Suspect graveyard burial (South Armagh, N. Ireland): Combined search, forensic anthropology and radiocarbon dating

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Case Study

Suspect graveyard burial (South Armagh, N. Ireland): Combined search, forensic anthropology and radiocarbon dating

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ABSTRACT

Geophysical investigation of a former convent graveyard for conversion to a community centre identified an unrecorded, unmarked burial below a later burial. Archaeological excavation confirmed the presence of skeletonized human remains, considered by police as a possible clandestine burial. Mortuary examination indicated the remains belonged to a mature adult female. To determine whether the deceased could be a recorded missing person, radiocarbon dating was undertaken on a femur and a rib bone. This is not always straightforward, and results showed two possible ages due to intercepts on either side of the nuclear weapons testing spike in atmospheric ^{14}C; however, the later dated burial allowed us to constrain the date of a rib to CE 1959. This study demonstrates that dating a second tissue with a longer turnaround time, such as a femur, can help to constrain which side of the bomb spike is most probable. This paper documents in one work the search, scene and sample and then advances this to resolution by anthropological analysis and radiocarbon dating of human remains.

1. Introduction

An unrecorded burial was discovered in 2016 during the exhumation of 43 skeletonised individuals who were buried at the Sisters of St Louis Convent Cemetery in Middletown, Co. Armagh, N. Ireland, which was in use from 1882 to 2004. Published case studies on the geophysical search for buried human remains e.g. Pringle et al. [1] on the osteo-archaeological characterisation of skeletal remains e.g. Nikita [2] and on the age-dating of such, especially by radiocarbon: see Brock & Cook [3] are abundant in the literature.

However, rarely are all three processes integrated, to show how remains are found, the individual examined and then a date for the remains provided. In this work we describe this process as an example of how geophysics in search, osteology and absolute dating can be joined-up to create a fuller picture of how the skeleton came to be in the location. Assessment of burials in graveyards may seem counter-intuitive, given that human remains are interred in these locations, usually with some kind of marker such as a headstone. However, locating unmarked burials in graveyards is a frequent practice as recording is not always accurate, headstones may be absent or decay, and human remains may be displaced in the subsurface ('coffin-slip', burrowing animals, ground disturbance) [4–6].

The most common need for burial-location assessment is due to the limited space available in religious and civil burial grounds [7]. However, the declining use of ecclesiastical buildings (churches, parochial buildings, convents, monasteries) has led to abandonment, disrepair, sale and sometimes refurbishment as commercial properties, dwellings and community centres [7]. Such redevelopment leaves the issue of buried human remains, which can be marked and left, or excavated, removed and re-buried: the reason for this study. Graveyards are not uncommon sites for clandestine burials, see Kaplan [8], sometimes as a result of homicide [9].

Brock & Cook p.4 [3] recount how radiocarbon dating "can be vital in cases of accidental discovery of human remains and where little contextual information is available and police need to investigate whether the remains are of forensic interest or archaeological in origin". Another study by Cook et al. [10] encompasses the findings of a forensic investigation, including the analyses of skeletal remains and the results from radiocarbon dating and isotopes. However, there are few studies that recount the process of forensic search, through osteoarchaeological analysis to dating, as we do here, providing an integrated account of each process, commonly known in forensic geology and geoforensics as the science of the Search, the Scene and the Sample. As Donnelly et al. p.16 [11] state "The expertise provided …. is generally regarded to fall into the three following categories; 1. ground search for burials, 2. crime scene examination and 3. geological trace evidence recovery and

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analysis". In this paper, part 3. comprises osteoarchaeological and radiocarbon, not geological investigation.

