

First isotope analysis and new radiocarbon dating of Trypillia (Tripolye) farmers from Verteba Cave, Bilche Zolote, Ukraine

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ABSTRACT – *This paper presents an analysis of human and animal remains from Verteba cave, near Bilche Zolote, western Ukraine. This study was prompted by a paucity of direct dates on this material and the need to contextualise these remains in relation both to the transition from hunting and gathering to farming in Ukraine, and their specific place within the Cucuteni-Trypillia culture sequence. The new absolute dating places the remains studied here in Trypillia stages BII/CI at c. 3900–3500 cal BC, with one individual now redated to the Early Scythian period. As such, these finds are even more exceptional than previously assumed, being some of the earliest discovered for this culture. The isotope analyses indicate that these individuals are local to the region, with the dietary stable isotopes indicating a C₃ terrestrial diet for the Trypillia-period humans analysed. The Scythian period individual has $\delta^{13}\text{C}$ ratios indicative of either c. 50% marine, or alternatively C₄ plant inputs into the diet, despite $\delta^{18}\text{O}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ ratios that are comparable to the other individuals studied.*

KEY WORDS – *Trypillia farming culture; AMS dating; radiogenic isotopes; stable isotopes; diet*

Prva analiza izotopov in novi radiokarbonski datumi poljedelcev kulture Tripolje iz jame Verteba, Bilche Zolote, Ukrajina

IZVLEČEK – *V članku predstavljamo analizo človeških in živalskih ostankov iz jame Verteba blizu kraja Bilche Zolote v zahodni Ukrajini. Študija je nastala zaradi pomanjkljivega števila datumov iz teh ostankov in iz potrebe po kontekstualiziranju najdb v odnosu tako do prehoda iz lovsko-nabiralniške družbe v poljedelsko v Ukrajini kot tudi glede na poseben prostor, ki ga imajo te najdbe znotraj kulturne sekvence Cucuteni-Tripolje. Novi absolutni datumi postavljajo ostanke faze BII/CI kulture Tripolje v čas ok. 3900–3500 pr. n. št., medtem ko je eden od pokopov zdaj ponovno datiran v čas zgodnjega skitskega obdobja, kar pomeni, da gre za ene najstarejših najdb te kulture. Analiza izotopov kaže, da so bili pokojni lokalni prebivalci regije, analiza stabilnih izotopov pa kaže na C₃ kopensko prehrano ljudi v času kulture Tripolje. Pokop iz skitskega obdobja kaže glede na $\delta^{13}\text{C}$ vrednosti na ok. 50% morske prehrane, oziroma na C₄ rastline, vključene v prehrano, kljub temu da so deleži izotopov $\delta^{18}\text{O}$ in $^{87}\text{Sr}/^{86}\text{Sr}$ primerljivi s preostalimi vzorci ljudi na najdišču.*

KLJUČNE BESEDE – *poljedelska kultura Tripolje; AMS datiranje; radioaktivni izotopi; stabilni izotopi; prehrana*

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Introduction

This paper presents the results of an analysis of human remains from Verteba Cave in Ukraine, a unique burial site, due to the fact that fragmentary disarticulated material of Trypillia date (Nikitin *et al.* 2010) are interred in the cave, and pathologies indicative of interpersonal violence are in evidence throughout the assemblage. The material at this site has been dated to the Eneolithic period (4900–2750 cal BC, continuing in use until the early Scythian period at *c.* 780–510 cal BC) (Nikitin *et al.* 2010 and this paper). It is likely that, given their stratigraphic context and associated material culture inventories, the original interments at Verteba belonged to the Trypillia farming groups that existed in this region of Ukraine during the Eneolithic period. However, despite a number of previous studies that consider the palaeopathology and ritual significance of this location (*e.g.*, Karsten *et al.* 2014; 2015a; 2015b, Kadrow *et al.* 2003, Kadrow, Pokutta 2016), most of these skeletal materials are undated in absolute terms, being placed in a late chronological position within the Trypillia sequence on the basis of ceramic typology and evidence from late period settlement sites (see Nikitin *et al.* 2010 and Kadrow, Pokutta 2016 for summaries of the history of investigations at this location).

The finds from this location are of some significance given the recent debate on the nature of the transition to farming in Europe in general (*e.g.*, Zvelebil 2009; Rowley Conwy 2011, and papers in both volumes), as Ukraine has good evidence for the indigenous adoption of farming; and in particular, these remains are important in relation to the nature of the Trypillia (Tripolye) farming culture of Ukraine (Ciuk 2008; Nikitin *et al.* 2010; Menotti, Korvin-Piotrowsky 2012; Chapman *et al.* 2014a; 2014b; Karsten *et al.* 2014; 2015a; 2015b), as they constitute some of the only human remains from this culture to be found so far.

Whilst Jordan K. Karsten *et al.* (2014; 2015a; 2015b) and Slawomir Kadrow and Dalia A. Pokutta (2016) have emphasised the ways in which these remains provide comparative materials for consideration of farming versus hunter-fisher-foragers lifeways in Ukraine (*e.g.*, the caries and enamel hypoplasia studies undertaken by Karsten and co-workers), and a unique opportunity to study the lives, deaths and cultural practices of the Cucuteni-Trypillia culture in Western Ukraine (as assessed by Kadrow and Pokutta), these studies have, unfortunately, relied on limited

absolute dating and a chronology that is primarily developed on the basis of associations between ceramic forms from other Trypillian sites. This is clearly unsatisfactory, as previous work has shown that relative chronologies can have considerable discrepancies when compared to absolute chronologies (*e.g.*, Telegin *et al.* 2002; 2003), and alongside these observations, the importance of the absolute dating of Verteba's burials can perhaps be further emphasised by noting that, despite the occurrence of over 1000 Trypillia settlement sites from *c.* 5400 cal BC onwards, skeletal remains and burials that date to the period before CII (pre-3400 cal BC) are almost unknown (Kruts 2008; Korvin-Piotrowskiy 2012).

As such, the current study not only provides an absolute dated context for human remains that are rare for the Trypillia culture in general, and unique in displaying secure evidence for interpersonal violence and a range of approaches to burial and body processing, but it also undertakes the first mobility ($^{87}\text{Sr}/^{86}\text{Sr}$, $\delta^{13}\text{C}$, $\delta^{18}\text{O}$) and dietary ($\delta^{13}\text{C}$, $\delta^{15}\text{N}$) isotope analyses of these individuals, allowing comparisons to previous studies (*e.g.*, Lillie, Richards 2000; Lillie *et al.* 2003; 2011 *etc.*). Due to their disarticulated nature, the precise context of these remains cannot be securely attributed to a late period in the Trypillian sequence (*contra* Karsten *et al.* 2014; 2015a; 2015b) without absolute dating, and the diverse range of funerary activities in evidence need to be placed securely within the evolution of this farming culture if their significance is to be accurately interpreted.

In addition, while Karsten *et al.* (2015b) have presented a bioarchaeological analysis (dental caries rates) of the dentitions of these individuals, and compared the results to previous analyses in Ukraine (*e.g.*, Lillie 1996), the fact that Trypillia populations have been shown to integrate both domesticated plants and animals, fishing, and the consumption of wild resources into subsistence strategies throughout the existence of this culture, and that there is a total absence of isotope analysis to assess the relative proportions of the resources exploited in the diets of these groups, necessitates assessment using the dietary stable isotope studies undertaken here in order to provide realistic comparative insights into subsistence practices, as the consumption of wild resources such as fish will not necessarily be visible from the dentition alone.

Finally, the fact that these remains are considered to represent secondary burials in a very structured ri-

tual context necessitates an analysis of these remains using mobility studies (*e.g.*, strontium ($^{87}\text{Sr}/^{86}\text{Sr}$), oxygen ($\delta^{18}\text{O}$) and carbon analyses ($\delta^{13}\text{C}$)) to distinguish between individuals of local and non-local origin (*Slovak, Paytan 2011*) in order to determine whether these individuals are in fact local to the region, and also to establish that they can realistically be shown to equate to the cultural groups in this region in the Eneolithic period. As such, this paper represents the first stages of an integrated scientific approach to the study of Verteba.

