MOTHER AND BABY HOMES COMMISSION OF INVESTIGATION

FIFTH INTERIM REPORT

15TH MARCH 2019

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Introduction

1. One of the major factors in the decision to establish this Commission of Investigation was the controversy about the burial practices at the Tuam Children's Home. As is now very well known, Catherine Corless established that the deaths of almost 800 children in the Tuam Home had been registered but there was no register of the burials of these children. She concluded that they were probably buried in the grounds of the former Home. The location and the manner of these burials became a major controversy.

2. The Terms of Reference of the Commission include, among other things,
   "To investigate post-mortem practices and procedures in respect of children or mothers who died while resident in these institutions, including the reporting of deaths, burial arrangements and transfer of remains to educational institutions for the purpose of anatomical examination;"

3. This report is concerned with the burial arrangements in the main institutions under investigation and with the transfer of remains to educational institutions for the purpose of anatomical examination. It is limited to burials and does not include any analysis of the causes of deaths or the registration of deaths. These issues will be dealt with in the final report.

Other institutions being investigated

4. The other institutions being investigated by the Commission are not covered in this report for a variety of reasons. Some of the other institutions do not have significant issues relating to burials either because they did not have any, or any significant number of, deaths or because the deaths did not occur in the institutions and the responsibility for burial did not lie with the institutions (for example, Dunboyne, the Castle). There is very little information available about deaths in some institutions (for example, Kilrush). The Commission's investigation of Regina Coeli is not yet sufficiently advanced. The deaths in all the institutions will be analysed in the Commission's final report and any further information on burials will also be included.

Terminology

5. The Commission is acutely conscious of the hurt that is often caused to former residents and their families when they come across words and terms that are no

longer acceptable. The Commission is writing a historical document so it is not possible to completely avoid using such terms.

"Illegitimate"

6. The term "illegitimate" is not acceptable and should never have been applied to any child. However, the fact is that it was used on official documentation until 1988 when the *Status of Children Act 1987* came into effect. The descriptions "legitimate" and "illegitimate" are used in very many of the documents being analysed by the Commission. In many cases, it is the description "illegitimate" which allows the Commission to correctly identify the children covered by its Terms of Reference.

"Home"

7. Former residents often object to the use of the word "Home" to describe the institutions. The Commission understands this and recognises that these were institutions and not "homes" in the normal meaning of the word. However, the Commission uses the historically correct title, for example, the Tuam "Children's Home". Pelletstown was the original name of St Patrick's, Navan Road. The Commission uses Pelletstown in order to avoid confusion with all the other institutions such as industrial schools and hospitals which are also called St Patrick's.

Burial ground

8. "Burial ground", "graveyard" and "cemetery" are usually regarded as synonyms nowadays. In the past, the words cemetery and graveyard applied to a designated burial area. A cemetery was generally a large burial ground especially one not in a churchyard. A graveyard generally adjoined a church. The governing legislation uses the more general term "burial ground" and this is the term used by the Commission.

Context

9. The Commission is conscious that this report is not placed in the social and economic context of the times as the final report will be. Some background information is given on the institutions in order to clarify their particular roles and who was responsible for burials. Neither Pelletstown nor Tuam was exclusively a home for unmarried mothers and their babies. Pelletstown was used to house orphans, abandoned children (who may have been "legitimate" or "illegitimate") and very sick children. Tuam was used to house homeless families and children of married parents who were unable to care for them. "Legitimate" children who were resident

in an institution with a parent are not within the Commission's Terms of Reference but those who were resident without a parent are. Bessborough, Castlepollard, Sean Ross and Bethany were almost exclusively mother and baby homes. Pelletstown and Tuam were local authority institutions while the others were private institutions.

Burials of children in non-institutional settings

10. The Commission has tried to establish what were the general practices in relation to the burial of children who died in the community in the first half of the 20th century but has had difficulty in finding solid evidence on the subject. There is anecdotal evidence that sometimes children who died were placed in a coffin with an adult. Similarly, there is anecdotal evidence that very small children were not buried in standard coffins but were either shrouded or placed in a small box. It is possible that children who were born at home and died very soon after birth had neither their births nor their deaths registered and were buried privately by their families.

Stillbirths

11. It is well established that stillborn children and unbaptised children were not generally buried in consecrated grounds but in cillíní. Sometimes the cillín was just outside the walls of a recognised burial ground. (Cillíní may also have been used for people who were not considered to be entitled to a Christian burial in a consecrated burial ground, for example, people who died by suicide.) It is very likely that all children who were born in mother and baby homes were baptised. There were stillbirths in the institutions being investigated. Stillbirths from Bethany were buried in Mount Jerome but it is not clear where stillbirths from the other institutions were buried. It seems unlikely that they were buried in the same place as baptised children.

12. It was standard practice in Dublin maternity hospitals for the hospital to arrange the burial of a stillborn child (regardless of status) without reference to the parent(s). This practice lasted at least until the 1950s.

13. It was not possible to register stillbirths until 1995.[1] Maternity homes were obliged to report the numbers of stillbirths to the Department of Local Government and Public Health (later the Department of Health).

[1] The *Stillbirth Registration Act 1994* came into effect on 1 January 1995.

Numbers of deaths

14. In analysing the information available about mothers and children who were resident in the various institutions, the Commission has paid particular attention to the deaths, the numbers involved, whether or not they were reported to other authorities when that was a requirement (for example, to the Department of Local Government and Public Health (later the Department of Health), the local health authority or the Coroner) and to the Registrar of Deaths. This involves very detailed examination of information from a number of sources, for example, the General Register Office (GRO) and returns made to the Department of Local Government and Public Health and then matching that information with the information compiled within the institutions. This exercise is complex for many reasons not least the sometimes different names and/or variations on spelling recorded in the different documents. These differences arise in some cases from the deliberate use of different names in order to maintain privacy or secrecy. More often, they arise because of different versions of the same name or simple errors such as mistakes in dates. The difficulties presented by the use of different names are described in Chapter 16 of the *Report of the Inter-Departmental Committee to establish the facts of State involvement with the Magdalen Laundries.*[2]

15. Children who were boarded out often took the surname of their foster parents. This was not illegal. Until the *Registration of Births Act 1996* came into effect, children were not given a registered surname. The child's forename was recorded as were the forename and surname of the parent(s) but there was no requirement that the child use a parent's surname. If a child who was born in an institution, and subsequently boarded out, was returned to the institution and died there, the name used may not match the original name in the institution.

16. The Commission considers that children who were sent to hospitals from the various institutions and who died soon afterwards in the hospitals should be included in the number of deaths in the institution. The GRO death registers record the information given by the informant. In some of these cases, they record the institution as the last known residence and in other cases the hospital or sometimes another location such as the home address of the mother is shown as the last known residence. This,

[2] Generally known as the McAleese Report: http://www.justice.ie/en/JELR/2013Magdalen-P%20III%20Chapter%2016%20Death%20(PDF%20-%20384KB).pdf/Files/2013Magdalen-P%20III%20Chapter%2016%20Death%20(PDF%20-%20384KB).pdf

obviously, makes it difficult to accurately identify the number of deaths. The Commission is not including children who had been in the institutions and who died after they were placed at nurse or boarded out.[3]

17. The Commission considers it important to try to trace all children who died and so it has devoted considerable time and resources to this particular exercise. There are extensive records in some cases and very sparse records in others. At this stage (March 2019) the Commission is close to finalising the detailed numbers and these will be included in the final report. In this report, the Commission gives information about the now known numbers involved. After further checking, some of these may change slightly but they can be taken as reasonably accurate.

18. All records from the various sources are not yet fully reconciled and, indeed, may never be. There are a small number of instances where, for example, the register of deaths records the last residence of a child as Bessborough or Tuam but there is no mention of this child in the records compiled in Bessborough or Tuam.

19. There are instances of deaths noted in the Tuam Children's Home records which are not on the register of deaths. The number of such discrepancies is very small and may yet be resolved. In the Commission's view, there is very little basis for the theory that the children concerned did not die but were "sold" to America. Children from Tuam were adopted to America (as were children from nearly all the institutions under investigation). These adoptions are generally recorded in the Tuam records. It is not obvious why subterfuges would be required to arrange such adoptions.

Presence of mothers

20. In the institutions other than Dublin Union/Pelletstown, the majority of child deaths occurred while the mother was also resident there. There is no information available about the involvement of mothers in decisions about the burial of the child. It seems likely that the mothers would have asked about the burial arrangements. It is not known if they were told or if they were involved in any way.

[3] Children "at nurse" were children who were placed by the mother or a voluntary agency in a private home or institution and a payment was made by the mother or agency for the child's upkeep. The *Children Act 1908*, as amended, required people taking nurse children to be registered – this issue will be dealt with in more detail in the Commission's final report. "Boarded out" children were children placed with families by the health authorities and the families were paid an allowance.

Finding out about burials

21. Within weeks of its establishment, the Commission wrote to the relevant religious orders asking for any information about the institutions they owned or ran. Specific information on burials was requested. The replies from the Sisters of Bon Secours (Tuam) and the Congregation of the Sacred Hearts of Jesus and Mary stated that the relevant information was no longer available to them because their records were all held by the Child and Family Agency (TUSLA). It took considerable time for the Commission to electronically copy these records and then analyse them. There is no information about burials in these records. Information about Tuam burials was also sought from Galway County Council. It did not have any documentary information on the subject.

Obligation to record burials

22. There was a legal obligation on local authorities to keep a register of burials in public burial grounds. It is the Commission's view that this obligation applied to Galway County Council in relation to the Tuam burial ground but there is no burial register. Carr's Hill in Cork was a public burial ground for which the health authorities were responsible. It seems that a burial register was compiled there but, unfortunately, the Commission has failed to find it; the HSE, which owns Carr's Hill, does not know if it ever held such a burial register.

23. There was no obligation on private burial grounds to keep a register of burials. However, three private burial grounds relevant to this report, Glasnevin, Mount Jerome and St Joseph's Cemetery, Cork, did keep proper records. There is no evidence that any record of burials was kept by the Congregation of the Sacred Hearts of Jesus and Mary in respect of burials in Castlepollard and Sean Ross. There was a canon law requirement to keep a record of burials.

Further information

24. The Commission is of the view that there must be many people who know more about the burials which are described in this report and who have not come forward with relevant information. The Commission would welcome any such new information.

Summary of findings

1. The major issues about burials arise in the cases of Bessborough and Tuam. It is not known where the vast majority of the children who died in Bessborough are buried. There is a small burial ground in the grounds of Bessborough. This was opened in 1956 for members of the congregation. It seems to have been assumed by former residents and advocacy groups that this is also where the children who died in Bessborough are buried as there are occasional meetings and commemoration ceremonies held there. The vast majority of children who died in Bessborough are not buried there; it seems that only one child is buried there. More than 900 children died in Bessborough or in hospital after being transferred from Bessborough. Despite very extensive inquiries and searches, the Commission has been able to establish the burial place of only 64 children. The Congregation of the Sacred Hearts of Jesus and Mary who owned and ran Bessborough do not know where the other children are buried.

Sacred Heart Homes

2. The burials of children who died in the three Sacred Heart Homes (Bessborough, Castlepollard and Sean Ross) are not recorded at all. More importantly, there is no certainty about where they are buried.

3. The Congregation of the Sacred Hearts of Jesus and Mary who owned and ran these institutions provided the Commission with an affidavit about burials generally and specifically about the Castlepollard and Sean Ross child burials but very little evidence was provided to support the statements in it. The affidavit was, in many respects, speculative, inaccurate and misleading.

4. The children who died in Castlepollard are likely to be buried in the burial ground there. However, there is no documentary evidence to confirm this.

Bessborough

5. As already stated, the Congregation of the Sacred Hearts of Jesus and Mary do not know where the children who died in Bessborough are buried. The Commission finds this very difficult to comprehend as Bessborough was a mother and baby home for the duration of the period covered by the Commission (1922 – 1998) and the congregation was involved with it for all of this time. The Commission finds it very difficult to understand that no member of the congregation was able to say where the children who died in Bessborough are buried.

6. The Commission tried to establish where the Bessborough children were buried. Cartographic and landscape assessment was undertaken of possible unrecorded burial arrangements in the Bessborough grounds. A site survey was also conducted. It is clear that there are a number of locations within the grounds where burials could have taken place. However, there is no significant surface evidence of systematic burial anywhere except for the congregation burial ground.

7. The Commission considers that it is likely that some of the children are buried in the grounds but has been unable to find any physical or documentary evidence of this. In particular, during the 1940s (when many of the deaths occurred) and when petrol was scarce, it would have been very expensive to arrange off-site burials. However, as no physical evidence of possible locations was found, the Commission did not consider it feasible to excavate 60 acres not to mention the rest of the former 200 acre estate.

Cork County Home

8. The Commission has established that, between 1922 and 1998, 552 “illegitimate” children died in Cork County Home/St Finbarr’s Hospital. So far, no burial records have been found for these children. It is likely that they are buried in Carr’s Hill Cemetery but there is no documentary evidence available.

Tuam

9. In the light of a great deal of inaccurate commentary about the Tuam site, the Commission considers it important to emphasise what it has established and what it has not established.

- The memorial garden site contains human remains which date from the period of the operation of the Tuam Children’s Home so it is likely that a large number of the children who died in the Tuam Home are buried there.
- The human remains found by the Commission are not in a sewage tank but in a second structure with 20 chambers which was built within the decommissioned large sewage tank.
- The precise purpose of the chamber structure has not been established but it is likely to be related to the treatment/containment of sewage and/or waste water. It has not been established if it was ever used for this purpose although soil analysis illustrates that it is likely it was so used for an unspecified duration. The Commission does not consider that any of its features suggest that it was

deliberately formed as a crypt or formal burial chamber. If that were the case, an entirely different type of structure would have been expected that would allow for easy human access.

- It has not been established that all the children who died in the Tuam Children's Home are buried in this chamber structure. There is some evidence that there may be burials in other parts of what were the grounds of the Home.

10. It seems clear that relatively extensive work and construction was conducted in and around the site of the Children's Home in Tuam, particularly during the July – December 1937 period. The Commission thinks it possible that the reworking of the old sewage tank and the construction of the second structure described above may have occurred at this time. If this is so, then the human remains found in the chambers are likely to date from after 1937. This raises the question of where the children who died before then are buried.

11. The more difficult question to answer is why the children were "buried" in such an inappropriate manner.

12. All the residents of the Tuam Home were the responsibility of the Galway and Mayo County Councils. It seems to the Commission that responsibility for the burials of deceased children rested with the local authorities and Galway County Council had a particular responsibility as the owner of the institution.

13. The Sisters of Bon Secours who ran the Tuam Home were unable to provide any information about the burials there.

14. The Commission is surprised by the lack of knowledge about the burials on the part of Galway County Council and the Sisters of Bon Secours. Galway County Council members and staff must have known something about the manner of burial when the Home was in operation. The Board of Health and its sub-committees sometimes held their meetings in the Home. Employees of Galway County Council must have known about the burials. County Council employees would have been in the grounds of the Home quite frequently as they carried out repairs to the building and possibly also maintained the grounds. It seems very likely that Galway County Council must have been aware of the existence of burials when they were planning the Athenry Road housing scheme in 1969.

15. The Sisters of Bon Secours continued to live and run a private hospital in the town of Tuam until 2001. They must have been aware of the building works which were carried out on the Children's Home site in the 1970s.

16. The Commission considers that there must be people in Tuam and the surrounding area who know more about the burial arrangements and who did not come forward with the information.

Dublin Union/Pelletstown

17. The burials of children who died in the Dublin Union institutions including Pelletstown are properly recorded in Glasnevin Cemetery.

Bethany

18. The burials of children from Bethany are properly recorded in Mount Jerome cemetery.

Anatomical subjects

19. There can be little doubt that most people will find the arrangements made for anatomical studies prior to the 1970s distasteful at a minimum. However, the burials of the anatomical subjects used by the Dublin Medical Schools are properly recorded in Glasnevin Cemetery. It has not been possible to establish anything about the burials of the child anatomical subjects used in the Galway Medical School as their names are not known.

Chapter 1: The law on burials

Summary

1.1 For the period covered by the Commission, the law on burials was set out in the *Public Health (Ireland) Act 1878 (Part 111)* and in the *Rules and Regulations for the Regulation of Burial Grounds 1888.*

1.2 In summary, the law provided that:

- Public burial grounds were run by local burial boards (local authorities) and were subject to statutory regulation and central government oversight (initially the Local Government Board for Ireland and after 1924, the Minister for Local Government and Public Health and the successors in title).[4]
- Private burial grounds, including those owned and operated by churches and religious institutions, were not subject to statutory regulation unless they applied to be licensed by the Minister or to be taken over by the burial board; in effect the 1878 Act and the 1888 regulations did not apply to private burial grounds. However, after 1948 any new such burial ground was not allowed to be operated without ministerial consent or approval, or planning permission.
- In public burial grounds, bodies were required to be buried in coffins. This did not apply to private burial grounds, including those owned by religious institutions.
- Burials in public burial grounds were required to be recorded in a register book provided by the local burial board. There was no registration requirement for burial in private burial grounds except in very specific circumstances relating to the registration of the death.[5]

Public burial grounds

1.3 The 1878 Act provided that, in general, the sanitary authority in each sanitary district was designated the "burial board" for the district, under the control and direction of the Local Government Board for Ireland. Following the establishment of the Irish Free State, the Local Government Board's functions were transferred to the Minister for Local Government and Public Health in 1924 and subsequently to the Minister's successors in title.[6] So, for almost all of the period covered by the Commission, the central government authority was the relevant Minister. In practice, the sanitary authorities and consequently the burial boards were the local authorities.

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[4] The successors in title during the period covered by the Commission were the Minister for Local Government from 1947; the Minister for the Environment from 1977; and the Minister for the Environment and Local Government from 1997. At present, the relevant Minister is the Minister for Rural and Community Development.
[5] This will be dealt with in the Commission's final report.
[6] See Footnote 1

1.4 The 1878 Act also provided that publicly owned burial grounds were transferred into the ownership of the burial boards which were given responsibility for their management and protection.

1.5 The 1878 Act gave the Minister the power to order that no new burial ground could be opened in any district without his or her approval, or to order that burials would be discontinued (wholly or subject to exception or qualification) in a particular district or burial ground. The Minister was also given the power to direct an inquiry into any matter in relation to a burial ground and to make an appropriate order arising from such an inquiry.

1.6 Any person who knowingly and wilfully buried a body, or acted or assisted in any burial, in violation of an order of the Minister under the 1878 Act was guilty of an offence.

1.7 The 1878 Act gave the Minister the power

> "…to make such rules and regulations in relation to the burial grounds and places of reception of bodies previous to interment under this Act as may seem proper for the protection of the public health and the maintenance of public decency".

The burial boards were obliged to comply with such rules and regulations.

1.8 The 1888 regulations required burial in "a coffin of wood or other sufficiently strong material".[7]

1.9 The *Open Spaces Act 1906*[8] gave local authorities the power to make bye-laws for the regulation of any open space or burial ground which they controlled.

Private burial grounds

1.10 The 1878 Act was mainly concerned with public burial grounds. It does have some provisions which are relevant to private burial grounds. It provided for the licensing of existing burial grounds on church/chapel premises. A licence could be granted "on application" to the Local Government Board and subsequently the Minister but there was no requirement to get a licence and, if a licence was granted, there was no penalty for breaching its terms. The Act also dealt with the right to interment, or absence of such a right, in private burial grounds but this is not relevant to the Commission's Terms of Reference.

[7] This remained the law until 2013; the Burial Ground (Amendment) Regulations 2013 (SI/ 144/ 2013), allows for "uncoffined burials" in certain circumstances.
[8] http://www.irishstatutebook.ie/eli/1906/act/25/enacted/en/html

1.11 Aside from these provisions, it is clear that the 1878 Act did not apply to non-public burial grounds. Section 199 provided that:

> "The provisions of this part of this Act shall not apply to any private and exclusive family mausoleum or burial place not being within the limits of any public burial ground."

The term "public burial ground" was not defined, but it seems clear that it was meant to refer to burial grounds provided by the burial boards. In effect, this means that private burial grounds, for example, those attached to churches or religious institutions were not regulated.

1.12 The 1878 Act did provide for the placing of any burial ground under the management of the burial board, in which case the Act would apply to it. The *Public Health (Ireland) Act 1896* [9] clarified that this included "any burial ground attached or contiguous to a Roman Catholic place of worship" where "the ownership…is not vested in any person or persons, corporation or limited company". However, unless this option was availed of, the 1878 Act did not regulate non-public burial grounds, other than in the very limited manner outlined above.

Glasnevin Cemetery

1.13 Glasnevin Cemetery is a private cemetery. Prior to 1970 it was governed by the *Dublin Cemeteries Act 1846* and the bye-laws made under that Act (see Chapter 7). Since 1970, it has been governed by the *Dublin Cemeteries Committee Act 1970*.[10] These are private Acts and they are applicable only to Glasnevin and a small number of other cemeteries in the Dublin area. Neither the local authorities nor the Minister with responsibility for oversight of public burial grounds has a role.

Mount Jerome

1.14 Mount Jerome is also a private cemetery. It is governed by Dublin General Cemetery Company's Acts 1933[11] which incorporated Acts from 1834 and 1874. Again, these are private Acts and apply only to Mount Jerome cemetery. Neither the local authorities nor the Minister with responsibility for oversight of public burial grounds has a role.

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[9] http://www.irishstatutebook.ie/eli/1896/act/54/enacted/en/print.html
[10] http://www.irishstatutebook.ie/eli/1970/prv/1/enacted/en/html
[11] http://www.irishstatutebook.ie/eli/1933/prv/2/enacted/en/html

Where a body may be buried

1.15 The *Local Government (Sanitary Services) Act 1948*[12] limits the places in which a body may be buried. Section 44 provides:

> "(1) …a person shall not, without the consent of the Minister, bury the body of a deceased person in a place which is not a burial ground for the purposes of this section.
>
> (2) The following (and no other) places shall be burial grounds for the purposes of this section—
>
> > (a) a place which is in lawful use as a burial ground and which was, immediately before the commencement of this section, in lawful use as a burial ground,
> >
> > (b) a place as respects which the Minister has, after the commencement of this section, given his approval to its being used as a burial ground,
> >
> > (c) a burial ground provided by a burial board under the Acts."[13]

1.16 The phrase "lawful use as a burial ground" was not defined. However, as burial grounds not operated by burial boards were not unlawful, any such grounds operating before 1948 seem to have effectively been given statutory recognition under the 1948 Act. This statutory recognition did not mean that they were subject to the requirements of the 1878 Act. Any new private burial grounds opened after 1948 needed the approval of the Minister but, again, they were not made subject to the requirements of the 1878 Act.

Register of burials

1.17 The 1878 Act provided for the keeping of a register of burials. The power to make rules and regulations under the 1878 Act in relation to burial grounds expressly included rules and regulations "for the proper registry of interments".

1.18 Section 191 of the 1878 Act provided that:

> "All burials within any burial ground provided under this Act shall be registered in a register book to be provided by the burial board providing such ground, and kept for that purpose; and such register book shall be so kept by some officer appointed by the said board to do that duty; and in such register book shall be distinguished in what parts of the burial ground the several bodies (the burials of which are entered in

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[12] http://www.irishstatutebook.ie/eli/1948/act/3/enacted/en/html

[13] This provision was amended by the *Local Government Act 1994*. The Minister's consenting role under s. 44(1) was transferred to the burial boards and a new s. 44(2A) was added, clarifying that burial grounds granted permission under the planning legislation, and those provided by local authorities, were also to be considered burial grounds for the purposes of s. 44(2).

such register book) are buried; and such register book, or copies or extracts thereof, or any document purporting to be a copy or extract thereof, shall be received in all courts as evidence of the burials entered therein. The clerk or secretary, or registrar to every burial board and cemetery company, or other authority having charge of any burial ground, shall make or cause to be made, at such times and in such manner as the Local Government Board may direct, a return of the names, addresses, dates of death and causes of death, so far as ascertained by him, of the persons whose bodies have been interred in such burial ground to the registrar of the district in which such persons resided at the dates of their deaths respectively, and such clerk, secretary, or registrar of each such cemetery company shall be paid therefor by the sanitary authority during the period he is required to perform such duty such sum as the Local Government Board may direct, not being more than threepence for each separate entry of death."

1.19 The *Public Health (Ireland) Amendment Act 1879* clarified that returns under this section were to be sent to the registrar of births and deaths of the district or the Registrar General of Births and Deaths in Ireland. The functions of the Minister under this provision were transferred to the Minister for Health in 1947.[14]

1.20 It is clear that the registration requirement extended only to burial grounds operated by the burial boards and therefore did not cover burials in religious premises or in other private places of burial.

Stillborn children

1.21 The *Births and Deaths Registration Act (Ireland) 1880 Act* made it an offence to "wilfully bury or procure to be buried the body of any deceased child as if it were still-born". It also made it an offence for "[a] person who has control over or ordinarily buries bodies in any burial ground" to "permit to be buried in such burial ground the body of any deceased child as if it were still-born". In the case of stillborn burials, such persons were required to have delivered to them, before burial, a certificate from a medical practitioner confirming the stillbirth, a declaration to that effect from a relative or an order from the coroner. These provisions were obviously aimed at stopping people from bypassing registration requirements in relation to infant deaths by passing them off as stillbirths.

[14] Health (Transfer of Departmental Administration and Ministerial Functions) Order 1947 (SI/58/1947).

More than one body in a coffin

1.22 There was also a provision in the 1880 Act, aimed at preventing the burial of persons whose death was not registered, by means of placing the body in a coffin with another body.

Chapter 2: Dublin Union/St Patrick's, Navan Road (Pelletstown) 1922 - 1985

Background

2.1 "St Patrick's, Navan Road, Dublin 7, originally known as Pelletstown and subsequent transfer to Eglinton House, Eglinton Rd, Dublin 4" is one of the institutions which the Commission is specifically mandated by its Terms of Reference to investigate. In accordance with its terms of reference and the criteria set out there, the Commission chose the Dublin Union[15] as one of the county homes to be investigated. In practice, Pelletstown and the Dublin Union were really one institution with separate premises. Pelletstown was frequently referred to as the "Pelletstown Auxiliary" as it was an auxiliary building to the South Dublin Union. Both sets of premises were owned and financed initially by the Dublin Board of Guardians and subsequently by its successors in title (for example, the Dublin Board of Assistance, the Dublin Health Authority from 1960 – 1970 and the Eastern Health Board from 1971 onwards).[16]

2.2 The South Dublin Union premises were in James's Street on the site of what is now St James's Hospital. The North Dublin Union and the South Dublin Union were amalgamated in 1918 as part of the changes to the Poor Law and the South Dublin Union premises then became the Dublin Union premises.[17]

2.3 Pelletstown[18] was run by the Company of Daughters of Charity of St Vincent de Paul.[19] The sisters and other staff who worked in Pelletstown were local government employees and paid as such.

2.4 From 1910 to 1919/20, Pelletstown was a National School and orphanage for the South Dublin Union. The Daughters of Charity became involved in Pelletstown in 1910; they were already involved in running a number of workhouses in Ireland. The Daughters of

[15] Changes to the Poor Law were made in the period just before and just after 1922. In most counties, the workhouses which were to be retained in use were renamed county homes. The Dublin workhouse was never given this name. Like all other former workhouses, it started to be called by a saint's name at some stage – St Kevin's. Locally, it was generally called simply "the Union".

[16] The Commission's final report will include details of the various changes in health authority structures.

[17] At some point, it began to be called St Kevin's Institution; there was also a St Kevin's Hospital on the site; it amalgamated with a number of other Dublin hospitals in the early 1970s and then became known as St James's Hospital.

[18] The Commission has decided to use the name Pelletstown in order to avoid any confusion with the many other institutions such as industrial schools, children's homes and hospitals which are or were also called St Patrick's.

[19] They were, and sometimes still are, known as the Sisters of Charity of St Vincent de Paul. As a result they are sometimes confused with the Irish Sisters of Charity. The Commission intends to use "Daughters of Charity" in order to minimise any such confusion.

Charity in Pelletstown were initially asked to provide "care instruction and industrial training of the children of the Poor". They were expected to cater for boys from age 3 to 14 and girls from age 3 to 15; they were then expected to "place the children in situations suited to their capacity". The specific role of Pelletstown was changed in May 1919. From 1919, Pelletstown was expected to cater for all mothers and infants; motherless children; all healthy children under age 5; and all sick children such as the Medical Officers considered would be suitably treated there.[20]

2.5 So, like Tuam, Pelletstown was not exclusively a mother and baby home. In later years, while it was mainly a mother and baby home, it continued to house very sick children, abandoned children and children who were considered not suitable for adoption. Occasionally, it also housed children who were awaiting a place in an industrial school.

Deaths in Dublin Union/Pelletstown

2.6 A full analysis of the deaths that occurred in the Dublin Union, including Pelletstown, will be included in the Commission's final report. This analysis is complex for many reasons not least that many of the children were sent there because they were very ill.

2.7 The births and deaths which occurred in Pelletstown were registered at the Castleknock Dispensary.[21]

2.8 The deaths which occurred in the Dublin Union, and its associated institutions including Pelletstown, were recorded in the Dublin Union Register of Deaths. These registers are held by the National Archives of Ireland. There are eight volumes (BG79/2/1-8), each covering a 4-6 year period between 1908 and 1951. For each entry, the deceased's date of admission to the Union, register number, name, religion, previous residence prior to admission to the Union, occupation, condition (single, married, widowed), the department of the Union in which the person was resident, date of death, cause of death and the medical officer who "disposed of"[22] the deceased were all recorded. Where relevant, children are identified in the register as "illegitimate", "deserted", "abandoned" or "at nurse". The parents of the child, if known, are usually identified in their record. If the child was "illegitimate", the mother and her occupation are noted. If the child was deserted, it was

[20] Correspondence between the Daughters of Charity and Dublin Union; provided to the Commission by the Daughters of Charity.

[21] NAI, Dublin Union Minute Books: BG 79/A/121, 5 January 1938 – 29 June 1938: Minutes of Board of Guardians Meeting, 19 January 1938: Report of Resident Medical Superintendent, Copy of Report by Mr James Cahill, re the Women and Children in Pelletstown Auxiliary, pp. 55-6.

[22] "How disposed of" is the heading used in the register.

noted where and by whom the child was found. If the child was a "nurse child", the name of the foster mother and her address were noted. However, in the majority of cases, these registers do not record the cause of death.

2.9 The Commission has examined these registers and extracted the details about all children who are registered. These details have then been matched with the information about deaths which is contained in the records which were compiled in Pelletstown (and now held by the Child and Family Agency (Tusla) and made available to the Commission). This exercise is almost, but not quite fully, complete but it is clear that there is a very close match between the various registers. It can reasonably be said that deaths were appropriately recorded.

Burials

2.10 Children who died in the Dublin Union premises – St Kevin's – and in Pelletstown were generally buried in Glasnevin Cemetery where detailed records are maintained. A very small number were buried in Mount Jerome. The Commission is continuing to check the burial places of a number of other children. Some of these were "legitimate" and it is possible that they were taken home by their families for burial.

2.11 In the majority of cases the children were buried in the "Poor Ground" burial plots, later renamed the "Angels' Plot"[23] in Glasnevin. They were buried there at the expense of the Dublin Union and its successors.

2.12 Appropriate records of the burials are maintained at Glasnevin in a Register of Poor Ground Burials. Volumes 27 – 37 of this register cover the burials between August 1919 and July 2002. The Commission has inspected this register and cross checked it with the names of the children known to have died in the Dublin Union, including Pelletstown.

2.13 The Register of Poor Ground Burials records the child's name, age, sex, religious persuasion, the date of death, cause of death, date of interment in the grave and the date of the issuing of the interment order. In contrast to the Dublin Union Register of Deaths, the cause of death for each child was always recorded in the Glasnevin burial register. The register also records the address the child came from, which in the case of these children was described as either the Dublin Union, St Patrick's, Navan Road or Pelletstown. It also records who made the burial arrangements, which for children from the Dublin Union, was a

[23] This term seems to have been used from the 1960s

named official employed by the Dublin Union and its successors in title. Where relevant, the child is described as “abandoned”, “deserted” and/or “illegitimate”. In the case of the latter, the mother’s name and her occupation are noted.

2.14 The Glasnevin Burial Registry records the name and location of each burial plot. The Poor Ground sections of the cemetery are divided into multiple squares, each representing a single burial plot. A series of horizontal and vertical lines divide the Poor Ground section, allowing for each specific burial plot to be located on a map of the section. The horizontal lines are designated by specific letters, and the vertical lines are represented by a number. The letters run from A-Z, through to Aa - Za, Ab – Zb and Ac to Zc. The numbers run from 1 to over 150, depending on the size of each Poor Ground section.

2.15 Again, the Commission has cross referenced the names of the children who died in the Dublin Union, including Pelletstown, with the names of those who are recorded in the Pelletstown records, the names on the Dublin Union Register of Deaths and the names in the Glasnevin Burial Registry. While some further checking needs to be completed, it is clear that the majority of the children are buried in Glasnevin and their names are recorded in the burial registers there.

Chapter 3: The Sacred Heart Homes

Background

3.1 The Mother and Baby Homes in Bessborough[24], Castlepollard and Sean Ross[25] were owned and run by the Congregation of the Sacred Hearts of Jesus and Mary. Unlike Pelletstown and Tuam, they were not local authority owned. They are sometimes described as "extern institutions" which means that they were not owned by the local health authorities but the local authorities could send people who were eligible for services to them. The local health authorities who sent mothers to these homes paid a capitation rate in respect of each resident. (The Commission's final report will look in detail at the financial arrangements.) These homes were entitled to take private patients.

Sources of Information

3.2 The records of admissions, births, discharges and deaths which were compiled in each of these institutions were handed over to the HSE in September 2011 and subsequently to the Child and Family Agency (TUSLA) in 2013.

3.3 The Congregation of the Sacred Hearts of Jesus and Mary told the Commission that they did not know where the children who died in Bessborough are buried. The Commission finds this difficult to comprehend as the congregation was still providing services to mothers and children right up to the end of the period covered by this investigation[26], that is, 1998, long after the other congregation institutions closed.

3.4 The congregation was unable to explain why there were designated child burial grounds in Castlepollard and Sean Ross but not in Bessborough. The congregation provided the Commission with an affidavit about burials generally and specifically about the Castlepollard and Sean Ross child burials but very little evidence was provided to support the statements in it. The affidavit was, in many respects, speculative, inaccurate and misleading.

3.5 In its affidavit, the congregation said that the child burial grounds in Castlepollard and Sean Ross were "created within existing by-laws and with the approval of the local Bishops".

[24] This is sometimes spelled Bessboro.

[25] This is sometimes spelled Shan Ross. It seems that Shan is an anglicisation of the Irish word "sean" meaning old and is not the male name Seán; the correct pronunciation would seem to be Shan Ross but the correct spelling is Sean Ross.

[26] The congregation told the Commission that the Mother and Baby Home closed in 1986. The Maternity Hospital closed in 1986 and it then became a "hostel" for unmarried pregnant women and for unmarried mothers and their babies. The congregation consider that it would be "misleading" to describe Bessborough as a mother and baby home after 1986. The Commission recognises that the character of the home changed as was the case with the other mother and baby homes which existed in the 1980s but it was still a mother and baby home.

The Commission is not aware of any bye-laws which would have applied to these burial grounds as they were not subject to specific legislation; any bye-laws made by local authorities would have applied only to local authority burial grounds. The congregation was unable to provide any information about such bye-laws and, in response to the initial draft of this report, acknowledged that there were no specific bye-laws which applied to religious burial grounds.

3.6 The Commission has not seen documentary evidence but it has no reason to doubt that the local bishops were aware of the existence of burial grounds in Castlepollard and Sean Ross and did approve. The involvement of local bishops and priests in the institutions will be documented in the Commission's final report.

3.7 The affidavit states that all of the children buried in the burial grounds of these two institutions were accorded the rites of the Catholic Church and the congregation "did not bury infants in unapproved cemeteries". These assertions may well be true but the congregation provided no evidence to support them. The congregation was unable to elaborate on what the rites of the Catholic Church in relation to child burials were. As the congregation accepts that it does not know where most of the Bessborough children are buried, it cannot definitively state that they were not buried in unapproved burial places.

3.8 The congregation also said that the infants buried at Sean Ross and Castlepollard "were laid to rest without any cost accruing to the coffers of the local or central government". This is not true in respect of some, if not all, of the burials. The Commission has seen evidence of bills for burials having been sent to a local health authority by Bessborough and a bill for coffins was sent by Sean Ross to a local health authority.[27] There is quite likely to be further evidence of such bills in the archives of other local authorities. The Commission recognises that it was reasonable for the congregation to bill the local authorities for the costs involved.

3.9 There was no legal requirement (see Chapter 1) to keep a register of burials in such burial grounds and no such registers seem to exist. Accordingly, there is no documentary evidence of these burials.

3.10 A Canon Lawyer has told the Commission that the 1917 Code of Canon Law requires the completion of a register of deaths after a funeral with details of the name and age of the

[27] Kilkenny County Archive, Kilkenny County Council Manager's Orders-Public Assistance Section: MO/PA/5/2 April 1947-31 March 1948

deceased, name of parents or spouse at time of death, what sacraments had been received and the place and date of the burial.

Chapter 3A: Sean Ross 1931 - 1969

3A.1 Analysis of the records compiled in Sean Ross and information on deaths provided by the General Registrar Office shows that over 1,000 children died in Sean Ross or in the District Hospital, Roscrea to which they were sent when they became very ill. Twenty nine mothers died; the majority of these deaths were related to the pregnancy/childbirth.

3A.2 There is a designated child burial ground in the grounds of the institution. The Commission was made aware of concerns about this burial ground and decided to undertake a geophysical study and subsequently a test excavation of the site. The results of this excavation are currently being examined.

Chapter 4: Bessborough 1922 – 1998

Background

4.1 Bessborough Mother and Baby Home was opened in 1922. It was owned and run by the Congregation of the Sacred Hearts of Jesus and Mary. The congregation had been invited to set up a mother and baby home in Cork by a senior official of the Cork Board of Guardians as it was already running a number of mother and baby homes in England and Scotland. The Board of Guardians official identified the Bessborough Estate, which was a Georgian house on 150 acres[28], as a suitable property. The congregation bought the property with financial assistance from the Archbishop of Westminster.

4.2 The objective of the Board of Guardians was to implement the policy of removing unmarried mothers and their children from workhouses and making provision for them in dedicated facilities or "special homes" as they were sometimes called. The first mothers and children who took up residence in Bessborough came from the Poor Law Union workhouses in Cork. Over the years, the Bessborough home accepted unmarried expectant mothers and unmarried mothers who had recently given birth who were admitted there and paid for on a capitation basis by the health authorities in all parts of the country. Bessborough also accepted private fee paying expectant mothers.

4.3 In the early years, expectant mothers who were resident in Bessborough did not give birth there. They usually gave birth in Cork District Hospital (see below). In 1930, a maternity ward was created within the home and, in 1935, the Sacred Heart Maternity Hospital was built alongside the Bessborough Home. From 1930 to the 1980s, most expectant mothers resident in Bessborough gave birth in the maternity ward/hospital. The Commission uses the term "Bessborough" to cover both the Home and the hospital except where the context shows otherwise.

Sources of information

4.4 The records of admissions, births, discharges and deaths which were compiled in Bessborough by the congregation were transferred to the HSE in 2011 and subsequently to the Child and Family Agency (TUSLA) in 2013. The Commission has made digital copies of these records and their analysis is near completion. These documents record the deaths of children, and the causes of death in many cases, but do not include any information about burials.

[28] The congregation told the Commission that a portion of land adjoining the estate was bought in 1930; this brought the total acreage to about 200 acres. About 100 acres were sold in 1973 for the building of the N25 and for social housing. The Commission understands that there are about 60 acres of ground around the building now.

Deaths in Bessborough

4.5 The Commission is aware that over 900 children who were born in, or admitted to Bessborough died in infancy or early childhood. Most died either in the Sacred Heart Maternity Hospital soon after birth or in the Bessborough Home itself to which infants were transferred some weeks after birth (many more died in the Home than in the Maternity Hospital). The Bessborough Home and the Sacred Heart Maternity Hospital kept separate death registers.[29] Deaths that occurred in the Home and deaths which occurred in the hospital were separately recorded and notified. This has led some commentators to suggest that the Bessborough authorities overstated deaths which occurred in the institution when reporting to the Department of Local Government and Public Health. The number of deaths reported to the department was the combined deaths in the two facilities as opposed to deaths which occurred in the Home only.

Cork County Home and Cork District Hospital/St Finbarr's

4.6 In the reorganisation of poor law institutions which occurred in the early 1920s, the Cork City Poor Law Union Workhouse became two separate but co-located institutions - the Cork County Home and Cork District Hospital. The Cork County Home is one of the county homes chosen by the Commission for investigation. The Commission is not investigating the Cork District Hospital but it does have a role in the story of both Bessborough Mother and Baby Home and the Cork County Home. Both the Cork County Home and the Cork District Hospital were renamed St Finbarr's in the 1950s. The Cork District Hospital/St Finbarr's had a maternity unit until 2007 when the Cork University Maternity Hospital opened.

4.7 A significant number of children born in or admitted to Bessborough (113) subsequently died in Cork District Hospital/St Finbarr's Hospital. Expectant mothers living in Bessborough, who required extra medical attention, were routinely transferred to St Finbarr's Hospital to give birth. A number of children born to Bessborough residents in Cork District Hospital/St Finbarr's Hospital died in that institution. The medical and administrative staff of Bessborough and Cork District Hospital/St Finbarr's Hospital assumed separate responsibility for registering deaths which occurred in their respective institutions.

4.8 The Commission has examined the records of deaths in the Bessborough Home itself and in the Sacred Heart Maternity Hospital and cross referenced them with information on Bessborough deaths (including those in Cork District Hospital/St Finbarr's) provided by

[29] The *Registration of Maternity Homes Act* 1934 made it obligatory for the administrators of all registered maternity homes to keep records relating to the reception and discharge of patients as well as a record of all births and deaths.

the General Register Office (GRO). There are some discrepancies between the death records maintained by the Bessborough authorities and those held by the GRO but they are small in number and the Commission is continuing to try to reconcile them.

Who was responsible for burials

4.9 While it was reasonably straightforward to reconcile institutional death records with those held by the GRO, the identification of the burial places of the children has proven to be very challenging. One complicating factor is that the administrators of Bessborough and Cork District Hospital/St Finbarr's appear to have taken separate responsibility for the burial of unclaimed remains in their respective institutions. The children who died included children of mothers who were being maintained by the local health authorities (public patients) and children of mothers who were paying privately (private patients). When the child of a public patient died in Bessborough or Cork District Hospital/St Finbarr's the mother had two options: to make private arrangements for the burial of the child or to let the administrators of the institution where the death occurred make burial arrangements on her behalf. While a small number of women made private arrangements,[30] most single women had neither the means, nor the familial support, to do so. In the majority of cases, the burial of a child of a public patient was arranged by the administrators of Bessborough or Cork District Hospital/St Finbarr's, most likely in conjunction with the health authorities who were paying for the mother and child.[31]

4.10 A number of the children who died in Bessborough were the children of private fee-paying residents. If the child of a private patient died while the mother was resident in Bessborough, the mother alone was legally responsible for the burial. However, private patients routinely discharged themselves from Bessborough, leaving children in the institution unaccompanied, in most cases awaiting informal adoption through the Catholic Women's Aid Society (CWAS).[32] This practice ceased in 1946 when Bessborough administrators were no longer willing to accommodate unaccompanied children born to private patients. CWAS records are held by the Child and Family Agency (TUSLA) and were made available to the Commission for inspection. These records show that the CWAS assumed responsibility for the cost of burial of children in their care. Burial arrangements for children born in Bessborough, who subsequently died while in foster care, were generally

[30] St Finbarr's Cemetery burial registers record some Bessborough child burials in separate non-perpetuity burial plots – see below.

[31] Kilkenny Board of Assistance Records contain an invoice from the Bessborough Home seeking to recoup the cost of an infant burial. A former administrator of St Finbarr's Hospital confirmed that the Board of Assistance/Southern Health Board arranged for the burial of unclaimed infants who died in Cork District Hospital/St Finbarr's Hospital.

[32] The Catholic Women's Aid Society was a privately run agency set up in 1919 to facilitate single women who sought to make private permanent fostering arrangements for their children.

arranged by foster parents who were then reimbursed by the CWAS. On rare occasions, foster parents handed the remains of a deceased child back to the society for burial.[33] It is reasonable to assume that the CWAS reimbursed the Bessborough authorities for the costs associated with the burial of unaccompanied infants maintained by the society in Bessborough. CWAS records do not record where children who died in its care were buried.

4.11 Work undertaken by the Child and Family Agency (TUSLA) has shown that St Anne's Adoption Society took responsibility for the burial of infants who died in Bessborough while under the auspices of St Anne's. St Anne's Adoption Society was registered with the Adoption Board in November 1954. The society facilitated the adoption of children born to single Irish women returning from the United Kingdom. Expectant single women, whose repatriation from the UK was facilitated by the society, were admitted to the Sacred Heart Maternity Hospital, Bessborough. Although these women were public patients, maintained in Bessborough by local authorities, St Anne's' Adoption Society appears to have taken responsibility for the burial of infants born to these women who died in Bessborough, Cork District Hospital/St Finbarr's Hospital or in foster care.[34]

4.12 The majority of recorded child deaths in Bessborough (in both the Bessborough Home and the Sacred Heart Maternity Hospital) occurred while the children were accompanied by their mothers. There is no information available about the involvement of mothers in the burial arrangements. In theory at least, the mothers were legally responsible for the burial of deceased infants but it seems unlikely that they had much involvement in making burial arrangements.

Where are the children buried

4.13 There is a small burial ground in the grounds of Bessborough. Some members of the congregation are buried there and their graves are marked in the normal way. It seems to have been assumed by former residents and advocacy groups that this is also where the children who died in Bessborough are buried as there are occasional meetings and commemoration ceremonies held there. There is a plaque there commemorating the children who died in Bessborough.

4.14 At an early stage, the Commission thought it unlikely that all the children who died in Bessborough were buried in this burial ground as it was not nearly large enough for the

[33] Records of the Catholic Women's Aid Society held by the Child and Family Agency (TUSLA).
[34] Child and Family Agency (TUSLA). St Anne's Adoption Society Registers. Also, Cork Diocesan Archives: Records of St Anne's Adoption Society and the History and Development of St Anne's Adoption Society.

number of children involved and, in any event, it would be unlikely that children would be buried in the same burial ground as members of the congregation.

Congregation knowledge of burials

4.15 Shortly after its establishment in 2015, the Commission asked the Congregation of the Sacred Hearts of Jesus and Mary for information about many aspects of Bessborough, including the burial arrangements. The congregation said it had very little information as the records compiled in the institution were held by the Child and Family Agency (TUSLA) and it did not have access to these records. As already stated, there is no information about burials in these records.

4.16 A number of members of the congregation provided affidavits and/or oral evidence to the Commission. They were able to provide remarkably little evidence about burial arrangements.

4.17 The congregation told the Commission that the burial ground in Bessborough was opened in 1956 for deceased members of the congregation and the congregation does not know where the vast majority of the children who died in Bessborough are buried. The Commission has not seen any evidence that the approval of the Minister for Local Government for the opening of this burial ground was sought or granted as required by the *Local Government (Sanitary Services) Act 1948* (see Chapter 1).

4.18 A member of the congregation who was in Bessborough for most of the period 1948-1998 told the Commission that she did not remember any child deaths during her time there but she implied that the children who did die there were buried in the congregation burial ground. In the years 1950-1960 (inclusive), 31 children died in Bessborough so it is rather surprising that she does not remember any deaths.

4.19 Another congregation member who was in Bessborough from 1978-1985 told the Commission that one baby died during her time there. She said that the manager of the maternity hospital (who was also a member of the congregation) "took over the arrangements for the burial". She "vaguely remembered" that the mother wanted the baby buried in St Michael's Cemetery but she did not know where the baby was actually buried. The Commission has established that there is no record of this baby in St Michael's burial records. She did not remember if the mother's family was involved in the burial arrangements but she was clear that the congregation had bought the coffin for the baby.[35]

4.20 In evidence to the Commission, a member of the congregation who was there in the 1980s said that there were two children buried in the burial ground during her time there and a third was disinterred elsewhere and reinterred in this ground. Another member of the congregation who was in Bessborough for a period in 1971 and again between 1975 and 1981 swore an affidavit in which she said that she remembered one child who died and was buried in the congregation's plot in the grounds. The recollections of these two congregation members seem to be incorrect. In fact, it would appear that there is only one child buried in the congregation's burial ground and that burial took place in 1994. The burial ground has some individual memorials to other children who died in Bessborough but it is unlikely that they are buried in this plot.

Investigation of possible burial sites in grounds of Bessborough

4.21 It is possible that children who died in Bessborough were buried within the grounds. However, to date, the Commission has found no physical or documentary evidence which indicates that this occurred.

4.22 The Commission engaged forensic archaeologists to carry out a cartographic and landscape assessment of possible unrecorded burial arrangements in the Bessborough grounds. As already stated, the grounds measure approximately 60 acres. It is also possible that burials took place in the grounds that no longer form part of the Bessborough estate, that is, a total area of 200 acres.

4.23 The forensic archaeologists and the Commission's researchers reviewed all available cartographic sources and aerial images in order to identify possible burials within the grounds of Bessborough. A site survey was also conducted. It is clear that there are a number of locations within the grounds where burials could have taken place. However, there is no significant surface evidence of systematic burial anywhere except for the congregation burial ground.

4.24 The third edition Ordnance Survey Map for the Bessborough area was produced in 1949/50. This identifies a southeast portion of the site as a "Children's Burial Ground". Such a label is not uncommon on this edition of maps and usually denotes a cillín (see

[35] This baby's remains were sent to St Finbarr's for a post-mortem examination. St Finbarr's almost certainly arranged the burial.

Introduction). It is possible that, in this case, the label may refer to the area north-west of the Keep folly, a small rectangular enclosure to the north-east or the wider field in which the label is located.

4.25 In the intervening years, groundwork has left this area in a highly disturbed state and there is nothing physical to mark it as a former burial ground. The Commission interviewed a landscaper who undertook extensive groundwork on the Bessborough Estate over a period of almost thirty years. The witness stated that he had personally undertaken excavations in the area marked "Children's Burial Ground". He said that it was necessary for him to dig six to eight feet deep across this site and that he found no evidence of human remains or any evidence to suggest that the site was formerly used as a burial ground.

4.26 The Commission examined vertical aerial photography taken by the Irish Air Corps in 1951. This series includes high resolution aerial photography of the Bessborough Estate.[36] The majority of child deaths at Bessborough occurred before 1951 (over 700) and it would be reasonable to expect that, if there were burials there, an aerial photograph taken in February 1951 would show up some ground disturbance, or anomaly on the landscape. If over 700 children were buried on the Bessborough Estate before 1951 the aerial photograph would be expected to give some indication of where the remains are located. The aerial photographs of the Bessborough site were examined by forensic archaeologists who determined that no visible features on the Bessborough landscape were indicative of any obvious site hosting the remains of such a large number of children.

4.27 Early in 2018, the Commission issued a national public appeal seeking information from individuals who may have personal knowledge, documentation, or any other information concerning the burial arrangements and/or burial places of children who died in Bessborough. Members of the public contacted the Commission, with mostly second-hand information, suggesting that children were buried in different parts of the estate. All of this information was followed up and the locations identified as possible burial sites by members of the public were assessed by forensic archaeologists. Some of these locations have been built on. To date, no physical or documentary evidence has been produced which suggests that any of the sites identified by members of the public contain human remains. An individual who gave a media interview claiming knowledge of child burials in Bessborough did not respond to the Commission's appeal and declined a request to assist the Commission.

[36] Military Archives, Vertical Aerial Photography, V190 #72; Cork-Douglas/Blackrock, 13 February, 1951.

4.28 The Commission considers that it is highly likely that burials did take place in the grounds of Bessborough. In particular, during the 1940s (when many of the deaths occurred) and when petrol was scarce it would have been very expensive to arrange off-site burials. However, as no physical evidence of possible locations was found, the Commission did not consider it feasible to excavate 60 acres not to mention the rest of the former 200 acre estate.

Other possible burial grounds

4.29 As stated, the Commission has not ruled out the possibility that former Bessborough residents were buried onsite. However, the Commission has also actively investigated the possibility that former residents may have been buried in other locations.

4.30 During the period under review, 1922-1998, eight burial grounds were in operation in Cork city and surrounding hinterland. These were:

- St Joseph's Cemetery, Tory Top Road, Cork.
- St Finbarr's Cemetery, Glasheen Road, Cork.
- St Michael's Cemetery, Mahon, Cork.
- Douglas Municipal Cemetery, Douglas, Cork.
- St Mary's Cemetery, Curraghkippane, Cork.
- St Catherine's Cemetery, Kilcully, Cork
- Rathcooney Cemetery, Glanmire, Cork.
- Cork District Cemetery (All Saints), Carr's Hill, Cork.

4.31 The Commission located and examined the burial records of seven of the eight burial grounds listed above. So far, the Commission has been unable to locate the burial records for Cork District Cemetery, Carr's Hill.

4.32 The burial records of four burial grounds - Douglas Municipal Cemetery; St Mary's Cemetery, Curraghkippane; St Catherine's Cemetery, Kilcully and Rathcooney Cemetery, Glanmire, contain no record of deceased Bessborough residents.

St Joseph's Cemetery, Tory Top Road, Cork

4.33 Prior to its handover to Cork Corporation in 1947, St Joseph's was a privately owned burial ground administered by the Society of African Missions (SMA).[37] Burial records for the

[37] Society of African Missions, Provincial Archive, Blackrock, Cork.

period prior to 1947 are held by Cork City and County Archives.[38] Burial records for the post 1947 period are maintained by Cork City Council.

4.34 The Commission has established that, in the period between the opening of the Bessborough Home in 1922 and March 1929, 54 children who died in Bessborough were buried in St Joseph's Cemetery. Of these, 50 were buried in the "Poor Ground" section at St Joseph's and burial expenses were paid by the Congregation of the Sacred Hearts of Jesus and Mary. Burials in the Poor Ground ceased in June 1928 except for one further burial in March 1929.

4.35 In November 1927, the congregation bought three adjacent burial plots in St Joseph's and a further four children were buried there.[39] No child burials are recorded in the congregation's burial plot after June 1928. It appears that, at this point, some alternative burial arrangements were made for deceased Bessborough children.

4.36 In the period 1922 to June 1928, a total of 63 child deaths are recorded in the Bessborough registers and the St Joseph's Burial records combined. Of these, 53 are buried in St Joseph's Cemetery. St Finbarr's Cemetery burial registers record that two Bessborough children, both of whom died in 1923, were buried in separate non-perpetuity graves there.[40] It is likely that these burials were arranged by relatives of the deceased children. The GRO records show that five of the remaining eight Bessborough children died after being transferred to Cork District Hospital. The South Cork Board of Public Assistance was responsible for arranging the burial of the unclaimed remains of patients who died in Cork District Hospital, including the unclaimed remains of deceased children. If the Board did arrange these five burials, it is likely that they are buried at Cork District Cemetery, Carr's Hill; however, the Commission has no documentary evidence of this. One of the children was the child of a private patient so it is possible that the mother made private arrangements for the burial. The Commission found no evidence about the burial of the remaining two children.

4.37 The identification of Bessborough children in St Joseph's burial records for this period is interesting for a number of reasons. First, it demonstrates that, from the inception of the Bessborough Home in 1922, the Congregation of the Sacred Hearts of Jesus and Mary assumed responsibility for the burial of children who died in Bessborough. Secondly, it

[38] Cork City & County Archives. St Joseph's Cemetery Collection; CP/CY/SJ/2/29-31 (1921-1947).
[39] Cork City & County Archives. St Joseph's Cemetery Collection; Register Book of Burial Plots and Burial Rights Therein; CP/CY/SJ/3. (Closed for Public Access).
[40] Cork City Council, St Finbarr's Cemetery Burial Records, 1947-98.

demonstrates that those infants were not buried in the grounds of Bessborough but were buried in a number of different locations.

4.38 The Congregation of the Sacred Hearts of Jesus and Mary paid the Society of African Missions ten shillings for the burial of each child in the "Poor Ground" section of St Joseph's Cemetery.[41] As these children were maintained in Bessborough by the various health authorities, the Congregation recouped the cost of the burials from the health authority responsible for each child's maintenance.[42] The abrupt cessation of child burials at St Joseph's in June 1928 may have had something to do with costs. If these deaths had occurred in Cork County Home, or Cork District Hospital, the South Cork Board would have arranged burials in its burial ground, the Cork District Cemetery at Carr's Hill, at no additional cost to the local authority. Considering that the next identifiable burial place of a Bessborough child is at this burial ground, in 1960, it seems plausible to suggest that the remains of unclaimed Bessborough children who died between June 1928 and 1960 may have been buried by the South Cork Board in Cork District Cemetery, Carr's Hill. However, the Commission has been unable to find any direct evidence of this.

St Michael's Cemetery, Blackrock, Cork

4.39 St Michael's Cemetery, Blackrock, Cork was opened in 1957 and is owned and operated by Cork City Council. St Michael's does not have a designated "Poor Ground" area. The South Cork Board of Public Assistance and its successors, Southern Health Board and HSE South, opened burial plots for their own use as required. The Commission identified two former Bessborough residents, both infants, who are recorded as being buried at St Michael's. One infant was born in Bessborough in 1958 and died aged ten days at St Finbarr's Hospital, Cork (formerly called the Cork District Hospital). The record shows that this infant was buried in a South Cork Board of Public Assistance burial plot along with five adults. The plot is unmarked. The second infant was born in St Finbarr's Hospital in 1986. Mother and child were transferred to Bessborough when the infant was aged 27 days. The infant subsequently died in Cork Regional Hospital aged 4 months. This infant is recorded as having been buried in a Southern Health Board plot along with a number of adults. The plot is unmarked by a headstone but a small plaque, placed by family members, marks the burial place.

[41] Cork City & County Archives; St Joseph's Cemetery Collection; CP/CY/SJ/2/29-31 (1921-1947).
[42] Kilkenny County Archive, Kilkenny County Council Manager's Orders-Public Assistance Section: MO/PA/5/2 April 1947-31 March 1948.

Cork District Cemetery (All Saints) Carr's Hill, Cork

4.40 The Commission identified documentary evidence which indicates that the unclaimed remains of at least one Bessborough child, who died in St Finbarr's Hospital, was buried in Cork District Cemetery, Carr's Hill. This three acre former famine burial ground had been administered by the Cork Board of Guardians, and subsequently by the South Cork Board of Public Assistance, since 1844. Land Registry records show that the South Cork Board of Public Assistance took full ownership of the burial ground in November 1944 and the site remains in the ownership of the South Cork Board's successors, the HSE.[43] The HSE has informed the Commission that it has been unable to confirm whether it ever held the Burial Register for this burial ground.

4.41 In 1994, a former Bessborough resident contacted the Congregation of the Sacred Hearts of Jesus and Mary requesting documentation about her time in the institution and making a formal inquiry about the burial place of her child. The child was resident in Bessborough with his mother in 1960 and subsequently died in St Finbarr's Hospital later that year. Bessborough records show that the congregation contacted the chaplaincy at St Finbarr's Hospital for information on the child. In response to a query from the chaplaincy, the administrator of St Finbarr's Hospital provided a full overview of the child's stay in St Finbarr's including the cause of death and the place of burial. The Board of Public Assistance had made arrangements for the child's burial in Cork District Cemetery, Carr's Hill, in December 1960.[44] In 1994, a member of the congregation told the mother of this infant that her child was buried in the congregation burial ground at Bessborough. However, records held by the administrator of St Finbarr's Hospital at that time recorded the child's place of burial as Cork District Cemetery, Carr's Hill.

4.42 As already stated, during the period under review, 1922-1998, a significant number of Bessborough children died in Cork District Hospital/St Finbarr's Hospital. The majority of these children were maintained in Bessborough by the South Cork Board of Public Assistance, who also administered Cork District Hospital/St Finbarr's and Cork District Cemetery (Carr's Hill). A former administrator of St Finbarr's Hospital, who had access to hospital mortuary records, confirmed to the Commission that the South Cork Board of Assistance assumed responsibility for the burial of Bessborough children who died in Cork District Hospital/St Finbarr's and that many of these children were buried in Cork District Cemetery, Carr's Hill.

[43] Land Registry, County Cork; Folio 53L.
[44] Southern Health Board, Administration Department, St Finbarr's Hospital, Letter dated 12 December 1994.

4.43 It should be noted that, during the period under review, several hundred neo-natal deaths were recorded among "legitimate" children born in, or admitted to, Cork District Hospital/St Finbarr's. The Commission identified hundreds of burial records relating to "legitimate" children who died there. For the most part, these children were buried in private and municipal burial plots in St Joseph's Cemetery and St Finbarr's Cemetery. Of the 552 "illegitimate" children who died in Cork District Hospital/St Finbarr's, (including 113 transferred from Bessborough), the Commission has identified the burial place of only five.

4.44 As already stated, the only Cork burial ground records which the Commission has not located are those associated with Cork District Cemetery, Carr's Hill. With the assistance of HSE staff, the Commission engaged with five former hospital administrators of St Finbarr's Hospital in a bid to locate the "Burial Books" maintained by the South Cork Board of Assistance relating to Cork District Hospital/St Finbarr's Hospital. The existence of these records was flagged in the 1994 correspondence between the then hospital administrator and the chaplaincy at St Finbarr's Hospital (referred to above). The Commission interviewed a former hospital administrator, and author of the 1994 correspondence, who stated that the records in question were mortuary records and were onsite at St Finbarr's Hospital at the time of his retirement in 2001. HSE staff undertook a thorough search of the medical records room at St Finbarr's Hospital and forwarded a detailed inventory of records held there to the Commission. However, the mortuary records, which are of considerable interest to the Commission, were not found. The Commission examined archival St Finbarr's Hospital records onsite, and in their off-site storage facility, but did not locate the mortuary records.

4.45 The Commission has recently discovered that a "Burial Book" relating to St Finbarr's Hospital was transferred to Cork University Hospital (CUH) in 2001. The Commission has issued a discovery order in respect of these records held by CUH and continues to work with the HSE in regard to this matter.

4.46 The Commission has also recently discovered that maternity records relating to St Finbarr's Hospital were transferred to Cork University Maternity Hospital (CUMH) when it opened in 2007. The Commission has requested access to the records held at CUMH and continues to work with the HSE in regard to this matter.

4.47 In a bid to locate the Burial Register associated with Carr's Hill Cemetery the Commission engaged with HSE South, Cork County Council, Cork City Council and the Cork City and County Archives. However, the Burial Register was not located. A former employee of St Finbarr's Hospital wrote to inform the Commission that he had visited Carr's Hill cemetery in the 1990s and was informed by a local resident that the Burial Register was maintained by a caretaker living nearby and that the site had been used by the South Cork Board of Assistance to bury infants and children up to at least 1962. Aerial photography, provided by the Military Archives, shows that Carr's Hill cemetery was still in use in 1951[45] and Southern Health Board correspondence confirms that the South Cork Board were using the site for infant burials in 1960. In a bid to locate the Burial Register and/or caretaker, the Commission undertook house-to-house inquiries at Carr's Hill. However, to date, this has also proved unsuccessful.

St Finbarr's Cemetery, Cork

4.48 In March 2017, the Child and Family Agency (TUSLA) discovered a deed in respect of a burial plot in the name of St Anne's Adoption Society in St Finbarr's Cemetery, Cork. The supervisor at St Finbarr's Cemetery confirmed that the plot was purchased by St Anne's Adoption Society in March 1978 and that four infants who died while in the care of the Society were buried there.[46] This burial plot is unmarked. The Cemetery Supervisor also flagged a burial plot originally registered to St Patrick's Orphanage, precursor of St Joseph's Industrial School, Greenmount. The burial plot was bequeathed to St Anne's Adoption Society when Greenmount closed in the 1950s. St Finbarr's Cemetery burial registers confirmed that 16 children who died in the care of St Anne's Adoption Society are buried in this plot.[47] This plot is marked by a headstone inscribed "Suffer Little Children". Four of the 20 children buried in St Anne's Adoption Society plots at St Finbarr's Cemetery had an association with Bessborough. One of these infants was born in Bessborough and subsequently died in St Finbarr's Hospital, following an extended stay there. A second infant was born to a Bessborough resident at St Finbarr's Hospital. This infant subsequently died in foster care. The remaining two infants were both born at St Finbarr's Hospital and were subsequently admitted to Bessborough unaccompanied. Both infants subsequently died in Bessborough while receiving palliative care. St Anne's Adoption Society took responsibility for their burials.

Adult burials

4.49 The Commission has established that, between November 1927 and January 1985, 12 adult women, all former residents of the Bessborough Home, were buried in a Congregation of the Sacred Hearts of Jesus and Mary owned burial plot at St Joseph's

[45] Military Archives Ireland. Vertical Aerial Photography, V190 #137; Cork-Carr's Hill, February 1951.
[46] St Finbarr's Cemetery: Section I, Row 18, Plot No.55.
[47] St Finbarr's Cemetery: Section K, Row 6, Plot No.44.

Cemetery.[48] This plot is marked by a headstone. However, the headstone lies in three broken pieces and the inscription is unreadable. It is unlikely that the headstone bears the names of women buried in this plot. The women buried here remained in Bessborough for extended periods working as domestic servants; their deaths were not childbirth related. One woman entered Bessborough in 1922, aged 20 years, and remained there until her death in 1984 - a period of 62 years. Another entered Bessborough in 1924, aged 21 years, and remained there until her death in 1985 - a period of 60 years.

4.50 The Commission has established that there were an additional 14 deaths of mothers who were Bessborough residents. Nine of these seem to be pregnancy of childbirth related.[49] The Commission has not been able to establish the burial place of these 14 women. Six were private patients. Eight mothers were public patients; two of these died in Bessborough, five in Cork District Hospital/St Finbarr's and one in Dungarvan County Home.

[48] St Joseph's Cemetery, Border St Dominick, Plot 191-93. The Congregation bought this plot from the Society of African Missions in December 1927. Cork City & County Archives. St Joseph's Cemetery Collection; Register Book of Burial Plots and Burial Rights Therein; CP/CY/SJ/3.
[49] The Commission is consulting medical experts on the issues here and will report further.

Chapter 4A Cork County Home

4A.1 The close interconnectedness of Cork County Home, Cork District Hospital/St Finbarr's Hospital and Bessborough, and the nature of their relationship with the South Cork Board of Public Assistance, makes it necessary to consider institutional deaths and burials of "illegitimate" children in Cork institutions under the Commission's remit. The Commission has established that, between 1922 and 1998, a combined total of 1,343 "illegitimate" children died; 771 died in Bessborough;[50] 552 died in St Finbarr's Hospital and 20 subsequently died elsewhere.[51] To date, as outlined above, the Commission has identified the burial places of just 64 children. Despite having undertaken an intensive investigation the burial locations of 1,279 of these children remain unknown. A common factor which links the majority of the yet unlocated children is that almost 92% were born to public patients maintained in Bessborough and Cork County Home by Boards of Public Assistance. Responsibility for the burial of the unclaimed remains of children fell to the South Cork Board of Public Assistance. Despite the absence of any documentary evidence, it is possible that these children were buried in Carr's Hill cemetery; in particular, it seems likely that the children who died in St Finbarr's are buried there.

[50] Child and Family Agency (TUSLA), Records of the Sacred Heart Home and Hospital Bessborough, 1922-98.
[51] Cork City & County Archives, Cork County Home Indoor Registers 1922-60.

Chapter 5: Castlepollard 1935 - 1971

Background

5.1 Castlepollard Mother and Baby Home opened in 1935 with the same arrangements as Bessborough. It was owned and run by the Congregation of the Sacred Hearts of Jesus and Mary. The original building was an old manor house. In 1941 a maternity home was built and became known as St Peter's Hospital. Castlepollard ceased to be a mother and baby home in 1971; the Midland Health Board bought the entire premises and started to use it as an institution for people with intellectual disabilities.

Sources of information

5.2 The records of admissions, births, discharges and deaths which were compiled in Castlepollard were left with the Midland Health Board when the mother and baby home closed. It is not entirely clear what happened to them after that. In September 2015, a member of the congregation said that some of the Castlepollard records "made their way" to Bessborough over the next number of years. Some were stored in Mullingar Hospital; it is not known why or for how long. A historian working in Bessborough in the early 2000s told the Commission that the Castlepollard records which were then in Bessborough were incomplete. The Castlepollard records which were held in Bessborough and those held in Mullingar were handed over to the HSE in 2011 along with the records from Bessborough and Sean Ross and are now in the possession of the Child and Family Agency (TUSLA). The Commission has made digital copies of these records and is in the process of analysing them. In 2018, the Department of Health gave the Commission copies of a series of registration of births books from Castlepollard covering the period 1948 – 1971. It is not known how or why these ended up in the Department of Health.

Deaths

5.3 From the records compiled in Castlepollard and the records provided by the GRO, the Commission has established that over 220 children died in Castlepollard (or in hospitals to which they were sent) and there were eight mothers who died from complications of pregnancy/childbirth.

Burials

5.4 In its affidavit, the congregation told the Commission that the Castlepollard burial ground is located within the 18th century walled garden complex.

> "The infants are buried at the rear-ground of the garden/cemetery where the marble memorial cross is located. There was an original 18th century pathway midway

across this garden. When one of the sisters […] died, in 1939[52], she was buried alongside this wall in the foreground of the garden/cemetery. This wall effectively became the marker point between the infant garden/cemetery and the burial place for the sisters of the congregation. Sometime after the congregation left Castlepollard the wall was demolished, and [a mother's] grave[53] became the marker point."

In the same affidavit the congregation said there were three members of the congregation and three mothers buried in this burial ground. Subsequently, the congregation said that there were two congregation members and one mother buried there.

Archaeological assessment

5.5 The HSE (which currently owns the buildings and surrounding land including the burial ground) provided the Commission with a copy of an archaeological assessment of the Castlepollard burial ground. This was carried out in 2017 by Eachtra Archaeological Projects Ltd on behalf of the HSE.

5.6 The archaeological report states that the burial ground is located in a rectangular area immediately south of the walled garden. It is bordered by a high stone wall to the north and a low stone wall to the south. Access is via a pedestrian iron gate decorated with a cross. This gate was erected in the late 1980s or 1990s and the remains of an earlier gate hinge are visible in the wall.

5.7 The archaeologists interviewed three people with "strong local links to Castlepollard and to the Mother and Baby Home". The archaeologists were told (in 2017) that:

- The graveyard was reorganised and cleaned up about 20 years earlier under the direction of a visiting nun. It had been arranged in two separate sections with a central dividing wall. The nuns were buried at the eastern end and the mothers and babies at the western end. In the reorganisation/clean-up, the dividing wall was removed, vegetation undergrowth was removed and the ground surface was levelled off between the two sections. Mounds or soil humps marking babies' graves were levelled off in the process. Soil was brought in during the levelling process. No bones were noted when the work took place. A white marble cross which had been located against a wall at the centre of the site was removed to the far western end following the removal of the central dividing wall.

[52] This particular Sister's grave does not seem to be marked in the burial ground and the death does not seem to have been registered.
[53] This mother's grave is marked in the burial ground and her death is registered.

- There was a caretaker who was responsible for burials; he was considered to have had a strong devotion to the nuns.
- The caretaker had explained that the burial ground was blessed by a priest and that both sections were consecrated.
- The burials were conducted with care and attention.
- The babies were buried wrapped in cloth and each baby was buried in its own single grave.

5.8 Apart from the information about the clean-up that occurred in the 1990s, all of the information provided by the local people is second hand. The Commission has no reason to doubt its general accuracy but it is not possible to prove any of it.

5.9 The archaeologists who carried out the 2017 assessments logged all the memorials[54] in the burial ground. These include headstones for a member of the congregation who died in 1964, another member who died in 1957 and a mother who died in 1939. There is a cross commemorating the members of the congregation and a plaque commemorating the babies who are buried there. There are 38 cobble stones; six of these have names painted on but none of these names appears in the register of deaths.

5.10 The wall on the northern side of the burial ground has a large number of iron nails embedded in the mortar. It had been suggested by some former residents that these were informal grave markers for child burials either as locational markers or markers of the fact of a burial. The archaeologists who examined the burial ground concluded that, while this is possible, they are more likely to have been installed as training nails for wall vegetation and pre-date its use as a burial ground. The congregation told the Commission that it believes the nails predate the mother and baby home by about 200 years and so could not possibly be grave markers; the congregation did not cite any evidence for this.

5.11 The archaeological assessment concluded that there was sufficient space in the burial ground for the number of children who died there.

Congregation evidence

5.12 Two members of the congregation who had worked in Castlepollard told the Commission that the workmen made coffins for the deceased children; one said the coffins were white.

[54] Memorials include permanent structures such as headstones as well as other markers such as crosses.

Commission conclusion

5.13 There was no legal requirement (see Chapter 1) to keep a register of burials in such burial grounds and no such registers seem to exist. Accordingly, there is no documentary evidence of these burials. However, the Commission has no reason to doubt that the majority of the children who died in Castlepollard are buried in this burial ground.

Chapter 6: Bethany Home 1922 – 1972

Background

6.1 Bethany Home was located in Blackhall Place, Dublin between the years 1922 and 1934 and in Orwell Road, Rathgar after that. The records of admissions, births, discharges and deaths which were maintained in the Home have been digitally copied by the Commission and are in the process of being analysed.

Sources of Information

6.2 The deaths of children born in, or admitted to, the Bethany Home were recorded in the Bethany Baby Book Register, which was kept and updated by the Home's authorities between the years 1922 and 1970. In two columns in that register, marked "where gone" and "later news", the death of each particular child was noted, along with the date of death and the location, in cases where the child did not die in the Bethany Home itself.

6.3 Details about the burial of children who died in the Bethany Home were published in 2010 after thorough research by Niall Meehan.[55]

6.4 Mount Jerome Cemetery in Harold's Cross, Dublin, was the main burial site for the children who died in the Bethany Home. The names from the Bethany Home records, including the Baby Book Register were checked against the burial register in Mount Jerome. The cemetery's burial registers show that 240 children who were born in, or at one time admitted to, Bethany Home, died between September 1922 and October 1964. This figure constitutes the majority of known deaths of Bethany Home children from the records made available to the Commission. The burial register also records the burial of 18 stillborn children from Bethany. There are at least 20 other children who died and are not recorded in the Mount Jerome burial register.

6.5 Of that 240, 213 were recorded as coming directly from the Bethany Home. The remaining 27 children were listed in the Mount Jerome burial records as coming from other addresses, with 24 of those being various hospitals around Dublin. The oldest age at death recorded was 36 months; the others were all aged 19 months or under.

6.6 The children who are buried in Mount Jerome are buried in a series of unmarked graves. In most cases, the costs of burial were met by the Bethany Home authorities. The

[55] See Niall Meehan, Supplement to *History Ireland*, Vol 18. No 5, September-October 2010 https://www.academia.edu/320793/Church_and_State_and_The_Bethany_Home

Mount Jerome records show that all were buried in graves located in sections 218 – 618 of the cemetery; all but five are located between sections 253 and 404. A monument to commemorate them, erected in 2014, is located in section 274 - roughly central to most of these sections of the graveyard.
http://www.mountjerome.ie/?map=mount-jerome-cemetery-map

6.7 The Bethany children were buried in ordinary public graves and grave plots in the cemetery, often in, or next to, those used for other private/public adult or child interments. They were not placed in a specific and separate "Poor Ground" section. Once a particular grave reached full capacity, it was simply closed and the next available grave with spare capacity was used.