2. Case background

Middletown is a small village in County Armagh, Northern Ireland (population, 352), approx. 1 km east of the border with County Monaghan (Republic of Ireland). The area is a glaciated terrane of drumlins composed of bedrock masses and glacial till, with lowland areas filled with post-glacial sands, redeposited glacial till, alluvium, fluvial deposits and peat. The church and graveyard studied here rests on alluvium with peat deposits. St Louis Roman Catholic convent was established here gradually through the early 1800s, with a school for girls added in 1878. The school became a national technical college in the 1960s however, a decline in the number of women wishing to take ecclesiastical orders and become church sisters in the late 20th century resulted in the closure of the convent in 2012. Refurbishment of the buildings began in 2010 and the survey of the burial ground took place in late 2009 and 2010, followed by the excavation of 43 known graves and removal of skeletal remains in April 2016. The skeletal remains were re-interred in a nearby sanctified Christian burial ground in late April 2016. A list of the 43 re-interred Sisters along with their date of death is included on the Sisters of Saint Louis newsletter [12].

However, an additional burial was identified by a geophysical survey, leading to the work presented here. This was considered an unmarked grave and thus a potential suspect burial, or possibly a homicide grave. At the time of exhumation/mortuary examination, possible explanations for the burial included the following:

1. The unknown remains belong to a nun who was an orphan and whose true birth details were never fully known and was buried with a fellow nun and unmarked.

2. This is a case of poor record keeping and a mistake was made which saw the unknown burial as unrecorded.

3. This is an unauthorised burial and is not a nun of the order and there is a suspicious element to it.

The aim of this work is to provide the context (geophysical search), the osteoarchaeological analysis, and radiocarbon dating, in order to consider the above possibilities.

3. Geophysical search

To assess the burials in the graveyard, an electro-magnetic (EM) survey of the graveyard was conducted in 2010, using a Geonics EM38 and including the area of grave-plots belonging to the convent. The proximity of the burials in the convent plot created some difficulty in separating possible inhumation-related anomalies. Therefore, the burials were individually mapped using ground-penetrating radar (GPR, Mala Geoscience 250 MHz and 500 MHz shielded antennas). Most burials showed typical hyperbolae at the top of inhumations (Fig. 1). However, one profile indicated an anomaly close to, and slightly deeper than, a marked, shallower burial (Fig. 1). Although this could have been taphonomic disarticulation, e.g. through coffin-slip (see above for explanation) or with no coffin 'cadaver slip', the flat ground and underlying geology of the cemetery made this unlikely, and an additional inhumation was suggested.

Excavation for re-internment was completed by the Police Service of Northern Ireland Disaster Victim Identification team and the 'extra' inhumation investigated following the removal of skeletal remains from the shallower burial dating to 1968 (convent records). The investigation confirmed an additional unrecorded burial which was a potential clandestine grave and possible homicide location, possibly due to sociopolitical conflict in the area during the late 1960s. The skeletal material was removed and transported to the State Pathologists Mortuary (Belfast Royal Victoria Hospital, N. Ireland) for further examination and radiocarbon dating was requested in order to give a definitive date and to rule out criminal activity.

4. Anthropological analysis

The unknown skeletal remains were placed into a white zipped forensic plastic bag and transported to the pathology laboratory in April 2016 for analysis. Visual examination showed a set of well-preserved partially complete human skeletal remains along with a ragged piece of black cloth measuring 9 × 3 cm (when unfolded) and a fragment of wood measuring 8.5 × 3 × 2.5 cm. A solitary iron nail measuring 3.5 cm in length and a small metal cross were discovered embedded within the wooden fragment (Fig. 2).

The neurocranium along with the superior portion of the nasal bones are present. The viscerocranium is missing and unfortunately no teeth were recovered from the burial. The right humerus and ulna and the left femur and fibula are present and are mostly intact. The head of the fibula is missing and taphonomic modification has resulted in erosion on the lesser tubercle of the humerus and on both epicondyles of the femur. A proximal phalanx of unknown side and number was discovered along with three right proximal segments of middle-lower ribs, one proximal segment of a left middle rib, three unidentified rib shaft fragments and the lateral border of the right scapula. The left ilium was recovered and exhibits moderate taphonomic erosion on the posterior iliac crest and on

