	21	0.25	416	0.07	57	0.7110	0.0019
TYN8	5	4394	1907	1.3	5.3	34	0.43	417	<0.056	61	0.7111	0.0018
TYN8	6	4699	2180	1.2	7.4	42	0.81	331	0.07	65	0.7118	0.0018
TYN8	7	5076	2349	1.3	7.5	47	0.62	259	0.06	68	0.7106	0.0018
TYN8	8	4573	2095	1.2	6.4	44	0.41	399	0.07	67	0.7130	0.0018
TYN8	9	4295	2048	1.3	7.0	54	0.53	472	<0.050	65	0.7117	0.0016
TYN8	10	3881	1520	1.0	4.5	17	0.25	563	0.08	58	0.7109	0.0016

observed in riverine or lacustrine populations with access to aquatic resources[47].

In general terms, dietary practises change slowly over the course of centuries, or millennia, maintaining through acute divergent events; it is related to locally available food products and culturally-based customs and taboos. In this study we used two samples from the modern living European population to capture the scale of dietary shift from the Migration Period. Samples were derived and measured from dental and bone material provided by the author[48], with the average of $\delta^{13}C$ values is – 20.88 ‰ and corresponding $\delta^{15}N$ values of 12.11 ‰. When compared to the studied prehistoric population, it may clearly be observed that the modern geographic analogue blends a mainly terrestrial diet indicated by sharp differences in nitrogen isotopic values. This can confidently be associated with the improved efficiency of modern agriculture, controlled feeding regimes, food processing and dental and hygiene practices.

The results of this study are, to some extent, comparable with the findings from other sites dated to the Roman and Migration periods in Europe. Our data indicates that the sampled Tyniec population maintained a varied diet, consuming fish, likely supplemented by birds and wild game, in addition to staple cereals, dairy, and, perhaps less often, meat from domesticated animals (Fig. 6)[49].

3.3 Human dental enamel TE and $^{87}Sr/^{86}Sr$ analysis

The study of prehistoric residence and mobility through $^{87}Sr/^{86}Sr$ isotope analysis during the Migration Period entails both a significant risk of error and the potential for groundbreaking insights. This research presents preliminary $^{87}Sr/^{86}Sr$ data from two male individuals interred at Tyniec upon Ślęża (graves 5 and 8; Tab. 6, Fig. 7). The burials analyzed belong to two distinct chronological phases of the cemetery and were selected based on their spatial placement and the biological profiles of the deceased[50].

The trace element analysis of individuals TYN5 and TYN8 reveals distinct compositional patterns, suggesting differences in either biological uptake or post-mortem diagenesis[51]. For individual TYN5, sodium (Na) and magnesium (Mg) concentrations gradually decrease across the sample series, suggesting leaching or alteration over time. A particularly notable pattern is observed in the copper (Cu)

47 Müldner/Richards 2007; Nehlich 2010.
48 Dalia Pokutta/LB, M3.
49 see also Depaermentier 2023.
50 see also Dąbrowski/Gronkiewicz 2021.
51 Tab. 6 Fig. 7.

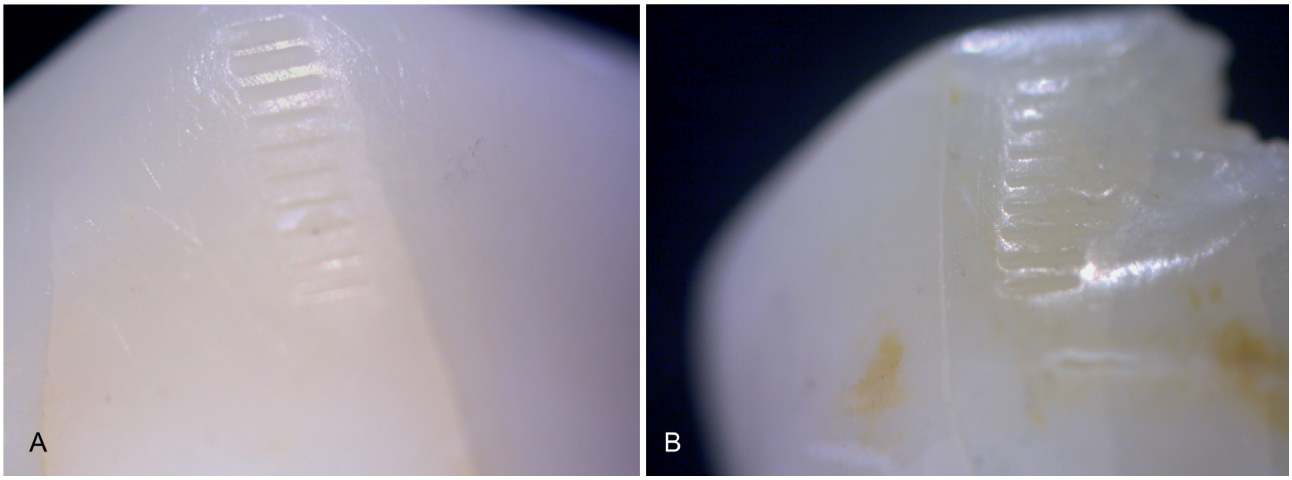

Fig. 7: Tyniec upon Ślęża: laser ablation working shots and dental samples analysed in this study; A) burial no. 5, adult male, premolar; B) burial no. 8, adult male, premolar. Magnification 30x, ARL Stockholm. Photo by D. Pokutta.

