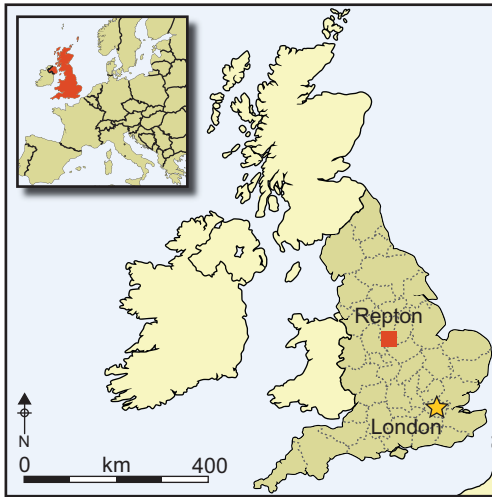


The Viking Great Army in England: new dates from the Repton chanel

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Archaeological evidence for the Viking Great Army that invaded England in AD 865 is focused particularly on the area around St Wystan's church at Repton in Derbyshire. Large numbers of burials excavated here in the 1980s have been attributed to the overwintering of the Great Army in AD 873–874. Many of the remains were deposited in a chanel, while others were buried in graves with Scandinavian-style grave goods. Although numismatic evidence corroborated the belief that these were the remains of the Great Army, radiocarbon results have tended to disagree. Recent re-dating of the remains, applying the appropriate marine reservoir correction, has clarified the relationship between the interments, and has resolved the previous uncertainty.

Keywords: UK, Repton, Viking Age, Viking Great Army, radiocarbon dating, marine reservoir effects

Introduction

Between 1980 and 1986, investigations in the vicinity of St Wystan's church at Repton in Derbyshire (Figure 1) uncovered a chanel deposit containing the disarticulated remains of at least 264 people under a low pebble mound (Biddle & Kjølbye-Biddle 1992, 2001). The bones were hypothesised to be those of the Viking Great Army that overwintered in Repton in AD 873–874, according to the Anglo-Saxon Chronicle (Swanton 2000). The excavators also discovered extensive evidence of a large defensive ditch and a number of furnished

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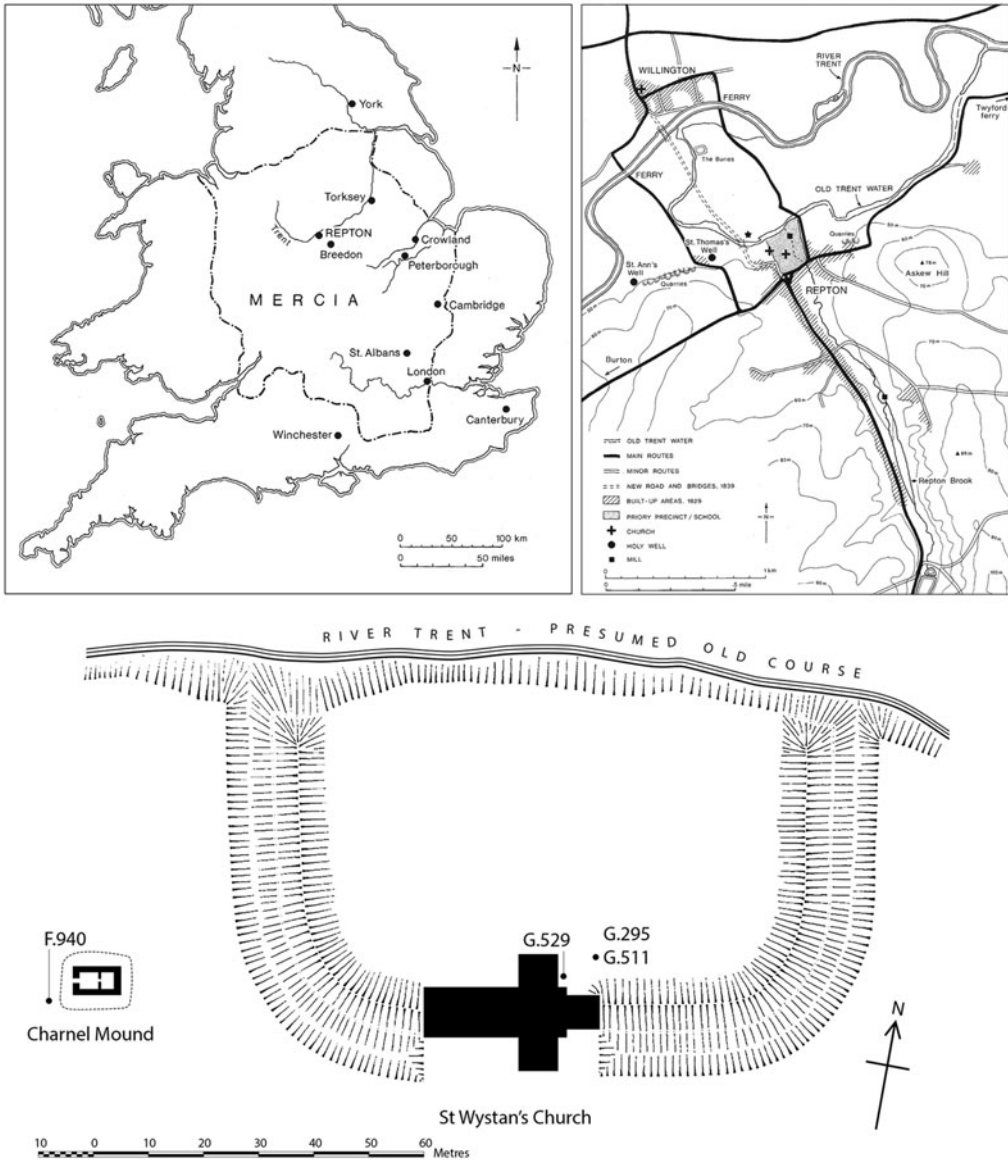


Figure 1. Location of Repton and site plan.

burials with distinctly Scandinavian-style grave goods. Numismatic evidence assigned both the chanel and the Viking graves to AD 872–75 (Biddle *et al.* 1986; Pagan 1986; Biddle & Kjølbye-Biddle 1992, 2001). Radiocarbon date determinations of bone collagen from the chanel deposit, however, seemed to disagree with the archaeological findings. Although several samples were consistent with a ninth-century date, a number dated to the seventh and eighth centuries AD, and thus seemed to belong to an earlier phase of activity (Biddle

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& Kjølbye-Biddle 2001). As a result, the identification of those buried in the charnel as members of the Great Army has been brought into question (e.g. Richards *et al.* 2004).