The AMS dating outlined below provides an absolute chronological age for each of the human individuals studied, enabling the current analyses to be considered from a precise, as opposed to relative (*e.g.*, *Karsten et al. 2014.19*) chronological perspective. As will be demonstrated, the absolute dating of comingled and disturbed skeletal remains is of fundamental importance when attempting to provide a secure and accurate interpretation of the evidence recovered at sites like Verteba.

The Trypillian Culture and Verteba Cave

The Trypillian culture is the Ukrainian element of the Eneolithic (Copper Age) Cucuteni-Trypillia culture that expanded across a significant area of eastern Romania, Moldova and western Ukraine, from Transylvania and the Carpathians in the east following the zonation of the forest-steppe in north-easterly direction up to the Dnieper River (*Korvin-Piotrovskiy 2012*). From south to north, the culture covers the Black Sea lowlands, extending some 150km up the Dnieper system to the north of Kiev. In the west, the Trypillia culture encompasses the River Prut to the foothills of the Carpathians, along with much of the Dniester and Bug (Buh in Ukrainian) river systems (Fig. 1). The initial formation of the culture is linked back to intensive contact with, and the expansion of, Balkan-Danube agricultural groups. The culture's name derives from the key sites of Trypillia in Ukraine and Cucuteni in Romania. Chronologically, the Trypillia culture spans the period *c.* 5000–2750 cal BC. In 1949, Tatiana S. Passek developed chronological phas-

ing for the Trypillia culture (originally using ceramic typologies), with this being subdivided into stages A (5000–4300 cal BC), B and C, and further subdivided into BI (4300–4100 cal BC) and BII (4100–3600 cal BC), and CI (3600–3200 cal BC) and CII (3200–2750 cal BC) (*Zbenovich 1996; Burdo, Kovalyukh 1998; 1999; Rassamakin 1999; 2012; Vidieko 2004; Nikitin et al. 2010; Korvin-Piotrovskiy 2012*).

In terms of subsistence strategies, the economy of Trypillia farmers was mixed, with the exploitation of both domesticated animals and plants occurring alongside the gathering of wild foodstuffs, hunting of wild animals, and fishing (*Pashkevych 2008; Markova 2008*). Material recovered from the fired clay floors of Trypillia culture houses includes imprints from hulled wheat and hulled six-row barley (*Lillie 2008.13*), and other species have been recorded, including bread wheat, broomcorn millet, pea, bitter vetch, pulses and grapes. Gathered wild plant species include cornelian cherry, plum, hawthorn, pear and wild grape (*Pashkevych 2008*). Domesticated animals include the characteristic range of species, such as cattle, sheep/goat and pig, with the wild fauna component including red deer, roe deer, wild pig and horse (*Markova 2008*). It is important to note that even during the middle phase of the culture, across stages BII–CI, when the ‘mega-sites’ discussed below were flourishing, at sites such as Kolomyishchina II (stage BII) and Kolomyishchina I (stage CI) wild animals accounted for *c.* 80% of their faunal assemblages (*Ellis 1984; Lillie 2004*).



Fig. 1. Map showing the extent of the Trypillia culture of Ukraine and neighbouring countries, key sites and the location of Verteba Cave ©WAERC University of Hull.

Settlement sizes varied from small settlements in the earliest phases of the culture to the ‘mega-sites’ of the middle phase (phase BII-CI at 4000–3200 BC) (Korvin-Pietrovskiy 2008; Chapman et al. 2014), with some 1300 settlements and cemetery sites recorded to date (Lillie 2008). The largest settlement site is Taljanky (also spelled Talyanki or Talianki), located between the Buh and Dnieper (Fig. 1), which is reported to have some 2700 buildings and to cover 450ha (Kruts 2008:58), a figure modified by the work of John Chapman et al. (2014a:154) to 340ha. Interestingly, both Taljanky and Maydanetske have been shown to contain between 20–25% more houses than indicated by previous estimates (*ibid.* 2014a and Kruts et al. 2011).

Vladimir Kruts (2008:55) has reported that at sites such as Luka Ustynska, Soloncheny II, Veremye, Nezvysko and Lipkany, only a few solitary interments have been found for the early and middle stages of Trypillia, between c. 4900–3400 cal BC, and that most of these finds are poorly preserved. This observation reinforces the significance of Verteba Cave to studies of the Trypillia culture. Therefore, the new ultrafiltration AMS dates and stable isotope evidence presented here are of considerable importance to studies of Eneolithic Trypillia culture farming in Eastern Europe, and the fact that there is evidence for interpersonal violence, and evidence of the processing of human remains for burial on some of the remains from this cave also adds to the significance of this site in providing new insights into the nature of Ukraine’s first farmers (Lillie et al. 2015).

Verteba Cave has a long history of investigation. It was originally discovered in 1822, although human remains were first recovered from a topsoil horizon of approx. 0.45m which covered the cave floor during excavations in 1876. Subsequent work recovered Trypillia material culture remains during a 3-year excavation period between 1890 and 1892, and then during excavations from 1898–1904. The material from these excavations is housed at the Museum of Archaeology in Krakow, Poland. Additional finds of human skeletal material were made during excavations in 1914, and reported in Polish language literature (Stojanowski 1948), as this region shifted in sovereignty between Poland and Ukraine.

The Verteba sequence comprises three cultural horizons which, on the basis of the material culture inventory, appear to date to the BII (4100–3600 cal BC), CI (3600–3200 cal BC) and CII (3400–2750 cal BC) periods of the Trypillian chronology, represent-

ing three local groups of this culture: Schypynetska (BI/CI – 3900–3450 cal BC), Koshylovetyska (CII – 3450–3100 cal BC), and Kasperivska (CII – 3125–2775 cal BC) (Nikitin et al. 2010:11). Unfortunately, repeated investigations in the cave from the 1800s onwards have resulted in the mixing of cultural horizons, such that the skeletal remains cannot be attributed to an archaeological period on stratigraphical grounds alone, despite the fact that there are areas in the deposits where some stratigraphic integrity appears to remain (Karsten et al. 2015b:566).

Recent research undertaken by Karsten et al. (2014; 2015) discusses the nature of pathology of the fragmentary remains from 21 individuals recovered during excavations undertaken in 2008 and 2012. However, it should be noted that, in failing to account for the probability that the remains represent different population groups from different periods, when comparing the Verteba remains to the earlier prehistoric (Mesolithic and Neolithic) populations interred in the Dnieper-Donets Mariupol-type cemeteries along the Dnieper and its tributaries (Lillie 1996; 1998; Potekhina 1998; 1999; Telegin et al. 2002; 2003), these authors erroneously conclude that significantly shorter bone lengths, in addition to higher rates of enamel hypoplasias (which are non-specific indicators of stress; Goodman et al. 1984; Goodman, Rose 1991) suggest that the Trypillian farming lifestyle was more stressful in terms of physiological perturbations when contrasted with the hunter-fisher-foragers of the Dnieper Rapids region. Given the fact that the earlier Mesolithic and Neolithic Dnieper-Donets populations were tall, with massive skeletons and very wide faces (with two variants in evidence – dolichocrany and mesocrany (Potekhina 1998)), and that Inna Potekhina (1998:67–68; 1999; also Telegin et al. 2002; 2003) has shown that the Dnieper-Donets populations differed markedly from the Trypillia, Sredny Stog and Kemi-Oba populations, with Trypillia populations being of smaller stature and more gracile, it is apparent that using long-bone lengths as a measure of population stress between groups that are distinct in both anthropological and chronological terms is a fundamentally flawed approach.

By extension, the comparison of hypoplasia rates between the Trypillia farming population at Verteba and the Dnieper-Donets hunter-fisher-foragers is also not necessarily a viable approach as, again, these are distinct groups (and sub-groups) with very different diets. Importantly, however, the nature of the subsistence strategies being followed by Trypill-

lia groups varies over time, and in the earlier to middle stages of this group's development, wild fauna, plants and fish have been shown to make up a significant proportion of their diets. While in many regions throughout Europe, farming is synonymous with elevated incidences of stress and caries *etc.*, with hunting and gathering lifeways usually associated with low levels of stressors (Meiklejohn, Zvelebil 1991; Lillie 1998), the variable nature of Trypillia subsistence strategies demands that the absolute dating of the population being studied is known in order to assess the developmental and subsistence stage that is being analysed.