and zinc (Zn) values: while Cu remains low (<1 ppm) in most samples, it spikes dramatically to 18.0–18.4 ppm in lines 7 and 8, accompanied by elevated Zn levels (>800 ppm). This sudden enrichment may indicate localized contamination by copper-rich sources, such as burial goods, soil, or groundwater. Iron (Fe) values also fluctuate but remain relatively moderate (152–593 ppm), suggesting limited diagenetic iron input. The manganese (Mn) levels are moderate, though slightly elevated compared to TYN8, possibly indicating some degree of diagenetic alteration. In contrast, individual TYN8 exhibits consistently low Fe (17–54 ppm) and Mn (3.3–7.5 ppm) concentrations, suggesting minimal diagenetic alteration. Cu values remain very low across all lines (0.08–0.81 ppm), and Zn concentrations are more moderate (110–563 ppm) compared to TYN5. No abrupt contamination signatures are evident for TYN8, and the Sr values remain stable, supporting the interpretation of relatively pristine preservation. Thus, TYN5 shows evidence of localized contamination with copper and associated trace elements, whereas TYN8 reflects a much cleaner diagenetic signature, indicating better preservation of the original biogenic composition.

For strontium isotopic measurements, samples were extracted from the crowns of premolars, which typically form between the ages of 5 and 6 years. As shown in Table 6, the individual from grave 5 exhibited relatively consistent $^{87}Sr/^{86}Sr$ values across ten spot measurements, ranging from 0.7109 to 0.7124, with a median value of approximately 0.7114. In contrast, the individual from grave 8 displayed greater isotopic variability, with $^{87}Sr/^{86}Sr$ values ranging from 0.7093 to 0.7132. The calculated mean value for grave 8 was 0.7113±0.0006 (2σ; MSWD = 1.8).

4 Discussion

4.1 Tyniec upon Ślęża: chronological context

The Migration Period remains largely understudied and poorly represented in the archaeological record of Poland, particularly in its southern regions[52]. One of the most prominent features is the complete absence of settlements and cemeteries, with the exception of Pomerania, and the Wielbark culture[53]. Skeletal inhumations disappear from the archaeological record, and the burial rites of this period are unknown. The main sources of information are stray finds and hoards of Roman coins, which can be dated with a high degree of accuracy[54]. Thus, the skeletal burial site in Tyniec upon Ślęża offers a unique opportunity to investigate the biological profiles of the inhabitants of Silesia during this turbulent era. No burials of children were found, and the age/sex profile of the deceased suggests selective burial practice. The graves were situated on a gentle hill, marked with stelae. No animal remains or typical cemetery debris were found on site, suggesting purposeful intent and limited reuse or custodial attendance. The sole evidence of plausible remembrance ceremonies is a large bonfire pit.

The grave furnishings clearly link some graves to chronological phases C3/D1, while later graves lack chronological indicators. The brooches correspond to group VI in the typology of O. Almgren[55] and exhibit features of types

52 Pazda 1980, map 8.
53 Kokowski 2010.
54 Jażdżewski 1968; Bursche 2020.
55 Almgren 1923.

162–167/168. Amber beads belong to types 429–430, and glass beads to types 35 and 276–277, according to the classification of M. Tempelmann-Mączyńska[56]. Such assemblages are characteristic of phases C3/D1–D2 (c. AD 360–430), although they most likely date to the later part of this interval[57]. The discrepancies between radiocarbon dating and archaeological chronological indicators require further explanation. The key concerns for developing an understanding of the Lower Silesian populations pertain to the dual potential for contact: inter-population communication and the overall influence of Roman provincial culture upon northern Barbaricum. Primary sources of contact likely came from the Black Sea region (cities of the Bosporus Kingdom and the Chernyakhov culture), the Danube (Roman provinces and adjacent barbarian territories), and the Rhine region (areas under Roman, and later Frankish control)[58]. Intensive commercial and political contact and exchange are documented through a significant volume of Roman provincial artifacts, such as coins, ceramics, glass items, glass beads, bronze, silver, and gold vessels, as well as certain amounts of precious metals in the form of simple objects or imitations of Roman patterns in local materials.