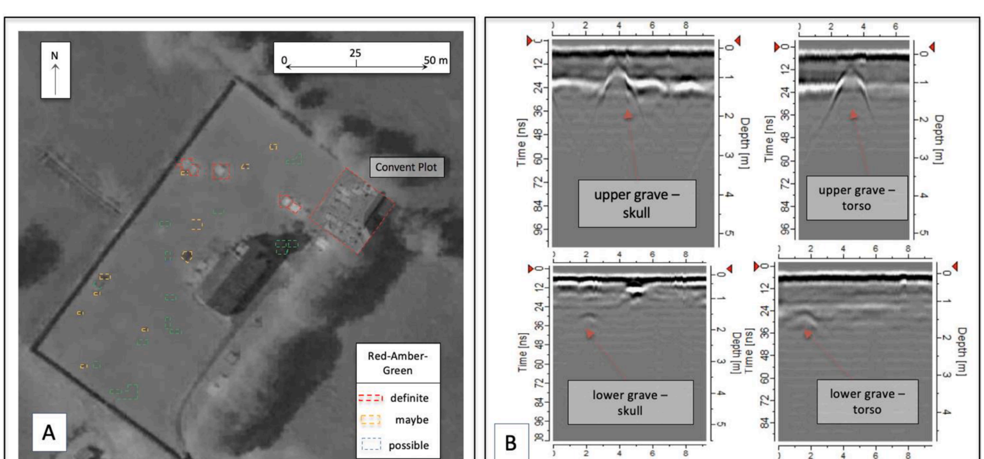

Fig. 1. Geophysical survey results. A. Electromagnetics plot, where a RAG (Red, Amber, Green) system was used to convey confidence limits on whether burials remained intact (see Ruffell & McAllister [5]. The convent burials were all designated as present, plus one additional burial. B. Ground penetrating radar profiles through the known (shallower) inhumation, with the 'extra' unknown, vague and deeper anomaly.

Fig. 2. Human skeletal remains and possible coffin material (metal cross, wooden fragment bottom left of image and scrap piece of black fabric next to the neurocranium far right of image) recovered from the Sisters of St Louis Convent Cemetery, Co. Armagh.

the surface of the acetabulum. No other skeletal elements were recovered. The bones predominantly displayed a medium brown colour along with light brown/tan and dark brown/black discolouration relating to the soil profile of the burial site [13,14].

An osteoarchaeological analysis can be useful for describing the condition of bone and estimating if they are likely to be contemporary or ancient remains. However, it cannot provide a definitive date of death. Therefore, an unidentified rib shaft fragment and a cross-section of the femoral mid shaft, including the entire thickness of the cortex, measuring 9.7 cm were selected for radiocarbon dating and isotopic analysis. These samples were chosen based upon the size and preservation of the skeletal material and to avoid destruction of key diagnostic elements [15,16]. The osteological analysis of biological sex, age-at-death and stature estimations were carried out on dry bone and the results were compared with reference parameters of known populations.

4.1. Sex determination

Biological sex was estimated using visual characteristics of the neurocranium and ilium along with osteometric measurements of the humeral and femoral heads [17–23]. The overall rounded shape of the cranial vault along with a smooth glabella profile, a small external occipital protuberance, a smooth nuchal region and rounded superior orbital outlines with sharp margins are indicative of a female individual [24]. This sex estimation was supported by the large, U shaped greater sciatic notch (>60°) on the left ilium along with a long preauricular sulcus and the osteometric measurements of the humeral (<42.67 mm) and femoral heads (<41.5 mm), suggesting that the individual was probably female [22].

4.2. Age-at-death

The age-at-death of the individual was estimated using skeletal maturity methods based upon epiphyseal fusion of the iliac crest [25] and the degree of degeneration of the articular surface [26,27]. Examination of the ilium showed complete union of the iliac crest suggesting that the remains are those of an adult aged > 23 years old [25]. The articular surface of the ilium exhibited a dense irregular surface with loss of transverse billows and granularity along with irregular changes to the apex giving an age-at-death range of 50–59 years [26]. However, as [28–32] have shown, the Lovejoy et al. [26] method tends to underestimate the age of older individuals, so the revised quantitative scoring system produced by Schmitt [27] was used. This technique involves recording four morphological characters of the sacropelvic surface (the auricular surface and the iliac tuberosity) independently of each other [27,33]. The revised method is appropriate as it considers the variability of the sacropelvic surface morphological changes between different populations and as it has been tested on independent samples [34]. The physical appearance of the sacropelvic surface showed no ripples, a combination of coarse granulation and partial porosities, a slightly raised apex margin and entheseal remodelling corresponded to an age-at-death of > 50 years [27]. Thus the combined methods suggest that this adult individual was > 50 years old at the time of death.