6.8 Mount Jerome Cemetery has kept very good records of all burials. The Mount Jerome Cemetery Register of Burials, Volumes 24 - 46, covers all burials in the cemetery between March 1919 and January 1967. In the case of the Bethany Home children buried there, the Register of Burials records the child's name, age, the cause of death, the date of death, the date of burial and the burial number it represented for the year. The Register also recorded the address the child came from which, for most, was Bethany Home, 23 Blackhall Place prior to October 1934 and Bethany Home, Orwell Road, for all burials subsequent to that. The Register also noted the grave number and section of the graveyard the child was buried in and the future capacity of the grave. In relation to the latter, all were marked "full" by the time the burial records were completed.

6.9 In all but 19 cases, the Mount Jerome Burial Register recorded the causes of death for each Bethany child who was buried there between 1922 and 1964.

6.10 The Burial Register had a column marked: "Address and Relationship of Attestant". This column was completed up to May 1929 but is blank after that. For most, the Matron of Bethany or her assistant was the attestant. However, in some cases the child's mother and her address (either Bethany if she was still resident there, or else her home address) were inserted.

Anatomical studies

6.11 The burial records show that the children were usually buried within two to three days of death. Therefore, unlike children who died in the Dublin Union and associated institutions (see Chapter 7), there is no evidence of any child from Bethany being used as an anatomical subject before being interred in Mount Jerome.

Chapter 7: Burial of Anatomical Subjects

Background

7.1 The sending of the bodies of unclaimed deceased residents (of all ages) from institutions such as workhouses/county homes and psychiatric hospitals to medical schools for the purposes of dissection and anatomical study was common practice across the UK and Ireland until the mid-1960s. The *Anatomy Act 1832*[56] gave legal backing to this practice. An *Irish Times* article on the subject in 1907 described the processes involved.[57]

7.2 A campaign to encourage voluntary donation was undertaken in the 1960s by the Professors of Anatomy in the various Irish medical schools.[58] This seems to have resulted in the ending of the practice of using unclaimed bodies; however, it remained legal to use them. An Inspector of Anatomy said that donated bodies had "almost replaced" unclaimed bodies in the Dublin medical schools at the time of his appointment in 1967. An internal Department of Health memorandum, dated 1984, states that the practice of using unclaimed bodies in anatomical studies had ceased.[59] This seems to have occurred because there was a sufficient supply of donated bodies.

Anatomy Act

7.3 The *Anatomy Act 1832* provided that it was lawful for any executor or other party who had lawful possession of the body of any deceased person (apart from an undertaker who had possession of the body for the purposes of burial) to allow the body to undergo anatomical examination unless the deceased person had expressly stated that this was not to happen. This had to be expressed in writing or orally in the presence of at least two witnesses; in effect, people had to specifically opt out. The husband, wife or any known relative of the deceased could also prevent such an examination. Bodies could not be sent to medical schools until at least 48 hours after death: this was to enable family members to claim the body and/or object to the body being sent for anatomical studies.

7.4 This meant that the body of any resident who died in an institution such as a workhouse, county home or psychiatric hospital could be supplied to medical schools if no relative claimed it within 48 hours of the death. In the case of deserted or abandoned children who died in these institutions, there was no one with the legal capacity to object to

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[56] It was introduced in order to regulate the practice of anatomical studies and to try to prevent illegal trafficking in corpses (including grave-snatching). The text is available at: http://www.irishstatutebook.ie/eli/1832/act/75/enacted/en/html
[57] Jerry Cassidy, "Food for the dissecting knife: How the anatomical schools are supplied with dead bodies", *Irish Times*, 13 April 1907.
[58] Statement by the Anatomical Committee of the Irish Medical Schools 2011.
[59] Department of Health file CBP-NF-0-49129.

the bodies being sent for anatomical studies. The bodies of "illegitimate" children that were unclaimed by the mother or any other relative, could similarly be used for anatomical studies. It is not known, but it seems unlikely, that the mothers concerned were made aware of the existence or requirements of the *Anatomy Act* at any stage during their stay in any of the institutions being investigated.

7.5 The *Anatomy Act* required that all bodies being removed for anatomical examination be placed in a "decent Coffin or Shell" before removal. The medical schools which received the bodies were obliged to ensure that the bodies, after the anatomical examination, were "decently interred in consecrated Ground" or in some public burial ground in use for people of the same religion as the deceased. The Act required that a certificate of interment be provided to the Inspector of the district[60] within six weeks of the receipt of the body but this was amended in 1871 to provide that this time period could be varied.[61] The 48 hour rule and the six week time limit applied to all bodies being sent for anatomical studies and not just to unclaimed bodies. The medical schools were required to maintain registers of bodies received for anatomical studies.

Compliance with the Act

7.6 It seems that the provisions of the *Anatomy Act* were not always strictly observed; in particular, the time limits seem to have been rarely observed. An internal Department of Health memorandum, compiled in 1983, notes that there were complaints in the 1960s from relatives of deceased former residents of a county home and a public nursing home. The memorandum does not give details of the nature of the complaints but it does note that the author held a file on one of the complaints.[62]

7.7 This memorandum makes it clear that the 48 hour rule and the six week limit were not implemented in practice; it noted that it was commonplace for the body to be removed for anatomical study on the day of the death and the bodies were "rarely" buried within the specified time.

7.8 A witness told the Commission that he had discovered his mother had given birth to a son in Pelletstown in 1947. The child died in St Clare's Hospital[63] a few weeks later. His body was removed to UCD the day after he died. The child's mother was resident in

[60] The Act provided for the appointment of Inspectors of Schools of Anatomy.
[61] It does not seem to have been varied but, as is clear in the text, it was not strictly adhered to.
[62] Department of Health File CBP-NF-0-49129.
[63] St Clare's Hospital was in Glasnevin. It was also part of the Dublin Union and specialised in dealing with gastroenteritis; many children from Pelletstown were sent there for treatment.

Pelletstown at the time of his death. It is theoretically possible that his mother consented to his body being sent for anatomical study but the 48 hour rule should have applied anyway. The child was buried in Glasnevin in 1949.

7.9 The Commission has since established that a number of children were transferred for anatomical studies from Dublin Union institutions before the 48 hour period for claiming the body was over. In general, burial took place two to three years after the death.

Separate burial spaces

7.10 The rules about burials (see Chapter 1) applied to the burial of bodies used for anatomical studies in the same way as all other burials. There is some evidence that those responsible for burials did not consider that the burials of bodies used for anatomical studies should be treated in the same way as other burials. In January 1961, the Galway County Chief Medical Officer wrote to the Department of Health to complain about the rules in relation to burials and to suggest that they were not being kept by medical schools:

> "A problem has arisen regarding the interment of such remains of bodies following their use for anatomical dissection.
>
> According to the Rules applicable to burial grounds for every person over 12 years of age a burial space of 9ft. x 4 ft. must be provided. This would mean that if the remnants of ten cadavers were to be interred, ten graves should be provided, ten graves which would prove very costly and indeed wasteful of graveyard space. The remains of a cadaver after dissection consists of dismembered bones, perhaps some entrails and muscles which could be easily accommodated in a coffin 3' x 12" x 9 ", and if placed vertically in the grave four such coffins could be accommodated in the space above prescribed. Markers, of course, would be placed over each coffin. There would be no intermixing of corpses. I understand that this procedure is adopted for other anatomical schools.
>
> I request a direction if the procedure suggested above would be allowed and approved of by your Department."

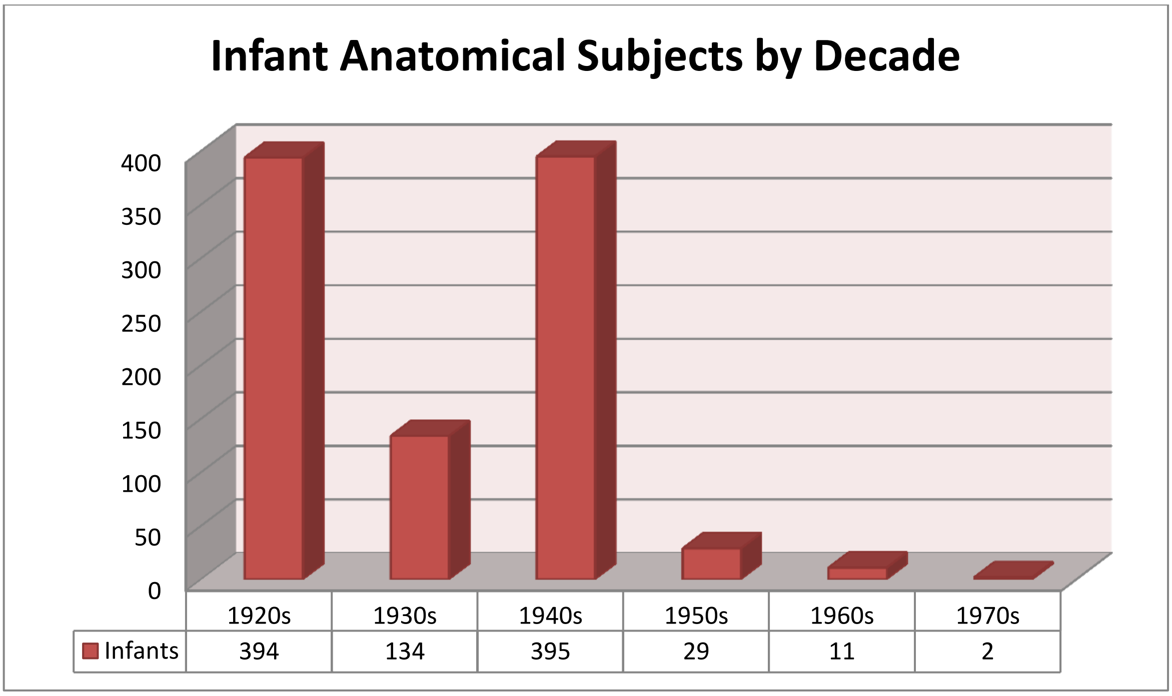
7.11 The Department's Inspector of Anatomy did not agree with the suggestion but a civil servant's note on the file states that "… it might be said that these Rules are not always (or even usually) strictly observed throughout the country".[64] The Galway County Medical

[64] Department of Health file SND-INA-0-516193.

Officer called to the department's offices to pursue his point but was met with the same response.[65]

Dublin Medical Schools

7.12 The Combined Anatomical Register of the Dublin Medical Schools shows that, between January 1920 and October 1977, the bodies of more than 950 children[66] who died in the Dublin Union and associated institutions, including Pelletstown, were sent to the medical schools at University College Dublin, Trinity College Dublin and the Royal College of Surgeons in Ireland for the purpose of anatomical studies.[67]



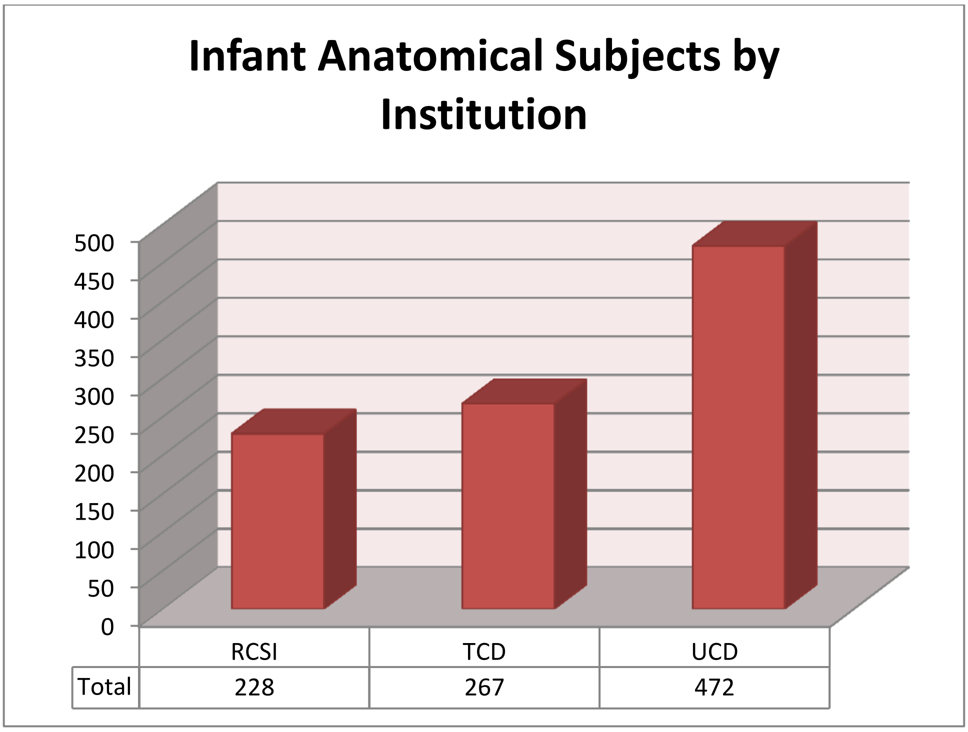
[68]

7.13 The Combined Anatomical Register of the Dublin Medical Schools records that all but 18 of the children received as anatomical subjects were "illegitimate" children. Children used as anatomical subjects in the Dublin Medical Schools were aged between 10 minutes and 15 years at the time of death. In addition, the register records that 27 stillborn infants were received as anatomical subjects. Many of the stillborn infants had a note reading "not to be

[65] *ibid*
[66] The Commission is checking the exact number involved; this represents 29% of all bodies received by the Dublin medical schools in this period.
[67] The Commission examined this register in UCD.
[68] These figures are based on the date of receipt of infants as anatomical subjects. In two cases it was not possible to establish a date of receipt.

interred" on their record.[69] It may be that stillborn infants were preserved as "wet specimens" for display purposes in medical schools.[70]

7.14 Not all deserted or abandoned children who died in Dublin Union institutions were sent for anatomical studies. There is no information available about the criteria (if any) used to choose which children's bodies were sent.



Burial in Glasnevin

7.15 The children from Dublin Union institutions whose bodies were used for anatomical studies were subsequently transferred from the three Dublin medical schools for burial in the Poor Ground section of Glasnevin Cemetery. They were clearly identified in the Glasnevin Poor Ground Burial Registry by the designation "AS" (anatomical subject). The time lag between when these children died, were received by the medical institution for anatomical study and were subsequently sent to Glasnevin Cemetery for burial varied considerably. Usually it was over a year between a child's death and the eventual interment of the remains in Glasnevin.

7.16 They were buried in different sections of the Poor Ground in Glasnevin: from 1919 to 1928 in St Paul's Poor Ground; from 1934, in St Patrick's Poor Ground; and from December

[69] Combined Anatomical Register of the Dublin Medical Schools pre 1972, University College Dublin, Special Collections.
[70] Stillborn infants received by the Dublin medical schools do not appear in the Glasnevin Cemetery Burial Records.

1945, anatomical study burials were placed in the newer South Poor Ground section of the cemetery.

7.17 Anatomical subject remains were not buried in a distinct section of the Poor Ground. They were buried in individual burial plots that were located next to those used for ordinary child and adult burials. The usual practice in Glasnevin Cemetery was for the remains of a number of anatomical subjects to be collectively buried in the same plot on the same day. For example, the Glasnevin Poor Ground Burial Register shows that on 20 May 1921, 33 anatomical study remains, all former residents of the Dublin Union, were buried in grave plots Sb 76-76.5, of the St Paul's Poor Ground. Eighteen of these were adults aged between 28 and 109. Fifteen were children; 14 were described as either "illegitimate" and/or deserted. Ten days later, 41 anatomical study remains, all originally from the Dublin Union, were buried in graves Rb 76-76.5, of the St Paul's Poor Ground. Ten were adult anatomical studies aged between 51 and 83. Thirty-one were children, described as either "illegitimate", deserted and/or nurse children. One child buried on this date is not recorded as an anatomical study in the Glasnevin Burial Register but he is recorded as one in the Anatomical Register of children from the Dublin Medical Schools.

7.18 This practice of adult and children remains being buried together on the same day within the same grave plots continued down through the years. On 21 July 1922, thirteen adult and nine children (all but one described as "illegitimate" and/or deserted) were buried in plots Wb 82-82.5 of the St Paul's Poor Ground. On 9 July 1924, 30 anatomical study remains, 15 adults and 15 children (all but one described as "illegitimate" and/or deserted) were buried in plots Tb 91-91.5 of the St Paul's Poor Ground.

7.19 On 7 July 1926, 16 anatomical study remains, seven adults and nine children (all described as "illegitimate" and/or deserted) were buried in plots Jb 69-69.5 of the St Paul's Poor Ground. On 30 April 1935, nine anatomical study remains, five adults and four children (two "illegitimate", one legitimate and one nurse child) were buried in plots Go 157-157 of the St Patrick's Poor Ground. Eight anatomical study remains, four adults and four children, were buried on each of three dates in January 1943. Of the twelve children, one was described as a nurse child, the others were recorded as being "illegitimate". All were buried in plots Bo 168.5-169 of the St Patrick's Poor Ground.

7.20 On 13 July 1946, 23 anatomical study remains, three adults and 20 children (all but one described as "illegitimate") were buried in plots Na 113-113.5 of the South section of the Poor Ground. On 11 July 1950, 21 anatomical study remains, eight adults and 13 children (all described as "illegitimate") were buried in plots Va 116-116.5 of the South section of the

Poor Ground. On 9 June 1960, 12 anatomical study remains, six adults and six children (all described as "illegitimate") were buried in plots Ia 104-104.5 of the South section of the Poor Ground.

Separate coffins

7.21 It is unknown if the remains of individual bodies used for anatomical studies were placed in separate coffins for burial in Glasnevin. A meeting of the Dublin Board of Guardians in 1907 heard accusations that in the medical schools, coffins were not being used for one body alone, but that the practice was simply to fill up a coffin with various body parts from various individuals who had been dissected.[71]

7.22 Glasnevin Cemetery is a private cemetery. At the relevant time, it was governed by the *Dublin Cemeteries Act 1846* and the bye-laws made under that Act.[72] The bye-laws (made in 1901) set out procedures to be followed if there was more than one body in a coffin:

> "In every case of an application being made for an order for burial of more than one body in a coffin, a notice or certificate in writing in the prescribed form shall be delivered or furnished to Head Office, duly signed by the applicant, containing to the applicant's best knowledge and belief, all the particulars indicated by such form respecting each of the bodies of the deceased persons contained in said coffin."

7.23 This clearly envisages the possibility of more than one body being in a coffin. The Dublin Cemeteries Committee (generally known as the Glasnevin Trust) which runs the Glasnevin Cemetery told the Commission that each of the anatomical subject burials was given an individual sexton's number indicating that for each register entry there was an individual coffin. "There are no annotations within the burial registers showing that permission was granted … to allow more than one set of remains per coffin."

7.24 A further bye-law provided that:

> "No coffin containing a body or portion of a body (save in the case where the person whose body is being buried had not been identified previous to burial) shall be admitted into the Cemeteries unless and except the name or names of the person or persons whose body or bodies etc. are contained in said coffin shall have been legibly inscribed on the lid of the coffin. In the case of stillborns the surname or

[71] North Dublin Union: Paupers' bodies for medical schools, *Irish Times*, 28 March 1907.

[72] The 1846 Act was replaced by the *Dublin Cemeteries Committee Act 1970* which is currently in force.

surnames of the body or bodies contained in the coffin shall be inscribed on the lid of the coffin."

7.25 A member of the cemetery staff was required to see that the names on the docket and the names on the coffin corresponded. The Glasnevin Trust told the Commission that, while each burial was required to be witnessed by a designated member of staff, the staff did not inspect coffins internally.

Galway Medical School

7.26 The Galway Medical School Anatomical Register[73] records details of approximately 690 deceased adults whose remains were transferred to the School of Anatomy, Galway Medical School,[74] during the years 1909-1997, for the purposes of anatomical study. The register includes all the required details about the deceased adults. It records human remains as they were received in chronological order and there is no break in the numerical assignation associated with each individual. There is no obvious gap or omission in the register.

7.27 During the period 1909-1920, the adult human remains were received almost exclusively from the South Dublin Union. From 1920 to 1950, human remains were received almost exclusively from the Ballinasloe Mental Asylum; the Castlebar Mental Hospital after 1950; and Ennis Mental Hospital after 1958. A small number of bodies were received from Galway Central Hospital/ Galway Regional Hospital[75] over the period 1909-1970, but again these were all adult remains.

7.28 The Galway anatomical register does not include any children. However, evidence exists that children's bodies were sent to the medical school.

7.29 The Department of Children and Youth Affairs *Report of the Inter-Departmental Group on Mother and Baby Homes* states that the Anatomy Department at University College Galway received the remains of 35 children from the Central Hospital/Regional Hospital, Galway in the years 1940-1964. It also states that the Galway Medical School received the remains of 27 children between 1960 and 1964; however, the Galway Anatomical Register records just 24 bodies in total during the same period and they are all adult remains.

[73] This is held by the Medical Council.
[74] Originally Queen's University Galway, then University College Galway, now NUI Galway.
[75] The old Galway workhouse became the Galway Central Hospital in the period 1922 - 1924. It was subsequently rebuilt and renamed the Regional Hospital. It is now the Galway University Hospital.

7.30 The Commission asked the current head of the anatomy department at NUI Galway for further information about this. He invited the Commission to see some extant historical documents from the department. One of the items examined was a "Receipt Book for the Removal of a Dead Body" issued to the department by a then Inspector of Anatomy. Details relating to 15 adult anatomical subjects were recorded as having been received on dates between October 1920 and March 1922; 11 remains were received from Ballinasloe Asylum and the remainder came from the Galway Workhouse/Union/Central Hospital.

7.31 A Department of Anatomy Mortuary Book recorded the reception of adult anatomical subjects from January 1878. The last entry seen by the Commission was made on 6 November 2017. All entries relate to adult anatomical subjects and correspond with the Galway Anatomical Register.

7.32 The third item was labelled "Day Book". This records single line handwritten entries relating to the anatomy department, including the purchase of materials and supplies. Although the Day Book covers the period 1920 to the 1970s, a large portion of the book covering the period 1931 to 1947 is missing. It has not been possible to determine when these pages were removed, or the reason why they were removed.

7.33 In what remains of the Day Book, it is possible to identify the reception of infant remains for use as anatomical subjects. In every instance, the body or bodies were supplied by a porter at the Central Hospital/Regional Hospital Galway. In every instance the infant remains were received by the head of the School of Medicine and Anatomy Department, University College Galway. He paid the porter 10/- for every infant body received. It appears that between April 1949 and November 1964, he received and paid for 35 infant anatomical subjects. None of these infants is recorded in the Galway Anatomical Register. Unfortunately, no records survive which name the children whose bodies were sold. It is possible that some of the bodies were stillbirths which, at the time, could not have been registered.[76]

7.34 Children resident in the Tuam Children's Home were routinely sent to Galway Central Hospital for treatment. The Commission has established that 86 children from the Tuam Home died there (see Chapter 8). The Commission has found burial records for 50 of these children in Bohermore Cemetery Burial Records. The records show that these children were generally buried within a few days of death so it seems unlikely that they were used for

[76] The *Stillbirth Registration Act 1994* came into effect on 1 January 1995. Prior to that, it was not possible to register stillbirths.

anatomical studies. The Commission has asked the HSE if any relevant records from the Galway Central Hospital can be located.

7.35 The current head of the Galway Anatomy Department told the Commission that, when he took up this post in 1995, there were many “wet” infant anatomical subjects preserved in the department. These unidentifiable infant remains were buried together in Rahoon Cemetery, Galway in 1995 with full funeral rites and with the permission of the Coroner.

Cork Medical School

7.36 The Commission has found no evidence that children were used for anatomical studies in the Cork Medical School.

Chapter 8: Tuam Children's Home 1925 - 1961

Background

8.1 The Commission's Terms of Reference describe the Tuam Children's Home as "Bon Secours Mother and Baby Home". This does not seem to have ever been the name of the Home.

8.2 The Tuam building was originally a Poor Law Union workhouse and was used as such until the early 1920s when a number of workhouses were closed and other changes were made to the Poor Law institutional arrangements in Galway.[77] It was occupied briefly by the Free State army after it ceased to be a workhouse and before it became the Children's Home. As part of the Poor Law reorganisation, another former workhouse, Glenamaddy, was designated as a Children's Home for children and unmarried mothers and was used as such in the period 1922 – 1925. It was run by the Sisters of Bon Secours and owned by Galway County Council. It was in very poor condition so the decision was made to use the former Tuam workhouse as the Children's Home. Children were moved from Glenamaddy in 1925. The Commission regards the Glenamaddy Children's Home and the Tuam Children's Home as one institution.

8.3 The title "Children's Home" was used by its owner, Galway County Council, for virtually all of its existence (it closed in 1961); the first record the Commission has seen of Galway County Council's use of "St Mary's Home" dates from 1960. Locally, it was known simply as "the Home". The Sisters of Bon Secours used the title "St Mary's Children's Home" but the Commission has not been able to establish when it first used this title.[78] The Archbishop of Tuam gave the Sisters approval to set up St Mary's Home as a separate foundation in 1956.

8.4 The Tuam Children's Home was owned by Galway County Council[79] and operated by the Sisters of Bon Secours[80]. The Commission has seen references to the existence of a

[77] Changes were made in nearly all other counties as well; further information about the re-organisation of Poor Law institutions will be included in the Commission's final report.

[78] Former workhouses which became county homes in the 1920s were generally known by their location. Gradually, they were given saints' names and these names became officially used from the 1950s onwards; locally, they continued to be known by their location.

[79] The grounds were owned at different times by different State bodies but the institution was the responsibility of Galway County Council for all of the period during which it was the Tuam Children's Home.

[80] The Sisters opened a hospital/nursing home called The Grove in Vicar Street, Tuam in 1945; it was sometimes called St Anne's. This was a private institution and had no official connection with the Tuam Children's Home. Between 1945 and 1953, the Sister who was the Superior in the Children's Home was also the Superior in The Grove. The Grove closed in 2001 and the premises are now owned by the HSE.

formal agreement between Galway County Council and the Sisters but, so far, has not been able to locate this. Galway County Council made the decisions on who entered the Home; it paid directly for external repairs to the building, rates, water rent and insurance. It also paid the salaries of the chaplain (who was allocated by the Archdiocese of Tuam) and the medical officer and it paid for the services of the maternity nurse. It paid a capitation rate to the Sisters for the upkeep of the residents. It did not pay salaries to the Sisters who worked there. Tuam Children's Home differed in this respect from St Patrick's, Navan Road/Pelletstown (see Chapter 2) which was owned and financed by the Dublin health authorities[81] and operated by the Daughters of Charity of St Vincent de Paul. The Daughters of Charity were paid as public servants to operate the institution and all costs were met by the Dublin health authorities.[82]

8.5 In 1931, Mayo County Council entered into an agreement with Galway County Council to send women and children from Mayo to the Tuam Children's Home. Mayo County Council paid capitation rates in the same way as Galway but was not involved in decision making about the Home.

8.6 The Tuam Children's Home was designated as a home for children and unmarried mothers. It was not used exclusively as a home for unmarried mothers or as a mother and baby home. It did house unmarried mothers and their children but it also housed children of married parents who were unable to care for them and it housed homeless families.[83]

8.7 Between 1925 and 1942, many of the decisions in relation to the Tuam Children's Home were made by the Galway Board of Health which was composed of members of Galway County Council.[84] The County Home and Home Assistance Committee, which was a sub-committee of the Board of Health but also included non-council members, was also involved in making decisions. The Board of Health and the County Home and Home Assistance Committee held a number of their meetings in the Tuam Children's Home. In 1942, the Board of Health ceased to exist and its functions were transferred to the County Manager when the *Public Assistance Act 1939* and the *County Management Act 1940* came into effect. From 1942, many of the decisions were made by the County Manager by way of Managers' Orders. National government also had a role in the decisions made. Many of the

[81] The different arrangements and titles of bodies for the delivery of health and public assistance services will be fully explained in the Commission's final report.
[82] The post 1922 structures for health authorities differed somewhat in Dublin.
[83] A small number of children who died in the Home were resident there with their families. "Legitimate" children accompanied by a parent or parents are outside the Commission's Terms of Reference.
[84] The *County Scheme Order, Galway No 1, 1923* provided for the establishment of the Board of Health and for it to establish sub-committees: http://www.irishstatutebook.ie/eli/1923/sro/920/made/en/print

decisions, for example, in relation to capitation rates, were subject to the approval of the Department of Local Government and Public Health between 1922 and 1947 and the separate Department of Health after that. Decisions on water and sewerage expenditure were subject to the approval of the Department of Local Government and Public Health between 1922 and 1947 and the separate Department of Local Government after that. Such expenditure frequently involved taking out loans from the Local Loans Fund. The Board of Public Works had a role in approving the use of these funds.

Deaths in the Tuam Children's Home

8.8 The Commission has established that a total of 973 children from the Children's Home died either in Glenamaddy, in the Tuam Home itself or in a hospital or institution soon after they were transferred there from Tuam. Of these, 79 children died in Glenamaddy. The Glenamaddy workhouse had its own burial ground so it is likely that the children who died there are buried in that burial ground. However, there is no burial register available for the period in question so this cannot be verified. The vast majority, 802, died in the Tuam Home itself. This number includes a significant number of "legitimate" children who are within the Commission's Terms of Reference because they were not accompanied by a parent and a small number of "legitimate" children who are outside the Commission's Terms of Reference because they were accompanied by a parent. (The children who were accompanied by a parent are less likely to be buried in the Tuam burial ground and are more likely to have been buried by their parents.) The details of the deaths of the children were established by the Commission from the records compiled in the Home (see below) and from a list provided by the General Register Office (GRO) and already in the public domain. There are six children whose deaths are recorded in the records compiled within the Home and who are not on the GRO list. The Commission has been unable to find any mention in the Tuam Home records of six children who are included in the GRO list.

8.9 When analysing the records, the Commission noted that a significant number of children who were resident in the Tuam Children's Home were transferred to the Central Hospital, Galway[85] when they became seriously ill. The Commission checked the Register of Deaths and found that 86 children who had been transferred there died soon after the transfer. Six other children died soon after leaving the Tuam Home: two children died in the County Home, Castlebar; one died in Crumlin Children's Hospital; one in St Bridgid's Industrial School for Girls, Loughrea; one in Clifden District Hospital and one died at home.

[85] The old Galway workhouse became the Galway Central Hospital in the period 1922 - 1924. It was subsequently rebuilt and renamed the Regional Hospital. It is now the Galway University Hospital.

The Commission has found burial records for 50 of the children who died in the Central Hospital, Galway – they are recorded as being buried in Bohermore Cemetery.

8.10 Twelve mothers who were resident in the Tuam Home died, the majority from complications of childbirth; some died in the Home itself and some in the Central Hospital, Galway. It is not known who took responsibility for the burial of these mothers. If the Central Hospital took responsibility for the burials it would be expected that they would be recorded in Bohermore cemetery but the Commission did not find any record of these burials there.

Sources of information on burials

8.11 There is remarkably little official documentation available about many aspects of the Tuam Children's Home and there is virtually no information about burials in the documentation that has been seen by the Commission. There are references in various documents provided to the Commission by Galway County Council and the Department of Health to inspections of the Home. However, until very recently, the Commission has seen only one report of an inspection; this is the inspection carried out in 1947 by the Department of Health. This report does not mention burials. In December 2018, the Commission received a number of files from the Department of Health which contain some inspection reports on the maternity wing of the Home and some other reports about the condition of the Home immediately before it was closed. Again, none of these reports contain any references to burials.

Records compiled in the Tuam Children's Home

8.12 The records of admissions, births, discharges and deaths which were compiled in the Tuam Home by the operators of the Home were left with Galway County Council when the Home was closed in 1961. (The County Council was probably the owner of the records anyway.) These then became the property of the Western Health Board when it was established in 1970. Subsequently they became the property of the HSE in 2005 and then the Child and Family Agency (TUSLA) in 2013. The Commission has made digital copies of these records and has almost completed analysing them. These records include details about the deaths of children and the causes of death in many cases but do not include any information about burials.

8.13 In the years since the Home closed, these records have been used mainly for tracing purposes. The Commission is concerned that some records may have been lost or destroyed over the years. It is impossible to establish if the records currently held by the

Child and Family Agency (and made available to the Commission) constitute all of the records left behind when the Tuam Home closed in 1961.

Galway County Council records

8.14 The extant minutes of the Galway Board of Health are held by Galway County Council. There is almost a complete set for the period 1922 – 1941 but there are some gaps and there are no surviving minutes for the year 1937. The Commission has examined these records in detail. There is no specific mention of burials in these minutes but there are a number of references to issuing tenders for coffins. The tenders were for coffins of various sizes. There is no mention of coffins actually being bought.

8.15 These minutes do contain extensive references to the water supply problems faced by the Tuam Home and to the various attempts to improve it and to connect the Home to the Tuam sewerage system – see below.

8.16 The meetings of Galway County Council, the Board of Health and its subcommittees were held in public and received extensive coverage in the local newspapers. The Commission has searched these newspapers for any references to the Tuam Children's Home.

8.17 Managers' Orders were not discussed publicly. The Commission has examined the Managers' Orders for the period 1942 – 1961 in order to find any references to the Tuam Children's Home. Again, there are references to the water supply and sewerage problems and to tenders for coffins but no specific reference to burials. The coffin tenders are for various sizes of coffins and seem to have been issued at six month intervals. The cost of the large coffins was questioned a number of times. However, there is no record of any coffin being bought in this period either.

8.18 Galway County Council told the Commission that it was unable to find any records which showed that the Council had any role in the administration or regulation of a burial ground in the grounds of the Children's Home. In oral evidence to the Commission, representatives of Galway County Council said that there are 233 burial grounds in County Galway listed on the Galway County Council register of burial grounds. There are two listed in Tuam. One is the very old burial ground in Templejarlath which is in High Street and the other is the burial ground on the Athenry Road across the road from the Children's Home and which is still in use. There are registers of burials for both of these burial grounds. The burial ground in the Tuam Children's Home is not on the register. The Tuam workhouse had a burial plot in the burial ground across the road from the building (for which there is a register of burials). There is no evidence that this plot was used for the burials of children or adults who died in the Tuam Children's Home.

8.19 The Tuam Children's Home was owned by a local authority and not by a religious order. The Commission considers that the general rules in relation to local authority burial grounds should have applied – see Chapter 1. Among other things, this meant there was a legal requirement to keep a register of burials. There is no evidence that such a register was compiled.

8.20 The first documentary evidence of Galway County Council's awareness of the possible existence of a burial ground in the grounds of the Tuam Children's Home dates from the 1970s (see below). The issue came to light during the building of the Dublin Road Housing Estate. This was a Galway County Council development which was built in four phases starting in 1972 and concluding in 1978. Galway County Council has documentation relating to the last two phases but not to the first two.[86] Documentation in relation to the first phase was sent to the Department of Local Government in 1969/70. The Department is currently searching its archives to see if this is available. The National Archives of Ireland does not have this documentation.

8.21 There is a document on a Department of Health file[87] which suggests that there may have been some rumours about the Tuam site in 1969. This is a handwritten note on a file dealing with the possible closure of some mother and baby homes. The note states "Surely the story about the Waterworks is not true? Do M[88] get police reports on abandoned dead babies?" The Commission interviewed a retired senior official of the Department of Health about this. He was able to give an indication of who the author was but that person is dead. He was not able to cast any further light on the matter. The Commission recognises that this note may be completely unconnected to Tuam but its creation in 1969 does coincide with the making of plans for the development of the Dublin Road Housing Estate. In the absence of any other related documents, the Commission is unable to draw any conclusions about this.

[86] At the time, local authorities did not need planning permission for their own developments so there would not have been any planning documents created. It is highly likely that there were detailed plans, including water and sewerage plans, bills of quantities and other construction documentation created at the time but Galway County Council has been unable to provide such documentation.
[87] Department of Health file INACT-INA-0-426512
[88] M was a section of the Department of Health at the time.

The Sisters of Bon Secours

8.22 Soon after its establishment in 2015, the Commission asked the Sisters of Bon Secours for any information or documentation they held on the Tuam Children's Home. In 2015, the Sisters provided a small number of documents which were largely concerned with the plans to close the Home in the period 1959 – 1961. They stated that they had left all relevant documents in Tuam when the Children's Home closed in 1961 and they believed that these documents were now in the possession of the Child and Family Agency. In March 2016, they provided some further documentation but this was largely concerned with correspondence after the closure of the Home. None of the documentation had any reference to burials.

8.23 The Sisters told the Commission that there is only one Sister alive who actually served in the Home. She served for only a few months and is now unable to assist.

8.24 The Country Leader of the Sisters of Bon Secours in Ireland provided an affidavit to the Commission in February 2018. This dealt with a range of issues including burial arrangements. She told the Commission that she does not know what the actual burial arrangements were. She said that the present Sisters are "shocked and devastated by what has come to light to date in relation to burials in the subsurface structure".

8.25 The Country Leader said that she understood that mother and baby homes "commonly had burial areas within their confines commonly referred to as "Angels' Plots"" and she would not have been surprised to learn there was such a burial situation in Tuam. She also said that she understood that it was common practice for such burial areas not to be publicly marked. The Commission is aware that the plot in Glasnevin Cemetery has been known as the Angels' Plot since the 1960s. It is not aware that any other similar plot was so named. There is no evidence that the burial plots in Castlepollard and Sean Ross were ever known as "Angels Plots".

8.26 The Country Leader apologised for the failure to provide a proper burial: "It is the view of the Sisters that the children who died at St Mary's deserved a proper burial and this did not happen. For this we express our deep sorrow and apologise unreservedly."

The burial ground/memorial garden

8.27 A walled off area, previously part of the grounds of the Tuam Home, has been maintained by local people as a "memorial garden" since the late 1970s. This garden was maintained with considerable care mainly by a local couple who, with a number of other local residents, formed a “Graveyard Committee” to maintain the area. The Graveyard Committee created a grotto at the south east corner of the garden in memory of the children who died at the Home; this was installed around 1990.

8.28 This area had been entirely enclosed by walls for some time. Two of the walls are higher and older than the others. Two more recently constructed walls on the western and northern boundaries of the garden had been built to fully enclose the garden with gated access. On the western side of the garden, one of the lower walls separates the garden from the back garden of a house in the Dublin Road Housing estate. On the northern side, a wall separates the garden from a children’s playground which was created in the 1980s also on part of the grounds of the former Tuam Children’s Home. Part of the eastern boundary is a much higher wall and was evidently, in part at least, a continuation of the long stone boundary wall that bounded the eastern perimeter of the Home and remains in situ. The southern boundary is of similar height and this forms a boundary with a number of other residential properties. Two gates allow access to the memorial garden; one in the north that leads to the children’s playground and the other to the west that leads to a gravelled road that provides access to the rear of a number of houses on the Athenry Road (R347) which are part of the Dublin Road Housing estate.

8.29 In October 2015, the Commission arranged for a geophysical survey to be conducted on the site. This was a non-invasive survey which was conducted over the surface of the ground inside the current boundaries of the memorial garden/burial ground. The sub surface of the site was not disturbed. The purpose of the survey was to detect the presence of possible sub surface anomalies. Ground Penetrating Radar, Magnetometry and Electrical Resistivity remote sensing methods were used. The report of this survey is at Appendix A.

8.30 This survey identified a particular area of interest and identified a number of sub surface anomalies that were considered worthy of further investigation. These were further investigated by a test excavation in November/December 2016 and in January/February 2017. In March 2017, the Commission issued a short statement setting out the most significant findings of the excavation.

> “Test trenches were dug revealing two large structures. One structure appears to be a large sewage containment system or septic tank that had been decommissioned and filled with rubble and debris and then covered with top soil. The second structure is a long structure which is divided into 20 chambers. The Commission has not yet determined what the purpose of this structure was but it appears to be related to the

treatment/containment of sewage and/or waste water. The Commission has also not yet determined if it was ever used for this purpose. In this second structure, significant quantities of human remains have been discovered in at least 17 of the 20 underground chambers which were examined. A small number of remains were recovered for the purpose of analysis. These remains involved a number of individuals with age-at-death ranges from approximately 35 foetal weeks to 2-3 years. Radiocarbon dating of the samples recovered suggest that the remains date from the timeframe relevant to the operation of the Mother and Baby Home (the Mother and Baby Home operated from 1925 to 1961; a number of the samples are likely to date from the 1950s). Further scientific tests are being conducted."

8.31 The detailed reports of this excavation and the further tests are at Appendix B and Appendix C.

8.32 The Commission's Terms of Reference require an investigation into burial arrangements. They do not give the Commission the responsibility to deal with inappropriate burial arrangements. For example, the Commission does not have the power to arrange for the exhumation of the bodies. Accordingly, the Commission reported its findings to the Minister for Children and Youth Affairs. Subsequently, the government decided that it would take responsibility for dealing with the matter even though it is arguable that, in this case, the onus of dealing with the inappropriate burial arrangements lies with Galway County Council as the owners of the site and of the Home.

8.33 In June 2017, the government established an Expert Technical Group to advise on options and appropriate courses of action available to the government at the Tuam site. Its report was published in December 2017.[89] In October 2018, the government announced its intention to conduct a forensic excavation of the available site.[90]

The Commission's investigation of the burial ground

8.34 The Commission appointed a forensic archaeologist to carry out preliminary investigations into the area described as the children's burial ground and ultimately instructed her to carry out limited excavations. She and her team of specialist archaeologists compiled the detailed reports.

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[89] https://www.dcya.gov.ie/viewdoc.asp?DocID=4515; the Commission had no involvement with this report. The members of the Expert Technical Group did not have access to the Commission's reports.

[90] https://www.dcya.gov.ie/docs/EN/Press-Releases-copy-dcya-gov-ie-2018/81/4983.htm

8.35 The Commission interviewed a number of people who had knowledge of the area. The Commission has not heard any evidence from individuals with **direct** knowledge of the burial arrangements. A local woman (who moved into the area in the 1970s) told the Commission that she was told by a former worker in the Home that the dead babies, including babies who were stillborn, were swaddled and buried. She did not ask where or how; she assumed that they were buried in what is now the memorial garden. This woman told the Commission that her husband had found bones in their back garden when he was sowing it; she believed that they were animal bones.

8.36 The Commission heard evidence from the two men who, as young boys in the 1970s, found evidence of bones at the site. They described how they had descended the southern wall leading into what later became the memorial garden. One of them remembers jumping off the wall and the ground giving way beneath him when he landed. When he and his friend explored what was underneath their feet, they saw bones at the bottom of a tank which also contained water. He remembers telling his parents about this and the ground was filled in shortly after that after being blessed by a priest. The other person has largely the same memory of the discovery except that he thought the tank was dry. He too had the same view that a priest came some days later and blessed the area which was filled in. A third person who gave evidence to the Commission remembers, as an adult in the 1970s, seeing a child running around a portion of the grounds of the Children's Home with a skull on top of a stick. She challenged the child and took the skull and when she went to investigate where it came from and return it she fell into a structure which she said was full of the swaddled bodies of children.

8.37 A local woman told the Commission that she remembered the construction of the Dublin Road housing estate. She said that mounds of earth were created during the construction and bones were visible in those mounds. She said the bones were collected in or near the playground area.

8.38 In 2014, An Garda Síochána conducted an investigation. The documentation collected and the analysis done were provided to the Commission. The Gardaí had met a number of people with knowledge of the Home and the burial ground including representatives of the Sisters of the Bon Secours and the two men who had found bones at the site in the 1970s. The Gardaí concluded from their analysis of maps and from inspection of the site that the burial ground was about three times larger than the area which is now maintained as a burial ground. They concluded that the back gardens of some of the properties on the Athenry Road were part of the burial ground.

Maps and aerial photographs

8.39 The archaeological team and the Commission's researchers examined, among other material, archival records held by Galway County Council and historic Ordnance Survey records, and accessed some aerial photography from the Military Archives. The area representing the memorial garden in part at least corresponded with a delineated area of ground that appeared on a six inch map dating from 1838. This area was an adjunct to the grounds of what was then a workhouse and was described as a "gravel pit". An Ordnance Survey map of 1892 showed for the first time the outline of a formal structure roughly in the same place; however, this structure was not expressly described. An Ordnance Survey map from 1927 labelled the area as "Sewage Tank".

8.40 A drawing for the Dublin Road Housing Estate from Galway County Council archives, apparently created prior to 1975, identified an area of ground which included the area of interest as a "burial ground". An additional plot of ground within the portion marked "burial ground" on this map lying outside of the memorial garden represents an access road that leads up to the current memorial garden. A later drawing of the Dublin Road Housing Estate dated 1978 identifies the "burial ground" in the same location; however, the insertion of this description on the drawing is located more proximately to the area where the memorial garden now stands.

8.41 A third drawing from Galway County Council which outlined plans for further development of the Dublin Road Housing Estate was produced around 1978. An area was marked delineating a "burial ground" but the writing signifying burial ground has moved somewhat closer to what is now the memorial garden. A further map obtained from Galway County Council contains a drawing with annotation "as constructed layout of County Council Estate Dublin Road Tuam"; on this particular edition of the map, the area previously identified as a burial ground has not been marked or labelled.

8.42 Conveyancing documents from Galway County Council in the 1980s describe the area in question as "indicated with the words sewage tank".[91]

8.43 An aerial photograph taken in 1974 obtained from Ordnance Survey Ireland demonstrates that an area overgrown with vegetation largely corresponds with the area from the housing estate drawings as a burial ground. A second aerial photograph from 1977 from

[91] Letter from the Council's solicitor to the Western Health Board's solicitor dated 2 June 1982

the Military Archives shows the same area as still overgrown.[92] A more recent aerial photograph obtained from Ordnance Survey Ireland which is dated circa 2015 shows both the memorial garden, walled off, with the remaining part of ground included in the area described as a burial ground now devoid of any of the overgrowth previously seen. This area to the west is currently used as an access way to the rear of a number of the houses on the Dublin Road Estate and for access to the memorial garden.

Galway County Council awareness of burial ground

8.44 There is evidence from the County Council archives that the Council was aware of the existence of a children's burial ground on the Tuam site in the early 1970s. The Council told the Commission that it was not aware that burials of the nature discovered by the Commission's investigation had taken place there. Some of the maps and aerial photography described above were available to the Council. The aerial photography illustrates that the walled off area identified locally as the memorial garden was an area that was walled off on all sides at some stage after 1977. Council records suggest that this occurred in the early 1980s and was possibly altered by raising the level of one of the walls in the early 1990s. The wall separating the memorial garden from what became the children's playground and also separating the area later utilised for the purposes of an access road was apparently built in the 1970s presumably during or proximate to construction of a phase of the Dublin Road Estate and before 1977. The most recent aerial photograph dating from 2015 when compared with the earlier aerial photos demonstrates the changes that took place between 1977 and 2015.

8.45 The minutes of a Galway County Council meeting of 17 December 1979 record a motion proposed by a Council member for development of a playground "…having regard to the existence of a memorial site, a children's Burial Ground, and another Burial Ground adjoining." The reference to the memorial site is to a civil war memorial for six men executed in Tuam in 1923. An estimate of costs involved was prepared which came to a total of £10,700. Two items on the costing are of note:

"6. Level rake and shed border areas and burial ground	1,100.00
7. Provide playing equipment on children's burial ground	2,000.00"

Approval was given in May 1981 for expenditure of £10,700.00 for the development of the open space and what was described as the "old children's burial ground".

[92] Military Archives Ireland. Vertical Aerial Photography, V456#23; Tuam, Co Galway, October 1977.

8.46 On 1 February 1991 a local priest wrote to the secretary of Galway County Council as follows:

> "I have been asked by the Sec of Athenry Rd Tobberjarlath Rd Residents Association to write to you concerning the condition of the children's burial ground in the former Home in Tuam. It is in poor condition with bones being exposed quite often as a result of children and animals digging. The residents are quite upset by this sight and are doing everything possible to protect the burial ground and to ensure that it is treated as a hallowed place.
>
> If you could use your office to have it concreted, we would be very grateful."

8.47 A Council engineer was directed to investigate and, after visiting the site, responded

> "The area in question is as indicated on the attached map. The area is grassed and on my inspection following numerous previous letters it was in a satisfactory condition. I have no evidence of bones being exposed. Indeed parents should be advising children that it was a formal burial ground and the parents themselves should thus control their children. I have no evidence of digging in the area during my inspection. The area is bounded by concrete walls and a small gate and I do not recommend any further action to be taken".

8.48 This reply suggests that there were other complaints – "numerous previous letters" - about the site but these have not been made available to the Commission.

8.49 A further letter from the Council to the priest on 5 March 1991 confirms that the Council was in the process of arranging to raise the wall adjacent to the playground and to padlock the entrance gate to this burial ground. The Commission notes that the wall bordering the playground is now higher than the wall which bears the entrance gate, so this addition to the wall may have taken place as indicated.

8.50 The Commission heard evidence from both the priest and the engineer. The priest said he had had no further dealings with the Council on the issue. The engineer said he did not remember anything about the site and he was unable to cast any light on the "numerous previous letters".

Results of the Excavation

8.51 The areas of interest identified in the geophysical survey were investigated by test excavations in November/December 2016 and in January/February 2017. The full reports of these excavations are at Appendix B and Appendix C. The following is a brief summary.

8.52 As the excavation was very likely to reveal human skeletal remains, steps were taken to ensure that anything that might be found within the test area was treated with utmost dignity and respect. Forensic protocols and archaeological standards conforming to the best practice guidelines were maintained throughout the excavation. A number of measures were also put in place to protect the integrity of the site and ensure the privacy of the work. The area known as the memorial garden was surrounded by plywood hoarding to inhibit line of sight and to assist in maintaining the security of the location. An Garda Síochána provided a 24 hour security presence at the site. Once excavation was underway, a scene tent was used to cover the trench areas.

8.53 Two structures were discovered. The location of the first structure discovered corresponds with the location of what is described as the "Sewage Tank" on the older Ordnance Survey and title maps. This structure had at some point been deliberately filled with a large deposit of stones, almost to the upper edges. Within the filled material, a glass double ended baby bottle with a made in Germany stamp was found. The Commission understands that pyrex and plastic replaced glass in this type of bottle to a large extent over the 1950s and 1960s, though production of this type of item likely stemmed from the 1920s through to the 1940s. A number of small enamel tin cups were also found at this location. One type of cup, in particular, had a children's nursery rhyme imprinted on it and enquiries confirmed that this cup was of Swedish design and produced between 1920 and 1940.

8.54 The second structure discovered proved to be of greater significance. It is a long structure built within the boundaries of the old sewage tank. It is divided into 20 chambers. Initially, a structure with two lids was discovered. One of the lids was completely intact and the other was partly broken. These lids were carefully removed and were found to have covered a chamber with a small division between two sections of the chamber. Human skeletal remains were immediately visible. Further excavations revealed more lids and, when they were removed, more human skeletal remains were found in the chambers underneath.

8.55 Samples of the remains were retrieved from within the chambers using customised telescopic equipment from the surface openings. The Commission did not consider physically entering the individual chambers because the size of the surface access points was very confined, there was a danger that any attempt at physical entry would have compromised the many skeletal remains and entry was, in any event, not considered to be safe.

8.56 The remains were first visually identified as human, and were subsequently confirmed as such by the Human Osteoarchaeologist who was part of the team. The remains which were recovered were carefully catalogued and detailed records were made of the location and context in which they were found.

Purpose of the structures

8.57 An archaeologist on the team appointed by the Commission considers that the logical intended use of the first structure discovered (described in the reports as "cesspool" or "sewage tank") was to receive sewage from the culverts and pipes found coming from the direction of the former Home. This was most likely used at one time as the primary filtration sewage tank for the workhouse/Home. This hypothesis is supported by the descriptions on maps. It is also supported by a reference from 1935 in documentation discovered in connection with a tender concerning the Home which reported that "the existing sewerage at the Home is defective, being merely drains **without pipes** leading to a septic tank outside the grounds" (emphasis added).[93]

8.58 The archaeologist thinks that it is possible that some of the chambers in the second structure (where the human remains were found) were designed to act as cesspools or tanks into which the waste would be deposited and were designed to allow liquid percolate from them into the surrounding soil area.

8.59 The Commission consulted a chartered consulting engineer with considerable experience in sewerage installations. His view was that the likely purpose of the chambers was the collection and holding of sewage but did not consider that the extent of the structures visible in photographs produced to him indicated use as a septic tank.[94]

8.60 Whatever the precise design the structure was built to serve, the Commission does not consider that any of its features suggest that it was deliberately formed as a crypt or formal burial chamber. If that were the case, an entirely different type of structure would have been expected that would allow for easy human access. Access to the chambers is only possible though the narrow openings with relatively fragile pre-cast concrete lids

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[93] Minute G5/16 29 November 1935.

[94] A septic tank operates by introducing the waste into the tank by pipe into a chamber where, solid material sinks to the bottom of the tank and forms a sludge as the waste is broken down. The fluid covers it over. Anaerobic activity then occurs where the solid material breaks down naturally while fluid that builds up is allowed to spill over into a second chamber. The same process occurs again allowing the smaller solid particles to fall to the bottom, where they break down. The water is then allowed to filter out of the tank into a filtration area.

permitting access. The openings were largely uniform in size and while large enough to permit a small adult to pass through with difficulty, were clearly not designed with human access in mind nor for access with a ladder. The depth of the chambers was 2.7 metres from the current ground surface to the top of sediment at the base. Entry by an adult would require considerable dexterity and exit would require even greater dexterity.

8.61 Without a full excavation it is not possible to conclusively say what was the exact engineering purpose of the structures but the Commission considers that it is very likely that it was sewerage related. This view is corroborated by some of the scientific testing carried out at the request of the Commission and described below.

Bon Secours response

8.62 The Commission provided Galway County Council and the Sisters of Bon Secours with the detailed technical reports in June/July 2017 and asked for their responses. Galway County Council did not respond. The Commission provided Galway County Council and the Sisters of Bon Secours with the first draft of this report in November 2018. Again, Galway County Council did not respond. The Sisters of Bon Secours commissioned an archaeologist to review the reports.

8.63 This review suggested that the archaeological reports did not adequately consider the possibility that the structure in which the human remains were found was designed as a burial vault and then used as such. The reports did consider such a possibility and the Commission also considered this. However, the Commission notes that there are a number of features that suggest the structure was constructed for the storage of cess/waste materials:

- There are eight basal openings along the northern walls of the eight easternmost chambers, that is, connected to the larger sewage tank; other breaches in the north wall suggest hydraulic flow between the large sewage tank at north and the enclosed chambers.
- The size of these basal openings at the north end are as small as 0.3m in width by a similar height, therefore too small for usable access; they would not allow for the placement of remains inside the chamber.
- The top openings are all approximately 0.84m in length by 0.29m, again restrictively small considering the size of the internal space (generally 1.6m x 0.95 and c. 2m in depth). In all, the openings are limited in size, and not designed to be accessed by

people (adults) and certainly not large enough to be accessed by a person and a ladder.

- The fluctuation of the water-table within the chambers was evidenced throughout the structure, an aspect which is acceptable for cesspool percolation but not burial.
- The top openings of the chambers were closed by relatively thin pre-cast concrete lids. These were light enough to be opened regularly but were not of a size or durability that one might expect from a ground vault slab. This is evidenced by the fact that 16 of the 21 lids were broken.
- It would be a very unusual decision to construct a burial vault within an operational, or recently operational, sewage tank that had, as yet, not been totally back-filled/disused.

8.64 The limited excavations conducted by the Commission have not revealed the existence of a sewage delivery pipe/culvert; however, soil analysis illustrates that it is likely that the chambers were used for an unspecified duration as sewage tanks. If, after full excavation, no sewage inlet into the chambered structure is found, the likelihood is that the chambers were either never used for sanitary waste, or that waste was delivered into the chambers from the top.

8.65 The Sisters of Bon Secours archaeological review also suggested that the Commission's archaeological reports did not identify comparable sites. The Commission's archaeologists did try to establish if comparable sites existed but did not find any. The review put forward seven different sites as possible comparators but none of these had features which are comparable to the Tuam site.

Water and sewage system at the Tuam Children's Home

8.66 The Commission attempted to establish the intended purpose of the structures uncovered in the excavation from any available records and sought out any historic commentary concerning the sewerage system in the Home and prior workhouse.

8.67 The town of Tuam had an inadequate water supply and sewerage system prior to and for the entire period of the existence of the Tuam Children's Home. The authorities recognised its inadequacy while it was a workhouse.

Pre 1922

8.68 The minute books of the Poor Law Board of Guardians[95] contain numerous references to problems with the sewerage system and sanitation in the Tuam Workhouse.

8.69 At a meeting of the Board of Guardians in June 1911 the Tuam District Council Engineer recommended that the Board should buy a field on the west side of the country road and south of the St Jarlath's College farm. The field, an acre in size, would be utilised for a new workhouse sewerage scheme which would cost £140. Sewerage from the institution would be carried through the field by pipes over a distance of 50 yards until it discharged into an open drain. A new septic tank, 6 feet long and 25 feet wide, would be constructed and the public road would now be 35 yards from the tank.[96] In August, the Local Government Board[97] contacted the Board of Guardians in relation to this scheme which was now estimated to cost £185. They were concerned that the plans made no provision to either cover the existing tank or the new one which would be constructed. There was also no provision made for any overflow from the new tank. They noted that such overflow should be provided for and the advisability of deciding on some arrangement to prevent sewage from accumulating in the old tank should be considered by the engineer. In response, the engineer stated that there was no provision to cover the new tank as the old one was there fifty years and had never been covered. He was of the opinion that it would be a waste of money. He stated that the purchase of a portion of land would deal with the passage of the overflow as the accumulation of any overflow from the tank would form as a cesspool there.[98]

8.70 By 1917 the Board of Guardians had become concerned that sewage was leaking into a neighbour's field. The report from the Board meeting published in the *Tuam Herald*[99] recorded that

> "Immediate relief could be effected by the constructions of a drain under the public road to intercept and drain the effluent and discharge it into the old quarry. It is found, as it is inspected, that the liquid will pass away through the fissures in the quarry, the Guardians should then proceed with the most urgent work of the construction of a suitable covered tank or tanks to take the place of the present dangerous open tank. It will be noted that the site of the present tank is not the property of the Guardians, but is rented at £3 per annum".

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[95] The Board of Guardians ceased to exist when the changes were made to Poor Law arrangements in the early 1920s.
[96] *Tuam Herald (hereafter TH)*, 3 June 1911.
[97] The Local Government Board had overall responsibility for the implementation of the Poor Law at this time.
[98] *TH*, 12 August 1911.
[99] *TH*, 22 September 1917

8.71 At a meeting of the Board of Guardians in May 1917, the question of adopting the proposed 1911 scheme for the improvement of the workhouse sewerage system was again considered. A concern was raised that if the sewage was deposited in an open field, as appeared from the plan, the people of the town would object because the road on one side of it was the most frequented walk in the town. One member stated that the people of the town had suffered enough from the present state of the sewerage system and it was only a waste of time and money if it was to be exposed on the other side. The engineer suggested an alternative plan of running the sewage up by the Railway Bridge and allowing it to discharge about 100 yards in a specific field, if the owner could be persuaded to sell part of the land.[100] Later the engineer reported back that the owner had little interest in selling.[101]

8.72 That September, the sewerage system was again addressed at a meeting of the Board of Guardians. The Local Government Board forwarded a report from its inspector, which stated that he had made an inspection of the septic tank and outfall sewer from the workhouse and considered the best method of dealing with the sewage was to abate the existing nuisance and prevent further nuisance. All the sewage was collected in an open tank on the south end of the workhouse and only 40 yards from the building. This tank, in such close proximity, was a menace to the health of the inhabitants and caused frequent expense. The overflow from it was conveyed in pipes and discharged on the surface of the land adjoining the pattern fence of the public road. In 1912, a scheme by a firm of Dublin engineers was considered and the inspector thought it desirable to put it into operation with certain modifications. This scheme had suggested roofing the septic tank and discharging the effluent into a field owned by the College at the southern side of the road. The plan was to acquire two acres of that field in which there was an old quarry which would admit all liquid to percolate away. The College stated that it would be willing to sell the two acres but it would also be willing to sell the half acre which just contained the quarry. The Board of Guardians decided to take steps to purchase the quarry and to request the Tuam District Council engineer to proceed with the work when permission to enter the land had been granted by the College. The engineer's estimate for his scheme was about £150.[102]

8.73 In May 1918, the Local Government Board sanctioned the scheme devised by the Tuam District Council engineer for the disposal of the workhouse sewage.[103] In July, the

[100] *TH*, 12 May 1917.
[101] *TH*, 26 May 1917.
[102] *TH*, 22 September 1917.
[103] *TH*, 25 May 1918.

Board of Guardians was informed that the work was currently being carried out.[104] It seems clear this work was carried out between June and September 1918. It is not entirely clear what exact plan was approved by the Local Government Board and put into operation by the Board of Guardians in the summer of 1918. It seems that the scheme which was implemented was a modification of the plan submitted by the engineer in June 1911. This means that it is likely that a new septic tank, 6 feet long and 25 feet wide was constructed. The original scheme was modified so that the sewage would be taken by pipes and emptied into an old quarry located in a portion of a field owned by St Jarlath's College, which the Guardians purchased. It is clear that, whatever scheme was implemented, it did not fully address the problems.

1922 - 1930

8.74 The Free State army occupied the building for some time prior to 1925. In March 1925, the Quartermaster General's Department of the army asked for sanction from the Army Finance Officer to spend £35 10s on cleaning out and putting the sewage disposal works in order.[105] The work was considered necessary because ''The sewage disposal plant having been a number of years without cleaning or overhaul, the whole plant is in need of thorough cleaning in order to put it in a satisfactory and sanitary state.'' The work to be done involved ''Cleaning out cess-pool and sludge chamber and carting away all sewage matter. Open and trim sides of drains on sewage farm.''

8.75 Within a few weeks, the army decided to evacuate the barracks and, as a result, the work was not needed.

8.76 Galway County Council decided to use the Tuam workhouse as the Children's Home in 1925. The problems with the water and sewerage system continued to be discussed. There are numerous references in the minutes of the Board of Health and in the local papers to problems including inadequate water supply, inadequate pressure, water being cut off intermittently, no water and sewerage connections for new houses and blockage/overflowing of sewers; here we concentrate on the references to the impact on the Tuam Children's Home.

8.77 In January 1928, a meeting of the Tuam Town Commissioners[106] discussed a Galway Board of Health proposal to initiate a new sewerage scheme in the town at a cost of

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[104] *TH*, 13 July 1918.
[105] Military Archive, File 20/Buildings/282.
[106] The Tuam Town Commissioners had no direct involvement with the running of the Home.

£7,000. Although a scheme was badly needed, this expenditure would only cover the cost of a partial scheme. The Tuam Commissioners objected to the likely possibility that the rate payers of the town[107] would have to foot the bill.[108] Following this a deputation, appointed by the Commissioners, met the Galway Board of Health. The deputation offered to agree to the scheme if a rate of ¼ pence in the pound on the county was approved, with the rate payers in Tuam agreeing to pay the balance. They considered that they were justified in asking rate payers in the county as a whole to contribute as the Children's Home was a "County charge" and that it should be included in any new sewerage work being undertaken. However, the Board of Health would not agree to their suggestion.[109]

8.78 The water supply, and especially the issue of having adequate water pressure, was a constant concern for households on the outskirts of the town, in particular in the Dublin Road area where the Children's Home was located. This issue was discussed at the first meeting of the newly appointed Tuam Waterworks Committee in August 1928. The Chairman of the committee expressed his concerns about the fact that the town reservoir seldom had more than five feet of water in it at any time.[110] In November 1929, the same committee passed a resolution calling the immediate attention of the Board of Health to the Tuam water supply problem. It was stated that the town's waterworks were now unable to guarantee a continuous supply to the people of the town and in particular to the institutions on the Dublin Road. It seems that the water supply was intermittently cut off and this was regarded as a great source of danger to public health. It was believed the six inch water pipes in the system were choked up and were no longer able to meet the water demand for the town. The Committee called on the Board of Health and the Minister for Local Government and Public Health to sanction a loan of £6,000, repayable in forty years, from the Local Loans Fund for the purpose of laying down a nine inch pipe and improving the Tuam water supply.[111] The Board of Health meeting was told in December 1929 that any loan from the Local Loans Fund for the improvement of the Tuam Waterworks would have to be repaid in 25 years.[112]

8.79 The superintendent of the waterworks, in reply to a letter from the Department of Local Government and Public Health reported that the Tuam Children's Home got a supply of water only at night as the pressure during the day was inadequate. The superintendent

[107] "Rates" was local authority taxation payable by all property owners.
[108] *TH*, 21 January 1928
[109] Minute GC5/6 February 1928; *TH*, 10 March 1928.
[110] *TH*, 11 August 1928.
[111] *TH*, 2 November 1929.
[112] Minute GC5/8 December 1929

had visited the Home early in December and noted that there would have been a water shortage at the time only for the rainwater going into the tanks.[113]

8.80 Because of the requirement to pay back a loan within 25 years, the Waterworks Committee decided to scrap the improvement scheme and instead concentrate on cleaning the existing pipes and installing a new water engine, storage tank and pump for which they asked the Board of Health for a £2,000 loan in February 1930.[114]

8.81 A town public meeting in March 1930 called on the Waterworks Committee to stop the practice of cutting off the water supply at night. However, the Committee decided that this would not be possible as it would mean that no water at all would be available to the houses and the Children's Home on the Dublin Road, due to the lack of water pressure. The Committee decided that in order to give residents on the Dublin Road a chance to get water, the water supply would have to be cut off from the rest of the town and let up the Dublin Road on Sunday, Tuesday and Thursday nights.[115]

8.82 That September, a letter from the Department of Local Government was read out at the latest meeting of the Tuam Waterworks Committee. The Minister outlined the findings of a report by his engineering inspector who recently inspected the site of the waterworks. The inspector believed that the scheme outlined was the most economical method of improving the poor water supply. He added that in the near future it would be necessary to lay a second main from the reservoir to the town or else to supply a high level service tank at the fair green.[116]

8.83 The Board of Health noted that an amount of £2,400 would actually be required.[117] The Minister for Local Government and Public Health agreed that a loan of £2,000 could be made available from the Local Loans Fund; this was increased to £2,400 in November 1930. Tenders were invited in early 1931. At the same time an application was made for a subsidy out of the Unemployment Relief Grant towards the cost of the scheme. This was refused because employment would be generated by the works anyway. It seems that this caused the Board of Health to not proceed with the scheme.[118]

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[113] *ibid*
[114] *TH*, 1 February 1930.
[115] *TH*, 29 March 1930.
[116] *TH*, 27 September 1930.
[117] Minute GC5/10
[118] At the time, the Board of Health had been temporarily replaced by a Commissioner.

8.84 In December 1930, a deputation from Tuam looked to proceed with a partial sewerage scheme costing an estimated £7,000. It was pointed out that almost 100 new houses had been recently built in the town and none had access to any sewerage facility. Following this, the Galway Board of Health approved a £7,500 loan for work on this partial sewerage scheme.[119] At a subsequent meeting of the Tuam Commissioners, it was reported that a delay in beginning the new sewerage scheme was likely because land for way-leaves and septic tanks would need to be secured first and it was probable the owners of such land would not give their consent.[120]

1931 - 1936

8.85 Progress on obtaining a new water and sewerage scheme for Tuam stalled as a dispute arose between the Town Commissioners, the Board of Health and the Department of Local Government and Public Health over obtaining grants to help fund the project. In October 1932, the Town Commissioners stated that plans and proposals for further housing schemes in the town were now being held up for want of a proper and adequate sewerage system.[121] At two separate monthly meetings of the Tuam Commissioners in 1933, resolutions were passed calling on the Board of Health to conduct a proper survey of the town for the purpose of getting a comprehensive sewerage scheme designed and then put into operation. It was stated that the question of securing a sewerage scheme for Tuam had now been ongoing for twenty-five years. In December, it was reported that the Board of Health engineers had now prepared a full sewerage scheme and that this was awaiting the sanction of the Board and the Department of Local Government and Public Health to be put into operation.[122]

8.86 In February 1934, a meeting of the Galway County Council agreed to make the cost of undertaking the Tuam sewerage scheme a county charge (on account of the Children's Home) and the overall estimated cost was put at £21,200. The Department agreed to contribute £7,000 with the balance being paid for by the Galway County and Tuam urban rate payers. It was specifically stated at this meeting that the Children's Home had yet to be provided with or connected to a sewerage scheme. The Council agreed that if there was anything like an outbreak of fever in the institution, which was a real possibility at any time, it might prove much more costly to the public services than this proposed sewerage scheme.[123] That October, Galway County Council agreed to the raising of a £15,000 loan to

[119] *TH*, 27 December 1930.
[120] *TH*, 1 February 1931.
[121] *TH*, 1 October 1932.
[122] *TH*, 8 July; 23 December 1933.
[123] *TH*, 24 February 1934.

cover the cost of the sewerage scheme. It was reported that the only issue left to be resolved was the drawing up of an agreement between the Council and the Board of Health, whereby the Council would guarantee the repayment of half the instalment of the principal and the interest.[124]

8.87 In October 1934, tenders were invited for the construction of a maternity hospital at the Children's Home.[125] Despite this, no work on the new sewerage scheme was undertaken over the next fourteen months.

8.88 It is clear that mains sewerage had not been extended as far as the Home by 1935. "The Secretary of the Homes and Home Assistance Committee wrote enquiring if the **new sewerage scheme** will extend as far as the Children's Home, as the existing sewerage at the Home is defective, being merely drains without pipes leading to a septic tank outside the grounds…" (emphasis added)

8.89 Although it was reported that the Department of Local Government and Public Health had sanctioned a new housing scheme involving the construction of seventy houses on the Dublin Road in July, in December the editor of the *Tuam Herald* was complaining that there was still some inexplicable hold up in beginning the sewerage work. The latest setback was due to a dispute between the contractor and the local branch of the Irish Transport and General Workers Union (ITGWU) over the proposed wages for the workmen. The paper bemoaned: "The Sewerage Scheme has been the subject of spasmodic agitation for the last ten or fifteen years and it is about time now that it was finished with."[126]

8.90 The dispute between the contractor and the ITGWU dragged on until April 1936. Finally, a settlement was reached and on 24 April work on the long awaited sewerage scheme commenced, although the press reported the scheme would only be a partial one. Work began near where the new housing scheme had been completed. It was reported that there was an initial workforce of twenty which would increase to around 100 men over the next few weeks. An unemployment relief grant of £5,700 had been made in 1935/6 for the sewerage scheme and the provision of water supplies to specific areas.[127] The Department of Local Government and Public Health had also supplied a £4,000 grant towards the cost of

[124] *TH*, 27 October 1934.
[125] *Connacht Tribune*, 27 October 1934; it seems that a separate maternity hospital was not built but a maternity unit was provided within the existing building. In October 1936, a grant of £550 towards the cost of this was made by the Hospitals Trust – DLGPH Annual Report 1936/7
[126] *TH*, 27 July; 14 December 1935.
[127] DLGPH Annual Report 1935/6, Appendix IX

the scheme (a reduction from the £7,000 they were reported to have agreed to in 1934).[128] Discussing the progress of the work a week later, the *Tuam Herald* noted that a new pipe had been laid from the new housing scheme to Vicar St and from Vicar St to the part of the Galway Road known as 'The Claureen'.[129]

8.91 That August, the sewerage scheme contractors agreed to link up the sewerage with the new houses on the Dublin road, following a request to do so at the latest meeting of the Tuam Town Commissioners.[130]

8.92 It is unknown if this work also connected the Children's Home to this new sewerage system. There is no reportage of any such work by the papers. However in October, the *Tuam Herald* reported that a deputation of tenants in the new houses on the Dublin road had met the Tuam Town Commissioners to complain about the "offensive and unhealthy stench from the sewerage outlet from the Children's Home". The Clerk was asked to write to the Board of Health about the issue.[131] There is no newspaper record of this issue being raised at any meeting of the Galway Board of Health from then until the end of the year.

1937 - 1939

8.93 Nevertheless, in January 1937, the *Connacht Tribune* reported on a meeting of the Galway County Home and Home Assistance Committee where a petition, signed by a number of residents at Tubberjarlath, Tuam, was read out. The residents were calling for the removal of the cesspool at the back of the Children's Home which was now in close proximity to a large number of houses occupied by the tenants of the Town Commissioners' houses. The petition stated that the smell from the cesspool was "intolerable and highly dangerous to the health of a large number of residents and their families in the locality". It added that if something was not done to remove the cesspool, they would have to take more serious action in the matter.[132] In response, the Committee's Secretary stated that on 17 November 1936 the County Home and Home Assistance Committee "had sent plans etc. for a new system of drainage and sewerage from the Children's Home **to connect with the new sewerage system** in Tuam but no reply had yet been received from the Department". (emphasis added) An order was made again asking the Local Government Department to expedite the matter and to send a copy of the petition to them.[133]

[128] *TH*, 18/25 April 1936.
[129] *TH*, 30 May, 1936.
[130] *TH*, 29 August 1936.
[131] *TH*, 10 October 1936.
[132] *Connacht Tribune*, 23 January 1937.
[133] *Connacht Tribune*, 23 January 1937.

8.94 This would suggest that, as of January 1937, the Children's Home had not been connected to the new town sewerage plan.

8.95 In May 1937, the Homes and Home Assistance Committee invited tenders for the construction of drainage works at the Home.[134] In May 1937, the *Tuam Herald* reported that a meeting of the Galway County Homes and Home Assistance Committee had accepted a tender from Galway contractors for drainage work to be carried out at the Children's Home Tuam at a cost of £791 5s 5d.[135] Two months later, the Committee reported that the contract for the above drainage work had been signed and that the contractor was ready to begin the work.[136]

8.96 A proposal to start construction of a new "drainage scheme" at the Children's Home was evidenced by a note for tender in the *Irish Independent* in 1937. No documentation has been found which supplies any detail as to what was proposed in this scheme.

8.97 That September, a letter from the County Engineer was submitted to the Committee outlining improvements that were required for the lavatory system at the Children's Home. The engineer stated that the existing lavatory system was very unsatisfactory and not suitable for the new drainage scheme as the type of cisterns installed for the flushing were inadequate. He strongly recommended the erection of new lavatories with special ''Epic Flushing'' cisterns which

> "…will give an almost continuous flushing system, which is desirable for an institution of this kind. The buildings where the lavatories are contained require to be taken down and reconstructed as they are all in a very dilapidated condition and without light or ventilation. I recommend the erection of new buildings with tiled floors and tiled walls to a height of 4 feet and with proper ventilation and light. During construction of the new sewer, I discovered that most of the new sewer was not conveyed to the septic tank, but deposited in the old trenches and in a well which I found in the ground. This is due to the fact the flushing system is bad. It is desirable that this work should be done before the present contract is complete. As the present floor level of the lavatories requires to be raised it would be cheaper to have it done by the present contractors so as to make the necessary construction, otherwise it will mean excavation later which will cost more money".

[134] *TH*, 22 April 1937
[135] *TH*, 22 May 1937.
[136] *TH*, 17 July, 1937.