The direct or indirect presence of Asian nomads, particularly the Huns, can be documented from the mid-5th century AD. Recent genetic analyses of a dual burial from Czulice (Poland), in which two boys of mixed Hunnic-European ancestry were reported, corroborate earlier findings[59]. The direct presence of Hunnic military forces is inferred from the discovery of double-conical beads, the so-called *sword-amulets*[60]. One such bead, along with a sword, was found at a cemetery in Dobrodzień-Rędzin in Silesia[61]. This custom is associated with the Huns[62]. Similar artifacts have been found in Żerniki Wielkie (grave of a Hunnic warlord)[63], and in Dobieszewice (near Bydgoszcz)[64]. These finds can be linked to the Hunnic infiltration of Central Europe during the reign of Attila[65].

The contact between modern southern Poland and the Roman Empire during the Migration Period can be divided into several phases, each linked to the political history of Roman Danubian provinces. The initial phase, 300–375 AD, is marked by strong Roman military and political dominance in the region. After the victorious wars of Diocletian, Galerius, and Constantine the Great over the Sarmatians, in 322 AD, Rome imposed agreements on favorable terms for the Empire, and the Romans took control of the Sarmatian lands near the Cisa River. Between 322 and 332 AD, the Romans constructed the so-called *limes Sarmatiae*, a system of fortifications surrounding the Sarmatian lands, stretching from Aquincum to Viminacium[66]. By 332 AD, the Goths had been defeated by Constantine the Great, resulting in 40 years of stability and peace in the Danube region, interrupted only by several unsuccessful barbarian raids during the reigns of Constans and Constantius II[67].

Roman domination over the central Danube ended during the reign of Valentinian I (364–375 AD). Between 366 and 373 AD, the Roman Empire undertook extensive actions to reconstruct and strengthen the Danubian limes. In 375 AD, the Roman army made a final attempt to regain military control over the region[68]. This period of Roman decline saw the territories of modern-day Poland marked by relative stability, prosperity, and intensive contacts with the Danubian provinces of the Empire[69]. This is attested by the significant volume of bronze coin hoards dating to the Constantine dynasty. Coins of Valentinian I and Valens are the most common Roman imports in Poland in the mid-4th century AD[70].

The second phase, beginning around 370 AD, witnessed fundamental ethnic, political, and cultural changes between the Black Sea and Danube regions. The Hunnic invasion of the Black Sea regions triggered mass migrations of other peoples to the west and south[71]. The invasion of 375 AD led to the destruction of the cities of the Bosporus Kingdom and the Chernyakhov culture[72]. This period is also marked in archaeological record by the disappearance of certain glassware previously found on sites in the north during phases C/D[73]. In the years that followed, the Empire's Danubian provinces experienced uprisings by Visigothic and Pannonian federates, as well as destructive raids by other barbarian groups. In 385 AD, the Sarmatians invaded Pannonia; in 391–392 and 395 AD, large parts of Thrace and Illyricum were devastated by the Huns. In 395 AD, Pannonia

56 Tempelmann-Mączyńska 1985.
57 Gralak/Waniek 2021.
58 Fig. 1.
59 Niebylski *et al.* 2024.
60 Amulets tied to the hilt of a sword to enable a firmer grip during combat.
61 Szydłowski 1977.
62 Werner 1956; Olczak 1972; Kim 2016.
63 cf. Zotz 1935; Mączyńska/Jakubczyk 2017.
64 Olczak 1972.
65 Werner 1956; Kim 2016; Rodzińska-Nowak 2020.
66 Soproni 1969.
67 Mócsy 1962; Barkóczi 1980.
68 retaliatory expedition against the Kwadi: see Soproni 1959; Wielowiejski 1970; 1981.
69 Okulicz 1965; Godłowski 1969; Pazda 1980.
70 Godłowski 1979.
71 Altheim 1959; Kim 2016.
72 Gąjdukević 1971.
73 Okulicz 1965.

was invaded by the Markomans, and in 401 AD, Raetia and Noricum were invaded by the Vandals[74].

Between 405 and 406 AD, an extremely powerful and destructive invasion by numerous barbarian groups led by Radagais resulted in the destruction of Pannonia and Northern Italy[75]. In 406/407 AD, Germanic tribes breached the limes on the Rhine, and the following year, the entire western Illyricum was plundered and depopulated as a result of a Hunnic invasion led by Uldin[76]. During this time, significant changes occurred among the Huns. Under the rule of Ruas, and later Attila (433–453 AD), they formed a powerful confederation of various barbarian tribes subject to their ultimate sovereignty, and the 'Empire of Attila' extended from the Volga to the Rhine[77].