The evidence for inter-personal violence on these skeletal remains consists of unhealed depression fractures on at least twelve of the twenty-one individuals analysed by Karsten *et al.* (2015). In this sample, four skulls were shown to exhibit two or more fractures, while four skulls were also shown to have evidence of healing. This latter observation is important in indicating that, while a significant number of these injuries were due to peri-mortem events, in at least four cases the evidence suggests more than one occurrence of inter-personal violence. Malcolm Lillie *et al.* (2015) reported the case of a young adult, possibly a female (aged around 18–22 years at death; and probably towards the lower end of this range) who exhibited multiple peri-mortem injuries, including penetrating impact damage on the back of the vault at lambda, with blunt force compression in evidence and fragmentation of the vault (comminuted fracture, *i.e.* a break or splinter of the bone into more than two fragments) (*ibid.* 2015.57). The cranium of this individual also has evidence of the removal of bone from the right side of the vault, and cut marks on the left side of the vault, superior and posterior to the mastoid process, indicating cutting of the attachments of the neck muscles and tendons in order to detach the head from the body (Lillie *et al.* 2015.58).

While it has been suggested that during stage CII of Trypillia, *i.e.* during the final stages of cultural development, evidence of conflict is attested through the development of fortifications at a number of settlement sites (Korvin-Piotrovskiy 2012.6–18), the complete lack of dating of the Verteba skeletal remains studied by Karsten *et al.* (2014; 2015) again means that there are no secure chronological grounds from which to attribute the interpretations of the inter-personal (peri-mortem) violence to this (CII) stage of Trypillia (*contra* Karsten *et al.* 2014; 2015). As such, the current dating programme is aimed at re-

addressing this oversight, while also determining the timing of the inter-personal violence and assessing the subsistence stage that these individuals represent in the Trypillia cultures development.

Material and methods

The finds reported here were recovered during excavations undertaken by two of us (MPS, AGN) between 2005 and 2008 when *c.* 64m² of the cave sediments were excavated. All of the finds were allocated specimen numbers, as presented in Tables 1 and 2 (below). One of us (MPS) curates the finds; they are accessible by arrangement with the Borschiv Regional Museum, Ministry of Culture and Arts of Ukraine, Podillya Region, Ukraine.

Excavations between 2007 and 2008 were undertaken at a distance of *c.* 70m from the cave entrance. In addition to the crania discussed here, at the time of the excavations there were post-cranial skeletal remains in association, including ribs and rib fragments, vertebrae, sacrum and fragments of long bone (comprising a total of fourteen samples, which were originally analysed by Alexey G. Nikitin *et al.* (2010) for ancient DNA studies). More recent investigations undertaken in 2012 have suggested that a minimum of 36 individuals, recovered as comingled secondary burials, mixed with pottery, ceramic figurines, stone and bone tools, and faunal remains, are represented by the finds from Verteba (Karsten *et al.* 2014), although as noted below (also Lillie *et al.* 2015), the complete lack of dating means that contemporaneity has not yet been established for this material.

The analysis of seven crania (one comprising the cranium plus mandible and six that are represented only by the cranium) from the excavations at Verteba Cave included osteology, pathology, cranio-metrics and sampling for laboratory analysis undertaken by two of us (IP, ML) in September of 2011. The initial work entailed the field recording of ageing and sexing data, and the recording, measurement and sampling of the skulls for AMS dating (Tab. 1). Stable isotope analysis was subsequently undertaken on these samples at the University of Oxford (Oxford Radiocarbon Accelerator Unit) (AMS dating and $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ stable isotopes analysis) and the Laboratory for Archaeological Chemistry, University of Wisconsin ($^{87}\text{Sr}/^{86}\text{Sr}$, $\delta^{18}\text{O}$, $\delta^{13}\text{C}$).

Four of the seven crania considered in the current study were located in a cavity in the floor of the cave. The material at this location included an aurochs

(*Bos primigenius*) horn, apparently resting on a large stone 'pedestal', along with individuals 1 and 4–6. To the north of this material, there was a stone wall about a foot high 'blocking' the passage to the site from the other cave chamber. Cranium 2 was located in the north-eastern quadrant of the excavated area about 1m from the main group of crania. Two other skulls, individuals 3 and 7, were recovered from the south-eastern area of the earlier 2007–2008 excavations approx. 1.4m from the main group. The excavation areas yielded a range of material culture remains, such as charcoal, pottery and faunal material, some of which have been dated by one of us (AGN); this material indicates continued use of the cave from 3950–3540 cal BC, and into the Bronze Age at c. 1000–500 cal BC (Nikitin 2011) and the Early Scythian period at c. 780–510 cal BC (this report).

AMS dating

AMS dating for the seven crania was undertaken at the Oxford Radiocarbon Accelerator Unit with funding from the NERC-AHRC National Radiocarbon Facility (NRCF – Project – No. NF/2011/2/18). Seven samples were processed, using a modified version of the R. Longin (1971) method of collagen extraction (see Brock et al. 2010). Approximately 600mg of material was drilled per sample, and these samples were then subject to acid-base-acid wash pre-treatment (using 0.5M hydrochloric acid and 0.1M sodium hydroxide), gelatinized, and ultrafiltered at 30 kDa to remove contaminants at a molecular level (Brown et al. 1998). The samples were then burnt on a CF-

IRMS system (see Brock et al. 2010), graphitized using an iron catalyst (see Dee, Bronk Ramsey 2000), and run on the ORAU HVEE AMS (Bronk Ramsey et al. 2004). The collagen produced from this process was also weighed in triplicate and measured for carbon and nitrogen stable isotope ratios on an Elemental Analyser linked to a continuous flow Sercon dual inlet mass spectrometer. The calibration standard used on the mass spectrometer is alanine. The faunal samples were also processed using a modified version of the Longin (1971) method; however, the base wash and ultrafiltration steps were not required. Statistical analysis of the radiocarbon dates was undertaken following guidance in Oxcal, wherein the R_combine function was applied to assess whether the dates represented a single event, *i.e.* where the samples would derive from the same radiocarbon reservoir at the same time (https://c14.arch.ox.ac.uk/oxcalhelp/hlp_analysis_eg.html#r_combine).

¹³C and ¹⁵N stable isotope analysis of bone collagen

Stable isotope analysis of carbon and nitrogen from bone collagen allows for a direct assessment of pre-historic dietary pathways and protein source, particularly in the last c. 10 years of the individual's life (Schwarcz, Schoeninger 1991), although as noted by Robert E. M. Hedges and Linda M. Reynard (2007) this is an approximate estimation that is dependent upon the skeletal element analysed. Carbon isotope measurements of human and animal bone collagen reflects the protein component of ingested foods, which can be used to infer potential sources of dietary carbon, alongside providing information regarding ecological niches, vegetation patterning and habitat (Schoeninger, DeNiro 1984; Lee-Thorp, Van der Merwe 1987). Stable carbon isotope ratios ($\delta^{13}\text{C}$) measured from bone collagen can allow us to distinguish between dietary protein from marine, terrestrial and freshwater resources (Schwarcz, Schoeninger 1991; Cerling et al. 1997; Richards 2002; Eriksson et al. 2008). In addition, $\delta^{13}\text{C}$ values are influenced by the composition of the local vegetation. Plant species that utilise different photosynthetic pathways, *e.g.*, predominantly C₃ (Calvin-Benson) and C₄ (Hatch-Slack), produce distinct $\delta^{13}\text{C}$ values (as the pathways discriminate against ¹³C during photosynthetic fix-

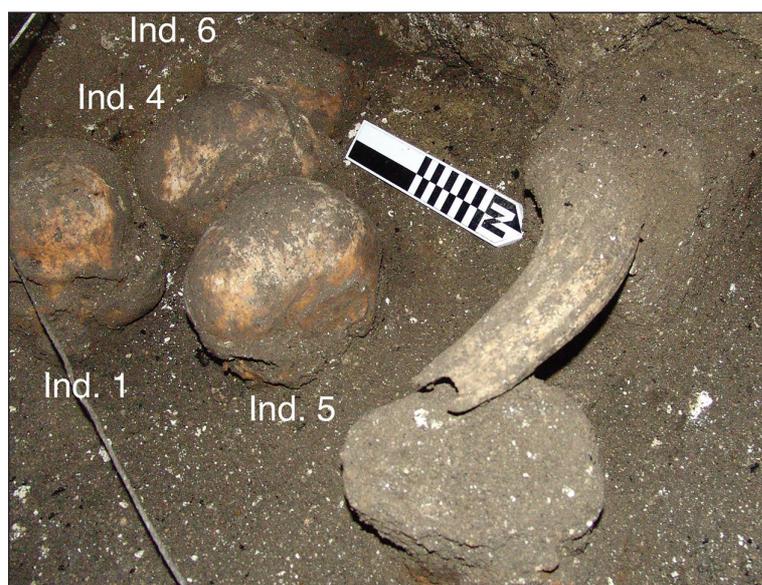


Fig. 2. Skull deposit at Verteba Cave: four human skulls to the left of the picture, with an auroch horn resting on a large stone pedestal in the centre-right of the image (photo by M. Sokhatsky, 2008).

ation of CO₂ to different extents) (Park, Epstein 1960).