The committee decided to carry out the engineer's recommendations, subject to departmental approval.[137]

8.98 In the July meeting of the County Homes and Home Assistance Committee, plans had been submitted to erect a new laundry at the Children's Home and these were sent on to the Department of Local Government and Public Health for approval.[138] Yet over a year later the Committee was still discussing the proposal to erect a new laundry and also a disinfecting chamber at the Children's Home. The department had so far refused to sanction the work because it believed the local Galway engineer selected to oversee the project did not have the necessary or sufficient experience. The committee was read a letter from the matron of the Children's Home asking if anything could be done to speed up the erection of the new laundry, as the present one was in a very bad state. The committee decided to send another letter to the department asking it to either sanction the proposal to allow a local engineer to oversee the works or else to recommend another engineer whom they could appoint.[139]

8.99 The problem of securing an adequate water supply for the Dublin Road area also continued to persist. The November 1937 meeting of the County Homes and Home Assistance Committee was addressed by the Medical Officer for the Children's Home. He explained that there were frequent shortages in the water supply to the Home and that the issue had become especially serious since those houses built under the housing scheme near the Home had been occupied. He noted that the area where the Children's Home was located was always the last part of the town which got water from the town reservoir and the demand from the new houses was also now impacting on their supply. His concerns were referred to the Board of Health.[140]

8.100 In January 1937, the Tuam Town Commissioners had discussed an offer from the Galway Board of Health to transfer a triangular plot of ground, near the Children's Home, to the County Homes and Home Assistance Committee in exchange for the land required to widen the Dublin road at this point. It was noted that the piece of land was valuable and that about six houses could be built on it. However the Commissioners decided to leave the matter in abeyance.[141] Eventually in July 1940, it was reported that a meeting of the Tuam

[137] *TH*, 18 September 1937.
[138] *TH*, 17 July 1937.
[139] *TH*, 22 October 1938.
[140] *Connacht Sentinel*, 16 November 1937.
[141] *TH*, 9 January 1937.

Town Commissioners had agreed to transfer this plot of land to the Board of Health.[142] That November, tenders were invited for work to knock part of the existing boundary wall, including gates and piers on the Athenry-Tuam road at the Children's Home, and to build a new boundary wall to enclose an additional plot near the road as well as a new wall to replace an old fence.[143]

8.101 Meanwhile, the Tuam sewerage scheme had been approved by the Department of Local Government and Public Health with the intention that the work would be carried out in two separate portions. By July 1937, the first portion of the Tuam sewerage scheme had been completed and put into operation.[144] This portion of the scheme was described (in 1941) by the Secretary of the Galway Board of Health as containing "a septic tank and filter beds".[145] No work was commenced on the second portion of the scheme for several months. Only in November did the Galway County Council sanction the raising of a £12,000 loan by the Board of Health for the provision of the second section of the new sewerage scheme for Tuam.[146] Sometime in 1938/9, a Local Loans Fund loan of £5,400 was approved for the Tuam Sewerage Scheme.[147]

8.102 In September 1938, the Galway Board of Health invited tenders for the extension of the sewerage system in the town of Tuam. The works included the provision and laying of nine inch and 250 lineal yards of twelve inch sewer pipes, the construction of a syphon and manholes, the making of house connections and other incidental works.[148]

8.103 Work on the second portion of the Tuam sewerage scheme began at some point after and continued through the spring of 1939 in areas such as the Galway Road. Meanwhile in July, tenders were invited for the supply and installation of electrical laundry equipment and structural alterations to the laundry premises at the Children's Home. A month later a tender for this work was accepted by the County Homes and Home Assistance Committee.[149]

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[142] *TH*, 6 July, 1940.
[143] *TH*, 23 November 1940.
[144] *TH* 24 April 1937
[145] *TH* 12 April 1941; the secretary is reported as saying that the first section had been completed in 1939 but all the evidence suggests it was completed in 1937.
[146] *TH*, 20 November 1937.
[147] DLGPH Annual Report 1938/9, Appendix II
[148] *TH*, 17 September 1938.
[149] *TH*, 22 July; 19 August 1939.

1940 onwards

8.104 Work on the second portion of the Tuam water scheme continued until its completion in March 1941. In January 1940, a deputation appeared before a meeting of the Galway Board of Health to discuss ways to expedite the extension of Tuam's waterworks system. A report outlined the necessary works which were needed which included sourcing additional water as well as constructing an elevated reservoir near the Dublin Road. The report recommended that a new eight inch diameter main was necessary and should be laid from the reservoir to the town square and then from the square onto the Children's Home with other smaller extensions. The Chairman of the Tuam Waterworks and Sewerage Advisory Committee was part of the deputation that addressed the Board. He explained that between 300 and 400 new houses had been built in the town and all of these were connected to the water supply. The result was that people in the centre of the town were not now getting an adequate supply, even in the middle of the day. In response, the Board agreed to expedite the new water scheme.[150] In July, the Consulting Engineer for the Galway County Home and Home Assistance Committee wrote stressing the fact that the water supply to the laundry in the Children's Home was not reliable and that the water was very hard. To solve the issue he suggested the construction of an underground storage tank which would collect rain water from the roof of the institution. This was rejected as the Committee declared that work on the Tuam water system would soon ensure a plentiful supply of water.[151] That same month the County Home Committee, on account of war in Europe, decided to prepare a tunnel at the Children's Home for use as an air raid shelter by the occupants. The committee also decided to have red crosses painted on the roof of the Home.[152] The Commission has seen no evidence to show that the air raid shelter was ever built or that the crosses were painted on the roof.

8.105 By June 1941, the Board of Health Engineer told the Board that the Children's Home was dealing with the constant issue of low water pressure because the main leading to it was not able to carry enough water.[153] Due to the World War, it appears that no new water scheme was actually begun in Tuam. A report from the Galway County Council in May 1946 stated that the extension of the Tuam water supply had been held up for several years. It noted that the existing waterworks provided a supply for a town of about half the population now resident in the borough area. The result was that in the new housing schemes and in the higher parts of the town only a very poor water supply was available. The *Tuam Herald* noted that as far back as 18 November 1944, the County Council had approved the raising

[150] *TH*, 13 January 1940.
[151] *TH*, 13 July 1940.
[152] *TH*, 20 July, 1940.
[153] *TH*, 14 June 1941.

of a loan of £16,000 for this work.[154] However, in June 1947 the Tuam Town Commissioners were informed that the continued delay in beginning the water scheme was due to the fact that the acquisition of the additional water rights required had not yet been completed.[155] This issue was finally resolved and in November the Galway County Council was reported as agreeing to raise a loan of £25,600 to cover the cost of the Tuam water supply extension scheme. The original estimate had been £15,800.[156]

8.106 Yet it was reported at a meeting of the Tuam Town Commissioners in March 1948 that the town's water supply "was never as bad in terms of quality and quantity". The chairman stated that cases of scarlet fever were now being reported in the town, caused by the insufficient and impure water supply. He stated that two years earlier a water extension scheme had been decided on at that time when the water supply problem was critical. Two years had also passed since certain water rights were secured. Though the County Manager had given assurances that work would finally begin in January, nothing had happened and now some parts of the town had no supply at all; sanitary accommodation was rendered useless and in parts of the town the water was simply too dirty for drinking purposes. After discussion, it was decided to send protests to the Ministers for Health and Local Government about the delay in the water extension scheme.[157] Work on the water scheme seems to have finally begun in early August. At a meeting of the Tuam Town Commissioner in September, the County Manager stated that work had begun on the construction of the new water storage tank. Yet the meeting still had to deal with complaints from residents about the frequent practice of turning off the water supply at night to parts of the town, to ensure other parts and the likes of the Children's Home had an adequate supply. The Commissioners bemoaned that nothing could be done to remedy this until the water extension works were completed and the town given a proper supply to meet the demand.[158]

8.107 In October 1949, the County Manager addressed a meeting of the Tuam Town Commissioners and informed them that there should be a marked improvement in the Tuam water supply within days. A new eight inch main pipe from the reservoir to the town had been laid and would reach upper Bishop St, resulting in a "big" improvement in the water pressure throughout the town.[159] Work on the water scheme seems to have finished sometime after. At a meeting of the Commissioners in 1954, it was reported that around

[154] *TH*, 11 May 1946.
[155] *TH*, 7 June 1947.
[156] *TH*, 22 November 1947.
[157] *TH*, 27 March 1947.
[158] *TH*, 11 September 1948.
[159] *TH*, 8 October 1949.

£90,000 had been spent on the water extension. Despite this, a lack of water supply was still being reported in parts of the town on occasion.[160]

8.108 During 1951 and 1952 the Galway County Council also made several applications to the Department of Health for an extensive extension of the Children's Home. The work was estimated to cost £82,000 and the Council got an agreement from the Hospitals Trust to cover half of the sum. However, the Department replied that this amount of money could not be given from the Hospitals Trust funds.[161] By September 1952, the Council was still waiting on the Department to sanction the improvements scheme.[162] Nothing more was reported in the press and it is assumed the scheme simply fell through because of a lack of support from the department.

When the chambered structure was built

8.109 It seems clear that relatively extensive work and construction was conducted in and around the site of the Children's Home in Tuam, particularly during the July – December 1937 period. The Commission thinks it possible that the reworking of the old sewage tank and the construction of the second structure described above may have occurred at this time. If this is so, then the human remains found in the chambers are likely to date from after 1937. This raises the question of where the children who died before then are buried.

Scientific testing

8.110 As already described, the excavation had established that there were human remains at the site. The Commission decided to have tests carried out on a sample of those remains and on the surrounding soil.

Bone Analysis

8.111 Eighteen of the 20 chambers contained visible examples of human remains of infants or juveniles. While no remains are immediately visible in the two remaining chambers, they are likely to contain human remains as scientific sampling of the soil from these chambers had indicators of bone decomposition. No adult bone (18 years or over) was visually identified or collected, and all identifiable skeletal remains within the chambers appear to be from either infants of less than one year or young children between one and six years. It was not always possible to correctly identify the precise age group and many bones were

[160] *TH*, 8 May 1954.
[161] *TH*, 8 September; 6 October 1951.
[162] *TH*, 13 September 1952.

simply classified as “juvenile” which specifically refers to individuals aged six years or less at the time of death.

Articulation

8.112 In archaeological terms, if bones are found in an order and proximity that is to be expected if the body decomposed in situ, they are referred to as being in an “articulated” state. The Osteoarchaeologist on the team undertook a detailed study of photographs of the visible deposits within each chamber in order to determine if there was any evidence of articulation. There was some evidence of articulation from this visual inspection. This evidence is limited to the particular instances described here.

8.113 A significant quantity of bones was visible in one chamber. In particular, cranial remains from either an infant or young juvenile were visible at the northern end. Along the eastern side of the chamber, at least two separate concentrations of ribs, which appear to be in an articulated state, were visible along with bones of a possible left arm (left humerus and ulna). Two shin (tibiae) bones also appear close together in this area along with a concentration of possible infant vertebrae. All of these may represent the, at least partially, articulated remains of an individual or individuals.

8.114 At the southern end of this chamber there was also a significant concentration of skeletal remains. Two further individual sets of possibly articulated infant ribs were identified. Two mandibles were identified which are probably from infants of less than one year old. The Osteoarchaeologist was of the view that it was probable that the articulation of the ribs in particular demonstrated that they have remained there since the body of the child had decomposed.

8.115 Significant quantities of skeletal remains were also present in another chamber. In one concentration of bone, a possible ischium was identified under the right ilium (both are parts of the hip) with possible articulated vertebrae identified. These were seen adjacent to a set of right ribs and another set of possibly articulated bones that could not be identified. A right humerus probably from an infant of less than one year old was identified beside a radius and another long bone which may well be an ulna. These are the bones that form the arm. The Commission has been advised that the occurrence of these three bones being found together is unlikely to be coincidental and there is provisional evidence of articulation here. It is possible that the arm bones along with the set of the right rib bones, the possible scapula and the articulated vertebrae and the pelvis are all approximately in situ as they would be in the approximate correct position for an infant lying on its left side.

8.116 Near the southwest corner of this same chamber three further concentrations of apparently articulated ribs were evident suggesting possibly two individuals. A right scapula was observed adjacent to one of those set of ribs which may suggest some degree of articulation.

8.117 In the same chamber cranial remains were identified which appear to represent the relatively intact cranium of an infant or young juvenile. The left frontal and temporal bones are in the correct position for an articulated infant/juvenile cranium. A larger cranial fragment underlies the two and that larger fragment may be a parietal or the squama from the occipital.

8.118 Within another chamber, a small collection of bones is visible in the south west corner. Left ribs and a possible scapula (shoulder blade) were suggestive of the articulated remains of a young juvenile as well as a number of ribs, vertebrae and an ulna. Based on the length of this ulna, the age-at-death of the individual is approximately 4.5 years.

8.119 The fusion of bones within the vertebral body fuse at different times as a child develops. The cervical (neck) vertebrae the body and neural arch are fused by the age of four. The thoracic vertebrae (torso) which articulate with the ribs fuse by the age of six. The lumber vertebrae (lower back) fuse by the age of five. In another chamber, the Commission has been told that some fusion of vertebrae suggest the presence of an individual in this chamber aged between four and six years at the time of death. A concentration of cranial bones can be seen nearby. Within the same chamber a left maxilla, of a probable young juvenile, is visible in the south east corner of the tank. It is probable that the first left upper deciduous molar had erupted at the time of death. In another chamber, there is a concentration of cranial bones. Both sides of the skull can be seen along with the back of the skull and some parts of the cervical vertebrae which appear to be largely intact also evidence some degree of articulation.

8.120 The chambers contain a mixture of infants and young juvenile bones. A cranium present in one chamber is potentially from an individual aged between 1.5 and 2.5 years, maybe even slightly older. What is unusual about the identification of this skull is that it is complete and sits above the sediment. This suggests that it was introduced to the chamber at a later date, that is, it was deposited possibly from another location. A humerus lying near this cranium shows post mortem erosion. This type of erosion was not evident in most of the visible remains observed which appeared largely to be in exceptional states of preservation.

This suggests that this long bone may also have been redeposited having suffered differential erosion elsewhere.

8.121 The assessment by the Osteoarchaeologist was that it is probable that complete bodies were deposited in the chambers. If bones had been dug up elsewhere and redeposited in the tanks, it would be expected that there would be much more fragmentation and damage. It would be very unlikely that bones as small as juvenile cranial would survive the transfer. Furthermore, it would be expected that redeposited earth would also be visible within the chambers. The sediment visible within the tanks appeared from visual examination to have been placed there as a part of the normal fluctuations of water levels within the chambers rather than from soil thrown in from above.

Water influx

8.122 When the chambers were opened and inspected, the sediment was relatively dry with no visible water present. There was however evidence that waters levels in the chambers had fluctuated. If complete bodies had been deposited within the tanks and were not covered by earth, then fluctuations in the water table would have allowed these bodies and later body parts and bones to float and disperse. There were obvious bone concentrations found in the south side of the chambers which reflect the normal drainage of the site with the higher ground to the north. Further evidence of water fluctuation can be found in a chamber where a single infant/ young juvenile probable hand phalanx (finger bone) was attached to the south facing wall. The hand phalanx was located above the current sediment level suggesting that there was at some point water present.

Soil Sampling

8.123 Soil samples taken from the chambers were forensically recovered and sent to a soil scientist who specialises in volatile organic chemistry. The soil scientist carried out what is termed volatile organic compound analysis on thirty two soil samples.

8.124 The Commission sought to determine from the soil recovered within the chambers whether they had ever been utilised for the containment or filtration of sewage and whether or not it was possible to establish if the bodies of the children in question decomposed in situ or elsewhere.

The science of soil testing

8.125 Soil is a mixture of inorganic and organic material. The organic material reflects the planted animal material that is deposited or decomposed within the soil and also human organic inputs to the soil. A process of gas chromatography spectrometry is used to characterise and identify organic compounds in order to ascertain what the inputs to the soil actually were. A comparison of the distribution of the actual volatile compounds found in samples can then be compared to published data from other soil sampling. The Commission was interested specifically in the origin of the material surrounding the remains discovered including the possibility of human decomposition and the presence of human sewage.

8.126 During the decomposition of animal (including human) bodies large quantities of cholesterol are released. Substances known as coprostanol and epicoprostanol have also been found in association with body decomposition. These biomarkers are also found in sewage but the relative concentration patterns differ greatly between samples from faecal sewage and material that was deposited as a result of body decomposition. In faecal matter and sewage, the cholesterol concentrations are much lower than those of coprostanol and epicoprostanol. On the other hand, cholesterol concentrations in material associated with human decomposition are considerably higher than the stanol concentrations found in faecal or sewage material (coprostanol and epicoprostanol). Faecal bile acids may also be indicative of the presence of sewage.

Analysis of samples

8.127 In general, the quantities of solid organic compounds were very low, lower than would have been expected from sewage. The volatile organic compounds were indicative both of elements of sewage and decomposition of human remains. The solid organic compounds isolated indicated that the primary component in those samples was human decomposition rather than sewage. Samples were not taken from the very bottom of the chambers due to the potential destruction this would have caused.

8.128 There were some exceptions from the general findings. The ratio between the stanols and cholesterol found in one particular sample suggested that this sample originated from predominantly sewage. Lower ratios observed in the other samples from the remaining chambers suggest mixed origins from sewage and from body decomposition. Some samples also yielded the presence of faecal bile acids, indicative that sewage had been present in those chambers. Control soil samples were also taken from soil just outside of the chambered structure. These analysed samples had generally lower biomarker concentrations than the samples that were collected within the chambers.

8.129 The scientific evidence suggests that at least some of the chambers in which human remains were found were at some stage used to receive sewage. There is evidence of water ingress and fluctuations and it is possible that the sewage filtered into the chambers by virtue of this process. Relatively low concentrations of biomarkers in many cases meant that actual sewage was not present in the samples and they were considered to contain material other than sewage. There remains the possibility that quantities of sewage had been removed from the chambers before the deposition of the human remains. A second possibility is that some soil may have been added at the time when the bodies were introduced or soil may have seeped in through the lids to some of the chambers and possibly through the openings at the base of some of the tanks. All of the bones observed were considered to be of human origin. In areas where there was a high concentration of bones accumulated, there were hot spots for compounds characteristic of bone decomposition which is what would be expected, given that the chambers have been covered over for many years and contained such large numbers of bones.

8.130 The soil scientist confirmed that the findings of the Osteoarchaeologist in relation to articulation corroborated the findings that human remains decomposed in situ. The Commission does not consider that there is any real doubt that a considerable number of the children in the tanks decomposed in this way.

Radiocarbon Dating

8.131 The Commission sought to establish approximately when the infants and juveniles whose bones were discovered had died. The Commission provided six infant bone samples to a Radiocarbon Dating Laboratory in Scotland. All six samples had been found inside the chambers. These samples have since been recovered by the Commission and are securely held by the State Pathologist on behalf of the Commission.

The science of radiocarbon dating

8.132 The process of radiocarbon dating is used to date, among other things, bone, cloth, wood and plant fibres that were created in the relatively recent past. The method of radiocarbon dating is made possible by isolating a radioactive isotope called Carbon-14. Carbon has other isotopes which are usually not radioactive (such as Carbon-12) which makes a relative comparison possible. Cosmic rays create Carbon-14 atoms that when combined with oxygen form carbon dioxide which find their way into plant fibres. Animals and people in turn eat the plants and as a consequence take in the Carbon-14. At a certain point in time, the human body has a certain percentage of Carbon-14 and at the same time all living plants and animals have the same percentage of Carbon-14. Once a living organism dies, it stops taking in the new carbon and the Carbon-14 begins to decay and is not replaced. Other carbon isotopes such as Carbon-12 do not decay and remain constant in the sample. By looking at, for example, the ratio of Carbon-12 to Carbon-14 in the subject sample and then comparing it to the ratio of Carbon-12 to Carbon-14 in a living organism, it is possible to determine the age of a formerly living thing relatively accurately using a mathematical formula.

8.133 Decay of Carbon-14 occurs at a constant rate. Between 1955 and 1963 atomic bomb testing doubled the amount of Carbon-14 in our atmosphere. Any bones containing the higher levels of Carbon-14 must have been born in the nuclear era which, from atmospheric records maintained, is considered to be after 1955. Following an international nuclear test ban treaty, the atmospheric concentration of Carbon-14 has gradually reduced starting around 1963/64.

8.134 Any short lived sample that has a ratio of Carbon-12 to Carbon-14 of a value greater than 1 must have been alive after 1955. In human bone, the datable portion where the levels of carbon can be measured within the bone is in a protein within the bone called collagen. In new born or close to new born babies, because bone collagen in infants is formed from the mother's dietary intake, the dated sample must be projected forward by one to two years to ascertain the actual age at death of the child. All of the samples analysed were from children of less than one year of age.

Results of radiocarbon dating

8.135 All of the samples produced calibrated age ranges within the period within which the Tuam Children's Home was operational. Two of the bones sampled put the years of death within the nuclear era 1956-1957. If the time lag of one to two years as described is applied to those figures this would put the actual years of death of those two individuals at around 1957-1959. The remaining four samples were in the pre nuclear era (pre 1955). The calibrated range using the radiocarbon dating for the other four samples was

1. 1800-1940
2. 1935-1955
3. 1925-1955
4. 1930-1955

8.136 The carbon fraction available for measurement in the pre nuclear era is much smaller because of the much lower levels of Carbon-14. It is less than one. As a consequence of this, these samples have multiple possible calibrated age ranges and produced calendar ages in the pre modern 1650-1950AD range. However, all the samples produced age ranges within the period of operation of the Children's Home. The two samples that existed during the nuclear age enabled much more precise dating (both samples being dated between 1957 and 1959) which is why the calibrated range is so small in those two cases.

Artefacts of interest

8.137 A plastic bottle lay directly on the surface of the sediment within one of the chambers. This was recovered at the request of the Commission. This was a bottle which was marked '*Castrol GTX'* which was printed directly onto the plastic bottle which was empty. The text on the label read *'Castrol GTX high performance raw oil contents 500ml* Castrol (Ireland) Limited. Enquiries made by the archaeologist confirmed that this product was released into the UK market for the first time on 18 April 1968. Therefore, the product would have been available on the Irish market on or after that date. This information proves that this particular chamber at least was accessible either temporarily or for an extended period of time post 1968.

8.138 In another chamber, a piece of timber which was visible has an unusual angle and is reminiscent of the angles often seen on coffins. Other pieces of wood were found within the chambers but they appeared more crude and of the type that would be expected to be used in forming the chambers by way of shuttering. In another chamber there is possible wickerwork identified.

Commission conclusions

8.139 It seems clear that many of the children who died in the Tuam Home are buried in the chambers described. It is unlikely that the children who died prior to 1937 are buried there as it would appear that the structure was put in place around this time. There is evidence that the burial grounds may extend beyond the area of the current Memorial Garden.

8.140 This was not a recognised burial ground or purpose built burial chamber. It did not provide for the dignified interment of human remains.

8.141 It is not clear if it was a blessed/consecrated Catholic burial ground either. In June 2014, the Archbishop of Tuam issued a statement in which he said, among other things, that "It will be a priority for me, in cooperation with the families of the deceased to seek to obtain a dignified re-interment of the remains of the children in consecrated ground in Tuam". This seemed to the Commission to imply that the current burial ground was not consecrated ground. The Archbishop told the Commission that, in his view, it is more likely than not that this ground would have been blessed in the past even if there is no record of this.

8.142 The more difficult question to answer is why the children were "buried" in such an inappropriate manner. It has not been possible to establish who actually physically conducted the burials. It seems likely that the burials were conducted on the instructions of the Sisters. As is described above, the burial process required lifting a concrete lid. It is highly unlikely that the Sisters actually conducted the burials themselves.

8.143 All the residents of the Tuam Home were the responsibility of the Galway and Mayo County Councils. It seems to the Commission that responsibility for the burials of deceased children rested with the local authorities. In particular, Galway County Council had a legal responsibility to keep a record of burials.

8.144 Galway County Council members and staff must have known something about the manner of burial when the Home was in operation. As outlined above the Board of Health and its sub-committees sometimes held their meetings in the Home.

8.145 Employees of Galway County Council must have known about the burials. County Council employees would have been in the grounds of the Home quite frequently as they carried out repairs to the building and possibly also maintained the grounds. It is known that there was a caretaker while the Home was in operation but it is not clear if he was employed by the Sisters or by the County Council.

8.146 The Sisters of Bon Secours continued to live and work in Tuam until 2001. They must have been aware of the building works which were carried out on the Children's Home site in the 1970s.

8.147 The Commission considers that there must be people in Tuam and the surrounding area who know more about the burial arrangements and who did not come forward with the information. It is, of course, still possible for them to come forward.

EMC Radar Consulting

atlas geophysical

Report to the Independent Commission of Investigation (Mother and Baby Homes and certain related matters) on the Findings from the Geophysical Surveys of the Memorial Garden, Tuam

Date: 13th November 2015

Contents

Purpose of the Geophysical Surveys

The Mother and Baby Home Commission of Investigation wishes to locate the position of a disused cesspit believed to lie, at least in part, beneath the Memorial Garden in Tuam, Co Galway, Eire. Evidence from a number of witnesses suggests that human remains have previously been found within this cesspit. The Commission would also like information on potential burial evidence from in or around the former cesspit.

Geophysical Methods Applied

The original work plan and method statement envisaged using three geophysical survey methods, namely Resistivity, Magnetometry and Ground Penetrating Radar (GPR).

Although Resistivity is the main geophysical method recommended for the discovery of burials (for example, in the English Heritage guidelines), GPR can be as successful in uncovering burial evidence and is routinely used for the detection of buried structural material such as cess pits. Neither method detects human remains: both detect either the effects of ground disturbance, the products of decomposition (provided that the burial is of recent date) and the presence of associated anomalous material, such as air gaps. The advantage of GPR over Resistivity is its ability to detect changes with depth. The potential disadvantage is that not all soils are suited to GPR survey. The suitability of the soil for GPR survey was not known in advance and therefore the proposal was to use all three methods.

The first survey completed was that using the GPR and this proved to be entirely successful in gathering good quality data. It was therefore decided that there was no need to use Resistivity as this would have provided less information than the GPR. On analysing the GPR results, it became evident that the entire memorial garden is covered with a layer of material, believed to be concrete. Since depth discrimination is not a primary function of a Resistivity survey, the presence of this presumed concrete layer would have prevented a Resistivity Survey from gaining meaningful results and the decision to rely on GPR is therefore vindicated.

It was considered more important to deploy a magnetometer since there was a possibility that the cesspit was of brick construction and Magnetometry is an excellent detector of brick structures. However, unlike GPR, Magnetometry is also unable to distinguish discrete changes in subsurface data with depth. Two attempts were made at completing Magnetometry surveys on site. Although this gave some information, there was no area free from subsurface material that allowed the equipment to be properly calibrated. The subsequent analysis of GPR data, revealing the presence of a layer of material across the site is significant in this respect.

The primary source of evidence for the investigation of this site is therefore the GPR survey.

Summary of Findings

The site of the memorial garden has not only been backfilled, it has effectively been levelled and, in the process, much of the former cesspit has been destroyed and distributed across a larger area of the site, primarily towards the North.

Nevertheless the ground plan of the former cesspit has been identified as have a number of other features, notably what appears to be a wall separating the former Home from the area of the cesspit. There are two separate construction phases to this wall, the later one enclosing a slightly larger area than formerly. Drawing ICIMBH_TuamGeo_001.pdf which accompanies this report shows the cess pit footprint within the context of the memorial garden.

There is some evidence suggestive of the existence of pipes in the ground. This is incomplete, presumably due to the levelling of the site and the consequent destruction of the structures it contained. Almost all identifiable features are effectively discontinuous, indicating a high level of attrition. For example, in many places it is difficult and/or impossible to establish whether a linear feature observable in the time slice data represents the remains of a wall or of a subsurface pipe. This is part of the evidence for the destruction of the former cesspit.

As originally expected, it was not possible to identify the position of any burials within the memorial garden. There are a number of reasons for this. Firstly, GPR detects associated disturbance, voids or fluids, not the actual human remains. Over time, buried bones take on the electromagnetic (EM) properties of the soil which surrounds them. Without a difference in EM properties between the human remains and the surrounding environment, it is impossible for a radar to distinguish this type of target. Air gaps and disturbed ground are detectable. Unfortunately, the majority of the site has been disturbed by backfilling and destruction to a point where it is impossible to distinguish any particular area as being the likely site of a grave or graves. The entire area has been disturbed, not merely parts of it.

Size is also a factor. The majority of burials within this area were expected to be of neonatal infants and the size of any remains, particularly given the processes of decomposition and any post-depositional attrition, were unlikely to be sufficient for detection by the 400MHz antenna used. Finally any lack of formality in the burial process would hinder detection, particularly in the complicated environment resulting from the backfilling process.

The lack of detection of burials, formal or informal, does not imply a lack of buried human remains.

The Presentation of the GPR Data

In the detailed commentary which follows, evidence from both 2-dimensional and 3-dimensional GPR is presented (see also **How GPR works**, p19). GPR is not an optical method and the 2-dimensional data, although it presents the same information as would an archaeological vertical section, cannot and does not present the data in the same visual format. It is important to understand that each signal returned to the radar antenna represents a change in materials rather than a specific material. The stronger the signal amplitude, the greater the change in the electromagnetic properties of the two (or more) materials. It is therefore possible to infer that anomalous material is present. It is not possible to be completely certain what the actual materials are. The strength of signal amplitude is given by the degree of black and white, grey indicates continuity and a lack of anomalous material.

The 2-dimensional survey profiles have been assembled into a 3-dimensional data block from which horizontal plans, known as time slices, have been extracted at a range of depths. The precise depths have been chosen in function of change in the data patterning. Since there is evidence of air gaps within the data, it is likely that these are quasi-horizontal rather than physically horizontal. In the time slices, anomalous material is highlighted in black only. White indicates homogeneous material.

It is important to note the caveat in respect of physical depth (See **Velocity Calibration**, p20). GPRs measure depth extremely accurately in nanoseconds time. However radio waves do not travel at a constant speed. In particular, the changing water content of the soil with depth means that the transmission velocity varies in a vertical direction. This makes a one-off translation of nanoseconds time into metres and centimetres virtually impossible with the same degree of accuracy.

Ground Plan of the Memorial Garden

All 2-dimensional data are depicted running from (site) North to (site) South from left to right. All time slices extracted from the 3-dimensional data show (site) East at the top of the page. Site North differs a few degrees from conventional North. The adjacent playground lies to the site North of the memorial garden. The wall containing the main entrance gate is site West and the corner containing the statue lies in site SE. Figure 1, the time slice from the surface, shows the layout described.

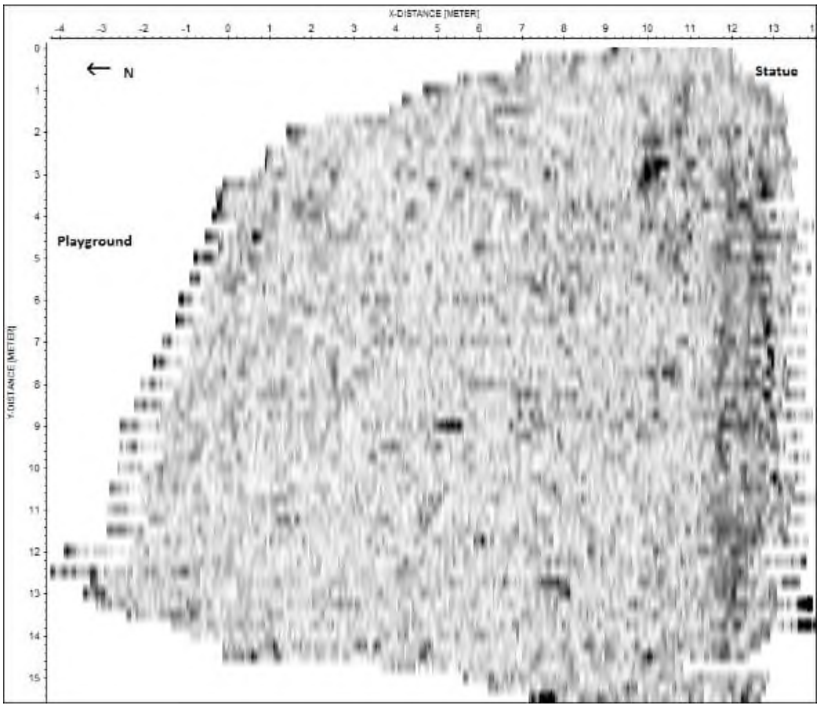


Figure 1: Outline of the Survey Area and External Reference Points.

The Evidence for Destruction of the Cess Pit

Before the survey was begun, it was known that the site had been backfilled with rubble and soil and the 2-dimensional survey data initially confirmed this. However, reviewing successive survey lines illustrates a near complete lack of continuity between one line and the next. Since the survey parameters were determined in order to maximise data retrieval, the discontinuities shown are not the result of the data collection process. They are the result of the condition of the materials in the ground.

Two sets of examples to illustrate this are shown in Figures 2 and 3. Both figures show adjacent survey lines from different parts of the site. The signal variation along the line travelled by the radar is immediately apparent. The visual impression is one of rubble rather

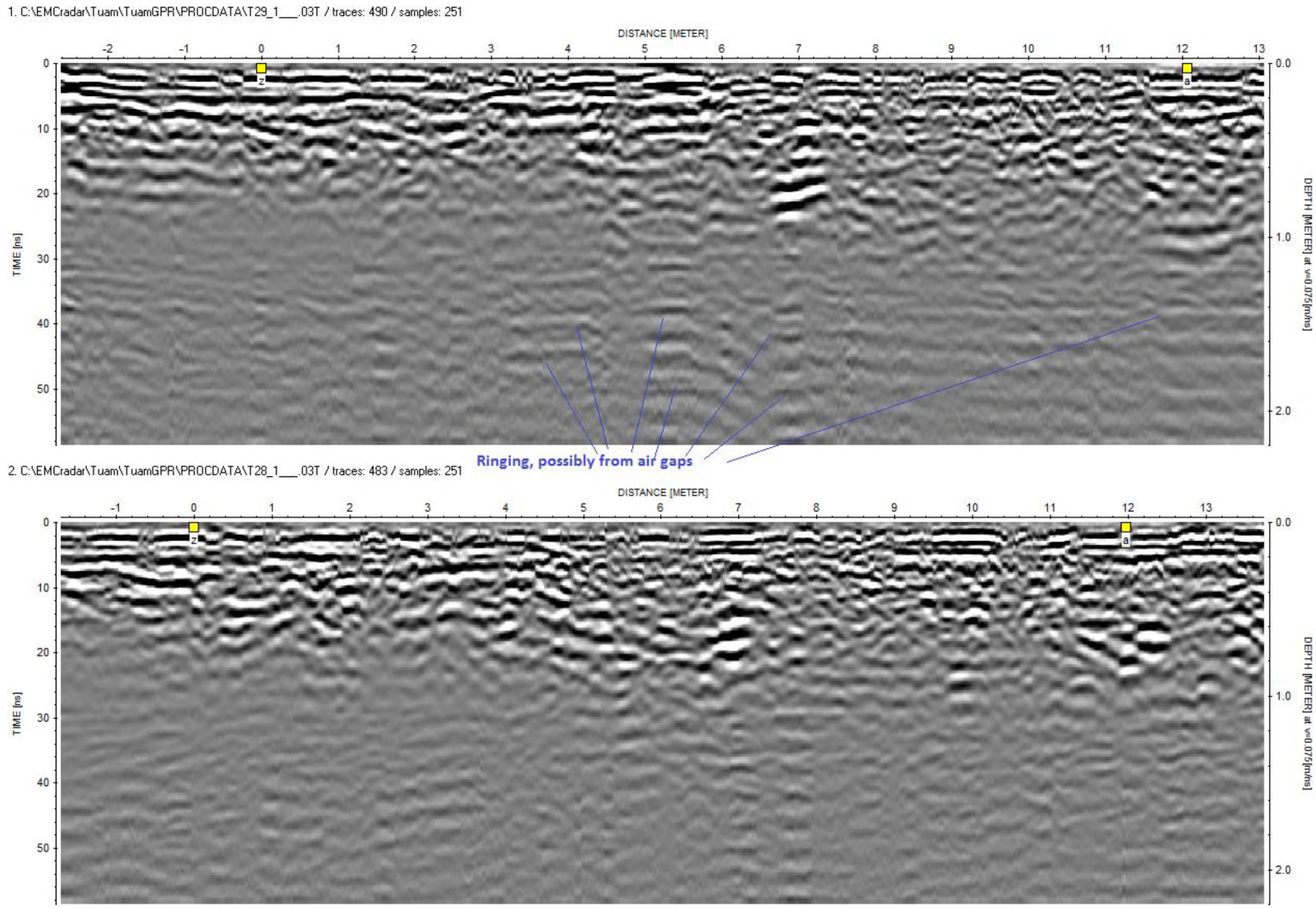


Figure 2: Survey lines 28 and 29 at 9.25m and 9m from the East end of the survey area.

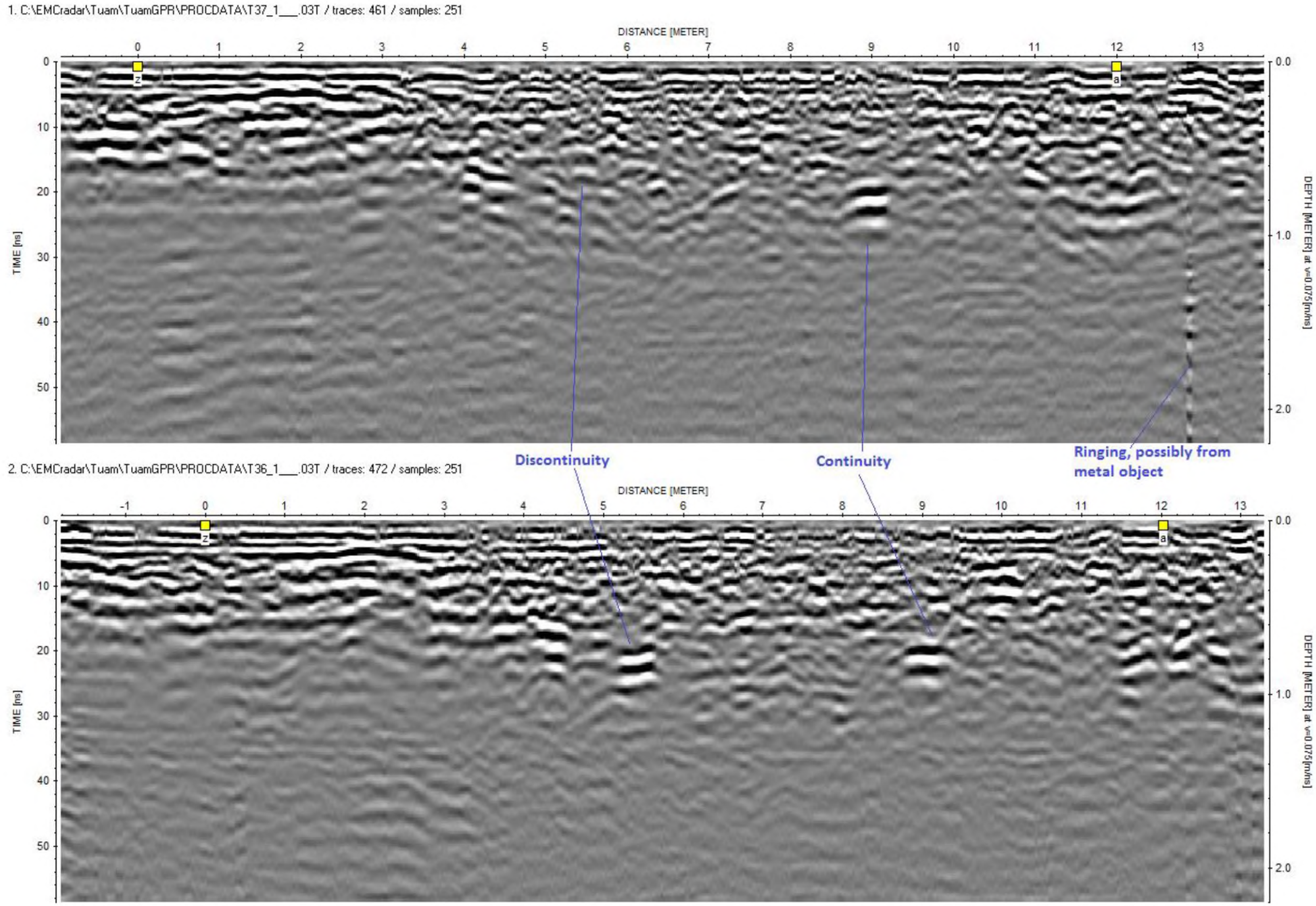


Figure 3: Survey Lines 36 and 37 at 7.5m and 7.25m from the East end of the survey area.

than continuous surfaces although there are very short sections of continuous signal. Although these lines are adjacent pairs, there is almost no continuity in signals from one line to the next. This patterning is typical where a built structure has been significantly damaged.

One other aspect of the data is also typical across the full data set i.e. the prevalence of echo effects (known as ringing). These are often the result of air gaps, in this case of the order of 9-10cm. There is no evidence that, with a few exceptions, the majority result from buried metal objects since the signal strength from a metal object is very much greater than that from an air gap (cf Figure 3).

The other main evidence for destruction of the cess pit comes from the time slices extracted from the 3-d data. Had the site merely been backfilled, a speckled pattern across the area of the survey would be a reasonable expectation with continuous black areas indicating extant surfaces. There are no large surfaces in the 3-d data. Instead there are some short sections, for example, the corner visible in Figure 4. The majority of the patterning indicates broken sections of material.

The conclusion is therefore that either during the backfilling of the site, or before, the structure of the cess pit and any other standing structures have been destroyed.

The Evidence for the Footprint of the Cess Pit

The primary evidence for the footprint of the Cess Pit comes from the 26ns time slice, approximately equivalent to just over 1m in depth. Figure 4 shows a broad sweep of strong signal adjacent to the South wall of the memorial garden which appears to broadly equate with the southern edge of the former cess pit although it is not possible to say how far this extends below the floor beds, the wall or the ground beyond.

The footprint of the East and North walls is largely missing except for the solid NE corner which is still in evidence. There is a line of strong signal returns along the western edge which may be the remains of a western limit to the former cess pit. The majority of signals returned by anomalous material lies within these boundaries i.e. within the footprint of the former cess pit. The northern limit of both the NE corner and the possible western limit ends at c. x = 3.9m, which also implies that this is the footprint of the former cess pit.

It is evident from the scattered nature of the signals within this footprint that there are short lengths of continuous material but no continuous floor. This is true of all depths in the 3-d data. The 26ns time slice is the most coherent outline from the GPR data. This therefore forms a definitive footprint and also supports the contention that the former cess pit has been destroyed. This time slice has been incorporated into drawing ICIMBH_TuamGeo_001.pdf which accompanies this report.

It is not possible to determine, on the basis of the GPR signals, the material from which the cess pit was constructed. Brick can sometime be diagnosed on the basis of the air gaps formed either within the brick itself from indented surfaces or from deteriorating mortar. The incomplete nature of the structure makes this impossible to identify.

There is another series of signals to the North of the former cess pit, forming the outline of a partial rectangle with a strong reflector contained within the area. This feature is fully discussed under the **Evidence for the Wall** and **Feature X** (see pp 13 and 15).

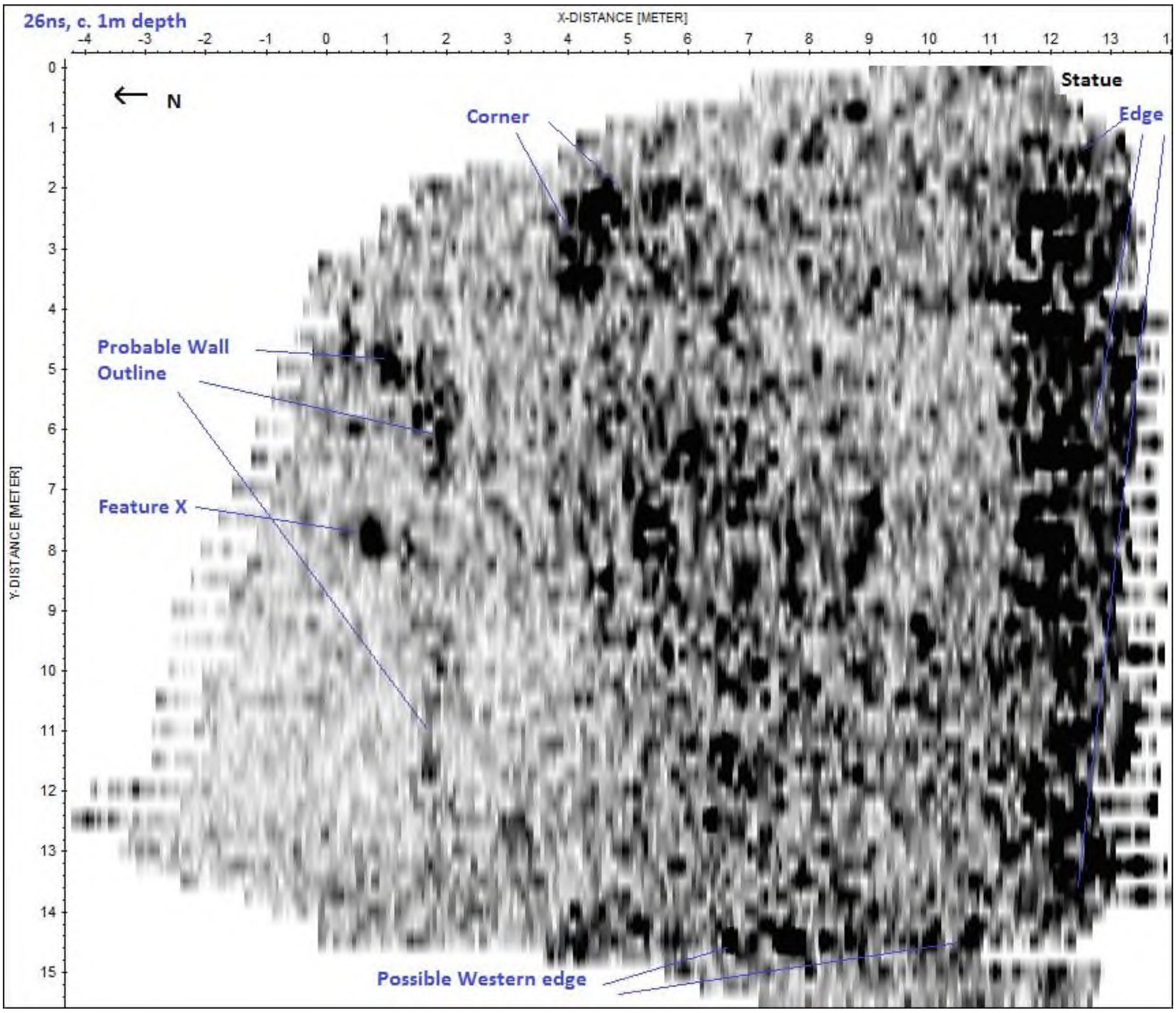


Figure 4: Time Slice extracted at 26ns (c. 1m) showing the footprint of the former cess pit.

The Evidence for Material having been spread across the site

The evidence for material having been spread across the site begins with the cess pit footprint outlined in Figure 4, the 26ns time slice. This appears to be what remains of the base of the former cess pit. A little higher up in the subsurface, at 20ns (or c. 82cm), there is a much wider spread of material particularly towards the North and the probable wall dividing the Home from the cess pit (Figure 5). This material includes a few larger features which appear to be displaced structural material.

The evidence for the southern wall is as substantial as evidenced by the deeper time slice and very similar in patterning. Figure 6 illustrates that there is some continuity across the site, suggestive of parts of a former floor remaining in situ. The apparent variation in the depth of this floor is most likely to be due to uncorrected topographic variations in the current surface, rather than the layout of the material returning the signals. The structure is, however, anything but solid as witnessed by the variations both horizontally (Figure 5) and vertically (Figure 6).

The NE corner is no longer visible, nor is it possible to infer the line of the eastern wall. The reason for this is the appearance of material between the northern edge of the cess pit at c.

3.9m along the x-axis (itself no longer discernible) and the presumed boundary wall of the Home.

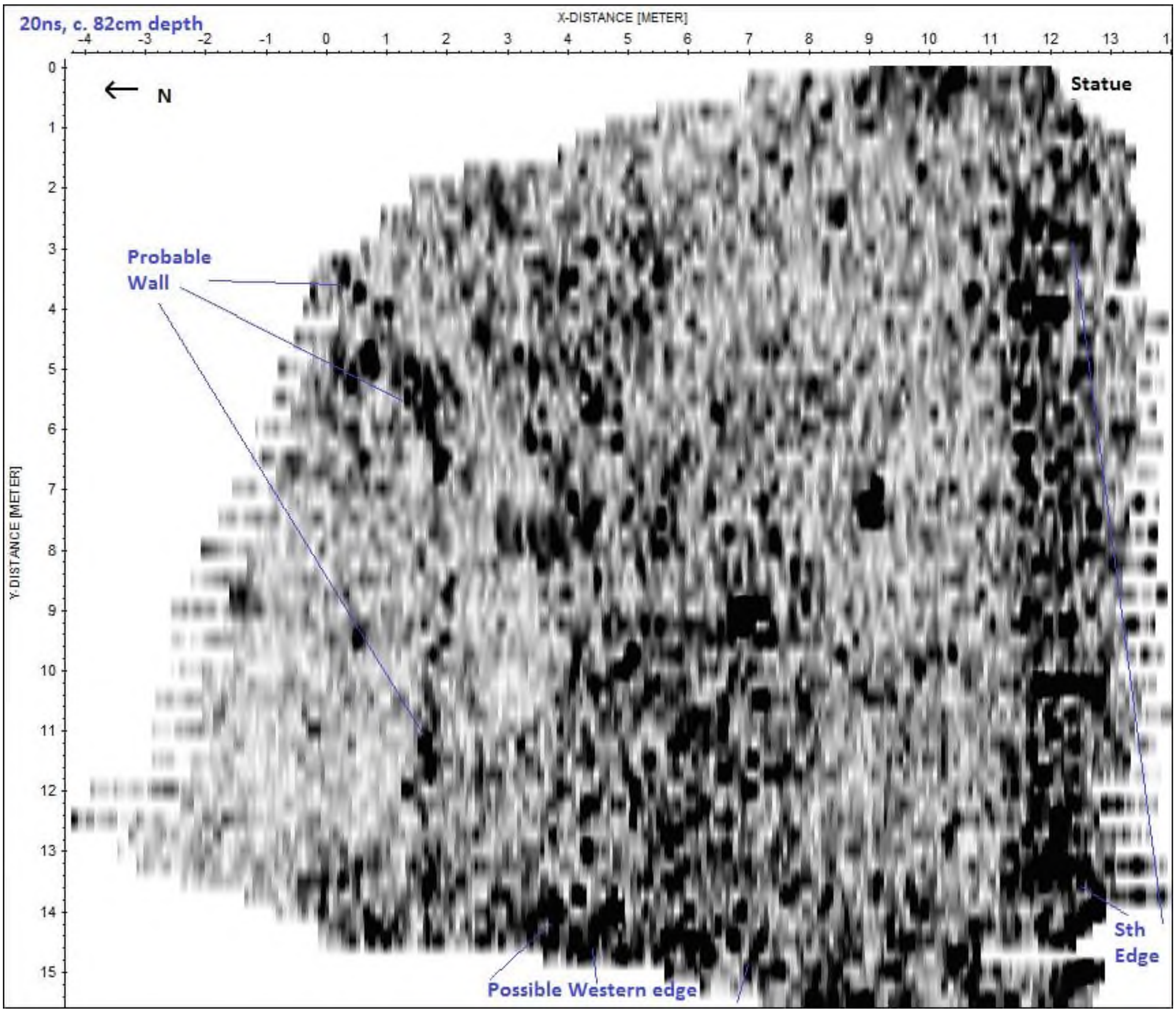


Figure 5: Time Slice at c. 20ns (c. 82cm) showing the spread of material towards the North and the changing outline of the probable wall.

Viewed in 2-d, the various objects which fill this gap form irregular layers which strongly resemble backfill. A good example of this is visible in Figure 3 between x = 2.8m and 3.9m. Although the bottom of the profile appears to dip at this point, there is actually a small rise at surface level just beyond i.e. from 3.9m onwards. Since the data has not been topographically corrected, the slight rise at surface level appears deeper than it actually is below ground. It therefore looks as though material originating from the North and East sides of the former cess pit has been used to backfill the area between the cess pit and the garden wall visible in both time slices (Figures 4 and 5).

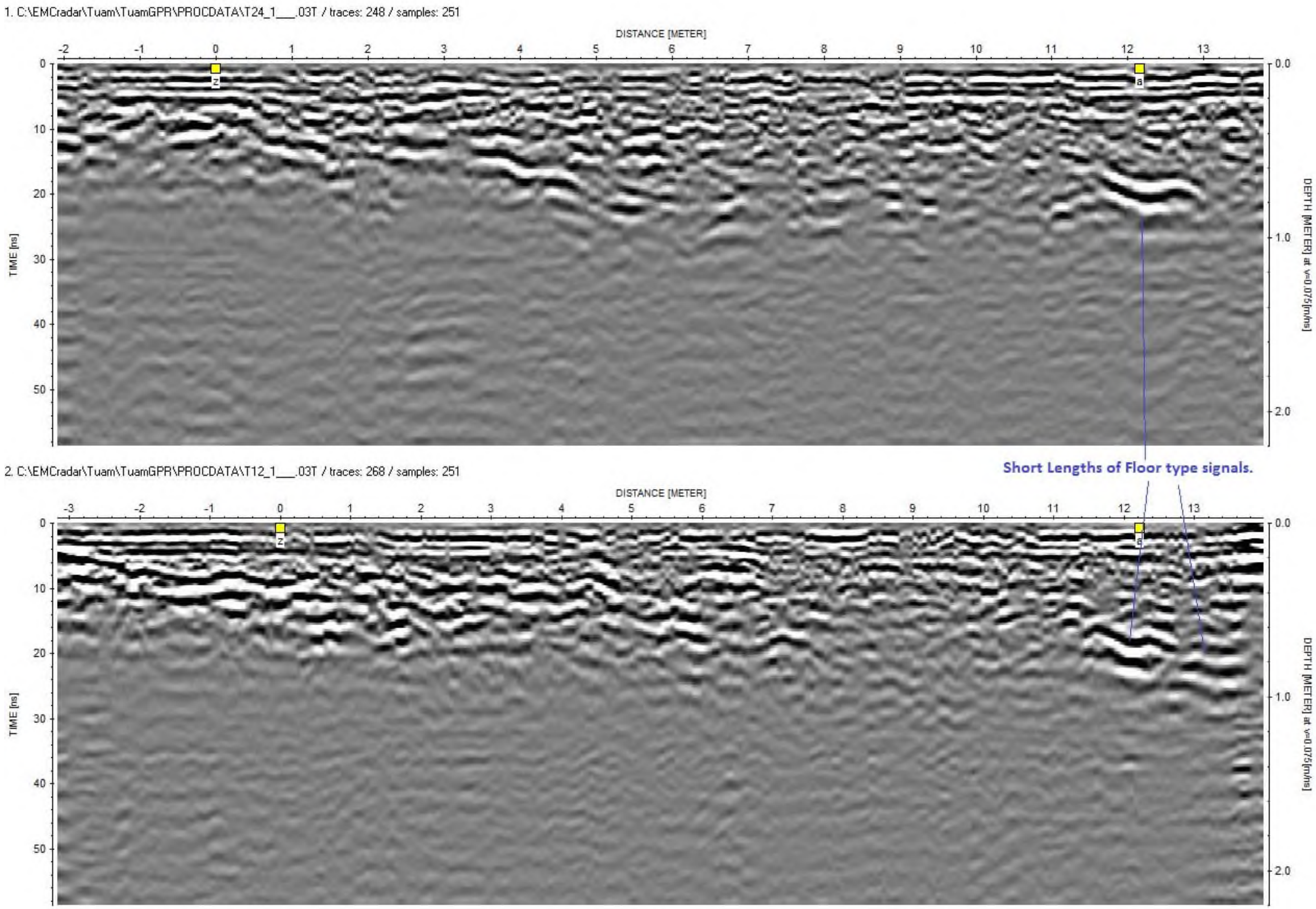


Figure 6: Survey lines 24 and 12 (y = 10.25m, y = 13.25m) showing some consistency in floor type signals along the southern wall and also a degree of variation.

Moving upwards towards the surface, the 17ns or c. 72cm time slice shows a number of changes from the 20ns time slice. The South wall of the former cess pit is still visible although the remains are more sparsely distributed. There are relatively few strong signals from the area of the cess pit itself which reaches from x = c.3.9m over to the South wall (Figure 7). The building materials that are visible lie between the cess pit and the wall of the Home. The backfill which is visible could have been brought into the site but could also potentially be some of the missing material from the damaged cess pit. The presence of large slabs such as that visible at (2.9, 2 to 2.5) suggests material displaced from the adjacent cess pit. Material further to the West, for example, centred on (3.8, 10.25 to 10.5) is similar.

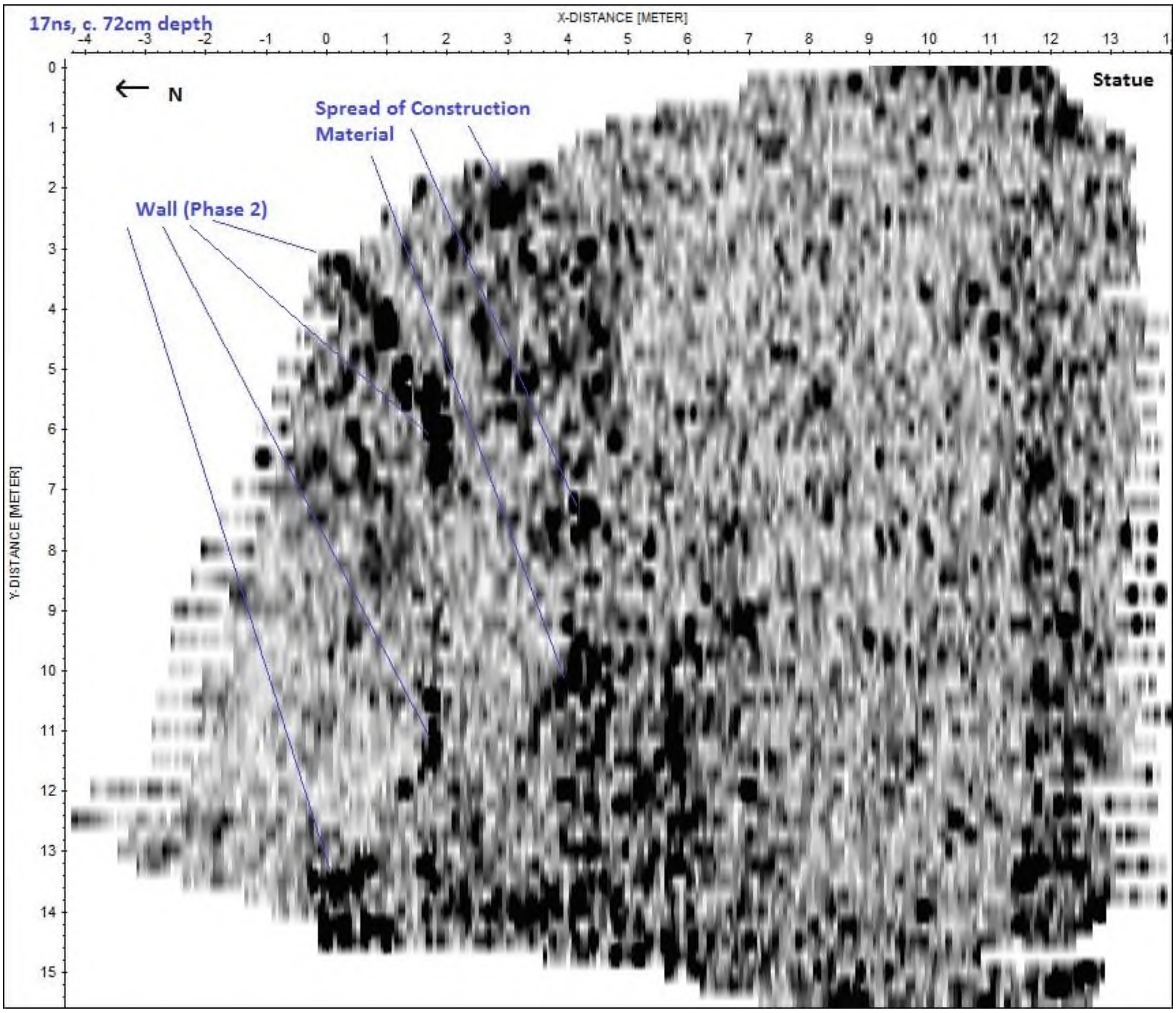


Figure 7: Time Slice at 17ns (c. 72cm) showing a spread of construction material

Along the western edge, there appears to be a solid line, potentially part of a feature outline from c. x = 3.9 towards the northern limit of the survey area. Although this could be a feature leading from the cess pit towards the North, looked at in 2-d, this appears to be mostly layered backfill (Figure 8).   If this was an original feature in situ, then it has also been destroyed.

The line immediately to the East of this feature (directly above in Figure 7) appears to form part of the boundary wall. Viewed in 2d, this is possibly the case (Figure 8) although it could also be displaced construction material (line 11, Figure 8) and it is, in any case, closely

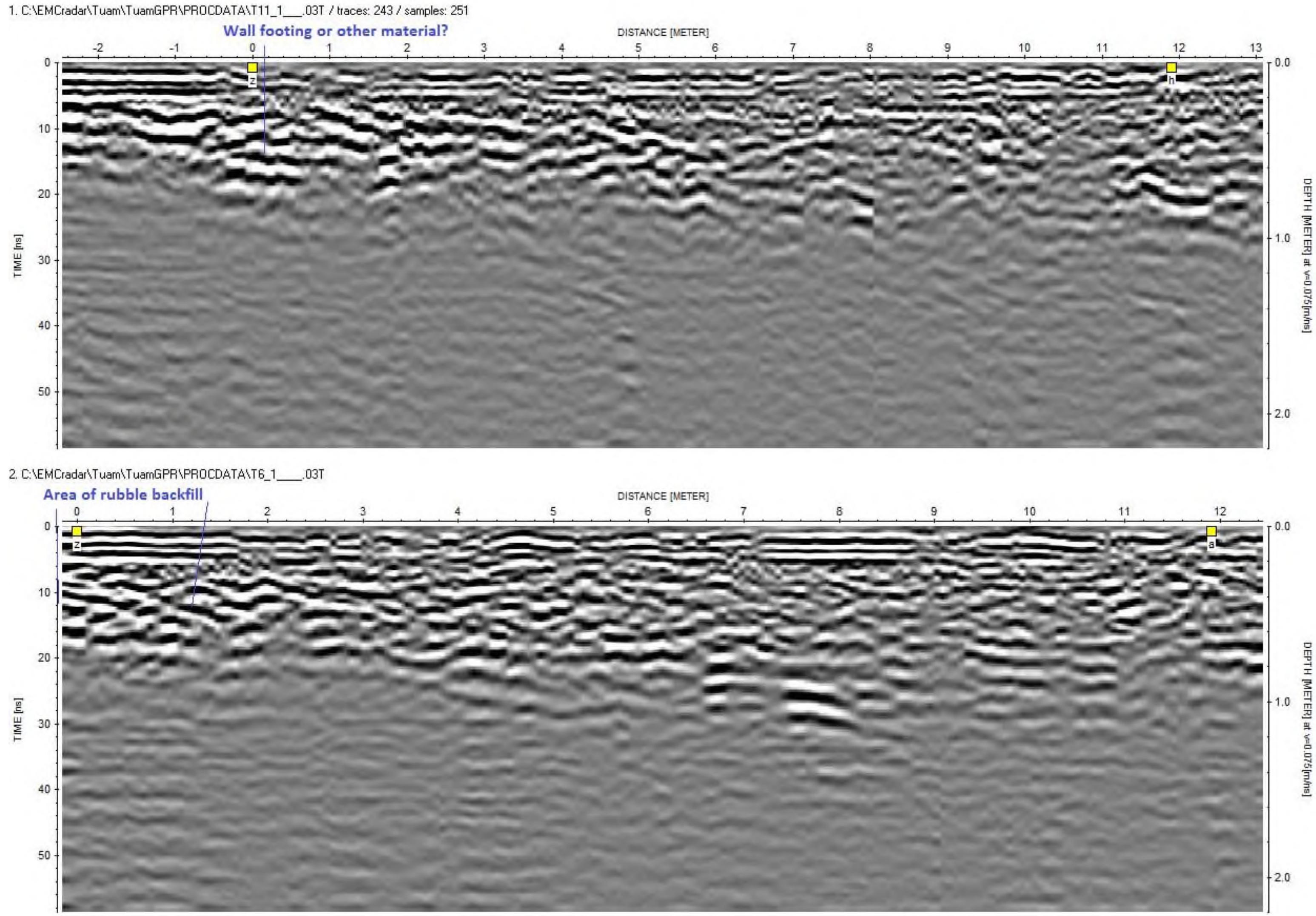


Figure 8: Survey lines 11 (y = 13.5m) and 6 (y=14.5m) showing possible wall footing and rubble backfill.

surrounded by rubble formed from similar material.

Immediately above this level, at 16ns or c. 66cm, the outline of the cess pit disappears completely. This implies that there is possibly less than 0.5m of the pit structure in or near its original position and that it is now primarily covered by soil (Figure 9).

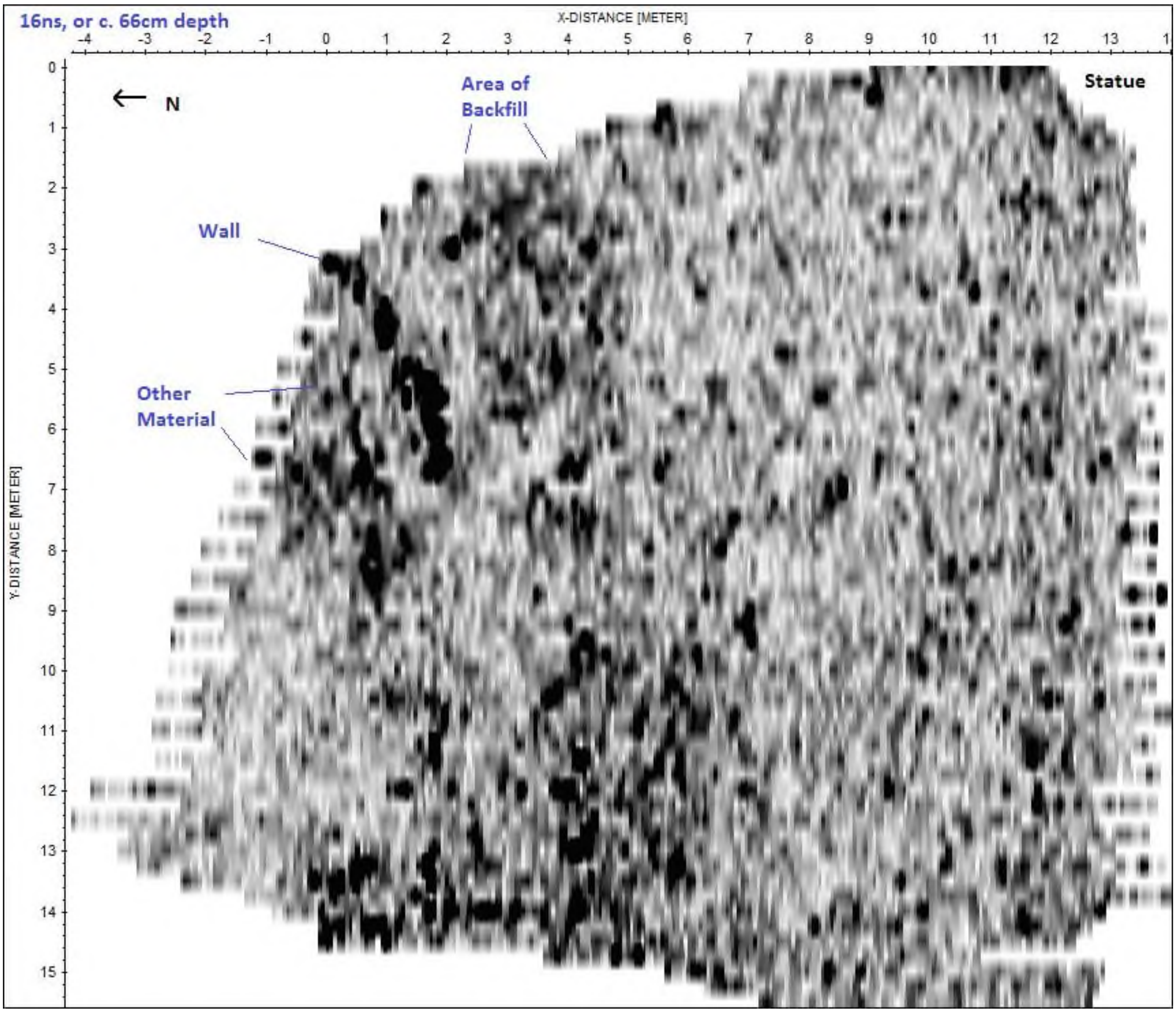


Figure 9: Time Slice at 16ns (c. 66cm) depth showing primarily backfill material.

The boundary wall between the Home and the cess pit is partially visible, primarily in the eastern section. The main features are two areas of backfill: the one between the cess pit and the boundary wall and another inside the boundary wall.

Both inside and outside of the boundary wall, the lines of backfill follow a parallel path to the curve of the wall. The size of the rubble forming the backfill is less than in the lower levels but still appears to be construction type rubble. It is not possible to be definitive as to whether the origin of this material is the cess pit or whether this is rubble brought in but the evidence from lower down suggests the former, at least to the South of the wall (rhs in Figure 9).

The material lying within the boundary wall is largely indeterminate beyond potentially being construction type material but part at least is associated with Feature X (Figure 4) and possible service pipes. This is discussed in **Feature X and Possible Service Pipes** (p15).

The possible feature leading from the area of the cess pit towards the North, along the western edge of the survey area is still in evidence.

The Evidence for the Wall between the Home and the Cess Pit

There are two different outlines for the feature which appears to be a wall dividing the area of the Home from that of the Cess Pit. The lower of these is depicted in Figure 4, the time slice at c. 26ns. By 20ns this outline is changing to include a slightly greater area within the grounds of the Home (Figure 5). Comparison of Figure 5 with Figure 4 shows that the outline stretches further East at the higher level than at the lower one. The western edge is also now visible, suggesting that this relates to a later phase of the structure, the footings from the previous version having been removed at an earlier date. Figures 5 and 7 illustrate the line of the second, extended, phase of the wall.

Figure 10 shows the minimal amount of material left in situ which might constitute wall footings, in some instances in situ (evidenced by vertical stacking of signals) and in others lying to one side. The survey lines illustrated in Figure 10 lie along y = 4.75 and y = 5 in the time slices i.e. they lie in the NE area where the partial outlines of both lines are visible in Figure 5. These survey lines also illustrate that the potential footings to the North (i.e. those further to the left) lie at a lower level than those further to the South. Around 20ns is the depth at which they are both visible, implying that the remains of the earlier wall are the footings only. This positioning is consistent with an original wall having been levelled and a newer wall being extended further into the area of the cess pit i.e. to the South and East.

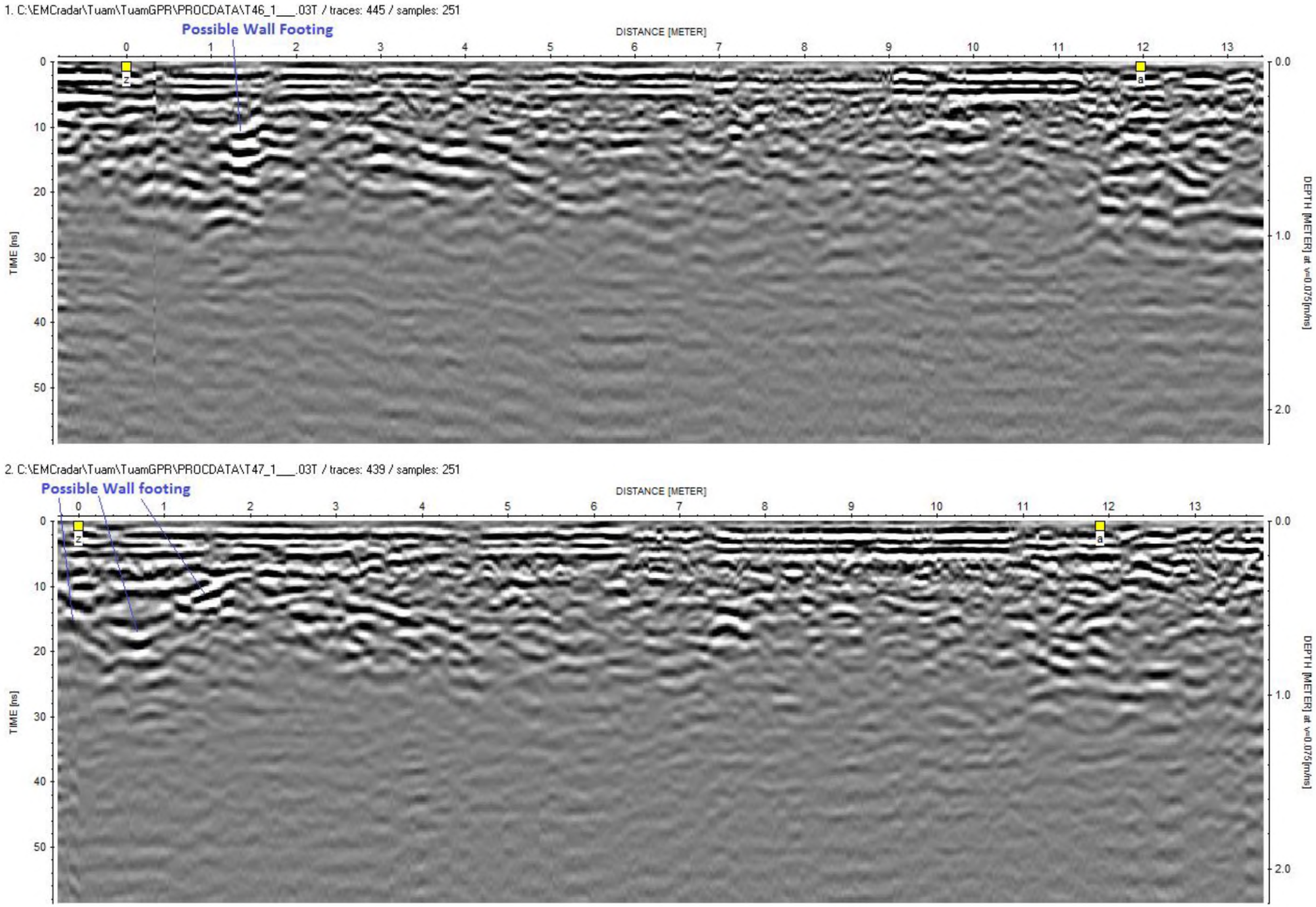


Figure 10: Survey Lines 46 & 47 (along y = 5m and y = 4.75m) showing possible wall footings

Feature X and Possible Service Pipes

There is some evidence in the GPR data for the existence of service pipes but, as the data is not continuous, this also serves to underline the destruction of the site. Feature X in Figure 4 marks the spot where a cover can be seen to lie directly above two very short lengths of smaller linear features. This feature is illustrated in vertical section in Figure 12. The relevant signals are marked in line 34 but can clearly also be seen in line 35. The near perfect hyperbola in the southern (rhs) pipe indicates a smooth, potentially undamaged, surface.

The pipes themselves lie at 27ns i.e. just below the level shown in Figure 4. The cover is likely to be concrete. It cannot be metal or the radar would be unable to detect the underlying material.