First inhumations in Tyniec upon Ślęża can be linked to the period c. 390–430/440 AD. The graves contain artifacts typical of phase D of the Migration Period, and it is important to highlight the historical context with which they are associated. Graves from Tyniec dating to the mid-5th century AD and later contain almost no grave furnishings, which seems to reflect the drastic changes taking place during the 430s AD. During this period, significant changes took place among the Huns. Under the rule of Ruas, and later Attila (433–453 AD), they established a powerful confederation of various barbarian tribes under their ultimate authority, with Attila's empire extending from the Volga to the Rhine[78].

The rise and expansion of the Huns brought about a cultural collapse in the southern part of modern-day Poland during the 430s AD, as the nomadic empire blocked traditional routes connecting the Hungarian Basin with the north. During this period, the archaeological record provides clear evidence of Hunnic presence and dominance. Burials of Hunnic warriors have been found in Jakuszowice[79], Jędrzychowice[80], and Przemęczany, near Kraków[81]. Other Hunnic artifacts (earrings, buckles) have been identified at Mymoń[82], Świlcza[83], and Strzegocice[84]. A golden necklace was discovered in Rędzin[85], near Wrocław, and a partially preserved Hunnic cauldron was found in Opawa (Slovakia)[86]. As mentioned, sword-amulets were found in three different locations, and they are believed to have been made in Pannonian glass workshops[87].

The current evidence indirectly supports the idea of a Hunnic short-term supremacy over Silesia and Lesser Poland during Attila's reign[88]. This proposed invasion by the Huns (or associated tribes) may have followed a path from the Moravian Gate, along the Oder, destroying settlements of the Przeworsk culture in Silesia and along the upper Vistula, and decimating Lesser Poland. However, it seems far-fetched to directly link the Tyniec upon Ślęża cemetery to a *hypothetical* Hunnic invasion of southern Poland around the mid-5th century AD.

Despite the sparse archaeological record, particularly with regard to human remains dated to the 5th century AD in the vicinity of Wrocław, the available evidence includes only the cemetery at Tyniec upon Ślęża and a solitary burial of a Hunnic warrior. Additionally, unpublished findings suggest the discovery of further human remains from the region, notably the skeleton of an adult female recovered from a local cave and radiocarbon-dated to the Migration Period[89]. Preliminary isotopic analyses indicated that this female exhibited signs of severe malnutrition and most likely died as a result of starvation. Although the material record points to an apparent *demographic hiatus*, the existence of these burials implies the persistence of human activity in the area. Funerary practices, however limited in number, attest to the continued presence of living communities, as individuals do not inter themselves. Such evidence suggests that small-scale, transient, or episodic human settlement endured during this period of disruption.

4.2 Tyniec upon Ślęża: comments on diet and residency

Studies of dietary practices among 1st-millennium AD communities have demonstrated that human nutrition was primarily based on the consumption of C3 plants, supplemented by terrestrial animal protein. Up until now, the body of evidence suggested that the consumption of marine or aquatic resources played a relatively minor role.[90] Results from other studies similarly reveal consistent dietary pat-

74 Mócsy 1962.
75 *Ibid.*
76 Maenchen-Helfen 1973; Kim 2016.
77 Altheim 1975; Kim 2016.
78 Altheim 1975; Kim 2016.
79 Rodzińska-Nowak 2020.
80 Krause 1904.
81 Wawrzeniecki 1912, 50–51.
82 Cabalska 1966.
83 Gruszczyńska 1984.
84 Madyda-Legutko 1978.
85 Grempler 1901.
86 Godłowski 1969; Rodzińska-Nowak 2020.
87 Olczak 1974.
88 see also Godłowski 1969.
89 P. Dąbrowski, pers. comm.; isotopic data by D. Pokutta, unpublished.
90 Knipper *et al.* 2013; Reitsema/Kozłowski 2013; Vytlačil *et al.* 2018.

terns across different social groups and relative stability in food supply during both the Roman and Migration periods[91].

Our findings indicate that the inhabitants of Lower Silesia during the Migration Period incorporated aquatic foodstuffs into their diet, particularly salmon and sturgeon. The increased reliance on aquatic resources at Tyniec upon Ślęża may not necessarily indicate a deliberate cultural preference for fish consumption. Instead, it could reflect an adaptive response to severe disruptions in terrestrial food supplies, potentially caused by Hunnic incursions into Lower Silesia. In a context where cultivated fields were abandoned and herds decimated, aquatic resources would have provided a reliable and accessible alternative, underpinning a crisis-driven dietary shift. Similar patterns of *crisis fish diets* have been observed archaeologically elsewhere[92]. In Roman Britain, fish consumption was generally limited, primarily associated with elite diets and urban centers. However, zooarchaeological analyses of 109 sites reveal a notable increase in fish remains during the later Roman period, particularly in towns and villas. This uptick is interpreted as a response to declining agricultural productivity and social instability, prompting communities to exploit more accessible food resources. Stable isotope analyses further support this trend[93]. Studies indicate a dietary shift towards increased marine protein intake during the 4th and 5th centuries AD, suggesting that communities adapted their subsistence strategies in response to environmental and socio-political challenges.