4.3. Stature

The stature of the individual was estimated by measuring the maximum lengths of the intact long bones (femur and humerus) using an osteometric board, with a preference given to the bone with the least standard deviation (i.e. the femur). The measurements were calculated using the regression formulae for Caucasian female populations [35]. The left femur measured 450 mm, giving an estimated stature of 165.25 cm +/-3.72 cm (5 feet 4 in.). The right humerus measured 300 mm, giving an estimated stature of 158.77 cm +/- 4.45 cm (5 feet 2 in.).

However, in order to compensate for the progressive decline of stature in older adults, associated with increased bone resorption resulting in deprivation of bone mineral density, stature estimations were adjusted following the stature correction method for female individuals aged > 45 years [36]. The correction method is considered the most appropriate technique for estimating loss of stature due to data utilized from two large longitudinal studies of males and females over a 5–10-year period [36,37]. As the exact age of the individual is unknown the age point of 55 years (identified from rounding up the auricular surface midpoint age range estimation of 50–59 years) was taken and gave an approximate correction value of 2.75 cm.

This value was subtracted from the overall maximum stature estimations resulting in a final femur stature estimate of 162.5 cm +/-3.72 cm (5 feet 3 in.) and a final humerus estimated stature of 156.05 cm +/- 4.45 cm (5 feet 1 in.).

4.4. Non-Metric traits

Non-metric (discontinuous morphological) traits are osseous anomalies in the normal anatomy of the skeleton which are possibly influenced by sex, genetics and developmental and environmental factors [38,39]. A non-metric cranial trait was observed on the left orbital rim of the frontal bone approximately 25 mm lateral to the midline. The supraorbital nerve usually transmits through a supraorbital notch. However, a common non-metric variation is the bridging of this notch resulting in a supraorbital foramen. Clinical studies have reported that this anatomical variation occurs in 17.7 % to 35.4 % of cadaver populations and varies between males and females and between populations [40–45].

4.5. Non-specific infections

Healed periosteal lesions, in the form of relatively smooth, remodelled and organised lamellar bone, were observed on the anterior aspect of the mid femoral diaphysis. The lesion is focal and affected approximate 25 % of the bone [46]. Periosteal new bone formation (periostitis) is a nonspecific inflammation of the periosteum which can occur as a primary or as a secondary response to a variety of local or systemic inflammatory and infectious diseases such as inflammatory bowel diseases and trauma such as stress fractures [47,48]. The condition is frequently encountered on the tibia diaphysis, possibly due to the proximity of the periosteum to the surface of the skin making it more exposed to trauma and a cooler environment for bacteria in comparison to the femur which is protected by muscle and fat tissue, and displays symptoms including pain, swelling and mobility of the affected limb [49–51]. Anthropological studies have shown that the condition occurs in 3 %-77 % of past populations and varies greatly according to sex, era and population [50]. However, the prevalence of periostitis in modern populations is difficult to establish as reliable epidemiological studies involving large samples have not been produced, possibly due to clinical objectives concerning the diagnosis and treatment of the condition rather than recording frequencies of occurrences.

