Journal of Archaeological Science 132 (2021) 105437

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: www.elsevier.com/locate/jas

Multi-proxy analyses reveal regional cremation practices and social status at the Late Bronze Age site of Herstal, Belgium

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ARTICLE INFO

Keywords:
Landscape use
Late bronze age
Meuse valley
Strontium isotopes ratios
Radiocarbon dating
Cremated human remains

ABSTRACT

The funerary Bronze Age culture in the Belgian part of the Meuse valley is poorly understood due to the challenging nature of cremation deposits that dominate the archaeological record. Only a few sites were analysed in that region, limiting the possibilities to reconstruct the development of Bronze Age populations in Belgium. Due to its good preservation and detailed excavation reports, the site of Herstal (Belgium) offers a unique opportunity to finally gain new insights into the life and death of those buried in the Meuse Valley during the Late Bronze Age. A total of 21 graves were analysed using a multi-proxy approach, combining grave typology, osteoarchaeology, strontium isotope ratios ($^{87}Sr/^{86}Sr$), and radiocarbon dating. The $^{87}Sr/^{86}Sr$ results show that the individuals of Herstal most likely used a variety of local food supplies while having interactions with other populations in and beyond the Meuse Valley, as demonstrated by the bronze artefacts and ceramics displaying clear influences from Germany, Southern Netherlands, and North-West France. The cemetery most likely shows a local burial style with the presence of two (or even three) individuals in several cremation deposits containing a number of privileged individuals who had access to bronze trading networks.

1. Introduction

Cremation was one of the main funerary practices in Belgium from the Late Neolithic to the Early Medieval period, and in particular during the Late Bronze Age (LBA) and Early Iron Age (EIA) (Capuzzo et al., 2020; De Mulder, 2011). In the past decades, Belgian cremated human remains have only been studied in a limited number of cases due to their challenging nature and the possible lack of information on funerary practices of the LBA leaves many questions about the importance of the Meuse Valley and its past populations unanswered.

Several Bronze Age chronologies for Western and Central Europe were proposed based on metal objects and ceramics (Brun, 1986; Brun and Mordant, 1988; Hatt, 1961; Müller-Karpe, 1959; Reinecke et al., 1965; Sperber, 1987). Unfortunately, chronologies based on bronze objects, whose dating is relatively more accurate, are not directly applicable to Belgian funerary sites since most of the metal objects dating to the Bronze Age (2100–800 BCE) were found in rivers and not associated with funerary structures, or were burned and heavily

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https://doi.org/10.1016/j.jas.2021.105437
Received 11 January 2021; Received in revised form 10 June 2021; Accepted 23 June 2021

fragmented (Genvier et al., 2019; Van Impe and Warmenbol, 2017; Warmenbol, 2001, 2019a). This hindered the development of a clear Belgian Bronze Age typo-chronology in comparison to other parts of Western Europe (Roberts et al., 2013). Research on the LBA in Belgium began in the second half of the 19th century, with a particular focus on ceramics recovered from cemeteries to establish a typo-chronology for Belgium (Desittere, 1968). However, the radiocarbon dates do not always correspond with the typo-chronology (De Mulder, 2013). Recently, a more accurate chronology of LBA-Early Iron Age cemeteries was established in the northern and western parts of Belgium based on new ^{14}C dates on cremated bones from Flemish sites (De Mulder et al, 2007, 2008, 2011; Roberts et al., 2013). Such a chronology is still lacking for the southern part of Belgium, in the area of the Meuse Valley, where mainly inhumations were radiocarbon dated (Leclercq, 2014a; Warmenbol, 2019b).

Belgium has two main river basins, the Scheldt and the Meuse Valleys, named after the two major rivers crossing the country (Fig. 1). Based on the variety of objects and artefacts, the Scheldt and the Meuse Valleys were previously presented as reflecting distinct commercial networks and populations during the Bronze Age (Mariën, 1951; Warmenbol, 2002, 2015). The Scheldt basin represented connections with the Atlantic complex (North-West France and Southern England) based on the bronze objects, while the Meuse Valley demonstrated links with the North Alpine complex (East of France, the Rhine area and West of Switzerland; Mariën, 1951; Warmenbol, 1988a), and more specifically showed a strong *Rhin-Suisse-France orientale* (RSFO) influence, based on the ceramics dating mostly to 1100–900 BCE (De Mulder, 2011, 2013). During the LBA, the difference between the two valleys is less rigid. The Scheldt Valley presents a large number of cremation graves, mostly urnfields, while the practice of inhumation seems to have been preferred in the south of the Meuse Valley. The Scheldt Valley has received more attention due to various ^{14}C dating campaigns in Flanders over the years. In contrast, the lack of in-depth studies of the Meuse Valley, except for the site of Rekem (Temmerman, 2007, Fig. 1), provides only limited data.

The cremation process destroys valuable features in the skeleton and as such, age and sex estimations of cremated human remains is particularly challenging as the traditional methods for sexing and ageing are based on unburnt skeletons (Brooks and Suchey, 1990; Buckberry and Chamberlain, 2002; Demirjian et al., 1973; Ferembach et al., 1980; Liversidge et al., 1998), and diagnostic elements required for applying those methods are often fragmentary or otherwise unobservable. Fortunately, these scientific methods are constantly being refined, and ageing and sexing methods using metric and non-metric traits based on unburnt skeletal material were tested on burnt human remains resulting in adjustments to existing methods and the development of new ones (e. g. Cavazzuti et al., 2019a; Hlad et al., 2021; Oliveira-Santos et al., 2017; Veselka et al., 2021a). Additionally, the high temperatures reached during cremation heavily alter the structure and chemical composition of bone (Snoeck et al. 2014a, 2016). However, calcined bone proved to be a reliable substrate for strontium isotopes analysis (^{87}Sr/^{86}Sr) in archaeological contexts (Snoeck et al., 2015) enabling to gather information about mobility and landscape use of those that practiced cremation as a burial ritual (e. g. Cavazzuti et al., 2019b; Snoeck et al., 2016, 2018).

These new developments allow in-depth studies of the Meuse Valley in general and in particular the well-reported and preserved LBA site of Herstal, Belgium (Fig. 1). This cemetery is one of the few Meuse Valley sites, with Rekem (Neerharen), Maastricht (Ambyerveld), and Weert (Boshover Heide) (Bloemers, 1988; Dyselinck and Warmenbol, 2012; Van Impe, 1980), presenting bronze objects that were associated with funerary contexts (Fig. 1). Unfortunately, most of these objects were too fragmented and/or burned to be used as chronological proxies with the exception of three objects: the bracelet and the hair ring from Grave 9