Regarding mobility and strontium isotope analysis, the results presented in this study must be considered preliminary. Several factors complicate interpretation, including the unclear demographic situation in Lower Silesia during the Migration Period, the variable preservation quality of the recovered dental material, the absence of extensive comparative isotopic datasets, and the broadly similar dietary practices prevailing across much of the European continent at that time. As a result, our findings are reported with caution, and definitive conclusions regarding the residential histories of the individuals analyzed cannot yet be drawn. A major limitation of the present study stems from the fact that Tyniec upon Ślęża remains the only fully excavated Migration Period cemetery identified in the vicinity of Wrocław. This scarcity of comparative archaeological material severely hampers a comprehensive understanding of the demographic processes in the region during this period. To confidently classify individuals as either *local* or *non-local*, it is essential to establish the presence and characteristics of both *Population A* (the donor, representing the local resident group) and *Population B* (the recipient, representing incoming migrants), following Lee's theory of migration[94].

In the absence of evidence for such populations, additional burial grounds or associated settlement sites, any interpretation of isotopic signatures remains speculative. Earlier Polish archaeological scholarship regarded Lower Silesia as experiencing full scale hiatus[95]. The possibility of complete population replacement during the Migration Period, coupled with the lack of corroborative archaeological and isotopic data, precludes firm conclusions regarding the residence patterns of the Tyniec individuals. Future research must prioritize the discovery and analysis of additional Migration Period sites in Lower Silesia in order to provide a broader and more robust contextual framework, ultimately addressing the current gaps in our demographic knowledge.

4.3 Regional strontium isoscape: geology and $^{87}Sr/^{86}Sr$ signatures variability in Lower Silesia

In recent years, significant efforts have been made to systematically measure strontium isotopic values (baselines) for use in prehistoric mobility studies. Currently, the available information regarding the spatial variability of $^{87}Sr/^{86}Sr$ signatures in Poland is primarily based on studies by Zieliński *et al.*[96] and, to a lesser extent, by Hoogewerff *et al.*[97]

The data reported in this study focus on a relatively small and well-defined territory and indicate high variability in $^{87}Sr/^{86}Sr$ values for the sub-soil cover in the Wrocław area[98]. The Wrocław region is situated between two major geological zones. The older formation includes the Sudetes and the Fore-Sudetic Block, composed of sporadically outcropping igneous and metamorphic rocks of Proterozoic–Palaeozoic origin[99]. The younger unit, the Fore-Sudetic Monocline, consists of Permian-Mesozoic sedimentary rocks. These two basins are divided by the metamorphic Oder Block, which runs linearly between them. The deposition of the Palaeozoic series within the Sudetes is attributed to the Hercynian composite orogeny[100]. The soils of the Sudetes are dominated by cambisols, with eutric cambisols

91 Jørkov *et al.* 2010; Knipper *et al.* 2013; Fornander *et al.* 2015.
92 e. g. late Roman Britain; Cool 2006.
93 see also Müldner 2013.
94 Lee 1966.
95 e. g. Żerelik, 2007, 34–35.
96 Zieliński *et al.* 2018; 2021.
97 Hoogewerff *et al.* 2019.
98 Tab. 3; 4.
99 Mierzejewski 1993.
100 Różycki 1968; Zieliński *et al.* 2021.