In mammalian bone collagen, the isotopic shift between consumer and diet (e.g., $\Delta^{13}\text{C}_{\text{diet-body}}$) is approx. 1‰ (DeNiro, Epstein 1978; Casey, Post 2011). Nitrogen stable isotope ratios ($\delta^{15}\text{N}$) are used to establish the trophic level of an organism in the food web, with $\delta^{15}\text{N}$ enrichment of approx. 3–5‰ (e.g., $\Delta^{15}\text{N}_{\text{diet-body}}$) observed incrementally through the food chain (Schoeninger, DeNiro 1984; Mülleder, Richards 2005). One limitation of the study of stable isotopes from bone collagen is that they reflect dietary proteins, but not the full dietary spectrum (Keegan 1989; Hedges 2003). In addition, depending on the skeletal element analysed, the rate of collagen turnover (synthesis) varies between cortical and trabecular bone (Babraj et al. 2002; Hedges et al. 2007). This also varies between different elements, and turnover rates also decrease with age. As such, Table 1 provides the age and sex distribution of the samples analysed (based on dental wear and cranial suture closure – recognising the limitations and caveats that need to be addressed in using these criteria for estimating age, e.g., Lillie 1998).

Strontium, oxygen and carbon analysis of enamel bioapatite

Strontium (radiogenic) and oxygen (stable) represent two independent isotopic systems that can be investigated to infer information about mobility (from the local underlying geology) and climate, respectively. Assuming that an individual consumes their food and water mainly from local sources, strontium and oxygen isotopes can be used to characterise their childhood residence (Montgomery et al. 2007). In general, older rocks have a higher ratio, while younger rocks have a lower ratio. The ratio of sediments depends on the ratios of the rocks from which they derive. The ratio $^{87}\text{Sr}/^{86}\text{Sr}$ moves unaltered from soil nutrients, derived from sediments, into the food chain and the human skeleton. Biosphere strontium values ($^{87}\text{Sr}/^{86}\text{Sr}$) reflect the age and type of the underlying geology, with factors such as geological drift, dust, and rainwater contributing to (and occasionally heavily influencing) isotopic values (Price et al. 2004). Most of the strontium in our bodies is deposited in our bones and teeth.

Oxygen ($\delta^{18}\text{O}$) measurements for humans predominantly reflect the local drinking water, which for the most part is derived from rainwater. Oxygen isotope ratios in rainfall vary, largely based on latitude, elevation, temperature, and distance from source. The

heavier isotope (^{18}O) precipitates more easily, so the ratio becomes lighter with lower latitudes and elevations, warmer temperatures, and proximity to source. Oxygen isotopes are less geographically specific than strontium and more difficult to interpret. Although oxygen isotope ratios in a region change with climate, $\delta^{18}\text{O}$ in modern precipitation are often used as a proxy for the local baseline. In the case of Verteba, the nearest recording station was at Lviv, some 175km northeast, but in the same general landscape as the cave at Verteba. The mean and 1 s.d. $\delta^{18}\text{O}$ at Lviv was $-10.5\text{‰} \pm 2.8$, with a wide range between -14.9‰ and -7.6‰ . The $\delta^{18}\text{O}$ in human tooth enamel is measured in carbonate, using PDB dolomite as a standard, and these values must be converted to be comparable to $\delta^{18}\text{O}$ in precipitation.

The chemistry of tooth enamel is measured, as this material develops during early childhood and remains unchanged through life, and in many cases long after death. Thus differences between childhood isotope values in enamel and the isotope ratio of the place of burial indicate mobility during life, i.e. movement to a new place (Montgomery 2002). The enamel bioapatite of humans (and indeed all mammals) is precipitated from blood biocarbonate, which exchanges freely with body water (Passey et al. 2005). Combined, these factors constitute the pool that determines bioapatite $\delta^{13}\text{C}$, $\delta^{18}\text{O}$ (Jeffrey et al. 2015), and $^{87}\text{Sr}/^{86}\text{Sr}$ (Kohn, Cerling 2002). In $^{87}\text{Sr}/^{86}\text{Sr}$, no fractionation is evident between diet and consumer tissues (Montgomery 2002). For oxygen ($\delta^{18}\text{O}$), the bulk fractionation rate, $\Delta^{18}\text{O}_{\text{diet-body}}$ is approximately -9‰ to -8‰ (Longinelli 1984; Luz et al. 1984; Pellegrini et al. 2011), with the bulk value representing the three oxygen reservoirs present in PO₄, CO₃, and OH⁻ groups (which contain oxygen contents of 35%, 3.3%, and 1.6%, respectively) (Cerling, Sharp 1996). The fractionation rate for $\delta^{13}\text{C}$ measurements ($\Delta^{13}\text{C}_{\text{diet-body}}$) of enamel bioapatite is approx. -12‰ (Cerling, Harris 1999).

The primary aim of this stage of the analysis was isotopic provenancing of the human remains, to distinguish local from non-local individuals among the samples from the site. Two faunal samples in the form of mandibular molars from domestic pig or wild boar were taken to provide an estimate of the local baseline or background range for strontium isotopes. Statistical analyses for bone collagen isotope values (carbon and nitrogen) and enamel apatite isotope values (strontium, oxygen, and carbon) were performed using the freeware statistics package 'R' (<http://www.r-project.org/>) by CB.

Results

AMS dating

The calibrated ultrafiltered AMS dates (Tab. 1) place the skeletal material that was investigated as part of the current study primarily within phase BII of the Trypillian farming culture. This dating indicates that the human skeletal material is in an earlier phase of this culture than has previously been recovered in Ukraine (Figs. 3, 4).

The distribution of the calibrated date ranges (Figs. 3, 4) would appear to indicate that we may well be looking at multiple phases of interment at this location, or alternatively that the material that is found in secondary contexts is derived from multiple phases of interment at a primary location, either elsewhere in the vicinity of the cave, or from within the cave itself.

The R Combine function in OxCal was applied to the AMS dates; this is a tool designed to compile the dates and provide a weighted mean of the ^{14}C determinations. OxCal performs a chi-squared test (χ^2) to analyse whether the dates are consistent with being of the same date (e.g., all individuals dying at the same time). For the radiocarbon dates from Verteba, the R Combine function fails ($T = 25.210$ (5% 12.6)), thus demonstrating that the human AMS dates from the cave site are statistically incompatible with a single event.

Figure 4 highlights the fact that the calibrated dates separate out into what appears to be three discrete phases, an observation that would not be inconsistent with the evidence from the palaeopathology (as discussed above). Individuals M5 and A22 (recovered in 2005) were not dated as part of the current study, but were dated to 3620–2940 cal BC (4550 ± 90 BP – Ki-13388) and 4650–2670 cal BC (4910 ± 400 BP – Ki-14308) during previous work (Nikitin et al. 2010),

with M5 recently redated to 781–511 cal BC (2490 ± 30 BP – Beta-465022). The earlier dates have high errors of ± 90 yrs and ± 400 years, respectively, which extend the ranges well beyond the main cluster at Verteba.

Stable isotope analysis

$\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ analysis of diet

Stable isotope analysis of carbon and nitrogen was undertaken on five faunal samples and nine human samples. The results are presented in Figure 5 and Table 2.