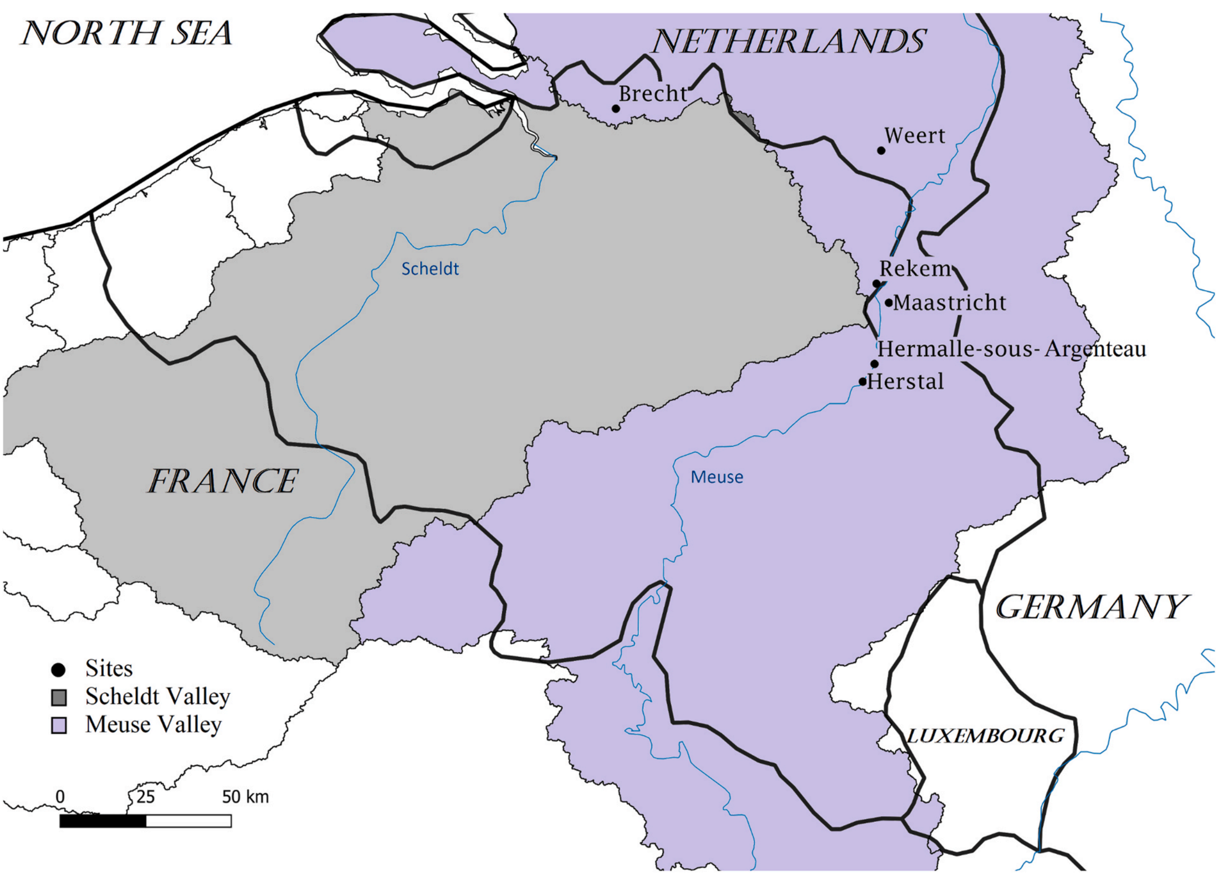

Fig. 1. The Scheldt and the Meuse Valleys in Belgium and location of Herstal and other LBA sites.

and the pin from Grave 10 (Alenus-Lecerf, 1974; Lecarme and Warmenbol, 2014). In 1974, the site was dated to the LBA-EIA (1000–600 BCE) using ceramics and the hair ring from Grave 9 (Alenus-Lecerf, 1974), but in 2014, a review of the ceramic and the pin from Grave 10 suggested an earlier date, around 1300–1200 BCE, that was attributed to the transitioning of Middle Bronze Age (MBA) to LBA (Lecarme and Warmenbol, 2014; Leclercq, 2014b). These ornaments clearly demonstrated an Atlantic and regional German and southern Dutch influence (O'Connor, 1980). The presence of these bronze objects and the variable styles of the ceramics show those buried in Herstal had access to an important network of trade and exchange.

While new typological, material culture, and dating studies have provided some crucial information about local and regional chronologies and networks in the Meuse Valley during the LBA, much more information is needed to understand the past life of the individuals that lived there and to improve our understanding of their possible interactions with the Scheldt Valley and the Alpine complex. The multi-proxy study of LBA cremated human remains from Herstal, combining grave typology, osteoarchaeology, strontium isotope ratios ($^{87}Sr/^{86}Sr$) and concentrations [Sr], and radiocarbon dating, provides essential information on mobility, landscape use, funerary practices, and intra- and inter-population dynamics in that area. It also lays a solid foundation for future studies focussing on mobility, landscape use, and funerary practices in the Meuse Valley in Belgium, France, and The Netherlands.

2. Materials and methods

The site of Herstal is situated at Pré Wigier (Liège) in Belgium (Fig. 1). It was discovered during building activities in 1960–1961 and a rescue excavation was undertaken in 1965–1966. Twenty-one graves were excavated and, apart from Grave 2, all were recorded as flat tombs. In Grave 2, the cremated remains were buried in an urn possibly covered by a small mound (Alenus-Lecerf, 1974; Skinkel, 2005).

In five of the graves, two separate deposits of cremated bones were present. Graves 2, 3, and 4 contained an urn with cremated bone material (deposit A), while another bone deposit (B) was observed in an accessory vase or cup within the urn. In Graves 6 and 7, one cremated bone deposit was buried in an urn (deposit A) and the other in the pit (deposit B) surrounding the urn (Alenus-Lecerf, 1974). Another remarkable aspect of the funerary ritual in Herstal is the use of shale stone lids that cover 57% of the graves (12 out of 21). This practice was observed in only one other Belgian site from the same region, Hermalle-sous-Argenteau, situated less than 10 km from Herstal (Fig. 1). This LBA urnfield contained 158 cremations of which only 17 (ca. 11%) presented a closing slab in shale or limestone (Marchal et al., 2012).

Detailed information about the different methods used in this study can be found in Appendix A. In summary, to characterize the cremation graves of Herstal, the descriptions in the archaeological report were used together with the typological classification of De Mulder (2011; Appendix B), created to describe the cremation burials in the Scheldt valley (Alenus-Lecerf, 1974; De Mulder, 2011). For the osteoarchaeological study, all the cremation deposits were studied according to the reviewed standards as described by Maat (1997), and the British Association for Biological Anthropology and Osteoarcaheology (Mitchell and Brickley, 2017). Information on age, sex, and pathological anomalies were obtained using the various methods as described in detail in Appendix A.

All $^{87}Sr/^{86}Sr$ and [Sr] analyses were carried out at the Université Libre de Bruxelles (ULB) and the Vrije Universiteit Brussel (VUB) following Snoeck et al. (2015) for $^{87}Sr/^{86}Sr$ analyses and Sengeløv et al. (2020) for [Sr] measurements. A total of 98 calcined human bone fragments from 21 graves were used for analysis. From each cremation deposit, if available, a diaphyseal, rib, and cranial fragment was selected. Since Graves 2, 3, 4, 6, and 7 had two bone deposits (A and B), both deposits were sampled. In cremations, it is not always possible to ensure the remains are from one individual only. By carrying out $^{87}Sr/^{86}Sr$ analyses (and also radiocarbon dating) on several fragments per deposit, the presence of more individuals may be highlighted than was initially assessed using osteoarchaeological analyses alone (Veselka et al., 2021b; c). Therefore, for single cremation deposits two to five samples were selected (except for graves 13 and 19 where a limited number of suitable fragments was available), while for the graves with double deposits (A and B) between five and ten bone fragments were sampled for strontium isotope analyses. All radiocarbon dates were performed on sixteen of the same samples selected for $^{87}Sr/^{86}Sr$ analyses.