Although there is continuity between these two survey lines and it also makes intrinsic sense that there should be a connection between the buildings of the Home and the cess pit, the feature does not continue either to the West or to the East. It can therefore be inferred that any related service pipe turns through an angle at or near this point. There is a linear feature at the more shallow level of 23ns (c. 95cm) which appears to connect to the more substantial line, noted in Figure 9, which in turn leads directly into the cess pit (Figure 11). This increases the probability that this dark line leading in to the area of the cess pit was originally

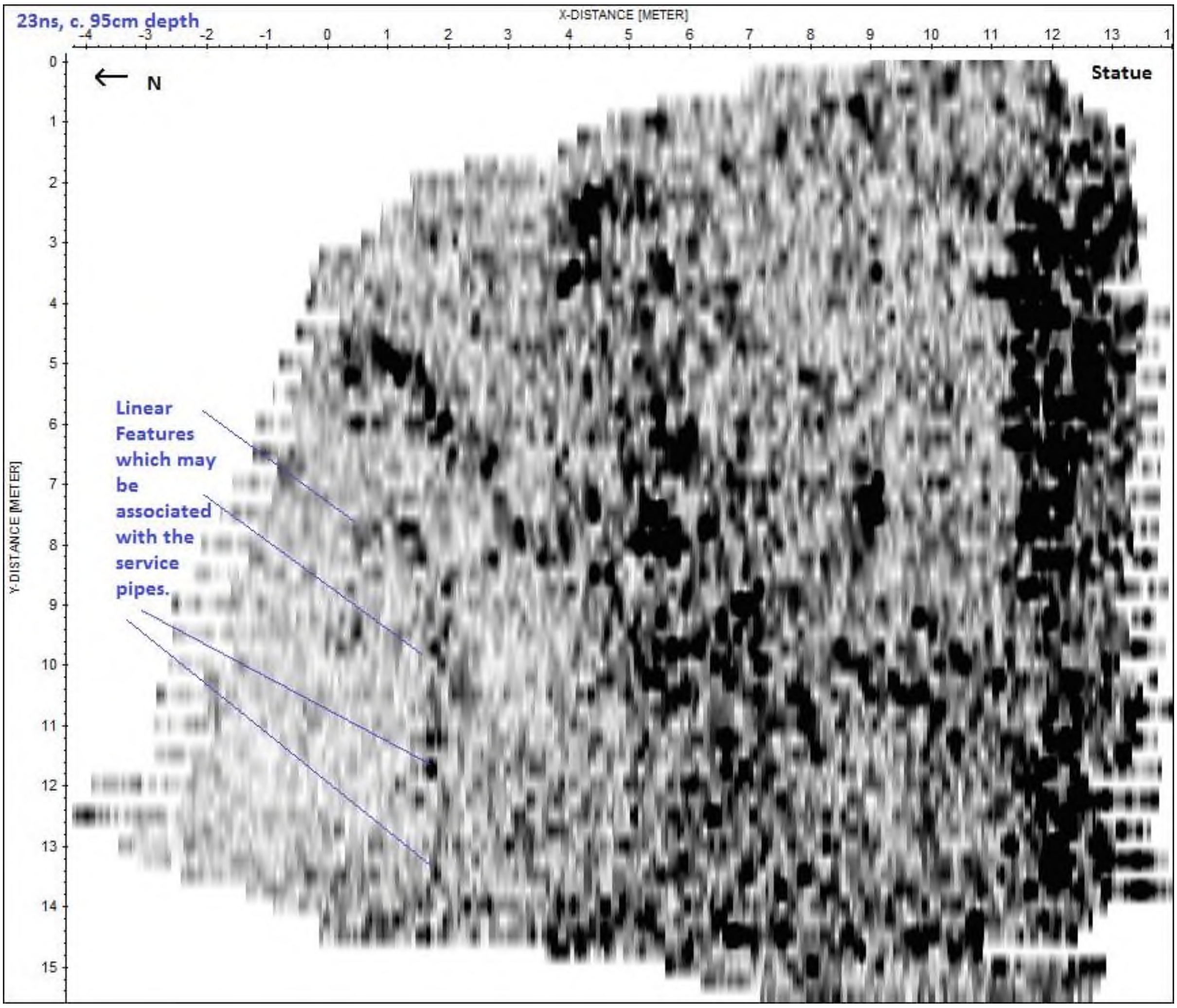
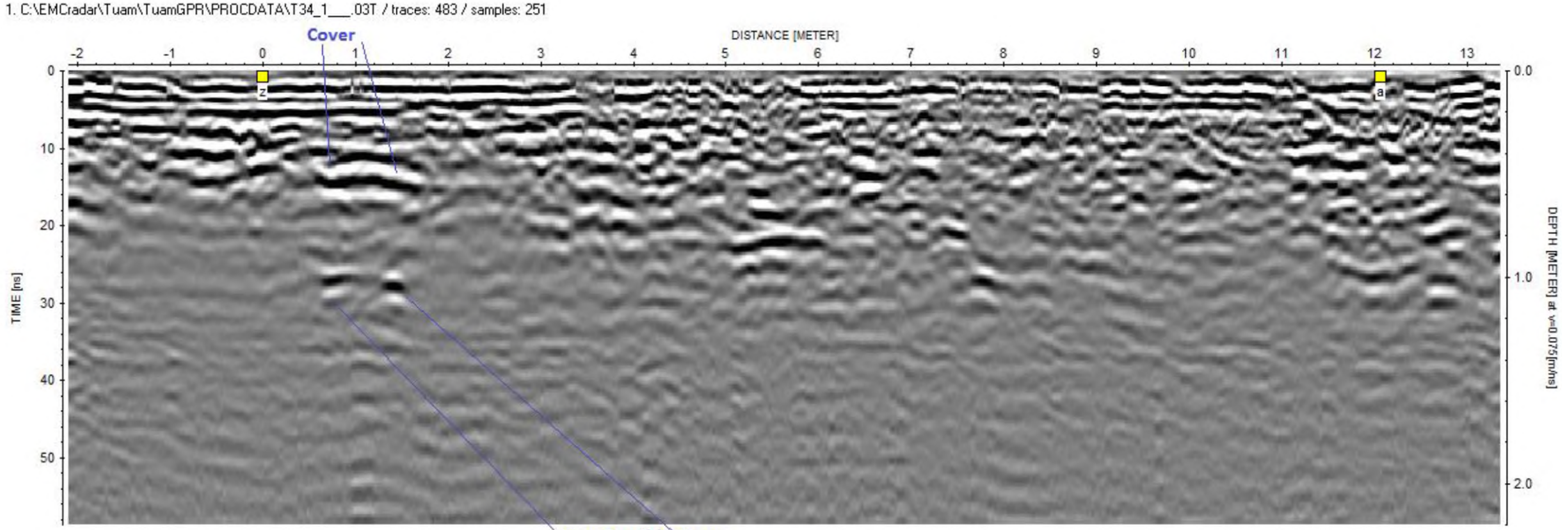


Figure 11: Time Slice at 23ns (c. 95cm) showing a linear feature in the vicinity of the pipe evidence.



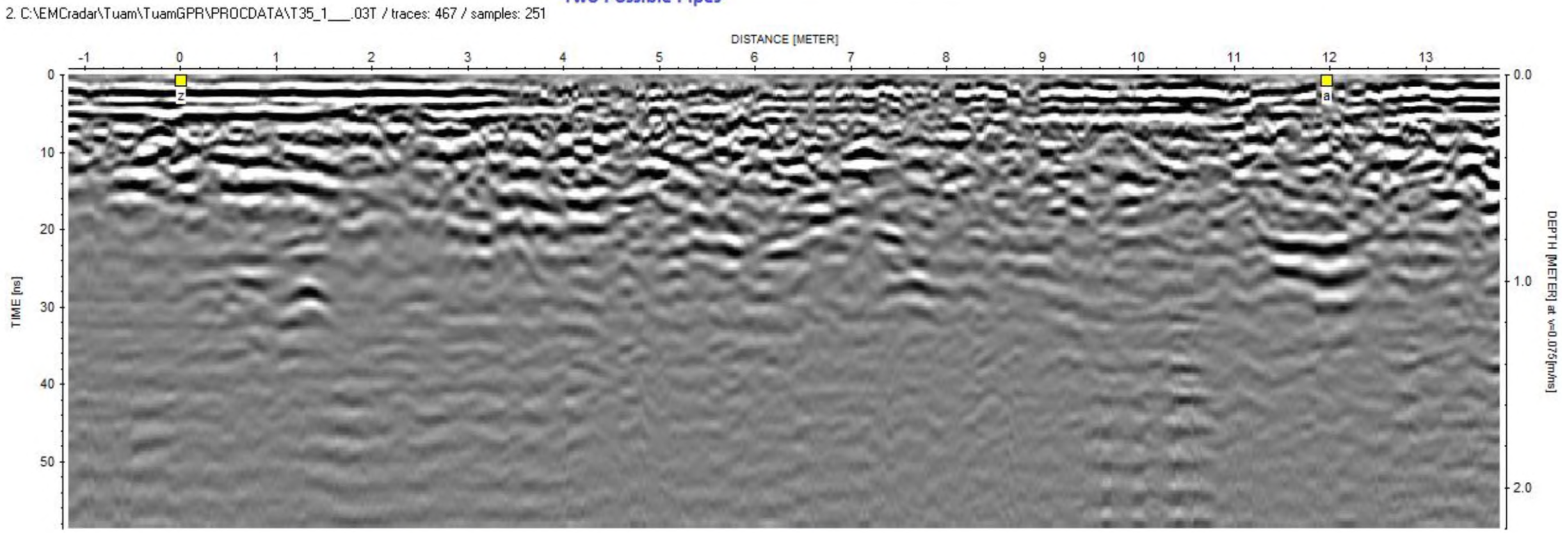


Figure 12: Survey Lines 34 (y=8m) and 35 (y=7.75m) showing evidence for former pipes in situ.

an inlet.

It is also likely that many of the dark lines visible within the boundary of the wall on Figure 9 (for example) represent remains of similar material no longer in situ. It is not possible to tell the nature of most of this material beyond commenting that it gives a similar signal response to the remainder of the material distributed as backfill across the site.

There are, however, other indicators of demolished channels and/or pipework elsewhere on the site both in the quasi-horizontal plane (Figures 9 and 13) and vertically, especially in the area of the southern wall of the cess pit. The lack of continuity across the site suggests that these are all either damaged or no longer in situ.

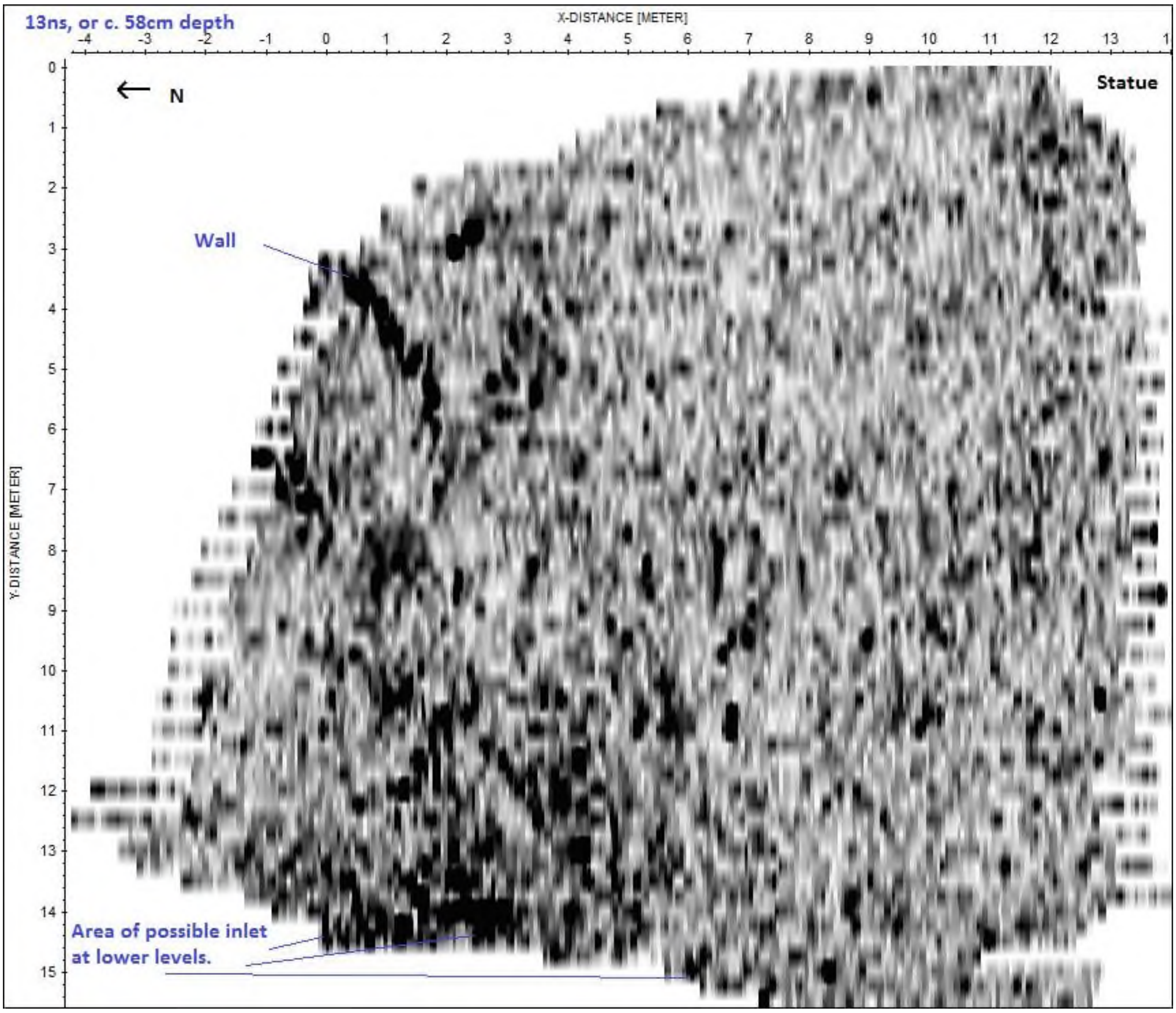


Figure 13: Time Slice at 13ns (c. 58cm) showing a number of linear features.

The Concrete Layer

There is a layer of material, close to the current ground surface, which covers the whole of the site. Information received suggests that this is concrete. There is no evidence in the GPR data of reinforcement which allowed the survey to present the detailed data contained in this report. Every survey line contains this same stratigraphic change. The depth varies a little across the site. Figure 14 illustrates this layer change for survey lines 15 and 49.

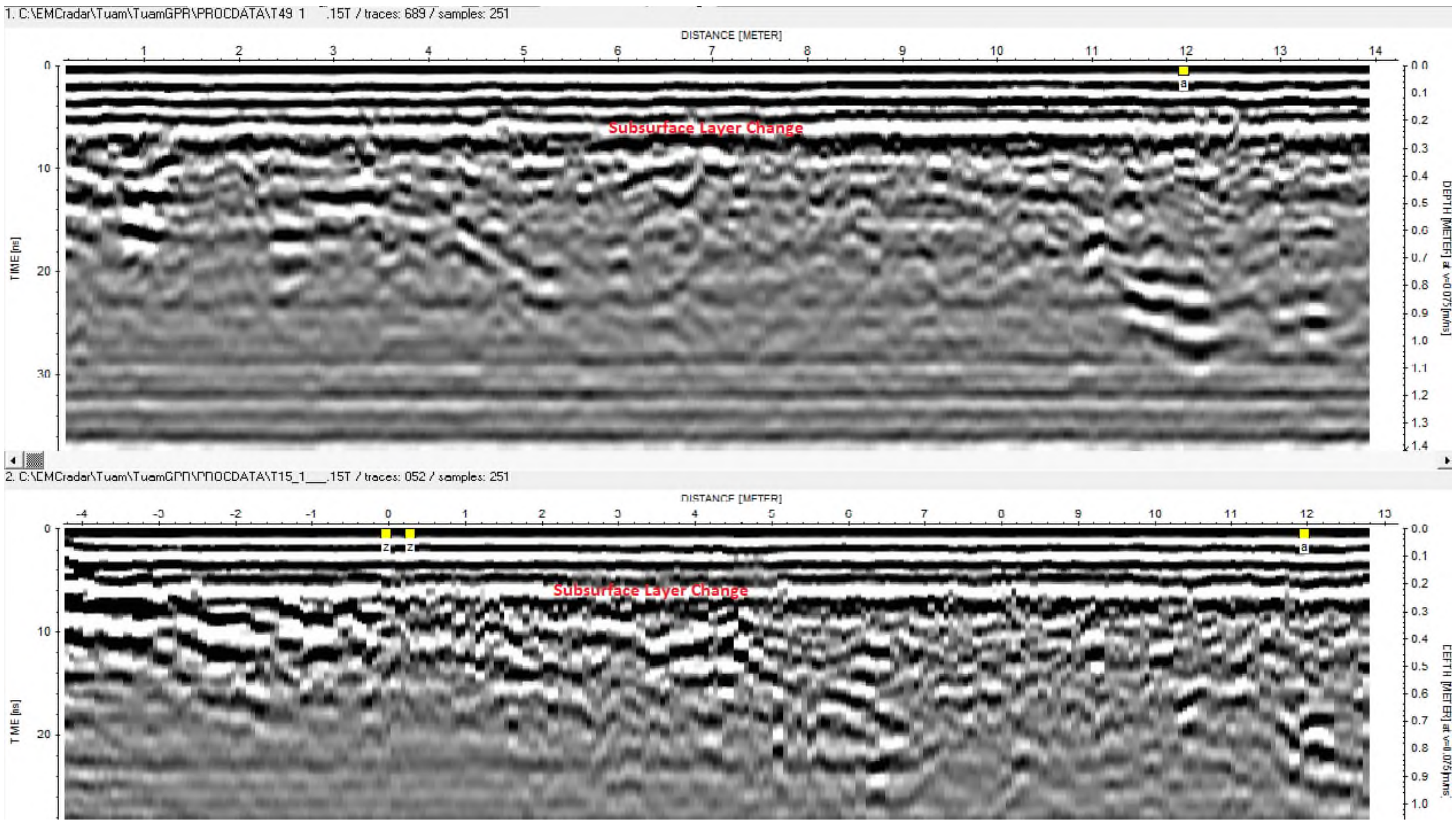


Figure 14: Survey lines 15 and 49 illustrating the evidence for stratigraphic change close to the surface.

The narrow black and white banding at the top of each survey line is the direct signal from transmitter to receiver which indicates the position of the current ground surface. Below this is a wider black/white/black signal which indicates the position of the stratigraphic change.

How GPR works

GPR works by emitting a series of electromagnetic pulses (radio waves) from the transmitter. Portions of these signals are returned to the receiver antenna each time a material with different electromagnetic properties is encountered. The signal is always from the change from one material to the next, never solely from one material. It is therefore not usually possible to characterise materials on the basis of signal strength.

GPRs can only resolve targets in function of the wavelengths emitted. There needs to be a space of 1 wavelength between adjacent objects for them to show as separate objects so that it is possible for certain features to be masked if they are in the vicinity of large amounts of other material. The blocks of signal visible in the 2-d data presented in this report are formed by a combination of 2 signals. The first of these indicates the movement of the signal into the material and the second the movement back out into the surrounding environment. Unless the object is equivalent to or greater than the size of the wavelength, these two signals cannot be separated. This is what forms what appear to be blocks of signal. They cannot be taken as indicators either of size or of shape.

Interpretation of the returned signals relies on understanding the subsurface conditions and the materials to which the GPR is responding. As described above in the introduction to the **Evidence for the Destruction of the Cess Pit**, there is considerable evidence in the data for air gaps within the subsurface. However it does not appear that the high amplitude signals being reflected are the result of air gaps since the primary evidence is relatively low amplitude ringing (echo effects). This implies that there are small quantities of air trapped within the rubble comprising the backfill. This is consistent with the evidence for smoothing over of the site at the near surface shown in Figure 15.

On the basis of the patterning within the data, the major signal returns appear to relate to buried structural material rather than air gaps. It is not possible to determine the nature of this material in terms of brick, concrete, stone etc.

GPRs measure very accurately in nanoseconds time. They cannot automatically measure depth in metres and centimetres because radio waves do not travel at a constant speed. The transmission velocity is determined by the electromagnetic properties of the material being surveyed. It is therefore necessary to calibrate transmission velocity for every site surveyed.

In order to be able to locate the detected features accurately, two parallel survey reference lines were laid out across the survey area, line a to the West and line z to the East. The distance between the two reference lines is 12m. The data was collected orthogonally to these reference lines.

In the 2-d data, the markers “a” and “z” indicate the position of the relevant survey line. In the time slices, line z lies parallel to the y-axis at x = 0 and line a lies parallel to the x-axis at x = 12.

The position of the survey reference lines was established using GPS and this forms the basis on which Figure 4, the 26ns time slice, has been plotted in the accompanying drawing ICIMBH_TuamGeo_001.jpg.

GPR Equipment and Survey Parameters

The GPR surveys were carried out using a GroundVue 3 GPR in single channel mode and a 400MHz antenna. The frequency of antenna used was determined by the need for depth penetration of up to 3m.

The survey parameters were:

- A survey depth of 60ns, equivalent to 3m in dry soil or 2.33m in the site conditions;
- A sampling interval along the line of travel of the radar of 32mm;
- A transect spacing of 25cm between successive survey lines.

The sampling interval was set in order to maximise efficient data collection without prejudicing the detection of smaller targets. The transect spacing was set in order to meet the Nyquist requirement for full data collection. This optimises the images produced in time slice which has been essential for the understanding of this particular site.

Velocity Calibration

As explained above in **How GPR works**, it is necessary to calibrate the transmission velocity of the electromagnetic pulses on site. The default image produced by a radar of any given target is a hyperbolic curve. The shape of this curve reflects the transmission velocity as well as the radar characteristics. Curve fitting has been used to determine the transmission velocity.

This site was relatively complicated in that curve fitting gave a changing velocity profile with depth. Within the first 6ns, a result of 0.1m/ns, indicating reasonably dry soil, was obtained. Lower down the values varied from 0.07m/ns down to 0.05m/ns. The lower values of transmission velocity indicate the presence of water, increasing with depth.

Unfortunately it is not currently possible to calibrate GPR data using a graded scale of velocities. An average velocity of 0.075m/ns has therefore been used to translate the depths in nanoseconds on the 2-d data. For the time slices extracted from the 3-d data, the depths have been derived by calculating the first 6ns of depth at 0.1m/ns and the remainder at the average value of 0.075m/ns.

There are two potential inaccuracies therefore in the depths. Firstly radio waves travel through air at 0.3m/ns so that all air gaps within the data will be understated. Secondly, the precise variation of water content and therefore of speed may not conform to the average at any given position. Subject to the foregoing the depths given in this report should be a reasonable estimate of actual.

The Magnetometer Survey

Methodology

The Magneto MX V3 system consists of a wheeled cart which accommodates five gradiometer probes at 0.25m centres. RTK-GNSS (Global Navigation Satellite System) is coupled to the system to locate the survey readings.

The cart was manoeuvred across the survey area by hand in a series of parallel transects.

This is a rapid non-invasive survey technique, meaning no part of the equipment is inserted into the ground and that it is designed to cause minimum disturbance.

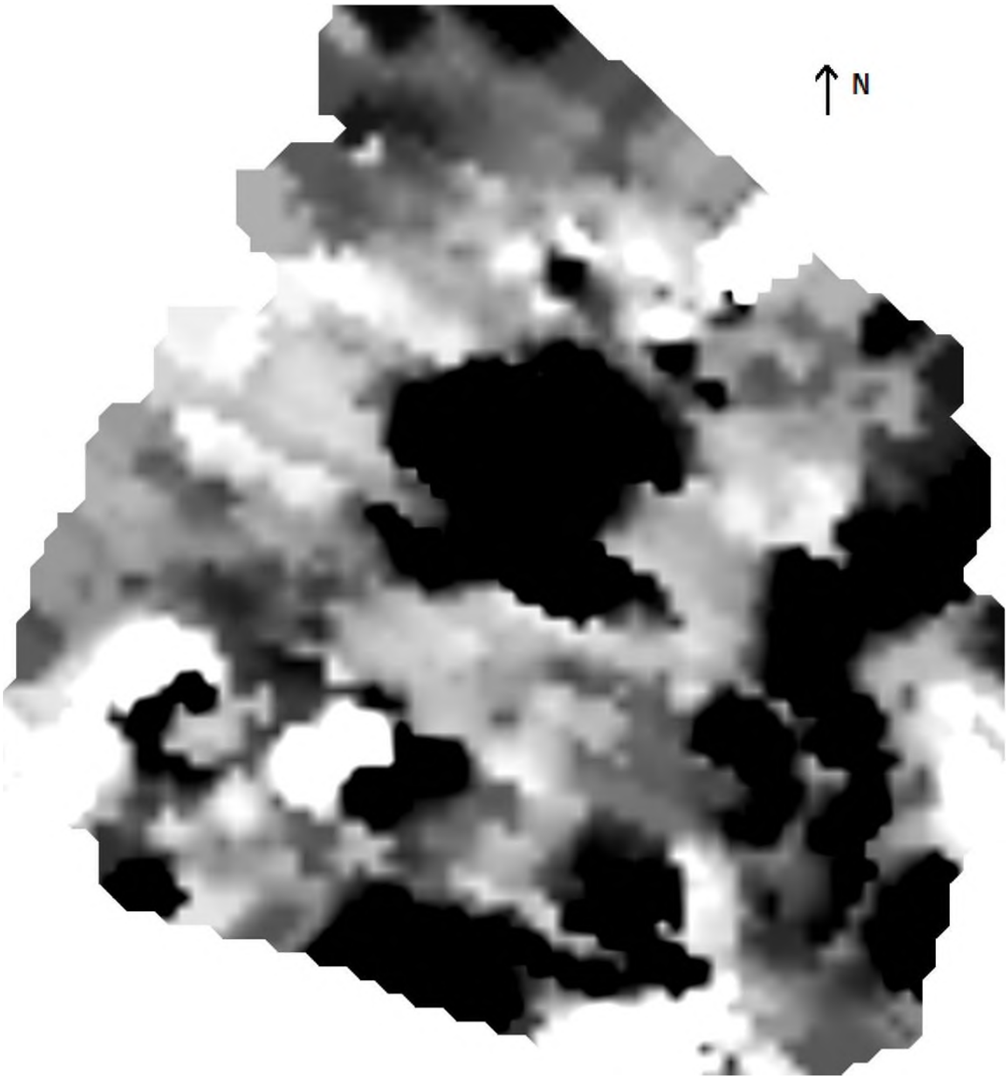


Figure 15: The Results of the Magnetometer Survey

The results of the magnetometer survey do not reflect the detailed results of the GPR survey. One reason for this is the distortion caused by the continuous layer across the site, close to the surface, of what is assumed to be concrete. This has prevented proper calibration of the magnetometer since there is no area free of building material. However the results are not random. The near central anomalous dark area corresponds to an area known to contain rubble. This can be seen in Figures 4 and 11 but also in Figure 16. The GPR signals visible in Figure 16 do not represent material in the ground. They are echo effects from voids higher up, the result of backfilling with building material, interpreted on the basis of the GPR survey, as material removed from the cess pit and spread towards the North as backfill. The magnetometer results are therefore consistent with those of the GPR survey, albeit strongly influenced by the presumed concrete layer close to the surface of the site.

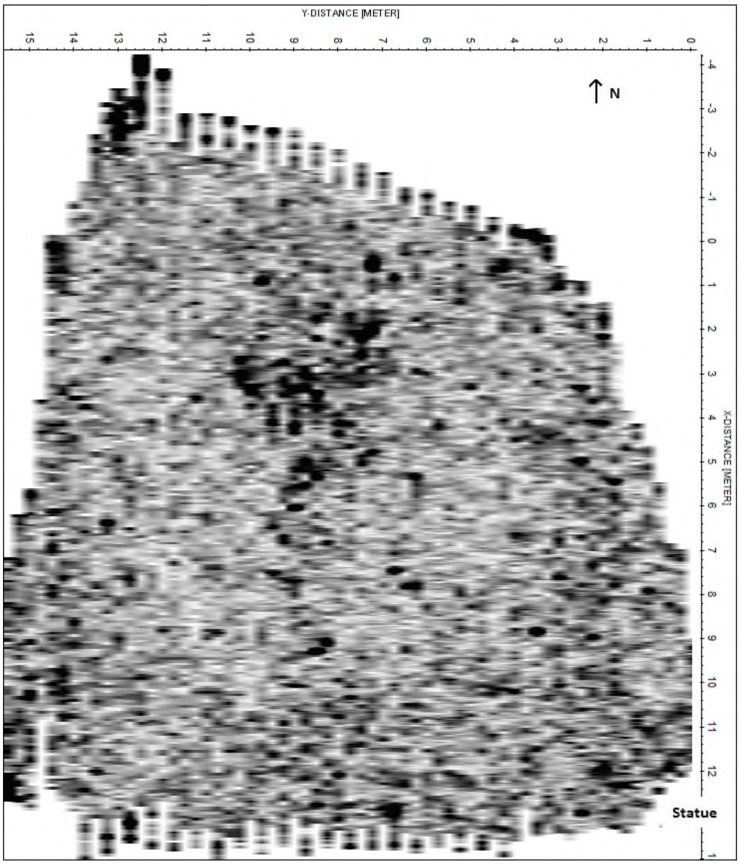


Figure 16: Time Slice at 40ns showing echo effects from air within the rubble above.

Date of the Geophysical Surveys

Both surveys were completed on Friday, 9th October 2015. The GPR survey was completed first and the magnetometer survey carried out thereafter.

Further Information

Any queries arising from the content of this report or the GPR survey to which it refers should be addressed in the first instance to Mrs Erica Carrick Utsi, EMC Radar Consulting.

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15th December 2016

Results of Phase II Site Investigations at the reported 'Children's Burial Ground', Dublin Road Housing Estate, Tuam, Co. Galway.

Report to The Mother and Baby Home Commission of Investigation

Niamh McCullagh, MA, MSc, MCSFS,
Forensic Archaeologist

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EXECUTIVE SUMMARY

- The test excavation was completed to the forensic standard outlined in the proposal dated 10th August 2016.
- The 2 trenches proposed and an additional 2 trenches were opened in the course of the excavation, a total of 14 % of the site.
- A number of historic waste treatment features were identified in these trenches phased from c. 1840s – 1930s.
- A feature of primary significance was uncovered, Feature 1. It contained juvenile human remains in significant quantities.
- The base of feature 1 is approximately 2.70m below the present ground surface and may be composed of 12-14 internal chambers.
- The base of this feature was not accessible and thus remains un-investigated
- Within these limitations six samples of human remains were recovered for analysis.
- Trenches excavated exposed 4 internal chambers within Feature 1. These were uncovered and their lids removed for visual inspection.
- Juvenile Human remains in an excellent state of preservation were identified in significant quantities in each of the inspected internal chambers of this feature.
- The physically recovered human remains represent a Minimum Number of Individuals of 10 with age-at-death ranges from approximately 35 foetal weeks to 2-3 years.

- Additional human remains in significant quantities were observed *in situ* within the inspected internal chambers or tanks.

- No human remains were recovered from pipes, inlets or any other structures identified during the course of the test excavation.

- Radiocarbon dating of samples recovered from feature 1 placed the remains as from the timeframe relevant to the operation of the Mother and Baby Home at this location.

- Feature 1 was constructed as a sewage treatment facility.

- Environmental analysis from soil samples retrieved from the inspected chamber of Feature 1 revealed human decomposition products associated with formula fed babies.

- A sizeable quantity of artefactual evidence associated with the Mother and Baby Home was recovered.

- A decision on the future of the site needs to be made as soon as possible to prevent potential damage to the remains that lie here. There is a risk of disruption to preservation of context, articulation evidence and the preservation of DNA. While this threat is not immediate it does exist.

- It is not appropriate to leave juvenile human remains in this specific context.

1. Introduction

This report presents the results in full of a Test Excavation undertaken at the site of the reported ‘Children’s Burial Ground’ at the Dublin Road Housing Estate, Tuam, Co. Galway. This excavation was undertaken on behalf of the Mother and Baby Home Commission of Investigation with the cooperation of An Garda Síochána and represents Phase II of on site investigations. Niamh McCullagh, Forensic Archaeologist, directed all works on site. This reports presents the methodology, results in full, condition of the site post excavation and the requirement to proceed to the next phase of enquiry. The scale and significance of findings in this phase is such that careful consideration is required before moving forward.

1.2 Aims and Objectives of the Excavation

This Test Excavation took place at the Request of the Mother and Baby Home Commission of Investigation, herein MBHCOI, under the Commissions of Investigation Act 2004, Sections 8, 26 and 28. On the 1st of September 2016 a warrant was issued by Judge Yvonne Murphy to the Director of the site in accordance with Section 26 of the Commission of Investigations Act 2004. This warrant Authorised Niamh McCullagh to exercise the powers given under section 28 of the Act in relation to premises known as the Children’s Burial Ground located in the Dublin Road Housing Estate, Tuam, Co. Galway, see **Appendix I**.

The MBHCOI identified four main lines of enquiry in relation to the ‘Children’s Burial Ground’ that required a physical examination of the subsurface at the site. The matters requiring investigation as outlined by the Commission were:

i. To establish if there are human remains at this location
ii. To establish the date range of the interment of these human remains.
iii. To establish if there are human remains contained within the structure of the reported ‘cesspit’.
iv. To provide a demographic profile of human remains which are recovered.

A controlled forensic excavation of a sample of the site, informed by the results of the enquiries to date, was deemed the most appropriate response at this juncture in their enquiries. The Test Excavation proposed to address these four main concerns while taking into account that any human skeletal remains uncovered at the site, whilst being of evidential value, must be treated with dignity and respect.

1.3 Test Excavation

As the Commission did not see a full excavation as necessary at this point, the investigative strategy that was utilised is what is termed a ‘test excavation’ approach. This approach has the minimum impact on the site while allowing relevant evidence to be recovered.

The four concerns of the Commission were to be addressed by conducting a test trench method of excavation. This ensured that the remaining section of the site was undisturbed and available for future investigations. The trench design proposed consisted of 2 trenches; anomalies established in the course of excavation on site required an adjustment as directed by the Commission to include a 3rd and 4th trench. The result was a total of 14% of the site area was subjected to investigation.

1.4 Forensic Archaeology

The site investigation required a full forensic control to be in place and to direct works on site; this is due to the modern nature of the site and the expected results. As a suitably qualified and experienced Forensic Archaeologist Niamh McCullagh, recognised as an Expert Witness, was appointed this task.

The timeframe under consideration was from 1925-1961, the duration of the operation of the Mother and Baby Home associated with this site. The modern nature of the site gave rise to the potential for it to become regarded as a crime scene. DNA may need to be secured and all evidence collected is required to be of a standard submissible in a criminal court of law, that is, to the evidential standard that is required by forensic cases.

Traditional archaeology focuses on a cultural interpretation of the past as opposed to events. Standards of evidence and interpretation are not subjected to the scrupulous standards required by a court of law. While methods used are similar the interpretations are not, neither are the forms of evidence gathered.

1.5 Archaeological Associations

Upon initial investigations this site was listed as a recorded monument thus affording it a level of protection under the National Monuments Acts 1930-2004. Upon following proper procedure and contacting the National Monuments Service to inform them of our proposed excavation the site was downgraded to a redundant record, see **Table 1.1,** due to the fact that the reported burial ground dates to the 20th Century. Due to the nature of the site and its association with the site of a former 19th century Union Workhouse a license eligible archaeologist was on site for the duration of works in line with best practice.

Table 1.1: Site Data

Site Data	
Identifying Site code	**MBHCOI_TM1016**
Date of commencement	Saturday 1st of October 2016
Date of termination of excavation	Friday 28th October 2016
Date of full withdrawal from site	Monday 5th December 2016
Townland	Farrannabox, Tuam, Co. Galway
National Grid Reference	544557, 751176
Elevation OD	42m
SMR Number	GA043-141----, classified as a redundant record as of 10 August 2016
Description “This record was created on foot of a report of a children’s burial ground at this location. Further research has indicated that the burial ground dates to the 20th century and, as such, it does not come within the remit of the classification for this class used by Archaeological Survey of Ireland.” (Archaeology.ie)	

Site Location Map from the Archaeological Survey of Ireland
source: archaeology.ie © Ordnance Survey Ireland

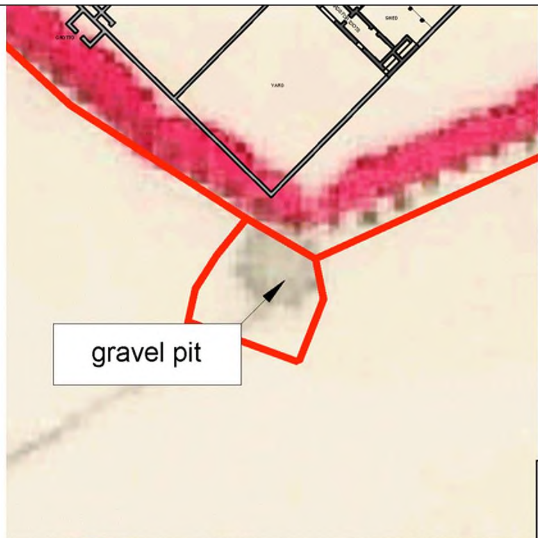
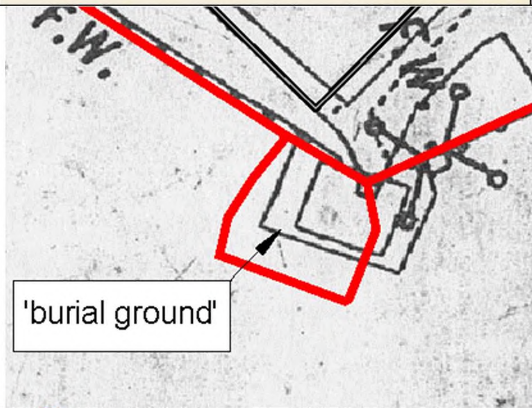
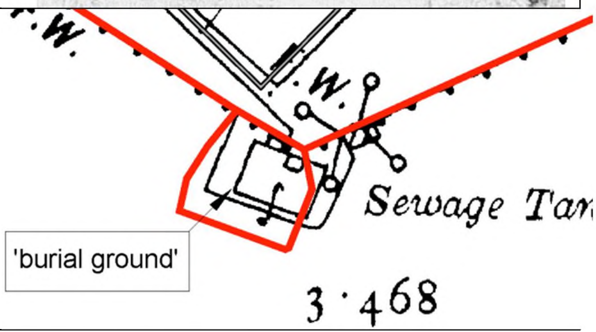
1.6 Mapping and Aerial Photography of the Site

The site under investigation is currently located within the grounds of a Galway County Council residential housing estate to the south east of the town of Tuam, Co. Galway.
This housing estate is known as the 'Dublin Road Housing Estate' and lies within the townland of Toberjarlath and Farrannabox. The site is to the south east of an open plan public space within the housing estate to the rear of the properties.

The Dublin Road Housing Estate was constructed in a number of phases between 1973 an 1979. The housing estate was constructed at this location following the demolition of what was originally built as a Union Workhouse and later was to the become the Mother and Baby Home that occupied this site. A desktop review was conducted of the mapping and photography available of this location to structural developments at this site and their potential impact on the site of the 'Children's Burial Ground'.

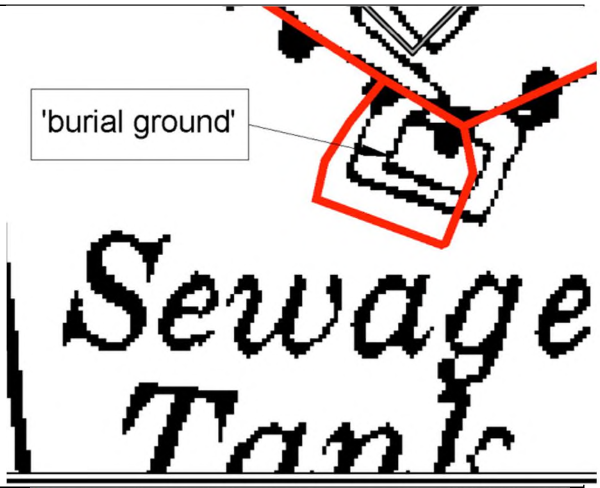
An examination of Galway Co. Council records relating to the building of the housing estate was also conducted and the results of both are presented here in **Table 1.2**. It is acknowledged here that full archival research into the records relating to the site of the former Union Workhouse/Mother and Baby Home such as those in the Tuam Herald Archive would be highly advisable in order to fill in dating issues for structures encountered on site.

Table 1.2: Desktop review of mapping and aerial photography

A Detail of historic 6” Map dated 1838, the area of interest is identified as a gravel pit.	
B Detail of historic 25” Map dated 1892 by Ordnance Survey Ireland; the area of interest takes its current form but is not labelled.	
C Detail of 25” Map dated 1927 by Ordnance Survey Ireland; the area of interest is first labelled ‘Sewage Tank’.	

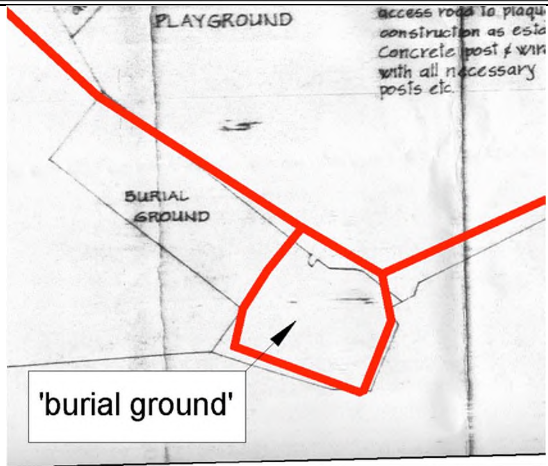
D

Detail of 6” map dated c. 1900 revised 1930s-1940s, the form of the area of interest remains the same as does the identity as a ‘Sewage Tank’



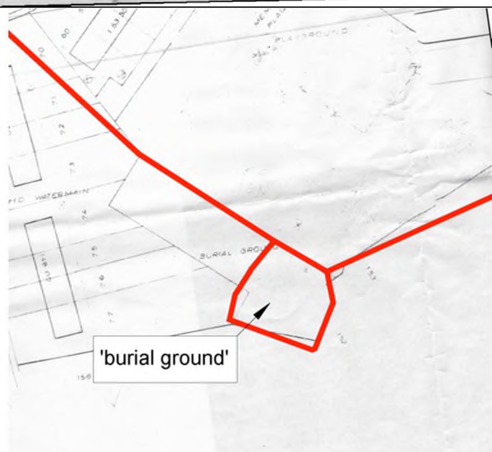
E

Detail from Galway Co. Council map of Plans for Dublin Road Housing Estate, dated 197? (pre 1975). Note identification of ‘Burial Ground’ on plan.



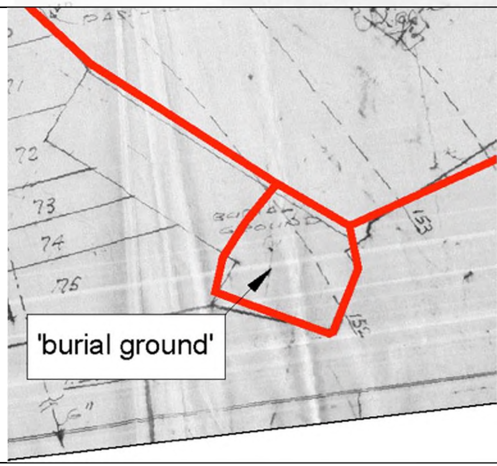
F

Detail from Galway Co. Council map of Plans for Dublin Road Housing Estate dated 1975. Note identification of ‘Burial Ground’ on plan.



G

Detail from Galway Co. Council map of Plans for Dublin Road Housing Estate, circa 1978. Note identification of ‘Burial Ground’ on plan.



H

Detail from Galway Co. Council map of Plans for Dublin Road Housing Estate, February 1979. Note identification of 'Burial Ground' is absent

I

Detail of Aerial Photograph from Ordnance Survey Ireland flown 14th April 1974

J

Detail of Aerial Photograph from Irish Military Archives flown 27th October 1977

K  Detail of most recent Aerial Photograph from Ordnance Survey Ireland

1.6 Mapping

Mapping was sourced from Ordnance Survey Ireland and from the Galway Co. Council Archive for the Dublin Road Housing Estate, see **Table 1.2 A-K**. The site is located directly on the townland boundary between Toberjarlath and Farrannabox. Though it later is clearly associated with the Union Workhouse of Toberjarlath, it lies in the adjacent townland, Farrannabox.

The site of what is presently referred to as the 'Children's Burial Ground' first appears on the 6" historic mapping dated 1838 as a gravel pit, **Table 1.2, A**. In the 25" historic map dated 1892, when the workhouse is in situ, the site has become more defined, **Table 1.2, B**. There is clearly an outer boundary wall around a square structure. This remains the general overview that continues throughout the map series. The 25" 1927 edition, **Table 1.2, C,** now labels this location as a 'Sewage Tank'. The site of the Workhouse is now labelled in this edition as a 'Children's Home'. The 6" mapping dated 1900 but revised in the 1930s and 1940s retains the description of the site as a "Sewage Tank", **Table 1.2, D**.

Copies of maps acquired from the Galway Co. Council Housing Archive (**Table 1.2, E-H**) are the first to illustrate this location as a 'Burial Ground'. Three different editions of planning maps for the Dublin Road Housing Estate from the 1970s record this location and an additional expanse to the west as 'Burial Ground'. This additional area is significant as it presently is offered no recognition for its potential status. The fourth and final plan dated 'Feb '79' with the housing estate complete sees the label of 'Burial Ground' having been removed or not included, **Table 1.2, H**.

1.7 Aerial Photography

Aerial Photography dated 14th April 1974 illustrates the Workhouse/Mother and Baby Home mid demolition, **Table 1.2, I**, site works are taking place to the north however the structure and the burial ground to the south remain untouched and appear quite overgrown. At this point phase 1 and 2 of the Galway Co. Council housing scheme is evident.

The Irish Military Archive contained images of the site that were flown on the 27th of October 1977, **Table 1.2, J**. In this image it can be seen that former Workhouse/Mother and Baby Home has been completely demolished. It is reported on the 21st of January 1976 as having been completely demolished, **Appendix III Plate 1.1**. The area of interest to this investigation has been retained during the building of the housing estate and mirrors that on the Galway Co. Council plans for the housing estate. It remains overgrown and undisturbed during building works.

The most recent image of the site illustrates that though they are unmarked the boundaries of what is now referred to as the 'Children's Burial Ground' and the open area to the west remain unchanged to the present day though the surface has clearly been altered, **Table 1.2, K**. Documentary evidence from Galway Co. Council reports that in 1981 topsoil was introduced to the location and placed over the burial ground and also what is now the playground, **Appendix III Plate 1.2**.

1.8 Methodology for Phase II

The investigative strategy utilised for this investigation was the 'Test Excavation' approach as previously outlined. The trench design proposed was altered through the course of the works on site resulting in a total of 14% of the total site area being subjected to investigation. The initial location and size of the trenches selected for excavation were informed by the results of the desktop review and a Geophysical Survey of the site conducted in October 2015.

The geophysical survey illustrated, through the use of ground penetrating radar and magnetometry, the presence of a boundary wall traversing the northern part of the site. This survey also indicated the probable edges of a cesspit and potentially pipes leading to the cesspit from the north (i.e. the location of the former Workhouse/Mother and Baby Home), note the darker areas highlighted in **Figure 1.1**. The main trench (Trench 1) transecting the site was designed to cover the maximum area of the strongest of the linear anomalies detected in the survey. The width of the trench would be 1m in width up to 3m from each wall and would widen to 2m across the central 11m of the cutting, for safety reasons, **Appendix III Plate 1.3**.

A second trench (Trench 2) was opened over what appeared to be a 'corner' identified in the geophysical survey, the corner of the former cesspit. The investigation of this smaller trench was inserted as the quality control and as a validation of the excavation strategy, providing additional weight of evidence.

Early findings from Trench 1 identified a structure of significant size to contain quantities of juvenile human remains. This structure, in line with archaeological convention, became known as Feature 1 and will be referred to as such throughout this report. The unusual size and situation of this feature made remains inaccessible however it was determined the full extent of the structure had to be established within this phase of investigation. Based on these initial results the Commission requested alterations to the investigation strategy.

Due to the significance of Feature 1 it was decided that additional trenches would be opened to the east and west. These would be more informative, for Commission purposes, than completing the northern extent of Trench 1. Additional trenches, T3 and T4 were opened to the east and west in order to establish the extent of the main feature, **Table 1.3 and Appendix IV Figure 1.2**.

Table 1.3: Dimensions of Excavated Trenches

Trench 1	13.4m x 1m x 2m
Trench 2	2.4m x 2m
Trench 3	2.85m x 1.1m
Trench 4	3.1m x 3m

Excavation methodology took place as per the proposal dated 10th August 2016. The trenches were initially opened using a track machine (3 Tonne). This is fitted with a grading bucket to remove the relevant sections of sod over concrete capping. This removal of overburden was monitored by archaeological personnel. Once significant strata were encountered all mechanised excavation ceased and excavation proceeded manually.

In adherence with best practice, manual archaeological excavation conformed to the Museum of London Archaeological Standards (MoLAS) and the codes of practice of the Institute of Archaeologists of Ireland (IAI). This necessitates single context archaeological recording, through written description, scaled photographs and surveyed drawings. The written descriptions of soils, scaled photography and scales section and plan drawings (at 1:10 and 1:20) were archived by register on site – a practice referred to as preservation by record. Significant features were further recorded through the use of rendered photogrammetry. A detailed record of the archaeological site work undertaken has been retained and the site archive is available on request.

Forensic Archaeological standards were maintained in accordance with the 'Standards and Guidance for Forensic Archaeologists' (Powers and Sibun, 2011), prepared for the Chartered Institute for Archaeologists, UK and the Handbook of Forensic Anthropology and Archaeology (World Archaeological Congress Research, 2011), Blau, S. & Ubelaker, D. (eds). Please see technical note in **Appendix II** for further details.

This excavation had the high potential to reveal human skeletal remains hence all work ensured that any such remains were treated with the utmost dignity and respect while maintaining forensic protocol. Due to the circumstance in which remains were found accessibility was a key issue thus remains were left in situ where possible. Samples were taken for radiocarbon analysis and remains excavated that were at risk have subsequently been deposited with the Office of the State Pathologist at the direction of Galway County Coroner Dr Val Costello.

A number of measures were put in place to protect the integrity of the site and retain respect and dignity for such a sensitive project. The site was surrounded by plywood hoarding to inhibit line of sight and security of the location and staff was maintained throughout the excavation by the 24/7 presence of An Garda Síochána. Once excavation was underway sensitive areas of the site were covered by a commercial marquee acting as a scene tent to protect sensitive evidence, to prevent overlooking and keep open trenches safe, **Appendix III Plate 1.4.**

2. Results

2.1 Stratigraphic Evidence

Aidan HARTE

The following describes the stratigraphy found and the features identified within each trench. Traditionally, archaeological stratigraphy is detailed from the earliest deposits to the latest, within a given cutting. The context numbers attributed to each deposit, layer and masonry wall are illustrated in a stratigraphic matrix, **Appendix IV Figure 2.1**. The full context register is available in **Appendix V**.

The following are the results of archaeological testing within each of the trenches and is described below with numbered features and contexts reflecting the order in which they would have occurred in the development of the site.

Trench 1

Trench 1 was orientated northeast – southwest. It was 13.37m in overall length, **Appendix IV Figure 2.2** The trench measured 2m in width except for the southernmost 3m, which was limited to 1m in width due to the high boundary wall at this end. Trench 1 reached a total depth of 2.7m below present ground level. (For ease of description, northeast is considered as north in the text below).

At the northern end of the trench, a stone-built culvert or drain (C.20) was found, **Appendix III Plates 2.1, 2.2**. This entered the trench from a north-easterly direction, beneath a disused boundary wall (C.19). It was discovered at its southern end, where internally the space measured 0.45m in width and 0.45m in height, **Appendix IV Figure 2.3**. Each side wall comprised of up to four courses of limestone blocks (max. 0.3m x 0.2m x 0.1m) bonded with lime mortar. Smaller stones were used on the top of these side walls to support a single large flat lintel stone. The culvert (C.20) could be seen to extend north-eastwards for over 5m in length and appeared to have been contemporaneous with the large tank to the south

(Feature 2/C.8, discussed below), **Appendix III Plate 2.3.** However, the southern end of the culvert had been altered at a later stage, see below and **Appendix III Plate 2.4.**

A wall foundation (C.19) traversed the trench at the northern end, **Appendix IV Figure 2.2**. Orientated east-west, a length of 1.88m of this was exposed. The wall foundation consisted of roughly hewn limestone blocks, squared to courses and bonded with lime mortar. Up to three courses were visible, giving a maximum height of 0.29m, **Appendix IV Figure 2.4.** The stone used was up to 0.45m x 0.2m x 0.15m in size and formed two separate sections of wall, up to 0.6m in width, divided by a saddle-stone at the centre. This saddle-stone (0.79m x 0.29m x 0.09m in size) represented an entrance-way, below which the culvert (C.20) ran. The saddle-stone had been smoothed/worn by use and a 'spud'-mark was visible on the western upper face – this would have held the pivot of a gate, **Appendix III Plate 2.5**. It is noteworthy that the location of this boundary wall and entrance complement the positioning of the culvert beneath. While no clear stratigraphic relationship was evident, it is most likely the boundary wall and culvert were contemporaneous with one another.

A large masonry built tank occupied much of the central portion of the trench (C.8), referred to as Feature 2. This is likely contemporaneous with the culvert (and boundary wall C.19) found to the north, **Appendix IV Figures 2.2 and 2.4**. Only the western wall of this rectangular tank structure was not exposed within the trench. Internally, the tank measured 2.5m north-south x 1.22m and 2.28m in height at north. There were multiple material types used in the construction which were suggestive of two phases of work. All walls of the tank used large limestone blocks (0.42m x 0.25m x 0.2m), which were squared to courses with some use of quoins. These were bonded with mortar. The north wall of the tank extended east, past the eastern wall of the tank, beyond the limit of the trench. This was the highest wall, built entirely of limestone and was slightly thicker than those that connected to it (0.46m in thickness). Two ceramic sewage pipes had been inserted 0.48m from the base on the south face (within the tank structure) and these were related to the pipes seen in the culvert to north (C.20).

The east, west and south walls of the tank (C.8) were all quite similar, **Appendix III Plate 2.6**. Each was approximately 2.1m in height, 0.44m in width and built using stone, concrete and occasionally brick. Each of these walls had a large opening within each face that had been lintelled using shuttered concrete, 0.32m in thickness, **Appendix IV Figures 2.4 and 2.5.** The concrete lintel fixed an iron grille that extended to the floor of the tank where it was again fixed in concrete. The openings measured 1.52m in height, 1.5m in width at the west and east walls and 0.9m in width at the south wall. These openings provided grated gaps through which liquids might flow, the floor being smooth, flat concrete. The system was therefore logically, to take water from the culverts/pipes, through the north wall and distribute that water in 3 directions, holding back any material of a significant size. This was the function of the tank.

Notably however, the western and eastern walls of the tank structure did not tie with the masonry of the northern wall. This, together with the difference of materials and dimensions, suggest that the western, eastern and southern walls were added in a later phase. Similarly, the two pipes that flow into the tank from the northern wall are associated with alterations to the culvert (C.20), **Appendix III Plate 2.9**. The eastern pipe could be seen to bend upwards from the tank, while the western pipe turned to the west. Therefore the eastern pipe is that which joins the culvert, a drop down of approximately 1m, **Appendix III Plates 2.8 and 2.9**. The western pipe may also join to a culvert to the northwest beyond the scope of this investigation. It is probable that the northern wall of this tank (C.8), formerly acted as the north wall of a much larger cesspit that was fed by multiple culverts.

Soft dark brown coarse sandy silt (C.16) was found to line the base of the tank (C.8). This was up to 0.35m in thickness and spread into the openings of the grilles. This accumulated deposit represented the last use of the tank and the second phase of the cesspit as a whole.

A large deposit of friable angular and sub-angular stones (C.9) of all sizes (up to 0.4m x 0.35m x 0.2m) was then used to fill the tank, almost to the upper edges. This material had frequent inclusions of metal, glass, ceramics and occasionally plastics and animal bone. The entire deposit had silted up over time and measured 1.72m in thickness. This material was comparable to a rubble deposit outside of the tank (but south of the north wall of C.8) that tapered southwards (C.6). The latter was again unsorted large stone in a matrix of grey sandy silt, with a multitude of inclusions, **Appendix IV Figure 2.2**. It spanned a north-south length of 5.85m and was at least 1.4m in thickness (it was visible through the grilles on each side from the inside of the tank C.8). Where this material was found at the south it diminished considerably before stopping short of Feature 1/C.5.

A small area to the north of Feature 1 (C.5) was cleared to the base. This found the natural subsoil at the base of the original cesspit, 2.68m below ground level, and consisted of compact light grey gravel, over mottled yellow natural clay. Here on the western side of the trench, a feature was identified, **Appendix IV Figures 2.2. and 2.6**. Orientated north-south, it comprised two blocks on the eastern side (each 0.21m x 0.21m x 0.08), separated by 0.04m, with a footing for a third block further south again (C.36). The eastern side of this feature was not entirely exposed but consisted of two red bricks (max. height 0.14m). The space between was a cement concave channel, 0.23m in width, 0.56m in length (C.36). From the limited insight into this feature, it can been interpreted as a defined drainage channel, walled with spaced bricks to act as filtration. This likely directed liquids to the south. Where the bricks and blocks are missing at the southern side, it is to facilitate the construction of Feature 1/C.5, **Appendix III Plate 2.10 and 2.11**.

Feature 1 was identified quite early in the investigation and represents yet further tanks (C.5). In Trench 1, this has been constructed on top of the features at the base of the original cesspit, **Appendix IV Figures 2.4 and 2.6.** It was exposed at a point in the trench that was just 1m in width but expanded to 2m, **Appendix IV Figure 2.2.** The north-south extent of the feature was 1.62m, and the full height was measured at the north-face as 2.2m. The walls, both internally and externally, have been shuttered with concrete, possibly encasing the stonework. The extent of the masonry is not clear due to the masking of the shuttering but it certainly exists as a stone wall at the base of the north-face. Wall thickness can be estimated to be 0.15m. At the top, a homogeneous concrete lid capped the walls and continued beyond the limit of the trench to the west and east. This was 0.13m-0.15m in thickness. Timber form-work had been used to create two rectangular openings in this top lid, orientated north-south and 0. 32m apart.

The eastern opening had half of an original cover remaining (this was a pre-cast concrete slab 0.36m in width and 0.05m in thickness). The other covers on this side were two pieces of rough concrete. This opening measured 0.86m x 0.29m and accessed Tank A, **Appendix III Plate 2.12**. Internally, Tank A measured 1.3m north-south x 0.6m and was 1.98m from the opening to the deposits within (C.10 and C.12). A central wall divided the interior into east (C.10) and west (C.12), and this was just 0.57m above the deposits at either side, **Appendix IV Figure 2.7**. Both deposits appeared to consist of dark brown silt (C.10 and C.12). The western opening had a complete original pre-cast concrete cover, 0.92m x 0.36m x 0.05m covering an opening 0.83m x 0.28m. This accessed Tank B, which was larger, measuring 1.37m north-south x 0.86m in width, and was 1.92m from the opening to the deposit within it (C.11). This deposit was a brown silt with much debris, **Appendix IV Figure 2.8**. The examination of the deposits within these tanks was limited by the lack of light and restricted access through the openings. They both contain inclusions of human remains, timber and an assortment of debris.

While no connections (i.e. pipes, conduits etc.) were seen between these tanks, internally the base of the north walls in each tank seemed to suggest voids opening in that direction. These could be seen with greater clarity externally, at the base of the north wall, **Appendix IV Figure 2.6**. A breech on the eastern side of the north wall, at the base, measured 0.28m in height and 0.2m in width, **Appendix III Plate 2.11**. This corresponded to Tank A and was filled with stone and debris. Just 0.2m further west along the base of the wall, a second void, 0.32m high and 0.3m wide, was similarly filled with stone and debris. A further breach was indicated at the western limit of the exposed north wall of Feature 1. These latter two voids related to Tank B. These 'voids' occur 1.9m from the top of Feature 1, a depth that correlates to the deposits within the tanks (C.10, C.11 and C.12).

The basal deposit to the north of Feature 1/C.5 was soft, dark grey, coarse sandy silty clay with frequent fine angular pebbles (C.18), **Appendix IV Figure 2.4**. This deposit also contained occasional flecks of mortar/concrete and was on average 0.35m in thickness (max. 0.44m). This material could not have been deposited in this position prior to the construction of C.5 and likely represents the subsequent saturation by either the water-table or the waste-water from within the tanks (Feature 1).

What is clear is that this fluvial action caused the erosion of the concrete shuttering, and perhaps the fabric of the north wall, of the adjacent tanks. Notably, no human remains were recovered from this deposit and it also appeared to be beneath the rubble back-fill C.6, suggesting that the silty clay element potentially derived from the functioning of Feature 2. However, the rubble C.6 and other layers (C.7, C.13 and C.17) have subsided into this area proving an explanation as to the unusual stratigraphy abutting Feature 1.

In support of the hypothesis that the backfill layers had subsided into position was a layer of firm mottled orangish brown clayey silt (C.17). This overlay the rubble C.6 and was only 0.02m in thickness. It contained sand, charcoal and only occasional angular stones, indicative of wash-out from the layer to the north. Over this, a thick layer of dark yellowish brown, coarse sand with bands of grey/brown silt had been deposited (C.13). This layer contained much angular stone but also cinders, charcoal and ash. Up to 0.6m in thickness, it filled the area between Feature 1 (C.5) and Feature 2 (C.8) and was likely set down as a series of dumps of hearth waste, between which water had pooled (i.e. the silt lenses within), **Appendix IV Figure 2.4**. At the same time that this domestic waste layer was forming, a deposit of very soft dark grey clayey silt formed (C.14) abutting the north wall of Feature 1. This was approximately 0.4m in thickness and had poorly defined horizons with surrounding layers, as it had clearly formed as a result of fluctuations in the local water-table. It included sandy elements and a quantity of disarticulated human remains, **Appendix III Plate 2.13**. The composition of the deposit was very similar to that of the underlying layer (C.18) and it likely derived from here and the voids in the north wall of Feature 1. The sandy layer C.13 covered over the latter deposit. Another disposal layer was identified over the sandy layer C.13. This was blackish grey sandy silt with frequent inclusions of angular pebbles (C.7). A variety of material was found throughout the layer, including modern glass, metal, butchered animal bone and even a fragment of 19th-century clay pipe, indicating that it had been material likely accumulated over a significant duration or redeposited from elsewhere.

The whole phase associated with the backfill of Feature 2 and the area to the south of it was sealed by firm brownish yellow clay (C.4). This spanned a north-south extent of 6.75m and was on average 0.18m in thickness. This was a redeposited natural subsoil and must have been used to denote the disuse of Feature 2. It also subsided into the depression adjacent to Feature 1 and the remaining depression here was filled with a mixed deposit of soft greyish black silt (C.3). The latter may have accumulated over time and contained lenses of redeposited natural subsoil and inclusions of charcoal metal and other debris. Therefore, this final backfill is a mix of other layers (i.e. C.4 and C.7).

At the northern end, at the area between the culvert (C.20) and the north wall of Feature 2 (C.8) a backfill was identified and consisted of dark brownish grey stony silt (C.15). The cut had originally been made to replace the culvert from this point with ceramic sewage pipe connecting to Feature 2. This had been backfilled and where the join with the culvert had been made it was covered with a metal plate and a large boulder (the metal plate was similar to that used in C.27 – see below), **Appendix III Plate 2.4**.

The entire trench was sealed by a layer of firm dark grey sandy silt, between 0.2m – 0.35m in thickness (C.2). This was a disused topsoil layer containing inclusions of metal and plastic construction debris. It was ultimately covered with dark brown silt loam that forms the current topsoil layer (C.1).

Trench 2

Trench 2 was situated at the eastern part of the site and measured 2.4m x 2m, aligned northeast-southwest (for the purposes of description northeast is considered as north). The objective of the positioning of the trench was to locate and assess the nature of an anomaly identified in the geophysical survey. This was a masonry wall and the excavated trench depth was 1.08m below ground level, **Appendix III Plate 2.14 and Appendix IV Figure 2.9.**

The masonry wall ran beneath the northern and eastern trench edges (C.21). The uppermost part of this masonry was 0.37m below the current ground level and a maximum height of 0.45m of the wall was exposed, **Appendix IV Figure 2.10, Appendix III Plate 2.15.** It was constructed of roughly hewn limestone blocks, up to 0.43m x 0.2m x0.1m in size, and while only the south and west faces were visible within the trench, at least 2 uneven courses remained. Both sections of wall were bonded with mortar and no concrete or brick was evident. This was clearly not a wall foundation and continued below the fill within the trench. The east-west section at the north side of the trench aligned with the north wall of Feature 2 in Trench 1 (C.8), while the north-south section of wall was aligned with a poorly preserved wall in Trench 3 (C.28).

The lowest layer was a fill deposit of stone rubble in a matrix of dark brown clayey silt (C.22). A thickness of 0.46m of this material was excavated and found it to contain fragments of glass, butchered bone and degraded metal fragments. This material correlates to the rubble backfill found in Trench 1 (C.6 and C.9). Both the rubble deposit and the masonry wall were covered by a layer of greyish brown sandy silt, 0.18m in thickness (C.23). This layer corresponds to the grey layer in other trenches (C.2, C.26 and C.33). Finally, the current topsoil layer was found to comprise brown loam (C.24).

Trench 3

This trench was inserted at the southern corner of the site to assess the potential extent of Feature 1 (as found in Trench 1). The trench was orientated northeast – southwest and measured 2.85m x 1.1m (as with other trenches, northeast is treated as north here for the purpose of description). The discrete scale of this trench was largely due to the quality of the geophysical survey results in this part of the site.

Within this confined cutting, the stratigraphically earliest feature recorded was a short section of masonry at the northeast corner of the trench (C.28). A total length of 0.35m was exposed and only the western face was visible to two courses within the trench, **Appendix IV Figure 2.9**. The wall, although damaged was constructed of limestone blocks, up to 0.27m x 0.25m x 0.1m in size, set in lime mortar. This clearly correlated with the north-south section of wall C.21 seen in Trench 2.

The eastern end of Feature 1 was found centrally, where the concrete lid of the feature extended from the western side of the trench, **Appendix III Plate 2.16**. The extent exposed measured 1.58m north-south by 0.85m (C.29). Only a portion of the northern external wall was exposed and this was shuttered with concrete, again possibly encasing the stonework (as in Trench 1).

At the top of Feature 1, a homogeneous concrete lid capped the walls of the tank below but clearly did not continue further east, **Appendix IV Figure 2.9.** Timber form-work had been used to create a rectangular opening in this top lid, orientated north-south. This opening had a complete original pre-cast concrete cover, 0.94m x 0.37m x 0.06m covering an opening 0.85m x 0.28m, **Appendix III Plate 2.17**. The thickness of the top lid was 0.12m. Internally, the tank measured 1.25m north-south x 0.64m and was 1.93m from the opening to the top of the deposit within, The deposit appeared to consist of dark brown silt, stones, metal debris, timber and an amount of human remains, **Appendix IV Figure 2.11.**

A further notable aspect of this tank was that internally, the east and south walls were not shuttered with concrete. The fabric of the masonry visible on these sides is of mortared limestone blocks, which, together with the orientation of the walls, links them to the external and earlier wall C.28 (and by association C.21 and C.8 north wall), **Appendix III Plate 2.18**. A black stain was seen to denote a 'tide-mark' only on these un-shuttered walls, 0.83m below the top of the tank, **Appendix III Plate 2.19**.

Internally, at the base of the north wall of the tank (1.6m from the top), a square opening was evident. Examined at a distance, this was also shuttered in concrete and approximately 0.25m square. This opening extended through the wall to north where it had been closed using a metal cover, since displaced, similar to that which had closed the opening above the culvert in Trench 1 (C.15/C.20). These features – the tank (C.29) and the external masonry (C.28) had been covered by greyish brown sandy silt (C.26). This was only 0.08m in thickness in places but equates to the grey layer seen elsewhere that served as a surface until more recently. As before the current topsoil was brown loam up to 0.55m in thickness (C.25).

Trench 4

This trench was inserted at the south western part of the site to assess the potential extent of Feature 1. At this location the geophysical survey had had limited results and the trench was therefore excavated from west to east. Similarly aligned with other trenches, Trench 4 measured 3.1m northwest – southeast x 3m and was excavated to a depth of 1m, **Appendix IV Figure 2.12.**

Along the western edge of the trench were the remnants of a masonry wall orientated roughly north - south (C.30). This used a mix of roughly hewn limestone blocks and sub-rounded pebbles set in lime mortar. Only the eastern face of the wall was within the trench and only a single course was exposed. This measured just 0.17m in height and an exposed length of 2.5m. It likely represented a footing or 'robbed-out' foundation for a boundary wall as it appeared to be parallel to the existing boundary wall. The central part of the trench was devoid of archaeological features, **Appendix III Plates 2.20 and 2.21.**

In the eastern half of the trench, the upper course of a north-south wall was identified extending from the north for a length of 1.83m and was 0.34m in width (C.31). This was constructed of limestone flags, up to 0.25m x 0.2m x 0.06m in size, set in lime mortar. West of this wall, running alongside, was a soft greyish brown deposit of stone and pebbles in a matrix of silt (C.32). This measured 2.66m in length and varied between 0.24m – 0.28m in width and represented the backfill of the construction trench associated with wall C.31. A sandy deposit was noted at the southeast corner but was not excavated.

Feature 1 was identified as extending from the eastern trench edge. The extent of the tank that was exposed measured 1.64m north-south by 0.94m (C.35). None of the external faces of the walls of this tank were exposed. At the top, a homogeneous concrete lid capped the walls of the tank below but clearly did not continue any further west than C.31. Timber formwork had been used to create a rectangular opening in this top lid, orientated north-south, which had been covered with four broken slabs and a corrugated iron sheet. The westernmost opening was examined and was found to measure 1.12m x 0.28m, the top lid was 0.1m in thickness at this point. Internally, the tank measured approximately 1.45m north-south x 0.45m and was 1.8m from the opening to the top of the deposit within, **Appendix IV Figure 2.13.**

The deposit appeared to consist of dark brown silt, stones, metal debris, timber and occasional bone. Internally, the west and south walls were not shuttered with concrete, similar to the walls seen in trench 3. The masonry visible on these sides was of mortared limestone blocks, to 12 courses that, together with the orientation of the walls, links them to the external and earlier wall C.31 (and by association C.28, C.21 and C.8 north wall). A black stain was again seen to denote a ‘tide-mark’ on these un-shuttered walls, 0.83m below the top of the tank. No voids or other conduits were seen on any part of the walls.

The entire trench was covered with firm brownish grey sandy clay (C.33), up to 0.67m in thickness. This represented the disused topsoil and contained occasional flecks of charcoal, mortar and other debris. This in turn was covered by the present topsoil layer – a dark brown silt up to 0.35m in thickness (C.34).

2.2 Discussion of Site Stratigraphy and Phasing

The archaeological test excavation identified a number of elements that correlate with the results of the previous geophysical survey. The layout of what is now referred to as the ‘Children’s Burial Ground‘has changed multiple times but the physical boundaries of the site have remained largely unchanged.

The earliest feature is that of gravel pit shown on the 1838 1st edition six-inch Ordnance Survey map, **Table 1.2, A**. There was no evidence to definitively indicate this phase but the lowest natural gravels found beneath C.5 and C.36 may possibly represent this. The second phase consisted of a large rectangular cesspit. This is indicated on the 1892 1st edition 25” Ordnance Survey, showing that it was contemporaneous with, and built for, the adjacent Union Workhouse, **Table 1.2, B**. This cesspit was represented by the north wall of Feature 2 (C.8 as identified during the excavation), the walls in Trench 2, the south and east walls of Feature 1 in Trench 3, as well as the south and west walls of Feature 1 in Trench 4. This corresponds well with the results of the geophysical survey, delineating a rectangular stone-built tank, 12m by 8.2m in extent (in imperial measurement this equates to 13 yards by 9 yards, or 39 ft. by 27ft.). The depth of the cesspit would have been approximately the same as the base of C.8, i.e. 2.28m (7’6”) below current ground level. This was fed by two culverts from the north. The connection between the culvert and the north wall of the cesspit had been altered subsequent to this phase.

The third phase of activity at the site saw the alternation of the cesspit with the construction of Feature 2. This rectangular masonry structure was built to form a manhole-type filtration system within the earlier cesspit structure. This rectangular structure measured 2.5m by 1.22m (8’ 2.5” by 4’) with large open grilles to the west, south and east. The two pipes in the north wall conveyed materials from the culverts at north. A second rectangular area marked on the 25” 1927 Ordnance Survey map, **Table 1.2, C**., outside of the main cesspit and displaced to the north, was yet another of these filtration tanks – the function of which may have been to slow effluent waste even further, before it could flow through to Feature 2. The function of Feature 2 then must have been used to retain any sizable material, permitting the old cesspit to function as the final filtration/percolation tank. While not a septic tank in the modern sense, it does seem to have compartmentalised the waste-water within different tanks, the final tank, and largest, being that of the earlier cesspit.

In the fourth phase, the old cesspit and Feature 2 were infilled with rubble. It seems that the culverts at the north would still have been operational to collect surface water from the grounds of the Children’s Home and direct that storm water to the now in-filled disused septic tank. This ground water would have percolated through the rubble fill but the fill itself would not have been an appropriate means of managing sewage. Simultaneously, or rationally very shortly before, the long concrete capped Feature 1 was constructed along the southern edge of the old cesspit. Where investigated, this feature utilised the old southern wall of the cesspit and the east and west walls to form the ends. It is 11.8m in length and 1.6m in width. Four chambers or tanks were examined but it is not possible to determine if these connected with adjoining tanks. The easternmost tank did have an inlet/outlet opening at the base of the north wall but this was purposefully blocked. The voids seen at the base of the north wall in the centre (i.e. Trench 1) were likely formed by the rupture of the masonry due to water pressure, **Appendix III Plate 2.11**. There was also no visible inlet pipe at the eastern end. Feature 1 was therefore not a septic tank, as the effluent could not have filtered from one tank to the next. These tanks are not easily accessible in order to clear the accumulation of any waste and may have been seen as a short-term measure of waste management.

The dates of these phases can be summarised as follows. Phase one would have ended at the commencement of the Union Workhouse, circa. 1847. Phase two therefore runs until there are clear problems with the cesspit and a new system is put in place, circa. 1880-1900. This unusual septic tank system remains in use until such time as the shuttered concrete Feature 1 becomes necessary, approximately from 1910s-1930s. The fourth and final phase of waste management must relate to the expansion of the town's sewage system in the 1930s. Arguably, a new series of septic tanks were under construction when the public sewage system was also being developed. This would account for the unusual layout of the tanks of Feature 1. Phase four, as a sewage system, therefore potentially extends from the 1930s until such time as the Children's Home was connected to the mains sewage system.

3. Human Remains Evidence

The most significant result of this test excavation was the location of juvenile human remains both inside and outside of Feature 1. Remains lie at depths of c. 2.5m below current ground level. Due to the size of the feature they are contained within and the nature of their location, it was impossible to fully excavate the deposits safely and without causing significant damage and destroying extremely fragile and friable juvenile remains and essential evidence. At the time of writing they remain in situ.

