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BREAKING TRADITIONS: AN ISOTOPIC STUDY ON THE CHANGING FUNERARY PRACTICES IN THE DUTCH IRON AGE (800–12 BC)*

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Urnfields in the Dutch river area were replaced by cemeteries with a mixture of cremation and inhumation graves around the sixth century BC. *This study provides the first biogeochemical evidence that the Iron Age communities were heterogeneous in terms of geological origins. The high percentage of non-locally born individuals (~48%) supports the hypothesis that the change in burial practice was the result of the influx of foreign people, who were being allowed to keep their own burial customs, whereas some of the local inhabitants adapted the burial rites of foreign cultures, leading to a heterogeneous burial rite for some centuries.*

KEYWORDS: PALAEOMOBILITY, STRONTIUM ISOTOPE ANALYSIS, BURIAL RITE, IRON AGE, THE NETHERLANDS

INTRODUCTION

The practice of cremation was the predominant form of disposal of the dead from the Dutch Late Bronze Age (1100 BC) until the late Roman period (AD 270). The archaeological analysis of prehistoric urnfields, summarized by Hessing and Kooi (2005), and the growing number of physical anthropological investigations of cremated human remains provide in-depth knowledge about prehistoric cremation rites in the Netherlands. After 500 BC, a shift in burial ritual took place, resulting in the replacement of large collective urnfields by dispersed clusters of cremation graves, probably connected to single families (Fontijn 1996; Gerritsen 2003).

Several hypotheses have been proposed to explain this change, focusing, for instance, on the supposed demographic decline at the end of the Early Iron Age and changes in regional habitation patterns. Both theories stem from the easing of the pressure on agricultural land and the subsequent loss of function of urnfields as territorial markers (Roymans 1991; Roymans and Kortlang 1999; Gerritsen 2003). Others argue that ideological and social transformations induced the change in burial ritual (Fontijn 1996; Hessing and Kooi 2005). Gerritsen (2003) has already suggested the possibility of a direct relationship between the change in the use of urnfields and wider social and economic developments.

Moreover, a deviation of the standard rite had developed, especially in the river area of the central Netherlands. Here, at least from the sixth century BC onwards, a considerable proportion

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of the deceased were inhumed, not cremated (van den Broeke and Hessing, 2005; van den Broeke, 2014). All these changes may, for instance, be related to the introduction of foreign cultures: external contacts, such as exchange networks, alliances, clientship relations and group migration, may therefore have been integrated with the changes in burial rite in the Dutch Iron Age from about the sixth century onwards (Gerritsen 2003; Roymans 2004).

The application of strontium isotopes in archaeological mobility studies has matured over the past three decades. Archaeological human and animal keratin, bone, dentine and enamel have been subject to strontium isotope analyses to study migration, specifically at the individual level (Bentley 2006 and references therein). Dental enamel is the preferred material for analysis because of its resistance to diagenetic alteration (Budd *et al*. 2000). Unfortunately, the enamel crowns of erupted dental elements easily break down when exposed to intense heat (Schmidt 2008). As a result, dental enamel rarely survives the process of cremation. This fact therefore precludes the use of strontium isotopes to investigate ancient palaeomobility patterns for the thousands of cremated inhabitants of late prehistoric times in the Netherlands, although recent publications suggest that calcined bone may deliver reliable biogenic strontium isotope data in the future (Harvig *et al*. 2014; Snoeck *et al*. 2015).

Until about 20 years ago, incidental Iron Age inhumations had only been found in the western and northern coastal areas in the Netherlands, usually in settlement contexts (e.g., van Trierum, 1992; Hessing 1993; van den Broeke and Hessing, 2005). More recent archaeological excavations in the river area, however, have revealed several Iron Age cemeteries amounting to more than 40 individuals in total (van den Broeke and Hessing, 2005; van den Broeke, 2014). Consistent with burial customs in that period, most inhumation graves lack grave goods. A few, however, do contain grave furnishings that resemble grave rituals from both the German Middle Rhine area (van den Broeke and Hessing, 2005; van den Broeke, 2014) and the French Marne–Aisne area (La Tène: Hulst 1999; Roymans 2009; van den Broeke 2014). This study presents the first isotopic evidence that migration may have played an important role in the change of the local Iron Age burial rituals in the Dutch river area.

STRONTIUM ISOTOPES IN ARCHAEOLOGY

Isotopes of different elements have commonly been used to explore the extent of human mobility in Iron Age Europe (e.g., Jay *et al*. 2007, 2013; Scheeres *et al*. 2013; Wilhelmson and Ahlström 2015), animal trade or exchange (Minniti *et al*. 2014), the provenance of textiles (Frei *et al*. 2009, but see von Holstein *et al*. 2015) and iron objects (Brauns *et al*. 2013). Except for the latter material group, studies apply $^{87}Sr/^{86}Sr$ to infer information about provenance. The radiogenic strontium isotope ^{87}Sr is derived from the radioactive decay of ^{87}Rb (Steiger and Jäger 1977). Spatial variations in the initial amount of ^{87}Rb in geological bedrock in combination with the different age of the lithology result in the geographical variation of ^{87}Sr (e.g., Capo *et al*. 1998). Consequently, the ratio $^{87}Sr/^{86}Sr$ acts as a geological signature and can help assign the provenance of people and animals to specific geological sources (e.g., Bentley 2006; Hobson *et al*. 2010; Bataille and Bowen 2012).