The date and identification of the Repton charnel is important for a number of reasons. Despite significant evidence for a Scandinavian presence in England in the ninth century AD, securely identified Scandinavian inhumations, and thereby direct osteological evidence for a migrant population, are rare (Richards 2002; Redmond 2007). The nature and magnitude of Scandinavian migrations to England in the early medieval period is still disputed (e.g. Sawyer 1957; Hadley 2006; Leslie *et al.* 2015; Kershaw & Røyrvik 2016). The size and nature of Great Army winter camps has been used as a proxy to estimate the size of the invading forces, but with divergent results (cf. Sawyer 1962; Hadley *et al.* 2016). An accurate understanding of the chronology at Repton is therefore essential for improving our knowledge in these areas.

Here we present new radiocarbon dates of bone material from Repton to elucidate the dating of the charnel deposit. We take into account marine reservoir effects (MREs) on human bone, and use contextual information with Bayesian modelling to constrain the dates further. The results show that all dated remains from the charnel deposit are consistent with a single late ninth-century event. Beyond the context of Viking Age England, the material presented here demonstrates the need to account fully for MREs, in particular when working with secondary burials or material where ^{14}C dates seem inconsistent with other forms of evidence.

Background

Excavations were carried out in Repton between 1974 and 1980 by Harold Taylor, Martin Biddle and Birthe Kjølbye-Biddle, with the initial aim of investigating the origins of the Anglo-Saxon church of St Wystan (Taylor 1989; Biddle & Kjølbye-Biddle 1992, 2001). Repton was a significant royal and ecclesiastical centre in the Anglo-Saxon kingdom of Mercia. It was the location of a double monastery for men and women ruled by an abbess, established in the third quarter of the seventh century (Biddle & Kjølbye-Biddle 1985). According to the Anglo-Saxon Chronicle, the Viking Great Army took up winter quarters in Repton in AD 873, driving the Mercian king Burghred into exile in Paris (Swanton 2000). A large defensive ditch abutting St Wystan's church was discovered during the excavations, and was interpreted as part of a D-shaped enclosure, using the church as a gatehouse, with the River Trent forming a natural line of defence to the north (Figure 1). Several burials with grave goods of a distinctly Scandinavian type were discovered within and around this enclosure. Most notable was a double grave of two men, of which one (G.511) was furnished with artefacts including a sword of Peterson type M, and a silver Thor's hammer pendant (Figure 2). Strontium and oxygen isotope analysis of tooth enamel from these two individuals has demonstrated that they both grew up in a region commensurate with values expected from southern Scandinavia (Budd *et al.* 2004).

The mass burial of at least 264 people, largely comprised of men aged 18–45, was found beneath a mound in the vicarage garden to the west of St Wystan's church (Biddle & Kjølbye-Biddle 1992, 2001). This charnel deposit was placed inside the eastern compartment of a partially levelled, two-celled building of seventh- to eighth-century date,

thought to have been a chapel forming part of the Anglo-Saxon monastery. Despite the wholesale disturbance of the bones when the deposit was first uncovered in the seventeenth and early nineteenth centuries (Degg 1727; Bigsby 1854), some of the long bones found in 1982 were still stacked chanel-wise in position. A layer of clean red marl had been placed beneath the bones in preparation, demonstrating that deposition occurred as a single event. Artefacts found among the bones included an iron axe, two fighting knives and five silver pennies datable to AD 872–874 (Pagan 1986).

Following the closure of the mound over the bone deposit, burial continued in the area around St Wystan's from the later ninth century onwards. Importantly, a number of burials, referred to as cemetery 3M, were cut directly into the mound itself, over the chanel deposit. Of particular significance is a grave (feature F940) found immediately outside the mound to the south-west. This contained four juveniles aged between 6 and 17, carefully arranged with a sheep jaw placed at their feet (Figure 3). A square stone setting beside the grave seems to have held a substantial marker of unknown type. The location of this grave and the deliberate arrangement of the four bodies suggest that it could have been a sacrificial deposit intended to mark the completion of the chanel mound.

In 1995, a set of 22 samples were AMS ¹⁴C dated at the Van de Graaf Laboratorium at the University of Utrecht (Biddle & Kjølbye-Biddle 2001). Terrestrial calibration of these determinations resulted in dates that, in many cases, were either inconsistent with the archaeological evidence, or yielded imprecise calibrated ranges. Notably, dated bones from the chanel appear to fall into two separate

groups (Figure 4). One group of at least four different individuals seemed to date from as early as the seventh or eighth century, with the remainder fitting with a ninth-century

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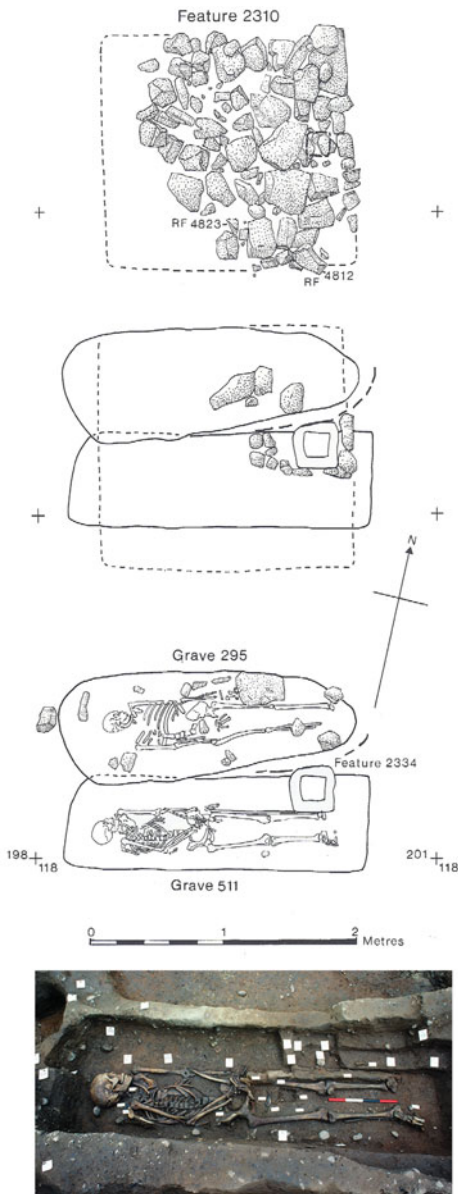


Figure 2. Plan of the double grave (G.511 and G.295); and photograph of G.511 (© M. Biddle).