Remains within Feature 1 were identified visually and confirmed by Dr Linda Lynch, Human Osteoarchaeologist. Biased, or non-random, samples of these remains were recovered in order to send for radiocarbon dating. Remains outside Feature 1, directly abutting the north wall were excavated and recovered by hand, their location represents leaching or fluvial action through the compromised base of the tank. These remains were less biased but more damaged in condition due to their post mortem context; excavated from soil in comparison to being recovered from the sealed tank represented by Feature 1.

3.1 Human Remains Evidence and Analysis

Dr Linda G. LYNCH

Human remains were specifically recovered in association with a concrete capped feature, measuring 11.8m in length, 1.6m in width, and approximately 2.2m in depth, and orientated approximately northwest/southeast, located along the southern boundary of the site. This Feature 1, comprising a series of internal tanks or chambers, was built into the southern side of the original cesspit associated with the workhouse, which occupied the site. Four of the tanks were examined: two in Trench 1, and one each in Trench 3 and 4. At present, the exact number of tanks is unknown. The tanks were accessed via narrow openings at the top, which were each sealed with a simple concrete lid. In some cases the original lids had cracked/split and were replaced with cruder concrete sections. During the current phase of investigation, the examination of the four tanks comprised opening the lids and making a record of the interior from outside the tanks. None of the tanks was physically entered due to their size. Human skeletal remains were identified in each of the four internal tanks, while human remains were also recovered immediately to the north of Feature 1 in Trench 1, outside of Feature 1, specifically in C.13 and C.14, associated with ruptured voids in the north wall of Feature 1. The eastern tank in Trench 1 was numbered as Feature 1A. It had an internal wall, orientated north/south, which divided the interior into east (C.10) and west (C.12). The wall was just 0.57m above the deposits at either side. The western tank in Trench 1 was numbered Feature 1B (C.11). The single tanks identified in Trench 3 and Trench 4 where recorded as Feature 1.

3.2 Methodology

No definitive *in situ* human skeletal remains were identified and the entire assemblage of bone comprises disarticulated bones. These are bones that have completely separated from whatever bone they may have originally adjoined. This typically occurs when, after burial/deposition, the remains of an individual are disturbed, for example through later burials in the case of a cemetery, inadvertently by redevelopment of a burial site, or by animal activity, or through context driven taphonomic changes. The analysis of disarticulated bones differs somewhat from the analysis of the intact skeleton of an individual. One of the primary aims of analysis is to establish the minimum number of individuals (MNI) represented by a sample of bones. The most simple method is by bone counts, for example, if there are five adult male left femora (thigh bones) identified in a sample then that sample represents at least five adult male individuals. This can be refined further by taking age at death and sex into account. Thus the aforementioned sample may also contain two right femora from female adults, and perhaps other skeletal elements of a juvenile, so that the MNI now rises to seven adults and a juvenile. This method was employed during the current analysis. In the case of the human remains recovered in the course of this test excavation, all were from juvenile individuals. The method used in the recovery of the bones is provided below in the relevant sections.

All of the human skeletal elements recovered during the excavation were given an exhibit number, **Table 3.1**, and records were also made of the location and context of the find.

Almost none of the bones were processed further on recovery: in a minor number of cases bone fragments were washed with water and a soft brush to aid the identification process. A full osteoarchaeological recording of each bone fragment was then undertaken on-site and a catalogue was compiled, see **Appendix VI** for full catalogue. Age determination of the various skeletal elements was undertaken using the recognised standards in *Juvenile Osteology* (Schaefer et al. 2009). It is not possible to accurately determine the sex of juvenile individuals through general morphological analysis. Measurements (all in mm) were taken using a Powerfix® electronic digital calipers on complete bones following the recommendations in the aforementioned publication (ibid). In the catalogue, measurements of incomplete long bones are described as 'current length'. Otherwise 'L' denotes length of complete bone, 'D' denotes midshaft diameter, while 'W' denotes the width of the distal metaphysis of the humerus or the femur. In some case, particularly the scapula (shoulder blade) and maxilla (upper jaw), measurements are numbered: these numbers correspond to specific measurements listed in *Juvenile Osteology* (ibid.). Each fragment of bone was also weighed (g) using a Kenex® Notebook NB-2000, which weighs in 0.1g increments. Some fragments however were so slight that they did not register on the scale and so were recorded as the minimum weight of 0.1g. The total weight of bone recovered was 163g, and the heaviest bone fragment recovered was a left temporal (22.5g) of an infant aged approximately 6-12 months (ID1093), retrieved from Feature 1B in Trench 1. In some cases teeth still embedded in alveolar bone were weighed as a single unit and this is noted in the catalogue.

Table 3.1: List of finds by exhibit number

Exhibit No.	Date	Description	Location	Seized by	Catalogue No's	No. Of Frags
LL001	06.10.2016	Juvenile left femur	TR1A, F1Aii, C010, NW corner	LL	1090	1
LL002	06.10.2016	Juvenile left temporal	TR1A, F1Aii, C010, NW corner	LL	1091	1
LL003	06.10.2016	Juvenile right parietal	TR1A, F1Aii, C010, NW corner	LL	1092	1
LL004	07.10.2016	Juvenile left temporal	TR1A, F1Bii, C011, NW corner	LL	1093	1

LL005	07.10.2016	Juvenile right parietal	TR1A, F1Bii, C011, W	LL	1094	1
LL006	07.10.2016	Juvenile left ulna	TR1A, F1Bii, C011, W, directly associated with LL007	LL	1095	1
LL007	07.10.2016	Juvenile distal first foot phalanx	TR1A, F1Bii, C011, W, directly associated with LL006	LL	1058	1
LL008	11.10.2016	Juvenile thoracic arch	TR1A, C014, N side of ?inlet to F1B, associated with LL009	LL	1089	1
LL009	11.10.2016	Juvenile sternal rib end	TR1A, Co14, N side of ?inlet to F1B, associated with LL008	LL	1064	1
LL010	11.10.2016	Juvenile left radius	TR1A, interface between F1A and C013	LL	1087	2
LL011	11.10.2016	Juvenile femur, humerus, ulna, rib	TR1A, C013, from sondage by F1B	LL	1060-3	7
LL012	17.10.2016	Multiple juvenile bones	TR1A, CO13, immediately to N of F1	LL	1001-55	133
LL013	18.10.2016	Multiple juvenile bones	TR1A, C014, voids to N of F1	LL	1065-75	15
LL014	19.10.2016	Multiple juvenile bones	TR1A, CO14, from void into F1A	LL	1056-7	2
LL015	19.10.2016	Multiple juvenile bones	TR1A, C014, general	LL	1076-86	2
LL016	27.10.2016	Soil	TR1A, F1BiW, C011, soil assoc. w/LL005-7, taken 07.10.2016	LL	-	-
LL017	27.10.2016	Juvenile rib	TR1A, C001/2, taken 03.10.2016	LL	1088	1
LL018	28.10.2016	Juvenile femur	TR4, C033	LL	1089	1

Although the bones were initially recorded by hand on-site, this data was later transcribed into a Microsoft Access database to facilitate analysis of the information. Most individual bones were given a unique identification number (ID) (*n.b.* none of the bones were physically marked during the analysis). For example, each tooth and the bone of a mandible are given a unique identification number. This enables total bone counts to be more accurate, and helps in matching bone fragments together. There were some exceptions in the cataloguing where, for example, multiple cranial vault fragments were all allocated a single ID number (for example ID1050 from Exhibit No. LL012 comprised 41 vault fragments of a young infant). In total, 95 entries are listed in the inventory. This represents a total of 182 individual fragments of bone, with fragments of the cranium and ribs in particular being grouped together for individual contexts.

Fourteen fields were used to compose the database. As mentioned, each individual bone was given an 'ID' (1) number: these run from ID1001 through to ID1095. The exhibit number (2) was recorded, as well as the archaeological feature (3) and context number (4). The actual bone type (5) was listed, as well as a corresponding code (6) (based on Chamberlain and Witkin 2000), which simply allows easy manipulation of the dataset. The side (7) from which the bone came from is recorded, 'L' for left and 'R' for right. There are three listings for age-at-death. The first 'Age1' (8) simply summarises if the bone was from an adult ('AA', 18+ years) or a juvenile ('JUV', <18 years). The second 'Age2' (9) recorded the age within a smaller age group: in this current case, 'INF' infant <1 year, 'JUV1' 1-6 years, 'JUV2' 7-12 years, and 'ADOL' adolescent 13-17 years. The third 'Age3' (10) records if a more specific age-at-death could be established. Again this allows for easy manipulation of the data. The sex (11) of the individual may also be recorded; presently the sex of none of these individuals is known. There is then a field to record the fragment in detail (12), given a description of preservation, any measurement, any observations, and any links with other bone fragments. Finally, the number of fragments (13) per ID number was recorded, as well as the weight (14). No definite pathological lesions were observed – although it is acknowledged that very few of the bones had been washed prior to record, which may have obscured subtle lesions. Calcified plaque was identified in two teeth (ID1036-7).

3.3 Human Remains Retrieved From Within Feature 1, Trench 1

Although it was not possible to directly access the tanks containing the human remains it was essential to retrieve samples in order to establish the date of the skeletal remains. Therefore samples of human bones were picked up from the surfaces of the sediments in the tanks from the openings at the top of the tanks using a long-handled grip picker and a long-handled scoop. Bones were only removed from Feature 1A and 1B in Trench 1.

Feature 1A

Three bones were removed from the northwest (ii) corner of the eastern internal division of Feature 1A (C.10) and these are summarised in the **Table 3.2** below

Table 3.2: Human remains recovered from Feature 1A

ID no	Exhibit No.	Bone	Side	Age-at-death	No. Of frags	Weight*
1090	LL001	Femur	L	Infant *c.* 1.5 mths	1	3.4
1091	LL002	Temporal	L	0-6 mths	1	5.1
1092	LL003	Parietal	R	0-6 mths	1	8.8

The bones were all in an excellent state of preservation with almost no fragmentation and/or erosion. All of the bones were recovered together from the same location. There is no duplication of elements. The minimum number of individuals represented in one young infant, aged between 0-6 months at the time of death, and probably specifically aged between 1-2 months. All three of these bones were submitted for radiocarbon dating.

Feature 1B

Human skeletal remains were recovered from the northeast (i) and northwest (ii) corners of this tank (C.11). The recovered bones are summarised in **Table 3.3**.

Table 3.3: Human remains recovered from Feature 1B

ID no	Exhibit No.	Location	Bone	Side	Age-at-death	No. Of frags	Weight*
1093	LL004	NW (ii)	Temporal	L	6-12 months	1	22.5

1058	LL007	NE (i)	Foot phalanx	?	Infant	1	0.1
1094	LL005	NE (i)	Parietal	R	6-12 months	1	13.1
1095	LL006	NE (i)	Ulna	L	3-6 months	1	1

As with the bones in Feature 1A, these bones were in an excellent state of preservation. The foot phalanx was discovered after retrieval, stuck in soil adhering to the parietal bone. These bones appear to represent a minimum of two individuals, an older infant aged between 6-12 months at the time of death (cranial bones) and a younger infant aged between 3-6 months (ulna). These bones, the exception being the foot phalanx, were submitted for radiocarbon dating.

3.4 Human Remains *In Situ* in Feature 1, Trenches 1, 3, and 4

As mentioned earlier, four of the tanks or chambers within the larger structure Feature 1 were opened to determine the nature of their contents. Two, Feature 1A and 1B, were in Trench 1 with one each in Trench 3 and 4. Human remains were retrieved from both Feature 1A and 1B in order to provide samples for dating and the analysis of those bone has been detailed above. The total depth of the tanks appears to be approximately 2.2m, 2.7m below present ground surface, with the only access through very narrow slits at the top. It was not possible to physically enter the tanks. However, the interiors were extensively photographed. All four tanks had deposits in the base that comprised soil, rubbish, and bones. In some cases it was possible to identify bones that were within the tanks although, in most instances, the identification is tentative and may only be confirmed on actual retrieval.

Trench 1, Feature 1A

This was the eastern tank that was opened in Trench 1. A low wall divided the base, with C.10 to the east and C.12 to the west. Human skeletal remains were identified in both sections. An annotated photograph of the base is shown in **Appendix III Plate 3.1**, while

Appendix III Plates 3.2 to 3.5 show the identified fragments in detail. The identified human remains are summarised in **Table 3.4**.

Table 3.4: Identified human skeletal remains within Feature 1A, Trench 1

Photograph reference	Details
a	Infant (0-12 months) cranial and long bones
b	Possible juvenile (0-6 years) cranium
c	Possible juvenile (0-6 years) bones
d	Possible juvenile (0-6 years) cranial fragments
e	Infant (0-12 months) cranial fragments

There was no immediate evidence of any articulated remains. Details of bones recovered from F1A were described above, and these were recovered from the area marked '(a)' in **Appendix III Plate 3.1**.

Trench 1, Feature 1B

This was the western tank that was opened in Trench 1. Human skeletal remains were identified in the base of this tank (C.11). An annotated photograph of the base is shown in **Appendix III Plates**, while **Appendix III Plates 3.7** to **3.8** show the identified fragments in detail. The identified human remains are summarised in **Table 3.5**.

Table 3.5: Identified human skeletal remains within tank Feature 1B, Trench 1

Photograph reference	Details
a	Infant (0-12 months) cranial fragments
b	Infant (0-12 months) cranial fragments, unidentified bones, and possible articulated ribs?

It is possible that there are two infant ribs lying immediately adjacent to each other in a small cavity in the north wall of the tank, **Appendix III Plate 3.8**. If these are infant ribs, they are likely to have originated from an articulated individual within this tank. However, it is not definite that these are actually infant ribs and this evidence remains speculative. Details of bones recovered from F1B were described above: the temporal was recovered from area '(a)' while the three remaining bones were recovered from the area marked '(b)' in **Appendix III Plate 3.6.**

Trench 3, Feature 1

A single capped tank was opened within this trench. **Appendix III Plate 3.9** is an annotated photograph showing the locations of identified human remains within the tank, and these are then detailed in individual photographs, **Appendix III Plates 3.10** through **3.14**. The identified human remains are summarised in **Table 3.6**.

Table 3.6: Identified human skeletal remains within single tank in Feature 1, Trench 3

Photograph reference	Details
a	Infant (0-12 months) ribs
b	Juvenile (0-6 years) cranial fragment
c	Infant (0-12 months) cranial vault fragments
d	Juvenile (0-6 years) cranial fragments
e	Infant (0-12 months) cranial fragments
f	Juvenile (2-3 yrs) skull

An apparently intact juvenile skull (f), **Appendix III Plate 3.13** and **3.14**, was present in the southwest corner of the tank. It was possible to approximately estimate the age-at-death of the juvenile as the dentition were visible, and it is estimated this individual was *circa* 2-3 years at the time of death. The skull was upright, in the supine position. There was no immediate evidence of any articulated remains.

Trench 4, Feature 1

A single capped tank was opened within this trench. **Appendix III Plate 3.15** is an annotated photograph showing the locations of identified human remains within the tank, and these are then detailed in individual photographs **Appendix III Plates 3.16** and **3.17**. The identified human remains are summarised in **Table 3.7**. There was no immediate evidence of any articulated remains.

Table 3.7: Identified human skeletal remains within single tank in Feature 1, Trench 4

Photograph reference	Details
a	Infant (0-12 months) left scapula and vault fragment
b	Infant (0-12 months) mandible and ribs

3.5 Human Remains Retrieved: North of Feature 1, Trench 1

The infill to the north of the north wall of Feature 1 (that is, outside Feature 1A and 1B) was excavated down to a depth of 2.7m below current ground level. As mentioned earlier, voids were apparent near the base of the wall: these appear to represent ruptures, probably due to water pressure. The bones were recovered from within the actual voids, as well as in the earth adjacent to the ruptures. All human remains in this area were contained within two contexts, C.13 and C.14. Both C.13 and C.14 appear to have been formed through a combination of intermittent dumping of material and fluctuations and silting caused by changes in the water table (A. Harte, *pers. comm*.). No *in situ* remains were present. During excavation, when these human remains were identified, the excavation team immediately began sieving the material through 2mm meshes in order to maximise recovery. However, it became apparent very quickly that, the sieving resulted in minimal recovery of bones with maximum input of time as almost all bone was being retrieved by manual excavation. These bones will first be examined by context. However, in reality, both C.13 and C.14 were very similar: indeed one broken rib fragment of a young juvenile in C.13 (ID1012) was found to fit exactly with another fragment recovered in C.14 (ID1064). Therefore, following the separate assessments of C.13 and C.14 below will be a section which aims to determine a MNI for the two contexts combined.

Context 13

In total 142 fragments of human bone were recovered from C.13 weighing a total of 88g. All were from juvenile individuals. A minimum of five juveniles were identified in the recovered bone. The evidence is summarised in **Table 3.8**. If should be noted that ID1003 may be from an older infant than the 35 week old foetus.

Table 3.8: Minimum number of individuals C.13

Age-at-death	ID no.	Bone/s	Details
35.0+/-2.2 foetal wks	1014 possibly 1003	Left ulna Left scapula	The left ulna provides an age-at-death from its complete length, the scapula is incomplete but is clearly from a very young infant
1.5-3 mths	1027	Right humerus	Age obtained from long bone length
c. 1.5-3 mths	1028	Right humerus	Incomplete, but same size as ID1027
6-9 mths	1018 1022	Right ilium Right femur	Age obtained from complete ilium, femur is incomplete but clearly and older infant (that is, between 6-12 mths)
1-2 yrs	1045	Right maxilla	Age from maxilla and associated teeth
2-3 yrs	1035 1040	Left and right maxilla	Age from maxilla and associated teeth

In general, the bones were in a relatively good state of preservation, **Appendix III Plate plate 3.18**, although there was some post-mortem fragmentation. There was minimal erosion of the bone surfaces. A number of bones appear to have been gnawed by rodents. These include a right tibia (shin bone) of a young juvenile aged between perhaps 1-3 years at the time of death (ID1023), and the right frontal (forehead, ID1049, **Appendix III Plate plate 3.19**) and left rib (ID1005) of a young infant aged between 0-6 months at the time of death. Two bones, the right temporal (side of head, ID1048) of a young infant (0-6 months) and the left scapula (shoulder blade) of a very young infant (ID1003), both had green staining. The bones were recovered lying together with a piece of copper alloy wiring in between, **Appendix III Plates 3.20, 3.21, 3.22**. The copper alloy causes staining such as this.

Two teeth had slight deposits of calculus or calcified plaque on the buccal (cheek) aspect. These were an upper deciduous first molar (ID1036) and an upper deciduous second molar (ID1037), both from the same individual who was aged between 2-3 years at the time of death.

Context 14

In total 31 fragments of human bone were recovered from C.14 weighing a total of 19.3g. All were from juvenile individuals. A minimum of three juveniles were identified in the recovered bone. The evidence is summarised in **Table 3.9**.

Table 3.9: Minimum number of individuals C.14*

Age-at-death	ID no.	Bone/s	Details
*c.*38-40 foetal weeks	1083	Left maxilla	Metrics indicate age-at-death
c. 1-6 months	1078	Right humerus	All indicate a young infant but unlikely to be neonate
	1076	Left scapula	
	1077	Right scapula	
c. 2-5 years	1059	Thoracic arch	Neural arch fused, unfused to body

* this does not list all the bones of these individuals, just the bones used to establish MNI

These bones were in a similar condition to those recovered from c.13. The bones were in a relatively good state of preservation with some post-mortem fragmentation. There was minimal erosion of the bone surfaces. A number of bones again had evidence of gnawing by rodents. Four fragments were affected: a rib shaft (ID1072), a left rib (ID1069), and a right rib (ID1071) of the young juvenile, and the right radius (ID1085) of the infant.

MNI of Context 13 and Context 14 Combined

The combined MNI for the two contexts to the north of Feature 1 in Trench 1 are presented below in **Table 3.10**.

Table 3.10: Minimum number of individuals C.13/C.14[1]

Age-at-death	ID no.	Bone/s	Details
35.0+/-2.2 foetal wks	1014	Left ulna	Age-at-death from diaphysis
38-40 foetal wks	1078 1003+ 1083	Right humerus Left scapula[2] Left maxilla	Age-at-death from maxilla, other bones suggested on basis of size
1.5-3 mths	1027	Right humerus	Age obtained from long bone length
c. 1.5-3 mths	1028	Right humerus	Incomplete, but same size as ID1027
6-9 mths	1018 1022	Right ilium Right femur	Age obtained from complete ilium, femur is incomplete but clearly and older infant (that is, between 6-12 mths)
1-2 yrs	1045	Right maxilla	Age from maxilla and associated teeth
2-3 yrs	1035 1040	Left and right maxilla	Age from maxilla and associated teeth

The other bones listed in **Table 3.9** for the young infant (1-6 months) and the young juvenile (1-5 years) may be from the relevant individuals listed in **Table 3.10**. Likewise, the thoracic vertebra of a 2-5 year old juvenile (ID1059) recorded in C.14 may be from the 2-3 year old represented by the maxillary remains (ID1035, ID1040): there is no substantial evidence to indicate the presence of two juveniles aged 2+ years[3]. The MNI is seven juveniles, with the eldest being between 2-3 years at the time of death.

3.6 Other Human Skeletal Remains

One fragment of bone (ID1088) was recovered from the general topsoil in Trench 1. This was the sternal end of perhaps the fourth or fifth rib of a young (0-6 months) infant.

[1] This does not list all the bones of these individuals, just the bones used to establish MNI

[2] Here this is tentatively identified as being from the neonate, although it could be from the younger foetus

[3] *N.B.* the age range of 2-5 years for the thoracic vertebral arch is based on the fact that that by the age of 2 years the posterior arch has fused and this arch would then normally fuse onto the body of the vertebra by the age of 6 (Scharfer et al. 2009, 114, 119-21). The arch is from an individual aged anywhere between 2-5 years but is most likely to be at the younger end of that scale.

One bone fragment (ID1089) was retrieved from C.33 in Trench 4. This was the femur of a neonate individual. C.33 was a firm brownish grey sandy clay, up to 0.67m in thickness, which represented the disused topsoil and contained occasional flecks of charcoal, mortar and other debris. It lay directly under the present topsoil (A. Harte, *pers. comm*.).

3.7 Discussion

The total quantity of human bone recovered during the recent test excavations at the memorial garden associated with the former Bon Secours Mother and Baby Home in Tuam, Co. Galway, was 182 fragments of bone weighing 163g. The minimum number of individuals represented by the bones recovered from within the tanks of Feature 1 in Trench 1 and from the excavated deposits to the north of Feature 1 in Trench 1, is ten individuals. Two additional bones, each representing infants, were recovered from topsoil layers in Trench 1 and Trench 4. All remains were juvenile in origin and ages-at-death identified ranged from 35 foetal weeks to 2-3 years. Examination of photographs of the unexcavated tanks revealed juvenile human skeletal remains within each of the tanks, with the eldest identified individual being approximately 2-3 years at the time of death. At present, it is not possible to accurately determine the numbers of individuals within any of the tanks.

No definitive *in situ* burials were identified. However, two possible articulated infant ribs in Feature 1B, **Appendix III Plate 3.10**, suggest the possibility that there may originally have been at least one articulated skeleton within this tank. All of the bones recovered from the tanks were in an excellent state of preservation, including delicate infant skull bones. It is suggested that the tanks were their original place of deposition and that their remains gradually became disarticulated through fluctuations in seeping water and silting deposits. In addition, much of the debris that is now within many of the tanks was likely disposed of much later. It would be expected that there would be more fragmentation of the bones if they were contemporaneously deposited with the debris. It is also interesting to consider the cranium of the 2-3 year old juvenile found in the tank in Trench 3, **Appendix III Plates 3.9**, **3.13** and **3.14**. This skull is noticeable because of the fact that it is in the supine position (lying on the back), and is aligned with the adjacent wall, suggesting that it may represent the actual deposition of a body within the tank, laid in an extended position with the head to the south, which stayed largely intact and *in situ* in comparison to any other potential burials. It may be significant that this was the only tank that had a clear inlet/outlet point at the northern end.

In contrast to the bones within the tanks, the bones found outside and to the north of the tanks were more fragmentary. These appear to have suffered from the manner of their deposition: that is, the contexts in which they were contained appeared to have been formed through silting and fluctuating of the water table. It is not known where these bones were originally deposited. However, it is possible that at least some came through from the tanks in Feature 1 through the ruptures that were visible in the walls. Some bones were recovered from within these ruptured voids, **Appendix III Plate 3.23**. It is also noted however, that at least some of the bones in C.13 and C.14 were quite complete: perhaps there are actual inlet/outlet pipes in some of the tanks, not identified during the recent test excavation, which allowed large pieces of bone through. Alternatively, it is possible that some individuals were deposited within the area of the original cesspit, to the south of Feature 1. Again, only further excavation can address this.

The bones within C.13 and C.14 had also suffered from rodent gnawing – it is unknown if this occurred when the bones were in their original place of deposition or when they can to rest in the area in which they were found. The disarticulated nature of the bones is perhaps most succinctly illustrated by the finding of right temporal (side of head, ID1048) of a young infant (0-6 months) and the left scapula (shoulder blade) of a very young infant (ID1003), lying adjacent to each other, with a piece of copper wiring between the two, **Appendix III Plate 3.22**. Both bones had been stained green through the copper alloy.

4. Artefactual Evidence

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In the course of the investigation, hundreds of objects were recovered. Artefactual evidence such as this is of primary importance in providing a date range to the activity that formed given deposits, in addition to interpreting the function of those deposits and related features. It is important to recognise that artefacts of an early date may be residual within contexts of a later date, and also that objects from later times can potentially infiltrate earlier deposits depending on composition and environmental factors. The date range of a given context is defined by both the earliest time at which an event can have happened, giving a *terminus post quem*, and the latest date at which it can have happened, giving a *terminus ante quem.* Due to nature of the deposits under examination, the *terminus post quem* is the more reliable end of the range.

A full list of artefacts recovered is given in **Appendix VII**. As all other trenches were limited to upper layers, Trench 1 provided the most useful assemblage of artefactual evidence. The deposit (C.18) that lies directly on the floor of the cesspit, but abutting a later feature (C.5), produced ten fragments including glass, wire, brick and slate. The most diagnostic piece was a broken blue-glass bottle marked with 'Milk of Magnesia registered trade mark' in raised relief. These embossed and registered bottles of this product belong to the period 1910–1960.

The lowest layers within the rectangular masonry feature (C.8 and C.16) produced an assortment of material – plastics, metals, glass, ceramics and brick – demarcating final stages/disuse of this feature. A bone-handled toothbrush (C.16, find 125), is an example of an artefact that although invented in the 19th century continued in use into the 1940s. A fragment of a plastic comb here is important as such plastics did not become widely available until the late 1930s (C.16, find 126). There was definitively earlier material in form of enamelled chamber pots (10 fragments). These types of vessels came into widespread production in the 1870s and fell out of vogue in the 1930s (that is not to say that they did not continue in use beyond this date). These artefacts likely provide a *terminus post quem* for the deposit in the late 1930s/early 1940s.

The main disuse of Feature 2 (C.8) and the cesspit more generally was signified by the rubble layer C.6/C.9, and most of the artefacts recovered came from this deposit. There were items of potentially 19th century date recovered throughout, such as clay pipe stems (C.6 find 5 and C.9 find 117) and a clay pipe bowl (C.6 find 227). Amongst numerous metal fragments were an array of enamelled tin kitchenwares and pots (C.6 finds 6-9 and C.9 finds 83, 88-91, 93 and 94). As stated above the date range for this type of material is generally accepted as 1870-1930. There were however, three small enamelled children's cups, each embellished with a line from the nursery rhyme 'Mary had a little lamb' on the exterior, **Appendix III Plate 4.1**. This particular type of cup is of Swedish origin and can be shown to date from the period 1920 – 1940.

The most notable glass artefact recovered was a baby bottle with openings each end (C.6 find 1), **Appendix III Plate 4.2**. This was embossed with a 'Made in Germany' stamp and such items were common from the 1920s onwards. Pyrex, and then plastic, replaced glass from the 1950s and 1960s respectively but the double-ended glass bottle seems to have been typical of the 1930s and 1940s.

The remaining 73 glass fragments recorded from these deposits mostly represent various types of bottles. Of note is that 11 examples relate to medicine or chemical bottles. These include vials and chemist bottles with markings such as 'Virols'. It seems that screw-top bottles are prevalent within the deposits and therefore, post-date the 1920s. A solitary aerosol can appears to be the likely latest dated artefact from the upper parts of C.9 (find 112), realistically suggesting a date not earlier that 1950. Therefore, the deposit of rubble may have formed during the 1930s/1940s, only becoming finally sealed in subsequent decades.

South of Feature2/C.8, the rubble deposit (C.6) was covered with a layer (C.13) that consisted of periodical deposits of possible domestic waste (i.e. hearth waste etc.). The items recovered from this material was similar to that of the rubble layers, with a multitude of largely undiagnostic fragmented metal pieces – padlock, nails, bolts, iron pipes, lead pipe, bucket, cans, wiring, hearth grate etc. Of note were two small metal artefacts, a safety-pin

(C.13 find 225, found in close association with human remains) and a small sized copper-alloy ring (C.13 find 186, possible personal effect). Glass bottles and window glass shards were also recovered, as were ceramics of various types. Clay pipe bowls and a stem fragment were found and are probably residual evidence of the 19th- or earlier 20th century. There was clearly more personal item within this deposit than others. A broken dolls eye (C.13 find 257) and a piece of fabric (C.13 find 256) were both found in association with human remains, while 4 plastic buttons and one bone button (C.13 finds 193 and 35) were also found.

Two plastic artefacts were noteworthy; a fragment of a luminous plastic hair comb (C.13 find 34) and a plastic food scoop branded as 'Tru Food' (C.13 find 258). As mentioned above, any plastic comb is unlikely to pre-date the 1930s, and the colour of this fragment is probably places it later still. The plastic scoop is a measure for baby formula. TruFoods were a brand producing a range of baby foods, including dried baby formula, in the 1960s and 1970s, and subsequently merged with Cow & Gate. This latter date in the range can be accepted as the *terminus post quem* for this deposit.

A further layer above this was considered to be largely *in-situ* (C.7). The assortment of material was very similar to that of the underlying layer (C.13). Of particular note here were clay pipe bowls and a stem fragment (C.7 find 159) of probable 19th century date alongside a plastic baby formula scoop, marked 'water scoop' one one side and 'Tru Foods' on the other (C.7 find 166). This mirrors the date range of the earlier layer but a 'Club Orange' can was found within it. Although perhaps an intrusive object, the drinks can suggests a 1960s or 1970s date.

Deposits containing artefactual evidence adjacent to Feature 1/C.5 at the southern end had been disturbed by post-depositional fluvial activity. The deposit over the rubble (C.14) contained mixed material - metals, a battery cell, a whiskey bottle, wood, fabric and buttons. Apart from the two buttons, there were also six beads (C.14 finds 211-213). Stratigraphically later, deposit C.4 was also likely a disturbed deposit formed from soils that surrounded it. The artefactual evidence reflected this with similar assemblages of glass, clay pipe and metal. However, plastic 'Captain Crisps' and 'Southalls' towel packets were recovered, the latter with the Guaranteed Irish symbol which did not come into being until

1974. Therefore, this deposit dates to the late 1970s. This is significant as the northern edge of Feature 1 would have been exposed until this period.

A deposit of greyish soil was identified in each trench (C.2, C.23, C.26 and C.33). The artefacts from this layer included Bovril jars, beer bottles, plastic bottles, fabrics, ceramics and metal fragments. Some plastics and metal fragments related to construction materials. Two bullet casings were found within this layer at the southern end of Trench 1. The most informative item came from trench 4, an Irish pingin (1p) dated 1971. This grey layer was not formed until the 1970s. Finally, topsoil was spread across the site, the finds from this material have no implication on our understanding of the site, as it was introduced by Galway County Council.

The assemblage of material found during the investigative works show that the initial phases of the cess-pit were maintained and archaeologically sterile. The earliest layers contained artefacts relating to the late 19th/early 20th century. This material is almost entirely domestic (i.e. plates, cups, chamber pots, bottles etc.). As the stratigraphy formed this early material remained in a residual capacity within the deposits. However, later materials (plastic combs and scoops) were deposited as the layers accumulated, until finally the latest fills clearly post-date 1970.

5. External Specialist Analysis

5.1 Radiocarbon Dating Results

Six samples of juvenile human remains were sent to Dr Gordon COOK in SUERC Radiocarbon Dating Laboratory in Scotland for analysis, full report see **Appendix VIII**. The results can be summarised with osteoarchaeological analysis as follows:

Table 5.1: Summary of dating evidence associated with human remains

Sample point	**Exhibit #** **MBHCOI_ TM1016_**	**Calibrated Range of interest**	**Age at Death**	**Condition**
Feature 1 C.10	LL001	1800-1940	c. 1.5 months	Excellent
Feature 1 C.10	LL002	1935-1955	0-6 months	Excellent
Feature 1 C.10	LL003	1925-1955	0-6 months	Excellent
Feature 1 C.11	LL004	1930-1955	6-12 months	Excellent
Feature 1 C.11	LL005	1956-1957	6-12 months	Excellent
Feature 1 C.11	LL006	1956-1957	3-6 months	Excellent

5.2 Environmental Sampling results

A sample of 'soil' recovered from and associated with **Exhibit LL005** was sent to Dr Lorna DAWSON of The James Hutton Institute, Aberdeen, Scotland; for full report see **Appendix IX**. It was deemed not to be a typical soil and contained markers of faeces. Observed patterns within this sample indicated this faecal matter was of human origin. Exceptionally high levels of plant sterols together with low concentrations of plant-wax *n*-alkanes and fatty alcohols were detected in the sample. It is possible that this sample was in fact a product created by human decomposition, including faecal matter, from infants fed with formula milk containing vegetable oils.

Patterns of stanols, sterols and hydrocarbons found in the sample are not consistent with sewage waste from adult humans however the context from which the sample was retrieved was biased and not a true representation of the deposits within Feature 1.

6. Conclusion

6.1. Condition of Site Post Excavation

The decision was taken by the MBHCOI to backfill the site upon completion of the 4 trench investigations. Each of the internal chambers within Feature 1 was sealed with custom made steel lids, **Appendix III Plate 6.1** and permeable membrane, **Appendix III Plate 6.2**. Each trench was then backfilled in entirety. Human remains recovered were deposited with the Office of the State Pathologist upon instruction from the Galway County Coroner Dr Val Costello. Artefacts recovered were catalogued and moved to a secure storage facility.

In order to proceed to the further investigative work at this location a number of measures need to be put in place in order to secure Feature 1 and the upstanding boundary walls. Any excavation work undertaken here needs to access depths of 2.75m+ below present ground surface level; as such, Health and Safety measures need to put in place to mitigate the significant risks posed by the site.

Consultation with an Engineering contractor has informed that Structural Piling will need to be put in place around Feature 1 to allow it to be excavated manually and relevant evidence to be recovered to the highest possible standard. This process will take a number of weeks to implement. In the intervening period and in the absence of An Garda Síochána site presence, timber hoarding will remain in place directly around the site to in an attempt to protect from trespassers. An additional security measure was taken to secure the surface of the site from intrusion; topsoil at the site was stripped, a permeable membrane was laid and grade 804 gravel was laid all across the surface. This will allow heavy machinery on site for the purposes of the Site Investigation and highlight any disturbance that is attempted thus providing a meagre but necessary level of subsurface security. This layer artificially creates a sterile context through which disturbance may be detected thus if evidential security and continuity at the site is compromised investigators will be in full knowledge of this upon commencing the next phase.

Human remains currently lie in a context with a potential depth of 2.75m. They are subjected to the movement of ground water due to the nature of the feature they are contained within. Due to the potential interment of 50+ years it is unlikely a short delay will cause significant deterioration of remains. In the interim the site can be sealed and secured. However the preservation of DNA and the interpretation of evidence relating to articulation may be affected. Upon completion of this Phase II, how this investigation proceeds to the next phase is more significant on ethical and humanitarian grounds; it is not appropriate to leave juvenile human remains in this specific context for an extended period of time, this matter needs to be resolved with immediacy.

6.2 Conclusion

Excavation works undertaken in Phase II of this site investigation proceeded as per the proposal, with the minor exception of trench design. The most significant discovery from this work was the location of juvenile human remains in association with a historic waste treatment facility; a concrete built tank with numerous internal chambers.

This test excavation set out to answer four specific lines of inquiry that were posed by the MBHCOI. The excavation and subsequent analysis of evidence by specialists allowed for these queries to be addressed in full:

i. **To establish if there are human remains at this location.**
   There are juvenile human remains at this location, they are in a unique context and a complex depositional arrangement.

ii. **To establish the date range of the interment these human remains.**
   Results of radiocarbon dating of 6 skeletal elements recovered from inside feature 1 range from 1935-1957 with 1 sample ranging from 1800-1940.

iii. **To establish if there are human remains contained within the structure of the reported 'cesspit'.**

Remains were recovered from the internal chambers of a feature associated with the management of sewage waste.

iv. **To provide a demographic profile of human remains which are recovered (and observed).**

Remains that were recovered combined with those that were observed *in situ* represent a demographic profile of the following:

Minimum number of Individuals: 14

Age at death: 33 foetal weeks to 2-3 years.

7. Qualifications and Experience of Contributors

Niamh McCULLAGH BA MA MSc MCSFS

Forensic Archaeologist, Project Director Phase II

Niamh is a consultant Forensic Archaeologist specialising in the search, location and recovery of human remains in a forensic context. She is the Senior Forensic Archaeologist to the Independent Commission for the Location of Victims Remains and has assisted An Garda Síochána in the investigation of multiple cases. She has A BA Major in Archaeology (University College Cork, 2001), MA Archaeology (University College Cork, 2002) and MSc Forensic Archaeology and Crime Scene Investigation (Bradford University, 2007). She is recognised as Professional Member of the Chartered Society of Forensic Sciences, an Expert Witness in Ireland, a member of the Irish Association of Forensic Practitioners and have worked with police forces across the UK both on casework and in a training capacity.

Aidan HARTE, BA MA MIAI

Senior Archaeologist and GIS Specialist

Aidan is a qualified archaeologist and geographer, with over 15 years' archaeological experience in Ireland, the UK and France. He is a license eligible Archaeologist and an expert in the field of Archaeological Excavation as recognised by the Department of Arts, Heritage, Regional, Rural and Gaeltacht Affairs. He also works as a Senior Team member on a consultation basis with the Independent Commission for the Location of Victims Remains through his company Munster Archaeology. He has been a full member of the Institute of Archaeologists of Ireland since 2007 and has served on the Board of Directors for the Cork Historical and Archaeological Society since 2013. Aidan has lead excavations and surveys of over 35 archaeological sites, of various type, size and period, in a variety of locations and conditions.

Linda LYNCH. MA PhD MIAI

Human Osteoarchaeologist

Linda is a professional, Archaeological consultant and Human Osteoarchaeologist with over 20 years' experience in Irish archaeology. She is a license eligible Archaeological excavation expert and a leading professional in the field of Osteoarchaeology in Ireland. She has particular expertise in issues similar to those encountered at the Children's Burial Ground at Tuam. Her Masters Degree in 1998 focused on neonate and infant remains. In 2014 Linda was awarded a PhD in research that focused on human remains from 19th Century Workhouse burials. Linda was also the specialist employed to examine the skeletal remains recovered from the Archaeological excavation adjacent to Tuam Poor Law Union Workhouse (License 10E0117). She has a significant profile as an accomplished and published specialist.

8. Appendices

Appendix I: Warrant issued

Mother and Baby Homes Commission of Investigation

Commissions of Investigation Act 2004

Sections 8, 26 and 28

WARRANT

TAKE NOTICE THAT in accordance with Section 26 of the Commissions of Investigation Act 2004 (hereinafter 'the Act')

Niamh McCullough

Of Cork in the County of Cork

Is a person appointed under Section 8 of the Act and is hereby Authorised to exercise the powers given under section 28 of the Act in relation to the premises known as the Children's Burial Ground located in the Dublin Road Housing Estate, Tuam, Co Galway.

Dated this 1st day of September 2016

Judge Yvonne Murphy

JUDGE YVONNE MURPHY
CHAIRPERSON OF THE COMMISSION

Appendix II: Technical Note

The archaeological theories and techniques used during this search and excavation were in accordance with those outlined in publications such as:

1) 'Standards and Guidance for Forensic Archaeologists' (Powers and Sibun, 2011) prepared for the Chartered Institute for Archaeologists, UK.

2) Component Standards for Archaeology and Anthropology issued by the Chartered Society for Forensic Sciences, UK (www.forensic-science-society.org.uk).

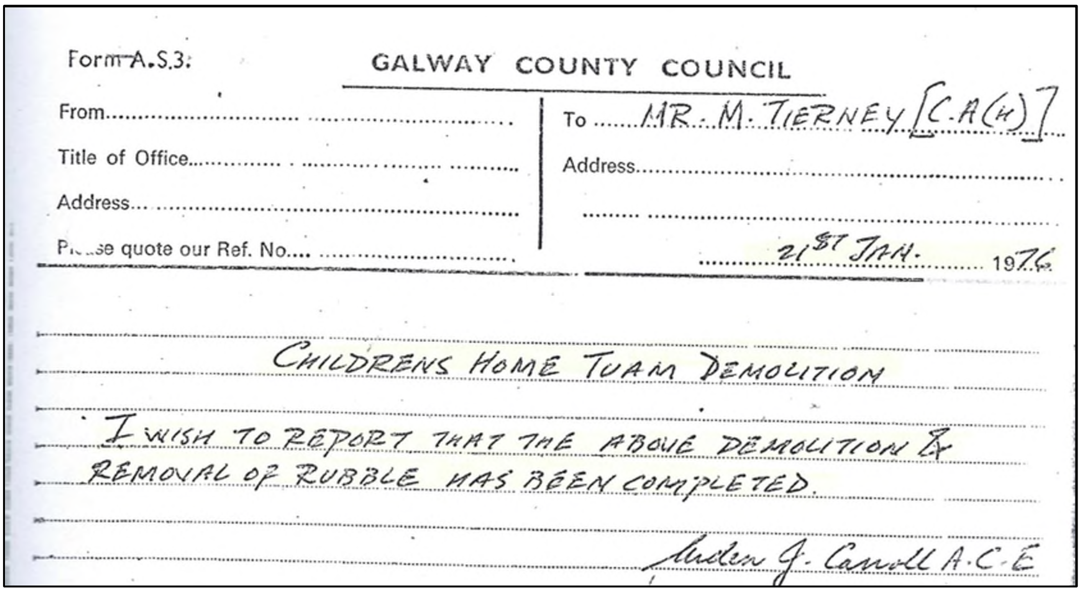
3) Handbook of Forensic Anthropology and Archaeology (World Archaeological Congress Research, 2011), Blau, S. & Ubelaker, D. (eds).

4) 'Management of Archaeological Projects' (MAP2), produced by English Heritage (Andrews 1991).

5) Technical papers issued by the Institute for Archaeologists of Ireland (www.iai.ie).

6) Museum of London Archaeological Service Archaeological Site Manual (MoLAS, 1994).

Appendix III: Plates



Form A.S.3. GALWAY COUNTY COUNCIL

From.. To ......MR. M. TIERNEY [C.A(H)]

Title of Office.. Address..

Address.. ....

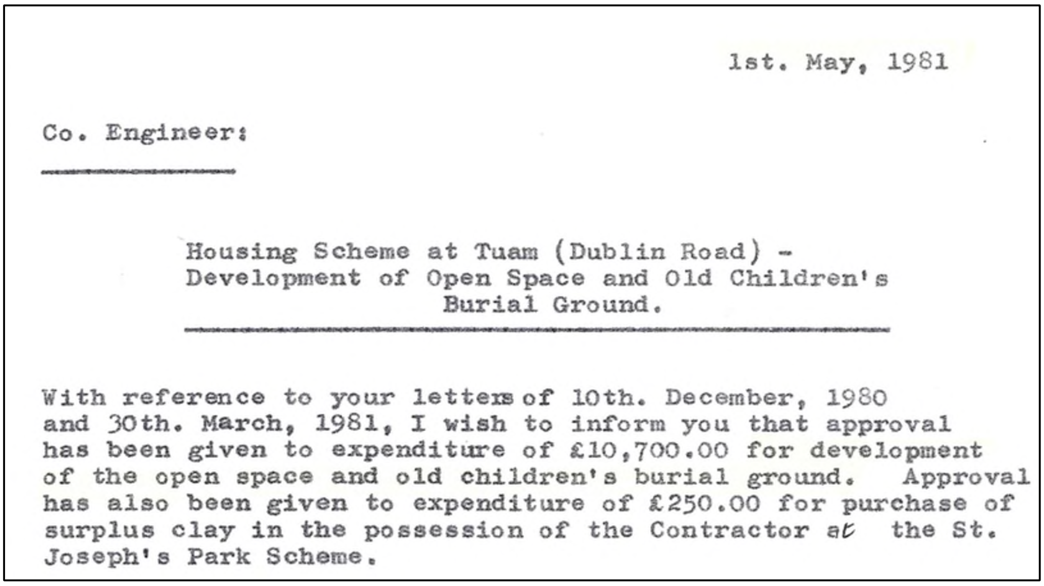
Please quote our Ref. No.................................. ......21ST JAN........ 1976

CHILDRENS HOME TUAM DEMOLITION

I WISH TO REPORT THAT THE ABOVE DEMOLITION & REMOVAL OF RUBBLE HAS BEEN COMPLETED.

Aiden J. Carroll A.C.E

Plate 1.1: Report dated 21st January 1976



1st. May, 1981

Co. Engineer:

Housing Scheme at Tuam (Dublin Road) - Development of Open Space and Old Children's Burial Ground.

With reference to your letters of 10th. December, 1980 and 30th. March, 1981, I wish to inform you that approval has been given to expenditure of £10,700.00 for development of the open space and old children's burial ground. Approval has also been given to expenditure of £250.00 for purchase of surplus clay in the possession of the Contractor at the St. Joseph's Park Scheme.

Plate 1.2: Sample from reports relating to works associated with 'Old Children's Burial Ground'

Plate 1.3: Pre-excavation plan of Trench 1

Plate 1.4: Securing excavations on site

Plate 2.1: Stone built culvert

Plate 2.2: Interior of culvert

Plate 2.3: Culvert and tank associated (Feature 2/C.8)

Plate 2.4: Later alterations to culvert

Plate 2.5: Saddle stone

Plate 2.6: South wall of tank

Plate 2.7: North wall of tank with inlet pipes

Plate 2.8: Pipes with infill

Plate 2.9: Pipes post-excavation

Plate 2.10: Excavation of base of Feature 1, C.17;

Plate 2.11: C.36 post-excavation

Plate 2.12: Openings to Feature 1

Plate 2.13: Example of juvenile human remains from C.14

Plate 2.14: Masonry wall exposed in Trench 2

Plate 2.15: Masonry wall from west

Plate 2.16: Trench 3, Feature 1 from south

Plate 2.17: Opening of tank in Trench 3

Plate 2.18: Stone wall to south and east, and shuttered concrete additions to north and west.

Plate 2.19: ‘Tide-mark’ on East wall

Plate 2.20: Trench 4 with Feature 1 and boundary wall.

Plate 2.21: Trench 4 Feature 1

Plate 3.1: Trench 1, Feature 1A, C.10 on right, C.12 on left, annotated photograph of identified human remains.

Plate 3.2: Trench 1, Feature 1A, C.10, detail of infant bones (a), see plate 3.1

Plate 3.3: Trench 1, Feature 1A, C.12, detail of juvenile cranium (b)

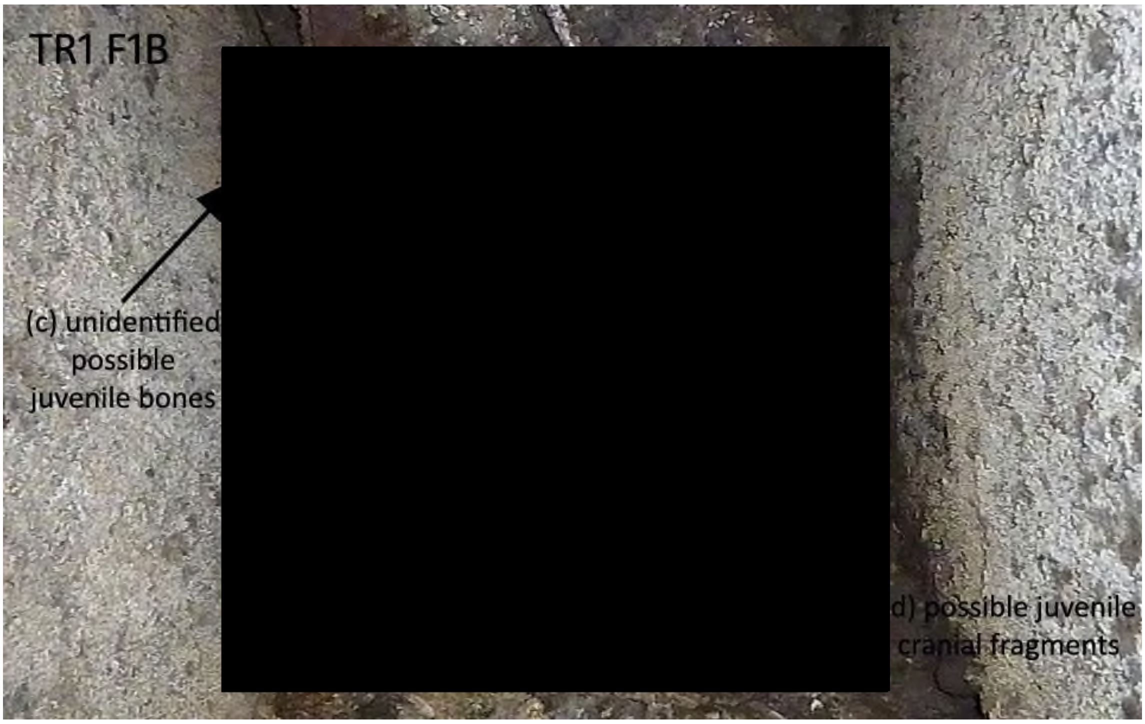


Plate 3.5: Trench 1, Feature 1A, C.12, detail of possible juvenile bones (c) and (d)

Plate 3.6: Trench 1, Feature 1A, C.10, detail of infant cranial bones (e)

Plate 3.7: Trench 1, Feature 1B, C.11, annotated photograph of identified human remains

Plate 3.8: Trench 1, Feature 1B, C.11, detail of infant bones (a)

Plate 3.9: Trench 1, Feature 1B, C.11, detail of infant bones (b)

Plate 3.10: Trench 3, Feature 1, annotated photograph of identified human remains

Plate 3.10: Trench 3, Feature 1, detail of infant ribs (a)

Plate 3.11: Trench 3, Feature 1, detail of juvenile cranial fragments (b)

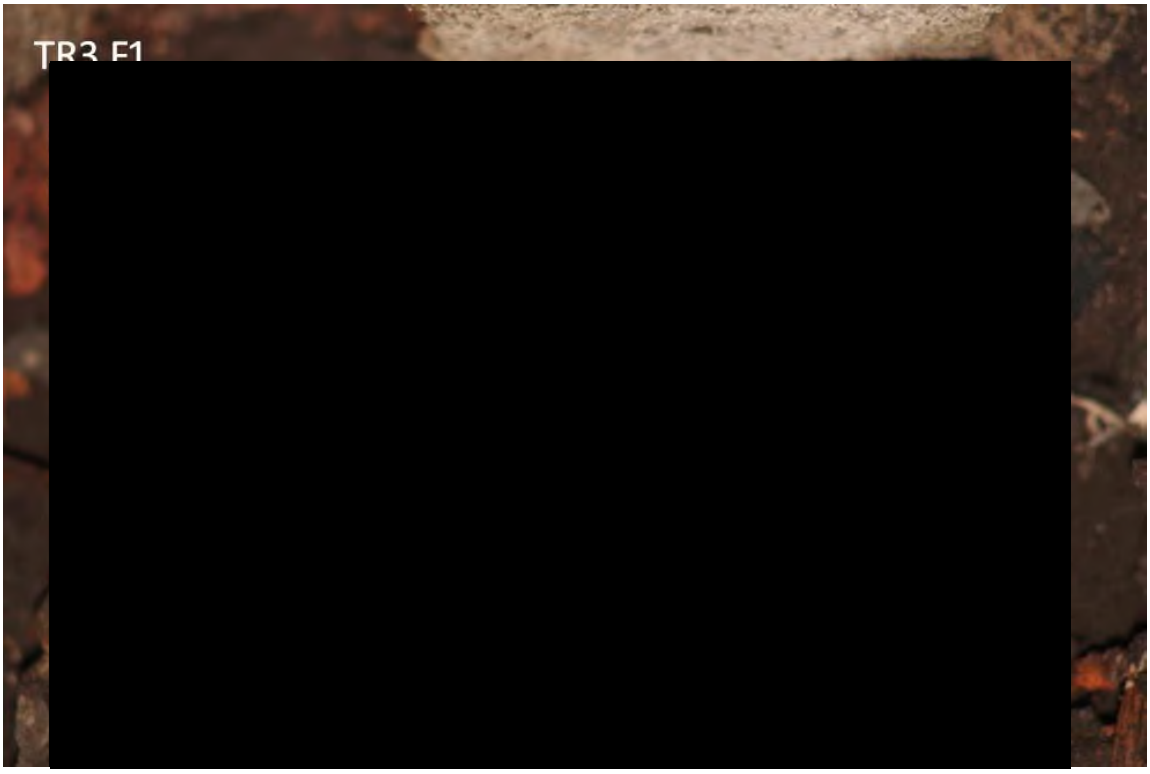


Plate 3.12: Trench 3, Feature 1, detail of infant cranial fragments (c)

Plate 3.13: Trench 3, Feature 1, detail of infant and juvenile remains (d), (e), and (f)

Plate 3.14: Trench 3, Feature 1, detail of juvenile cranium (f), showing dentition, *circa* 2-3 years old at time of death

Plate 3.15: Trench 4, Feature 1, annotated photograph of identified human remains

Plate 3.16: Trench 4, Feature 1, detail of infant bones (a)

Plate 3.17: Trench 4, Feature 1, detail of infant bones (b)

Plate 3.18: Good preservation of dental remains, TR1, C.13

Plate 3.19: Rodent gnawing on frontal bone, TR1, C.13

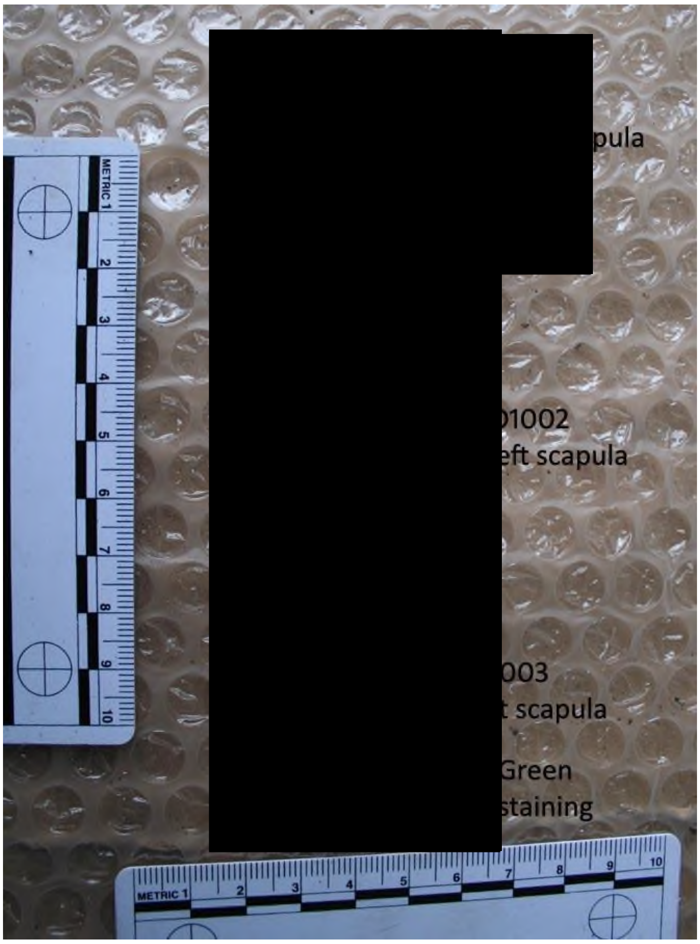


Plate 3.20: Infant scapulae and green staining, TR1, C.13

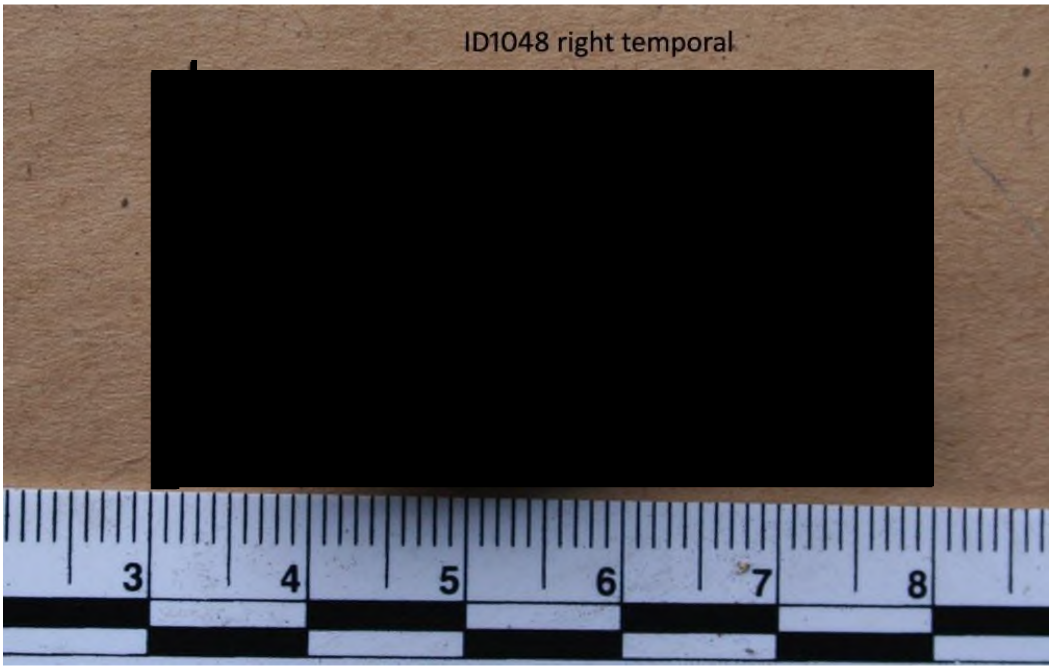


Plate 3.21: Right temporal with green staining, TR1, C.13

Plate 3.22: Copper wire *in situ*, which lead to staining of bones, TR1, C.13

Plate 3.23: Human remains within ruptured void of north wall F1A

Plate 4.1: Example of enamelled children's cup

Plate 4.2: Glass baby bottle

Plate 6.1: Sealing of chambers prior to backfilling site

Plate 6.2: Permeable membrane

Appendix IV: Figures

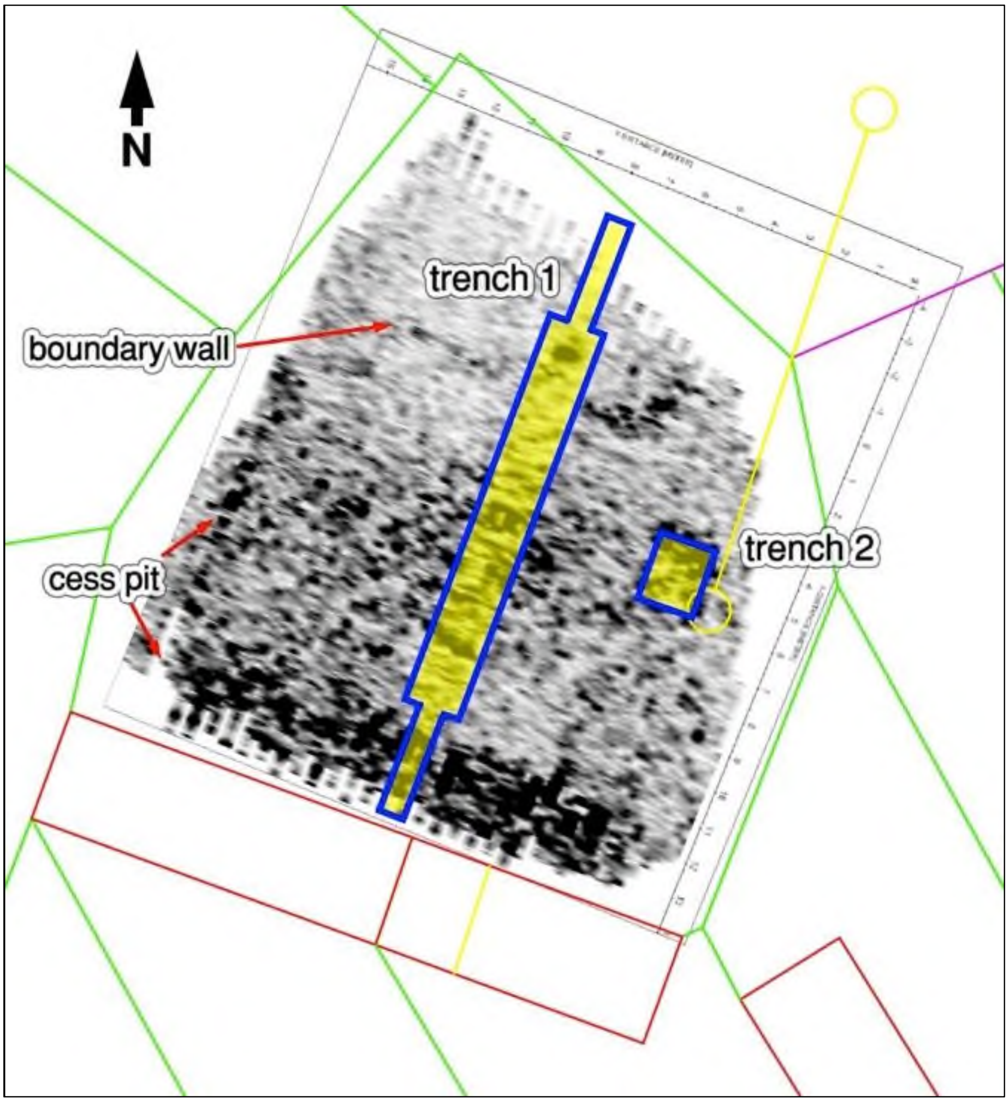


Figure 1.1: Proposed trench layout over the geophysical survey results

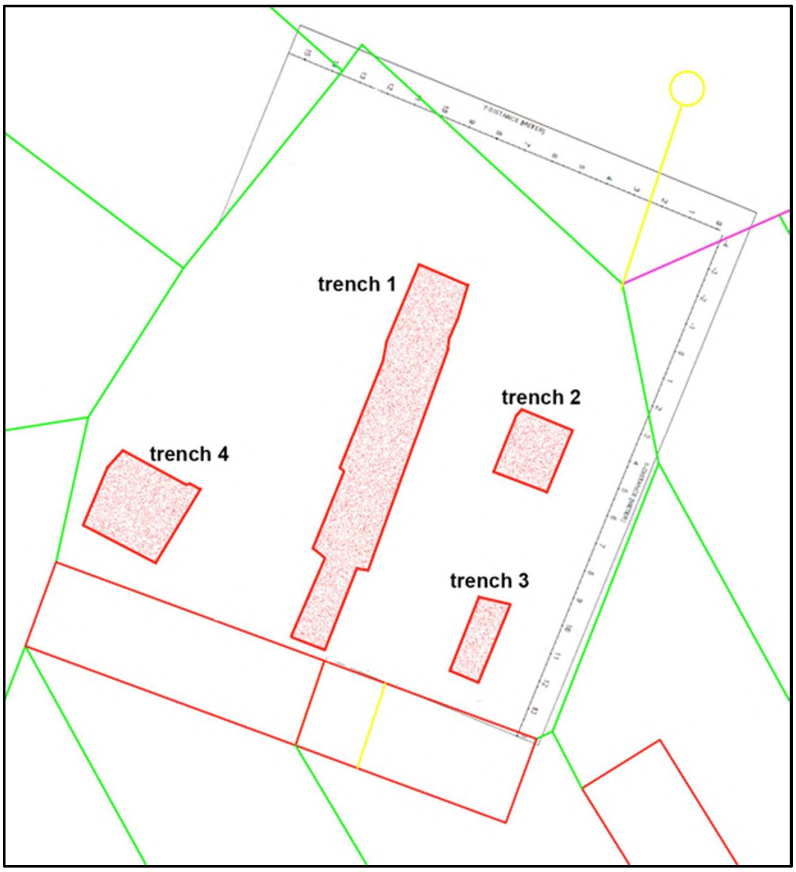


Figure 1.2: Final trench layout

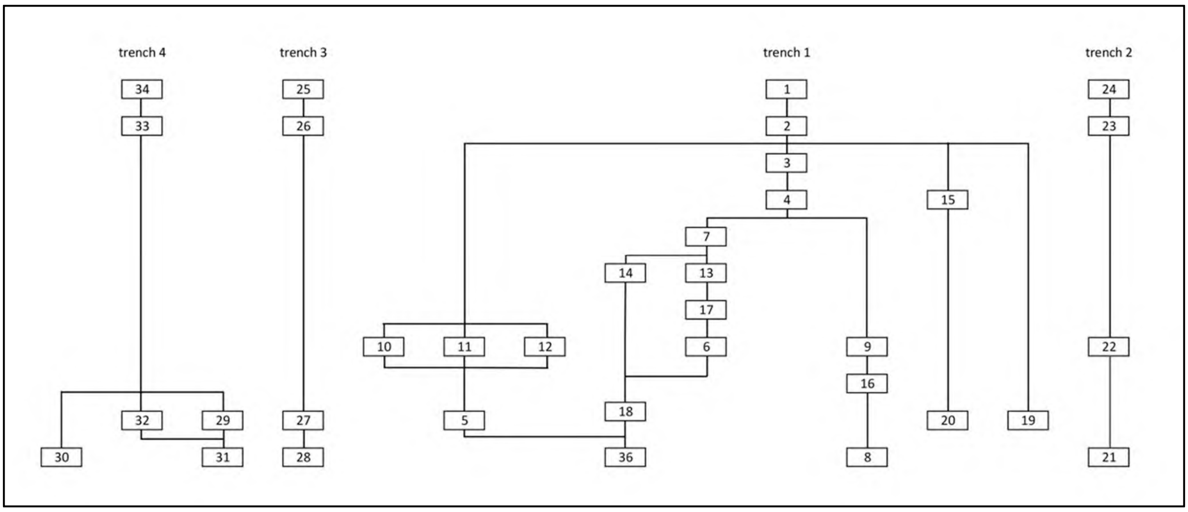


Figure 2.1: Stratigraphic Matrix for Site MBHCOI_TM1016

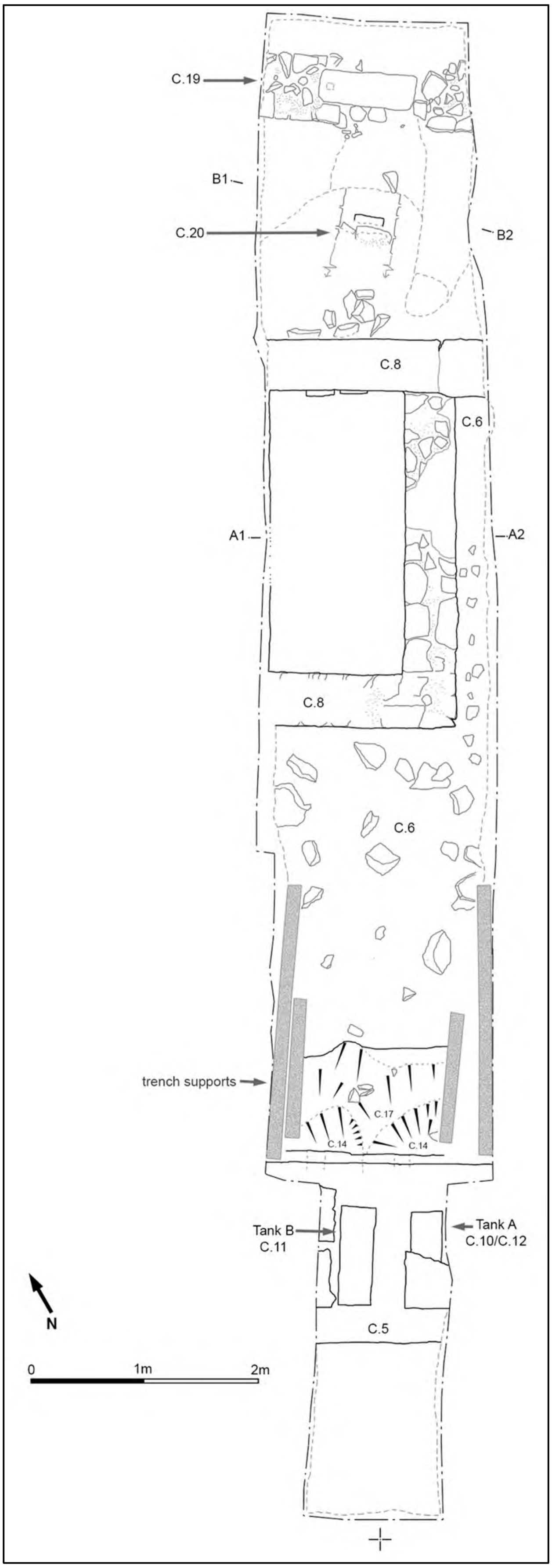


Figure 2.2: Plan drawing of results of Trench 1.