Strontium passes from the geological bedrock to soil through weathering. Subsequently, the strontium is taken up from the soil by vegetation (for controlling factors, see Isermann 1981; Dijkstra *et al*. 2003) and released into our food chain (Miller *et al*. 1993; Capo *et al*. 1998; Price *et al*. 2002; Bentley 2006). Although animals excrete most ingested strontium via the kidneys and bile, a small proportion (the net retention is essentially zero: $\leq 1\%$ of the intake) is retained in the body and incorporated in the structure of hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$), which is the main component of bone and dental enamel (for references, see Nielson 1986). In contrast to bone, the resistance of dental enamel to diagenetic alteration makes it the preferred material for strontium isotope investigations. Moreover, enamel undergoes hardly any change after mineralization due to the loss of the enamel-forming cells (ameloblasts) after eruption (Jussila *et al*. 2013). Hence, different dental elements isotopically reflect different periods in life as the mineralization age varies between dental elements, ranging from the perinatal period (first molars, M1) to approximately 16 years of age (third molars, M3) in permanent dentition (Nelson and Ash 2010). Strontium isotope analyses of dental elements therefore provides information on childhood geological provenance.

Isotope geochemistry has proven to be particularly useful for the identification of non-locally born individuals and aids in gathering vital information about the role migration had in observed cultural changes or adaptations. A prerequisite for the correct interpretation of the strontium isotope data is the generation of regional or national isotopic databases to enable a precise definition of the local strontium isotope signature. To date, these databases are available for certain countries and regions in Europe (e.g., Evans *et al*. 2009, 2010; Frei and Frei 2011; Willmes *et al*. 2014; Kootker *et al*. 2016b), but much work still needs to be done to map (prehistoric) Europe, enable a more quantitative interpretation of the data and assess the feasibility of strontium isotopes for provenancing archaeological human and faunal remains. Consequently, strontium isotope analysis is mainly a method to identify individuals alien to the investigated region, rather than to assign a possible geological provenance (Montgomery 2010). In certain cases, overlapping $^{87}Sr/^{86}Sr$ ratios between geographically different regions will hamper a correct interpretation of the data (e.g., Maurer *et al*. 2012; Kootker *et al*. 2016b). As a result, an $^{87}Sr/^{86}Sr$ ratio compatible with the expected local signature may lead to an incorrect interpretation as a locally born individual, particularly if only one isotopic proxy is employed in the study. In addition, geologically diverse regions that exhibit wide ranges of $^{87}Sr/^{86}Sr$ ratios will obscure possible migrants. Both these limitations of the method may result in the underestimation of the identified number of non-local individuals; however, this outcome is preferable to the overestimation of migrants, as the interpretative consequences may be less severe (Laffoon 2012).

THE ARCHAEOLOGICAL SETTING

The samples analysed in this study represent 34 human and faunal individuals from nine archaeological sites at seven different locations in the Dutch central river area; Geldermalsen, Meteren, Tiel, Beuningen, Oosterhout, Ressen and Lent (Fig. 1). In late prehistoric times, the central and southern Netherlands, the former of which includes the above-mentioned sites, were part of the same cultural sphere, originally termed Niederrheinische Grabhügelkultur (Kersten 1948). Despite a common cultural background, the central and southern Iron Age populations followed their own burial customs. Amongst thousands of cremation graves, only two Iron Age inhumation burials have been found in the Dutch southern aeolian sand district (Kortlang 1999; Jansen *et al*. 2011). In contrast, it can be postulated that between 800 and 350 BC, each urnfield in the Dutch central river area includes one or several inhumation burials. Here, favourable preservation conditions for organic remains such as bone are found in this area. Consequently, in the southern part of the Netherlands, where the sandy soils are acidic, it could be speculated that many inhumation burials (without grave goods) are unobservable due to poor preservation conditions. Consequently, inhumation may have been a more common burial rite during the Dutch Iron Age than has hitherto been assumed (Gerritsen 2003).