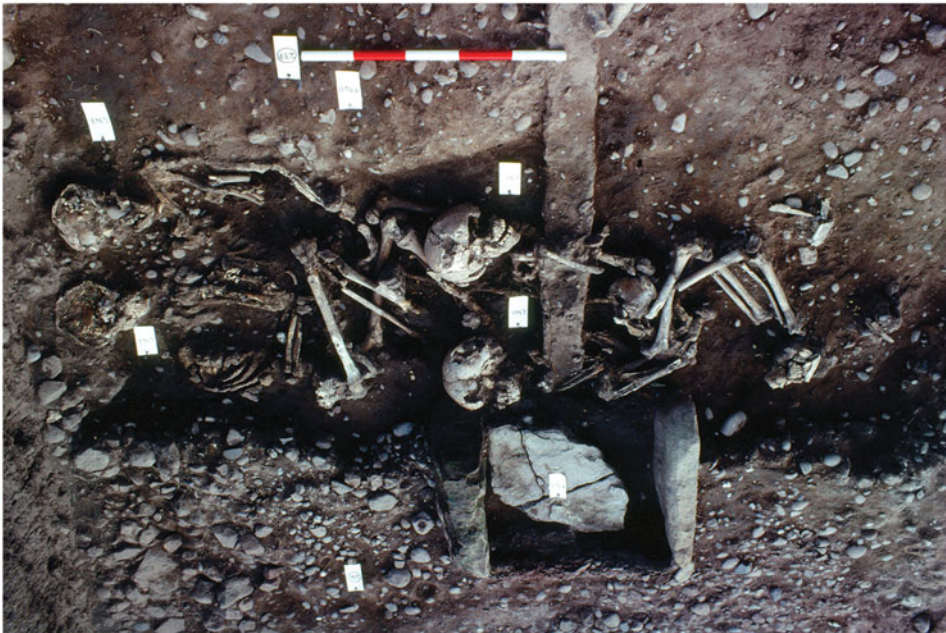
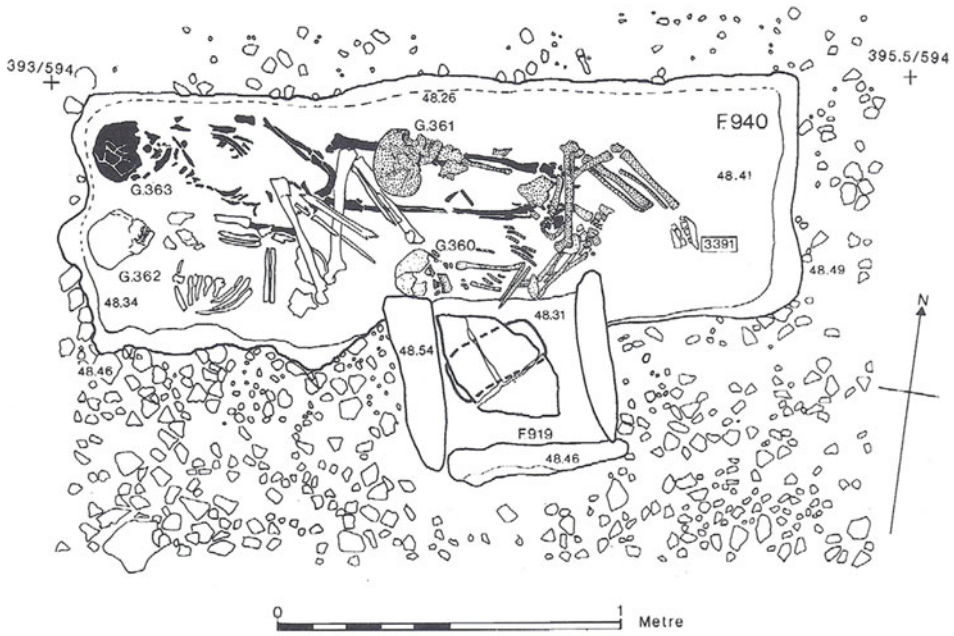


Figure 3. Plan and photograph of the juvenile grave, F940 (© M. Biddle).