5. Radiocarbon dating/isotopic analysis

Radiocarbon dating and isotopic analysis was carried out at the ^{14}CHRONO Centre for Climate, the Environment and Chronology (Queen's University Belfast) on two bones: a femur and a rib. Collagen was extracted following a routine ultrafiltration method [52]. Freeze-dried collagen was combusted to carbon dioxide (CO_2) in a sealed tube with an excess of copper oxide (CuO) and converted to graphite using the zinc reduction method [53]. The $^{14}C/^{12}C$ ratio was measured using a 0.5Mv National Electrostatic Corporation accelerator mass spectrometer and blank corrected using measurements on the Latton mammoth bone collagen [54]. The $^{14}C/^{12}C$ ratio was normalised to the HOXII standard (SRM 4990C; National Institute of Standards and Technology) and corrected for isotope fractionation using the AMS measured $\delta^{13}C$. The conventional radiocarbon age and one standard deviation were calculated following Stuiver and Polach [55] with the Libby half-life of 5568 years. ^{14}C data for modern samples are presented as $F^{14}C$ values [56]. The maximum of the measurement statistics and the variance of seven to eight two-minute AMS runs for each sample were used for the 1σ uncertainties.

$\delta^{13}C$ and $\delta^{15}N$ were measured in duplicate on a Thermo Delta V Isotope Ratio Mass Spectrometer (IRMS) coupled to a Thermo Flash 1112 Elemental Analyzer (EA). Replicates of seven archaeological bone collagen samples were used to estimate the instrumental measurement uncertainties for $\delta^{13}C$, $\delta^{15}N$, and atomic C:N to ± 0.22 ‰, ±0.15 ‰, and ± 0.2, respectively (1 sd). As conventional, results were calculated relative to the international standards VPDB ($\delta^{13}C$) and AIR ($\delta^{15}N$).

Radiocarbon ages are not equivalent to calendar years because the production of ^{14}C in the atmosphere and the rate of exchange of carbon dioxide with the ocean are not constant. A correction for this can be made through the use of calibration curves constructed from known age material. Calibration of radiocarbon dates from the period 1650–1950 CE yield a broad range of possible calendar dates due to the variability in the calibration curve caused by input of ^{14}C-depleted fossil fuel carbon into the atmosphere as well as natural variations. This problem can be alleviated if one has a series of radiocarbon dates such as tree-rings separated by some number of rings or, in the case of forensics, bones with differing carbon turnover rates. In addition to natural atmospheric ^{14}C variations, the mid-1950s and 1960s saw a proliferation of nuclear testing which created an artificial spike of ^{14}C which peaked in 1963 and tailed off after the moratorium on above ground testing. This so-called bomb spike in ^{14}C provides a very useful marker for samples after 1955 although usually results in two distinct probable age ranges on either side of the 1963 peak. The use of two tissue types with different carbon turnover times, can sometimes resolve which side of the bomb peak is correct. For calibration of the bone collagen ^{14}C values we assumed the person had lived in the Northern Hemisphere and used the on-line CALIBomb software [57] with the Northern Hemisphere Zone 1 compilation of atmospheric CO_2 and tree-ring measurements [58] linked to the Northern Hemisphere IntCal20 calibration curve [59]. The calibration curve was smoothed by the estimated carbon turnover times for the femur and rib to mimic the natural averaging of bone carbon during growth and to reduce the number of calendar age ranges of <1 year duration.

The use of radiocarbon ages for forensics also requires consideration of the estimated age, sex and health of the subject, the particular bone or tissue sampled and the diet of the individual over the time period of the bone formation. As described earlier, the anthropological investigation of the age indicates the subject was a female > 50 years of age and had suffered from periosteal lesions that affected approximately 25 % of the femur. The lesions had healed which implies new bone formation. In adult females the collagen turnover rate in the femur has been shown to be approximately 4 % per year which decreases to about 3 % per year by age 80 [60]. The carbon in the collagen is thus likely to be >10 years older and may even be up to 30 to 35 years older than the date of death in some individuals [61,62] although this may be affected by the new bone formation in the healed lesions. Rib bones remodel on the order of a few years [63]. We use an estimate of 20 years for carbon turnover in the femur and 3 years for the that in the rib.