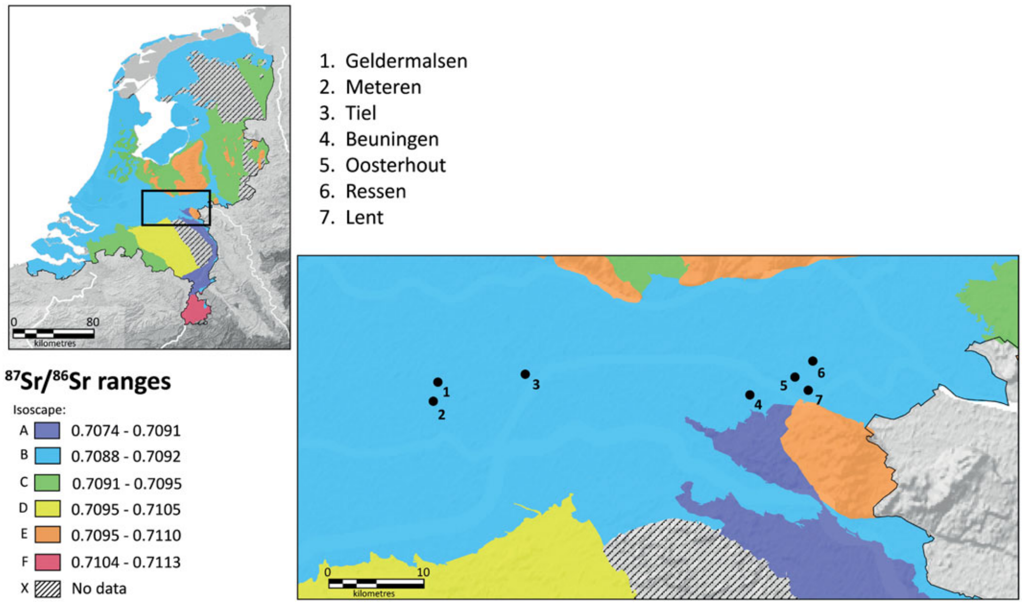

Figure 1 *A detailed section of the Dutch river area in the $^{87}Sr/^{86}Sr$ isoscape map of the Netherlands, with the sites mentioned in the text (Kootker et al. 2016b). [Colour figure can be viewed at wileyonlinelibrary.com]*

The Middle Iron Age cemetery in Geldermalsen-Middengebied, excavated in 1992, was the first to be discovered in the Netherlands that contained inhumations (Hulst 1999). Together with 16 cremation burials, the skeletal remains of seven individuals were excavated, spatially separated from the cremation pits. In 1999, in Meteren - De Bogen, a barrow was found that had been used from Late Neolithic times onwards. The skeletal remains of five individuals were recovered: two of which were dated to the Middle Iron Age (Meijlink 2001). Another Middle Iron Age skeleton was unearthed alongside 47 cremation graves in the cemetery of Meteren - De Plantage in 2009 (Jezeer and Verniers 2012), bringing the final number of Iron Age buried individuals in the Geldermalsen region to 10.

During the 1990s, archaeological field campaigns unearthed dozens of new settlements and cemeteries in Lent, Oosterhout and Ressen. These sites are located directly north of Nijmegen and within 5 km of each other. Next to 30 cremation burials, 23 inhumation burials were uncovered at three separate cemeteries in Lent. At Lent-Steltsestraat, 15 inhumation graves were recovered, intermingled with 17 cinerary graves (van den Broeke and Hessing, 2005; van den Broeke, 2008, 2014). The archaeological excavations in Lent-Lentseveld revealed four inhumation burials amongst eight cremation graves (van den Broeke and Daniël, 2011). The Lent cemeteries were in use contemporaneously (Early Iron Age, 800–500 BC). Another four Middle Iron Age (500–250 BC) inhumation burials were unearthed in Lent - Laauwikstraat-zuid, probably the successor of the Steltsestraat cemetery. North-west of Lent, in Oosterhout, three inhumation burials have been uncovered, dating to the earlier part of the Early Iron Age (van den Broeke, 2003, 2014). North of Lent, at the archaeological site of Ressen-Zuiderveld, two inhumations dating to the Early and Middle Iron Age have been excavated amongst 27 cremation burials (Ball and Daniël 2010). Archaeological excavations in Beuningen-Keizershoeve II, in 2012, revealed a final four Early/Middle Iron Age inhumation burials (Blom *et al*. 2012).

THE GEOLOGICAL SETTING

All of the archaeological sites are located in the Holocene river area of the central part of the Netherlands; an area where the surface geology is characterized by the fluvial deposits of the rivers Rhine and Meuse. In this particular part of the Netherlands, the local bioavailable $^{87}Sr/^{86}Sr$ range is defined as 0.7088–0.7092 (isoscape B: Kootker *et al*. 2016b; see Fig. 1). Within a 1–15 km distance of the archaeological sites, however, the geology becomes more heterogeneous, and both more and less radiogenic conditions are found. The area located directly south of the Lent–Ressen–Oosterhout area, for instance, is characterized by $^{87}Sr/^{86}Sr$ ratios ranging from 0.7095 up to 0.7110, due to the presence of remnants of ice-pushed ridges, which consist of Tertiary marine clays and Scandinavian-derived glacial deposits (boulder clay, isoscape E: see Kootker *et al*. 2016a). The Rur Graben also lies within 30 km of all of the archaeological sites. Here, the sediments include reworked aeolian loess and sandy loess deposits, with elevated strontium isotope ratios up to 0.7105 (isoscape D; Schokker *et al*. 2007). Therefore, it has to be taken into account that strontium ratios incompatible with the local values do not necessarily indicate long-distance mobility or migration, but might be indicative of intra-regional movements ($\leq$ 30 km radius).

MATERIALS AND ANALYTICAL METHODS

Sampling and analytical procedure

Tooth enamel samples were taken from 23 individuals: (possible) males ($n = 8$), (possible) females ($n = 11$), one unsexed adult and children ($n = 3$). The aim was to sample the first permanent molar to capture the $^{87}Sr/^{86}Sr$ ratio of the earliest period of childhood (0–3 years). Unfortunately, only five first molars were available for analyses. Incisors, premolars and molars that mineralize later in life were sampled in the remaining 18 individuals. The sampled incisors and premolars mineralize slightly later than the first molar, from a few months of life to 2 years up to 5–7 years of age. The selected second and third molars, however, are indicative for geological residence between the ages of 2.5–8 years and 7–16 years respectively (Woelfel and Scheid 2002). In addition to the human samples, molars of 11 medium and large domestic mammals were sampled to provide a preliminary insight into husbandry practices.