The radiocarbon dating procedure followed the KIK-IRPA protocol (Boudin et al., 2015; Van Strydonck et al, 2005, 2009; Wojcieszak et al., 2020) and is fully described in Appendix A. Sixteen fully calcined bone fragments from nine different graves (2, 4, 6, 7, 9, 10 14, 19, and 20 – not enough material was available for Grave 3) were radiocarbon dated at the Royal Institute for Cultural Heritage (KIK-IRPA, Brussels, Belgium) and were selected to cover all areas of the cemetery, as well as to better understand the double deposits (A and B). Radiocarbon dates were calibrated using the software OxCal 4.4 (Bronk Ramsey, 2009) and the IntCal20 calibration curve (Reimer et al., 2020). To calculate the beginning, the end, and the duration of the cemetery use a chronological model was constructed in OxCal 4.4 using a single-phase model with the radiocarbon dates constrained between a Start and an End boundary. The duration was calculated using the tool Difference (Bronk Ramsey, 2009). Multiple radiocarbon measurements from Graves 2, 4, 6, and 7 were statistically tested using the R_Combine tool in OxCal 4.4, which provides information on the consistency of the time series via a χ^2-test (Ward and Wilson, 1978). To pass the χ^2-test the resulting value indicated as T in OxCal 4.4 must be below the calculated 5% threshold value (p-value < 0.05), where df stands for degrees of freedom. In that case, the dates can be considered contemporary, thus potentially corresponding to the same chronological event (Lozano Medina and Capuzzo, 2020). Time differences between not contemporary radiocarbon dates were estimated using the tool Difference in OxCal 4.4.

To evaluate the relationship between grave typology and grave deposits A-B, grave goods, sex, and the presence of a lid, a Pearson's χ^2-test was performed. A Kolmogorov Smirnov test was conducted to test the relationship between grave typology divided in two categories ('urn' and 'no urn') and the total weights of the cremation deposits, disregarding the contexts with more than one osteoarchaeologically identified individual. The relationship between typology and age was assessed via a Mann-Whitney *U* test. Jonkheer-Terpstra and Kruskal Wallis tests were performed to compare total weight and age and those two variables with the presence of a lid, metal, and pit, respectively. For all tests, statistical significance was set at $p < 0.05$.

3. Results

3.1. Radiocarbon dates

The ^{14}C dates (Table 1; Fig. 2) from the Herstal cremation deposits range from the later part of the MBA to the LBA (from the end of the 12th century BCE to the end of the 9th century BCE), following the chronological framework in use for the northern part of Belgium. The OxCal modelling places the beginning of cemetery use between 1160 and 1026 BCE and abandonment of the cemetery between 893 and 780 BCE for 2σ probability. The duration of site use covers a time span between 196 and 304 years for 1σ probability (Fig. 3). More precise and accurate radiocarbon dates with narrower confidence intervals were obtained for Grave 2 (2905 ± 18 BP) and Grave 7 (2790 ± 17 BP) by performing a χ^2-test (Table 1, Fig. 2). However, for Grave 4, the χ^2-test indicated that the dates with ID 08055 and 08066 in deposit A are too far apart and do not belong to the same chronological event (T = 7.5; 5% = 3.8; df = 1), with 08055 between 64 and 185 years older than 08066 for 1σ probability. Consequently, dates from Grave 4 allowed us to identify the remains of at least two individuals that probably lived and died in different time periods. The same was observed in Grave 6 (T = 20.3; 5% = 9.5; df = 4).

Table 1
Radiocarbon dates and $^{87}Sr/^{86}Sr$ of the calcined human diaphyses from Herstal (full data in Appendix E).

CRUMBEL ID	Grave and bone deposit	Lab number	Uncal BP	Cal BCE (2σ-95.4%)	$^{87}Sr/^{86}Sr$
04230	2A	RICH-28688	2896 ± 24	1200 BCE – 1006 BCE	0.7124
04238	2B	RICH-28710	2917 ± 27	1211 BCE – 1016 BCE	0.7124
–	2	R_Combine	2905 ± 18	1196 BCE – 1013 BCE	–
08055	4A	RICH-28092	2901 ± 25	1201 BCE – 1008 BCE	0.7121
08066	4A	RICH-29015	2806 ± 24	1043 BCE – 899 BCE	0.7134
04236	6A	RICH-28697	2730 ± 26	921 BCE – 816 BCE	0.7117
08049	6A	RICH-29024	2718 ± 26	911 BCE – 811 BCE	0.7129
01035	6B	RICH-27245	2799 ± 28	1043 BCE – 842 BCE	0.7117
04231	6B	RICH-28686	2808 ± 24	1043 BCE – 901 BCE	0.7117
08016	6B	RICH-29025	2673 ± 25	900 BCE – 797 BCE	0.7131
08051	7A	RICH-28185	2773 ± 23	993 BCE – 835 BCE	0.7125
04235	7B	RICH-28696	2810 ± 25	1046 BCE – 900 BCE	0.7129
–	7	R_Combine	2790 ± 17	1008 BCE – 897 BCE	–
04239	9	RICH-28709	2770 ± 26	992 BCE – 833 BCE	0.7116
04237	10	RICH-28687	2859 ± 25	1116 BCE – 931 BCE	0.7129
01036	14	RICH-27246	2882 ± 27	1196 BCE – 936 BCE	0.7135
08088	19	RICH-29014	2754 ± 25	978 BCE – 826 BCE	0.7109
08125	20	RICH-28698	2787 ± 34	1014 BCE – 834 BCE	0.7122

Radiocarbon dates clearly demonstrated the presence of at least two individuals buried in the same grave, whereby one individual was dated to the 10th century BCE (ID 04231, 01035 – deposit B; T = 0.1; 5% = 3.8; df = 1) and the other to the 9th century BCE (08049, 04236, 08016 – deposits A & B; T = 2.8; 5% = 6; df = 2). The group of dates formed by ID 04231 and 01035 is between 62 and 150 years older (1σ probability) than 08049, 04236, and 08016 grouped together.