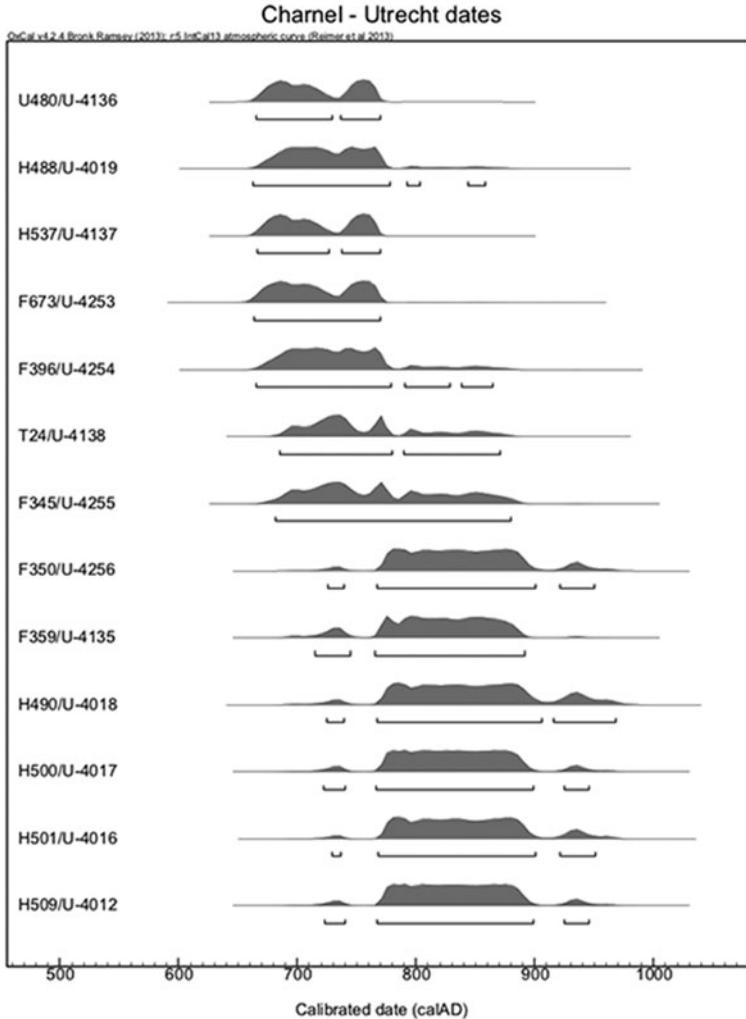


Figure 4. Plot of the terrestrial calibration of the Utrecht radiocarbon dates.

date. This suggested, therefore, that the bones were not all from a single contemporaneous group, making them incompatible with a population derived from the Viking Great Army of AD 873–874. An alternative hypothesis (Richards *et al.* 2004) suggested that some of the charnel bones may have come from the older cemetery of St Wystan's church, uncovered during the excavation of the ditch for the winter camp in AD 873–874 and reburied beneath the mound in the vicarage garden.

Another explanation for the apparent disparity between the radiocarbon dates and the archaeological evidence may lie in a lack of MRE corrections. ^{14}C is not equally distributed across the biosphere and marine ecological zones. After production, it is incorporated into the terrestrial food chain by being fixed from atmospheric CO_2 via photosynthesis. Carbon

exchanges in dynamic equilibrium with sea-surface ocean waters, and yet due to the large size of the ocean carbon reservoir and the slow rate of mixing throughout, there is an offset between the ^{14}C concentration in the ocean and that of the atmosphere. This offset averages around 400 years (Aitken 2013). These differences are reflected in consumers and passed on up the food chain. It has been demonstrated elsewhere (e.g. Ascough *et al.* 2012) that MREs can significantly influence the ^{14}C concentration of radiocarbon dates determined from humans and fauna that may have consumed marine-derived proteins. Similar effects are seen in freshwater contexts such as lakes and rivers (e.g. Cook *et al.* 2001).

To correct for MREs, a local reservoir value (ΔR) must be established to take into account any differences between the global average marine reservoir offset and local variations (Cook *et al.* 2015; Russell *et al.* 2015). A particular challenge for the Repton material is the determination of an appropriate 'local' value for what appears to be a highly mobile group of people, whose collagen probably represents carbon assimilated from a range of geographic sources. Although the isotope data from the double grave suggests a southern Scandinavian origin for those two men, this relates to their childhood; the collagen dated here pertains to more recent diets over the 10–15 years preceding their death. As historical sources suggest that the Great Army was active in England for at least a decade before arrival in Repton (Swanton 2000), it is uncertain whether Scandinavian reference data would provide accurate ΔR values for these individuals.

It is also necessary to estimate the proportion of marine foods in each individual's diet. This can be reconstructed from stable isotope data in a number of ways, all of which are approximations and are associated with varying degrees of confidence (for a review, see Phillips *et al.* 2014). The simplest methods rely on linear interpolations between end-members that represent a fully terrestrial or fully marine diet (e.g. Arneborg *et al.* 1999), whereby isotope data from a given individual are compared against values measured from humans or animals consuming only terrestrial or marine proteins respectively. Both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ can be used in this way, but $\delta^{15}\text{N}$ values are particularly sensitive to local environmental conditions (Szpak 2014), and can also vary for physiological reasons, such as weaning or nutritional stress (e.g. Fuller *et al.* 2005). In addition, there may be systematic geographic differences in $\delta^{15}\text{N}$ values between Scandinavia and the British Isles from the early medieval period, and the input of dietary protein from freshwater food sources can also obscure their interpretation (Cook *et al.* 2001; Bonsall *et al.* 2007; Pollard *et al.* 2012; Chenery *et al.* 2014). Consequently, we used only $\delta^{13}\text{C}$ values for dietary reconstruction and MRE corrections.

Materials and methods

Materials

The new samples (Table 1) were selected to provide a more detailed dating sequence than the previously published dates. Three samples came from burials in cemetery 3 to the north of the church, thought to be contemporaneous with the charnel deposit. These are the Viking double grave (G.511 and G.295) and a grave with five coins dated to AD 872–875 (G.529). Eight samples were selected from within the charnel deposit, which has been dated

Table 1. Material sampled with uncalibrated ^{14}C dates, stable isotope data and calculations of % marine consumption through $\delta^{13}\text{C}$ linear interpolation. # = AMS derived $\delta^{13}\text{C}$ value, * = IRMS derived $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values.