A detailed description of the sample and strontium column extraction protocol is given elsewhere (Kootker *et al*. 2016a). The isotope compositions were measured by thermal ionization mass spectrometry using a Finnigan MAT-262 RPQ-plus instrument at the Vrije Universiteit Amsterdam. The strontium ratios were determined using a static routine and were corrected for mass-fractionation correction to an $^{86}Sr/^{88}Sr$ ratio of 0.1194. All measurements were referenced to the within-run value of the NBS987 standard, which gave a mean $^{87}Sr/^{86}Sr$ value of 0.710228 ± 0.000009 (2SE) over the course of the study ($n = 10$). The samples were run to an internal precision of ±0.000010 (2SE) or better. The total procedural blanks contained on average 53 ± 15 pg ($n = 8$).

Delineation of the bioavailable $^{87}Sr/^{86}Sr$ signature

The delineation of a local bioavailable strontium signal is a complex task, as it is unknown from which geological resources strontium entered the food chain during the Iron Age in the Dutch river area (e.g., Maurer *et al*. 2012). Differences in (origin of) diet, therefore, may have had a profound effect on the local $^{87}Sr/^{86}Sr$ ratio. Kootker et al. (2016b) suggested a combined approach to establish the local bioavailable strontium range, using an isoscape map (if available), with biosphere samples (if available) and a statistical assessment of the population to be investigated. In the current study, the bioavailable isoscape map of the Netherlands and a statistical approach were combined to deduce a bioavailable local $^{87}Sr/^{86}Sr$ signature.

Statistical assessment

The data sets were analysed using SPSS 22.0 (IBM SPSS Statistics for Macintosh, Armonk, IBM Corp.). Dependent on the distribution of the data sets, assessed by Shapiro–Wilk tests ($p > 0.05$) and homogeneity of variances, as assessed by Levene's test, independent sample *t*-tests or their non-parametric equivalent, Mann–Whitney *U* tests, were performed to test for statistically significant differences between groups.

RESULTS

Human $^{87}Sr/^{86}Sr$ data

The strontium isotope data are presented in Table 1 and Figure 2. The strontium isotope values of the humans vary between 0.70882 and 0.71296. Statistical tests were conducted to quantify differences between (possible) males ($n = 8$) and (possible) females ($n = 11$) and between two different age groups (20–40 years, $n = 11$; 30–60 years, $n = 6$). An independent sample *t*-test showed no statistical significant differences in the mean $^{87}Sr/^{86}Sr$ ratios between males and females ($t(17) = 0.274$, $p = 0.787$). A non-parametric Mann–Whitney *U* test determined that there were no statistically significant differences in median $^{87}Sr/^{86}Sr$ ratios between different age groups either ($U = 16$, $z = -1.709$, $p = 0.980$).

Faunal $^{87}Sr/^{86}Sr$ data

The faunal $^{87}Sr/^{86}Sr$ ratios vary between 0.70878 and 0.71257 (Table 1), and overlap with the human strontium data. Median human and faunal $^{87}Sr/^{86}S$ ratios were not statistically different (Mann–Whitney *U* test: $U = 114$, $z = -0.460$, $p = 0.663$).

The local $^{87}Sr/^{86}Sr$ signature

A statistical assessment reveals a non-normal distribution of the human data set ($W = 830$, df = 23, $p = 0.001$). Removal of the extreme low and high $^{87}Sr/^{86}Sr$ ratios ($n = 11$) resulted in a positively skewed normally distributed data set ($W = 830$, df = 12, $p = 0.05$) in which the mean and median coincide (both 0.7089; see Table 2). The trimmed 'local' data set comprises values between 0.70882 and 0.70932, exceeding the maximum value of the isoscape B (0.7088–0.7092: Kootker *et al*. 2016b) by 0.00012. To avoid the overestimation of potential migrants and to take possible intra-population variations in diet into account, in this study human $^{87}Sr/^{86}Sr$ ratios ranging from 0.7088 to 0.7093 are considered to be consistent with the direct surrounding environment.

As mentioned earlier, more and less radiogenic values do occur within a few kilometres south of the sites Beuningen, Oosterhout, Ressen and Lent (Fig. 1). The low number of burials (both cremations and inhumations) present at the sites under investigation, however, suggest that the cemeteries were in use for a limited period of time, and by a single local community (~10–20 individuals: see Fokkens 1997; Gerritsen 2008). Hence, in this study all individuals who exhibit $^{87}Sr/^{86}Sr$ ratios inconsistent with the delineated local $^{87}Sr/^{86}Sr$ range are assumed not to be members of the local community who used the burial site, and therefore are considered to be of non-local descent.