3.2. Typological classification

In Herstal, four types of cremation graves were identified according to the typology classification of De Mulder (2011): 1) type A: urn graves containing burnt bone material and possible grave goods (57%; 12/21); 2) type B: urn containing burnt bone and pyre remains, such as charcoal (10%; 2/21); 3) type C: the so-called "bone pack-graves", bundled burnt bone material suggestive of the use of an organic container (19%; 4/21); and 4) type G: dispersed burnt bone material within the burial pit (10%; 2/21) (typology list in Appendix C). Compared with other contemporaneous urnfields within the Meuse basin such as Hermalle-sous-Argenteau (BE), Maastricht (NL), and Brecht (BE) which is geographically just at the edge of Meuse valley but culturally related to Scheldt valley (Bracke et al., 2017; Dyselinck, 2014; Lemmers, 2011; Marchal et al., 2013, Figs. 1 and 4), more than half of the Herstal grave types had a container (i.e. grave type A or B) as was observed in Maastricht and Brecht (Bracke et al., 2017; Dyselinck, 2014), demonstrating similarities between the Meuse and Scheldt valleys where 56% of the graves are classified as type A or B (De Mulder, 2014). Grave type C, however, seems to be almost exclusively present along the Meuse river (Maastricht, Hermalle-sous-Argenteau, and Herstal), while grave type G is only reported for the Belgian sites (i.e. absent in Maastricht). In addition, the presence of a bone-potsherd mixture in Graves 5, 18, and 19 of Herstal, whereby the quantity of ceramic fragments is much higher than that of the bones in Grave 18 (80g of ceramic for 25g of bones) and Grave 19 (220g of ceramic for 10g of bones) (Alenus-Lecerf, 1974), is not found in any other site from the comparison and is not characteristic of any grave type.

3.3. Osteoarchaeological results

The total weights of the cremation deposits vary between 5 and 971 g for the graves with a MNI of 1 and from 652 to 750 g for the graves with a MNI of 2 (Appendix C). Comparing the total weights to those reported

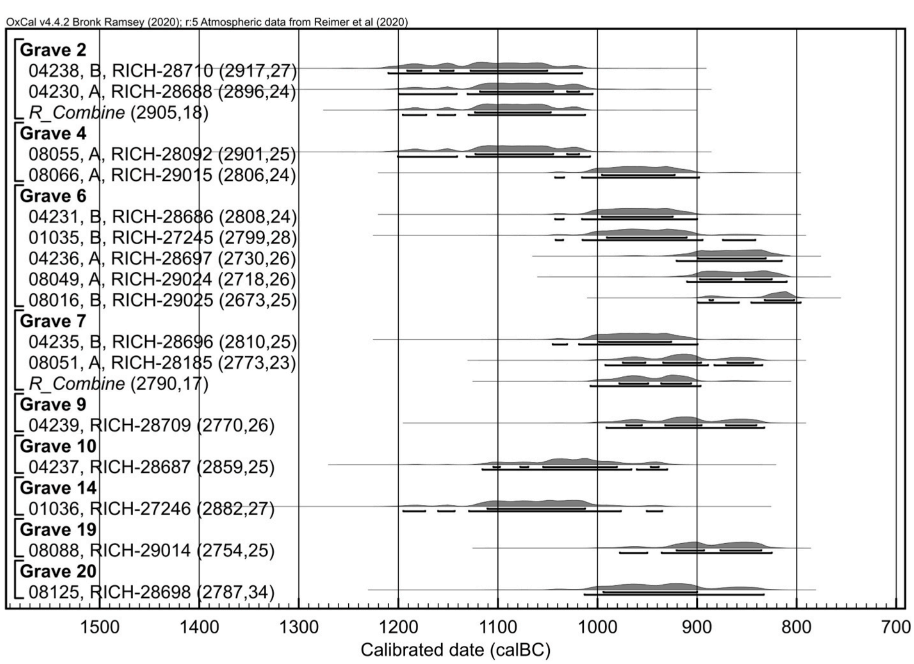

Fig. 2. Calibrated radiocarbon dates from Herstal and combined dates (*R_Combine*) from Graves 2 and 7.

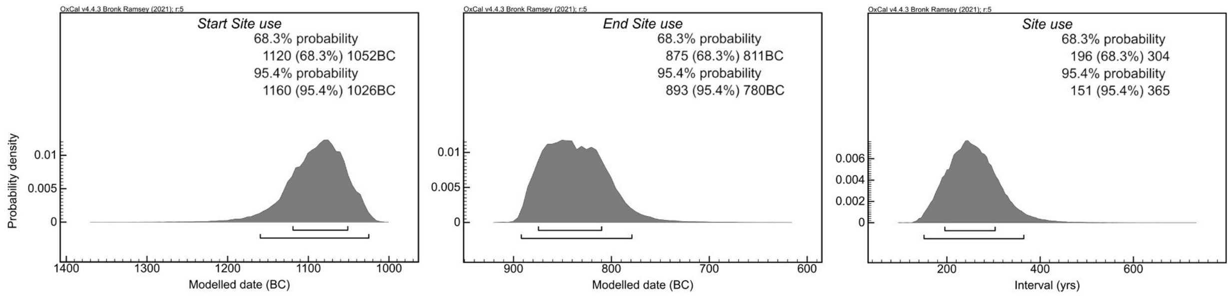

Fig. 3. OxCal boundaries estimating, from left to right, the beginning of the cemetery use, its abandonment, and the duration of the site use.

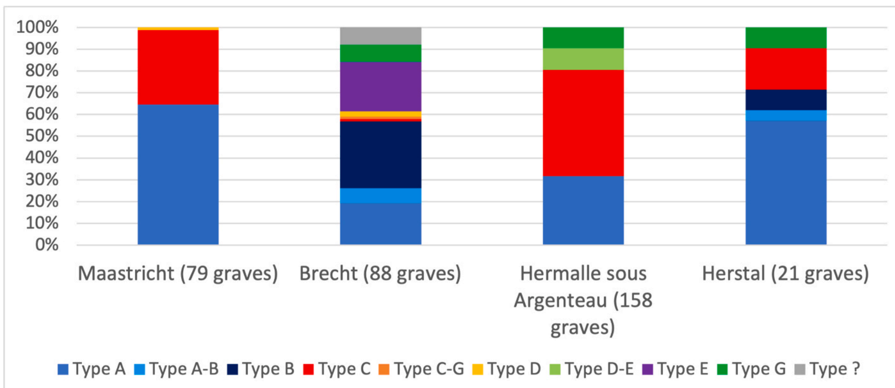

Fig. 4. Sites of the Meuse valley by grave typology.

for a modern human adult skeleton, between 1220 g and 1945 g, (Gonçalves et al., 2013; Jantz and Bass, 2004; McKinley, 1993), it is postulated that not all the cremated bone material from each individual was deposited in the tombs. The macroscopically assessed combustion degree varies between stages IV and V (Wahl, 2008), whereby the majority of cremations (18/21) contained almost exclusively fully calcined bones, suggesting that the pyre temperature was at least 650 °C for a sufficient amount of time (Snoeck et al., 2014b; Van Strydonck et al., 2005). Seven out of 21 graves (33%) contained burnt animal bones, with Grave 9, the most well-furnished of the cemetery (Warmenbol, 1988b), containing the most (26g). Nineteen graves had a minimum number of individuals (MNI) of one. Graves 3 and 6 contained the remains of at least two individuals, based on the morphological difference of two humeral heads (Grave 3), the presence of two right petrous parts, and observed age differences in the teeth (Grave 6). The presence of at least two individuals in Grave 4 determined by the radiocarbon results was not observed osteoarchaeologically.