The faunal samples analysed had an average $\delta^{13}\text{C}$ of $-20.3\text{‰} \pm 1.1$ and an average $\delta^{15}\text{N}$ value of $7.7\text{‰} \pm 1.7$. The values for $\delta^{13}\text{C}$ demonstrate a clear C3 terrestrial diet signal, which is commensurate with the environmental evidence from the region (Konoplya et al. 2008). It is perhaps a little difficult to draw further conclusions from the animal fauna, as the sample size is restricted due to the context and the secure identification of two of the samples beyond those available is limiting. The only caveat to the preceding observation is the pig sample with the more depleted carbon isotope value (which is perhaps due to the consumption of protein resources from under a forest canopy, thereby introducing a canopy effect on carbon isotopes; Hamilton et al. 2009), and the domestic dog sample (-19.8‰ for $\delta^{13}\text{C}$ and 9.6‰ for $\delta^{15}\text{N}$) which has values very close to that of the humans, suggesting that the dog consumed very similar diet to the human individuals. It would certainly be of further interest to obtain a radiocarbon age for the dog sample to see if it ties in with the human radiocarbon ages.

The humans have an average $\delta^{13}\text{C}$ value of $-19.2\text{‰} \pm 1.1$ and a mean $\delta^{15}\text{N}$ of $10.1\text{‰} \pm 0.5$; these values are also commensurate with the consumption of C3 terrestrial protein resources. The large s.d. on the $\delta^{13}\text{C}$ value is reduced when the outlier (M5) is re-

Skeleton No.	Excavation ID	Sex	Individual Age	Lab No.	AMS Age [BP]	Cal BC 2σ
Verteba-1**	3.17.1	Male	35–45	OxA-25991	4985 ± 30	3931–3670
Verteba-2*	3.16.1	Male	25–35	OxA-26201	4807 ± 33	3654–3522
Verteba-3*	3.18.1	Female?	18–22	OxA-26202	4863 ± 33	3709–3537
Verteba-4*ž**	3.14.1	Male?	30–40	OxA-26203	4976 ± 33	3911–3659
Verteba-5**	3.13.1	Male	30–40	OxA-26204	4888 ± 32	3758–3636
Verteba-6*ž**	3.15.1	Male	14?–20	OxA-26205	4855 ± 32	3708–3536
Verteba-7	1.1.1	Male	20–30	OxA-26207	4925 ± 33	3772–3648

Tab. 1. Age and Sex determination on human remains from Verteba collected during the 2007–8 field season with AMS radiocarbon ages calibrated to 2σ . Dates calibrated using OxCal v.4.1 (Bronk Ramsey 2012). *Individuals with damage/pathology in evidence; **crania in association.

moved from the sample, such that values of $19.55\% \pm 0.5$ are recorded, while the removal of the $\delta^{15}\text{N}$ value for this individual from the sample does not alter the results (Note: new dating has shown that this individual is no longer placed in the Eneolithic

period, being Early Scythian on the basis of a calibrated date range of 781–511 cal BC).

The small sample size could influence the applicability of statistical analysis of the data, but a two-tailed

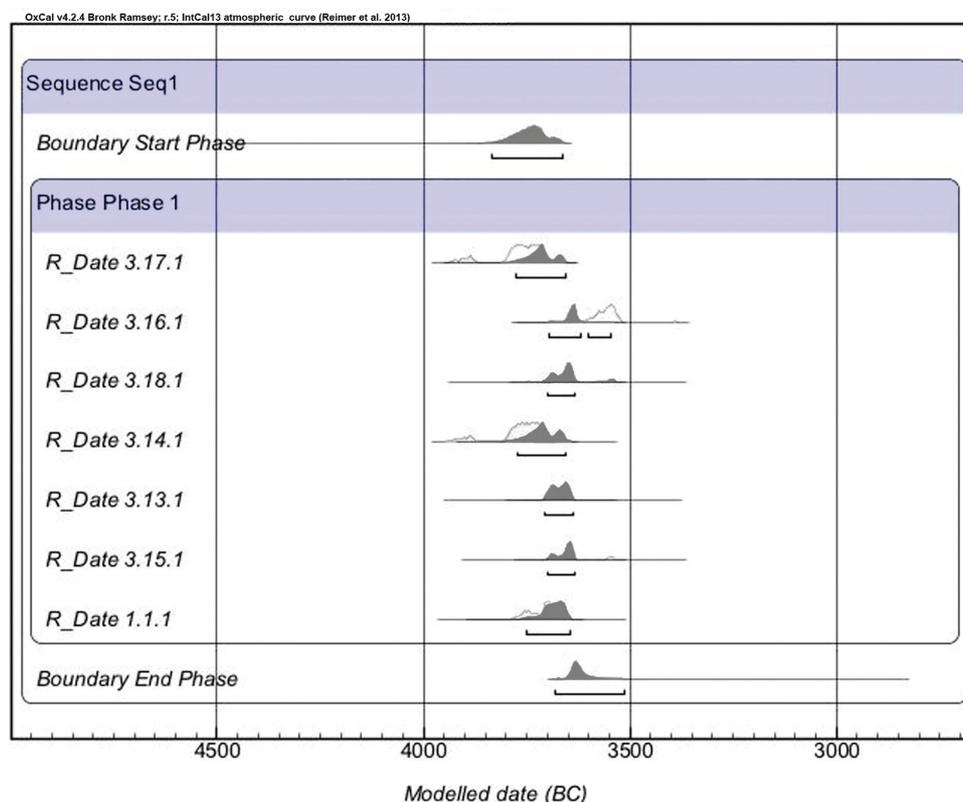


Fig. 3. Posterior density ages calibrated using the INTCAL13 curve on OxCal version 4.2.4.

Sample	Species	Age/Sex	Radiocarbon Age	Lab. Code	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	C:N	%C	%N
1 3.17.1	Human	Male 35–45	4985 ± 30	OxA-25991	-19.3	9.9	3.3	3.22	9.23
2 3.16.1	Human	Male 25–35	4807 ± 33	OxA-26201	-19.5	9.7	3.1	18.57	49.99
3 3.18.1	Human	Female? 18–22	4863 ± 33	OxA-26202	-20	10.4	3.2	16.66	44.99
4 3.14.1	Human	Male? 30–40	4976 ± 33	OxA-26203	-19.6	9.6	3.2	17.04	46.49
5 3.13.1	Human	Male 30–40	4888 ± 32	OxA-26204	-19	10.8	3.2	11.86	32.73
6 3.15.1	Human	Male 14?–20	4855 ± 32 4856 ± 33*	OxA-26205 26206	-19.4	9.5	3.2	14.02	37.88
7 1.1.1	Human	Male 30–40	4925 ± 33	OxA-26207	-19.6	9.9	3.2	15.44	42.48
A22	Human	Immature (>6yrs)	4910 ± 400**	Ki-14308	-19.7	10.7	3.3	***	***
M5	Human	Male (young)	4550 ± 90** 2490 ± 30****	Ki-13388 Beta-465022	-16.3	9.9		***	***
F2.6.7	Medium mammal	–	–		-19.7	6.4	3.2	***	***
F2.6.3	Large mammal	–	–		-20.4	6.4	3.1	***	***
F2.6.5	Pig	–	–		-22.3	6.5	3.2	***	***
F2.7.5	Red deer	–	–		-21.1	5.8	3.2	***	***
F2.6.6	Domestic dog	–	–		-19.8	9.6	3.1	***	***
F2.6.2	Pig	<6mths	–		-19.1	9.8	3.3	36.75	14.10
F2.6.4	Pig	10–18mths	–		-19.4	9.0	3.3	41.23	14.44

Tab. 2. Radiocarbon dates and carbon and nitrogen stable isotope results. * Duplicate date performed as part of internal consistency and quality control at ORAU. ** after Nikitin et al. 2010. *** Data not available. **** New dating by AGN for sample M5 at Verteba.

t-test (assuming equal variance) was undertaken on the human samples for sex differences, and no difference was observed in the p-values. Similarly, the variance in data for the all the humans compared to the fauna was tested (including the dog sample and then subsequently without it) and the difference in carbon was found to be significant with the dog included and removed ($p = 0.02$ and $p = 0.01$, respectively). The difference in nitrogen values proved significant when the dog sample was included (largely due to the extended range it produces when included in the animal group) and, predictably, the difference is not significant with the dog sample removed from the dataset.