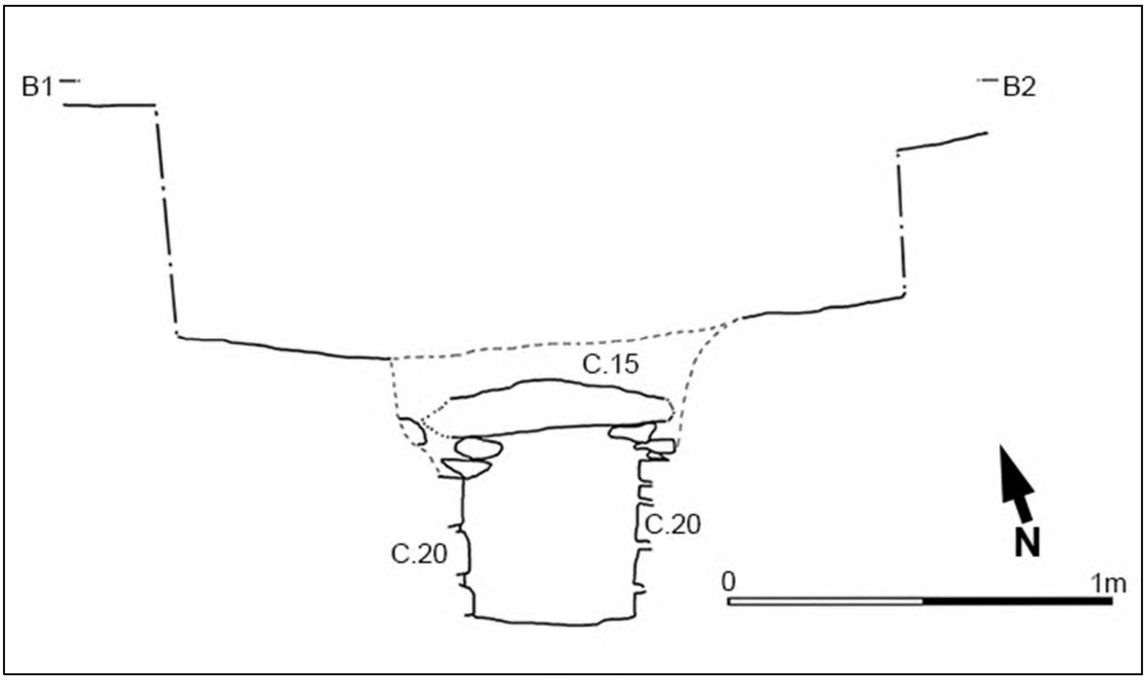


Figure 2.3: Section drawing of C.20, stone-built culvert

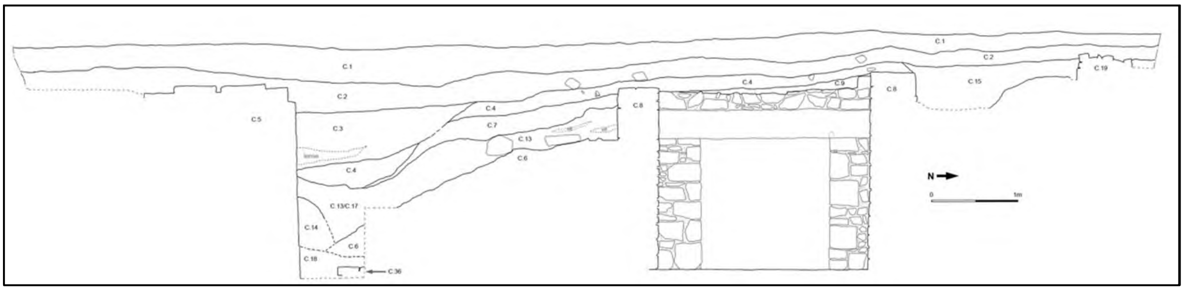


Figure 2.4: Section drawing of Trench 1

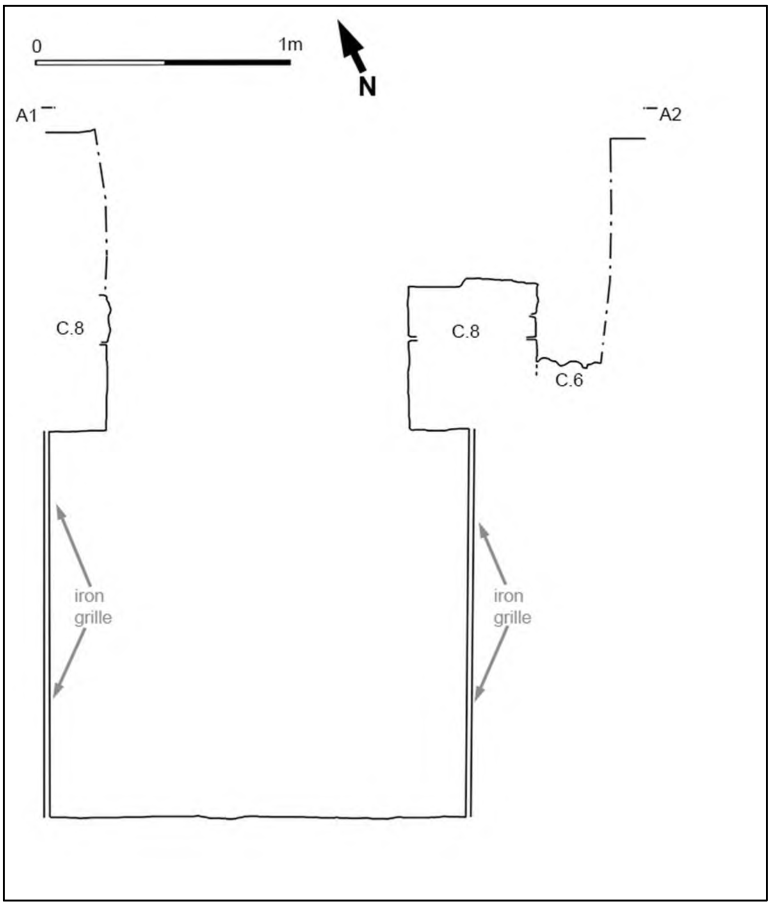


Figure 2.5: Section drawing of Feature 2

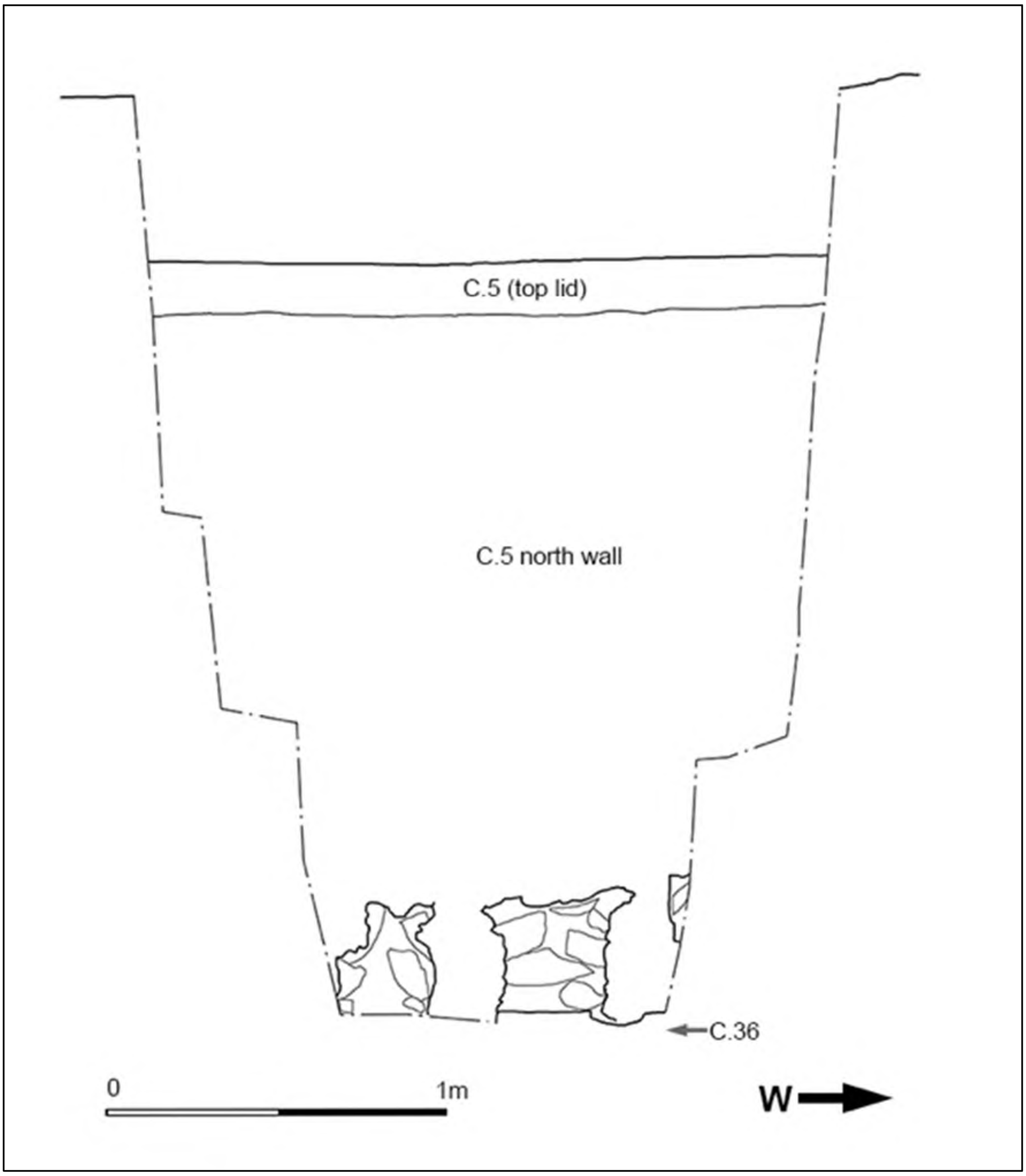


Figure 2.6: North elevation of Feature 1

Figure 2.7: Internal chambers, Feature 1A

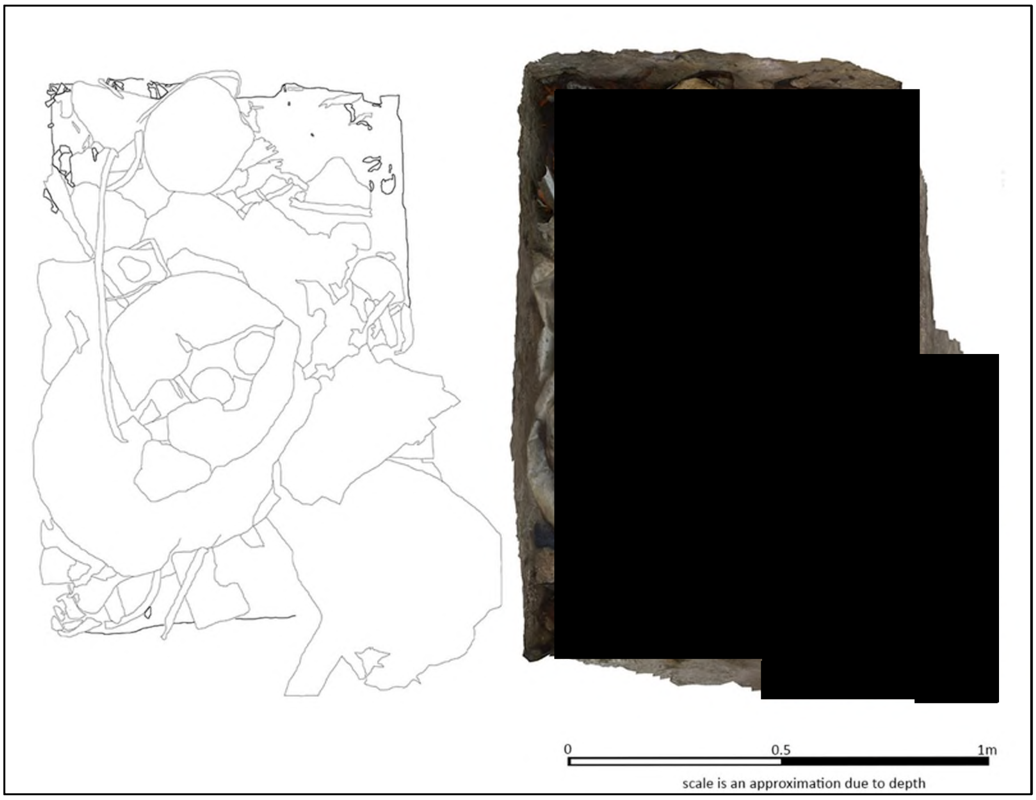


Figure 2.8: Internal chamber, Feature 1B Trench 1

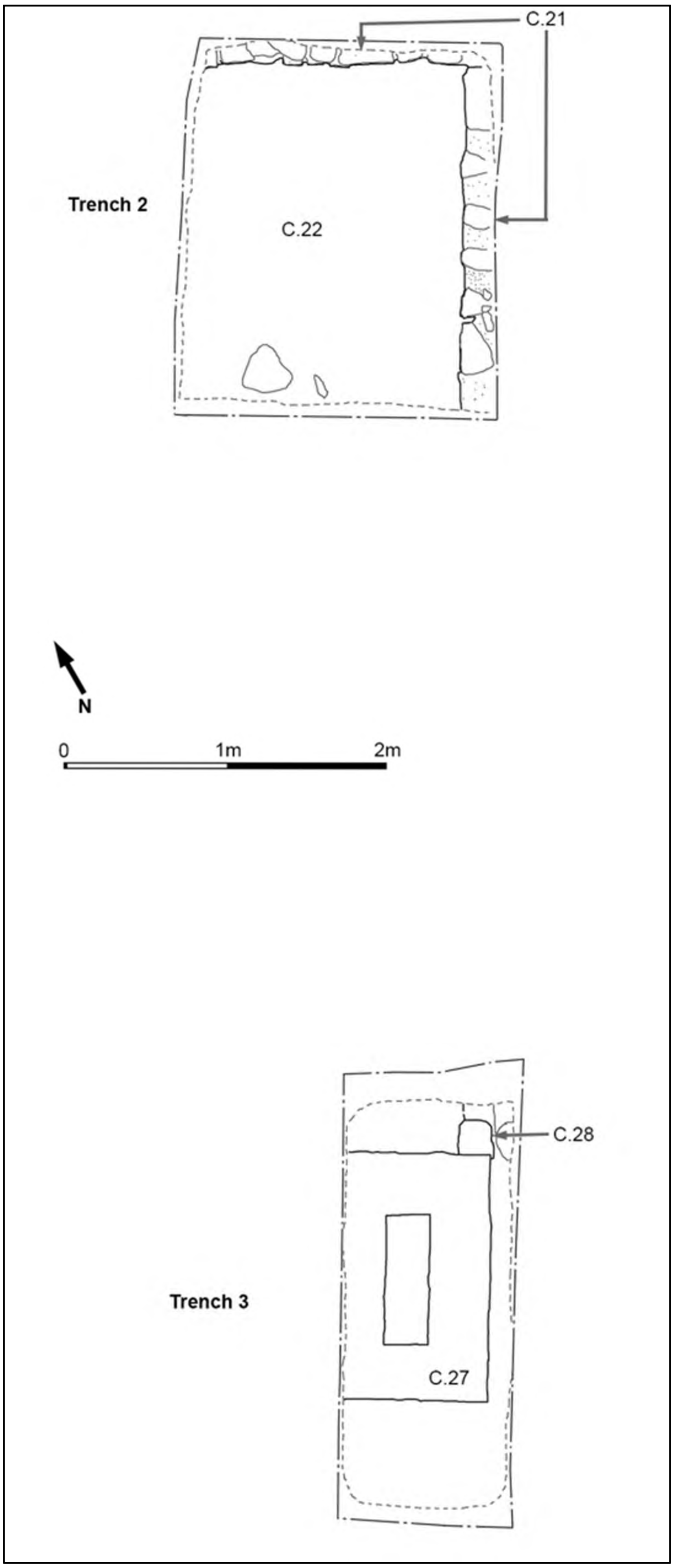


Figure 2.9: Plan drawings of Trench 2 and Trench 3

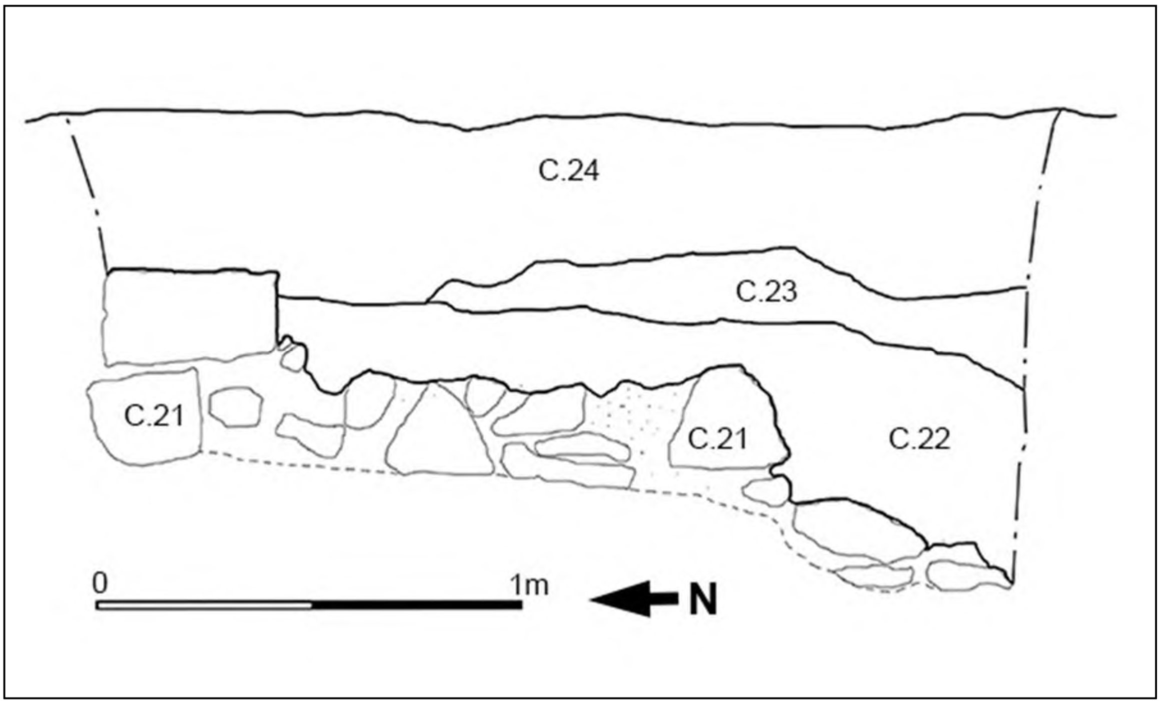


Figure 2.10: Section drawing Trench 2

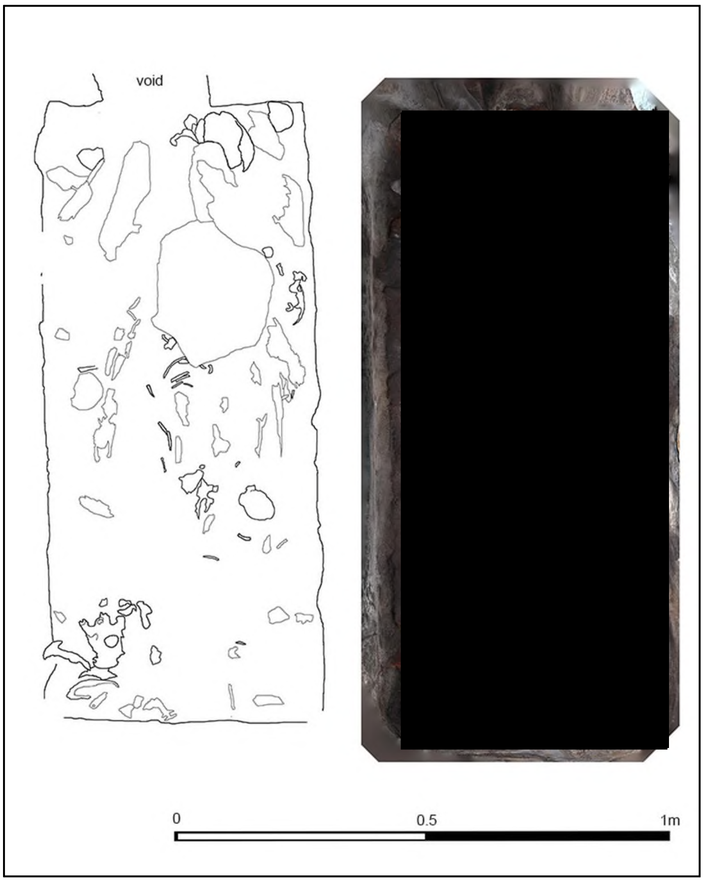


Figure 2.11: Internal chamber Feature 1 Trench 3

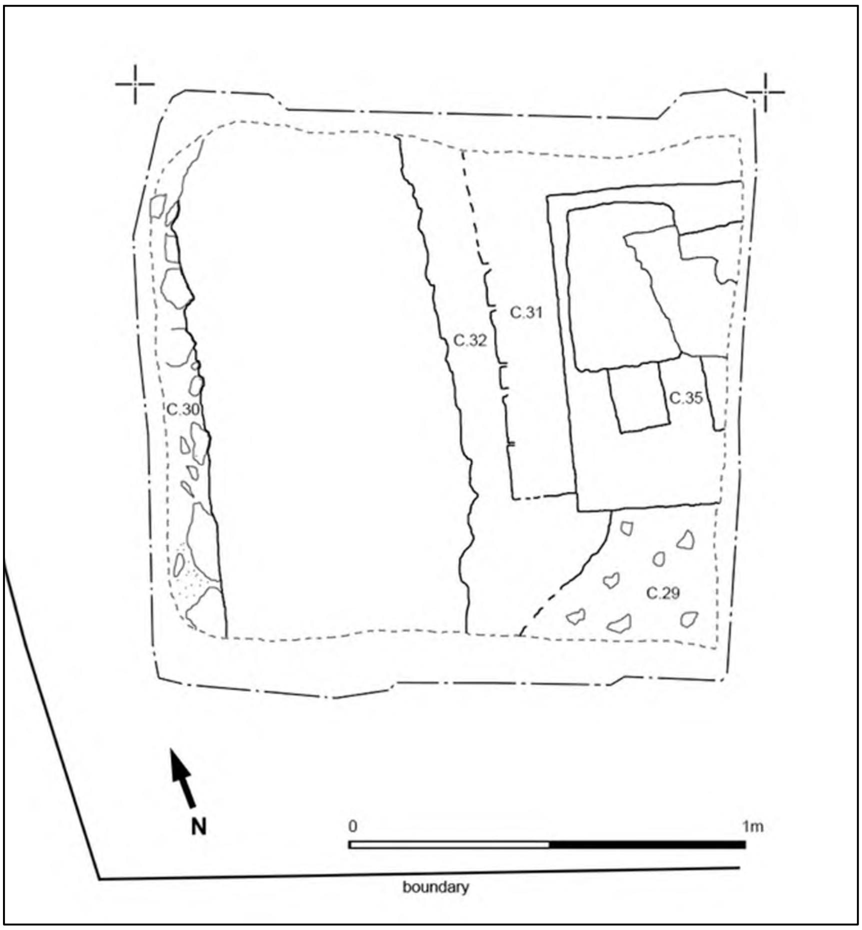


Figure 2.12: Plan drawing of Trench 4

Figure 2.1: Deposit within Trench 4 Feature 1

Appendix V: Context Register

MUNSTER ARCHAEOLOGY
Seirbhísí Seandálaíochta

Context'Register'	Sheet'No.'
Site'No.:'	1"
Site'Name:'TM1016'	

Context No.	Type	Area	Description	Plan No.	Date/ Initials
1"	Layer"	1"	Dark'brown"silt"loam,"topsoil"	2"	AH'03/10/16"
2"	Layer"	1"	Disturbed"greyish"brown"gravelly/sandy"silt,"universal"extent"	2"	AH'03/10/16"
3"	Layer"	1"	Dark"greyish"black"silt"and"stone"debris"	2"	AH'04/10/16"
4"	Layer"	1"	Mid-brownish"yellow"sandy"clay"redeposited"natural"subsoil"	2"	AH'04/10/16"
5"	Masonry"	1A"	Stone/concrete"structure"at"S"end"of"trench"1"(Feature"1,"where"F.1A"is"the"eastern" tank"and"F.1B"is"the"western"tank)"	1,"2,"8"	AH'05/10/16"
6"	Layer"	1A"	Sandy"stone"rubble"under"C.13,"equal"to"C.9"	1,"2"	AH'05/10/16"
7"	Layer"	1A"	Upper"dark"silty"layer"between"C.4"and"C.13,"abuts"C.8"	2"	AH'06/10/16"
8"	Masonry"	1B"	Mortared"Limestone"walls"of"central"rectangular"tank"(Feature"2)""	1,"2,"3"	AH'07/10/16"
9"	Fill/Deposit"	1B"	Loose"rubble,"upper"fill"within"C.8/Feature"2"	2"	AH'07/10/16"
10"	Fill/Deposit"	1A"	Fill"of"C.5,"F.1A"eastern-side"(not"excavated)"	E"	NMC'07/10/16"
11"	Fill/Deposit"	1A"	Fill"of"C.5,"F.1B"(not"excavated)"	E"	NMC'07/10/16"
12"	Fill/Deposit"	1A"	Fill"of"C.5,"F.1A"western-side"(not"excavated)"	E"	NMC'07/10/16"
13"	Layer"	1A"	Dark"orangish-brown"coarse"sand,"beneath"C.7,"south"of"C.8"	2"	AH'08/10/16"
14"	Fill/Deposit"	1A"	Grey/Brown"silt,"poss."equivalent"to"C.11/C12,"under"C.13"	1,"2"	AH'11/10/16"
15"	Fill/Deposit"	1C"	Redeposited"mottled"brown"silt"and"stone"over"southern"end"of"culvert"	1,"2,"3"	AH'13/10/16"

MUNSTER ARCHAEOLOGY

Context Register	Sheet No. 3
Site No.:	
Site Name: TM1016	

Context No.	Type	Area	Description	Plan No.	Date/ Initials
31	Masonry	4	Cess-pit wall, mortared limestone, north-south, same as C.21, C.28, C.8 north	7	AH 26/10/16
32	Fill/Deposit	4	Fill of construction trench along W side of C.31	7	AH 26/10/16
33	Layer	4	Greyish brown overburden/backfill	-	AH 26/10/16
34	Layer	4	Dark brown silt loam topsoil	-	AH 26/10/16
35	Masonry	4	Stone/concrete shuttered structure (Feature 1 western end) with opening to tank	7	AH 26/10/16
36	Masonry	1A	Possible drainage feature in brick running under C.5	1	AH 26/10/16

24	Layer	2	Dark brown silt loam, topsoil, same as C.1	5	MnC 24/10/16
25	Layer	3	Dark brown silt loam, topsoil, same as C.1 and C.24	6	MnC 24/10/16
26	Layer	3	Greyish brown sandy silt layer under C.25, equal to C.2 and C.23	6	MnC 24/10/16
27	Layer	3	Dark brownish black layer over concrete shuttering, same as C.3	6	MnC 24/10/16
28	Masonry	3	Short section of limestone wall at NE of trench 3, poss. same as C.21	4	MnC 24/10/16
29	Masonry	3	Stone/concrete shuttered structure with opening (Feature 1 eastern end)	4, 6	AH 26/10/16
30	Masonry	4	Early boundary wall footing, limestone, roughly north-south	7	AH 26/10/16

Appendix VI: Catalogue of Human Remains Recovered

MBHCOI-TM1016													
ID	Exhibit No	Feature	Context	Bone	Code	Side	Age1	Age2	Age3	Sex	Details	No of frags	Weight (g)
1001	LL012	N of F1	13	Scapula	SS	L	JUV	old inf/young juv			PM erosion to glenoid, sup + inf angle, otherwise well preserved, largest of ID1001-3	1	2.7
1002	LL012	N of F1	13	Scapula	SS	L	JUV	INF	6-12mths		complete except for tip of spine, smaller than 1001, 1/12.84, 2/8.34, 3/16.78, 4/-, 5/31.75, 6/43.34, 7/37.81, 8/16.19, 9/-, inferior glenoid to inf border 24.9	1	1.5
1003	LL012	N of F1	13	Scapula	SS	L	JUV	NEO?			PM erosion of glenoid, spine, superior angle. Smaller than 1002 Green staining posterior aspect at lateral margin, just inferior to glenoid, found with 1048	1	0.6
1004	LL012	N of F1	13	Clavicle	QC	L	JUV	INF			medial half, current L 26.9	1	0.2
1005	LL012	N of F1	13	Rib	QR	L	JUV	INF	young		x 9 left ribs, current lengths - 38.5,44.48, 36.31, 25.28, 33.58, 29.02, 38.97*, 38.32, 23.23, * possible rodent gnawing at medial end	9	2.1
1006	LL012	N of F1	13	Rib	QR	R	JUV	INF	young		x 3 right ribs, current lengths - 35.07, 28.41, 34.97	3	0.6
1007	LL012	N of F1	13	Vertebra	VL	L	INF	INF	young		x 1 left lumbar arch	1	0.2
1008	LL012	N of F1	13	Rib	QR	-	INF	INF	young		x 10 shaft fragments, current lengths 37.41, 40.73, 30.36, 32.47, 31.45, 18.03, 34.29, 17.23, 26.10, 22.05	10	1.6
1009	LL012	N of F1	13	Rib	QR	-	INF	INF	young		x 1 sternal end, current lengths 23.26	1	0.3
1010	LL012	N of F1	13	Rib	QR	-	INF	INF	young		x 6 very fragmentary shaft fragments, current lengths 18.04, 33.26, 18.49, 26.45, 20.06, 13.69	6	0.2
1011	LL012	N of F1	13	Rib	QR	L	JUV	JUV	young		x 2 left rib, almost complete except for medial ends, current lengths 104.08, 92	2	4.6
1012	LL012	N of F1	13	Rib	QR	R	JUV	JUV	young		x 1 right rib, almost complete, articulates with ID1064 from LL009 so total length is 115.61, current length 94.43	1	2.2
1013	LL012	N of F1	13	Rib	QR	-	JUV	JUV	young		x 2 shaft fragments, current lengths 33.31, 46.86	2	1.2
1014	LL012	N of F1	13	Ulna	UL	L	JUV	NEO	35.0+/- 2.2weeks		in 2 fragments, L 53.59, D 4.66	2	0.6
1015	LL012	N of F1	13	Radius	RR	L	JUV	INF	c.1.5mths		in 3 fragments, L 58.55, D 4.69	3	0.7
1016	LL012	N of F1	13	Metacarpal	YM	L	JUV	INF	neonate		1st metacarpal, L 9.38	1	0.1
1017	LL012	N of F1	13	Hip	IL	L	JUV	INF	young		complete, L 39.06 (slightly incomplete), W 33.63	1	1.2
1018	LL012	N of F1	13	Hip	IL	R	JUV	INF	6-9mths		complete, L 41.41, W 37.05	1	2.1
1019	LL012	N of F1	13	Hip	IL	L	JUV	JUV1	2-6 yrs		eroded PM at iliac crest, auricular ilium, and acetabulum, larger than 1017/8, matches 1020, incomplete but current L 63.28	1	5.8
1020	LL012	N of F1	13	Hip	IL	R	JUV	JUV1	2-6 yrs		quite incomplete, mainly acetabulum & auricular area, same size as 1019	1	2.1
1021	LL012	N of F1	13	Femur	FF	L	JUV	INF	young		just inferior to lesser tub to unfused distal metaphysis, smaller than 1022, D 6.62, current length 69.89,	1	2.4
1022	LL012	N of F1	13	Femur	FF	R	JUV	INF	older		lesser troc to just superior to popliteal area, larger than 1021, D 7.97, current length 81.59	1	2.1
1023	LL012	N of F1	13	Tibia	TT	L	JUV	JUV1	young		PM erosion at proximal & distal metaphyses, rodent gnawing just inferior to midshaft, D 10.3, current length 98.75	1	6.3
1024	LL012	N of F1	13	Unidentified	??						x 2 possible long bone fragments	2	0.4
1025	LL012	N of F1	13	Clavicle	QC	R	JUV	JUV1	young		ends eroded PM, medial end slightly expanded, current L 58.44	1	1.5
1026	LL012	N of F1	13	Vertebra	VC		JUV	JUV1	2-4 yrs		complete cervical arch, neural fused, unfused to body, between C3-5?	1	0.9
1027	LL012	N of F1	13	Humerus	HH	R	JUV	INF	1.5-3 mths		complete, L 78.58, D 6.46, W 20.73	1	2.8
1028	LL012	N of F1	13	Humerus	HH	R	JUV	INF	young		ends eroded PM, almost same size of 1027, D 6.35, current length 73.29	1	1.7
1029	LL012	N of F1	13	Mandible	MM	L	JUV	INF	0-3 mths		body L 36.04, total L 51.54, W 1918, contains 1030-1034, weight includes teeth	1	1.9
1030	LL012	N of F1	13	Tooth	E1	L	JUV	INF	0-3 mths		unerupted lower deciduous I1 in 1029	1	
1031	LL012	N of F1	13	Tooth	E2	L	JUV	INF	0-3 mths		unerupted lower deciduous I2 in 1029	1	

ID	Exhibit No	Feature	Context	Bone	Code	Side	Age1	Age2	Age3	Sex	Details	No of frags	Weight (g)
1032	LL012	N of F1	13	Tooth	E3	L	JUV	INF	0-3 mths		unerupted lower deciduous C in 1029	1	
1033	LL012	N of F1	13	Tooth	E4	L	JUV	INF	0-3 mths		unerupted lower deciduous M1 in 1029, Coc	1	
1034	LL012	N of F1	13	Tooth	E5	L	JUV	INF	0-3 mths		unerupted lower deciduous M2 in 1029	1	
1035	LL012	N of F1	13	Maxilla	XX	L	JUV	JUV1	2-3 yrs		PM erosion, matches 1040, contains 1036-9, weight includes teeth	1	5.5
1036	LL012	N of F1	13	Tooth	D4	L	JUV	JUV1	2-3 yrs		erupted upper deciduous M1, in 1035, slight calculus buccal aspect	1	
1037	LL012	N of F1	13	Tooth	D5	L	JUV	JUV1	2-3 yrs		erupted upper deciduous M2, in 1035, slight calculus buccal aspect	1	
1038	LL012	N of F1	13	Tooth	X6	L	JUV	JUV1	2-3 yrs		unerupted upper permanent M1, Crc, associated with 1035?	1	
1039	LL012	N of F1	13	Tooth	X1	L	JUV	JUV1	2-3 yrs		unerupted upper permanent I1, Crc, associated with 1035?	1	
1040	LL012	N of F1	13	Maxilla	XX	R	JUV	JUV1	2-3 yrs		incomplete, matches 1035, contains/assoc. 1041-4, weight includes teeth	1	5
1041	LL012	N of F1	13	Tooth	D4	R	JUV	JUV1	2-3 yrs		erupted upper deciduous M1 in 1040	1	
1042	LL012	N of F1	13	Tooth	D5	R	JUV	JUV1	2-3 yrs		erupted upper deciduous M2 in 1040	1	
1043	LL012	N of F1	13	Tooth	X6	R	JUV	JUV1	2-3 yrs		unerupted upper permanent M1, loose but probably associated w/1040	1	
1044	LL012	N of F1	13	Tooth	X1	R	JUV	JUV1	2-3 yrs		unerupted upper permanent I1, loose but probably associated w/1040	1	
1045	LL012	N of F1	13	Maxilla	XX	R	JUV	JUV1	1-2 yrs		almost complete, contains 1046-7, 4/40.73, weight includes teeth	1	4.2
1046	LL012	N of F1	13	Tooth	D4	R	JUV	JUV1	1-2 yrs		erupted upper deciduous M1, in 1045	1	
1047	LL012	N of F1	13	Tooth	D5	R	JUV	JUV1	1-2 yrs		erupting upper deciduous M2, in 1045	1	
1048	LL012	N of F1	13	Cranial	CT	R	JUV	INF	0-5 mths		petrous portion, fossa, & zygomatic process, L43.28, green staining on endocranial of superior aspect, for adjacent to 1003 copper alloy wire in between the two, tympanic ring fused but a little of Stage B	2	3.2
1049	LL012	N of F1	13	Cranial	CF	R	JUV	INF	young		right orbit & vault fragment, possible rodent gnawing at metopic suture	1	1.6
1050	LL012	N of F1	13	Cranial	CX		JUV	INF	young		x 41 vault fragments	41	9
1051	LL012	N of F1	13	Cranial	CX		JUV	INF	neonate?		x 4 vault fragments	4	2.1
1052	LL012	N of F1	13	Cranial	CX		JUV	INF	young		1 vault fragment, possible right frontal at anterior fontanelle	1	1.6
1053	LL012	N of F1	13	Unidentified	??	R	JUV	INF	INF/JUV1		x 5 irregular fragments of possible infant bones	5	0.9
1054	LL012	N of F1	13	Rib	QR	R	JUV	JUV	JUV		possibly 12th rib?	1	0.3
1055	LL012	N of F1	13	Auditory	AM	R	JUV	JUV	JUV		right malleus	1	0.1
1056	LL014	void into F1A	14	Metatarsal	ZM	R	JUV	INF	young		MT1 complete, L 16.37	1	0.4
1057	LL014	void into F1A	14	Tarsal	ZA	R	JUV	INF	young		talus, 12.39 long, 8.65 wide but slightly incomplete	1	0.2
1058	LL007	F1Bi W	11	Foot phalanx	ZP		JUV	INF	young		1st distal foot phalanx, 5.58mm in length, closely associated with LL005	1	0.1
1059	LL008	N of void to F1B	14	Vertebra	VT		JUV	JUV2	2-5 yrs		thoracic arch, possibly T3/4, associated with LL009/1064, neural fused body open	1	1
1060	LL011	sondage by F1B	13	Humerus	HH	L	JUV	INF			shaft only, eroded at ends, similar to 1078 but larger, deltoid to superior to olecranon fossa, D 6.57, current length 52.84	1	1.2
1061	LL011	sondage by F1B	13	Rib	QR	L	JUV	INF			left rib shaft, current length 43.45	1	0.3
1062	LL011	sondage by F1B	13	Ulna	UP	L	JUV	INF			proximal 1/4, current length 21.6, certainly infant but not a neonate	1	0.4
1063	LL011	sondage by F1B	13	Femur	FF	R	JUV	INF			inferior to lesser trochanter to superior to popliteal area, D 7.38, current length 36.02, distal half broken into 3	4	1.5
1064	LL009	N of void to F1B	14	Rib	QR	R	JUV	JUV1			sternal rib end, assoc. with 1059, matches directly with 1012/LL012, current length 42.94	1	0.6
1065	LL013	N of F1	14	Ulna	UP	R	JUV	JUV1?			shaft fragment inferior to ulnar tuberosity area to midshaft, D 7.86, current length 49.5	1	1.6
1066	LL013	N of F1	14	Scapula	SA	L	JUV	INF			unfused acromion head	1	0.1

ID	Exhibit No	Feature	Context	Bone	Code	Side	Age1	Age2	Age3	Sex	Details	No of frags	Weight (g)
1067	LL013	N of F1	14	Vertebra	VT		JUV	JUV1			unfused body, either the inferior or superior surface is eroded post-mortem	1	0.4
1068	LL013	N of F1	14	Rib	QR	L	JUV	JUV1			1 left rib, lateral end and head incomplete, current length 81.84	1	1.7
1069	LL013	N of F1	14	Rib	QR	L	JUV	JUV1			ends incomplete, current length 112.81, rodent gnawing at medial end	2	3.2
1070	LL013	N of F1	14	Rib	QR	R	JUV	JUV1			lateral end incomplete, current length 81.39	1	2.2
1071	LL013	N of F1	14	Rib	QR	R	JUV	JUV1			medial end of ?2nd rib, current length 28.31, rodent gnawing at lateral end	1	0.5
1072	LL013	N of F1	14	Rib	QR		JUV	JUV1			x 3 sternal ends, possible rodent gnawing at medial end visceral surface, current lengths 51.63, 34.92, 16.82	3	1.4
1073	LL013	N of F1	14	Rib	QR		JUV				x 2 possible rib shaft fragments	2	0.3
1074	LL013	N of F1	14	Hip	IL		JUV	INF?			fragment of possible iliac body	1	0.3
1075	LL013	N of F1	14	Rib	QR	R	JUV	INF?			medial end, head broken, current length 22.42	1	0.1
1076	LL015		14	Scapula	SS	L	JUV	INF	young		glenoid, superior, & medial borders fragmented PM, inferior glenoid to inferior tip 23.85	1	0.7
1077	LL015		14	Scapula	SS	R	JUV	INF	young		blade and fragment of lateral border, glenoid and all of medial half broken PM	2	0.5
1078	LL015		14	Humerus	HH	R	JUV	INF	young		proximal metaphysis broken PM, D 5.94, W 18.79, current length 66.57	1	1.7
1079	LL015		14	Rib	QR	R	JUV	INF			ends slightly incomplete PM, 1st rib, current length 28.21	1	0.3
1080	LL015		14	Rib	QR	R	JUV	INF			rib, possibly 3rd, current length 34.77	1	0.3
1081	LL015		14	Rib	QR	R	JUV	INF	young		rib, possibly 11th, current length 25.57, may be accidentally contaminated with oil	1	0.1
1082	LL015		14	Rib	QR	R	JUV	INF			sternal rib end, current length 30.48	1	0.2
1083	LL015		14	Maxilla	XX	L	JUV	INF	c.38-40wks		nasal spine and palatine incomplete, 2/23.28, no teeth present	1	0.7
1084	LL015		14	Fibula	BM		JUV	INF			possible shaft fragment, current length 27.61	1	0.3
1085	LL015		14	Radius	RP	R	JUV	INF			radial tuberosity to midshaft, rodent gnawing posterior of medial border near midshaft, current length 24.96	1	0.3
1086	LL015		14	Clavicle	QC	L	JUV	INF			midshaft fragment	1	0.2
1087	LL010	interface F1A & c13	13	Radius	RR	L	JUV	INF			minus distal metaphysis, D 4.22, present length 44.92	2	0.5
1088	LL017		1/2	Rib	QR	L	JUV	INF	young		sternal end of maybe 4th/5th rib, current length 39.14	1	0.3
1089	LL018		33	Femur	FP	L	JUV	INF	NEO/PERI		proximal metaphysis slightly incomplete PM, present to superior to popliteal area, D 4.96, current length 37.39	1	1.4
1090	LL001	F1Aii NW corner		Femur	FF	L	JUV	INF	c. 1.5 mths		complete and well preserved, L 85.54, D 7.26, W 23.02	1	3.4
1091	LL002	F1Aii NW corner		Cranial	CT	L	JUV	INF	0-6 mths		complete and well preserved	1	5.1
1092	LL003	F1Aii NW corner		Cranial	CP	R	JUV	INF	0-6 mths		complete and well preserved, chord H93.94 W81.12, arc H110 W92	1	8.8
1093	LL004	F1Bii NW	11	Cranial	CT	L	JUV	INF	6-12 mths		complete and well preserved	1	22.5
1094	LL005	F1Bi W	11	Cranial	CP	R	JUV	INF	6-12 mths		complete and well preserved, chord H100.45 W97.9, arch H124 W112, directly associated w/LL007/1058	1	13.1
1095	LL006	F1Bi W	11	Ulna	UU	L	JUV	INF	3-6 mths		slightly incomplete, L 72.15, D 5.28	1	1

Appendix VII: List of Artefacts

Trench	Number	Material	Type	Context	Description	INT	Date
1B	42	glass	bottle	2	1 oz Bovril bottle - complete	MNíC	14/10/2016
1B	43	glass	bottles?	2	glass sherds x7 (probably from bottles). 1x white piece - appears to be base of small rectangular bottle	MNíC	14/10/2016
1B	44	plastic	various	2	various moder plastic pieces: 1x packaging (?) The rest (x6) not v.identifiable but possibly from various containers	MNíC	14/10/2016
1B	45	fabric	clothing	2	fabric x3: possibly from socks/shirts	MNíC	14/10/2016
1B	46	ceramic	glazed	2	7x white glazed sherds - mostly crockery, 2x base pieces, 1x rim piece	MNíC	14/10/2016
1B	47	ceramic	glazed	2	3x glazed pattern pieces: 1x green,white and orange 2x brown glaze	MNíC	14/10/2016
1B	48	plastic	buttons	2	small white plastic button - modern?	MNíC	14/10/2016
1B	49	metal	various	2	various metal pieces x7 - wiring, piping and remains of metal can, v.corroded	MNíC	14/10/2016
1A	11	clay	pipes	4	clay pipe stem	MNíC	13/10/2016
1B	145	ceramic	glazed	4	2x white glaze, green glaze x1 (floor tile?)	MNíC	27/10/2016
1B	146	glass	bottle	4	7x green glass fragments, 1x green bottle rim, 5x clear glass fragments - 1 piece has "Pasteur" written on the side, probably from a milk bottle - 1x white glass	MNíC	27/10/2016
1B	147	glass	bottle	4	1x large almost complete clear bottle, 1x possible medical/pharmacy bottle - sub-rectangular in shape	MNíC	27/10/2016
1B	148	clay	pottery	4	terracotta fragment from large pot/pipe	MNíC	27/10/2016
1B	149	clay	pipes	4	clay pipe bowl	MNíC	27/10/2016
1B	150	plastic	packaging	4	"Captain Crisps" packet, Shellx100 motor oil bottle	MNíC	27/10/2016
1B	151	plastic	packaging	4	Southalls Towel packet (sanitary products)	MNíC	27/10/2016
1B	152	ceramic		4	top of bed post?	MNíC	27/10/2016
1A	1	glass	bottle	6	baby bottle w/ made in Germany stamp & oz/tblsp measurement on each side	MNíC	13/10/2016
1A	2	glass	bottle	6	bottle w/ phoenix emblem - "John Egan&Son Sligo Ballina & Tuam" on side	MNíC	13/10/2016
1A	3	glass	bottle	6	bottles x 2 w/ no discernible stamp	MNíC	13/10/2016
1A	4	glass	bottle	6	pharmacy (?) bottles x7 - 1x screwtop which looks quite modern - 2x slender bottles which look corked, 1x bottle top/glass stopper, 1x vial, 2x bottle ends	MNíC	13/10/2016
1A	5	clay	pipes	6	clay pipe stems x2, 1 w/ stamp on side but letters not discernible, other appears to have gnaw marks	MNíC	13/10/2016
1A	6	metal	enamel	6	enamel jug v.corroded	MNíC	13/10/2016
1A	7	metal	enamel	6	enamel plate -blue stamp on underside :"foreign"	MNíC	13/10/2016
1A	8	metal	enamel	6	enamel cup w/ "made in Czechoslovakia" on underside	MNíC	13/10/2016
1A	9	metal	enamel?	6	brown cup, v.corroded possibly enamelled	MNíC	13/10/2016
1A	10	various	miscellaneous	6	various objects -1x ceramic jar, 2x roof slates, 1x brick fragment "conc---" written on side, bucket handle, brick (?) frags x 2	MNíC	13/10/2016
1A	12	various	miscellaneous	6	plastic ties,green wire,fabric (sock?),crisp packet "King crisps", battery	MNíC	13/10/2016
1A	13	metal	various	6	metal plate? Possible hinge off door, 2x metal straps, 3x corroded/indistinguishable pieces	MNíC	13/10/2016
1A	14	metal	ballistics	2	2x bullets	MNíC	13/10/2016
1A	15	metal	nails	6	3x nails - carpentry?	MNíC	13/10/2016
1A	16	ceramic	glazed	6	white glazed x10 - mix of crockery frags and possible ramekin fragment, 1x blue willow pattern	MNíC	13/10/2016
1A	17	ceramic	glazed	6	4x brown glazed sherds	MNíC	13/10/2016
1A	18	stone	jar?	6	1x earthenware fragment, possibly from jug/bottle	MNíC	13/10/2016
!C	221	plastic	tray	6	ice cube tray	MNíC	27/10/2016
1C	222	leather	clothing	6	heel of a shoe	MNíC	27/10/2016
1C	223	metal	spoon	6	complete spoon	MNíC	27/10/2016
1C	224	metal	knob/handle	6	doorknob/handle?	MNíC	27/10/2016
1C	225	glass	bottle	6	"Power's" whiskey bottle (small)	MNíC	27/10/2016
1C	226	glass	bottles/jars	6	4x clear glass, 1x black, 1x green sherd	MNíC	27/10/2016
1C	227	clay	pipes	6	clay pipe bowl	MNíC	27/10/2016
1C	228	metal	lead	6	lead pipe x2	MNíC	27/10/2016
1C	229	metal	FE	6	corroded gutter/pipe	MNíC	27/10/2016
1C	230	metal	nails	6	nails x4	MNíC	27/10/2016
1C	231	ceramic	glazed	6	7x white glaze	MNíC	27/10/2016
1C	232	stone	pipes	6	pipe fragments x5	MNíC	27/10/2016
1C	233	miscellaneous		6	stone curbing? 1x metal band	MNíC	27/10/2016
1B	153	metal	nails	7	corroded metal nails of various sizes x22	MNíC	27/10/2016
1B	154	glass	bottles	7	12x clear glass sherds including 2x bottle/jar tops with indecipherable writing, 1x blue sherd, 2x green sherd, 1x brown sherd	MNíC	27/10/2016
1B	155	glass	bottles	7	6x small bottles: 1x brown glass; 1x clear bottle w/"Swan Ink" written on underside of one, 1x small screwtop bottle w/liquid inside, 1x bottle w/"Yeastmite" written on side	MNíC	27/10/2016

1B	65	glass	bottle	9	bottles x5 - almost complete: 3x brown glass, 1x blue glass, 1x green. "H.G. HOTCHKISS LYONS N.Y." written on base of blue bottle. "IGB 102 L 8" on base of green bottle. Brown bottle could be medicinal?	MNíC	20/10/2016
1B	66	glass	bottle/jar	9	mix of bottle necks and bases: 14x bases 3x necks. Only one screwtop w/lid still attached, triangular base w/ "D.D. Co.Ltd Reg No.746048" on underside. Rectangular bottle/jar w/ 8oz.on base, 1x rounded clear base w/ "NO MANUFACTURER WAY" on side w/ "RBB (?) 645" on underside	MNíC	20/10/2016
1B	67	glass	bottle	9	mixed glass fragments: 24x clear, 4x green, 1x blue, 1x brown - "Virols" written in cursive script on the side	MNíC	20/10/2016
1B	68	clay	pipes	9	1x pipe stem	MNíC	20/10/2016
1B	69	rubber?		9	rubber/foam from mattress?	MNíC	20/10/2016
1B	70	plastic?	bead	9	small orange plastic bead	MNíC	20/10/2016
1B	71	metal	battery	9	small corroded rectangular battery	MNíC	20/10/2016
1B	72	plastic	miscellaneous	9	plastic fragments - from packaging?	MNíC	20/10/2016
1B	73	fabric	miscellaneous	9	2x stripey blue fragment pieces - from mattress cover ? + small buckle. 1x yellow/black fabric pieces	MNíC	20/10/2016
1B	74	metal	FE	9	pot lid?	MNíC	20/10/2016
1B	75	ceramic		9	castor for furniture/stove?	MNíC	20/10/2016
1B	76	ceramic	glazed	9	coloured/patterned ceramics: 2x pink sherds, 3x blue willow pattern 3x fruit patterned, 1x brown glaze and 1x yellow/green glaze. Probably broken crockery	MNíC	20/10/2016
1B	77	ceramic	glazed	9	white glazed ceramics - mostly broken crockery x29, 1x cup piece "Jackson + Gosling Longton Made in England"	MNíC	20/10/2016
1B	78	ceramic	glazed	9	earthenware/ceramic sherds x13 cream/beige in colour "LIVERPOOL" stamped on base of one piece	MNíC	20/10/2016
1B	79	ceramic	glazed	9	brown glaze sherds x12 - mixed pieces most likely from pots/jugs, could possibly be stonewear pieces? 3 pieces appear to be from same vessel - yellowish brown in colour. 6x mix of rim and handle pieces, 1x possible pot lid, 1x bottle fragment	MNíC	20/10/2016
1B	80	ceramic	glazed	9	1x bottle	MNíC	20/10/2016
1B	81	ceramic	glazed	9	white ceramics x8 - large pieces, may be from sinks/toilets/other washroom related furniture	MNíC	20/10/2016
1B	82	stone?	painted/treated	9	possible floor tiles x4: 3x green, 1x brown	MNíC	20/10/2016
1B	156	glass	bottles	7	16oz.Bovril bottle	MNíC	27/10/2016
1B	157	glass		7	small white glass sphere w/metal hook - earring/bauble?	MNíC	27/10/2016
1B	158	metal	FE	7	corroded spoon	MNíC	27/10/2016
1B	159	clay	pipes	7	clay pipe bowls x2 - 1 w/partial stem and stand	MNíC	27/10/2016
1B	160	ceramic	glazed	7	5x white glazed, 2x willow pattern 3x green glaze, 3x brown glaze - most likely broken crockery fragments	MNíC	27/10/2016
1B	161	bone	worked	7	bone button	MNíC	27/10/2016
1B	162	metal	tin	7	corroded Club Orange drink can	MNíC	27/10/2016
1B	163	stone	slate	7	roof slate?	MNíC	27/10/2016
1B	164	clay	pottery	7	terracotta fragment from large pot/pipe x2	MNíC	27/10/2016
1B	165	plastic	miscellaneous	7	plastic casing, plastic wrapper, reflector light	MNíC	27/10/2016
1B	166	plastic	spoon	7	plastic spoon - probably for formula, "water scoop" written on handle w/ "Tru Foods" on underside	MNíC	27/10/2016
1B	167	plastic		7	2x decorative plastic pieces, look like fleur de lis	MNíC	27/10/2016
1B	50	metal	scissors	9	possible surgical/sewing scissors, v.corroded	MNíC	20/10/2016
1B	51	metal	shovel	9	shovel blades x2 : 1x possible spade (still has nail and partial haft attached)	MNíC	20/10/2016
1B	52	metal	lid	9	"HP" lid - probably from jar	MNíC	20/10/2016
1B	53	leather	clothing	9	shoes x3 - heel and sole of shoes/boots - could possibly be female based on the size	MNíC	20/10/2016
1B	54	wood		9	wood fragment with paint on it, possibly from furniture	MNíC	20/10/2016
1B	55	plastic	comb	9	blue plastic comb fragment (some teeth missing)	MNíC	20/10/2016
1B	56	plastic	packaging	9	plastic bottle w/ "Developing lotion" written on side (for hair dye?). Milk packet from "Rinkippen Dairy, Dublin Road, Tuam" - no obvious best before date	MNíC	20/10/2016
1B	57	metal	FE	9	corroded section of fireplace surround	MNíC	20/10/2016
1B	58	metal	FE	9	wheel lever for pipes?	MNíC	20/10/2016
1B	59	metal	FE	9	possible cast iron piece, maybe from fireplace/candle stick holder?	MNíC	20/10/2016
1B	60	stone	tile?	9	stone tile/flooring? X3	MNíC	20/10/2016
1B	61	glass	bottle	9	2x 16 oz.Bovril bottles, "I C B 417 2" on underside	MNíC	20/10/2016
1B	62	glass	bottle	9	clear glass screw top bottle - possibly "HP" bottle?	MNíC	20/10/2016
1B	63	glass	vial	9	medical vial w/rubber seal on top - for innoculation?	MNíC	20/10/2016
1B	64	glass	bottle	9	blue glass bottle/jar, rectangular in shape - "AKEN" written on one side	MNíC	20/10/2016

1B	83	metal	enamel	9	chamber pots x12. Varying in size but all white enamel w/ blue handles (where they survived). No obvious writing/stamps	MNíC	20/10/2016
1B	84	metal	plated	9	small metal spoon with some possible paint on	MNíC	20/10/2016
1B	85	stone	pot	9	possible paint pot - "Best Before 31st December 1932 (?) written on underside	MNíC	20/10/2016
1B	86	metal	copper alloy	9	metal fork w/some tines missing	MNíC	20/10/2016
1B	87	ceramic	glazed	9	pink and white china cup	MNíC	20/10/2016
1B	88	metal	enamel	9	plates x9 (relatively complete), 4x plate fragments. 1 plate has green "fleur de lis" (?) design around rim. 1 smaller plate has "foreign" written on underside and 1x small bowl	MNíC	20/10/2016
1B	89	metal	enamel	9	3x white enamel jugs - 2 have fl oz.scale on the inside	MNíC	20/10/2016
1B	90	metal	enamel	9	3x children's cups. Blue enamel with "Mary had a little lamb" rhyme written on side of cup w/ pic of girl and lamb	MNíC	20/10/2016
1B	91	metal	enamel	9	cups x10 : white enamel x7, 1x green enamel - no obvious writing/stamps	MNíC	20/10/2016
1B	92	metal	aluminium	9	pint can - "Swan Brand Made in England" stamp on bottom, probably flask/billy can	MNíC	20/10/2016
1B	93	metal	enamel	9	pots?x2 : 1x blue, 1x black	MNíC	20/10/2016
1B	94	metal	enamel	9	scraps x14 probably from larger bowls/basins - difficult to determine because of corrosion, handles x6	MNíC	20/10/2016
1B	95	metal	wires	9	barbed wire	MNíC	20/10/2016
1B	96	metal	lead	9	lead pipe	MNíC	20/10/2016
1B	97	clay	brick	9	brick fragment	MNíC	20/10/2016
1B	98	clay	terracotta?	9	pipe/pot fragments x4	MNíC	20/10/2016
1B	99	bone	worked	9	drop spindle? - oblong worked bone w/ treaded piece at the top	MNíC	21/10/2016
1B	100	metal	FE	9	door locks x2 - larger one is most likely for external door, keyhole quite large and thick panelling	MNíC	21/10/2016
1B	101	metal	FE	9	kettles x7: none are complete and are quite corroded; 4x handles, 1x lid, 2x bodies 1 of which still has handle attached	MNíC	21/10/2016
1B	102	metal	FE	9	window frame pieces x5: quite heavy, most likely C19th (workhouse era)	MNíC	21/10/2016
1B	103	metal	FE	9	fireplace pieces x9 - heavy cast iron, decorated but corroded	MNíC	21/10/2016
1B	104	metal	FE	9	metal guttering x3, corroded	MNíC	21/10/2016
1B	105	metal	FE	9	gardening equipment? Spade blade, teeth from a rake, and possible whet stone	MNíC	21/10/2016
1B	106	metal	FE	9	horse bit (?)	MNíC	21/10/2016

1B	107	metal	FE	9	door furniture (?) : 2x hinges, 1x handle	MNíC	21/10/2016
1B	108	metal	FE	9	ventilation grate?	MNíC	21/10/2016
1B	109	metal	cable	9	electricity cable? - thin wires surrounded by a thicker metal casing	MNíC	21/10/2016
1B	110	metal	FE	9	buckets/coal skuttles x4 - very corroded, only rim and handles survived	MNíC	21/10/2016
1B	111	metal	FE	9	pieces of frames from beds/other furniture x31 - very corroded, is possible that some larger pieces may belong to freestanding sinks/baths	MNíC	21/10/2016
1B	112	metal	tin	9	cans x9: 1x aerosol can with label partially survivng, but too difficult to discern; 1x formula tin, 1x paint can, 4x corroded cans	MNíC	21/10/2016
1B	113	metal	FE	9	small basin/bath - very corroded	MNíC	21/10/2016
1B	114	metal	FE	9	frame from larger basin/freestanding bath	MNíC	21/10/2016
1B	115	metal	FE	9	cast iron piece possibly from a gate/fence	MNíC	21/10/2016
1B	116	porcelain?		9	2x fragments from a sink/other bathroom furniture - quite thick and curved w/white glaze	MNíC	21/10/2016
1B	117	clay		9	pipe fragments x3	MNíC	21/10/2016
1B	118	metal	FE	9	various scra metal pieces: grating x5; 1x lead pipe, metal rods x5, metal bands x6 (from barrels?),	MNíC	21/10/2016
1B	119	metal	FE	9	large metal piece - possibly from machinery	MNíC	21/10/2016
1A	19	metal	padlock	13	rusted padlock, quite corroded, difficult to discern any date	MNíC	14/10/2016
1A	20	metal	FE	13	triangular shaped metal w/loop on top - possibly used to cover key/peephole	MNíC	14/10/2016
1A	21	metal	FE	13	corroded metal bauble w/ hole on top	MNíC	14/10/2016
1A	22	metal	wires	13	various nails/bolts quite corroded x23	MNíC	14/10/2016
1A	24	metal	can	13	corroded metal can/tin, possibly for paint?	MNíC	14/10/2016
1A	25	metal	various	13	various scrap metal pieces x12 - some look like metal pannelling?	MNíC	14/10/2016
1A	26	metal	FE	13	spanner/ratchet?	MNíC	14/10/2016
1A	27	metal	FE	13	pipes x4, guttering/shoring x4 - v.corroded	MNíC	14/10/2016
1A	28	ceramic	glazed	13	white glazed most likely crockery x15 - 2x cup (?) bases have "foreign made" stamp	MNíC	14/10/2016
1A	29	ceramic	patterned	13	2x willow pattern, 1x pink pattern, 1x brown pattern	MNíC	14/10/2016
1A	30	ceramic	glazed	13	1x green glaze sherd	MNíC	14/10/2016
1A	31	ceramic	glazed	13	4x brown glazed sherds: 1x spout/rim sherd, 1x handle sherd 2x plate/bowl sherds	MNíC	14/10/2016
1A	32	stone	jar?	13	stone/earthenware? Sherdsx 4 - possibly from large jars/pots	MNíC	14/10/2016
1A	33	clay	pipes	13	1x stem fragment, 3x bowl fragments	MNíC	14/10/2016

1A	34	plastic	comb	13	luminous orange comb fragment	MNíC	14/10/2016
1A	35	mixed	buttons	13	3x "pearly" buttons, 1x bone	MNíC	14/10/2016
1A	36	plastic	miscellaneous	13	5x plastic	MNíC	14/10/2016
1A	37	glass	bottle	13	screw top bottle "I C (?) E 386 A" written on underside	MNíC	14/10/2016
1A	38	glass	jar	13	jar x2: 1x complete (not screw top) "F+ C" on underside w/serial number (?) 016. 1x incomplete w/ "D.D. & Co. A510" on underside	MNíC	14/10/2016
1A	39	glass	bottle	13	fragmented blue glass bottle w/ cork in spout	MNíC	14/10/2016
1A	40	glass	bottle	13	various bottle fragments x15 +1 possible window frag?	MNíC	14/10/2016
1A	41	glass	bottle	13	2x bottle tops, 5x jar/bottle bases - 1 appears to be another "F+C" bottle. 1x " I C R 8 oz." on underside	MNíC	14/10/2016
1B	182	metal	various	13	handle x1, pipe frag x1, bucket/basin rim x1, wire x1	MNíC	27/10/2016
1B	183	plastic		13	wire casing	MNíC	27/10/2016
1B	184	glass	vase/bowl	13	clear glass sherd from large vessel	MNíC	27/10/2016
1B	185	glass	bottle	13	pharmacy bottle? Spade (from card suit) on underside	MNíC	27/10/2016
1B	186	metal	copper alloy	13	small ring (child's?)	MNíC	27/10/2016
1B	187	metal	nails	13	corroded nails of various size x42	MNíC	27/10/2016
1B	188	metal	various	13	wires x12, 1x wash	MNíC	27/10/2016
1B	189	metal	various	13	unknown scraps x 15, pipe w/copper wiring running through	MNíC	27/10/2016
1A	190	lead	pipes	13	lead pipe	MNíC	27/10/2016
1A	191	ceramic	glazed	13	9x white glaze, 1x green glaze sherd	MNíC	27/10/2016
1A	192	clay	pipes	13	clay pipe bowl	MNíC	27/10/2016
1A	193	plastic	buttons	13	small white plastic button - modern?	MNíC	27/10/2016
1A	194	metal	packaging	13	foil/metal from a tin?	MNíC	27/10/2016
1A	195	clay	pot	13	terracotta base fragment	MNíC	27/10/2016
1A	196	glass	bottles/jars	13	35x clear glass, 1x green sherd, 1x red glass, 1x blue glass, 2x clear glass bottle rims	MNíC	27/10/2016
1A	255	metal		13	safety pin found in association w/ H.R	MNíC	28/10/2016
1A	256	fabric		13	pieces of fabric found in association w/ H.R	MNíC	28/10/2016
1A	257	glass		13	semi-spherical piece (from doll's eye?) found in association w/ H.R	MNíC	28/10/2016
1A	258	plastic		13	formula spoon to N.of feature 1 - "Tru Food" written on underside	MNíC	28/10/2016
1A	197	metal	nails	14	corroded nails of various size	MNíC	27/10/2016
1A	198	metal	various	14	gutter/pipe x1, grate x1, pipe x1, hook x1	MNíC	27/10/2016
1A	199	metal	various	14	bottle/hot water bottle top, keyhole cover, metal washes x2? (corroded)	MNíC	27/10/2016
1A	200	carbon	battery	14	battery cell from car battery?	MNíC	27/10/2016
1A	201	metal	copper alloy	14	copper alloy wires	MNíC	27/10/2016
1A	202	cramp		14	cramp from fire	MNíC	27/10/2016
1A	203	metal	various	14	various corroded metal pieces x12	MNíC	27/10/2016
1A	204	glass	bottle	14	"Evan Williams" bourbon bottle 1oz.	MNíC	27/10/2016
1A	205	glass	bottle	14	complete bottle x2: 1x possible pharmacy bottle	MNíC	27/10/2016
`1A	206	glass	light?	14	possible signal light - bright orange	MNíC	27/10/2016
1A	207	glass	bottles/jars	14	clear glass sherds x 56, red glass x1, blue glass x 1, 3x bottle rims	MNíC	27/10/2016
1A	208	various		14	glass bottle stop x1 (?) pink plastic fragment x1, clay bottle stop/marble, 1x wire casing,	MNíC	27/10/2016
1A	209	wood		14	wood fragments x2	MNíC	27/10/2016
1A	210	material	clothing	14	sock/shirt piece	MNíC	27/10/2016
1A	211	plastic	buttons	14	buttons x2	MNíC	27/10/2016
1A	212	plastic	bead	14	3x beads	MNíC	27/10/2016
1A	213	metal	bead	14	small circular beads/eyes for fasteners? X3	MNíC	27/10/2016
1A	214	ceramic	glazed	14	1x brown glaze jug piece, 13x white glaze, 1x blue willow pattern	MNíC	27/10/2016
1A	215	clay	terracotta?	14	3x terracotta pot fragments	MNíC	27/10/2016
1B	120	leather	clothing	16	heel and sole of shoe, possibly female	MNíC	21/10/2016
1B	121	metal	enamel	16	children cups x10: 1x complete; 9x smaller pieces	MNíC	21/10/2016
1B	122	ceramic	glazed	16	4x white glazed sherds, 1x pink glaze, 1x half teacup	MNíC	21/10/2016
1B	123	ceramic	glazed	16	brown glazed rim from pot/bowl? + 1x small brown glaze sherd	MNíC	21/10/2016
1B	124	plastic	bottle	16	white plastic container - could be old vaseline/ointment pot	MNíC	21/10/2016
1B	125	bone	handle	16	bone handle from small brush/tooth brush	MNíC	21/10/2016
1B	126	plastic	comb	16	small comb - broken w/ some teeth missing	MNíC	21/10/2016
1B	127	metal	clip?	16	possible hair clip, but appears to be incomplete	MNíC	21/10/2016
1B	128	plastic	packaging	16	3x plastic packaging pieces	MNíC	21/10/2016
1B	129	ceramic		16	3x pieces from a sink/bath	MNíC	21/10/2016
1B	130	metal	nails	16	7x small nails, 2x large nails - very corroded, possibly for carpentry	MNíC	21/10/2016
1B	131	metal	FE	16	grate from fireplace	MNíC	21/10/2016
1B	132	metal	FE	16	metal pipe, quite corroded	MNíC	21/10/2016
1B	133	metal	FE	16	metal wires x6, 2x guttering, 1x small chain and hook (possibly for hanging basket?)	MNíC	21/10/2016
1B	134	metal	FE	16	bucket w/ cement inside	MNíC	21/10/2016
1B	135	metal	enamel	16	1x small chamber pot - probably for a child, 10x chamber pot/bowl fragments x10 (most are white enamel, but one pot is blue enamelled)	MNíC	21/10/2016

1B	136	metal	tin	16	2x paint cans (?), 1x blue enamelled can, 1x formula tin	MNíC	21/10/2016
1B	137	miscellaneous		16	possible pieces from bedroom furniture - bed frame piece, leg from chair/bed, and possible handle fragment	MNíC	21/10/2016
1B	138	wood	post	16	possible wooden post - very soft and degraded	MNíC	21/10/2016
1B	139	metal	FE	16	strap? With piece of concrete attached	MNíC	21/10/2016
1B	140	glass	bottle	16	fragmented 16oz.Bovril bottle	MNíC	21/10/2016
1B	141	glass	bottle	16	bottle tops x5, 2x jar rims	MNíC	21/10/2016
1B	142	glass	bottle	16	bottle end pieces x10 w/ no obvious writing/stamps on them	MNíC	21/10/2016
1B	143	glass	bottle	16	7x green fragments, 18x clear glass fragments	MNíC	21/10/2016
1B	144	clay	brick	16	2x brick fragments	MNíC	21/10/2016
1A	216	glass	bottle	18	Milk of Magnesia bottle	MNíC	27/10/2016
1A	217	glass	bottles	18	1x brown shard, 1x clear	MNíC	27/10/2016
1A	218	metal	wires	18	wires x3	MNíC	27/10/2016
1A	219	clay	brick	18	brick fragments x2	MNíC	27/10/2016
1A	220	stone	slate	18	roof slate x2	MNíC	27/10/2016
2	234	metal	FE	22	hinge	MNíC	27/10/2016
2	235	metal	FE	22	band from around guttering	MNíC	27/10/2016
2	236	metal	tin	22	base from an oil lamp	MNíC	27/10/2016
2	237	glass	bottles	22	bottles x4 : 2x pharmacy bottles - 1x clear, 1x brown - "Young's" beer bottle (?), 1x small clear bottle, 2x clear glass fragments 1x broken bottle	MNíC	27/10/2016
2	238	ceramic	glazed	22	2x white glaze, 1x brown glaze from mixing bowl	MNíC	27/10/2016
2	239	plastic	packaging	22	1x top off washing up liquid bottle, 1x plastic wrapper	MNíC	27/10/2016
2	240	metal	FE	22	large padlock, for external door?	MNíC	27/10/2016
2	241	metal	can	22	large oil can - very corroded	MNíC	28/10/2016
2	242	metal	enamel	22	large enamel basin	MNíC	28/10/2016
2	243	metal	pipes	22	corroded pipe fragment	MNíC	28/10/2016
2	244	metal	FE	22	possible bed frame	MNíC	28/10/2016
2	245	metal	enamel	22	small enamel/tin saucepan	MNíC	28/10/2016
2	246	ceramic		22	basin/sink fragment	MNíC	28/10/2016
3	247	metal	various	25	spring from bed?, metal rim	MNíC	28/10/2016
3	248	rubber?	hose	25	rubber hose from bicycle pump	MNíC	28/10/2016
3	249	plastic		25	plastic casing	MNíC	28/10/2016
3	250	glass	bottles	25	3x bottle ends - possibly from medical/pharmacy bottles - "Silvikrin" written on side of one. Larger fragment of bottle has stamp ---"OODALL" (Goodall?)	MNíC	28/10/2016
4	251	metal	coin	33	1p piece dated 1971	MNíC	28/10/2016
4	252	metal	copper alloy	33	belt buckle?	MNíC	28/10/2016
4	253	ceramic	glazed	33	base of white glazed plate	MNíC	28/10/2016
4	254	glass	bottles	33	brown glass bottle w/ screwtop. Liquid still inside - "Redbreast 12 years" on bottle top	MNíC	28/10/2016
4	259	plastic	tag	33	tag with "clinistix" written on it - medical?	MNíC	28/10/2016
1A	260	plastic		1./2	plastic casing	MNíC	28/10/2016
1B	168	ceramic	glazed	8.east	3x white glaze, 1x white plate sherd has "Made in England H&K Tunst--" on underside	MNíC	27/10/2016
1B	169	glass	bottles	8.east	glass sherds x3	MNíC	27/10/2016
1B	170	metal	various	8.east	metal pieces x7 - mix of nails and various scraps	MNíC	27/10/2016
1B	171	ceramic	glazed	8.west	1x white glaze piece, 1x terracotta piece	MNíC	27/10/2016
1B	172	glass	bottles	8.west	bottle top	MNíC	27/10/2016
1B	173	metal	foil	8.west	5x foil pieces	MNíC	27/10/2016
1B	174	charcoal		8.west	1x large charcoal fragment	MNíC	27/10/2016
1B	176	glass	bottles	9 extra	clear sherds x10, 1x Schweppes bottle end, 1x wine glass stem, 3x brown bottle sherds, 2x green sherds	MNíC	27/10/2016
1B	177	metal	FE	9 extra	cast iron piece possibly from fireplace	MNíC	27/10/2016
1B	178	metal	FE	9 extra	guttering fragment, ratched/spanner, corded wire	MNíC	27/10/2016
1B	179	ceramic	glazed	9 extra	jug top x1, 2x white glazed sherds	MNíC	27/10/2016
1B	180	ceramic		9 extra	sink/bath fragment	MNíC	27/10/2016
1B	181	clay		9 extra	terracotta pipe/pot pieces x2	MNíC	27/10/2016
1B	175				snail shell	MNíC	27/10/2016

Appendix VIII: Radiocarbon Dating Report

Radiocarbon Dating Report to the Mother and Baby Homes Commission of Investigation

Author: Professor Gordon T Cook

Date: 3rd November 2016

INTRODUCTION

This report relates to the radiocarbon dating of 6 infant bone samples (see Plates 1-6 below) submitted to the SUERC Radiocarbon Dating Laboratory by Aidan Harte on the 12th October 2016, on behalf of the Mother and Baby Homes Commission of Investigation in Ireland. The remains are from the reported 'Children's Burial Ground' related to St Mary's Mother and Baby Home at Tuam, Co. Galway. This Home operated between 1925 and 1961 and occupied a former Union Workhouse that was operational from around 1846 until 1916. There have been remains discovered associated with this workhouse in previous excavations c.100 m from the current location. However, the remains associated with the workhouse time frame were more formally buried than the 6 samples submitted to the laboratory.

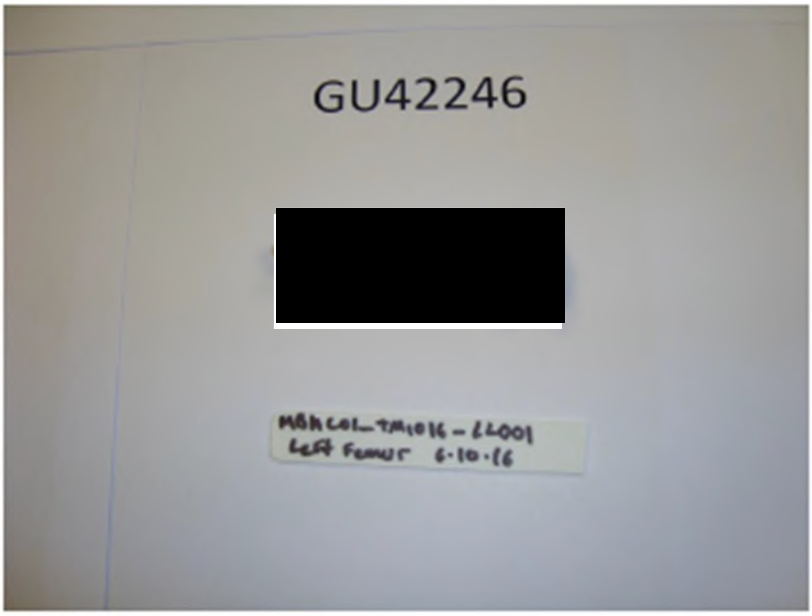


Plate 1: Left femur (Sample LL001) from an infant around 1.5 months of age. Our Laboratory Ref: GU-42246. Our Analysis Ref: SUERC-69881.

Plate 2: Left temporal bone (Sample LL002) from an infant around 0-6 months of age. Our Laboratory Ref: GU-42247. Our Analysis Ref: SUERC-69882.

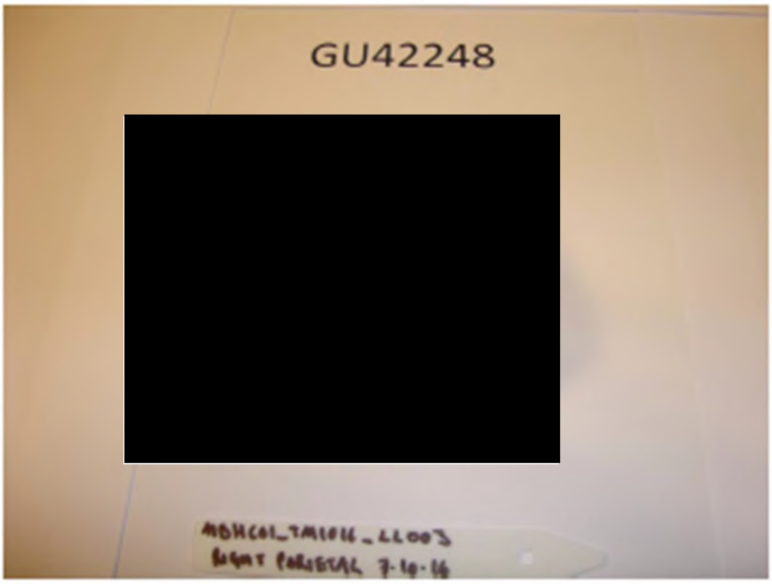


Plate 3: Right parietal bone (Sample LL003) from an infant less than 6 months of age. Our Laboratory Ref: GU-42248. Our Analysis Ref: SUERC-69883.

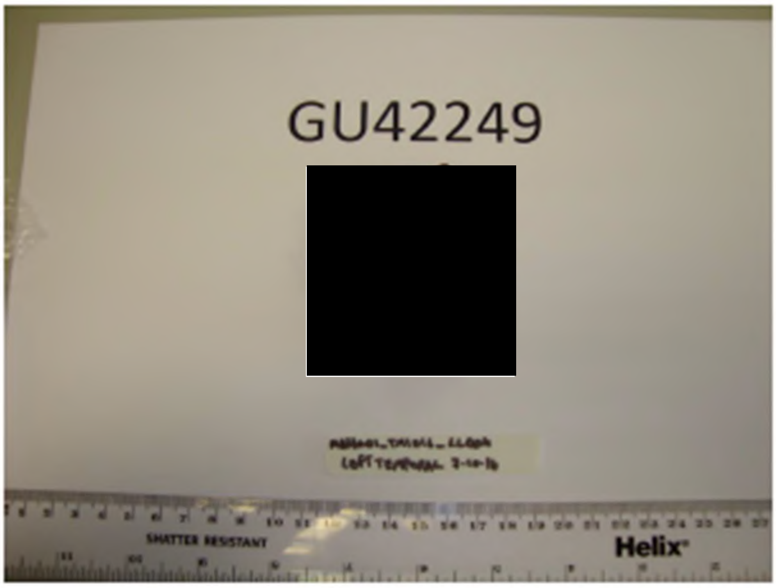


Plate 4: Left temporal bone (Sample LL004) from an infant of between 6 and 12 months age. Our Laboratory Ref: GU-42249. Our Analysis Ref: SUERC-69884.

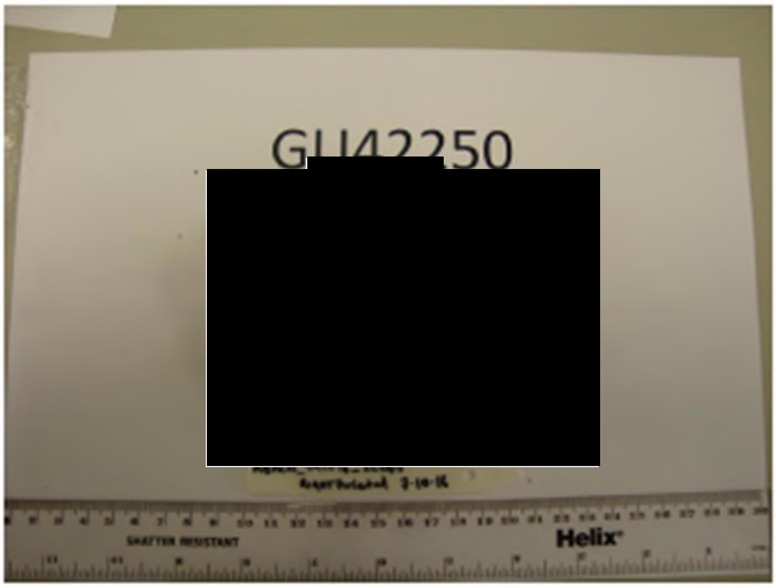


Plate 5: Right parietal bone (Sample LL005) from an infant of between 6 and 12 months age. Our Laboratory Ref: GU-42250. Our Analysis Ref: SUERC-69885.