Stable isotopes such as $\delta^{13}C$ and $\delta^{15}N$ provide only limited information on the geographic region where the person lived. They can indicate a diet high in C4 plants which might suggest a person from a region where maize or millet is the primary grain crop, although given modern, global diets this is uncertain. In some cases, diet can affect the radiocarbon ages of the bone collagen. Stable isotopes such as $\delta^{13}C$ and $\delta^{15}N$ are useful for estimating the amount of marine protein in the diet although interpretation can be complex. We analysed $\delta^{13}C$ and $\delta^{15}N$ of the collagen extracted from the rib and femur.

Radiocarbon and stable isotope results are given in Table 1. The atomic ratio of carbon to nitrogen (C:N) and the collagen yields are both indications that the bone collagen was well preserved with no extraneous carbon included [64]. The $\delta^{13}C$ value of the femur is typical of a terrestrial diet based on C3 vegetation (e.g. plants that form a 3 carbon chain in the first step of the photosynthetic cycle) which excludes C4 plants such as maize and millet whereas the $\delta^{15}N$ indicates a diet which includes animal protein and/or freshwater fish. The rib bone $\delta^{13}C$ value of −18.3 ‰ and $\delta^{15}N$ value of 11.7 ‰ may indicate a shift in diet to include some marine protein later in life. For comparison a 100 % marine diet would result in bone collagen $\delta^{13}C$ and $\delta^{15}N$ values around −16 to −11 ‰ and 15 to 20 ‰, respectively [65,66]. A thorough analysis of diet including comparison with isotopic values of terrestrial herbivores and plants as well as potential marine foods consumed would be needed to determine the percentage of marine protein in the diet of the individual studied. We have therefore assumed no significant percentage of marine protein in our analysis but it is unlikely that even as much as 20 % would alter our conclusions.

The radiocarbon ages, $F^{14}C$ values, calibrated age ranges and relative probabilities for the samples are given in Table 2. The calibration of the $F^{14}C$ value of the femur resulted in a numerous possibly age ranges between 1665 and 1949 CE at 95.4 % confidence limits (Fig. 3, Table 2). While the highest probability is for the age range cal CE 1718–1822, none of the age ranges can be ruled out from this radiocarbon age alone.

Table 1
Stable isotope results and collagen quality indicators.

Sample	$\delta^{13}C_{VPDB}$ (‰)	$\delta^{15}N_{AIR}$ (‰)	C:N	Collagen Yield (%)
Femur	−19.4	11.3	3.16	9.60
Rib	−18.3	11.7	3.06	14.7

Table 2
Radiocarbon ages, $F^{14}C$ values, calibrated age ranges and relative probability (in parenthesis) at 95.4% probability.

Sample	Lab ID	^{14}C BP	$F^{14}C$ (‰)	Cal age ranges (cal AD) (relative probability)
Femur	UBA-32477	157 ± 30	0.9807 ± 0.0036	1665–1705 (0.168) 1718–1822 (0.506) 1828–1884 (0.148) 1912–1949 (0.178)
Rib	UBA-39706	>modern	1.1829 ± 0.0041	1959.0–1959.5 (0.152) 1986.8–1988.7 (0.848)

The calibration of the rib $F^{14}C$ value resulted in two possible age ranges: 1959 or 1987–1989 rounded to the nearest year (Fig. 4, Table 2). The higher probability in the cal CE 1987–1989 range compared to cal CE 1959 is an artefact of the steep rise and slow fall of the bomb peak. The fact that the femur and rib are from the same individual makes the cal CE 1912–1949 age range for the femur the most likely. If we add the estimated carbon turnover time of 20 years to the most recent femur age range, then the latest possible year of death based on its calibrated age ranges would be 1969. This would rule out 1987–89 age range for the rib. However, a longer carbon turnover time for the femur is possible so we cannot be completely certain. The fact that the bones were discovered in a deeper grave below the intact skeleton of a nun who was