The human carbon and nitrogen isotope data is commensurate with the consumption of the fauna analysed (excluding the dog and two of the pigs) and the $\delta^{15}\text{N}$ spacing is approx. 3‰. If we compare the isotope data to some of the finds from Verteba Cave, namely the presence of BII, CI and CII Trypillian pottery from the local groups of Schypynetska, Koshylovetska and Kasperivska, this would appear to indicate that the Verteba human interments belonged to a population reliant on an agro-pastoral subsistence strategy with some potential inputs from wild resources.

Strontium, $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ analysis

Strontium analysis of tooth enamel (along with the analysis of $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$) was undertaken for eight human samples and two pig samples (*Sus domesticus*) at the Laboratory for Archaeological Chemistry at the University of Wisconsin-Madison. Table 3 details the results obtained for the human tooth enamel samples analysed, while Table 4 outlines the descriptive statistics for these samples.

Figure 6 outlines the isotope results for strontium (A), oxygen (B), and carbon (C). No true data outliers are identified for any of the isotope measurements taken (e.g., no individual sample has an isotope values that plots outside the 1.5 quartile range). The datum points in Figure 6 represent individual sample measurements.

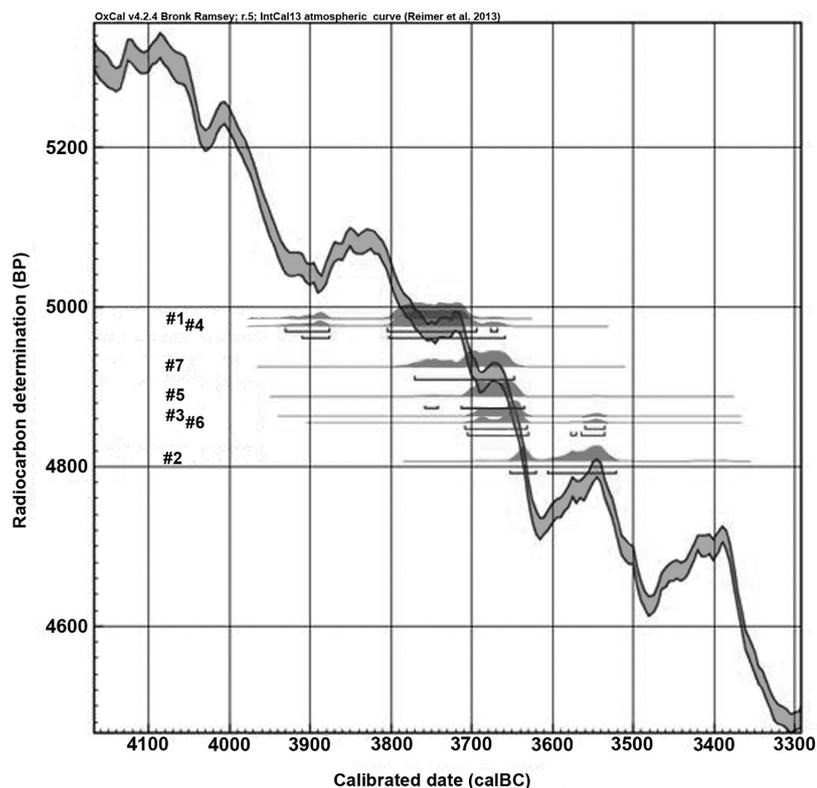


Fig. 4. Calibrated dates plotted on the radiocarbon curve – note that the location of the dates would indicate at least 2 or 3 discrete phases of deposition for these skulls.

One of the major considerations in strontium isotope analysis is the determination of the local background (or bioavailable) ratio from the place of burial. Verteba Cave, which contained the skeletons, is a limestone cavern, one of the largest in Europe, which is located (obviously) in a region of limestone bedrock. Limestone, an ancient marine deposit, has $^{87}\text{Sr}/^{86}\text{Sr}$ values that correspond to the ratio of sea-water at the time of deposition (Veizer 1989) ranging from approximately 0.707 to 0.709. Several factors can alter the expected geological signal of a location, such that a direct or proxy measurement of the local range is essential. In the case of Verteba, we measured two pig teeth as a proxy for the local signal. The two teeth measured 0.7091 and 0.7097, and probably provide a good estimate for the local range of values.

The most important aspect of the landscape at Verteba and a large area of this part of Ukraine, in terms of isotopes in humans, is the presence of deep deposits of loess, a fine-grain silt deposit which is carried long distances by the wind and deposited across much of Central and Eastern Europe. Rousseau *et al.* (2014) demonstrate that for European loess between 48°N and 52°N, the major sources were in the same latitudinal band and that the loess

was transported at low elevation and only over regional distances. Moreover, they observed a wide range of $^{87}\text{Sr}/^{86}\text{Sr}$ values in the loess, from 0.710 to 0.726 across that latitudinal band, with the highest value in eastern Ukraine. This high value for the loess in eastern Ukraine differs substantially from the observed values for fauna and human remains from Verteba reported in this study.

$^{87}\text{Sr}/^{86}\text{Sr}$ for human enamel averages 0.7096 with a very low s.d. and narrow range of variation. There were 6 males, 1 female, and one individual of indeterminate sex in the sample. There is no observed correlation between sex and $^{87}\text{Sr}/^{86}\text{Sr}$ values. Figure 6.a documents the narrow range of variation present and the close correspondence between the faunal and human values. There are no obvious outliers in the strontium isotope data, and the human enamel values appear very homogeneous. The strontium data suggest that there are no non-local individuals among the humans sampled and analysed from Verteba Cave.

One important issue with regard to mobility in this region concerns the nature and distribution of strontium isotope sources. The windblown loess covers large portions of Ukraine, probably with similar or identical strontium isotope ratios over long distances of perhaps hundreds of kilometres. For this reason, individuals coming from other areas, but still from a loess region, might have similar $^{87}\text{Sr}/^{86}\text{Sr}$ values and would not be identified as a non-local. The carbon and oxygen isotope data provide some suggestion that there may be a non-local individual present. The eight $\delta^{13}\text{C}$ values for human enamel (Tab.

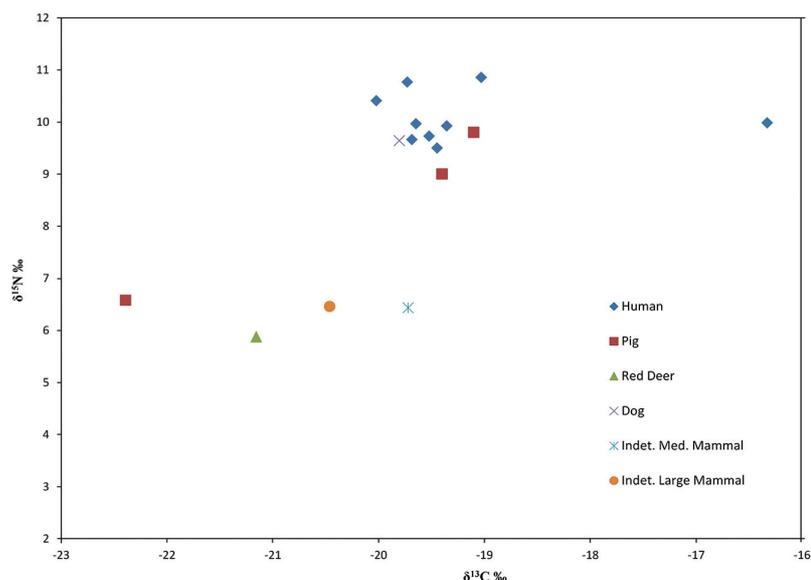


Fig. 5. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ bone collagen values for humans and fauna at Verteba.

2) average $-12.1\text{‰} \pm 1.3$ with a range from -13.1‰ to -9.4‰ .

A plot of $^{87}\text{Sr}/^{86}\text{Sr}$ vs. $\delta^{13}\text{C}$ (Fig. 7) reveals a single outlier (M5) with a distinctively less negative $\delta^{13}\text{C}$ value, which suggests that this person consumed a different diet, containing either marine or C_4 plants, as a child, in contrast to the remaining seven individuals who consumed a largely terrestrial diet of C_3 plants and animals consuming C_3 species. This is mirrored in the dietary isotope data where the nitrogen values are equivalent, but individual M5 is shown to have a more positive $\delta^{13}\text{C}$ of -16.3‰ . While this contrast is accounted for by the new dating of this individual to the Early Scythian period, it also indicates an individual who grew up in a different region or perhaps an individual with a distinctive childhood diet. The former would seem to be a more likely possibility, as it is some 450km from Verteba south-eastwards to Odessa on the Black Sea coast, the closest marine environment.