Grave or charnel bone ID	Cemetery	ORAU					Utrecht			Contextual date (AD)	Sex	Age	Species
		Lab. ID	^{14}C BP	$\delta^{15}\text{N}^*$	$\delta^{13}\text{C}^*$	% marine	Lab. ID	^{14}C BP	$\delta^{13}\text{C}^\#$				
G97	1	OxA-31451	1298±24	10.0	-19.2	21.2	-	-	-	700-800	U	juvenile	human
G529	3	OxA-12024	1281±27	11.2	-19.7	15.3	U-4011	1193±30	-20.3	872-875	M	adult	human
G511	3	OxA-12023	1250±25	12.3	-18.6	28.2	U-4020	1192±38	-20.0	874 or soon after	M	adult	human
G295	3	OxA-12004	1209±27	12.0	-19.0	23.5	-	-	-	874 or soon after	M	adult	human
G.511/7109	3	OxA-14570	1215±29	5.2	-20.7	3.5	-	-	-	874 or soon after	-	-	<i>Sus scrofa</i> tusk
G387	3M	OxA-12009	1233±25	10.3	-18.3	31.8	-	-	-	900-1000	M	adult	human
G360	F.940	OxA-12005	1230±24	10.0	-19.7	15.3	-	-	-	874 or soon after	U	juvenile	human
G361	F.940	OxA-12006	1193±25	9.8	-20.1	10.6	-	-	-	874 or soon after	U	juvenile	human
G362	F.940	OxA-12007	1218±25	11.7	-20.0	11.8	-	-	-	874 or soon after	U	juvenile	human
G363	F.940	OxA-12008	1236±25	12.2	-20.5	5.9	-	-	-	874 or soon after	U	juvenile	human
RF3391	F.940	OxA-12364	1199±27	6.0	-21.6	0	-	-	-	874 or soon after	-	-	<i>Ovis aries</i> mandible
X-03	charnel	OxA-13076	1273±27	11.6	-18.9	24.7	-	-	-	873-874	F	adult	human
X-17	charnel	OxA-31524	1256±28	11.9	-18.7	27.1	-	-	-	873-874	F	adult	human
X-23	charnel	OxA-31449	1267±22	10.5	-19.1	22.4	-	-	-	873-874	M	adult	human
X-70	charnel	OxA-31450	1217±28	11.7	-18.2	32.9	-	-	-	873-874	M	adult	human
H-537	charnel	OxA-31611	1333±25	10.7	-18.7	26.7	U-4137	1293±22	-19.9	873-874	U	adult	human
U-480	charnel	OxA-12001	1271±26	10.2	-19.2	21.2	U-4136	1292±23	-20.2	873-874	U	adult	human
F359	charnel	OxA-12002	1223±25	10.4	-19.1	22.4	U-1435	1207±27	-20.0	873-874	U	adult	human
F391	charnel	OxA-12003	1230±25	10.7	-18.9	24.7	-	-	-	873-874	U	adult	human

to AD 872–874 using numismatic evidence. To constrain the end date of the charnel, one sample (G.387) was selected from cemetery 3M, which is stratigraphically later than the charnel mound. The four young individuals from feature 940 (G.360–63) were also dated. The sheep jaw included in this grave provides a ^{14}C date from an animal with a purely terrestrial diet. Finally, a sample from the seventh- to eighth-century monastic cemetery (cemetery 1) was also included (G.97). In order to compare the validity of the former ^{14}C dates, five of the selected samples were taken from individuals previously dated in Utrecht.

Methods

Between 2002 and 2015, bone samples of approximately 500–1000mg dry weight were AMS dated at the Oxford Radiocarbon Accelerator Unit (ORAU), with collagen prepared following the methods outlined in Bronk Ramsey *et al.* (2004). Carbon and nitrogen isotopic compositions were determined using GC-C-IRMS on an aliquot of the same prepared collagen used for ^{14}C analysis, and are reported using standard delta notation relative to the reference standards Vienna Pee Dee Belemnite (V-PDB) and atmospheric nitrogen (AIR) for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ respectively.

OxCal v.4.2 was used to calibrate the radiocarbon determinations using the IntCal13 atmospheric curve and Marine13 marine calibration curve (Reimer *et al.* 2013). A local reservoir correction ΔR value of -47 ± 52 ^{14}C years was used for all samples, after the weighted mean value for Scotland determined by Russell *et al.* (2015), as no similar values are available for England. We also assessed relative differences between this and other possible ΔR values to test whether the conclusions that we reached still held true.

Stable isotope data were used to provide marine dietary estimates for each individual based on linear interpolation of bulk $\delta^{13}\text{C}$ collagen values, using the following equation to calculate the fraction of marine dietary protein (f_m) in any given individual n

$$f_m = \frac{\delta^{13}\text{C}_n - \delta^{13}\text{C}_{\text{terr}}}{\delta^{13}\text{C}_{\text{mar}} - \delta^{13}\text{C}_{\text{terr}}}$$

where $\delta^{13}\text{C}_n$ is the measured value for sample n , and $\delta^{13}\text{C}_{\text{terr}}$ and $\delta^{13}\text{C}_{\text{mar}}$ correspond to the isotopic values of fully terrestrial and fully marine end-members respectively. There are no known sources of C_4 foods, which can cause elevated $\delta^{13}\text{C}$ values in consumers, from medieval contexts in Northern Europe (Kosiba *et al.* 2007). Variation in $\delta^{13}\text{C}$ values should therefore relate entirely to differing consumption of marine food sources. For a terrestrial end-member, a $\delta^{13}\text{C}$ value of -21.0‰ was used, in accordance with values used elsewhere (Arneborg *et al.* 1999; Cook *et al.* 2015). This is close to the $\delta^{13}\text{C}$ value measured in the sheep jaw from feature F940 (-21.6‰), when a 1‰ offset for fractionation between diet and consumer is taken into account (Ambrose *et al.* 1997). A reliable marine end-member value is more difficult to obtain because there are no representative fully marine consumers from Repton. Instead, the reference value of -12.5‰ , suggested by Arneborg *et al.* (1999) in a study from Greenland, was used.

Quantifying the error associated with mixing models is complicated, as a wide range of both physiological and methodological factors affect the estimates (Hedges 2004; Cook *et al.* 2015). Although methods for quantifying and propagating errors have been

demonstrated elsewhere (e.g. Phillips & Gregg 2001), these may be less applicable to an archaeological context where the accuracy of the dietary end-members is uncertain. Therefore, despite compromising on precision, we add an unquantified general uncertainty of $\pm 10\%$ to each marine estimate here in accordance with common practice (Cook *et al.* 2015). Where possible, Bayesian modelling was used to constrain calibrated ^{14}C dates further by employing stratigraphic information and associated dated artefacts.