Table 1 *Human and faunal strontium isotope data from the Dutch river area (EIA, early Iron Age; MIA, middle Iron Age; IA, Iron Age; M, male; F, female; C, canine; M, molar). Dental element notation conforms to the FDI system (Fédération Dentaire Internationale), a two-digit system (ISO 3950) developed to associate information to a specific tooth. Syntax: <quadrant code><tooth code>. Permanent dentition quadrant codes start with 1 (right quadrant maxilla), followed by 2 (left quadrant maxilla), 3 (left quadrant mandible) and 4 (right quadrant mandible). Permanent dentition tooth codes start with 1 (central incisor) and end with 8 (third molar)*

Region	*Site*	*Project*	*Period*	*ID*	*Taxon*	*Biological sex*	*Age (years)*	*Dental element*	$^{87}Sr/^{86}Sr$	*± 2SE*
Nijmegen-Noord	Lent	Steltsestraat	EIA	Grave 1.9	*Homo sapiens*	M?	20–40	13	0.70882	0.00001
	Lent	Steltsestraat	EIA	Grave 5.5	*Homo sapiens*	–	7–9	12	0.70885	0.00001
	Lent	Steltsestraat	EIA	Grave 6.2	*Homo sapiens*	F?	20–40	35	0.70894	0.00001
	Lent	Steltsestraat	EIA	Grave 8.2	*Homo sapiens*	F?	25–40	31	0.70895	0.00001
	Lent	Steltsestraat	EIA	Grave 5.7	*Homo sapiens*	M	30–60	11	0.70899	0.00001
	Lent	Steltsestraat	EIA	Grave 5.8	*Homo sapiens*	M	25–40	46	0.70903	0.00001
	Lent	Steltsestraat	EIA	Grave 6.3	*Homo sapiens*	M?	> 25	11	0.70934	0.00001
	Lent	Steltsestraat	EIA	Grave 2.3	*Homo sapiens*	M?	20–45	13	0.71099	0.00001
	Lent	Steltsestraat	EIA	Grave 5.6	*Homo sapiens*	F?	40–70	45	0.71142	0.00001
	Lent	Steltsestraat	EIA	Grave 1.6	*Homo sapiens*	F?	30–60	48	0.71172	0.00001
	Lent	Steltsestraat	EIA	Grave 7.4	*Homo sapiens*	M	40–60	25	0.71296	0.00001
	Lent	Lentseveld	EIA	Grave 5	*Homo sapiens*	F	19–34	16 or 17	0.70884	0.00001
	Lent	Lentseveld	EIA	Grave 1	*Homo sapiens*	F	23–34	36	0.70932	0.00001
	Lent	Laauwikstraat	MIA	P10	*Homo sapiens*	–	26–40	14	0.71169	0.00001
	Ressen	Zuiderveld	MIA	S51	*Homo sapiens*	F	35–55	37	0.70897	0.00001
	Ressen	Zuiderveld		S34	*Homo sapiens*	M	45–55	45	0.71057	0.00001

(*Continues*)

Table 1 (Continued)

Region	*Site*	*Project*	*Period*	*ID*	*Taxon*	*Biological sex*	*Age (years)*	*Dental element*	$^{87}Sr/^{86}Sr$	± *2SE*
			E(/M) IA							
	Oosterhout	Eeuwige Lente	EIA	V3	*Homo sapiens*	F?	17–25	38	0.70916	0.00001
Nijmegen-West	Beuningen	Keizershoeve II	EIA	S56.2	*Homo sapiens*	F	25–40	46	0.70968	0.00001
	Beuningen	Keizershoeve II	E/MIA	S56.7	*Homo sapiens*	M	30–44	35	0.71223	0.00001
	Beuningen	Keizershoeve II	E/MIA	S56.6	*Homo sapiens*	–	< 18	16	0.71247	0.00001
Geldermalsen	Geldermalsen	Middengebied	IA	10/5	*Homo sapiens*	F	34–40	45	0.71224	0.00001
	Meteren	De Bogen	IA	Grave 6	*Homo sapiens*	–	15–18	46	0.71024	0.00001
	Meteren	De Plantage	IA	WP1001	*Homo sapiens*	F	30–40	27	0.70896	0.00001
Nijmegen-Noord	Lent	Lentseveld	IA	31.04	*Sus domesticus*	–	–	M	0.70887	0.00001
	Lent	Lentseveld	IA	14.64	*Sus domesticus*	–	–	M	0.70890	0.00001
	Lent	Lentseveld	IA	25.15	*Sus domesticus*	–	–	M	0.70905	0.00001
	Lent	Lentseveld	IA	29.08	*Sus domesticus*	–	–	M	0.71005	0.00001
	Lent	Lentseveld	IA	29.07	*Bos taurus*	–	–	M	0.71257	0.00001
Geldermalsen	Meteren	Lage Blok	MIA	363.2	*Bos taurus*	–	–	M	0.70878	0.00001
	Meteren	Lage Blok	MIA	29.07	*Bos taurus*	–	–	M	0.71019	0.00001
	Tiel	Passewaaij	IA	347.1	*Ovis aries/Capra hircus*	–	–	M	0.70880	0.00001
	Tiel	Passewaaij	IA	395.1	*Canis familiaris*	–	–	C	0.70950	0.00001
	Tiel	Passewaaij	IA	349	*Sus domesticus*	–	–	M	0.71062	0.00001
	Tiel	Passewaaij	IA	213	*Sus domesticus*	–	–	M	0.71256	0.00001