From the 23 individuals identified osteoarchaeologically, 11 individuals are estimated to be nonadult, eight adult, and four 'Indeterminate' (Appendix C). All age categories are represented, except for the neonate category. Sex estimation was possible in three out of eight adults (37%). The remains from Graves 4 and 12 are estimated to be male, while Grave 9 contains the remains of a female. The sex of the other adult individuals could not be determined. The differences in the total weight of cremation deposits with adult remains vs. nonadult remains were statistically significant ($U = 8.000$, $p = 0.01$), whereby nonadult remains weigh less than adult remains. The difference in typology between adults and nonadults is not statistically significant but the presence of an urn (vs. no urn) is ($D (13) = 0.243$, $p = 0.03$). No statistically significant difference between grave typology and any of the other variables was observed, which suggests a similar treatment of adult and nonadult individuals (Appendix D).

3.4. *Strontium isotope ratios ($^{87}Sr/^{86}Sr$) and concentrations ([Sr])*

The $^{87}Sr/^{86}Sr$ range from 0.7109 to 0.7138, with a mean value of 0.7123 ± 0.0006 (1SD – Fig. 6; Appendix E). Cranial fragments have $^{87}Sr/^{86}Sr$ between 0.7115 and 0.7138, diaphyses between 0.7109 and 0.7137, and ribs show $^{87}Sr/^{86}Sr$ between 0.7116 and 0.7137. [Sr] vary between 78 and 147 ppm. In 81% of the cases (17/21), the differences in $^{87}Sr/^{86}Sr$ between cranial, diaphyseal, and rib fragments are relatively small (<0.0010).

To contextualise the $^{87}Sr/^{86}Sr$, a local map of the biologically available strontium (BASr) was used (Fig. 5; Veselka et al., 2021c). The geology in that area is quite complex and a total of 26 plant samples from nine distinct locations in the Netherlands and Belgium were collected following the procedure detailed in Snoeck et al. (2020) (see Veselka et al., 2021c, for more details). The plant samples have $^{87}Sr/^{86}Sr$ ranging from 0.7088 to 0.7141. The BASr around Herstal is represented by the green and blue areas ($^{87}Sr/^{86}Sr$ ranging from 0.7090 to 0.7110). Only one individual, Grave 19, has an $^{87}Sr/^{86}Sr$ that falls within that range. The $^{87}Sr/^{86}Sr$ of the majority of the samples (85/98; 86%) correspond to the $^{87}Sr/^{86}Sr$ of the yellow and orange areas of the local BASr map, which are respectively located > 40 km and 5–10 km from the site (Figs. 5 and 6). The rest of the samples have $^{87}Sr/^{86}Sr$ consistent with the red areas (~15 km away from the site). This BASr map only uses 3 sampling spots of plants in the proximity of Herstal, further analysis and sampling of the other geologies in this complex area will allow to strengthen the results and interpretations.

4. Discussion

Following a review of the ceramics and the bronze grave goods, the consensus was that the site of Herstal was mostly in use from 1300 to 1100 BCE, and potentially up to 900–800 BCE (Lecarme and Warmenbol, 2014; Leclercq, 2014b). Sixteen OxCal-modelled new radiocarbon dates, however, show that Herstal cemetery was mostly in use for ca. 2–3

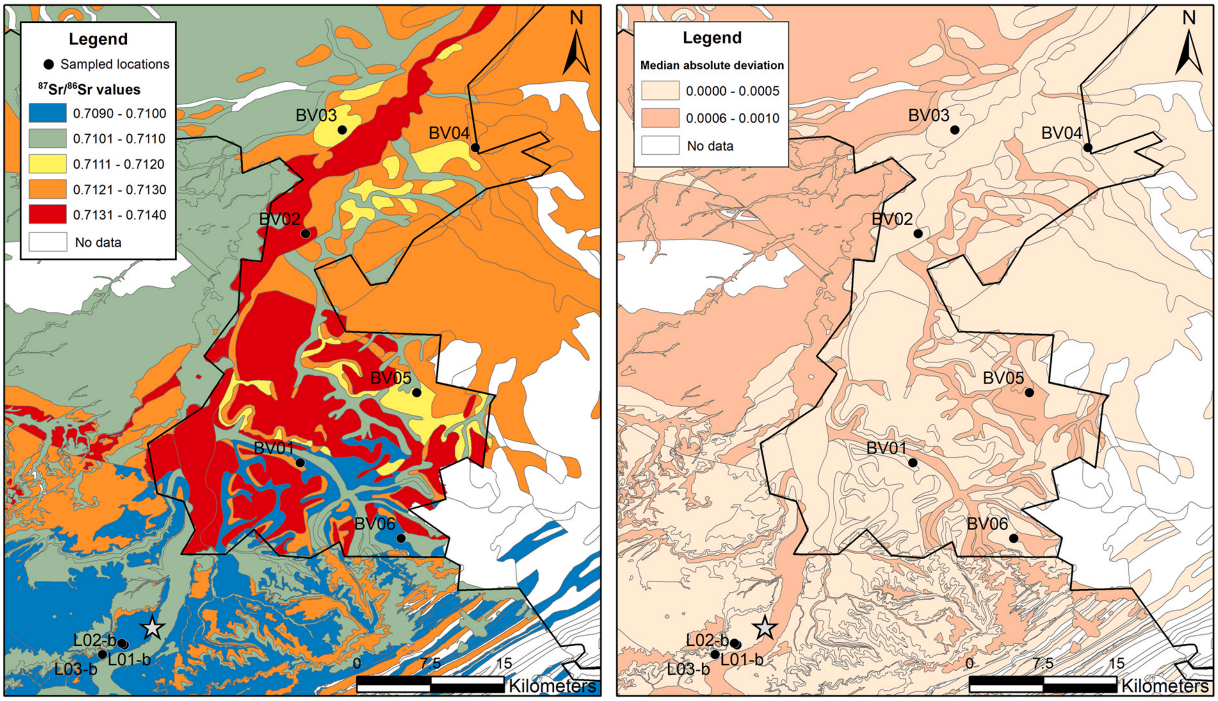

Fig. 5. Location of Herstal (grey star) and plant sampling points (black circles) with information on the biologically available strontium (left) median value; (right) median absolute deviation (MAD), Veselka et al., (2021c)

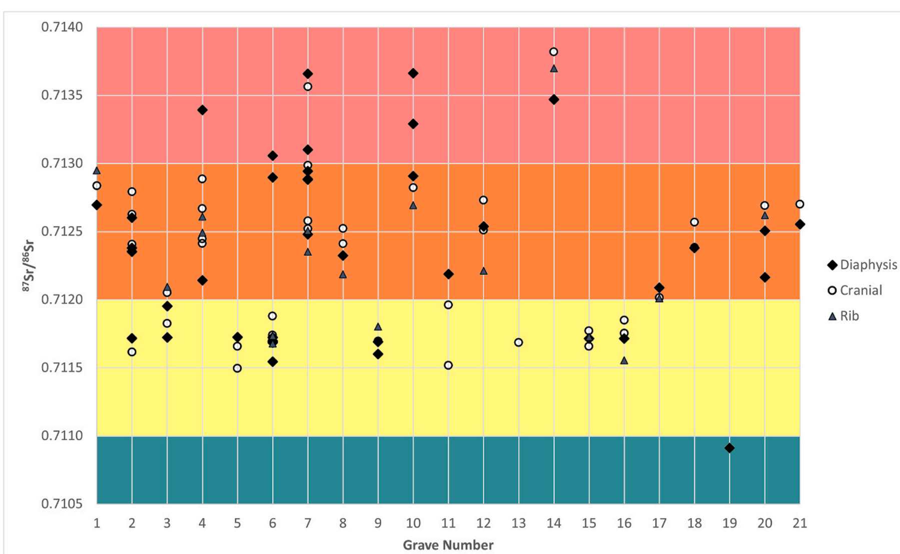

Fig. 6. $^{87}Sr/^{86}Sr$ from the Herstal individuals where the colours correspond to the plant $^{87}Sr/^{86}Sr$ from each area. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