Species	Individual	Sample ID	Element	Sex	$^{87}/^{86}\text{Sr}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$
Human	7	V1.1.1	Max right M2	M	0.709660	-13.12	-5.80
Human	3	V3.18.1 (1.2)	Max left P3	F	0.709741	-12.86	-6.98
Human	4	V3.14.1	Max right P4	M	0.709616	-11.99	-6.83
Human	6	V3.15.1	Max Right M1	M	0.709692	-12.86	-6.48
Human	2	V3.16.1	Max right P3	M	0.709312	-12.64	-6.31
Human	1	V3.17.1	Max Left M1	M	0.709842	-12.30	-6.39
Human	8	A22	Incisor	I	0.709344	-12.17	-5.83
Human	9	M5	Mand right PM2	M	0.709475	-9.12	-5.94
Pig	-	F2.6.2	Incisor	<6mths	0.7091	-	-
Pig	-	F2.6.4	Mand right PM2	10-18mths	0.7097	-	-

Tab. 3. Sr, $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ results from human and pig samples at Verteba.

	$^{87}\text{Sr}/^{86}\text{Sr}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$
Average	0.7096	-12.1	-6.3
SD	0.0002	1.3	0.4
min	0.7093	-13.1	-7.0
max	0.7098	-9.1	-5.8
Count	8.0000	8.0	8.0

Tab. 4. Descriptive statistics for strontium, carbon, and oxygen isotope ratios in Verteba human enamel.

The oxygen isotope data is also of interest, exhibiting a mean and s.d. of $-6.3\text{‰} \pm 0.4$, with a narrow range from -7.0‰ to -5.8‰ . A scatterplot of $\delta^{18}\text{O}$ vs. $^{87}\text{Sr}/^{86}\text{Sr}$ (Fig. 8) suggests that two groups may be present, one with more positive oxygen and lower strontium isotope ratios and the other with less positive oxygen and higher strontium. At the same time, the range of values for the oxygen isotope ratio is very low, and approximates the range of variation in a normal population. The two groups observed in the plot may not exist in reality. In sum, the isotopic provenance of the human tooth enamel from Verteba Cave generally suggests a pattern of limited mobility, although our ability to identify movement is likely constrained by the widespread distribution of similar $^{87}\text{Sr}/^{86}\text{Sr}$ in the region. The carbon isotope ratios highlight a distinctive diet for one of the eight individuals examined from Verteba, indicating that this individual may have been non-local, since the diet represented was unlikely to have originated in this area. The oxygen isotopes varied only slightly among the eight samples tested and as such are considered unlikely to provide information on mobility.

Discussion

A number of the analysed samples from Verteba have been attributed to the Trypillia farming culture of Ukraine, with later periods of activity in evidence. This site is a unique location in relation to this culture, and the evidence for interpersonal violence and processing of the deceased for inclusion in the cave deposits is also unique in light of the dating results discussed below.

Dating

The AMS dates primarily span the period 3800–3600 cal BC, which would place most of these individuals within Mykhailo Videiko's (2004) phase BII of the Trypillian culture. The BII stage of the Trypillian chronology began at c. 4100 BC, around the time of a major climatic shift in Europe c. 4200–3800 BC, which was accompanied by a decrease in solar insolation and a general cooling of the climate and increased aridity (Perry, Hsu 2000; Brooks 2006). Incidentally, during this stage, the exploitation of wild resources was particularly marked in areas where crop production or pastoral activities were limited by the environmental context, as at the forest/forest-steppe boundaries, necessitating the integration of hunting, foraging and fishing in order to ensure sustainability (Markova 2008.80).

The distribution of the calibrated date ranges (Figs. 3, 4) would appear to indicate that we may well be looking at more than one phase of interment at this location during the Trypillian phases of activity, or alternatively that the material that is found in secondary contexts is derived from multiple phases of

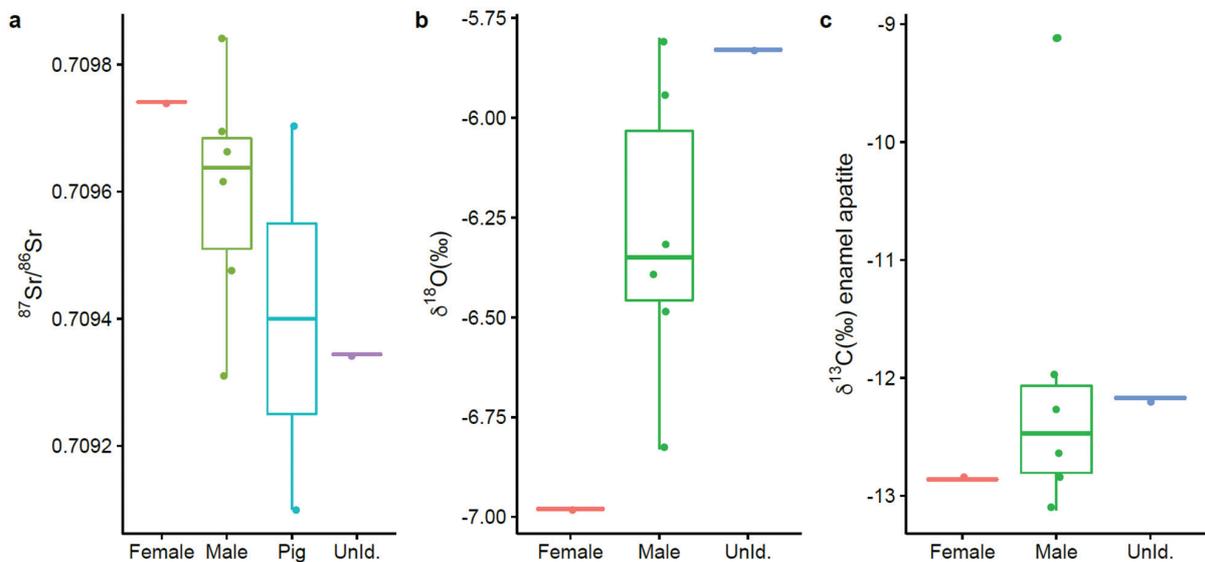


Fig. 6. Strontium, oxygen, and carbon isotope data for humans and pigs at Verteba.

interment at a primary location, either elsewhere in the vicinity of the cave, or from within the cave itself (as access to the cave was not restricted until recently). This observation is supported by the chi-squared test (χ^2) which was applied in order to analyse whether the dates are consistent with being of the same date, as the R_Combine function fails ($T = 25.210$ (5% 12.6)); this demonstrates that the human AMS dates from the cave site are statistically incompatible with a single event.

The fact that a number of the individuals studied exhibit evidence of both peri-mortem and healed injuries would lend support to the possibility that low-level inter-personal violence occurred regularly during this early stage of the Trypillia culture. This observation contradicts the suggestion that Trypillia groups engaged in violent interactions only in the final stages of cultural development (*Korvin-Piotrovskiy 2012.6–18*), and confirms our suggestion at the start of this paper that a lack of absolute dating means that there are no secure chronological grounds from which to attribute the interpretations of the inter-personal (peri-mortem) violence to stage CII of Trypillia, as suggested previously by Karsten *et al.* (2014; 2015).

Individual 2 lies across the period 3650–3520 cal BC, thus extending the sample date range into the CI phase of Trypillia. This ties in quite well with the pottery finds from the cave (*e.g.*, BII/CI pottery), but the presence of CI and CII pottery types may suggest that the skulls were in fact interred in the cave at the beginning of its use in the Eneolithic period rather than towards the end of this range. However, as outlined above, it should be noted that a number of the remains from the cave are not yet dated by absolute means, and also that Nikitin *et al.* (2010) have analysed a fibula and vertebra of Bronze Age date from this cave, and a mandible of Scythian age (this report), and the full duration of the interment of humans during the Trypillian (and later) periods at Verteba remains to be established, as does the actual chronological age of the remainder of the twenty-one individuals identified by Karsten *et al.* (2015). However, what is readily apparent is that the secondary nature of this material means that undated skeletal elements cannot be assigned to a precise Trypillia culture stage with any certainty unless absolute ages are obtained for these remains.