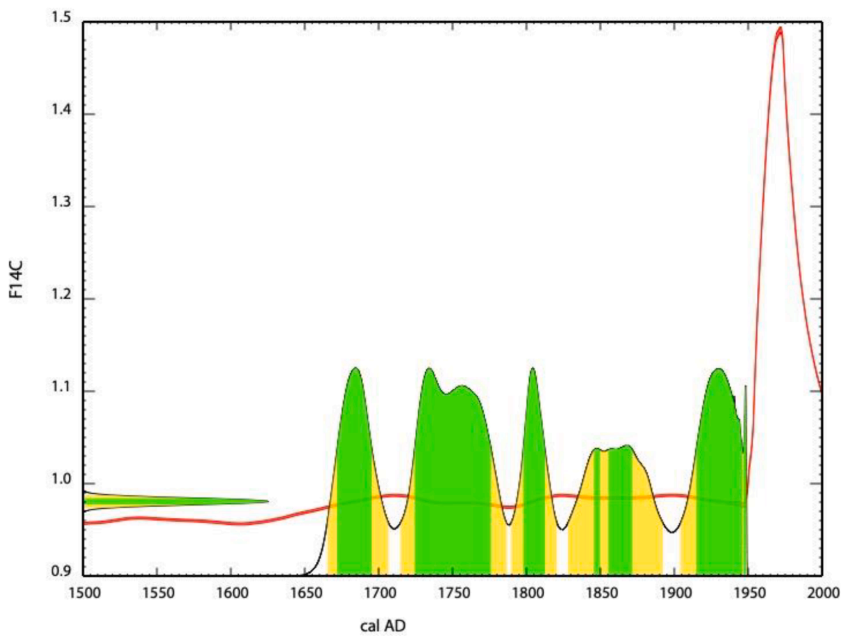

Fig. 3. Calibration plot for the femur sample with an $F^{14}C$ value of 0.9807 ± 0.0036. The $F^{14}C$ value is calibrated using CALIBomb, Reimer & Reimer [57], and the post-bomb atmospheric NH1 curve, Hua et al. [58], with 20 year smoothing. Green bands are 68.3 % probability ranges and yellow are 95.4 %.

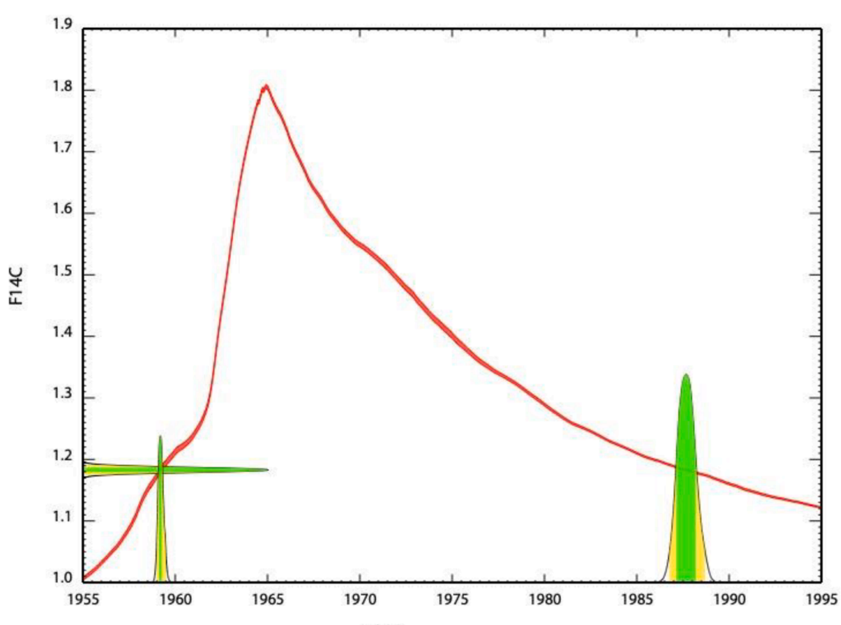

Fig. 4. Calibration plot for the rib sample with an $F^{14}C$ value of 1.1829 ± 0.0041. The date is calibrated using CALIBomb, Reimer & Reimer [57], and the post-bomb atmospheric NH1 curve, Hua et al. [58], with 3 year smoothing. Green bands are 68.3 % probability ranges and yellow are 95.4 %.

interred in 1968 suggests we can reject the more recent age range albeit with caution.