centuries between the time spans 1160–1026 BCE and 893–780 BCE for 2σ probability, slightly later than initially assumed, covering the Late Bronze Age to the EIA transition. Nevertheless, it has to be noted that Grave 20 contains a Schräghals-type pottery dated to 800–600 BCE, which could extend the use of the site to the EIA. Radiocarbon results on this type of pottery at the cemetery of Destelbergen confirmed the EIA attribution (De Mulder and Deweirdt 2012). Therefore, we could either infer a possible old-wood effect for the date RICH-28698 obtained on Grave 20 or, since the date is in agreement with the others, suggest that the bones of this individual were likely curated for a certain period following death and buried in a more recent urn".

The typological classification of Herstal presenting a majority of graves with a container supports clear links with the Scheldt Valley, but also shows regional and local variations, whereby 'regional' is referring to the Meuse Valley and 'local' refers to the area of and directly surrounding Herstal (diameter of ca. 10 km). Grave types C, present along the Meuse, and G, only observed in Belgium so far, may indicate a Meuse regional variation (Fig. 4). The use of shale stone lids, only recorded in Herstal and Hermalle-sous-Argenteau (located 10 km from each other), and the unique appearance of a bone-potsherd mixture in Herstal could even indicate a local tradition in the Herstal/Hermalle-sous-Argenteau area. The use of different materials as lids for the urn (e.g. stones, plates or textiles) were, however, observed in France, Spain, and in some Flemish sites (De Mulder, 2011; Froquet-Uzel, 2015; Roger and Pons, 2005). The use of those lids may have been related to different social status, different beliefs and customs but, since there is no statistical significance with any other variable in the site (Appendix D), more research is needed to assess the potential presence and influence of regional and local traditions in the Meuse Valley and in the area of Herstal and Hermalle-sous-Argenteau.

Another argument for such regional/local tradition can be found in the osteoarchaeological results where a large proportion of nonadults was observed (44%; 11/23) and the similarity in funerary rituals for adults and nonadults was highlighted. The minor variations in combustion degree and lack of statistically significant differences between adult and nonadult burials (except in terms of presence of container and total weight) suggest indeed that the nonadults received a similar burial ritual as the adults. The similarity of funerary treatment between adults and nonadults can also be observed in Bronze Age cemeteries in Ireland, Scotland, Scandinavia, and in the southern Carpathian Basin (Donnabháin and Brindley, 1990; Kamp, 2001; Ložnjak Dizdar and Rajić Šikanjić, 2020; Small et al., 1988; Welinder, 1998). However, the large number of nonadults at Herstal seems somewhat unique. In the Bronze Age populations from Scandinavia, only 20–30% of the individuals were nonadults (Welinder, 1998), whereas, on average, nonadults make up 35% of the cremated individuals in the Scheldt valley sites, except for Lemberge (East Flanders) where 50% (3/6) of the remains belonged to nonadult individuals (Beke et al., 2018; De Mulder, 2011). Clearly, only one of the Bronze Age sites in the Scheldt Valley and none of the Meuse ones, neither at Brecht (at least 27% - 15/41 identified clearly) nor Maastricht (at least 31% - 8/26 identified clearly), yielded such high percentages of nonadult remains. Other factors (e.g. partial excavation of the site, different burial rituals, fragility, and small size of the non-adult bones) may have influenced the retrieval of nonadult remains in other sites. More research on the link between age and sociocultural status is needed to better understand the role nonadults played in past Bronze Age societies and the timing of their transitions into maturity and/or adulthood. Indeed, the relationship between age, burial ritual, and grave goods is still poorly understood (e.g. are grave goods reflecting the sociocultural position the nonadult had achieved or, alternatively, would have achieved) (Kamp, 2001; Rebay-Salisbury and Pany-Kucera, 2020). The relatively high number of nonadults found at Herstal, therefore, may provide information on the sociocultural and economic status of nonadults in LBA societies and at the site in particular.

^{87}Sr/^{86}Sr can further be used to understand the local or regional importance of this cemetery. The ^{87}Sr/^{86}Sr of the human remains from Herstal cemetery are, all but one, higher than the ^{87}Sr/^{86}Sr of the modern plants growing near the site, but similar to those observed in plants growing just across the Dutch border (Figs. 5 and 6; Veselka et al., 2021c). The green, red, and orange areas (Fig. 5) could be considered as local, being located less than 15 km from Herstal. Yellow areas, however, are located much further away (>40 km). Still, ^{87}Sr/^{86}Sr measured in human remains that are consistent with the BASr of the yellow areas could, in fact, represent a mixture of resources originating from the blue, green, orange, and red areas. Considering the possible mixture of resources and due to the extremely high geological variability (and hence the very high BASr variability), no "non-locals" could be identified. However, it does not mean no individual could have come from further away. This idea is reinforced by RSFO/Atlantic ceramics found on the site. Those objects were probably either copied or produced locally and not imported. Nevertheless, the large spread in ^{87}Sr/^{86}Sr (0.7109–0.7138) seen in the calcined human remains of the same deposit and between deposits, it is more likely to suggest the cemetery was used by a regional population exploiting different parts of the landscape rather than large-scale mobility. In fact, the only individual that slightly stands out (though not statistically significantly) could be the one buried in Grave 19 (^{87}Sr/^{86}Sr = 0.7109). Interestingly, this individual is the only one that would traditionally have been considered as "local" as its ^{87}Sr/^{86}Sr is consistent with the BASr of the direct vicinity of the site (green area – Fig. 5). This shows, once again, the importance of characterizing the BASr of the studied area(s) and of analysing multiple cremated bone fragments per deposit (although this was not possible for graves 13 and 19 due to limited amount of suitable material available).

In Graves 2, 4, 6, and 7, the ^{87}Sr/^{86}Sr differences are larger and range from 0.0011 to 0.0016 (Fig. 7). Those differences could indicate mobility, the presence of multiple individuals in the grave and/or individuals that consumed foods from different geological areas with different ^{87}Sr/^{86}Sr signatures at different stages in their lives. The intra-grave difference is not always related to context A and B as can be seen in Fig. 7. For example, both contexts (A and B) of grave six contain bone fragments with low (between 0.7115 and 0.7120) and high ^{87}Sr/^{86}Sr (>0.7128). What we are trying to point out here, is that each time we see large differences between the different bone fragments analysed for the same grave, that grave had two deposits. Turnover will definitely impact this picture as different bones represent different life stages, but it is quite unclear for now how much. Further research is currently underway to better address this issue. Still, by analysing different bone fragments (cranial, ribs, diaphysis) from the same grave, we have a chance to assess this variability and, as shown in this paper, highlight the potential presence of different individuals.