Sr, ^{18}O , $\delta^{13}C$

The strontium data indicate that all of the individuals were local to the area, and there are no obvious outliers in this sample. Given the suggestion that the samples may represent more than one phase of deposition, and that the current sample is a sub-set of possibly around 30 or so individuals, additional studies may further enhance the resolution of this observation. The ^{18}O values, whilst possibly suggesting two discrete groupings, do not exceed the range of variation in a normal population, and again, further resolution might be forthcoming from additional analysis where suitable samples are available. The one outlier (M5) identified in the $\delta^{13}C$ values in this stage of the analysis, also corresponds to a similar outlier value when assessing the dietary isotopes, suggesting that M5 consumed a diet in which up to 50% of the dietary proteins were from non- C_3 food sources. The new dating provides some insights into this variation.

Diet

As indicated above, the stable isotope data ($\delta^{13}C$ and $\delta^{15}N$) would indicate that this population was consuming a mixed C_3 -based diet (again with the exception of M5), which in the case of Trypillia farming groups would include a variety of domesticated animals and plants alongside wild fauna, flora and fish. In addition, gathering and fishing are known to have contributed to the diets of human groups in the earlier stages of the Trypillia culture's development (*Korvin-Pietrovskiy 2012.10*). The presence of red deer and pig in the Verteba assemblage could indicate the consumption of wild fauna species, an observation that may well be reinforced by the fact that two of the pigs at Verteba plot out in the same area as the humans, and a domesticated dog (Fig. 5).

In the earlier stages of the culture's development a range of domesticated plant species were exploited,

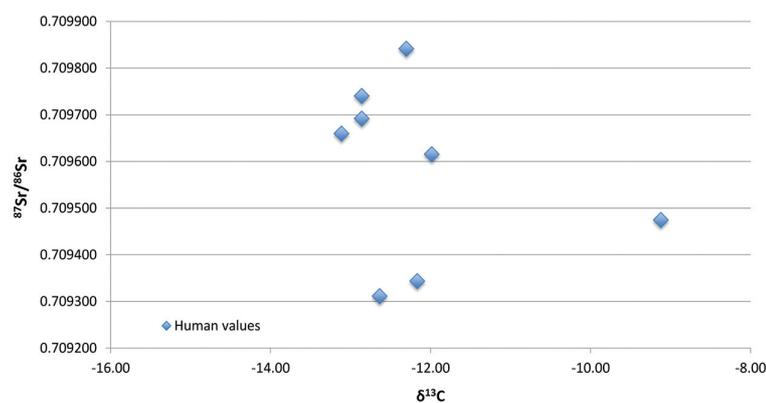


Fig. 7. Scatterplot $^{87}Sr/^{86}Sr$ vs. $\delta^{13}C$.

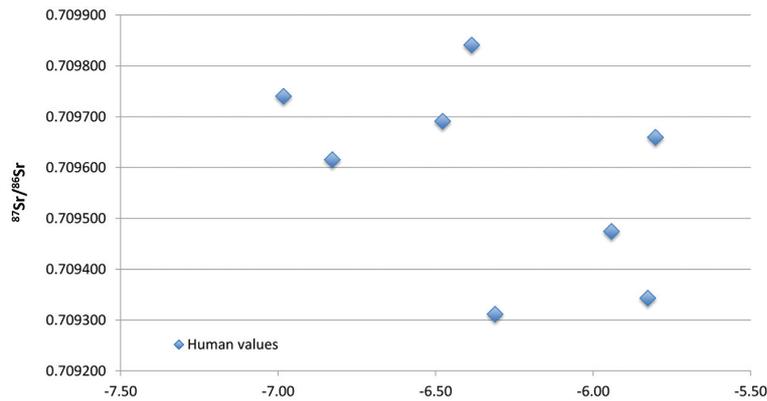


Fig. 8. Scatterplot $^{87}\text{Sr}/^{86}\text{Sr}$ vs. $\delta^{18}\text{O}$.

with emmer dominating in early assemblages, and einkorn, spelt, hulled and naked barley, as well as pulses/peas, *Vicia ervilia* (bitter vetch) and lentils, and flax, all attested during the main stage of cultural development (Pashkevych 2008). The range of wild plants exploited is outlined above, and given this broad spectrum of resource exploitation, especially in phase BII of this culture, the high incidences of caries and especially hypoplasias recorded by Karsten and co-workers (2014; 2015) is perhaps a little surprising, as it is clear that not all of these individuals are attributable to the latter stages of Trypillia. It would appear that further chronological resolution and dietary isotope analysis may be required to determine whether the remainder of the population excavated at Vertebe are all attributable to the earlier part of the culture chronology and also whether their diet remains consistent across all phases of activity at this location.

Conclusions

Vertebe cave offers unique insights into Trypillian society and burial practices across the period c. 3800–3600 cal BC, and beyond. To date, the failure of studies that integrate absolute dating in order to provide context to analyses of palaeopathology and diet have led to a situation wherein our understanding of the precise nature and significance of these parameters during the periods of interment at Vertebe remain fundamentally flawed.

The current study has sought to redress this limitation by applying AMS dating to individuals from this cave, and the initial results appear to indicate that, while we may well be seeing at least three discrete depositional phases in the cave sequences during the Eneolithic, and thus continued low levels of interpersonal violence during stages BII–CII of Trypillia, the new date on individual M5 suggests that ma-

terial of much later (Scythian) date is also incorporated into these deposits.

The analysis of strontium, $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$, and the dietary isotope analyses have shown that the individuals interred at Vertebe appear to have been local to the study area. The outlier identified in the $\delta^{13}\text{C}$ analysis is a young adult male (M5). This individual has been redated to the Early Scythian period at 780–510 cal BC and, as such, an explanation for

the differing $\delta^{13}\text{C}$ values for this individual when compared to the remainder of the population studied is forthcoming. Importantly, had the mobility and dietary isotope analyses not been undertaken, the redating of this individual would not have been undertaken, as the initial Kiev date appeared valid. With this in mind, studies of dental pathology (e.g., caries rates and incidence of enamel hypoplasias; Karsten et al. 2014; 2015a; 2015b) are called into question, as the rates of expression cannot be guaranteed to relate solely to the Trypillia farming groups in this region.

Despite this observation, it is important to highlight that the significant observation relating to Trypillia is that, on the basis of the dates obtained in the current study, the groups interred at Vertebe appear to have engaged in low levels of interpersonal violence from the BII/CI stage of this culture, thus contradicting the dominant theory in relation to this activity in the Trypillia farming culture.

Overall, this study has demonstrated that at Vertebe cave we have a unique resource that has the potential to provide information of fundamental importance to our understanding of the first farmers of Ukraine. However, the new dating has shown that, despite the existence of stratified deposits at Vertebe, the disarticulated human remains do not conform to either their stratigraphic context or the typological seriation as developed, i.e. not only Trypillia farmers were interred at Vertebe. In addition, while the isotope analysis for mobility has shown that these individuals were local to the region, the dietary isotope analysis (Fig. 5; Tab. 2) initially suggested that individual M5 differed considerably in terms of diet, this being despite the fact that an initial date on M5 indicated chronological equivalence with the main group. To that extent, the $\delta^{13}\text{C}$ ratio from the mobility isotopes part of the study also in-

indicated that this sample was not fully commensurate with the other data from this location. The re-dating of this individual during the production of this paper has shown that considerable discrepancies exist between the Kiev and Beta dating.

Fundamentally, then, the dating, mobility and dietary isotope analysis has provided considerable chronological, mobility and dietary resolution to the material from Vertebe Cave, which on current evidence

includes material from the Eneolithic through to Scythian age. The results of previous studies, which failed to undertake dating or isotope analysis, must be considered with caution, as it is clear that a wide range of periods are represented by the Vertebe samples, and the diets of the individuals interred at Vertebe are not necessarily all related to Trypillia farmers. Further dating, mobility and dietary resolution is clearly needed at this location.

ACKNOWLEDGEMENTS

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