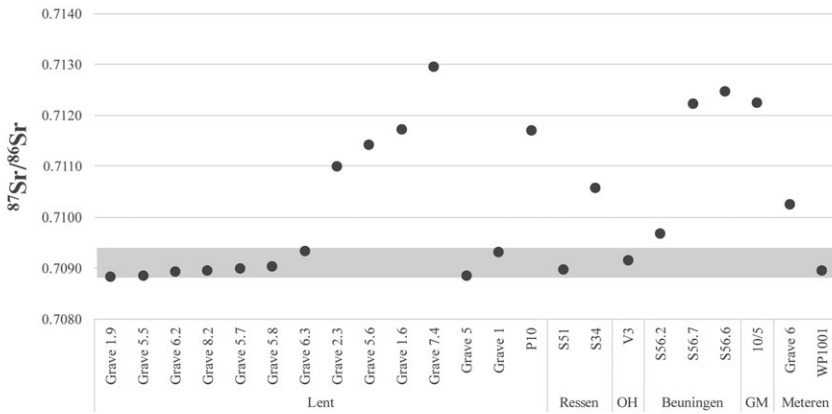

Figure 2 *Human $^{87}Sr/^{86}Sr$ data from six archaeological sites. The horizontal band marks the bioavailable strontium range (0.7088–0.7093) representative of the direct local environment. The standard errors in the analytical data are smaller than the plotted symbols. OH, Oosterhout; GM, Geldermalsen.*

Table 2 *Descriptive statistics for the complete and trimmed human 'local' data sets*

Statistic	*Complete*	*Local*
Mean	0.71019	0.70898
Median	0.70934	0.70896
Standard deviation	0.00144	0.00015
Count	23	12
Minimum	0.70882	0.70882
Maximum	0.71296	0.70932
Variance	5.00E-06	2.18E-08
Skewness (SE)	0.653 (0.48)	1.298 (0.66)
Kurtosis (SE)	−1.208 (0.94)	1.898 (1.279)

DISCUSSION

Human $^{87}Sr/^{86}Sr$ data

Twelve of the 23 human individuals (52.2%) exhibit $^{87}Sr/^{86}Sr$ ratios that are compatible with the local strontium signature (0.7088–0.7093). Eleven individuals (47.8%) display strontium isotope ratios that correspond to non-local origins: four males (Grave 2.3, Grave 7.7, S34 and S56.7), four females (Grave 1.6, Grave 5.6, S56.2 and 10/5), one unsexed adult (P10) and two children (S56.6 and Grave 6). The $^{87}Sr/^{86}Sr$ ratios of four non-local individuals (Grave 2.3, Grave 6, S34 and S56.2) correspond to areas in close proximity to the sites (0.7095–0.7110). The remaining seven individuals (30.4% of the investigated population), however, are characterized by more radiogenic values, varying between 0.7114 and 0.7129. In the Netherlands, elevated $^{87}Sr/^{86}Sr$ ratios up to 0.7113 are rare and to date only characteristic of the loess region in the province of Limburg. Values exceeding 0.7113 are expected to be present in the boulder clay areas located north of the archaeological sites, although the bioavailable strontium ratios for these regions have yet to be established (Kootker *et al*. 2016b). Both geological units are over 100 km distant from the sites under investigation. Hence, these individuals prove unquestionably that long-distance movement took place during the Early and Middle Iron Age in the Netherlands. This suggests that the introduction of inhumation in Iron Age burial practice in the Dutch river valley may be introduced or catalysed by settling migrant individuals. A minority of the non-local strontium values (36.4%) do occur in the near proximity of the sites. Gerritsen (2003), however, states that the people buried in the same cemetery were associated in life, such as in domestic groups or families. Therefore, Iron Age burial sites may be seen as *burial communities* that were used by local residents. Consequently, all non-locally born individuals ($^{87}Sr/^{86}Sr > 0.7093$) are assumed not to have been members of the local social communities.

For most individuals, teeth and molars were sampled that mineralize during later stages in life. If relocation took place during early childhood, the analysed dental elements will reflect the local conditions and conceal any information about early childhood residence. In addition, large areas of north-west Europe are predicted to have strontium isotope ratios comparable to isoscape B (0.7088–0.7092), which represents the local signal. Hence, the estimates of non-local individuals in Iron Age cemetery contexts in the Dutch river area must be considered as the minimum, as an influx from a large part of (north-west) Europe will not be detected.

Faunal $^{87}Sr/^{86}Sr$ data

The absence of a statistically significant difference between the median human and faunal $^{87}Sr/^{86}Sr$ ratio ($p \geq 0.05$) indicates possible similar geological areas of origin. Six animals exhibit more radiogenic ratios than the surrounding river sediments (> 0.7093). The strontium ratios of four of them, one dog (ID 395.1) and two pigs (IDs 29.08 and 349) and one cow (ID 29.07), are found in areas adjacent to the archaeological sites (0.7095–0.7106). At first sight, the isotope data point towards the presence of (long-distance) transport and exchange of animals in the Netherlands during the Iron Age, even with animals that were thought not suitable to transfer over large distances, such as pigs (*Sus domesticus*). The presence of non-locally born and raised pigs in Tiel and Lent, however, might also be linked with the preferred husbandry strategy. The scarcity of woodland in the river delta might have forced the Iron Age farmer to take the pigs to more distant forests for seasonal pannage. The origin of the remaining two animals, one bovine and one pig, could be found in the Dutch boulder clay areas, or further away (> 0.7125). The distance between the archaeological sites and the possible source areas is too large for the practised husbandry strategy to be considered as a possible explanation for the increased $^{87}Sr/^{86}Sr$ ratios. The exchange of animals for crops in the northern Dutch wetlands has already been suggested by Brinkkemper *et al*. (2006). Exchange may therefore be considered as a feasible explanation of the observed radiogenic signatures. Consequently, the data presented here may point towards the occurrence of long-distance acquisition, exchange or trade of animals or animal products in the Dutch Iron Age. Moreover, the presence of non-local animals can also be considered as evidence of human migration, suggesting that the migrating groups took their livestock with them.