Indeed, comparing ^{87}Sr/^{86}Sr from different bone fragments within the same grave provides additional information and further aids in determining the MNI. In Grave 4, the two radiocarbon dates (samples 08066 and 08055) together with the difference in ^{87}Sr/^{86}Sr (0.0013; Table 1; Fig. 8) indicate that the remains of at least two individuals were present in the urn, which was not observed osteoarchaeologically. In Grave 6, two deposits were present: one inside the urn (A), the second outside the urn (B), in the burial pit. Two nonadults were identified osteoarchaeologically based on the presence of two right petrous parts, and via the radiocarbon dates (Table 1). The diaphyseal samples from A (08049, 04236) and B (08016) are contemporary, while two samples from deposit B (01035 and 04231) are between 62 and 150 years older (1σ probability). Adding ^{87}Sr/^{86}Sr to the picture allows highlighting the presence of the remains of not only two, but possible three individuals in Grave 6. Both older samples as well as 04236 and all the non-dated ribs and cranial fragments have values between 0.7115 and 0.7119. However, the three radiocarbon-dated younger samples show a large difference in ^{87}Sr/^{86}Sr (>0.0012) with two samples having ^{87}Sr/^{86}Sr of 0.7129 and 0.7131, while the third one presents a lower value (0.7117) similar to that of all the other samples measured from Grave 6 (Fig. 8). Such large difference in ^{87}Sr/^{86}Sr between two diaphyses is unlikely to represent different times in an individual's life, but rather two distinct individuals. Nevertheless, more work to understand Sr turnover in human bones in needed. Considering the osteoarchaeologically identified, isotopic, and radiocarbon data together, it is likely to suggest that (part of) the remains of a third individual was present in deposits A and/or B.

The presence of the remains of individuals with significantly distinct radiocarbon dates needs to be investigated further. The inclusion of the remains of multiple individuals in the same cremation deposit in Herstal may have resulted from several factors, such as behavioral choices, simultaneous cremation events and/or using the same pyre site multiple times, whereby cremated remains from several ceremonies accumulated (un)intentionally (Booth and Brück, 2020). The excavation reports did not observe any old or more recent intrusions of Grave 6, suggesting that both deposits (A and B) were buried at the same time (Alenus-Lecerf, 1974).

The inclusion of (part of) the remains of a third individual in deposit A and/or B may have resulted from the (un)intentional accumulation of bone fragments in the pyre site, whereby some of them were included in the cremation deposit. No pyres sites have been discovered at Herstal or other urnfield cemeteries due to their position on the old surface and the impact of later erosion. In some cases, the difference in radiocarbon dates could be explained by the old-wood effect. However, this seems very unlikely for Herstal. Research on the choice of wood used as fuel in

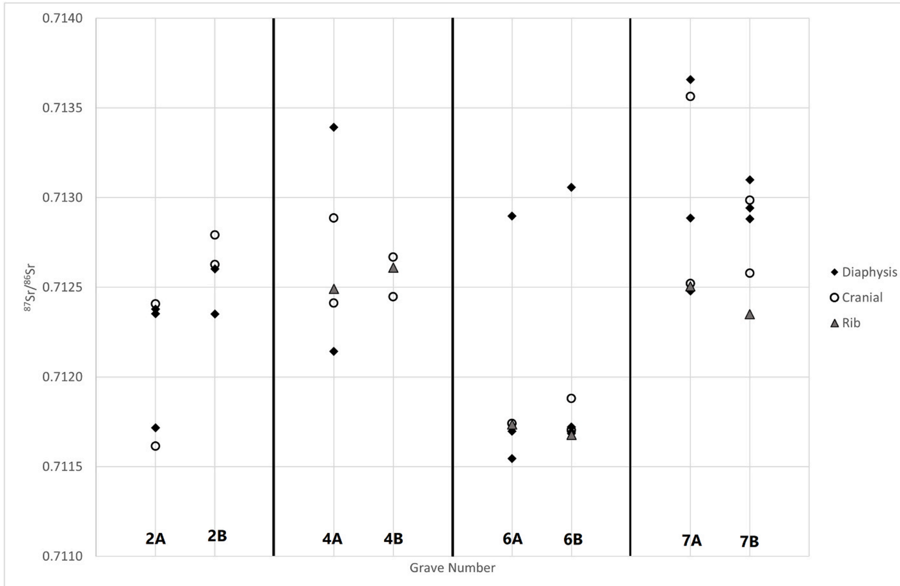

Fig. 7. $^{87}Sr/^{86}Sr$ from the graves with deposits A and B (grave 2, 4, 6, and 7) that showed large $^{87}Sr/^{86}Sr$ differences between the various skeletal elements.

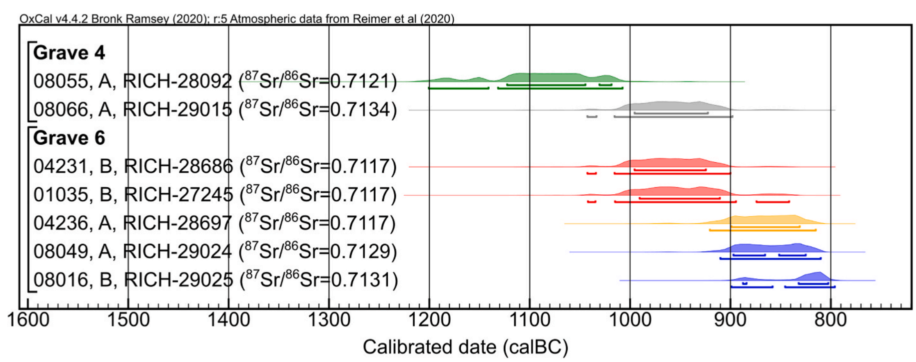

Fig. 8. Calibrated radiocarbon dates with $^{87}Sr/^{86}Sr$ isotope ratios from Graves 4 and 6 at Herstal. Each colour corresponds to a different individual (MNI = 5). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Bronze Age pyres in northern Europe indicated a selection of mixed timbers based on their availability around the site (Moskal-del Hoyo, 2012; O'Donnell, 2016). Therefore, the old-wood effect, if present, would have heterogeneously affected the cremated individuals and the difference in ^{14}C content of the cremated bone would be more statistically significantly dispersed (Snoeck et al., 2014a; Rose et al., 2020). Rather, other factors influencing the number of individuals within a cremation deposit, such as reusing of the grave or the pyre, or curation of the bones may have been at play.

Indeed, another hypothesis is that (part of) the remains of a deceased individual were kept and stored to be buried much later together with another individual. This practice has already been observed in several Bronze Age and Iron Age sites in Britain (Booth and Brück, 2020). This could be the case for Grave 4, since both deposits, A and B, were present in the urn. Again, traces of the reopening of the grave are lacking further supporting the idea that the individuals were buried at the same time and that a part of the remains may have been kept by family, kin, and/or friends until it was time to bury them together with the other individuals (Rebay-Salisbury, 2010). This implies that the remains must have been kept for a few decades and it is postulated the deceased would have been part of groups of individuals that had a defined relationship with them. If indeed this was the case, Graves 4 and 6 may have had a familial significance (Booth and Brück, 2020; Rebay-Salisbury, 2018).