Results and discussion

With the exception of one sample (G. 529), ^{14}C dates of material previously dated at Utrecht agreed within instrumental uncertainty for all samples, indicating the validity of the former ^{14}C determinations. It is not currently possible to correct for MREs in the full Utrecht dataset, as independently determined stable isotope data are not available from those samples. The published $\delta^{13}\text{C}$ values (Biddle & Kjølbye-Biddle 2001) were obtained via the AMS measurements and were probably affected by some form of fractionation associated with the sample preparation or measurement process. This is evidenced by comparing the Utrecht AMS and ORAU IRMS $\delta^{13}\text{C}$ values of the replicated samples, which gives an average difference of 1.1‰ (range $0.9\text{--}1.4\text{‰}$). This corresponds to an average variation in marine consumption of $12.9\pm 10\%$, which suggests that the Utrecht $\delta^{13}\text{C}$ values cannot be reliably used for MRE corrections.

Our $\delta^{13}\text{C}$ interpolations demonstrate some degree of marine protein consumption in all individuals, ranging from $5.9\pm 10\%$ to $32.9\pm 10\%$ (Table 1). As seen in the Utrecht dataset, terrestrial calibrations demonstrate that the age ranges of all samples are affected by a plateau in the calibration curve, giving dates that span the eighth and ninth centuries AD at 95.4% certainty (Table 2). Precision is further affected by the MRE corrections, whereby the necessary uncertainties applied to our calculations make the calibrated age ranges even wider. For several of the graves, however, contextual and stratigraphic evidence, combined with Bayesian modelling, significantly refines the age estimates.

We evaluated our choice of ΔR value to test the effect that this had on our conclusions by calibrating the date for G.529, which has a *terminus post quem* (TPQ) date of AD 872 (see below), using ten different ΔR values from a range of other Northern European locations. Although the range of reference values is high (from -131 ± 40 to 83 ± 48), the results show relatively little variation and are all consistent with the archaeologically derived date (Table S1). This demonstrates the robustness of our chosen value.

Individual and double graves

The sample from the monastic cemetery (G.97) is consistent with the archaeologically derived date of between the seventh and eighth centuries AD; this is true for both the terrestrial and marine calibrations (AD 663–769 and AD 686–885 respectively at 95.4% certainty).

Grave 529 provides the clearest evidence of the need for marine reservoir corrections at Repton. The sample yielded an uncalibrated ^{14}C date of 1281 ± 27 BP, which provides a terrestrial calibration of AD 670–770 at 95.4% certainty. This individual was buried with five silver pennies, two of Burghred and three of Alfred, dated to no earlier than

Table 2. Calibrated ¹⁴C dates, using both terrestrial and mixed marine/terrestrial calibration curves.

Grave or charnel bone ID	Cemetery	Lab. ID	¹⁴ C BP	Terrestrial calibration (cal years AD, 95.4% certainty)	Mixed marine/terrestrial calibration (cal years AD, 95.4% certainty)
G97	1	OxA-31451	1298±24	663–769	686–885
G529	3	OxA-12024	1281±27	670–770	690–939
G511	3	OxA-12023	1250±25	677–866	772–975
G295	3	OxA-12004	1209±27	715–890	773–972
G.511/7109	3	OxA-14570	1215±29	695–889	–
G387	3M	OxA-12009	1233±25	689–879	778–990
G360	F940	OxA-12005	1230±24	690–881	720–966
G361	F940	OxA-12006	1193±25	730–893	770–980
G362	F940	OxA-12007	1218±25	696–887	720–968
G363	F940	OxA-12008	1236±25	687–877	682–894
RF.3391	F940	OxA-12364	1199±27	721–893	–
X-03	charnel	OxA-13076	1273±27	665–775	694–951
X-17	charnel	OxA-31524	1256±28	672–866	724–977
X-23	charnel	OxA-31449	1267±22	677–773	693–948
X-70	charnel	OxA-31450	1217±28	696–888	780–1017
H-537	charnel	OxA-31611	1333±25	649–765	675–876
U-480	charnel	OxA-12001	1271±26	667–775	690–942
F359	charnel	OxA-12002	1223±25	695–884	773–980
F391	charnel	OxA-12003	1230±25	690–881	773–981

AD 873 (Biddle *et al.* 1986). This TPQ date makes the terrestrial calibration at the very least 100 years too early. With an estimated marine dietary input of 15.3±10%, a mixed marine/terrestrial calibration gives a date of AD 690–939 (95.4% certainty), which is consistent with the coin date. Taking the TPQ into account, the grave can be further constrained to AD 873–939.

A similar result is evident from grave G.387 from cemetery 3M. From its location, this grave must post-date the AD 872–874 date of the coins found among the charnel deposit, as it is stratigraphically later than the construction of the mound. From an uncalibrated ¹⁴C determination of 1233±25 BP, a terrestrial calibration yields a date of AD 689–879 at 95.4% certainty. While not entirely unfeasible, this result is inconsistent with the archaeologically derived date of AD 900–1000 for cemetery 3M. An MRE correction using an estimated marine dietary input of 31.8±10% gives a calibrated age of AD 778–990, which can be limited to AD 872–990 from the coin finds described above. Therefore, with the appropriate correction, this date is actually in good agreement with the archaeological evidence.

Individually, the fully terrestrial calibrations of the double grave of G.511 and G.295 give dates of AD 677–866 and AD 715–890 respectively (95.4% confidence). The early date for G.511 is inconsistent with our current understanding of the historical and archaeological evidence. The grave goods leave little doubt as to the Scandinavian cultural identity of