Identification of (cultural) provenance

To establish a more accurate provenance of the non-local individuals, more lines of evidence are required. The use of multiple isotope systems may improve the resolution, but the presence of archaeological markers would also be useful. Except for some fragments of Early Iron Age pottery in the female's grave (S56.2, Reigersman-van Lidth de Jeude and Drenth 2012), none of the Beuningen burials were equipped with cultural data. Although this conforms to the common method of grave furnishing in the Netherlands during the Iron Age, grave goods are occasionally found in all other investigated archaeological sites in this study (Table 3). Amongst the individuals selected for isotope analysis, grave inventories were exclusively associated with (possible) female graves. The grave inventory may be indicative of the inter-regional connections that existed in Iron Age society and/or the cultural background of the deceased. Arnold (2012) suggests, specifically for the Iron Age, that grave goods, in particular personal ornaments (jewellery), daggers and so on, may have been inherited and only buried once the heritage line was broken. The cultural artefacts themselves may therefore be seen as mnemonic items, reminiscent of the deceased cultural background and family history (van den Broeke and Hessing, 2005), and as such can be used as a proxy for identifying the (cultural) provenance of the deceased rather than for the geographical origin of the inhumed individual. Jewellery was found in five of the eight sampled decorated graves (Graves 5, 8.2, 10/5, WP1001 and V3), of which only three allow for a tentative suggestion for provenance.

The 34–40-year-old female from Geldermalsen-Middengebied (10/5) wore a bronze torc and had a bronze bracelet around each wrist: quintessential elements for the most common burial form in the Aisne–Marne region in northern France between 450 and 375 BC (e.g., Büchsenschütz 1995). In addition, three ceramic vessels, an iron knife and a pork rib had been

Table 3 *Graves with grave goods used in this study*

Site	*Project*	*Period*	*Structure ID*	*Sex*	*Age (years)*	*Grave goods*	$^{87}Sr/^{86}Sr$	*Reference*
Lent	Steltsestraat	EIA	Grave 8.2	F?	25–40	Hair rings or earrings	0.70895	van den Broeke (2014)
Lent	Lentseveld	EIA	Grave 5	F	19–34	Head ornaments, iron ring	0.70884	van den Broeke and Daniël (2011)
Ressen	Zuiderveld	MIA	Grave 1	F	35–55	Pottery ($n = 2$, possible cheese mould)	0.70897	Ball and Daniël (2010)
Oosterhout	Eeuwige Lente	EIA	V3	F?	17–25	Head ornaments, iron ring	0.70916	van den Broeke (2003, 2014)
Geldermalsen	Middengebied	MIA	10/5	F	34–40	Jewellery, pottery, knife, animal bones	0.71224	Hulst (1999)
Meteren	De Bogen	MIA	Grave 6	-	15–18	Molars, *Bos taurus*	0.71024	Meijlink (2001)
Meteren	De Plantage	MIA	WP1001	F	30–40	Jewellery, amber beads	0.70896	Jezeer and Verniers (2012)
Beuningen	Ewijk Keizershoeve II	EIA	S56.2	F	25–40	Fragments of pottery	0.70968	Blom *et al.* (2012)

placed near the woman's head (Hulst 1999). The pottery shows the strong northern French influences characteristic of the ceramic tradition of the southern part of the Netherlands around the fifth century BC, which is known as Marnian pottery. The region around the rivers Aisne and Marne in the Champagne region has biosphere $^{87}Sr/^{86}Sr$ ratios ranging between 0.7076 and 0.7100, with slightly more radiogenic values in the river valleys varying between 0.7101 and 0.7125 (Willmes *et al*. 2014). The active floodplain of the river provided excellent arable land for cereal cultivation during prehistoric eras, as shown by various archaeobotanical studies (e.g., Bakels 1999). As vegetation contributes significantly to the measured $^{87}Sr/^{86}Sr$ ratio of humans and animals due to its high strontium concentration, it is plausible to expect relative high strontium isotope ratios in human tissues (Burton *et al*. 1999; Bentley 2006). Hence, in addition to the archaeological markers, the high $^{87}Sr/^{86}Sr$ ratio of the female (0.71224) is also compatible with a provenance in the French Aisne–Marne region.