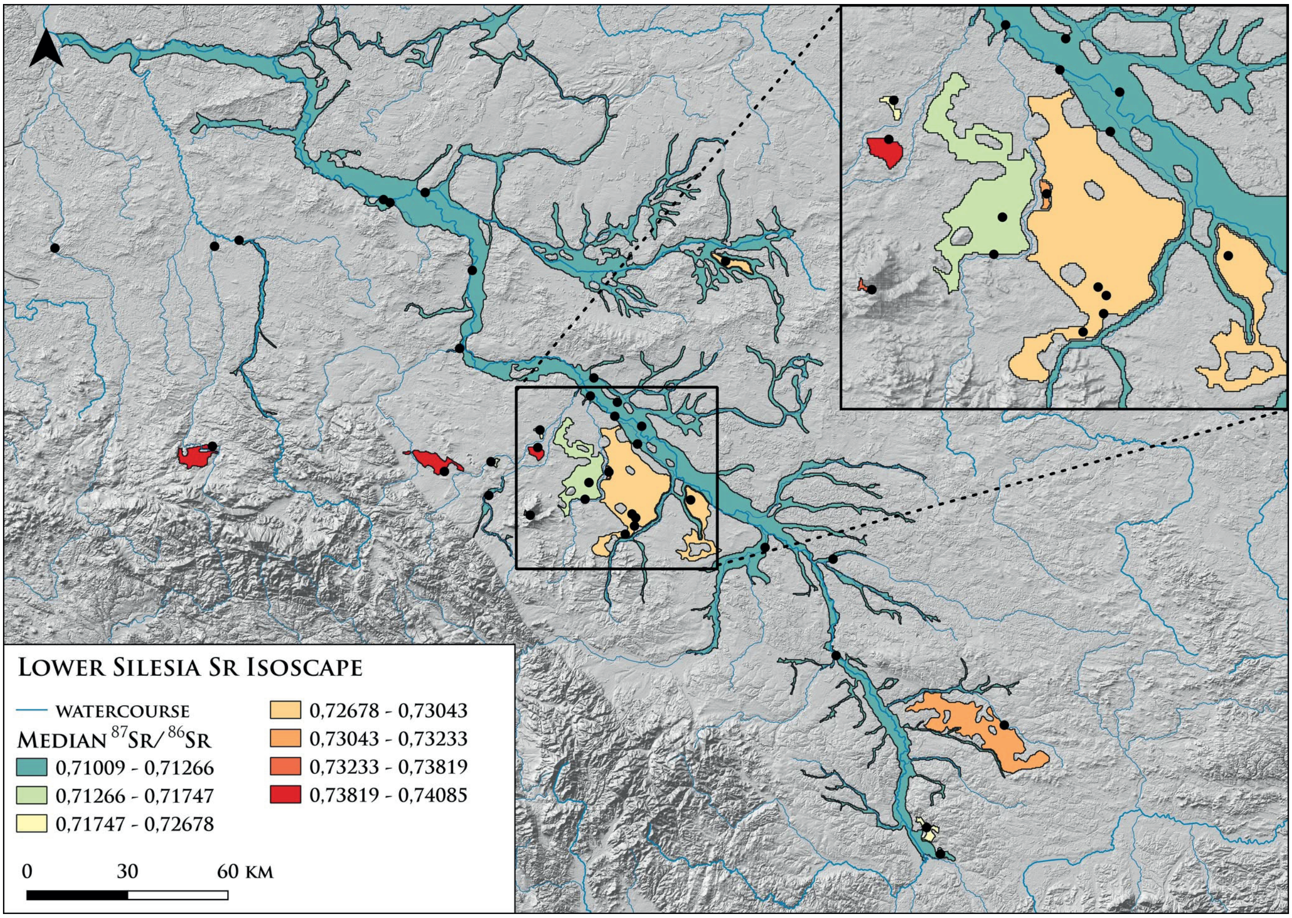

Fig. 8: Strontium isoscape of Lower Silesia, Poland: spatial distribution of $^{87}Sr/^{86}Sr$ signatures from soils and waters in territory of Wroclaw, based on Tab. 4, Tab. 5. Graphic by P. Tóth.

occurring on lower slopes and foot-slopes under both forest and arable land. Podzols appear sporadically, particularly over granites, gneisses, and sandstones. Intra-mountain basins are characterized by loamy stagnic luvisols, while river valleys feature fluvic cambisols developed from loam deposits over sands or gravels.

The central region, encompassing the Sudetes Foreland and the southern Silesian Lowlands, is covered by various luvisols formed primarily from loess, loess-like silts, and other Quaternary deposits. The extensive wet lowlands south of Wrocław are dominated by fertile chernozems ('black earths'). In the broad valley of the Oder River and its southern tributaries, gleyic fluvic cambisols and fluvic gleysols, developed from loams on river sands, are prevalent. In contrast, the north-western part of the Silesian-Lusatian Lowland is dominated by dry, nutrient-poor soils such as brunic and haplic arenosols and podzols, much of which is afforested[101].

As a baseline for isotopic studies of provenance and mobility in prehistory, part of Lower Silesia has been analyzed, characterized by $^{87}Sr/^{86}Sr$ values ranging from 0.712 to 0.740, with an average $^{87}Sr/^{86}Sr$ signature from the Oder River of 0.710[102]. It should be noted that approximately 90 % of all known archaeological sites dating from the Neolithic to the Medieval period are located in the analyzed territory[103]. Visualizations of the $^{87}Sr/^{86}Sr$ signature distribution in the Wrocław area are presented in Figures 8 and 9. The maps were generated using QGIS software[104]. Median $^{87}Sr/^{86}Sr$

101 Mierzejewski 1993.

102 note increased variability in isotopic signatures within the tributaries of the Oder; Zieliński *et al.* 2018.

103 Fig. 4; 8; 9.

104 The digital elevation model was based on data provided by Jarvis *et al.* (2008), and vector datasets were obtained from Natural Earth (www.naturalearthdata.com). Information on Quaternary deposits in Lower Silesia was sourced from the Geological Map of Poland at a scale of 1:500 000 (gis.pgi.gov.pl/en). To enable the visualization of spatial distributions of $^{87}Sr/^{86}Sr$ isotope signatures, the original geological raster map was first converted into vector format through polygonization.