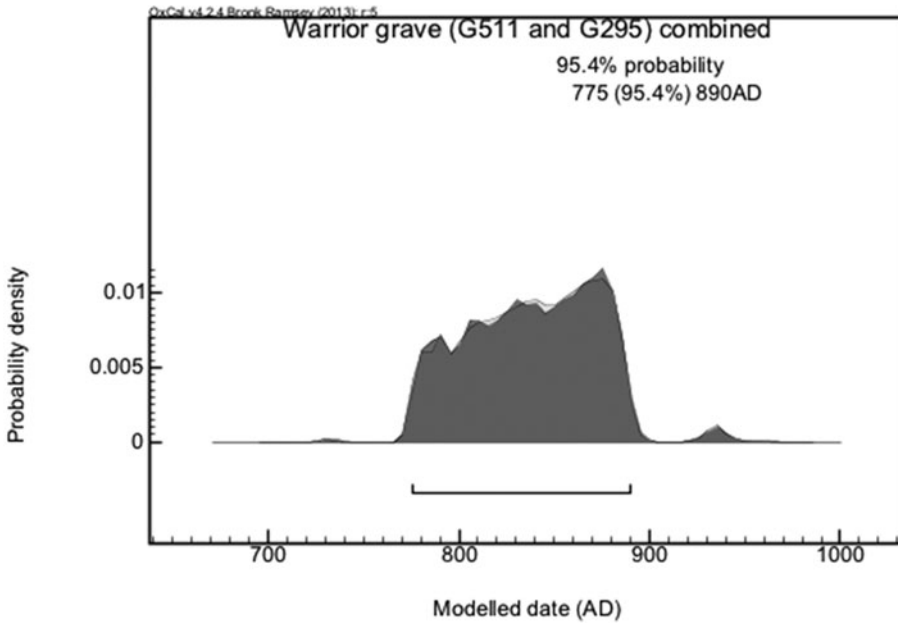


Figure 5. Plot of the combined mixed marine/terrestrial calibration of G.511, G.295 and the boar's tusk.

this individual, yet a date before AD 873 seems unlikely, as there is no evidence for a Scandinavian presence in Repton prior to this date. MRE corrections based on marine diet amounts of $28.2 \pm 10\%$ and $23.1 \pm 10\%$, however, give calibrated dates of AD 772–975 and AD 773–972 for G.511 and G.295 respectively. A boar tusk buried with G.511 yielded a calibrated date of AD 695–889, assuming a terrestrial calibration. As the three samples are clearly coeval, we can apply OxCal's Combine function to obtain a modelled date of AD 778–886 (95.4% confidence, $A_{\text{comb}} = 116.4\%$, Figure 5). Assuming a TPQ of AD 873 on the basis of the historical evidence narrows the date for the double grave to AD 873–886.

Juvenile grave, feature 940

Terrestrial calibrations of all four juveniles fall between AD 687 and 893 at 95.4% certainty, and the sheep jaw from the same deposit dates to AD 721–893. Marine foods appear to have formed a relatively small part of the diet of these individuals (ranging from $5.9\text{--}15.3 \pm 10\%$), yet MRE corrections move the calibrated dates to between AD 695 and 990. As the deposition of the four individuals and the sheep jaw was clearly simultaneous, we can use OxCal's Combine function to constrain a modelled and MRE-corrected date of AD 778–885 (Figure 6).

The juvenile grave is located just outside the edge of the stone kerb surrounding the charnel mound. There is no evidence that any of the graves in cemetery 3M pre-date the construction of the mound, and the grave cut of F940 carefully follows the alignment of the remaining burials. For this reason, it is highly unlikely that the grave pre-dates the AD 872 TPQ date for the construction of the mound. Therefore, we can tentatively accept

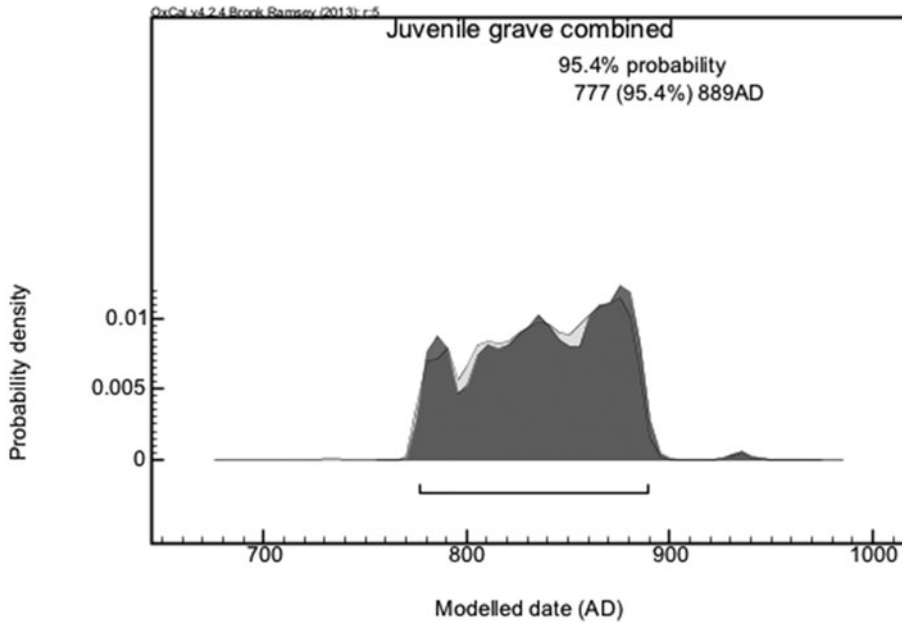


Figure 6. Plot of the combined mixed marine/terrestrial calibration of the burials in the juvenile grave (F.940).

this TPQ for the juvenile grave, which provides us with a very narrow date range of AD 872–885.

Charnel

With fully terrestrial calibrations, the charnel samples fall in a similar grouped pattern to the Utrecht dates, with some encompassing the presumed late ninth-century date, and others substantially pre-dating it (Figure 4). It is clear from the $\delta^{13}\text{C}$ values (-19.2 to -18.2‰ ; Table 1) that some individuals had considerable marine dietary input, up to a maximum of $32.9 \pm 10\%$ for sample X70. Individual MRE corrections shift the latest possible date for all samples to at least the late ninth, if not the tenth, century AD (Table 2; Figure 7). As such, a date of AD 872–874, as suggested by the archaeological and numismatic evidence, is consistent with all the bone samples dated here. If, as the archaeological context indicates, this is one deposit, then we can further apply a Combine function, on the assumption that the remains are coeval. This provides a combined date of AD 779–887 for the charnel deposit (95.4% certainty, $A_{\text{comb}} = 79.9\%$).