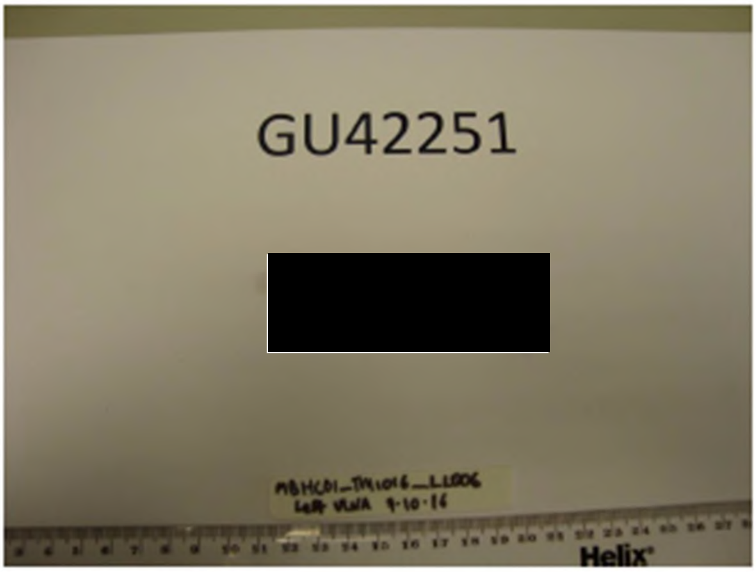


Plate 6: Left ulna (Sample LL006) from an infant of between 3 and 6 months age. Our Laboratory Ref: GU-42251. Our Analysis Ref: SUERC-69886.

BASIC RADIOCARBON PRINCIPLES AND ASSUMPTIONS IN THE METHOD

Radiocarbon, or ^{14}C, is cosmogenic, *i.e.* it is produced as a result of cosmic activity. The primary cosmic radiation is predominantly high energy protons (up to 10^{18} eV), which interact with atmospheric gases producing neutrons, protons, α-particles, *etc*. The neutrons are thermalised and captured by atmospheric nitrogen in the upper atmosphere, resulting in ^{14}C production by the following reaction:

$$^{14}N(n,p)^{14}C$$

^{14}C is radioactive and decays by β^- decay (E_{max} = 156 keV) back to ^{14}N. The physical half-life is 5730 years. The Libby half-life, which is used to calculate radiocarbon ages, is 5568 years. The natural rate of production is not constant, but is subject to short-term (century scale) and long-term (millennia scale) fluctuations. The short-term fluctuations are usually attributed to heliomagnetic modulation of the primary cosmic-ray flux (Stuiver 1961; Damon *et al.* 1989), *i.e.* changes in the solar sunspot activity where periods of high activity result in decreased cosmic ray incidence on the earth and hence a reduced ^{14}C production rate. The longer term fluctuations are attributed to geomagnetic modulation, *i.e.* the charged cosmic rays which create ^{14}C are deflected to a greater or lesser degree depending on the earth's dipole moment (Elsasser *et al.* 1956; Sternberg 1992). The ^{14}C produced in the upper atmosphere is rapidly oxidised to $^{14}CO_2$, which mixes with the stable CO_2 ($^{13}CO_2$ and ^{12}CO), resulting in an atom ratio for the three isotopes of approximately:

$$\begin{array}{ccccc} ^{12}C & : & ^{13}C & : & ^{14}C \\ 10^{12} & : & 10^{10} & : & 1 \end{array}$$

With the onset of the Industrial Revolution came man's first significant perturbation of the natural ^{14}C/stable carbon ratios in the environment. The massive burning of fossil fuels which, because of their age, contain no ^{14}C has resulted in the release of only stable CO_2 to the atmosphere ($^{12}CO_2$ and $^{13}CO_2$), thereby diluting the $^{14}CO_2$ activity (Suess 1953, 1955). This dilution, commonly known as the Suess Effect, was measurable in post-1890AD tree rings and by 1950AD the atmospheric activity was reduced by about 2% and 3% in the southern and northern hemispheres, respectively. The consequence of this from a radiocarbon dating viewpoint is that it is not possible to distinguish between a sample (organism) that died in the 17th century and whose activity has undergone around 300 years of decay and a sample that formed during the period 1890 to 1950 whose activity is influenced by the Suess Effect.

From the early 1950s came the onset of major programmes of atmospheric nuclear weapons testing which caused a significant increase in the atmospheric concentration of ^{14}C such that by 1963 the activity in the northern hemisphere was approximately double the natural level (Figure 1). However, following a test ban treaty, the atmospheric concentration has continuously decreased from around 1963/64 onwards as the excess $^{14}CO_2$ has been taken up by the oceans and the biota.

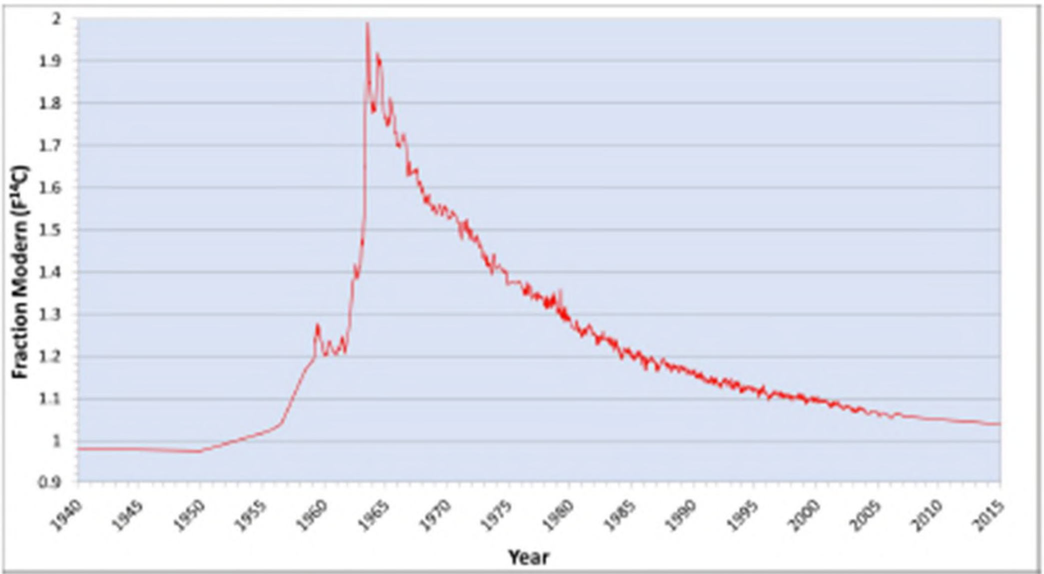


Figure 1: Atmospheric ^{14}C activity in the N Hemisphere during the period 1950–2015

Regardless of the route of formation, ^{14}C becomes incorporated into the food chain via photosynthesis by the primary producers, according to the following reaction.

$$6CO_2 + 6H_2O \xrightarrow[\text{Photosynthetic pigments}]{\text{Light}} C_6H_{12}O_6 + 6O_2$$

Subsequent transfer through the food chain results in radioactive labelling of all living organisms.

$$\text{Plant carbohydrates} \xrightarrow{\text{Transfer through food chain}} \text{Animal life}$$

N.B. As a consequence of atmospheric nuclear weapons testing, any short-lived sample that has a fraction modern value greater than 1 must have been alive after 1955 (see Figure 1). However, a problem arises when dealing with human bone. The dateable fraction is a protein termed collagen (see below) which, particularly in adults, turns over relatively slowly (Hedges et al. 2007). Consequently, it is not the ^{14}C within bone collagen formed during the year of death that is measured but an integration of collagen from formation and turnover processes over a number of years. Therefore, in the absence of other information, the use of single ^{14}C measurements on bone collagen from juveniles and adults can only provide very limited information, i.e. whether or not the person died during the nuclear era (because their ^{14}C activity was enhanced relative to the natural equilibrium living value).

There is one exception in which dating of single modern-period (i.e. within the nuclear era) bone samples can produce high precision estimations of year of birth. This is where the skeletal remains are of new-born or close to new-born babies. The shape of the ^{14}C bomb peak has been well constrained through extensive measurements of ^{14}C activities (Levin *et al.* 1994; Levin and Kromer 1997; Manning and Melhuish 1994; McGee *et al.* 2004) and the rapid annual changes provide the potential for a chronologically precise methodology (This also applies to components of human remains that exhibit either very fast carbon turnover). The bone collagen in infants is formed from the mother's dietary intake, and here, the ^{14}C will be relatively close to equilibrium with atmospheric levels. Broecker *et al.* (1959) derived an average value of <1 year for the period between initial fixation of carbon by plants and human consumption and a maximum lag of <6 months between carbon consumption and appearance in the blood. Therefore, a radiocarbon measurement made on the bone collagen should represent the ^{14}C activity of the atmosphere 1-2 years earlier than the year of death. The samples we analysed were all from children of <1 year of age and therefore a delay of 1-2 years should apply to them.

Under equilibrium conditions where the rate of production ≈ rate of decay, every living organism in the terrestrial biosphere is labelled with the same ^{14}C activity. On death, no more ^{14}C uptake occurs and only the decay process operates (see Figure 2).

$$^{14}_{6}C \longrightarrow {}^{14}_{7}N + \beta$$

This follows First Order Kinetics. For ^{14}C dating, re-arranging the first order decay equation ($A_t=A_0e^{-\lambda t}$) for t gives:

$$t = \frac{1}{\lambda}\ln\frac{A_0}{A_t}$$

Where t = time elapsed since death, in years B.P. (Before Present, where present is the year 1950)

A_0 = equilibrium living activity

A_t = activity remaining after time t

λ = decay constant = ln2/5568 = 0.693/5568

A_0 cannot be measured directly as this is the equilibrium living activity. The A_0 activity is related to that of a reference standard whose activity is measured in the lab. A_t is the activity of the sample material now and is also measured in the lab. The primary standard used in radiocarbon dating is wood growing in the year 1890, which is pre-Suess and pre-nuclear weapons testing effects. The ^{14}C activity of this material was 13.56 dpm/gram of carbon (226 Bq kg^{-1} of carbon). This was measured in the mid-20th century and corrected for 60 years decay to the year 1950. This material was very limited and now a secondary standard is used. This is currently oxalic acid (termed Oxalic acid II or SRM 4990C) produced by the National Institute of Standards and Technology (Maryland, USA). This oxalic acid was synthesised from beet molasses in 1977 and 0.7459 x oxalic acid activity = 1890 wood activity = A_0 when both the wood and the oxalic acid are corrected for fractionation. SRM 4990C is commonly referred to as the primary standard.

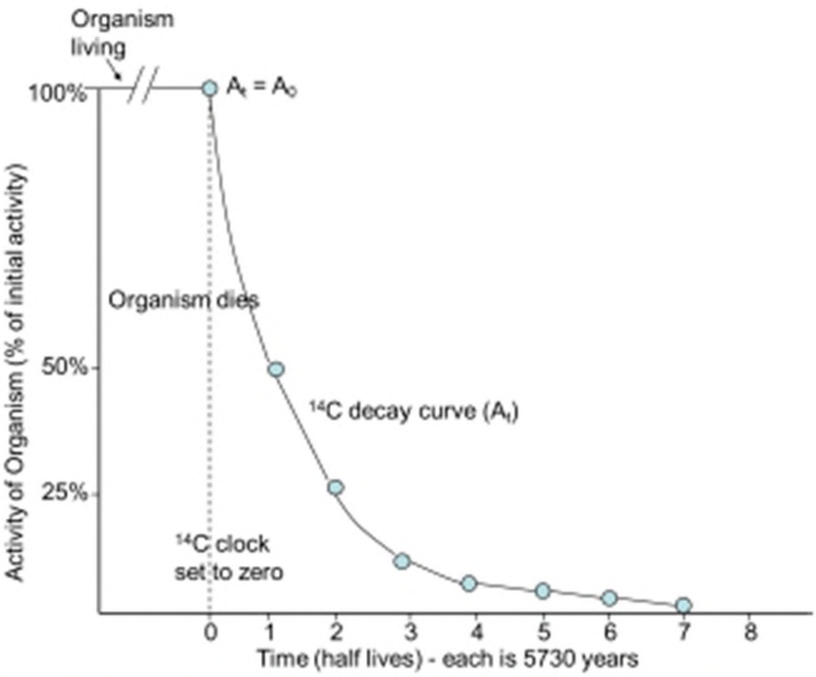


Figure 2: The decrease in ^{14}C activity of a sample organism with time.

Assumptions in the Method

There are 4 main assumptions in the radiocarbon method as follows:

1. The rate of production in the upper atmosphere has been constant throughout time.

2. The ^{14}C activity of the atmosphere and hence the biosphere, with which it is in equilibrium, has remained constant throughout time.

3. The rate of ^{14}C transfer between different reservoirs of the carbon cycle is rapid with respect to the average lifetime of ^{14}C.

4. The half-life is accurately known.

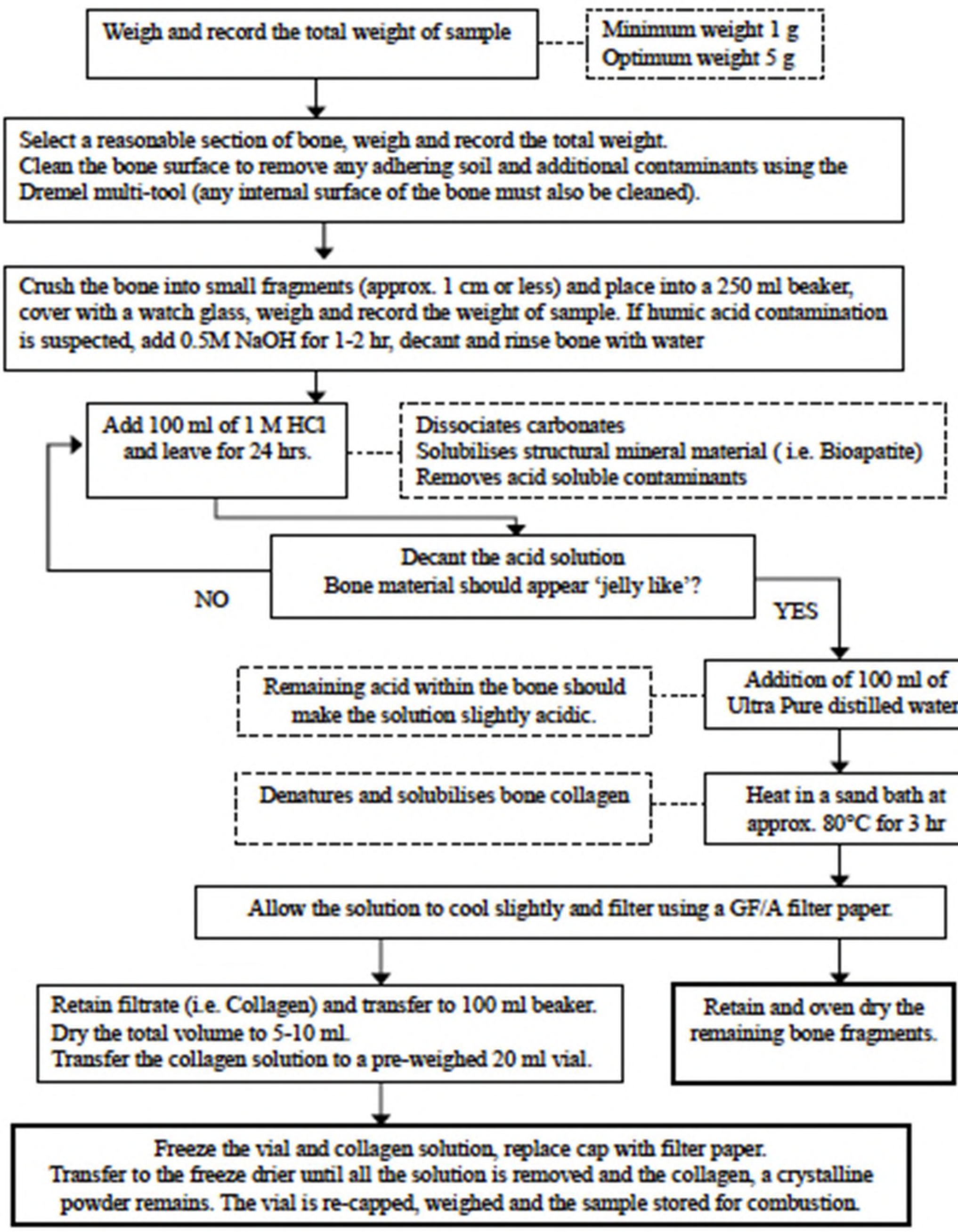
None are stricfly correct!

For 1: Long term (millennia scale) and short term (century scale) fluctuations have occurred as discussed above.
For 2: The above variations in the rate of production will influence the ^{14}C activities of the atmosphere and biosphere. In addition, there can be changes in reservoir size, *e.g.* due to temperature changes causing increases and decreases in polar icecap cover.
For 3: The oceans are depleted relative to the atmosphere and hence organisms living in the oceanic environment will be depleted. They have a "reservoir age".
For 4: The original Libby half-life is still used to calculate ^{14}C ages, even although we know it to be incorrect.
For 1, 2 and 4: Dendrochronological curves and U/Th dating on coral samples/varve sequences solve many of the problems. The dendrochronological curves are derived by radiocarbon dating 10 year spans of tree rings from absolutely dated tree ring sequences, which are continuous from present day to approx. 12,600 years BP (before present where present is 1950AD). Absolute age is plotted against radiocarbon age to produce a calibration curve against which radiocarbon ages of samples can be calibrated on a calendar year time-scale. Beyond approx. 12,600 BP the calibration data are based on independent U/Th age measurements made on coral and varve sequences, etc.
For 3: This reservoir effect has been measured in many locations. For the UK, the apparent age on death appears to be around the global average of 400 years but is variable through time (eg. Ascough *et al.* 2004).

SAMPLE PREPARATION

Bone consists of two basic fractions. The inorganic fraction is primarily calcium phosphate with an apatite-like structure, but incorporating a small percentage of carbonate (0.5-1% by weight) as a substitute for phosphate in the crystal lattice. The organic fraction is primarily a protein termed collagen.
Where the bone has not been cremated, our preferred procedure is to extract the collagen as a partially hydrolysed fraction (gelatin), followed by freeze drying.
Sub-samples were removed from each of the 6 bones, cleaned thoroughly and subjected to the collagen preparation process illustrated in the following flow diagram.

Preparation of bone collagen



Conversion of collagen to graphite for accelerator mass spectrometry (AMS) radiocarbon measurement

Combustion of the collagen samples for radiocarbon dating was undertaken according to the method of Vandeputte *et al.* (1996). Approx. 14-16 mg sub-samples of collagen were weighed into quartz combustion tubes containing copper oxide as a source of oxygen and silver foil to mop up halides and other contaminants. The combustion tubes were then evacuated, sealed and placed in a furnace at 850°C overnight. The CO_2 produced during the combustion was cryogenically purified and 3 ml sub-samples were converted to graphite for subsequent AMS measurement using the method of Slota *et al.* (1987).

SAMPLE MEASUREMENT

Radiocarbon (^{14}C) Measurements

^{14}C measurements on the graphite preparations was undertaken using our 250 kV Single Stage Accelerator Mass Spectrometer (SSAMS), manufactured by National Electrostatics Corporation. This spectrometer features a high intensity sputter ion source with a 134 sample capacity.

The SUERC Radiocarbon Laboratory does not have certification under the BS5750/ISO9000 Quality Assurance schemes, however, the laboratory takes part in all the major international inter-calibration studies and has been at the forefront in organising five of the last six. In addition, we have a fully implemented Quality Assurance manual which details all of the procedures employed in the laboratory and demonstrates how each sample is tracked through the laboratory. Details recorded include pre-treated sample yields, sample carbon graphitisation yields, etc.

The laboratory uses the primary ^{14}C standard, SRM-4990C, for all estimates of modern reference standard activity. Wheels of up to 134 samples, including standards, are measured and since measurements of such large numbers of samples can last several days, our procedures have to cope with changes in measurement conditions. To this end, samples are measured to completion in groups of 10 in only a few hours, with Oxalic acid II primary standards spanning groups for intergroup consistency. Each group of 10 samples contains: (i) one Oxalic acid II primary standard, (ii) one humic acid secondary standard of less than 1 half-life in age (used in 2 international inter-calibration studies: C-14 Cross-check Peat Sample and VIRI Sample T; the consensus value from the former study is 3374 ± 9 y BP and from VIRI it is 3360 ± 3 y BP), (iii) either a modern secondary standard material (TIRI Sample A (barley mash); the consensus value from this study is $F^{14}C = 1.1635 \pm 0.0041$ (when the activity is higher than the modern value it is expressed as a fraction modern ($F^{14}C$) rather than a radiocarbon age), or a background standard (interglacial wood, infinite age bone or geological carbonate depending on the type of unknowns being measured), and (iv) 7 unknowns. Such rapid analysis is relatively insensitive to longer-term drifts and changes are quickly apparent in the fast repeat measurements of individual samples, including primary and secondary standards. Operator intervention, to adjust the spectrometer or to change sample measurement parameters, can be immediate; each sample is automatically repeatedly measured in intragroup rotation until the sample total counting statistics and the scatter of the repeat $^{14}C/^{13}C$ measurements exceeds a quality threshold of typically 3‰, disregarding early inconsistent measurements as necessary.

Finally, time trends remaining in the completed data sets can be compensated for in subsequent data reduction and normalization.

Stable Isotope Measurements

Further 0.6 mg samples (approx.) of collagen were weighed into tin capsules for stable isotope measurements (^{13}C and ^{15}N and C/N ratio) using a continuous-flow isotope ratio mass spectrometer (Thermo Scientific Delta V Advantage (Bremen, Germany) coupled to a Costech ECS 4010 elemental analyser (EA) (Milan, Italy) fitted with a pneumatic autosampler. The EA is coupled to the mass spectrometer via a ConfloIV™ and samples are combusted in a single reactor containing tungstic oxide and copper wires at 1020°C to produce N_2 and CO_2. The gases are then separated in a 2 m stainless steel Porapak QS 50-80 mesh GC column heated to 70°C. Helium (100 ml/min) is used as a carrier gas throughout the procedure. N_2 and CO_2 enter the mass spectrometer via an open split arrangement within the ConfloIV™ and are analysed against their corresponding reference gases.
For every ten unknown samples, in-house gelatine standards, which are calibrated to the international reference materials USGS40, USGS41, IAEA-CH-6, USGS25, IAEA-N-1 and IAEA-N-2, are run in duplicate. Results are reported as per mil (‰) relative to the internationally accepted standards VPDB and AIR with 1σ precisions of ± 0.2‰ and ± 0.3‰ for $\delta^{13}C$ and $\delta^{15}N$, respectively. Any results for bone samples that have molar C/N ratios outside the range of 2.9-3.6 would be discarded as they would be deemed to represent collagen that has undergone post-depositional alteration (DeNiro, 1985).

RESULTS

We analysed the ^{14}C, $\delta^{13}C$ and $\delta^{15}N$, and determined the C/N ratio in the samples of collagen that were isolated from our samples referenced GU-42246 to GU-42251. The results are presented in Table 2 and the quality assurance results for the batch of analyses that included GU-42246 to GU-42251 are shown in Table 1.

QA Sample	Sample type	Consensus Age (years BP) or Fraction Modern ($F^{14}C$) ± 1σ	Age (years BP) or Fraction Modern ($F^{14}C$) ± 1σ (this batch)
C-14 Crosscheck/ VIRI Sample T	Humic acid	3374 ± 9 y BP 3360 ± 3 y BP	3349 ± 29 y BP
TIRI Sample A	Barley Mash	1.1635 ± 0.0041	1.1659 ± 0.0018

Table 1: Radiocarbon QA results for the batch of samples containing samples GU-42246 to GU-42251.

The QA data demonstrate that results in this batch of analyses are accurate as both the mean Humic Acid and Barley Mash secondary standard values are well within error of the consensus values produced by the worldwide radiocarbon community. The data are also precise as the standard deviation on the Humic Acid values is 29 years while the standard deviation on the fraction modern values for the Barley Mash standards is 0.0018.

Analysis Code	Exhibit Ref.	Bone Id.	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	C/N Ratio	Fraction modern ± 1σ
SUERC-69881	LL001	Left Femur	-19.2	+9.7	3.4	0.9851 ± 0.0033
SUERC-69882	LL002	Left Temporal	-19.7	+10.1	3.5	0.9734 ± 0.0035
SUERC-69883	LL003	Right Parietal	-19.6	+9.9	3.5	0.9754 ± 0.0035
SUERC-69884	LL004	Left Temporal	-21.2	+9.5	3.5	0.9746 ± 0.0035
SUERC-69885	LL005	Right Parietal	-21.9	+9.6	3.6	1.0639 ± 0.0038
SUERC-69886	LL006	Left Ulna	-21.5	+9.7	3.6	1.0641 ± 0.0039

Table 2. Radiocarbon and stable isotope results for bone samples GU-42246 to GU-42251 (Our Analysis codes: SUERC-69881 to SUERC-69886).

The C/N ratios for the samples of isolated collagen are within the limits for collagen that is unaltered (accepted range is 2.9-3.6) and therefore are deemed suitable for radiocarbon and stable isotope measurements.

DISCUSSION

The stable isotope values for the 6 samples are fairly typical of diets that are very dominantly derived from terrestrial resources. Therefore, there is no requirement to make any allowance for a marine reservoir effect. The calibration of the samples (LL001-LL004) with fraction modern values of <1 to produce calendar age ranges were undertaken using OxCal version 4.2 (IntCal 13 curve), while those with fraction modern values >1 were calibrated using the Post-bomb atmospheric Northern Hemisphere Zone 1 Curve (Bronk Ramsey 2013). The calibrations are illustrated in Figures 3-8. For some of the calibrations where the $F^{14}C$ values were in the 0.97-0.98 range, the later ranges do not have end-points, however, these cannot be beyond 1955 as at this point the $F^{14}C$ value in the atmosphere exceeds 1. I would not pay too much attention to the probabilities as these tend to reflect the shape of the curve, which is very complex from 1650 AD onwards, rather than true probabilities for the ages.

Similarly, for LL005 and LL006 which calibrate within the nuclear era, the later age ranges again do not have end-points. I checked these against the Queen's University Belfast calibration programme (CaliBOMB) and got values of 2009 for both. Again, do not pay too much attention to the probabilities. The small probabilities for the earlier age ranges (1956-1957) are due to the fact that the curve is very steep at this point while for the later age ranges it is quite a shallow curve. The calibrated age ranges are illustrated in Table 3.

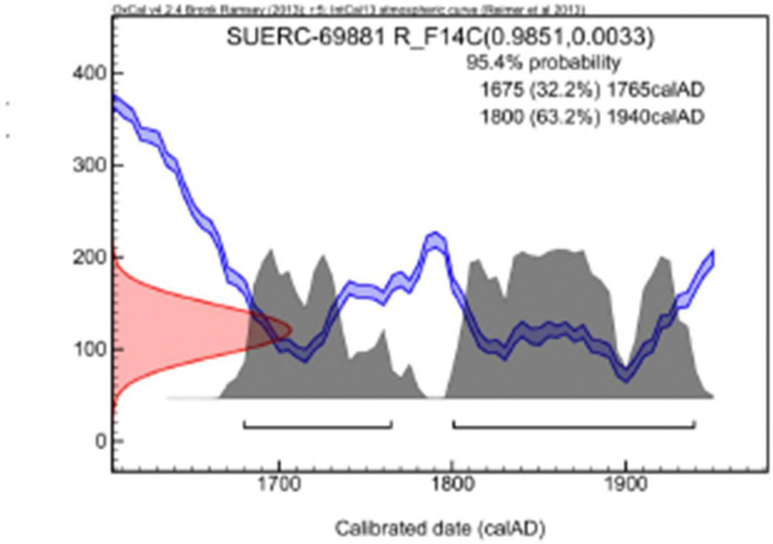


Figure 3: Calibration of bone sample GU-42246 (LL001) (Our analysis code SUERC-69881).

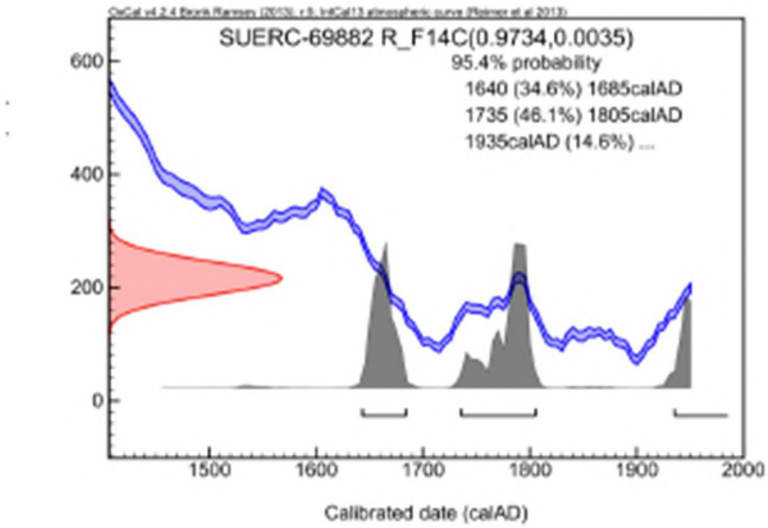


Figure 4: Calibration of bone sample GU-42247 (LL002) (Our analysis code SUERC-69882).

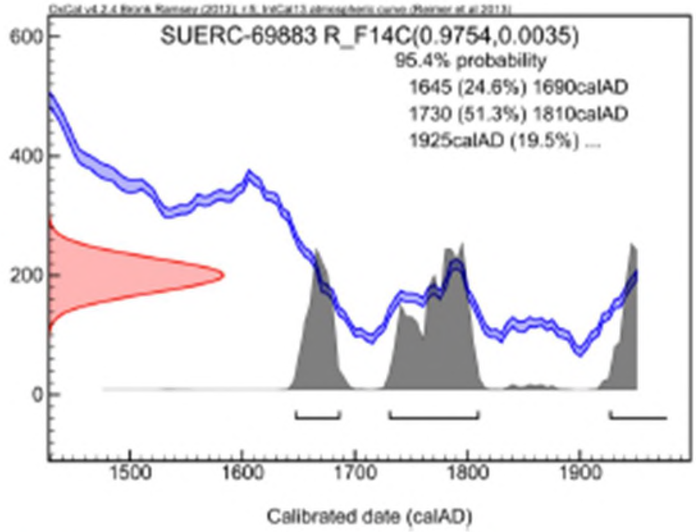


Figure 5: Calibration of bone sample GU-42248 (LL003) (Our analysis code SUERC-69883).

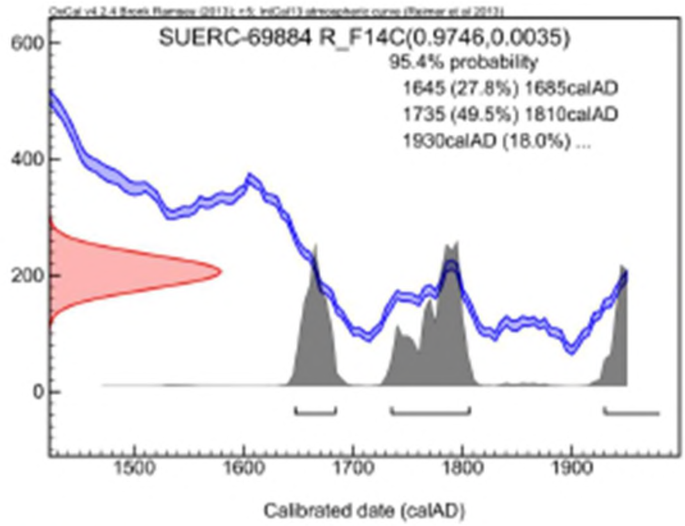


Figure 6: Calibration of bone sample GU-42249 (LL004) (Our analysis code SUERC-69884).

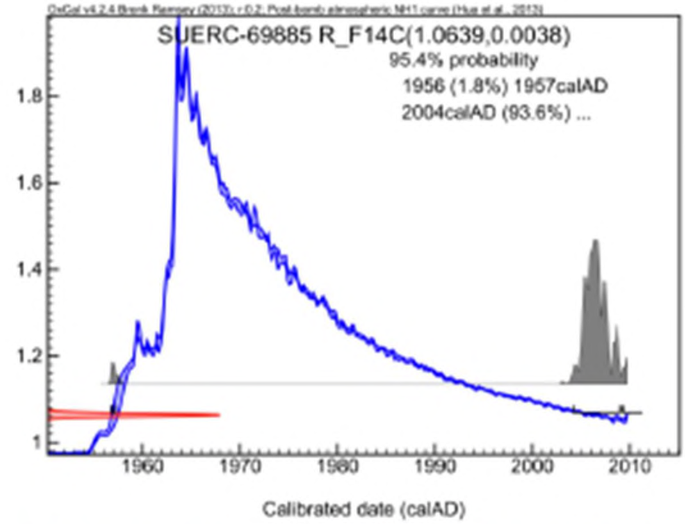


Figure 7: Calibration of bone sample GU-42250 (LL005) (Our analysis code SUERC-69885).

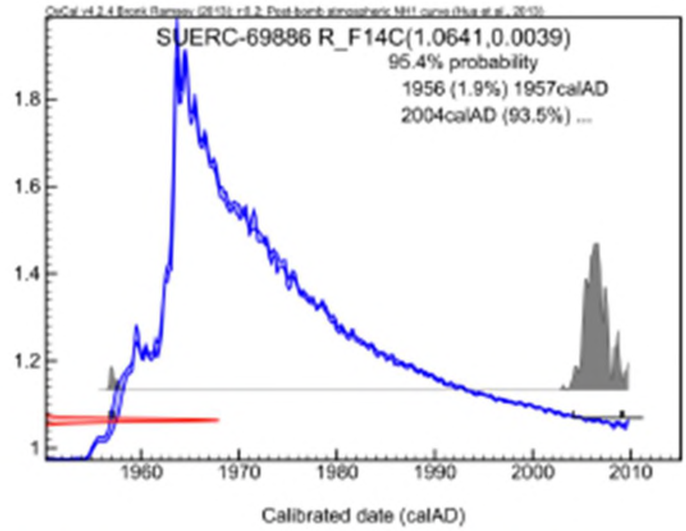


Figure 8: Calibration of bone sample GU-42251 (LL006) (Our analysis code SUERC-69886).

Sample	Calibrated Age Ranges (years AD)	Calibrated Range of Interest
LL001	1675-1765; 1800-1940	1800-1940
LL002	1640-1685; 1735-1805; 1935-1955	1935-1955
LL003	1645-1690; 1730-1810; 1925-1955	1925-1955
LL004	1645-1685; 1735-1810; 1930-1955	1930-1955
LL005	1956-1957; 2004-2009	1956-1957
LL006	1956-1957; 2004-2009	1956-1957

Table 3. Calibrated age ranges for LL001-LL006

CONCLUSIONS

The measured fraction modern values for LL001 to LL004 are all significantly <1 and all have multiple, possible calibrated age ranges, which is fairly typical for fraction modern ($F^{14}C$) values around 0.97-0.98. These typically produce calendar ages in the pre-modern 1650-1950 AD range as defined by Taylor *et al.* (1989). However, it is important to note that they all produce age ranges within the period when the Home operated. LL005 and LL006 have $F^{14}C$ values significantly greater than 1 and this clearly puts the years of death within the nuclear era (in fact, post-1955). Again, the earlier range of 1956-1957 is within the period of operation of the Home. If I apply a lag of 1-2 years as described by Broecker *et al.* (1959), this would put their years of death around 1956-1959.

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Addendum to Radio Carbon Dating Report of Professor Gordon T Cook

The measured fraction modern values for LL001 to LL004 are all significantly <1 and all have multiple, possible calibrated age ranges, which is fairly typical for fraction modern ($F^{14}C$) values around 0.97-0.98. These typically produce calendar ages in the pre-modern 1650-1950 AD range as defined by Taylor et al. (1989). The probabilities all reflect the area under the blue curve and so, where the curve is very steep, the probability is low. Therefore, I would disregard these as being unlikely to reflect the true probability of when death occurred but it is important to note that they all produce age ranges within the period when the Home operated. LL005 and LL006 have $F^{14}C$ values significantly greater than 1 and this clearly puts the years of death within the nuclear era (in fact, post-1955). Again, the earlier range of 1956-1957 is at a point when the blue curve is rising very steeply and hence the area under the curve (and consequently the probability) will be low. Again, I would discount the low probability for this age range as being an accurate reflection of when death occurred. This range of 1956-1957 is also within the period of operation of the Home and if I apply a lag of 1-2 years, as described by Broecker et al. (1959), this would put their years of death around 1956-1959.

Signed: Gordon T Cook

Gordon T Cook

Appendix IX: Environmental Sampling Report

Report

For Niamh McCullagh
The Mother and Baby Homes Commission of Investigation

(Criminal Procedure Rules [2015] Parts 16 and 19; Criminal Justice Act 1967, s. 9)

Report of Professor Lorna DAWSON and Dr Bob MAYES

Qualifications BSc, PhD, C.Sci, F.I.Soil Sci, FRSA (LD); BSc, MSc, PhD (BM),

Age Over 18

Occupation Soil Scientist and Organic Marker Chemist

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This report, consisting of 25 pages, is true to the best of our knowledge and belief and we make it knowing that, if it is tendered in evidence, we shall be liable to prosecution if we have wilfully stated in it anything which we know to be false or do not believe to be true.

We understand our duty as expert witnesses to the court to provide independent assistance by way of objective unbiased opinion in relation to matters within our expertise. We will inform all parties and where appropriate the court in the event that our opinion changes on any material issues.

We further understand that our duty to the court overrides any obligation to the party from whom we received instructions.

The examinations we make depend to some extent on items submitted to us and on information provided regarding the alleged circumstances of the case. Our conclusions normally relate to our examinations, those of our colleagues specified in this report, and of those submitted items and to the significance of our findings in the light of the alleged circumstances of the case. We are prepared to make any further examinations as requested by the Prosecution or the Defence, and we are prepared to test any alternative scenarios which may be put to us. If any information we have used should change significantly, or if further examinations are required, then we may need to revise our conclusions.

Signed Lorna Dawson Dated the 6th Dec 2016.

Signed R.W. Mayes Dated the 6th Dec 2016

Table of Contents

1. Qualifications and Experience

Prof. Lorna DAWSON

I am employed as a principal research scientist at the James Hutton Institute, Aberdeen, Scotland, where I am Head of the Soil Forensics Section and hold the qualifications of BSc (Honours) Geography (Edinburgh University, 1979), and a PhD in Soil Science (Aberdeen University, 1984). I am a visiting Professor in Forensic Science at the Robert Gordon University. I am a Fellow of the British Society of Soil Science, a Fellow of the Royal Society of the Arts, a Chartered Scientist and hold an Expert Witness certificate in both Criminal and Civil Law (Cardiff University, 2011, 2012). I have published widely on the subject of forensic soil science; published over 80 refereed publications, books and book chapters. I am an Expert Advisor with the National Crime Agency, have worked with numerous police forces in Scotland, England, Wales, Ireland & Australia over the last 12 years and have advised on over 80 cases, written over 70 Expert Witness reports, and presented evidence in 9, in the UK and overseas. During the past 12 years I have encountered the evidence type involved in this case on several occasions.

Dr Bob MAYES

I am a Research Associate at the James Hutton Institute where I was previously head of the Ecological Sciences GC and GC-MS laboratories, and hold the qualifications PhD from Queen's University of Belfast, MSc in Animal Nutrition from the University of Aberdeen and BSc in Physiology and Biochemistry of Farm Animals from Reading University. I am an expert in the analysis of wax markers and my research interests revolve around the application of this biomarker technology to measuring dietary intake, digestibility and plant species composition in grazing herbivores and to the characterisation of soil organic matter as applied in criminal investigations. I have worked with a number of police forces in Scotland, England, Wales & Ireland over the last 6 years, have written over 16 Expert Witness reports, and presented evidence in court with two of them. During the past 6 years I have encountered the evidence type involved in this case on a number of occasions.

2. Summary of findings

The sample examined is not a typical soil. It was shown from GC-MS analysis that there are markers of faeces (cholesterol, faecal stanols and faecal bile acids) in the sample. The observed patterns of these individual markers were typical of human faeces, and not of faeces from any herbivore (e.g. sheep, cattle, horses or rabbits), pigs or dogs. However, despite the high organic matter content of the sample, the concentrations of faecal markers were extremely low, compared with levels expected from decomposed faecal material (such as sewage sludge, septic tank sludge or manure). Thus either the faecal material had been considerably diluted by the presence of non-faecal organic matter, or the faecal markers had come from another source. The possibility that the faecal markers had originated from decomposing cadavers cannot be ruled out. The fatty acid, 10-hydroxy stearic acid, which is a recognised body decomposition marker, was found in the sample at low levels, but its origin in this case was not clear, because it is also found in human faeces. Any association of cadaver decomposition with the presence of faecal bile acids has yet to be established.

An unusual feature about the *n*-alkane/alcohol/sterol results of the sample examined was the exceptionally high levels of the plant sterols, β-sitosterol and campesterol, together with low (but detectable) concentrations of plant-wax *n*-alkanes and fatty alcohols. The observed *n*-alkane and long-chain fatty alcohol patterns were typical of those found in grasses and other higher plants, but their low concentrations relative to the plant sterol levels in the sample suggest that decomposed plant material was unlikely to be the source. We have also found unusually high levels of plant sterols in some samples of pig faeces, but in that particular case the pig feed (which we had analysed) was rich in β-sitosterol and campesterol.

There is the possibility that it was infant matter that was in the sample (including infant faecal matter) and that the high levels of plant sterols we detected in the sample could be as a result of infants being fed with formula milk containing vegetable oils. (Nearly all formula milks contain vegetable oils). The relative levels of plant sterols, *n*-alkanes and fatty alcohols in vegetable oils are similar to those found in the current analysed sample. Furthermore, although the patterns of *n*-alkanes and fatty alcohols can vary according to the type of vegetable oil, the patterns found in the sample examined were compatible with certain individual oils, or mixtures of oils.

The concentration patterns of stanols and sterols and hydrocarbons found in the sample are not compatible with that of sewage from human adults or from individuals eating solid food.

The alcohol/sterol fraction and hydrocarbon fraction profiles suggest that the sample examined is not material originating from a sewage treatment plant, septic tank or cesspit. It is unlikely that the specific location of the questioned case sample was a receptacle for sewage.

The sample does contain indicators which suggest that human faeces are present. However, the markers present are not compatible with that of sewage from human adults or children eating solid food. It has not originated wholly from a sewage treatment plant or wholly from adult faeces.

3. Information/Circumstances of Case

I, Lorna DAWSON, received an email from Forensic Archaeologist Niamh McCULLAGH, agent for The Mother and Baby Homes Commission of Investigation, on 25th October 2016, to enquire if we could examine a soil sample to establish whether there was human faecal matter contained within it.

4. Items Received

A sample labelled MBHCOI_TM1016, Exhib No. LLO16 Tr 1A, Feature 1B, Earth from Bone LL005, 6 and 7 was received into the James Hutton Institute Forensic Laboratory, lab 234, Aberdeen, on 4th November 2016.

5. Request or Purpose of Examination

We were requested that we, in the Soil Forensic Unit, examine and analyse the sample for human faecal material to establish if a system built for human effluent, from which the sample was taken, was ever used for this purpose.

6. Assumptions

It is assumed the sample was collected in a rigorous manner and that the sampling was carried out with due care and by adhering to established forensic sampling protocols.

7. Use of Assistants

In undertaking the work in this case I was assisted by other members of the Soil Forensic Unit Laboratory staff. Their involvement is described in the forensic case files and I have taken their contributions into account when we prepared this report. The involvement of other staff is fully recorded in case notes available for inspection at the laboratory if necessary. Mrs Jasmine ROSS, forensic laboratory manager, assisted myself in examining the sample, captured photographs, analysed the samples for organic markers and prepared the audit trail (Appendix 2, Table 1). Dr Bob MAYES interpreted the chromatograms for faecal markers. Dr Andy MIDWOOD, Head of Environmental and Biochemical Sciences Group and Prof. Colin CAMPBELL, CEO, James Hutton Institute, reviewed this statement. Dr Barry THORNTON analysed the sample for isotopic C and N. Prof Steve HILLIER excluded the crystals as not being asbestos by visual examination.

8. Nature of Examination

Soil is a mixture of both inorganic and organic material (Dawson and Hillier, 2010: Dawson and Mayes, 2014). The inorganic material can be characterised by its elemental composition (see glossary, Appendix 3) which generally reflects the geological material from which it was derived. The organic material reflects the plant and animal material having been deposited or decomposed within that soil and also human organic inputs to the soil (Dawson and Mayes, 2014). A combination of gas chromatography (GC) and gas chromatography-mass spectrometry (GCMS) can be used to characterise and identify many organic compounds in soils.

This report describes the soil examination and the organic analysis of the sample received on the 4th November 2016.

A full record of the work done in this case is available for inspection at Laboratory 234, the James Hutton Institute, Aberdeen.

An audit trail is in Appendix 1. A list of references used is in Appendix 2. A glossary of technical terms is in Appendix 3.

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9. Results

Soil description

The soil samples were examined under a macro lens and then under a microscope at times 20 magnification.

Table 2. Description of soil samples examined

Exhibit/Item Number	Location	Mineral Composition	Organic material and other fragments	Colour (Munsell colour chart)
Exhib No. LLO16 Tr 1A, Feature 1B	Earth from Bone LL005, 6 and 7	Few white stones rounded and sub-rounded, and angular and sub-angular. (calcite?), white aggregates, gravel, anthracite, red brick.	Woody bark, blue fibre, small bone fragments, green grass blades, dead deciduous leaf material, glass, paint. Possible asbestos fibres? (white/clear/needle like clusters of crystals, originally thought to be asbestos").	2.5Y 3/1 (very dark grey).

The soil samples were sieved through a 1mm sieve to provide two fractions. The finer fraction was prepared for subsequent organic profile characterisation. The coarser fraction was retained (Appendix 1, Table 1, Audit trail). Images of the finer fraction are in Appendix 5.

Visually the sample appeared similar, when compared with images of previous samples examined, to a "black earth" sample from (Barbara von der LUHE, 21 Jan 2013), which was known to have originated from material adjacent to a human cadaver. Small bone like fragments were observed in the sample (visual only; unconfirmed by anthropologist). White crystals were confirmed through visual assessment by mineralogist to not be asbestos. There were some grass leaf material in the sample; it is unclear whether those may have fallen into the sample on collection. These were not included in the sample analyzed.

Soil Organic Marker Analysis

Hydrocarbons

Figure 1 shows the hydrocarbons extracted from the case sample analysed by GC (fitted with a flame ionisation detector).

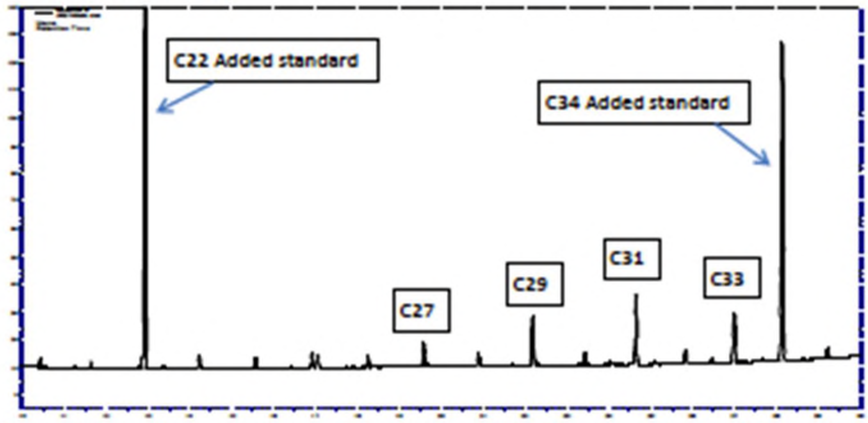

Figure 1. Gas chromatogram of the hydrocarbon fraction obtained from the analysed case sample.

The hydrocarbons found in the sample were odd-chain *n*-alkanes, dominated by hentriacontane (C31), nonacosane (C29), tritriacontane (C33) and heptacosane (C27). Shorter odd-chain *n*-alkanes and even-chain *n*-alkanes were also present at much lower levels. The *n*-alkane and alcohol patterns were typical of the patterns found in grasses and a large number of other higher plants but the concentrations were low (e.g. the C31 *n*-alkane was 23mg/kg in the sample examined, whereas in a typical grassland concentrations would range between 100 and 400 mg/kg).

Fatty alcohols, sterols and stanols

The fatty alcohol/sterol fractions extracted from the sample were analysed by GCMS and the results are shown in Figures 2 and 3. Figure 2 shows the complete chromatogram (total ion count) in which the even-chain fatty alcohols have been are identified. Figure 3 represents a partial chromatogram of the same analysis, showing the sterols and stanols present.

Even-chain fatty alcohols were detected, with 1-hexacosanol (C26), 1-tetracosanol (C24) and 1-octacosanol (C28) dominating. Also present were 1-eicosanol (C20) and 1- triacontanol (C30). 1-Docosanol (C22) was also detected, but co-eluted with a much larger amount of dioctyl phthalate, which can be leached out of various plastics (it cannot be ascertained if this substance was present in the case sample itself, or appeared as a contaminant from plastic sample packaging material).

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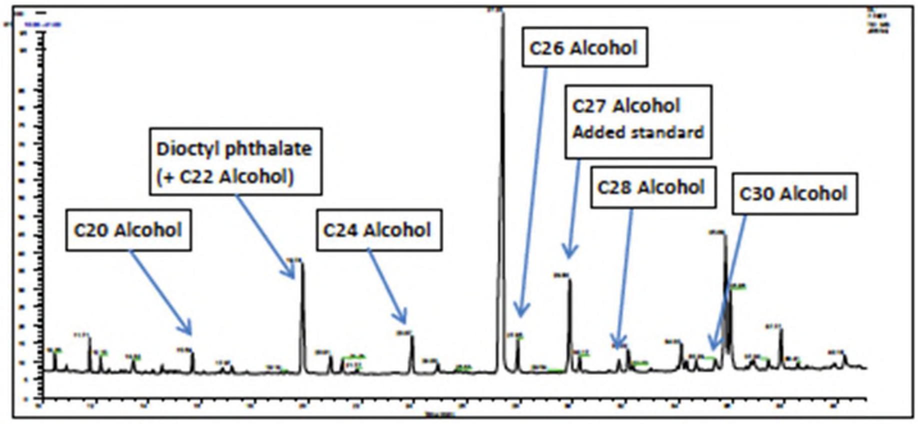

Figure 2. GC-MS (total ion count) chromatogram of the alcohol/sterol fraction obtained from the analysed case sample. Fatty alcohol peaks are labelled.

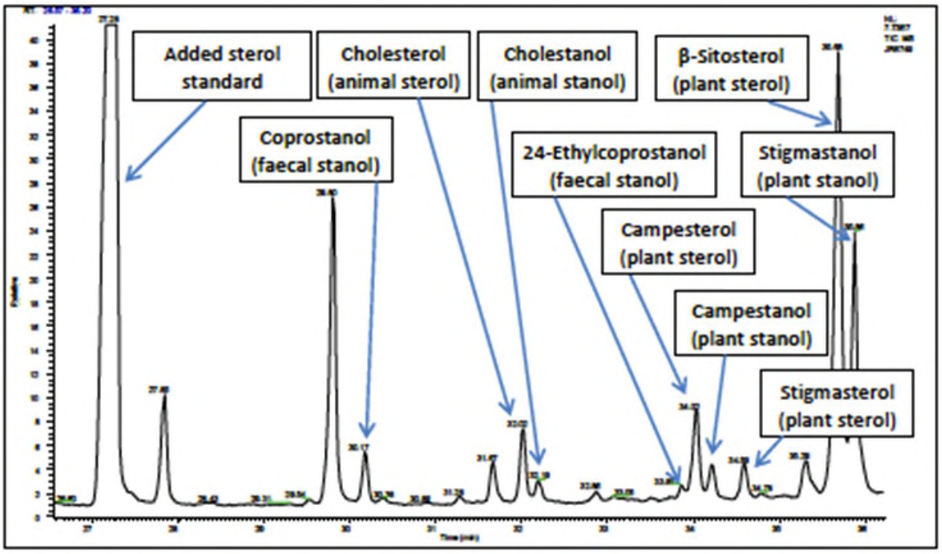

Figure 3. Partial GCMS (total ion count) chromatogram of the alcohol/sterol fraction obtained from the analysed case sample. Sterol and stanol peaks are labelled.

The pattern of fatty alcohols present was typical of the patterns found in grasses and a large number of other higher plants. The concentrations were much lower than in any grassland topsoils previously examined.

The case sample contained β-sitosterol, campesterol and stigmasterol, which are plant sterols found in most surface soils. Also present was the animal sterol, cholesterol, which is also very common in soils. The plant stanols, stigmastanol and campestanol, which are commonly found in soils as a result of microbial transformation of the plant sterols, were found in the case sample. Cholestanol was also present; this was likely formed in the soil by microbial action on cholesterol. Coprostanol and 24-ethyl coprostanol were also detected. These are occasionally found in soil samples and originate from faecal material by respective hydrogenation of cholesterol and β-sitosterol in the gut of animals, including humans. Trace amounts of epicoprostanol and 24-ethyl epicoprostanol were detected (not shown, but data available upon request) by selecting relevant single-ion fragments to create derived GCMS chromatograms (Note that 24-ethyl epicoprostanol co-elutes with campesterol and could not be seen in the total ion count (TIC) chromatograms shown in Figures 2 and 3.). Whilst the concentrations of plant sterols and stanols in the sample were relatively high, the levels of faecal stanols in the sample were low. The concentrations were much lower than in any soils previously examined.

Faecal bile acids and 10-hydroxystearic acid

An acid fraction was obtained from the case sample and was treated such that carboxyl groups on the acid molecules were methylated, and any hydroxyl groups present were silylated (as trimethylsilyl ethers); this was to render hydroxyl-acid compounds analysable by GCMS (in TIC mode). Single-ion GCMS chromatograms were generated from the TIC chromatographic data, following relevant ions for the bile acids, lithocholic acid (m/z = 372), deoxycholic acid (m/z =255) and hyodeoxycholic acid (m/z = 355), and for 10-hydroxystearic acid (m/z =273). Examination of the derived GCMS chromatograms indicated that lithocholic acid, deoxycholic acid and 10-hydroxystearic acid were detected at very low levels in the case sample; hyodeoxycholic acid was absent. The relevant GCMS chromatograms are not shown in this report, but are available upon request.

Total carbon and nitrogen, and stable isotope (13C and 15N) content

After drying and milling the sample, the total organic carbon and nitrogen content and respective ^{13}C and ^{15}N isotopes were determined by continuous flow - isotope ratio mass spectrometry linked to an elemental analyser. The total organic C content of the sample was 40% w/w.

Table 3 Isotope values of the analysed sample

$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
-24.40	11.6

Table 3 above shows that the isotope values for the sample were outliers compared to a large collection of top soil samples collected across Scotland and examined previously in a study by Thornton et al, 2015 (n=182). The mean (and standard deviation) isotopic values for the samples in the study by THORNTON were −27.7 ± 0.9‰ for ^{13}C and 3.6 ± 1.7‰ for ^{15}N. This corroborates the indications from microscopic examination that this sample was not a conventional 'soil'.

10. Interpretation and Conclusions

Replies to questions posed by Niamh McCULLAGH are listed below:

What is the sample?

Examination suggests that the sample is predominantly organic in nature. There are some traces of grass blades and woody material within the sample, tiny bone fragments (unconfirmed by anthropologist) within the sample, coal fragments, some brick, some crystals of unknown origin (confirmed as NOT being asbestos), few mineral grains and fibres of various colours. It does not appear to be a soil; there is very little natural soil aggregate formation, and only a few mineral grains intermixed. The sample contains some features of soil, although it was outside the normal isotopic N and C of over 100 soil samples previously examined across Scotland. It was not composed of predominantly plant organic material or of mineral material and most closely resembles a "black earth" sample we had previously examined which originated from close to a decomposing human body.

The main unusual feature about the alcohol/sterol results as determined was the exceptionally high levels of β-sitosterol and campesterol, relative to those of *n*-alkanes and fatty alcohols found in surface soils and vegetation. The plant sterols in the questioned sample were also much higher in concentration relative to faecal stanols and cholesterol in reference samples of faeces, sewage sludge, manures and materials associated with cadaver decomposition. We have also found unusually high levels of plant sterols in some samples of pig faeces, but in that particular case the pig feed (which we had analysed) was rich in β-sitosterol and campesterol.

The main compound which was of plant origin in the sample was the plant sterol β-sitosterol. There was also some campesterol, stigmasterol and stigmastanol and also *n*-alkanes and long-chain fatty alcohols of a typical plant pattern.

The high plant sterols which were detected in the sample could be from faeces from individuals fed on substances containing vegetable oils. The relative levels of plant sterols, *n*-alkanes and fatty alcohols in vegetable oils are similar to those found in the analysed sample (pers comm, Dr MAYES). Furthermore, although the patterns of *n*-alkanes and fatty alcohols can vary according to the type of vegetable oil, the patterns found in the sample were compatible with certain individual oils, or mixtures of oils.

Could there be human faeces in the sample?

The overall concentrations of faecal stanols were measurable, but were low. The relative ratio of coprostanol to 24 ethyl-coprostanol gives a profile consistent with human origin. We can exclude

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sheep, cow, horses, goats, dog and rabbit as the origin of these faecal stanols. We found definite lithocholic acid and a minute trace of deoxycholic acid, but no hyodeoxycholic acid in the sample. The pattern of faecal bile acids in the sample suggests that the faecal source is human and not pig.

If the sample was a mixture with adult (or juveniles on solid feed) human faeces present, then we would have expected much higher *relative* levels of the faecal stanols in the sample, so the sample is unlikely to be non-infant human faeces.

Summary

The patterns of stanols and sterols and hydrocarbons found in the sample examined are not compatible with that of human adult sewage. The alcohol/sterol fraction and hydrocarbon fraction profiles suggest that the sample examined is not material originating from a sewage treatment plant. It is unlikely that the specific location of the questioned case sample was a receptacle for sewage.

The sample examined has features consistent with having originated predominantly from decomposing remains of individuals whose diet had been predominantly vegetable oils.

In answer to the original question, the sample does show indicators which suggest that human faeces is present. However, the sample does not consist of wholly faecal material. It has not originated from a sewage treatment plant or from adult faeces.

At the time of writing we were requested to identify the crystals in the sample by XRD (Table 2).

Appendices

Appendix 1

Table 1 Audit Trail

MBHCOI_TM1016					
NOTE: All sample examination, description and preparation for analysis carried out in secure lab 234.					
04-Nov-16	one sample delivered by DHL Couriers.				
Date	Analyst	Sample ID	Method	Type	Hutton ID
04/11/2016	L. Dawson, J. Ross	Exhib No. LLO16 Tr 1A, Feature 1B	The sample was opened and half of the sample was transferred to a petri dish to dry. The remaining sample was retained in the original bag and stored in the fridge in lab 234.	soil	1246549
07/11/2016	L. Dawson, J. Ross	Exhib No. LLO16 Tr 1A, Feature 1B	The sample was examined and colour measured. Aretacts were removed to vial LAD1 before sieving through a 1mm sieve. The fine fraction was photographed. Coarse fraction to vial LAD2, fine fraction to vial LAD3.	soil	
07/11/2016	L. Dawson, J. Ross	LAD3	A portion of LAD3 was hand ground with an agate mortar and pestle. The ground sample was weighed out for *n*-alkane, alcohol, fatty acid and sterol analysis.	soil	
07/11/2016	J. Ross, G. Martin	LAD3	A portion of the ground sample LAD3 was given to Gillian Martin for Total Carbon analysis.	soil	
11/11/2016	J. Ross, G. Martin	LAD3	Sample LAD3 returned by Gillian Martin.	soil	
30/11/2016	L.Dawson, S. Hillier	Exhib No. LLO16 Tr 1A, Feature 1B	The sample was examined by Steve Hillier to confirm presence or absence of asbestos. Fibres were removed and given to Steve Hillier for XRD analysis (vial SH1).	fibres	

Appendix 2

References

Dawson, L.A. and Hillier, S. (2010) Measurement of soil characteristics for forensic applications. *Surface and Interface Analysis*. 42, 363-377.

Dawson, LA. and Mayes, RW. (2014) Criminal and Environmental Soil Forensics, In: B Murphy & R Morrison (eds), Introduction to Environmental Forensics, 3rd Edition. Academic Press.

Munsell (2000) Soil Colour Charts. Gretagmacbeth. 617 Little Britain Road, New Windsor, NY 12553.

Thornton et al, (2015) Distributions of carbon and nitrogen isotopes in Scotland's topsoil: a national-scale study. European Journal of Soil Science. 66, 1002-1011.

Appendix 3

Glossary of technical terms

Derivatisation of compounds of interest prior to analysis by gas chromatography:
The use of **BSTFA** reagent to convert any alcohol species present in the soil 'alcohol' fractions to **trimethylsilyl (TMS) ethers** not only improves gas-chromatographic separations, but with **GCMS** allows direct identification of peaks appearing on the gas chromatogram, since the individual **TMS** compounds have distinct characteristic mass spectra. Similarly, methylation of the carboxyl groups of organic acids improves improves gas-chromatographic separations; for hydroxyacids, such as the faecal bile acids and 10-hydroxystearic acid, to get good separations and distinct mass spectra, it is necessary to both methylate the carboxyl group and silylate the hydroxyl groups on the compounds.

Gas chromatography (GC): This is a method of separating and quantifying individual components (compounds) from complex mixtures, based on differences in relative affinities for a stationary phase (usually an immobilised liquid) and remaining in a vapour phase. The sample is introduced to a column (long tube) as a vapour, which is swept along the column by flow of an inert **carrier gas** (commonly nitrogen, helium or hydrogen). In the past, most gas chromatography was carried out using *packed columns* in which the stationary phase was supported by inert particles held throughout the length of the column. Most present-day applications involve the use of *capillary columns*, in which the stationary phase coats the inside of long, narrow silica, glass or metal tubing; capillary columns have much higher resolutions. As the sample vapour passes along the column, different components travel at differing rates, leading to separation of the components into individual peaks leaving the distal end of the column. The speed of passage and degree of separation is affected by the amount of stationary phase, carrier gas flow rate and column temperature. The instrument containing the column, the **gas chromatograph**, consists primarily of a temperature-programmable oven which encloses the column. Unless the sample is a gaseous mixture, samples to be analysed are usually dissolved in a volatile solvent, and introduced by means of a syringe, either directly onto the column (e.g. *cold on-column injection*), or an injection system, heated to vaporise the sample; the sample vapours are swept on to the column by the carrier gas. The separated sample component peaks reaching the lower end of the column are sensed by a *detector*, which gives an electrical response dependent on the size of the component peak. There are a number of different types of detector, dependent upon the components being analysed. For routine analysis of organic compounds the *flame ionisation detector* is most widely used. Some modern gas chromatography columns have been designed to allow compounds of relatively low volatility to be analysed, by running at high temperatures. The plant wax compounds and sterols/stanols described in the present report come under this category.

Gas chromatography-mass spectrometry (GCMS): This is essentially conventional gas chromatography fitted with a mass-selective detector, primarily for resolution of organic analytes. The separated compound molecules eluting from the chromatography column are transferred to a vacuum chamber, where they are ionised and separated and detected according to ion mass. In the most widely used configuration (as used in the work described in this report), the analyte molecules are ionised by bombardment with an electron beam (*electron ionisation*), which breaks up the molecules to produce a number of fragment ions. By using a fixed standard electron energy (conventionally 70eV), the relative percentages of the different fragment ions result in a reproducible *mass spectrum* which, being characteristic for different individual compounds, enables the compounds to be directly identified. Since the number of ions produced for a particular compound is dependent on the amounts of compound eluting from the GC column, quantitative analysis can be carried out. Counting all of the ions produced (*total ion count*, TIC) results in a gas chromatogram which is very similar to that obtained from a conventional gas chromatograph fitted with a flame ionisation detector.

Interpretation of gas chromatograms and quantification: In conventional gas chromatography, compound peaks can be identified from the *retention time*, which is the time after injecting the sample that the summit of the peak occurs; standard mixtures containing compounds of interest also need to be run under identical conditions (temperature, gas flow rate etc.) of the gas chromatograph. Peak sizes are usually determined in terms of peak areas, determined with specialist software built into a computing integrator or computer attached to the gas chromatograph. The accurate assessment of peak area is very much dependent on the correct positioning of baselines executed by the software; this is particularly important in situations where peaks may not be fully resolved.

The *n*-alkanes, fatty alcohols, sterols and stanols in the samples analysed in this report could be quantified by adding a known amount of relevant *internal standard* compound to the sample prior to extraction, purification and analysis. Ideally, a suitable internal standard compound should not be present in the samples, but have the same physical and chemical properties as the compounds being quantified. Ideally, a suitable internal standard compound should not be present in the samples, but have the same physical and chemical properties as the compounds being quantified. It has been shown that the concentrations of the chosen internal standards for *n*-alkanes and for fatty alcohols can be considered as having negligible concentrations in plant and soil samples. The internal standard used to quantify *n*-alkanes was tetratriacontane (C34).The fatty alcohol internal standard was1-heptacosanol (C27-ol), the fatty acid standard was hentriacontanoic acid (C31) and 5β-cholan-24-ol was added as the internal standard for the sterols and stanols.

ORGANIC MARKERS RELEVANT TO THIS REPORT

Plant wax compounds: Lipid (hydrophobic) compounds found in the surface wax of plants. These can be complex mixtures. The plant wax compounds mentioned in this report are listed as follows:

***n*-Alkanes**: straight-chain, C_{21}-C_{37}, with odd-chain compounds predominating

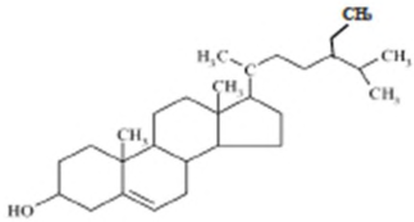
Primary long-chain fatty alcohols: straight-chain, C_{20}-ol - C_{34}-ol, predominantly even-chain

Sterols and stanols:

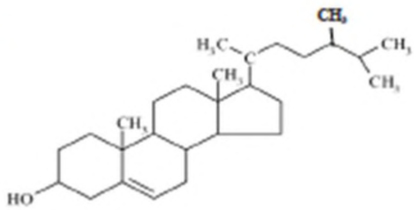
These, if present, occur in the 'alcohol' fraction eluted from silica-gel columns. Sterols are unsaturated (i.e. containing one or more double bonds) steroidal alcohols; stanols are saturated steroidal alcohols.

Sterols:

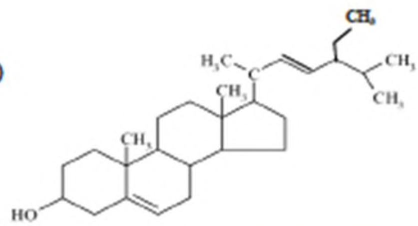
β-Sitosterol (24-ethyl cholest-5-en-3β-ol):
main sterol found in plants



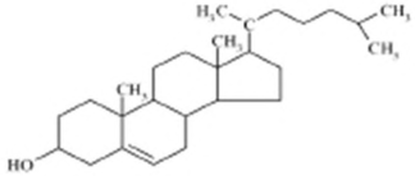
Campesterol (24-methyl cholest-5-en-3β-ol):
common plant sterol



Stigmasterol (24-ethyl 5,22-dien-cholestan-3β-ol)
common plant sterol

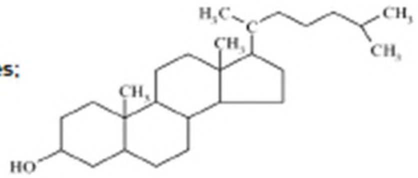


Cholesterol (cholest-5-en-3β-ol):
main sterol found in animals



Stanols:

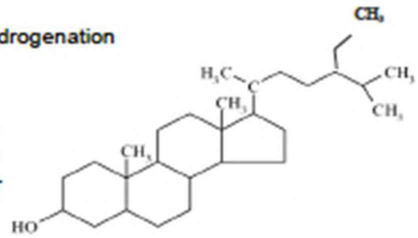
Coprostanol (5β-cholestan-3β-ol): hydrogenation product of cholesterol occurring in mammalian faeces; main stanol in human and pig faeces



Epicoprostanol (5β-cholestan-3α-ol): isomer produced from coprostanol by microbes under anaerobic conditions (e.g. septic tank)

Cholestanol (5α-cholestan-3β-ol): another isomer produced by hydrogenation of cholesterol under anaerobic conditions in the environment (not in the mammalian gut).

24-Ethylcoprostanol (24-ethyl 5β-cholestan-3-β-ol): hydrogenation product of β-Sitosterol; main stanol in herbivore faeces



24-Ethyl epicoprostanol (24-ethyl 5β-cholestan-3α-ol): isomer produced from 24-ethylcoprostanol by microbes under anaerobic conditions (e.g. farm slurry tank); minor stanol in fresh faeces

Stigmastanol (24-ethyl 5α-cholestan-3β-ol):
another isomer produced by hydrogenation of β-sitosterol under anaerobic conditions in the environment (not in the mammalian gut:

Campestanol (24-methyl 5α-cholestan-3β-ol): hydrogenation product produced by hydrogenation of campesterol under anaerobic conditions in the environment (not in the mammalian gut).

NB: The structural diagrams of the above stanols and isomers are generic. The numbers refer to the individual carbon atoms within the steroidal structure and the Greek letters (α and β) refer to whether the side group (e.g. the 'OH' group) is in a position above or below the ring structure. The same applies to 24-ethylcoprostanol, campestanol and their isomers.

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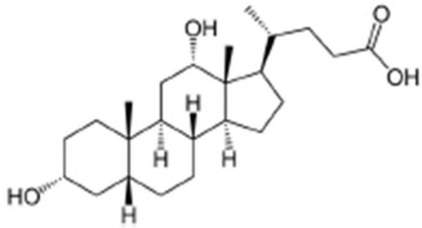
Faecal bile acids:

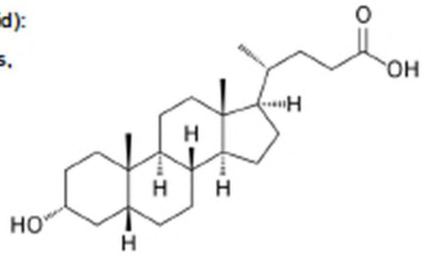
Bile acids are steroidal hydroxyl acids. The compounds of interest as markers found in faeces are secondary bile acids, which have been transformed by gut bacteria from primary bile acids (cholic acid and chenodeoxycholic acid) which had been secreted into the gut from bile.

Lithocholic acid (3α-hydroxy-5β-cholan-24-oic acid):

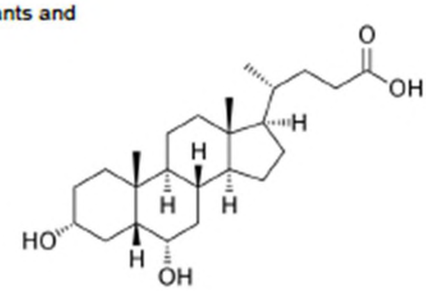
found in faeces of most mammals, including faeces from humans, pigs, ruminants and other herbivores.



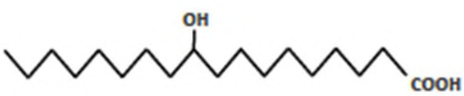
Deoxycholic acid (3α,12α-dihydroxy-5β-cholan-24-oic acid):
found in faeces of humans, ruminants and other herbivores, but not in pig faeces



Hyodeoxycholic acid (3α,6α-dihydroxy-5β-cholan-24-oic acid):
found in pig faeces, but not in faeces of humans, ruminants and other herbivores



10-Hydroxy stearic acid:



Produced from oleic acid by microbes under wet anaerobic conditions. It is a major constituent of adipocere, which is a white soapy substance originating from body fat and found in cadavers which had decomposed in a waterlogged environment. 10-Hydroxystearate is thus a useful body decomposition marker. It has also been found in human faeces.

Other terms used in this report:

Mineral - A mineral is a naturally occurring solid chemical substance, formed through geological processes, which has a characteristic chemical composition, a highly ordered atomic structure, and specific physical properties consequent upon its structure and chemistry.

Organic - Pertaining to a class of chemical compound that exist in or have been derived from plants or animals.

Appendix 4

Summary of procedure for the analysis of soil samples for organic lipid markers

High-purity solvents are re-distilled (*n*-heptane, ethanol and ethyl acetate) before being used.

The air-dried soil samples were hand milled in an agate mortar and pestle. Duplicate sub-samples of each soil (about 200mg) were weighed with alkane,fatty alcohol and sterol internal standard compounds from separate solutions of known concentration (C22 and C34 *n*-alkanes, C27 alcohol and 5β-cholan 24ol, respectively) into screw capped tubes with PTFE cap-liners, and heated overnight in sealed screw-cap vials with 1M ethanolic KOH at 90°C.

After cooling to 50°C and the addition of water, any hydrocarbons (including *n*-alkanes) and alcohols present were extracted twice with *n*-heptane. After removing the solvent, the heptane extracts were re-dissolved in heptane prior to being transferred to a small glass solid-phase extraction column packed with about 50mg of silica-gel. The hydrocarbons were eluted from the column with *n*-heptane. The solvent was then changed to 20% ethyl acetate/ 80% *n*-heptane (v/v) in order to elute any fatty alcohols, sterols and triterpenols (crude alcohol extract). The hydrocarbon extract was dried and redissolved in dodecane prior to analysis by GC. The crude alcohol extract was derivitised with a mixture of BSTFA and pyridine before drying and redissolving in dodecane prior to analysis by GC-MS.

The residue remaining after alkane and alcohol extraction was acidified and extracted with chloroform. The extracted compounds were added to an SPE column containing aminopropyl packing. The organic acids were eluted with a mixture of diethyl ether and glacial acetic acid. After drying the acids were converted to their methyl esters, by heating with acidified methanol and then further treated with BSTFA to silylate the hydroxyl groups (as trimethylsilyl ethers on hydroxy acids). The derivatised extracts were analysed by GCMS in TIC mode.

Appendix 5

Images of soil examined

Photographs of soil sample examined (fractions which passed through a 1mm sieve). (Scale = mm)

Plate 1 Sample from Feature 1 (<1mm sieved) at X20 magnification

Plate 2 Feature 1 Soil aggregates and white material at X40 magnification.

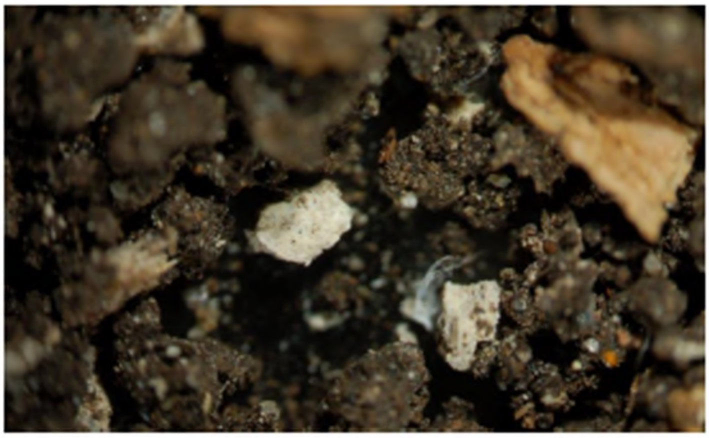
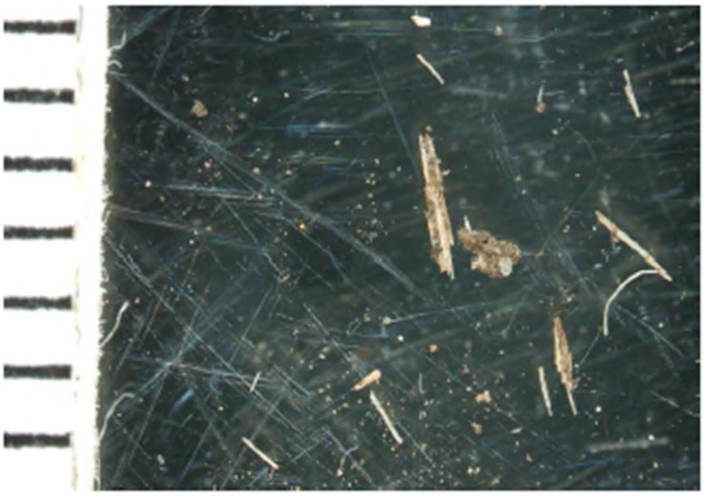


Plate 3 Feature 1 Fragment of bone at X40 magnification.