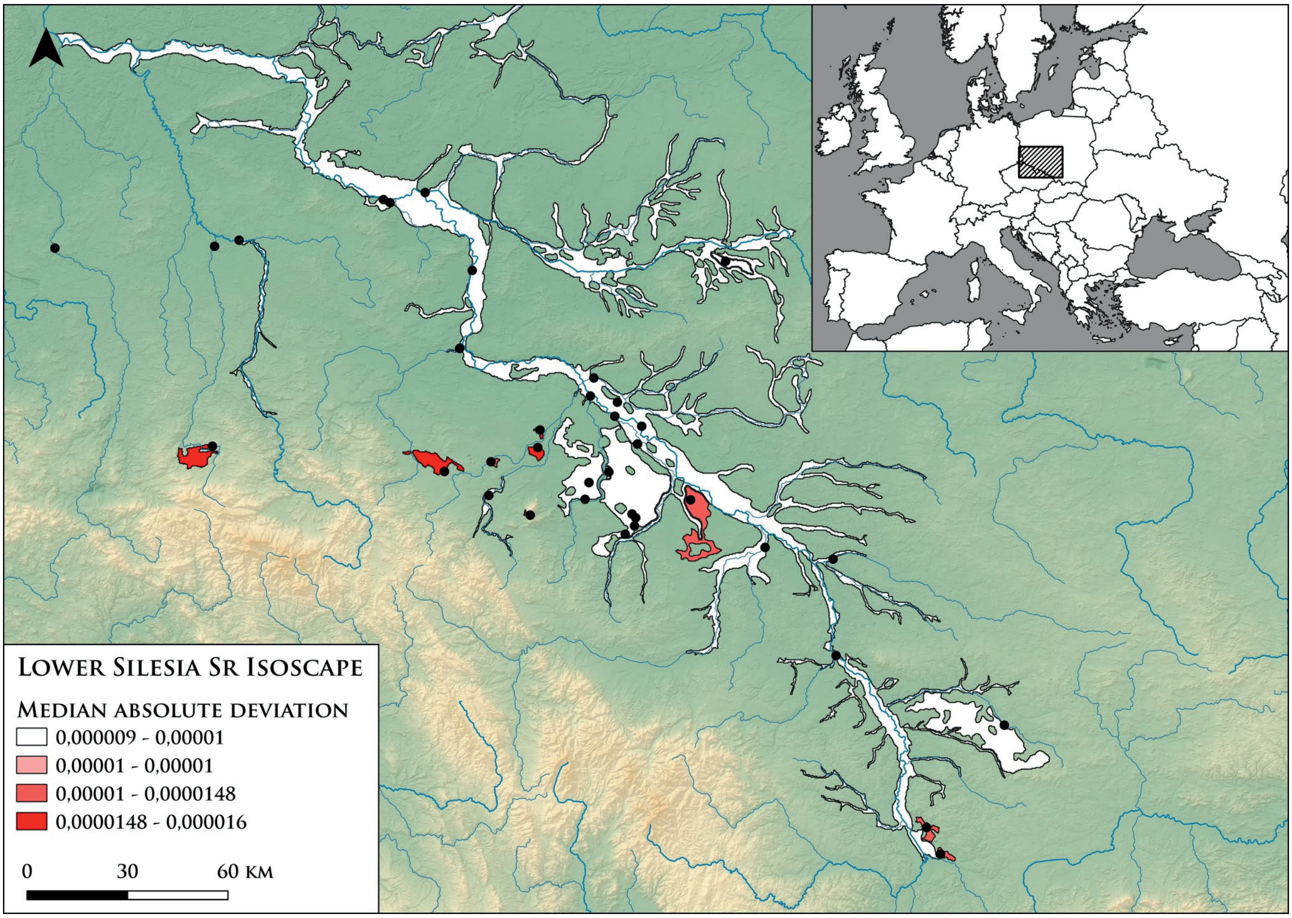

Fig. 9: Strontium isoscape of Lower Silesia, Poland: median absolute deviation map; based on Tab. 4 and Tab. 5. Graphic by P. Tóth.

isotope values and corresponding measurement precision (2σ) were subsequently linked to the vector geological data using spatial joining techniques. This approach allowed the integration of isotopic measurements with geological background data to produce detailed spatial representations of strontium variability across the study area.

4.4 Tyniec upon Ślęża: burial rites and cultural hybridisation in the Migration Period

The Tyniec upon Ślęża cemetery raises important questions regarding the variability or modification of burial practices and, more intriguingly, the potential local adaptation or continuation of mortuary expressions rooted in the Chernyakhov cultural sphere[105]. However, it should be noted that deviations from normative funerary traditions are a widespread phenomenon during the Migration Period, both at local and regional scales, as well as across broader European territories[106]. The territory occupied by the Chernyakhov culture extended from the Carpathian Mountains to the Dnieper and from the Danube and the Black Sea coast to the forest-steppe zone[107]. Broadly speaking, the Chernyakhov culture is characterized by considerable variability in funerary practices. This fluidity and diversity are particularly evident in materials from the southern extent of the Chernyakhov area. The coexistence of cremation and inhumation rites, alongside a wide range of funerary structures and grave goods, provides compelling evidence for the polyethnic composition of the Chernyakhov culture, traditionally linked to the Ostrogoths[108].