It is important to note that although the calibrated samples from cemeteries 1 and 3 are consistent with the archaeologically derived dates, the age ranges are wide due to a plateau in the terrestrial calibration curve. This is also the case for the charnel deposit. Therefore, the dates encompass both the period of the historically attested Viking presence in Repton, and the latest period of monastic use of the site. To model the effect of this plateau, OxCal's R_Simulate function can randomly generate calibrated distributions, assuming a true age of AD 873. This shows that the ages equivalent to AD 873 range widely, but that discerning

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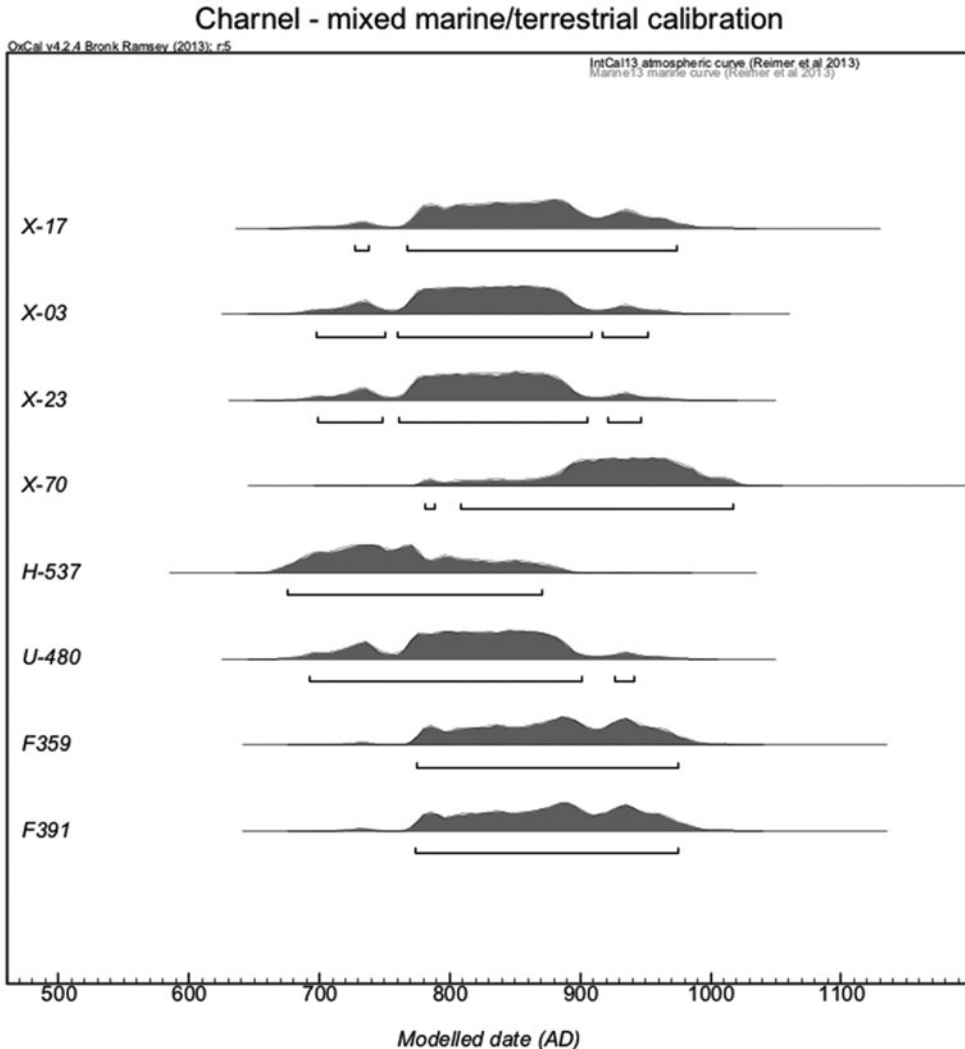


Figure 7. Plot of the combined mixed marine/terrestrial calibration of the new charnel samples.

samples from AD 873–874 from earlier periods, such as around AD 750 or AD 800, is possible. The plateau in the calibration curve artificially spreads ages to be too old, rather than too young. It is notable that the graves in cemetery 3, which yielded Viking Age grave goods, share a similar spread of calibrated date ranges with the charnel deposit.

Summary and conclusions

The data presented here clearly demonstrate that the apparent groupings seen in the previously published charnel ^{14}C dataset are a result of MREs, rather than a reflection of the true age of the samples. Significantly, our calibrations show that the deposit is fully

consistent with a single event dating to the late ninth century AD. Previous suggestions that some of the skeletal remains in the charnel originated from the monastic cemeteries, disinterred during the construction of the D-shaped enclosure, are founded entirely on the earlier dates previously accepted for some of the bones (Richards *et al.* 2004). The current results show that the radiocarbon dates do not support this line of argument.

Importantly, the very narrow date range of AD 872–885 for the juvenile grave helps support a Viking association for the charnel. Although an interpretation of this grave as sacrificial is uncertain, the deliberate arrangement of these four individuals, the sheep jaw and the possible grave marker in close proximity to the edge of the mound attests to its relationship to the charnel.

In summary, the new radiocarbon dates show that:

- MRE calibrations are vital for accurately dating the Repton material—the early dates from the charnel were caused by a lack of such corrections.
- The charnel is consistent with a single deposit in the late ninth century.
- The warrior double grave and the juvenile grave can both be constrained to narrow date ranges (AD 873–886 and AD 872–885 respectively), which are consistent with the archaeological and historical evidence.

The new data presented here fully support the hypothesis that the Repton charnel contains the remains of members of the Viking Great Army, and further confirms the chronology of the Viking use of St Wystan's church and its surroundings for burial. In addition to helping understand the movements of the Great Army and the subsequent settlement of a Scandinavian population in England, this study has broader implications in emphasising the importance of applying MRE corrections to radiocarbon dates from human bone. Isotope analysis of human tissues is becoming increasingly standard practice for studying geographic origins and aDNA methods are improving rapidly. This means that there is now greater potential than ever for the range of information that can be obtained from human remains alone. For charnels and other types of secondary burial, as well as other scenarios where context and stratigraphy are lacking or unclear, MRE corrections are essential. Sites with multiple burials and commingled remains may contain evidence for large populations; bioarchaeological data can therefore be used to inform about population dynamics or migration events. Similarly, for cases where radiocarbon dates seem anomalous or incompatible with other forms of evidence, correcting for MREs is strongly recommended. As the Repton example shows, such datasets benefit from reassessment if these corrections have not previously been applied, as failure to do so may lead to inaccurate or even erroneous interpretations.

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Supplementary material

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