In addition to a bronze bracelet, the 30–40-year-old female from Meteren - De Plantage was decorated with two unique sets of copper alloy (bronze sheet metal) and amber hair ornaments (Fig. 3; see, e.g., Langelaar 2012). Precise parallels for such ornaments have yet not been found in the Netherlands, nor anywhere else. These hair ornaments do mimic the well-known *Segelohrringe* (bronze rings with a rounded end and a glass bead), of which several have been found in graves from the same period in the northern Netherlands. These are interpreted as rich graves of presumed high-status individuals (e.g., Kooi 1983). The absence of similar amber hair ornaments therefore does not allow these grave goods to be interpreted as mnemonic items that could be associated with the deceased cultural background. Additionally, the 'local' $^{87}Sr/^{86}Sr$ of the female (0.7089) cannot be used to support claims about the hair ornaments as a cultural marker of long-distance networks. Further investigations into the use of grave goods in Iron Age grave contexts should provide additional information about the possible link between amber and bronze hair ornaments and cultural identity.

The bronze hair rings or earrings discovered next to the skull of a 25–40-year-old female (?) in grave 8.2 from Lent-Steltsestraat (van den Broeke, 2014, figs 107–8), also suggest a foreign 'dress code', despite her local $^{87}Sr/^{86}Sr$ ratio. The only other area in which this form of ornamentation is known is the Middle Rhine region (Heynowski 1992, 80–1).

Contextualizing the data

The presence of foreign individuals in Iron Age settlements is not uncommon in Europe. The quantity of observed non-local individuals within Iron Age burial sites, however, varies widely. A study into the diet and mobility of an Early Iron Age (800–460 BC) population from the Magdalenenberg site in Germany by Oelze *et al*. (2012) gave insight into an extremely mobile population. Of the 76 analysed individuals, approximately 79% ($n = 60$) could be inferred as non-local, which the researchers interpreted as indicative for the existence of far-reaching social and economic networks. The vast majority of research conducted in continental Europe, however, reveals lower percentages of foreign individuals. Investigations by Wilhelmson and Ahlström (2015) on the Swedish island of Öland, for instance, resulted in the identification of 32% of the population in the Swedish Early Iron Age (500 BC – AD 400) as being of non-local descent. In Italy and Germany, Scheeres *et al*. (2013) found that 19% and 12% of the investigated individuals were of non-local descent in Iron Age Monte Bibele and Nehringen respectively (450–250 BC). A similar percentage of foreign individuals (13%) was identified at the contemporaneous cemetery (420–240 BC) of Münsingen-Rain in Switzerland (Scheeres *et al*. in press). In the Czech Republic, Scheeres *et al*. (2014) show that the $^{87}Sr/^{86}Sr$ ratios of the minority of the La

Figure 3 *Amber and bronze hair ornaments. Three were found at either side of the cranium of a 30–40-year-old female in Meteren - De Plantage (copyright © ADC ArcheoProjecten). [Colour figure can be viewed at wileyonlinelibrary.com]*

Tène communities (380–250 BC) in Kutná Hora (12%) and Radovesice (11%) differ significantly from the regional isotopic baseline values.

Whether the change in burial rite in the central Netherlands was introduced or catalysed by the presence of foreign individuals and/or cultures remains debatable. We acknowledge that the results presented in this paper only represent data from the available inhumations, which in turn represent the minority of the investigated Iron Age societies. Moreover, in-depth research into the differences or similarities in the $^{87}Sr/^{86}Sr$ ratios between the inhumed and cremated individuals may provide some information about the relation between burial rites and geological/cultural descent. At the time of the research, it was thought to be impossible or unfeasible to conduct strontium isotope analyses on cremated remains. Recent studies by Harvig *et al*. (2014) and Snoeck *et al*. (2015), however, suggest that calcined bones may be useful for provenance studies; in particular, the petrous portion of the temporal bone (*pars petrosa osis temporalis)*. Future research into the isotopic difference between the two burial practices is required to validate the conclusion reached here that the presence of foreign cultures may have introduced a shift in the Iron Age burial practice from cremation to a mix of inhumation and cremation in the central river area in the Netherlands. After 350 BC, however, cremation was again the only burial rite (van den Broeke, 2014).

CONCLUSIONS

This study provides bioarchaeological evidence that long-distance migration, as well as long-distance movement of animals, took place in the Netherlands during the Iron Age. If these results are representative of the entire population, the relatively high percentage of non-locally born individuals (up to 48%) compared to Iron Age sites in Europe supports the hypothesis that the change in burials practice has been induced by the increasing heterogeneity of the population in terms of (cultural) provenance (see Gerritsen 2003; Roymans 2004). The presence of individuals from a different cultural background and/or geographical provenance may have led to the acceptance and/or the incorporation of new burial practices in the Dutch Iron Age burial rite. Only eight inhumation burials that were part of this investigation contained grave goods, of which the character of some point towards a foreign burial culture, such as the La Tène culture in the Aisne–Marne region in northern France. Remarkably, only one of these burials, in Geldermalsen, known as the 'La Tène burial', exhibits a more radiogenic $^{87}Sr/^{86}Sr$ ratio than the surrounding area. Based on the generated data, all other decorated inhumation burials may have belonged to native individuals, although the possibility cannot be excluded that these individuals came from distant geological areas where similar conditions prevailed or migrated to these sites at an earlier stage in life.

The data presented here show the potential of isotope archaeology to contribute to the study of the structure of Iron Age societies, their burial customs, and their development in time and space. In this study, the results support the hypotheses that the change in burial rite may have been the result of successive adaptations of the local inhabitants to foreign cultures and/or the allowance of the foreign people to execute their own burial culture in harmony with the natives, ultimately leading to a temporal heterogeneous burial rite in the Dutch Iron Age.

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