Throughout the Chernyakhov cultural domain, the distinction between cremation and inhumation is supplemented by a diversity of burial architectures, methods, and associated rituals. Particularly prominent are burial prac-

105 Gralak/Waniek 2021.

106 Kokowski 1992.

107 see Fig. 1.

108 Barnish 2007.

tices centered around anthropoid inhumation. "Pits with shoulders" are typical of burial grounds in the Black Sea region and the Prut–Dniester interfluve. Several cemeteries[109] exhibit a predominance of such "pits with shoulders," occasionally featuring timber linings at the grave base and uneven void spaces beneath, all displaying a western orientation and an absence of cremation material[110]. It has also been noted that Chernyakhov burials, including feasibly those at Tyniec upon Ślęża, may exhibit a deepened or undercut grave base, creating a "contoured" form that imitates an earthen coffin[111]. Notably, at the Tyniec cemetery, concave pits beneath the coffins were recorded, further suggesting parallels with these eastern mortuary traditions. Similar features were also observed at Kholmskoye, where the contoured grave base was described as a "pit-coffin"[112]. In several cemeteries of the Chernyakhov culture, anthropoid burial pits with base depressions were supplemented by wooden "ledges" or "shoulders" cut into the grave sides. Graves with both western and northern orientations are attested, with northern-oriented burials often distinguished by greater wealth and diversity of grave goods. Such mortuary practices suggests not only internal variability but also possible external cultural influences. One plausible source of inspiration is the Sarmatian tradition of "graves with shoulders"[113]. O. A. Gey observed key distinctions between Chernyakhov and Sarmatian grave constructions: while Chernyakhov timber reinforcements were typically positioned along the perimeter of the grave-cut, Sarmatian shoulder pads were confined to the long walls[114]. Furthermore, the height of the "shoulders" in Chernyakhov graves is generally lower than in Sarmatian examples.

However, the notion of direct cultural borrowing must be approached with caution. Sarmatian burials featuring shoulders in the Dniester-Danube interfluve ceased to function around 260–270 AD, whereas the appearance of Chernyakhov "earthen-coffin" graves in the Northern Black Sea region dates to approximately 310–330 AD[115], introducing a significant chronological gap. Thus, rather than direct continuity, it is more plausible that Chernyakhov burial forms were inspired by earlier Sarmatian models. Alternative sources of influence must also be considered. The ancient necropolises of the Greek cities of the Northern Black Sea region incorporated grave structures with stone elements, which may have inspired similar ideas[116]. Related burial traditions are also known from late Scythian funerary rites in the Lower Dnieper region into the third century AD.[117] Comparable structural features, such as ledges around the grave perimeter, are also documented in Roman Europe and Scandinavia[118].

Conclusions

The cemetery at Tyniec upon Ślęża provides rare and well-contextualized evidence for human presence in Lower Silesia during the early 6th century AD. The selective representation of certain age groups, coupled with the absence of children, indicates that the cemetery may not reflect a comprehensive burial community, but rather could have served as a military commemorative site.

The integration of archaeological and isotopic data reveals dietary diversity and individual life histories shaped by varied biogeographic trajectories. While terrestrial C_3-based resources formed the dietary core, nitrogen isotope values in several adults indicate regular consumption of freshwater fish, likely reflecting ecological availability and subsistence strategies adapted to local conditions. Variability in strontium isotope values points to differing patterns of residential mobility, but does not permit firm conclusions regarding origin or group composition. In a regional context marked by demographic instability and the scarcity of contemporary burial grounds, the Tyniec assemblage offers a valuable point of reference. It demonstrates the interpretive potential of integrated bioarchaeological approaches in exploring community organisation and lifeways during the poorly documented phase of post-Roman transformation in Central Europe.

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109 e. g. Kholmskoye, Rangevoye, Kamenka-Anchekrak, Viktorovka sites.
110 Symonovich 1967; Levinsky 1999.
111 Symonovich 1967; Nikitina 1996.
112 Gudkova/Fokeev 1984.
113 Gudkova/Fokeev 1984; Gudkova 1999; Simonenko 2004.
114 Gey 1999.
115 Vasiliev 2013.
116 such as the Bosporus Kingdom, Chersonese, and Tanais; see Magomedov 2001.
117 Magomedov 2001.
118 Lund/Hansen 1977; Keller 1971.

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