6. Conclusion

This study encompasses the findings of a forensic investigation including the geophysical survey, the analyses of skeletal remains and the results from radiocarbon dating.

The findings from the geophysical search at the convent cemetery revealed 43 known burials plus an additional unrecorded burial. Due to the number of reported missing persons in the area the unmarked grave was treated as a potential suspect burial/homicide grave.

The anthropological analysis revealed that the remains likely belonged to an adult female aged > 50 years. The results from stature demonstrated that the individual was approximately 162.5 cm +/-3.72 cm (5 feet 3 in.) in height and exhibited evidence of healed femoral periostitis along with a left supraorbital foramen. The results from radiocarbon dating produced one age range from the femur: 1665–1949 and two age ranges from the rib: 1959 and 1987–1989. If we add an estimated carbon turnover time of 20 years to the most recent femur date, then the latest possible year of death based on its calibrated age ranges would be 1969. This would rule out 1987–89 age range for the rib. However, a longer turnover time is possible so we cannot be completely certain. The fact that the bones were discovered in a deeper grave below the intact skeleton of a nun who was interred in 1968 suggests we can reject the more recent age range albeit with caution. In archaeological dating cortical bone is preferred because there is less chance of contamination from humic acids in the soil, however, for forensics, trabecular bones such as ribs or vertebra give a more reliable date of death due to the lower carbon turnover time. Our results are in agreement with previously published forensics studies indicating that, when no fingernails or soft tissue are available for radiocarbon dating, dating a rib bone is preferential to a femur for estimating date of death (Brock & Cook [3]). As the skeletal remains were discovered under the remains of a nun who was interned in 1968 this provides a *terminus post quem* leaving 1959 as the most likely date for the recovered skeletonised remains. The reported results did not compare to any record of a missing person from this time and of this age/sex/stature, thus remaining a mystery: conversely, no relevant homicide investigation records exist to warrant further analysis. The remains were re-interred at a nearby sanctified Christian burial ground in September 2016, alongside the 43 skeletonised individuals.

Our three aims were to consider:

1. The unknown remains being a nun in an unmarked grave, possibly co-mingled.
2. A case of poor record keeping with no extant documentary evidence.
3. An unauthorised burial (not a nun) with a suspicious element to it.

The authors consider 1. as unlikely, although the remains were fragmentary and the succeeding burial could have disturbed the underlying remains; 2. is most likely and 3. is unlikely, as this would have to have been an extremely sophisticated illicit disposal, to fake the death of a nun.

Although the focus of the investigation was to seek clarity on the human remains recovered it is worth mentioning that the presence of a small metal crucifix, a solitary iron nail embedded within a wooden fragment and a piece of black cloth (Fig. 2) are consistent with the burial practices of nuns belonging to a Roman Catholic religious order such as The Sisters of Saint Louis. In such a monastic order it was once custom to wear religious garb including a black habit, veil and a crucifix or rosary worn over the habit and around the neck in daily life. During the 1960s and 1970s the traditional habit was gradually modified to a secular dress for everyday life while burial practices still reflected traditional apparel in keeping with the religious order's identity [67]. Although these objects may indicate that unknown remains belong to a nun they do not however, verify that this is indeed a convent burial as such items can also be found enclosed within interments of Catholic congregation lay members. The burial practices of nuns in Ireland warrants further research however, it was not possible to explore or compare the objects in Fig. 2 with any other discovered artefacts from the excavation due to the nature and purposes of this investigation which focused on locating, identifying and radiocarbon dating the skeletal remains.

As aforementioned, multi-proxy investigations documenting the search, discovery, analysis and radiocarbon dating data, are rare in literature. In this study the authors have endeavoured to demonstrate the value of combining efforts in order to gain a wider overview of the scenario and establish a more precise date of death estimation than could be achieved from a single proxy. It is therefore recommended that a multi-proxy approach, including the excavation and analysis of associated artefacts, be employed for future forensic case studies so that all aspects of the search, recovery and identification findings can be fully investigated and collectively recorded.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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