For Graves 2 and 7 (Table 1; Figs. 2 and 7), while radiocarbon dates and osteoarchaeological analyses suggest the presence of only one individual in each grave, the various diaphyses show relatively large differences in $^{87}Sr/^{86}Sr$ (up to 0.0009 and 0.0012 respectively), which seems to indicate the remains of at least two individuals. Cranial fragments from Graves 2 and 7 also show large differences of 0.0012 and 0.0011 respectively, further supporting the fact that two individuals could have been buried together in those graves. The large intra-grave differences in $^{87}Sr/^{86}Sr$ could aid in determining the MNI, as was suggested by Veselka et al., (2021b), but other lines of evidence, such as osteoarchaeology or ^{14}C, are needed to confirm the presence of more than one individual, especially in such a geologically diverse area. The combination of osteoarchaeology, radiocarbon dating, and $^{87}Sr/^{86}Sr$ may permit to redefine the MNI in Graves 2, 3, 4, 6 and 7 which, interestingly, are the five graves with two deposits (A and B). However, a cut-off point (chosen to be 0.0010 in this study) is difficult to establish, as was also shown in Veselka et al., (2021c), where large intra-individual differences may have existed due to differences in bone turnover rates and localised mobility, and the large intra-grave differences in $^{87}Sr/^{86}Sr$ were not necessarily indicative of multiple individuals but rather of changes in food sources in a complex geological context. Indeed, in Grave 10 (single deposit) the difference in $^{87}Sr/^{86}Sr$ is as high as 0.0009 (close to the cut-off point of 0.0010 chosen in this study), which could also suggest the presence of potentially two individuals, but more information is needed on how turnover rates affect the strontium isotope ratios of different bones before being able to refine this interpretation.

Grave 6 is not only remarkable by the (potentially unintentional) presence of three nonadults in a single grave as opposed to other Bronze Age cemeteries in central Europe where commonly the nonadult is buried together with at least one adult (Rebay-Salisbury, 2018; Tankó and Tankó, 2012), but also by its 'rich' grave goods, which include a cup, an ovoid urn, a winding spiral, some buttons and rings, a rod, and a bracelet fragment (Alenus-Lecerf, 1974). Generally, the number and type of grave goods may provide information on the sociocultural status of the nonadults (Kamp, 2001; Rebay-Salisbury, 2018; Rebay-Salisbury and Pany-Kucera, 2020). When comparing the grave goods from Grave 6 to those of the most well-furnished grave of Herstal, Grave 9, several similarities were observed. Both graves contained a winding spiral, rings, and bracelet fragments and in both cases, the bronze objects were burned. Grave 9 contained the remains of an adult female, while in Grave 6, one of the nonadults was aged 7–12 years of age (the other one was only 0–6 years). It is possible that those similarities may imply that the 7-12-year-old was already considered to have an adult status at this age or that the family of the nonadult enjoyed a relatively high sociocultural status resulting in a more prominent status of the nonadult (Ložnjak Dizdar and Rajić Šikanjić, 2020).

The cemetery of Herstal, therefore, appears to present differences in grave typology, such as the shale stone lids and potsherds-bones mixture, double/multiple individuals in the same grave, a relatively large number of nonadult individuals, a large range of regional $^{87}Sr/^{86}Sr$, and a cremation deposit where multiple nonadults were buried together. All this suggest Herstal was a regional cemetery, sharing typological similarities with other sites from the Meuse valley, but with local traditions used by local individuals of which a number of them had a higher sociocultural status and used different food supplies. At Herstal, the notion of a higher sociocultural class is supported by the presence of metal objects, which is often rare in LBA cemeteries (e.g. Rekem, Maastricht and Weert) and by the presence of 'foreign' ceramics that were probably copied and produced locally. The cemetery of Herstal suggests a movement of objects or an imitation of certain practices/traditions instead of the movement of individuals and seems to reflect the ideology in which the emphasis lies on the collectivity of the group as the constituent element such as it is the case in the Lower Rhine region in Germany and the Netherlands (Roymans and Kortlang, 1999). More research, however, is needed in the Meuse valley to confirm this and to see if Herstal is a unique case or if several sites from that area belong to a similar local/regional group of indviduals with similar local/regional traditions.

Our multi-faceted approach enabled observing a possibly regional and local burial tradition, the potential presence of familial ties, and the influence of local and foreign styles related to grave type and goods in the cemetery of Herstal. Our research has clearly shown that revisiting older cremation deposits by applying novel techniques improves our understanding of regional population dynamics and funerary practices in the past and contributed to the research of LBA-EIA populations in the Meuse Valley.

5. Conclusions

Our study has clearly demonstrated that a multi-proxy approach yields new insights in the development of the social organization of the Herstal cemetery. This society seems to have had a divergent tradition regarding burial practices and/or rituals compared to other contemporaneous cemeteries from the Scheldt and Meuse Valleys. Our results revealed differences in grave typology, presence of double or even triple cremation burials, a large number of nonadults and the somewhat unique presence of multiple nonadults being buried together in an urn. Furthermore, the possible container reuse (e.g. an urn) and potentially keeping and storing cremated individuals for a longer period of time above ground, as shown by combining osteoarchaeological, isotopic, and radiocarbon data, may indicate familial relationships in the cemetery of Herstal, that may have spanned across several decades. This new data could markedly enhance our knowledge of the social organization of LBA societies in the Belgian part of the Meuse Valley.

Although large variability exists in $^{87}Sr/^{86}Sr$, the individuals from Herstal are proposed to have lived in or close to Herstal, consuming foods that originate from areas nearby or surrounding the cemetery, which are characterised by a complex geology. This study also showed the importance of characterising the BASr of the studied region and, in the case of cremation deposits, the need to take multiple samples per deposits, for both radiocarbon dating and strontium isotope analyses. Further research in that area is needed and will provide more information about the regional tradition of the Meuse valley to increase our knowledge about that territory, its populations, and different influences.

Declaration of competing interest

None.

Acknowledgments

This work was supported by the FWO and the F.R.S.-FNRS under EOS 30999782 project – CRUMBEL. AS thanks F.R.S.-FNRS for her doctoral fellowship, ES and MH thank FWO for their doctoral fellowships. CS thanks F.R.S.-FNRS for his post-doctoral fellowship. VD thanks the F.R.S-F.N.R.S. for funding. We wish to thank the Herstal municipal museum for the loan of the bones and the access to the site bibliography. Wendy Debouge and Jeroen de Jong from the Laboratoire G-Time (Geochemistry: Tracing by Isotope, Mineral, and Element), Université Libre de Bruxelles (Belgium) are acknowledged for their help with the strontium isotope analyses by MC-ICPMS. Philippe Claeys, Steven Goderis and Martine Leermakers from the Vrije Universiteit Brussel (VUB – Belgium) are thanked for their help with the strontium concentrations measurements by ICP-MS.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jas.2021.105437.

Funding

The FWO/F.R.S.-FNRS - EoS project CRUMBEL (30999782).

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