Plate 4 Feature 1 Fibres removed for X-ray Diffraction (XRD) analysis



31st May 2017

Directed Site Investigations at the reported *'Children's Burial Ground'*, Dublin Road Housing Estate, Tuam, Co. Galway: Results of Phase IIA

Report to The Mother and Baby Home Commission of Investigation

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EXECUTIVE SUMMARY

- This excavation was completed to forensic standards and within the parameters requested by the Mother and Baby Home Commission of Investigation.

- This investigation (Phase IIA) was an extension of Phase II and was designed to expose the extent of Feature 1, the chambered tank structure identified in 2016.

- A further 16 chambered tanks were exposed bringing the total to 20 individual chambered tanks along the extent of Feature 1.

- The base of Feature 1 is approximately 2.70m below the present ground surface, was not accessible and thus, was not forensically examined as part of this phase of works.

- The structural nature of Feature 1 limited investigations to visual observation and soil sampling.

- Each chamber has an opening at the top. Eight chambers have clearly defined openings at the base, with more indistinct breaches at the base in others.

- It is highly likely that this structure was originally constructed for the treatment of sewage waste.

- Juvenile human remains, in significant quantities, were observed in 18 of the total 20 chambers.

- Juvenile human remains observed were in an excellent state of preservation.

- Evidence exists that supports potential articulation of these remains at the time of interment.

- Osteological observations support the age range representing of individuals being infant, less than 1 year of age, and young juvenile, from 1-6 years of age.

- Archaeotanathology indicates there have been significant fluctuations of the water-table within the individual chambers.

- Soils analysis indicates the presence of the biomarkers of human sewage and human decomposition products within the chambered tanks, however the timing of when these activities occurred cannot be ascertained.

- A decision on the future of the site needs to be made as soon as possible to prevent potential damage to the remains that lie there. There is a risk of disruption to preservation of context, articulation evidence and the preservation of DNA. While this threat is not necessarily immediate it does exist.

- It is not appropriate to leave juvenile human remains in this specific context.

1. Introduction

This report presents the results in full of an extension of site investigation work carried out at the site of the reported 'Children's Burial Ground' at the Dublin Road Housing Estate, Tuam, Co. Galway in November 2016. This further excavation was undertaken on behalf of the Mother and Baby Home Commission of Investigation, herein MBHCOI, with the cooperation of An Garda Síochána, and represents Phase IIA of site investigations.

A significant sub surface feature, Feature 1, was identified in Phase II. This required further investigation on behalf of the MBHCOI in order to establish its full extent and if further human remains are present. Niamh McCullagh, Forensic Archaeologist, directed all works on-site for the duration of Phase IIA.

This report presents the methodology, the results in full, including human remains, artefacts recovered, and soils analysis. Finally the condition of the site post excavation is described. The scale and significance of findings in Phase IIA further highlights the requirement that careful and swift consideration is undertaken to decide upon the future of human remains at the site.

1.2 Aims and Objectives of the Excavation

This excavation took place at the request of the MBHCOI, under the Commissions of Investigation Act 2004, Sections 8, 26 and 28. This additional excavation was undertaken under the same warrant that had been issued on the 1st of September 2016 by Judge Yvonne Murphy, in accordance with Section 26 of the Commission of Investigations Act 2004. This warrant authorised Niamh McCullagh to exercise the powers given under Section 28 of the Act in relation to premises known as the Children's Burial Ground located in the Dublin Road Housing Estate, Tuam, Co. Galway, see **Appendix I**.

On the 13th of December 2016 the MBHCOI requested specifically that the structure identified as Feature 1 in Phase II be exposed completely and investigated further. This phase was designed to be an non-intrusive investigation, with observations to be made on the contents of each chamber and a contemporaneous photogrammetric record be made. No human remains were to be recovered during this phase. An additional request was made for soil sampling to be undertaken whilst on site to inform the MBHCOI regarding the potential the chambers had been used for the storage of sewage. No other areas of the site were disturbed during the course of this work.

The matters requiring investigation for Phase IIA were:

i. To establish the extent of the previously identified feature, Feature 1, found in Phase II.
ii. To establish if there were further human remains at this location.
iii. To conduct a comprehensive soil sampling exercise in order to detect if Feature 1 had been used to store human sewage.

A controlled forensic excavation, focused on Feature 1, took place from the 30th of January to the 10th of February 2017. Additional analysis was conducted post-excavation amounting to a further three months in duration to bring the project to the production of report.

1.3 Test Excavation

As the MBHCOI could not justify a full excavation at this point, the investigative strategy that was utilised for Phase IIA is what is termed a 'test excavation' approach. This method uses focused trenches rather than open area excavation and is designed to have minimum impact on the site while allowing relevant evidence to be recovered. The three concerns of the Commission were to be addressed by conducting this test trench method of excavation over the structure Feature 1. This ensured that the remainder of the site was undisturbed and available for future investigations.

1.4 Forensic Archaeology

The site investigation required a full forensic control to be in place and to direct works on site; this is due to the modern nature of the site and the modern context of expected results. Niamh McCullagh, as a suitably qualified and experienced Forensic Archaeologist, was appointed this task.

The timeframe under consideration was from 1925-1961, the duration of the operation of the Mother and Baby Home associated with this site. The modern nature of the site gave rise to the potential for it to become regarded as a crime scene. All evidence collected is required to be of a standard submissible in a criminal court of law, that is, to the evidential standard that is required by forensic cases.

In traditional archaeology the emphasis is generally on a cultural interpretation of the past, as opposed to specific, individual events. Standards of evidence and interpretation are not subjected to the scrupulous standards required by a court of law. While methods used are similar the interpretations are not, neither are the forms of evidence gathered.

In adherence with best practice, manual archaeological excavation conformed to the Museum of London Archaeological Standards (MoLAS) and the codes of practice of the Institute of Archaeologists of Ireland (IAI). This meant documentation through single context archaeological recording, by written descriptions, scaled photographs, and surveyed drawings. The written descriptions of soils, scaled photography, and scaled section and plan drawings (at 1:10 and 1:20), were archived by register on-site – a practice referred to as preservation by record. In this case, for management of space, the void that was created by the construction of each chamber was also given a context number. The contents of each chamber were further recorded through the use of rendered photogrammetry. A detailed record of the archaeological site work undertaken has been retained and the site archive is available on request.

Forensic archaeological standards were maintained in accordance with the 'Standards and Guidance for Forensic Archaeologists' (Powers and Sibun, 2011), prepared for the Chartered Institute for Archaeologists, UK, and the Handbook of Forensic Anthropology and Archaeology (World Archaeological Congress Research, 2011), Blau, S. & Ubelaker, D. (eds). Please see technical note in **Appendix II** for further details.

1.5 Methodology for Phase IIA

The investigative strategy utilised for this investigation was similar to the 'Test Excavation' approach, which has the minimum impact on the site while allowing relevant evidence to be recovered. This protects the integrity of the human remains and the deposition site.

The excavation design consisted of placing a single trench directly over the area of interest. The location and size of this single trench was informed by the results of the desktop review, the geophysical survey conducted (Utsi, 2015), the initial test excavation (McCullagh, 2016), and as requested by the Mother and Baby Home Commission of Investigation. This excavation had a high potential to reveal further human skeletal remains, hence all work ensured that any such remains were treated with the utmost dignity and respect while maintaining forensic protocol.

The excavation methodology for Phase IIA was conducted as per the proposal for Phase II dated 10th August 2016. Forensic control was maintained throughout the site investigation. All mechanical works were monitored by archaeological personnel and all manual excavation was undertaken by qualified archaeological personnel. The site investigation was implemented in the following stages:

1. The location of the chambered structure was identified on the surface of the site.
2. Topsoil and gravel, the overburden, was removed using a track machine fitted with a grading bucket (3 Tonne) under archaeological supervision. This was carried out in two stages; initially the Western extent of Feature 1 was exposed followed by the Eastern extent of the chambered structure.
3. Once overburden was removed, manual excavation by archaeologists exposed the fractured lids or coverings over each of the chambers identified and an appropriate record was made prior to the next stage.
4. Each of these lids was then removed and the internal structure and contents were assessed and appropriately recorded.
5. A temporary timber covering was placed over each opening for the duration of works on site.
6. The extent of the opened trench was covered by commercial marquee for the duration of works.

Any human remains uncovered on site whilst being of evidential value, were treated with dignity and respect. As the extent of Feature 1 was uncovered, each chamber was covered as work progressed (unless that chamber was being recorded at that the time). Once excavation was underway the trench was protected by a commercial marquee that acted as a scene tent to shelter sensitive evidence, to prevent overlooking, and keep the open trenches safe, **Appendix III Plate 1.1.**

A number of additional measures were put in place to protect the integrity of the site and in respect of the sensitivity of such a project. The site was surrounded by plywood hoarding to inhibit line-of-sight and to offer security to the location and to staff for the duration of works. Security of the site was also maintained throughout the excavation by the 24/7 presence of An Garda Síochána.

2. Results of Excavation

2.1 Structural Evidence

Aidan HARTE and Niamh McCULLAGH

Feature 1 (C.5 etc.) can be clearly seen depicted in the geophysical results, see **Appendix IV Figure 2.1 FIGURE**. The layout drawing illustrates the archaeological features as uncovered during excavation. Overlain are the interpreted extensions of those masonry features, as identified from the geophysical survey. The latter has been re-worked to reflect the actualities of the archaeological remains.

2.2 Nineteenth Century Cesspit

These results alter the extrapolated measurements of the overall cesspit as calculated in Phase II. Consequently, the cesspit likely measures 11.16m x 8.02m internally. Note that the northeastern corner is not clear in the geophysical survey. This may be the result of infill of the cesspit originating from this location but may also highlight further masonry features in this direction. The internal rectangular feature within the cesspit at north (i.e. Feature 2) does not form a clear anomaly in the magnetometry/gradiometry survey results (Utsi, 2015). It is therefore possible that further divisions of the original cesspit exist but cannot be coherently mapped from the geophysical survey alone.

2. 3 Feature 1

The focus of this investigation was on Feature 1, see **Appendix IV Figure 2.2** for site matrix. Feature 1 may generally be described as a later addition within the 19th Century workhouse cesspit that had been located during Phase II. It consists of stone walls, shuttered with concrete, utilising the southern end of the earlier cesspit. The stone and mortar constructed southern wall of the cesspit and southernmost 1.6m of both the East and West walls of the cesspit, form boundaries of Feature 1. This is clearly visible internally to C. 50/52 and C.104/105 and in places along the length of the southern wall where the concrete shuttering has not been placed on the pre-existing wall e.g. C. 71, C.75, C.73, indicating the time frame and sequence of construction that occurred here.

2. 3. 1 Openings

Within the separate tanks that form Feature 1, a number of observations can be made. Without exception, all tanks have access through an opening at the top of the tank, C. 5. There are 21 openings that correspond to 20 internal chambers; C.50, C.52, C.54, C.56, C.58, C.60, C.62, C.64, C.82, C.84, C.86, C.88, C.90, C.92, C.94, C.96, C.98, C.100, C.102 and C.104, see **Appendix III Plates 2.1 & 2.2**. The size of the openings at the top of each tank is essentially identical; each opening averages 0.84m in length (minimum 0.82m and maximum 0.85m), and averages 0.29m in width uniformly. This further supports the view that timber formwork was used in the construction of the concrete cap closing the tank; see **Appendix IV Figure 2.3 & 2.4 and Appendix III Plates 2.3.**

2. 3. 2 Lids/Covers

A lid had covered each of the 21 openings. Lids believed to be the original lids are of similar construction and material as the concrete capping, **Appendix III Plates 2.4**. These were pre-cast concrete, approximately 6cm in thickness. A number of these had been broken and replaced throughout the history of use of the chambers. In some instances, although fractured, most of the original lid was found covering the opening. Most repairs or replacements were found at the northern half of each opening. While in some cases materials such as corrugated steel was used, it was more commonly outsized crude concrete slabs that replaced broken portions of lids **Appendix III Plates 2.5 & 2.6.** In the case of C.86/87 the covering lid had completely degraded and soil compaction was all that remained over the opening.

2. 3. 4 Internal openings

All further noted breaks, gaps and openings are at the base of the northern wall within each tank. These openings are well-defined in the eight easternmost chambered tanks. The first tank on the eastern end (C.50) has a squared opening to north, estimated between 0.25m - 0.31m in width. This opening extended through the wall to north where it had been closed using a metal cover. This may have been unintentional but does provide a clarity on the construction of the opening. It seems that the opening was shuttered with concrete, using formwork, during the construction of the north wall. The position at which it enters the chambered tank is slightly off-centre to the west.

The next chambered tank to the west, C.52, has a squared opening that has been blocked with debris which had seemingly originated at north. It has an estimated width of approximately 0.36m and is off-set significantly to the west of centre. The internal face of the north wall here has an observable kink, whereby the footing appears to have been stepped back, by as much as 80mm.

Tank C.54, the next chamber to the west, again has a squared basal opening. Although some debris is present within the opening, it is clearly defined, with an estimated width of 0.37m, centrally positioned in relation to the tank. The basal opening in the next tank to the west, C.56, is again squared with an approximated width of 0.34m. Notably, this opening is displaced to the east of the tank, so much so that the eastern dividing wall appears to have been recessed to accommodate it. Chambered tank C.58, to the west, again has a squared opening at the base. This is also heavily displaced to the east and has an estimated width of 0.32m. Further west, chambered tank C.60, has a squared opening at the base between 0.3m and 0.32m in width. Debris has partially filled the opening which is set slightly off-centre to east.

The opening at the base of the chambered tank to the west, C.62, is particularly interesting in that it has been largely blocked from the far side (north) by large pieces of limestone and mortar. This has preserved some of the timber form-work at the head of the opening. It is 0.36m in width and very slightly off-set to the west. Finally, the next chambered tank to the west, C.64, has a basal opening measuring between 0.38m – 0.4m and is positioned almost flush with the eastern wall of the chamber. The eastern wall of the chamber appears to lean eastwards as it rises.

These formal openings, all occur in the north wall and at the eastern end of Feature 1. Where most clearly evident (C.58, C.62 and C.64), the height is greater than the width of the openings. The depth of each opening is that of the thickness of the wall but in most instances debris has been displaced through the openings from north.

The position of the openings, relative to the tanks is interesting, as it suggests that the northern wall – and its openings - was constructed before the internal dividing walls. However, seemingly no further deliberate openings were made along the remaining section of northern wall to the west. It is worth noting that breaks, gaps or other breaches in the north wall are evident in most of the other tanks to the west, with the exception of the westernmost end tank C.104. These breaches in the western half of the north wall are most substantial in tanks C.84, C.86, C.88, C.94 and C.96.

Chambered tank C.84 is interesting due to the fact that though there is a crude breach at the base of the wall, the shuttered concrete above suggests that a squared opening had been constructed but was subsequently filled in and shuttered over. The regular form of other breaches may also be resultant of a similar construction. At chambered tank C.88 the breach is very regular except for at the top and at C.94 it appears stones may have been used to fill the opening and were then crudely concreted over. Alternatively, the creation of these breaches (i.e. through hydraulic erosion) has removed sections of the regularly coursed masonry found within an otherwise homogeneous wall. Nevertheless, it is clear that the base of the northern wall of Feature 1 has deliberate openings at the eastern end and is similarly breached at many points along the remainder.

In every chambered tank, the south wall is limestone and mortar construction. At the end tanks (C.50 and C.104) the end walls are of the same construction and extend beyond Feature 1 to the north. This southern wall is therefore the original cesspit wall. The northern wall appears to have been constructed to separate a rectangular space which was to be divided into 20 voids/tanks.

2. 4 Discussion

The purpose of this structure remains largely unclear but it does seem plausible that each chambered tank was expected to act as a cesspool. A 'cesspit' is a place/tank in which waste material collects and is emptied manually at intervals, while 'cess pool' by definition is a place in which waste is deposited but allowing the liquid part to percolate into the surrounding soil.

A septic tank, by contrast, necessitates the filtration of all material so that solid waste is broken-down before percolating elsewhere. It is possible that the eight eastern tanks were designed to act at cesspools, liquids percolating into the former cess pit to the north. However, during the course of construction, this design template may have been abandoned, opting instead for simple cess pits that were not to be emptied. It must be understood that this would have been a very short term out-look for any sanitation project.

The cast concrete cap (C.5) was created *in-situ*. The basal timbers of the casting boards are still in place in some instances (most notable at C.62)**, Appendix III Plate 2.7,** and much of the timber debris within the tanks may have originally been part of this. Also of interest is tank C.102, which has a low dividing wall in the interior, while C.82 immediately to the west has two openings at the top. It is likely this was done in error and that the double openings of C.82 were in fact meant to access two separate tanks at C.102. Following the cast, the internal wall of C.102 was reduced in height.

3. Human Remains Evidence

3.1 Human Remains Evidence and Analysis

Dr Linda G. LYNCH

This report details the osteoarchaeological assessment of the photographic record of the most recent investigations (Phase IIA) by the Mother and Baby Homes Commission Of Investigation (MBHCOI) of the site at Tuam. Previous test excavations identified juvenile (<18 years) human skeletal remains within, and to the exterior (north) of, four underground tanks associated with a larger concrete structure (McCullagh 2016).

3. 2 Methodology

Unlike the initial test excavations in Phase II, no skeletal remains were recovered during the most recent archaeological investigation (Phase IIA). The surfaces of the deposits in the 16 tanks were almost 2m below the upper capped concrete surface. Photogrammetry was undertaken, which enabled the whole surface of each deposit to be photographed in detail. Human skeletal remains were identified in 14 out of the 16 tanks exposed during this investigation.

A composite photograph of each tank was processed by A. Harte for planning purposes. These composites are used in this report as the base photograph of each chambered tank, which are examined separately below. Each composite photograph is annotated (in terms of skeletal remains), and more detailed descriptions of identified, and unidentified, human remains is provided, including more specific photographs. In some cases, it was possible to identify individual bones. While every group of bones, or actual identifiable bones, are indicated in each tank, not every single fragment of bone is highlighted.

No adult bone (18+ years) was identified, and all identifiable skeletal remains within the tanks appeared to be from either infants (<1year) or young juveniles (1-6 years). It was not always possible to correctly identify the age group and many bones are simply classed as juvenile – in this instance 'juvenile' specifically refers to individuals aged 6 years or less at the time of death.

A number of instances of possible articulated human skeletal remains were identified on the surfaces of the sediments within the tanks. However, this does not necessarily indicate *in situ* remains. It appears likely that there has been considerable fluctuation in water levels in the tanks since the human remains were originally deposited, resulting in a redistribution of skeletal elements. This will be further examined in the discussion.

As a reference guide to the photographs and text, where some technical language is used, there are diagrams of the main bones of the human skeleton, the main elements of the infant cranium, anatomical directions, and a glossary of osteoarchaeological terms in Appendix VI, A-D.

3. 3 Human Skeletal Remains (as determined from photographic analysis)

In total, 16 additional tanks were opened during the present investigation. Human skeletal remains were identified in 14 of them. In most of the photographs, north is always to the top, unless otherwise stated.

C.50/51

This is the easternmost tank of Feature 1. It was identified in Phase II and reported on in full (see McCullagh 2016)

C.52/53

This tank is immediately to the west of tank C.50/51. It comprises a single narrow chamber. **Appendix III Plate 3.1** is a general annotated photograph of the base of the tank, while **Appendix III Plate 3.2** to **3.7** show the identified elements in more detail. Human remains were identified on the surface of the sediment, at the north end of the tank (a), along the eastern side (b) and (c), and at the southern end (d).

The identified human remains are summarised in **Table 3.1**.

Location as indicated in primary photograph Plate 3.1	Details	Plate reference (see Appendix III)
a	Multiple cranial remains of infants (<1 year) and/or young juveniles (1-6 years)	3.2
b	Collection of possible infant (<1 year) remains including two separate sets of possible articulated ribs, and other possible indicators of articulation	3.3
c	Infant (<1 year) cranial fragment and long bone	3.4
d	Multiple possible infant (<1 year) remains including two individual sets of possibly articulated ribs and two mandibles	3.5, 3.6, 3.7

Table 3.1: Identified human skeletal remains within tank C.52/53

A collection of primarily cranial remains is present at the northern end of the tank (see **Appendix III Plate 3.2**), which may be from either infant/s (<1 year) and/or young juveniles (1-6 years). It is possible that multiple individuals are represented here. There is some suggestion of articulation in the bones indicated in **Appendix III Plate 3.3**, located along the east side of the tank, which appear to comprise infant remains (<1 year). At least two separate concentrations of ribs appear in an articulated state, while a possible left humerus and ulna (upper arm and forearm bones) are in the approximate location for being articulated. It may also be more that coincidence that there are two tibiae (shin bones) close together. There also appears to be a concentration of possible infant vertebrae.

A possible infant cranium and long bone was identified along the middle of the eastern side of the tank (see **Appendix III Plate 3.4**).

At the southern end of the tank a significant concentration of skeletal remains was identified (**Appendix III Plate 3.5**). Two individual sets of possibly articulated possible infant ribs were identified. In addition to a large concentration of possibly infant/young juvenile cranial remains, ribs, and long bones, two mandibles were identified. The first mandible (**Appendix III Plate 3.6**) is probably from an infant <1 year at the time of death. Another probable infant mandible (<1 year) was also identified (**Appendix III Plate 3.7**).

C.54/55

This tank was immediately to the west of tank C.52/53. It comprised a single narrow chamber. Human remains were identified in the deposits. **Appendix III Plate 3.8** is a general annotated photograph of the base of the tank, while **Appendix III Plates 3.9-3.13** show the identified elements in more detail, while other information is detailed in **Appendix III Plates 3.14** and **3.15**. Human skeletal remains were identified in the southern half, (a) and (b), of the tank.

The identified human remains are summarised in **Table 3.2**.

Location as indicated in primary photograph Plate 3.8	Details	Plate reference (see Appendix III)
a	Various infant (<1 year) and/or young juvenile (1-6 years) remains	3.9, 3.10
b	Infant/young juvenile cranial remains (<6 years), adjacent to animal bone, with an infant (<1 year) femur and associated possible hand bones suggesting some possible articulation	3.11, 3.12, 3.13

Table 3.2: Identified human skeletal remains within tank C.54/55

Infant (<1 years) and/or young juvenile (1-6 years) skeletal remains were identified just to the south of the middle of the tank (see **Appendix III Plate 3.9**). There was no evidence of articulation.

An infant femur (thigh bone) and hand bones were identified in the northern end of the tank (**Appendix III Plate 3.11**), which may suggest some degree of articulation (**Appendix III Plate 3.12**). In addition, cranial remains of an infant were identified underlying what appears to be a large animal bone fragment in the southwest corner of the tank (**Appendix III Plate 3.13**).

Two small possible fragments of human bone were tentatively identified attached to the north-facing wall of the tank (**Appendix III Plate 3.14**).

A possible piece of wickerwork (**Appendix III Plate 3.15**) was identified at the northern end of the tank (see **Appendix III Plate 3.8** for location).

C.56/57

This tank was immediately to the west of tank C.54/55. It comprised a single narrow chamber. Human remains were identified in the deposits. **Appendix III Plate 3.16** is a general annotated photograph of the base of the tank, while **Appendix III Plate 3.17** to **3.23** show the identified elements in more detail. Skeletal remains were identified at the northern end of the tank (a), near the centre (b), and in the southern half (c) and (d).

The identified human remains are summarised in **Table 3.3**.

Location as indicated in primary photograph Plate 3.16	Details	Plate reference (see Appendix III)
a	Multiple infant (<1 year) and/or young juvenile (1-6 years) cranial bones	3.17
b	Infant (<1 year) and/or young juvenile (1-6 years) cranial bone	3.18
c	Multiple possible infant (<1 year) long bones	3.19
d	Cranial remains of at least two young juveniles (1-6 years), as well as other skeletal remains	3.20, 3.21, 3.22, 3.23

Table 3.3: Identified human skeletal remains within tank C.56/57

Multiple infant/young juvenile bones (that is, <6 years) were evident in the areas marked (a), (b), and (c) in **Appendix III Plates 3.17-3.19**. In **Appendix III Plate 3.17**, a thoracic vertebral arch of a young juvenile (1-6 years) is also visible.

Multiple juvenile cranial fragments were present at the southern end of the tank and some of these are indicated in **Appendix III Plate 3.20**. At least two young juveniles (1-6 years) appear to be present. On the right side of the photograph is the occipital squama (back of skull) and right temporal (side of skull) of a possible young juvenile (1-6 years). The other left and right temporals, occipital squama and pars lateralis, and pars basilaris, in the main area of the photograph, are probably all from another juvenile individual. These bones form the sides, back, and base of the skull. The pars lateralis appear at least partially fused to the squama, which typically occurs between 1-3 years of age (after Schaefer et al. 2009, 15). The pars basilaris is completely separate: this typically fuses to the pars lateralis between the ages of 5-7 years (ibid.).

Some additional skeletal remains were identified in the southern end of the tank and these are specifically highlighted in **Appendix III Plate 3.21-3.23**. A set of infant/juvenile ribs were visible along the west-facing wall, which may suggest some degree of articulation (**Appendix III Plate 3.21**). The mandibular remains of a young juvenile were also evident in this area (**Appendix III Plate 3.22**). It is tentatively suggested that the first and second deciduous molars may have been erupted at the time of death which would indicate an individual aged between approximately 2-4 years at the time of death. A probable young juvenile (1-6 years) thoracic arch is visible adjacent to the mandible. Finally, there was a concentration of possible juvenile ribs and vertebrae (**Appendix III Plate 3.23**) near the southeast, which may suggest some articulation.

C.58/59

This tank was immediately to the west of tank C.56/57. It comprised a single narrow chamber. Human remains were identified in the deposits. **Appendix III Plate 3.24** is a general annotated photograph of the base of the tank, while **Appendix III Plate 3.25-3.32** show the identified elements in more detail. Human skeletal remains were identified in the northern half (a) and in the southern half, (b) and (c).

The identified human remains are summarised in **Table 3.4**.

Location as indicated in primary photograph Plate 3.24	Details	Plate reference (see Appendix III)
a	Numerous possible infant remains, with some possible articulation	3.25, 3.26, 3.27
b	Possible infant hand bones, possible infant/young juvenile articulated vertebrae and ribs	3.28, 3.29, 3.30
c	Infant bones	3.31

Table 3.4: Identified human skeletal remains within tank C.58/59

A large amount of human skeletal material was evident at the northern end of the tank (**Appendix III Plate 3.25**), with multiple cranial possible infant bones evident, as well as various bones of the limbs and a pelvic bone (**Appendix III Plate 3.26**). A possible infant ulna and radius were tentatively identified which may be in an articulated state (**Appendix III Plate 3.27**).

Other possible infant bones were also identified on the east side of the tank (see **Appendix III Plate 3.24-3.28**). Possible infant hand bones were identified (**Appendix III Plate 3.29**): the fact that they are adjacent is suggestive of some degree of articulation. More convincing evidence of articulation was evident in a set of possible infant/young juvenile thoracic vertebrae and left ribs (**Appendix III Plate 3.30**). In the latter, the medial ends of the ribs appear to be in the general position for articulation with the left transverse process of at least two thoracic vertebrae. This could also be a young juvenile individual. Finally cranial and rib remains from a possible infant were also identified (see **Appendix III Plates 3.31**).

In addition to the skeletal remains evident in the sediment, an infant/young juvenile hand phalanx was identified attached to the concrete cladding of the tank in the northwest corner (**Appendix III Plate 3.32**). This was located above the extant sediments.

Finally, the remains of a black, probably plastic, hair comb (**Appendix III Plate 3.33**) were identified near the northern end of the tank (see **Appendix III Plate 3.25** for location).

C.60/61

This tank was immediately to the west of tank C.58/59. It comprised a single narrow chamber. Human remains were identified in the deposits. **Appendix III Plate 3.34** is a general annotated photograph of the base of the tank, while **Appendix III Plate 3.35-3.37** show the identified elements in more detail, while another detail is shown in **Appendix III Plate 3.38**.

The identified human remains are summarised in **Table 3.5**.

Location as indicated in primary photograph Plate 3.34	Details	Plate reference (see Appendix III)
a	Multiple infant (<1 year) and possible young juvenile (1-6 years) bones	3.35, 3.36
b	Infant bones (<1 year)	3.37

Table 3.5: Identified human skeletal remains within tank C.60/61

Infant and possible juvenile cranial fragments, and other bones, were evident at the northern end of the tank (**Appendix III Plate 3.35-3.36**), while infant bones were present at the southern end (**Appendix III Plate 3.37**).

A piece of timber on the western side of the tank, near the southern end (**Appendix III Plate 3.38**) appeared quite angled. It is possible that this may have been deliberately shaped and is suggestive of a coffin.

C.62/63

This tank was immediately to the west of tank C.60/61. It comprised a single narrow chamber. No human skeletal remains were identified in the deposits. **Appendix III Plate 3.39** provides a composite image of the surface of the sediments.

C.64/65

This tank was immediately to the west of tank C.62/63. It comprised a single narrow chamber. Human remains were identified in the deposits. **Appendix III Plate 3.40** is a general annotated photograph of the base of the tank, while **Appendix III Plates 3.41** and **3.42** show the identified elements in more detail. The human remains, (a) and (b), appear to be confined to the northern half of the tank.

The identified human remains are summarised in **Table 3.6**.

Location as indicated in primary photograph Plate 3.40	Details	Plate reference (see Appendix III)
a	Possible infant (0-12 months) cranial bone	3.41
b	Possible infant possible petrous portion (part of temporal bone of cranium) and another possible bone fragment	3.42

Table 3.6: Identified human skeletal remains within tank C.64/65

A fragment of a possible infant cranium is clearly visible at the northern end of the tank (area marked (a) in **Appendix III Plate 3.40**, see **Appendix III Plate 3.41**). In the area marked (b) in **Appendix III Plate 3.40**, the identification of the possible petrous portion (**Appendix III Plate 3.42**), is also tenuous: in some photographs it more closely resembles a piece of timber while it others it appears to resemble a petrous portion. The 'possible bone' in **Appendix III Plate 3.42** is also tentatively identified: it may be timber or metal.

C.102/10/12

This is the easternmost tank identified in Trench 1 in Feature 1 during Phase II. It was previously reported on in full (see McCullagh, 2016).

C.82/11

This is the westernmost tank identified in Trench 1 in Feature 1 during Phase II. It was previously reported on in full (see McCullagh, 2016).

C.84/85

This tank was immediately to the west of tank C.82/11. It comprised a single narrow chamber. Human remains were identified in the deposits. **Appendix III Plate 3.43** is a general annotated photograph of the base of the tank, while **Appendix III Plate 3.44-**

3.50 show the identified elements in more detail. Human skeletal remains were identified in the north (a), middle (b) and (d), and south (c) of the tank.

The identified human remains are summarised in **Table 3.7**.

Location as indicated in primary photograph Plate 3.43	Details	Plate reference (see Appendix III)
a	Multiple bones of at least one infant (<1 year), with evidence of articulation	3.44, 3.45, 3.46
b	Possible infant (<1 year) bones	3.47
c	Probable infant (<1 year) remains, with evidence of articulation	3.48, 3.49
d	Single possible fragment of human bone	3.50

Table 3.7: Identified human skeletal remains within tank C.84/85

Multiple, apparently primarily infant, skeletal remains were evident at the northern end of the tank, marked (a) in **Appendix III Plate 3.43**. These are highlighted in **Appendix III Plates 3.44-3.46**. The infant left temporal, indicated in **Appendix III Plate 3.44**, and highlighted in **Appendix III Plate 3.45**, is probably from an individual aged between 0-5 months at the time of death (after Humphrey and Scheuer 2006; referenced in Schaefer et al. 2009). A concentration of overlapping cranial bones, again probably from an infant, as well as long bones, was also visible in this northern area. At least two of the bones, **Appendix III Plate 3.46**, are suggestive of articulated forearm bones (radius and ulna).

A number of bones, possible from an infant/s, were also present along the western wall (see **Appendix III Plate 3.47**).

Numerous skeletal remains were present in the southern end of the tank and are detailed in **Appendix III Plates 3.48** and **3.49**. Certainly infant remains (<1 year) were present, although it is entirely possible that bones of young juvenile/s (1-6 years) are also present.

The ribs indicated in **Appendix III Plate 3.48**, may be articulated. In particular the ribs that overlie the cranial fragment and are also visible in **Appendix III Plate 3.49**, are aligned as if they were still at least partially articulated. A possible radius and ulna (bones of the forearm), which are visible in **Appendix III Plate 3.49**, also may be in an articulated state. In addition, the two parietals (left and right sides of the skull), indicated in **Appendix III Plate 3.49**, appear to represent a relatively intact cranium, particularly with the presence of a left petrous portion of the temporal (side of the skull).

A single fragment of bone was identified in the east (see **Appendix III Plate 3.50**).

C.86/87

This tank was immediately to the west of tank C.84/85. It comprised a single narrow chamber. No human skeletal remains were visibly within the extant deposits. **Appendix III Plate 3.51** is a general photograph of the surface of the tank sediments.

C.88/89

This tank was immediately to the west of tank C.86/87. It comprised a single narrow chamber. Human remains were identified in the deposits. **Appendix III Plate 3.52** is a general annotated photograph of the base of the tank, while **Appendix III Plates 3.53-3.60** show the identified elements in more detail. Human skeletal remains were identified throughout the length of the tank in at least five concentrations, running from (a) in the north end to (e) in the southern end.

The identified human remains are summarised in **Table 3.8**.

Location as indicated in primary photograph Plate 3.52	Details	Plate reference (see Appendix III)
a	Multiple bones of infants/young juvenile (<6 years)	3.53
b	Multiple bones of infants/young juvenile (<6 years)	3.54
c	Multiple bones of infants/young juvenile (<6 years)	3.55
d	Multiple bones of infants/young juvenile (< 6 years)	3.56
e	Multiple remains including loose cranium of a 1.5-2.5 year old and two possible infants (3 humeri)	3.57, 3.58, 3.59, 3.60

Table 3.8: Identified human skeletal remains within tank C.88/89

Juvenile human skeletal remains were visible throughout the length of this trench, as indicated in **Appendix III Plate 3.52**. Numerous fragments of infant and/or juvenile bones were present in the areas marked (a), (b), and (c), and also in (d), see **Appendix III Plates 3.53-3.56**. In the area (d), a possible humerus was identified from either an infant (<1 year) or a young juvenile (1-6 years), (see **Appendix III Plate 3.56**).

The southern end of the tank, indicated as (e) in **Appendix III Plate 3.52**, contain the most diagnostic fragments in tank C.88/89. Most notable, is the complete cranium (**Appendix III Plate 3.57**). The dental remains of this individual suggest that the mandibular second deciduous molars were just beginning to erupt at the time of death. This suggests an age of perhaps 1.5-2.5 years, although it would not be unexpected if the actual age-at-death was slightly older. The cranium is clearly disarticulated and is the only complete skull in all of Feature 1 which lies completely above the sediment of the tank. Other fragments were identifiable in this area. Three possibly infant (<1 year) possible humeri (upper bone of the arm) were identified in this area (**Appendix III Plates 3.59** and **3.60**), although only one could be identified as a possible right humerus (**Appendix III Plate 3.60**). This suggests the remains of two possible infants. The right thoracic/lumbar arch, visible in **Appendix III Plates 3.58** and **3.60**, had not fused to the left at the time of death, which suggests certainly an individual less than 2 years, and probably an individual less than 1 year (an infant). The arch appears small in comparison to the possible humeri, but this is not conclusive evidence of a third younger infant. A juvenile vertebral body was also identified in **Appendix III Plate 3.59**. The shape suggests an individual aged between 1-6 years at the time of death, that is, a young juvenile.

The right humerus in **Appendix III Plate 3.60**, is one of the few long bones which appears to show some, presumably post-mortem, erosion of the distal end (near the elbow).

C.90/91

This tank was immediately to the west of tank C.88/89. It comprised a single narrow chamber. Human remains were identified in the deposits. **Appendix III Plate 3.61** is a general annotated photograph of the base of the tank, while **Appendix III Plates 3.62-3.69** show the identified elements in more detail, with an additional feature indicated in **Appendix III Plate 3.70**. Human skeletal remains were identified near the middle of the tank (a), and in the southern half, (b) and (c).

The identified human remains are summarised in **Table 3.9**.

Location as indicated in primary photograph Plate 3.61	Details	Plate reference (see Appendix III)
a	Single young juvenile (1-6 years) cranial fragment	3.62
b	Probable infant (<1 year), with possible articulation	3.63, 3.64, 3.65
c	Infant/young juvenile (<6 years) remains of possibly two individuals, with possible articulation	3.66, 3.67, 3.68, 3.69

Table 3.9: Identified human skeletal remains within tank C.90/91

A fragment of a juvenile cranium was present on the western side of the tank (a), see **Appendix III Plates 3.61** and **3.62**. Two major concentrations of human bone were present in the southern half of the tank. The first (b), see **Appendix III Plates 3.63** and **3.64**, contained a probable/possible infant cranial bones, a set of infant right ribs, a right ilium (part of the right hip bone), infant arm bones, and a possible infant scapula.

When examined more closely (**Appendix III Plate 3.64**), a possible ischium (another part of the hip) was identified under the right ilium, and possible articulated vertebrae were also identified. These were adjacent to the set of right ribs and another set of possibly articulated bones that could not be identified. In addition, the aforementioned arm bones can also be seen in more detail in **Appendix III Plate 3.65**. In this case a right humerus, probably from an infant (<1 year) was identifiable, with an unsided radius and another long bone which may be an ulna. These are the bones that form the arm. The occurrence of these three bones together is unlikely to be coincidental and these arm bone may be approximately articulated. In fact, it is possible that the arm bones along with the set of right ribs, the possible scapula, the possible articulated vertebrae, and the pelvis bones are all approximately *in situ* as they would be in the approximate correct position for an infant lying on the left side.

Near the southwest corner of the tank, another dense concentration of skeletal remains was present (see **Appendix III Plates 3.66-3.69**). Identified bones included those of the cranium, ribs, a right scapula, and a possible ulna.

Three concentrations of apparently articulated ribs (**Appendix III Plate 3.67**) were apparent which suggests possibly two individuals. A right scapula was recovered adjacent to one set of right ribs (**Appendix III Plate 3.68**), which may suggest some degree of articulation.

Cranial remains were identified (**Appendix III Plate 3.69**), which may represent a relatively intact, but collapsed cranium of an infant or young juvenile (<6 years). The left frontal and temporal in particular are in the correct position for an articulated infant/juvenile cranium (see **Appendix VI B**), while a larger cranial fragment underlies the two: that larger fragment may be a parietal or the squama from the occipital.

Finally, the remains of a blue shoe from a young juvenile was present near the northern end of the tank (see **Appendix III Plates 3.61** and **3.70**).

C.92/93

This tank was immediately to the west of tank C.90/91. It comprised a single narrow chamber. Human remains were identified in the deposits. **Appendix III Plate 3.71** is a general annotated photograph of the base of the tank, while **Appendix III Plates 3.72-3.76** show the identified elements in more detail. Human skeletal remains were identified in the northern end (a), and in the southern half, (b), (c), (d), and (e), of the tank.

The identified human remains are summarised in **Table 3.10**.

Location as indicated in primary photograph Plate 3.71	Details	Plate reference (see Appendix III)
a	Young juvenile juvenile (2-6 years) cranium	3.72
b	Possible young juvenile (1-6 years) mandible	3.73
c	Multiple fragments including long bones of juveniles possibly aged *c.* 2 years (or slightly older)	3.74
d	Ribs and possible scapulae of young juvenile (1-6 years), possible articulation	3.75
e	Possible cranial vault, probable juvenile (<6 years)	3.76

Table 3.10: Identified human skeletal remains within tank C.92/93

Cranial remains are present in the northeast corner of the tank (**Appendix III Plate 3.72**). These may comprise a quite complete cranium, as at least the left parietal and left temporal (sides of skull) and the frontal bone (forehead) are present. The metopic suture appears fully closed. This typically fuses between the ages of 2-4 years (after Schaefer et al. 2009, 38).

Along the eastern wall of the tank there is a fragment of a cranium, and a mandible (**Appendix III Plate 3.73**). The mandibular symphysis is fused indicating an individual >1 year at the time of death (after Schaefer et al. 2009, 64). Indeed, the mandible actually appears quite robust and certainly indicates a juvenile at least aged between 1-6 years, but could be older. Unfortunately the teeth are unobservable. A possible hand phalanx was also identified but it was not possible to determine if there was any fusion of the proximal epiphysis (which would be expected in an adolescent individual).

Multiple bones were present just to the south of the central area of the tank (**Appendix III Plate 3.74**). A possible right tibia was present. The length of this was estimated based using the approximate estimated width (0.40m) of the tank near the base: the tibia was determined to be approximately 140mm in length, which suggests an age-at-death of approximately 2 years (after Maresh 1970). This was slightly unexpected as the tibia appears quite robust. However, the perspective at a depth of *circa* 2m is quite deceptive. The proximal end of a right femur (hip end of thigh bone) of a juvenile (1-6 years, age cannot be specifically determined although it may be similar in age to the aforementioned tibia) was identified overlying a cranial fragment. A vertebral body was also identified although unfortunately, it was not possible to assess the degree of fusion, if any, with the neural arch, which would help in determining the age-at-death.

A small collection of bones is visible in the southwest corner of the tank (**Appendix III Plate 3.75**). It was difficult to determine what bones are present. However, it is suggested that they are young juvenile (1-6 years) in origin and may comprise some left ribs and possibly the acromion of the scapula (shoulder blade), which may be suggestive of some degree of articulation. In the southeast corner, a possible cranial vault fragment was identified (**Appendix III Plate 3.76**).

C.94/95

This tank was immediately to the west of tank C.92/93. It comprised a single narrow chamber. Human remains were identified in the deposits. **Appendix III Plate 3.77** is a general annotated photograph of the base of the tank, while **Appendix III Plates 3.78-3.83** show the identified elements in more detail. Human skeletal remains were identified in the northern end, (a) and (b), and in the southern half, (c), (d), and (e), of the tank.

The identified human remains are summarised in **Table 3.11**.

Location as indicated in primary photograph Plate 3.77	Details	Plate reference (see Appendix III)
a	Probable infant (0-12 months) left femur	3.78
b	Cranium of young juvenile (1-6 years)	3.79
c	Concentration of bone, at least one juvenile, possibly aged 4-6 years	3.80, 3.81
d	Cranial remains of probable young juvenile (1-6 years)	3.82
e	Maxilla of young juvenile (1-6 years)	3.83

Table 3.11: Identified human skeletal remains within tank C.94/95

An infant left femur was identified in the northwest corner (**Appendix III Plate 3.78**), while a cranium, lying with the base facing upwards, was identified in the northeast corner (**Appendix III Plate 3.79**). The cranium is probably from a young juvenile (1-6 years).

A concentration of bones was apparent near the middle of the tank, (c) and (d), which mostly comprised disarticulated cranial fragments of at least one young juvenile (1-6 years), as well as a number of ribs, vertebrae, and at least one long bone. The ulna, identified in **Appendix III Plate 3.80** and **3.81**, is estimated to be approximately 140mm in length, which would suggest an age-at-death of approximately 4.5 years (after Maresh 1970). A body of a vertebral (actual vertebrae unidentified) appeared to be at least partially fused to the neural arch (which completes the bony channel for the spinal cord). These elements fuse at different times in different vertebrae: in the cervical (neck) vertebrae the body and neural arch are fused by 4 years, in the thoracic (which articulate with the ribs) vertebrae those elements fuse by 6 years, and in the lumbar (lower back) vertebrae the body and arch fuse by 5 years (after Schaefer et al. 2009, 120-121). There is certainly some fusion in the vertebrae observed in tank c.62, although it is not possible to confirm which vertebra it actually is. It does however, at least suggest the presence of an individual aged perhaps between 4-6 years at the time of death. A concentration of cranial bones lay nearby (see **Appendix III Plate 3.82**). Finally, the left maxilla of a probable young juvenile (1-6 years) was identified in the southeast corner of the tank (see **Appendix III Plate 3.83**). The rate of eruption and/or development of the teeth was not observable although it is probable that at least the first left upper deciduous molar had erupted.

C.96/97

This tank was immediately to the west of tank C.94/95. It comprised a single narrow chamber. Human remains were identified in the deposits. **Plate 3.84** is a general annotated photograph of the base of the tank, while **Appendix III Plates 3.85-3.87** show the identified elements in more detail. Human skeletal remains were identified at the northern (a) and southern ends (b) of the tank.

The identified human remains are summarised in **Table 3.12**.

Location as indicated in primary photograph Plate 3.84	Details	Plate reference (see Appendix III)
a	Cranial bones, ribs, possible scapula of at least one infant/young juvenile, some possible articulation	3.85
b	Infant (0-12 months) remains including possible an articulated cranium and cervical vertebrae	3.86, 3.87

Table 3.12: Identified human skeletal remains within tank C.96/97

At least two separate cranial bone fragments were visible at the northern end of the tank (see **Appendix III Plate 3.85**). In addition, there appeared to be a set of ribs (medial ends) overlying a possible scapula (lateral border), which may suggest some degree of articulation. It is difficult to determine the age at death but the remains would certainly appears to be either infant (<1 year) and/or young juvenile (1-6 years).

A number of infant bones were identified in the southern end of the tank (**Appendix III Plate 3.86**). Cranial remains are clearly visible in two locations, as well as numerous rib and vertebral bones, and a left tibia. The main concentration of cranial bones (see **Appendix III Plate 3.87**), comprised a left and a right parietal (sides of the skull) and an occipital (back of the skull), as well as some possible cervical (neck) vertebra. This suggests that these elements may be largely intact and may retain some degree of articulation (see **Appendix VI B**).

C.98/99

This tank was immediately to the west of tank C.96/97. It comprised a single narrow chamber. Human remains were identified in the deposits. **Appendix III Plate 3.88** is a general annotated photograph of the base of the tank, while **Appendix III Plate 3.89-3.91** show the identified elements in more detail. Human skeletal remains were identified at the northern end of the tank (a), near the centre underneath a fallen slab (b), and in the southern half (c).

The identified human remains are summarised in **Table 3.15**.

Location as indicated in primary photograph Plate 3.88	Details	Plate reference (see Appendix III)
a	Possible infant (<1 year) cranial fragments.	3.89
b	Possible young juvenile (1-6 years) possible vertebral body	3.90
c	Possible young juvenile (1-6 years) cranial fragment	3.91

Table 3.13: Identified human skeletal remains within tank C.98/99

Possible infant cranial bones are present at the northern end of the tank (**Appendix III Plate 3.89**). A possible young juvenile (1-6 years) possible vertebral body was identified under a fallen slab near the east wall (**Appendix III Plate 3.90**), while a possible juvenile (<6 years) cranial fragment is present in the southern half (**Plate 91**).

C.100/101

This tank was immediately to the west of tank C.98/99 and to the east of tank C.104/105: the latter was identified in Trench 4 of the first phase of archaeological investigations. Tank C.100/101 comprised a single narrow chamber. Human remains were identified in the deposits. **Appendix III Plate 3.92** is a general annotated photograph of the base of the tank, while **Appendix III Plates 3.93-3.94** show the identified elements in more detail.

The identified human remains are summarised in **Table 3.14**.

Location as indicated in primary photograph Plate 3.92	Details	Plate reference (see Appendix III)
a	Young juvenile (1-6 years) cranial fragments	3.93, 3.94

Table 3.14: Identified human skeletal remains within tank C.100/101

A probable young juvenile (1-6 years) cranial, comprising at least two individual bones, was identified underlying the large fallen slab in tank C.100/101 (see **Plates 3.93-3.94**).

3. 4 Discussion

In total, 16 tanks were identified, opened, and recorded during the most recent phase (Phase IIA) of archaeological investigations at the former Bons Secour Mother and Baby Home in Tuam, Co. Galway. These 16 tanks, along with four identified and examined in 2016 (Phase II), were contained within a long concrete structure, built into the southern wall of the large cess pit associated with the Poor Law Union Workhouse which originally occupied the grounds. Human skeletal remains had been identified in all four tanks examined in 2016 , and human bone was also recovered, in a disarticulated state in deposits to the north of the north wall of the concrete structure. Samples of human bone taken from inside the tanks returned radiocarbon dates ascribed to the twentieth century. All identified human skeletal remains from 2016 were juvenile (<18 years) in origin, and specifically were from infants (<1 year) or young juveniles (1-6 years) (see McCullagh 2016).

No skeletal remains were physically removed during the Phase IIA investigation, and all osteoarchaeological analysis in this phase is based exclusively on the assessment of photographs taken of the 16 tanks. Human skeletal remains were identified in 14 out of the 16 tanks: the exceptions were tank C.62/63 and tank C.86/87. It should not be assumed however, that there are *no* human skeletal remains in those two tanks: the presence of human remains was only confirmed in tank C.100/101 when the camera was able to photograph underneath a fallen slab of concrete. It is probable, given that it is now known that there are human remains in at least 18 of the total of 20 tanks in Feature 1, that there are in fact human remains in tanks C.62/63 and tank C.86/87, but that they are simply not immediately visible on the surface.

It is impossible, given the limitations of the present archaeological investigation, to estimate the numbers of individuals represented in the tanks. It is clear however, that many tanks contain a mixture of infant (<1 years) and young juvenile (1-6 years) bones. For example, tank C.84/85 contained a large concentration of bones in the southern end of the tank where both infant (<1 year) and young juvenile (1-6 years) remains were identified. Only actual physical investigation could reveal the numbers of individuals deposited in Feature 1.

A cranium was present in tank C.88/89, possibly from an individual aged between 1.5 and 2.5 years, although it is possible that the individual was slightly older. This skull was unique in terms of complete crania in that it was sitting on the surface of the sediments. Also all other cranial fragments were at least partially embedded in the sediments, while tank C.50/51 (examined in 2016) contained a partially embedded cranium which may represent a relatively intact skeleton (McCullagh 2016). In contrast, the cranium in tank C.88/89 clearly lay on the surface of the sediments. This may suggest that the latter cranium was perhaps thrown into the tank in more recent decades and may even have originated from another location. It was interesting that, adjacent to the cranium, is an infant humerus which shows post-mortem erosion: this was quite unique in terms of the observed general preservation of other skeletal remains in the tanks as the bones were invariably in an excellent state of preservation. Again, it is possible that this long bone originated elsewhere (where it may have suffered the post-mortem erosion) and was subsequently redeposited within tank C.88/89.

In contrast to the aforementioned cranium and humerus in tank C.88/89, there were numerous examples of bones which appeared to be in at least some form of articulation, though not necessarily *in situ*. Possible articulated skeletal remains were identified in tanks C.52/53, C.54/55, C.56/57, C.58/59, C.84/85, C.90, C.92/93, and C.96/97. Most of these comprised sets of ribs, which appeared to have collapsed on top of each other, as would be normal in a decomposing body: up to four sets of ribs ('set' referring to a set of left ribs or a set of right ribs) were identified in tank C.90/91. In a number of cases, the bones of the forearm (radius and ulna) were tentatively identified lying together, suggesting some degree of articulation, such as in in tank C.58/59 and tank C.84/85. In tank C.90/91, numerous bones were suggestive of an infant lying on its left side.

The 'articulation' is not as clear as it would be in remains that had actually been buried. The nature of the tanks has dictated the current state of the skeletal remains. As was surmised in the original osteoarchaeological assessment (McCullagh 2016), it is probable that complete bodies were deposited in the tanks: this would at least explain the excellent state of preservation of the observable bone. If the bones had been dug up elsewhere and then redeposited in the tanks, it would be expected to see much more fragmentation and it would be unlikely that there would be relatively intact juvenile crania, such as in tank C.92/93 (see **Appendix III Plate 3.72**) and tank C.96/97 (see **Appendix III Plate 3.87**). In addition, it would be expected that the redeposited earth would be visible in the tanks. Instead however, all visible sediments in the tanks may in fact be formed as part of normal fluctuations within and into the tanks.

It is probable that there was some fluctuation in terms of water levels within the tanks. It was evident in most tanks, that the sediments (now quite dry), had shrunk back from the edges of the tanks. This would suggest that, at one stage, the interiors of the tanks may have been substantially wetter. Assuming that complete bodies were deposited in the tanks (with no actual burial in the sense of covering the remains with earth), then fluctuations in the water table would have allowed bodies, and later body parts and bones, to float and disperse across each tank. In forensic contexts it is known that 'dangling appendages' will separate from the main carcass, and the water action will allow for additional dispersal (Haglund and Sorg 2002). Interestingly, a lot of the bone concentrations were on the south sides of the tanks: this would represent the normal drainage of the site where the higher ground was to the north. The assumed fluctuations in water levels would certainly account for the somewhat unusual manifestations of 'articulation', for example where sets of ribs in particular were commonly identified. Interestingly, in some tanks skeletal remains were identified which were not within the sediments. In tank C.54/55 two possible fragments of bone were noted on the north facing wall of the tank (**Appendix III Plate 3.14**), although the identification was quite tenuous. However, more conclusively, in tank C.58/59 a single infant/young juvenile probable hand phalanx was recorded attached to the south-facing wall of the tank (**Appendix III Plate 3.32**). The hand phalanx in particular was located well above the current sediment level, suggesting that there was indeed fluctuation in the water table within the tanks.

The age-at-death span of the skeletal remains examined in 2016 was from 35 foetal weeks to 2-3 years (McCullagh 2016). No skeletal remains were recovered during the most recent investigation. However, the osteoarchaeological assessment of the photographs suggests a similar age range for the individuals identified in the newly examined tanks: all of the skeletal remains were probably from individuals aged less than 6 years at the time of death (that is, infants <1 years and young juveniles aged 1-6 years). In reality, most were probably in the younger end of that scale. However, there was an exception. In tank C.94/95 a vertebra and an ulna were identified that are probably from an individual aged between 4-6 years at the time of death.

Finally, again referring to the deposition of the remains, one piece of timber had an unusual angle in tank C.60/61 (see **Appendix III Plates 3.37** and **3.38**). This was reminiscent of the angles which may be seen in a coffin and the timber does not appear as crude as most of the shuttering from the construction of the tanks which had collapsed in. However, the identification of this 'coffin' is tenuous and should not be taken as conclusive. The possible wickerwork identified in tank C.54/55 (see **Appendix III Plate 3.15**) may be related to the deposition of a body or bodies but again the identification is not definite. It is unknown if the black plastic comb in tank C.58/59 (see **Appendix III Plate 3.33**) and the blue shoe in tank C.90/91 (see **Appendix III Plate 3.70**) are contemporary with the deposition of human remains.

4. Artefactual Evidence

This excavation was intended to be non-intrusive exercise and solely for the purposes of establishing the extent of Feature 1 and provide an indication of the extent of the deposition of human remains contained therein. Excavation was not possible due to limited accessibility and resulting safety issues, thus artefact recovery did not take place. There was a single exception to this.

It was observed that a piece of evidence in the form of a plastic bottle lay directly on the surface of C. 95 within chambered tank C. 94. There was ongoing consultation and agreement with the MBHCOI throughout the work, and it was acknowledged at the time that it was pertinent to recover this as an exhibit, as it could be done so without causing disturbance to the deposit (C.95) and human remains therein. The context could be considered secure and thus the bottle of significant evidential value.

This bottle may be described as a moulded green plastic bottle with the label 'Castrol GTX' printed directly onto the plastic, it was empty of contents. The text on the label reads in full "Castrol GTX HIGH PERFORMANCE MOTOR OIL", "CONTENTS 500ml" and "CASTROL (IRELAND) LIMITED". There is no evidence remaining of a serial number or other individual identifying features. The bottle was in an excellent state of preservation despite being slightly crushed on one side. The green plastic had degraded slightly with a gold foil cover remaining over the bottle opening. There was no evidence of the original bottle cap, see **Appendix III Plates 4.1 and 4.2.**

Subsequent enquiries with the manufacturer revealed that this product was released into the UK market on the 18th April 1968. This particular product did not exist prior to this date. It would have been available in the Irish market on or after this date but not before**, see Appendix III Plate 4.3. '***This product used the same technology of 'liquid tungsten' as the new formula Castrol, it was an instant success and has become one of the longest lasting of the Castrol brands'* (Information supplied by Joanne Burman of the BP Archive, BP International, Coventry, United Kingdom).

These findings indicate that these chambered tanks were accessible, either temporarily or for an extended period of time, post 1968. When combined with the radiocarbon dating of Phase II (1925-1957) and based on the history of the site-use, this evidence makes it highly likely that the chambered tanks were accessed at, or during, the time of the construction of the Tuam Road Housing Estate. Other debris within the chambered tanks support the suggestion that there is, what can be considered non-domestic, waste disposed in these tanks subsequent to the deposition of the human remains, e.g. contents of C.11/82 see **Appendix IV Figure 4.1.**

5. Environmental Sampling results

Soil samples were submitted to Dr Lorna DAWSON at the James Hutton Institute, Scotland. Samples were subjected to Volatile Organic Compound (VOC) analysis, organic analysis and isotope analysis. VOC analysis was conducted on an initial 32 soil samples submitted to Lorna DAWSON. This was followed by and independent alkane/sterol/alcohol analysis on 11 of what were considered the most 'interesting' of the samples. These samples were selected based on the initial screening, the results of which are described in full in **Appendix VII**.

5.1 Examination

Soil is a mixture of both inorganic and organic material (Dawson and Hiller, 2010; Dawson and Mayes, 2014). The Organic material reflects the plant and animal material having been deposited or decomposed within that soil and also human organic inputs to the soil (Dawson and Mayes, 2014). A combination of gas chromatography and gas-chromatography spectrometry (GCMS) can be used to characterise and identify many organic compounds in oils, both volatile and physical which helps ascertain what those inputs likely were.

Comparison of the distribution of the volatile compounds found in the samples with published data describing the range of volatile compounds found in the samples with published data describing the range of volatile compounds produced during decomposition of mammalian tissues, including humans (Vass et al., 2004, 2008; Vaas, 2012) allows the interpretation of contact with human decomposition products to be made. This use of the odour of decomposition is relatively recent and is considered an experimental technique for intelligence and is still under development (Dawson, Sheperd and Mayes, **Appendix VII)**.

5. 2 Summary of Findings

The examination confirms that there is evidence that this site had previously been used as a sewage treatment facility. The result of these tests cannot categorically establish if the sewage treatment facility was in use contemporaneous with the deposition of human remains.

These tests also cannot contribute to the hypothesis of whether the human remains had decomposed prior to being deposited in the tanks or if they were deposited and decomposed *in situ*. A number of compounds indicative of bone decomposition, ketones, aliphatic alcohols and *n*-aldehydes, were found in locations with high bone density.

Some of the results from soil sample analysis indicate the presence of faecal material but it is also likely that the human remains have contributed to these indications. There were markers of human sewage in the chambered tanks as well as human decomposition products. Dr DAWSON found that it was difficult to say categorically if the chambered tanks were in use at the time the bodies were deposited there.

The samples were found to have very low concentrations of biomarkers that would typically indicate sewage. Dr DAWSON found that the reasons for low biomarker concentrations found in samples are not easy to assess. If the chambers represented a closed cesspit or sewage treatment facility it is possible that the collected sewage had been removed before the deposition of the human remains. Soil may have been added at the time of deposition or soil may have seeped in from the roofs or openings at the base. If there were one or more pipe outflows (i.e. the facility was a septic tank, or was connected to a sewer outflow), it is expected that little sewage would be left behind. These low values could be as a result of several actions; old sewage, partial removal of sewage or the mixing of other inert material such as soil from elsewhere.

6. Conclusion

6.1. Condition of Site Post Excavation

Following the completion of the investigations of Feature 1, a series of stages of covering layers, both permeable and impermeable, were placed over the concrete tank to protect the chambered tanks from intrusion and to ensure that the site was secure in terms of safety and preservation. These measures are not intended for permanency.

The entire length of the top of the concrete tank (C.5) was first covered with heavy gauge plastic, this was followed by custom designed steel sheets. This was followed by further heavy gauge plastic, to delay oxidation/corrosion, followed by a layer of topsoil, over which a permeable breathable membrane was laid. Finally, a layer of gravel was spread over all of the aforementioned covering layers. The site was levelled and left in a tidy condition prior to departure (see **Appendix III Plates 6.1 and 6.4**).

All reasonable measures were put in place to secure the site temporarily, with a consideration of a <6-month time frame. The hoarding surrounding the site is also a temporary measure that has been in place since September 2016 and may significantly deteriorate within a short timeframe. The gate through the hoarding was fixed with a lock and a copy of the key to the lock was passed to An Garda Síochána, Tuam. The MBHCOI is also in possession of a key. This lock can be 'cut' at any time and should not be considered prohibitive nor a long-term solution.

6.2 Conclusion

The full extent of the chambered structure was investigated from the near-surface during this phase. The complex nature of the site limited the extent of investigative work to observation and full recording, in conjunction with a soil sampling programme conducted in the latter half of site work.

The structure itself, Feature 1, is a later addition to the 19th century workhouse 'sewage tank' that appears on the 1892 edition of the Ordnance Survey mapping (McCullagh, 2016). It has been constructed on the internal face of the south wall of the stone and mortar 'sewage tank', and it may be considered a possible upgrade to the pre-existing sewage treatment facility. The walls are constructed of stone and shuttered concrete. Each of the twenty chambers has been constructed with shuttered concrete with the easternmost chambers having openings at their base, 2.75m below current ground surface. Structural evidence suggests it is possibly an unfinished or abandoned structure as discussed in Section 2. The exact date of construction of Feature 1 is unclear. However, radiocarbon dating and archaeological evidence from Phase II indicates construction would have taken place pre 1940.

As described in section 3, 18 of the 20 chambers in Feature 1 contained observable juvenile human remains; the two remaining chambered tanks would require further investigation. Osteological analysis considers the observable human remains here to be excellently preserved. Articulation at the time of deposition is considered probable. It was not possible to determine through soil analysis if the facility was in use for sewage treatment during the time of the deposition of human remains.

The results of this investigation highlight further the extent of juvenile human remains that are deposited at this location. This is not a recognised formal burial situation. The structural evidence here implies that a sewage treatment facility was reused for the interment of juvenile human remains.

Acknowledgements

The authors of this report would like to acknowledge the invaluable co-operation of An Garda Síochána, Tuam, Galway County Coroner, and the Office of the State Pathologist for their assistance on site during excavations.

7. Qualifications and Experience of Contributors

Niamh McCULLAGH BA MA MSc MCSFS

Forensic Archaeologist, Project Director Phase IIA

Niamh is an independent consultant Forensic Archaeologist specialising in the search, location and recovery of human remains in a forensic context. As a Forensic Archaeologist, Niamh has worked nationally and internationally on both current and historic casework and she also provides input to training capacity for Forensic Archaeologists. Niamh is Senior Forensic Archaeologist to the Independent Commission for the Location of Victims Remains and has assisted An Garda Síochána in the investigation of multiple criminal cases. She has a BA Major in Archaeology (University College Cork, 2001), MA Archaeology (University College Cork, 2002) and MSc Forensic Archaeology and Crime Scene Investigation (Bradford University, 2007) and has published a number of papers in relation to her specialism. She is recognised as Professional Member of the Chartered Society of Forensic Sciences, an Expert Witness in Ireland, a member of the Irish Association of Forensic Practitioners and has represented Forensic Archaeology at a European level.

Aidan HARTE, BA MA MIAI

Senior Archaeologist and GIS Specialist

Aidan is an independent, qualified Archaeologist and Geographer, with over 15 years' archaeological experience in Ireland, the UK and France. He is a license eligible Archaeological Excavation Director as recognised by the Department of Arts, Heritage, Regional, Rural and Gaeltacht Affairs. He also continues to work as a Senior Team member with the Independent Commission for the Location of Victims Remains. He has been a full member of the Institute of Archaeologists of Ireland since 2007, has served on the Board of Directors for the Cork Historical and Archaeological Society since 2013 and has more recently been recognised as an Affiliate Member of the Chartered Society of Forensic Sciences. Aidan has lead excavations and surveys of over 35 archaeological sites, of various type, size and period, in a variety of locations and conditions. Following his primary degree, his master's degree in 'Methods and Practices in Irish Archaeology' (UCC) specialized in the use of GPS/GIS for which he was awarded the 'Past Perceptions Prize' 2002. With a diverse range of research interests, he has published papers on survey methodology, GIS and multiple archaeological site types.

Linda LYNCH. MA PhD MIAI

Human Osteoarchaeologist

Linda is a professional archaeological consultant and human osteoarchaeologist with over 20 years' experience in Irish archaeology. A member of the Institute of Archaeologists of Ireland, she also served on the Board for three years. She is a license-eligible archaeological excavation expert and a leading professional in the field of osteoarchaeology in Ireland, with a significant profile of publication and lecturing. She has particular expertise in issues similar to those encountered at the Children's Burial Ground at Tuam. Her Master's degree in 1998 focused on neonate and infant remains from *cillíní* or 'children's burial grounds'. In 2014 Linda was awarded a PhD in research that focused on human remains from 19th century workhouse burials. Linda was also the specialist employed to examine the skeletal remains recovered from the archaeological excavation adjacent to Tuam Poor Law Union Workhouse.

8. Appendices

Appendix I: Warrant issued

Mother and Baby Homes Commission of Investigation

Commissions of Investigation Act 2004

Sections 8, 26 and 28

WARRANT

TAKE NOTICE THAT in accordance with Section 26 of the Commissions of Investigation Act 2004 (hereinafter 'the Act')

Niamh McCullough

Of Cork in the County of Cork

Is a person appointed under Section 8 of the Act and is hereby Authorised to exercise the powers given under section 28 of the Act in relation to the premises known as the Children's Burial Ground located in the Dublin Road Housing Estate, Tuam, Co Galway.

Dated this 1st day of September 2016

JUDGE YVONNE MURPHY
CHAIRPERSON OF THE COMMISSION

Appendix II: Technical Note

The archaeological theories and techniques used during this search and excavation were in accordance with those outlined in publications such as:

1) 'Standards and Guidance for Forensic Archaeologists' (Powers and Sibun, 2011) prepared for the Chartered Institute for Archaeologists, UK.

2) Component Standards for Archaeology and Anthropology issued by the Chartered Society for Forensic Sciences, UK (www.forensic-science-society.org.uk).

3) Handbook of Forensic Anthropology and Archaeology (World Archaeological Congress Research, 2011), Blau, S. & Ubelaker, D. (eds).

4) 'Management of Archaeological Projects' (MAP2), produced by English Heritage (Andrews 1991).

5) Technical papers issued by the Institute for Archaeologists of Ireland (www.iai.ie).

6) Museum of London Archaeological Service Archaeological Site Manual (MoLAS, 1994).

Appendix III: Plates

Plate 1.1: Protection offered by commercial marquee.

Plate 2.1: Openings within C.5 looking west

Plate 2.2: Openings within C.5 looking east

Plate 2.3: Timber formwork *in situ* at C.46/47/62/63

Plate 2.4: Concrete lid consistent with original concrete structure

Plate 2.5: Repairs an replacements to lids

Plate 2.6: Evidence of damage to original lids.

Plate 2.7: Timber *in situ* for cast concrete cap (C.5) at C.73/74/92/93

Plate 3.1: C.52/53, annotated photograph of sections of identified human remains, see Plates 3.2-3.7

Plate 3.2: C.52/53(a), detail of infant cranial bones, see Plate 3.1

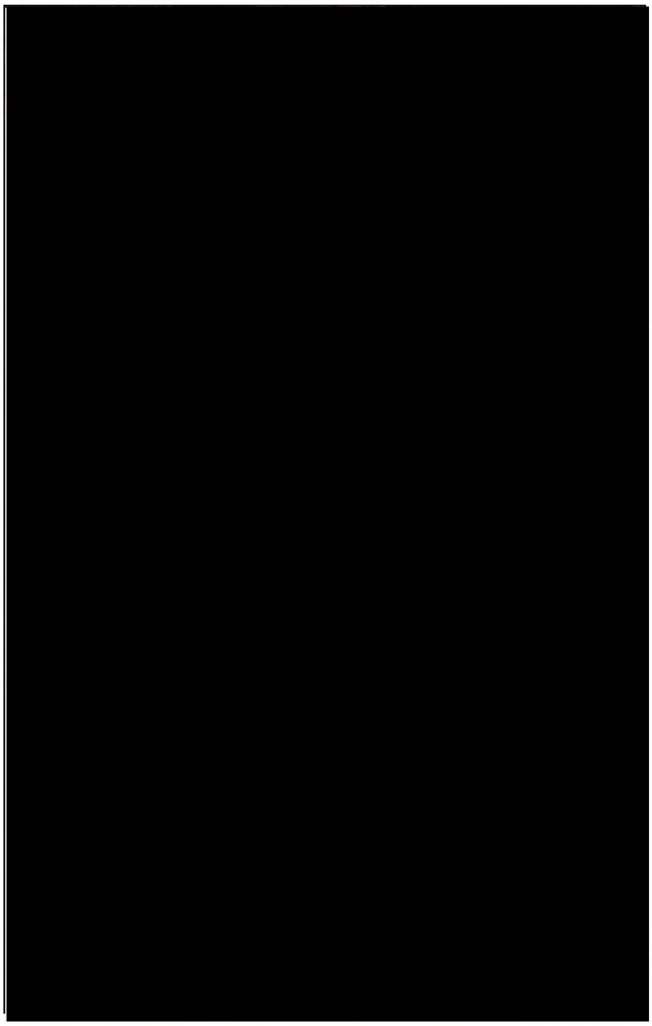

Plate 3.3: C.52/53(b), multiple infant bones at east end of tank, see Plate 3.1

Plate 3.4: C.52/53(c), infant cranium and long bone, see Plate 3.1

Plate 3.5: C.52/53(d), concentration of skeletal remains from multiple individuals, see Plate 3.1

Plate 3.6: C.52/53(d), detail, infant mandible, located at bottom edge of Plate 3.5

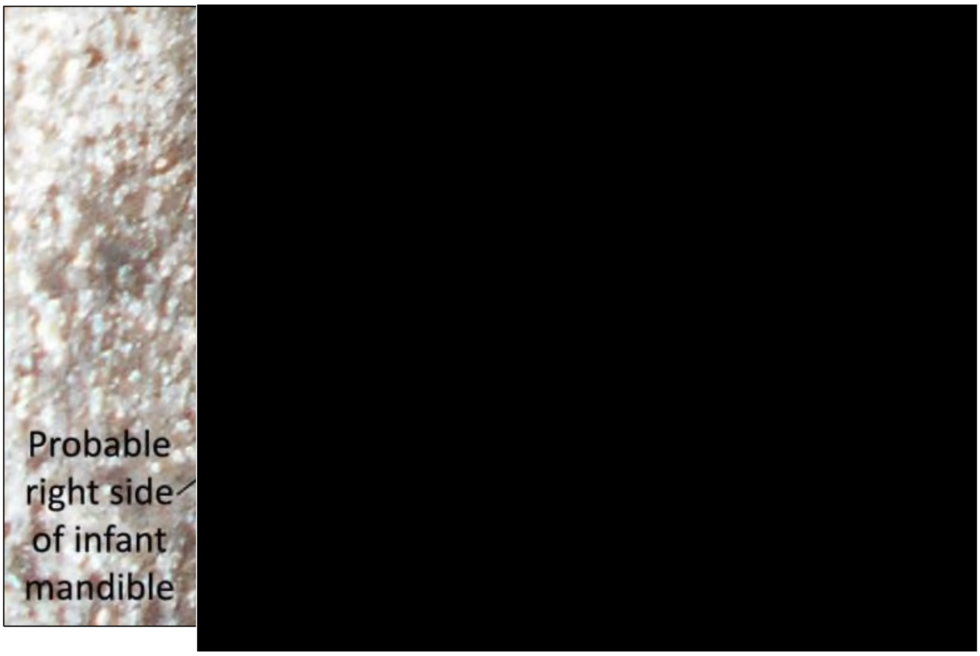

Plate 3.7: C.52/53(d), detail, infant mandible, north to bottom, located at right side of Plate 3.5

Plate 3.8: C.54/55, areas with identified human remains, see Plates 3.9-3.15

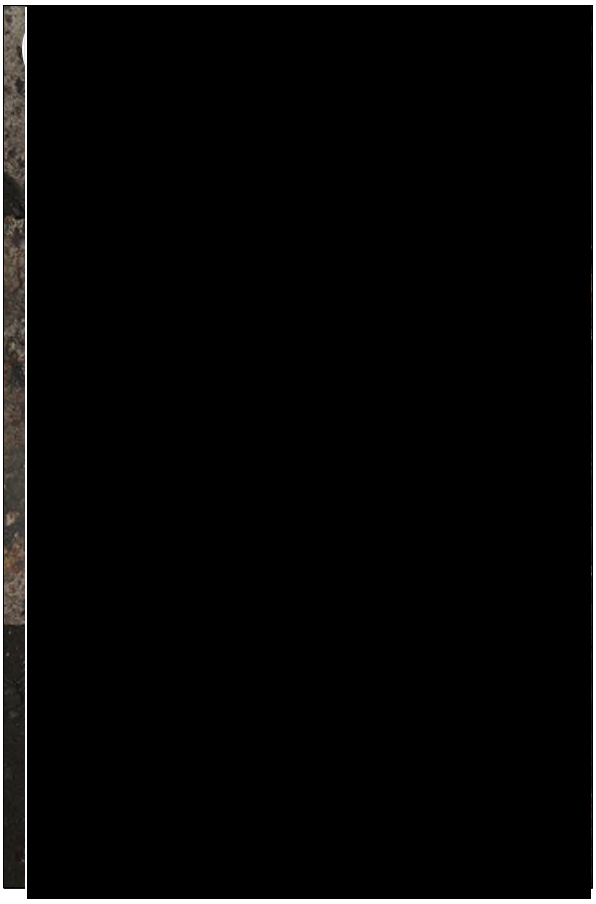

Plate 3.9: C.54/55(a), detail of infant/young juvenile bones (the petrous portion is part of the temporal bone of the cranium which houses the components of the ear), see Plate 3.8

Plate 3.10: C.54/55(a), detail of possible infant petrous portion (the petrous portion is part of the temporal bone of the cranium which houses the components of the ear) in area (a), see Plate 3.8

Plate 3.11: C.54/55(b), infant bones near south end of tank, see Plate 3.8

Plate 3.12: C.54/55(b), detail of infant femur and hand bones, possible indication of articulation, identified at western edge of tank, see Plates 3.8 & 3.11

Plate 3.13: C.54/55(b), detail of infant/juvenile cranial fragments with animal bone, identified at south end of tank, see Plates 3.8 & 3.11, north to bottom

Plate 3.14: C.54/55, north-facing wall of tank showing location of two fragments of possible human bone

Plate 3.15. Possible wickerwork located at northern end of tank C.54/55, see Plate 3.8

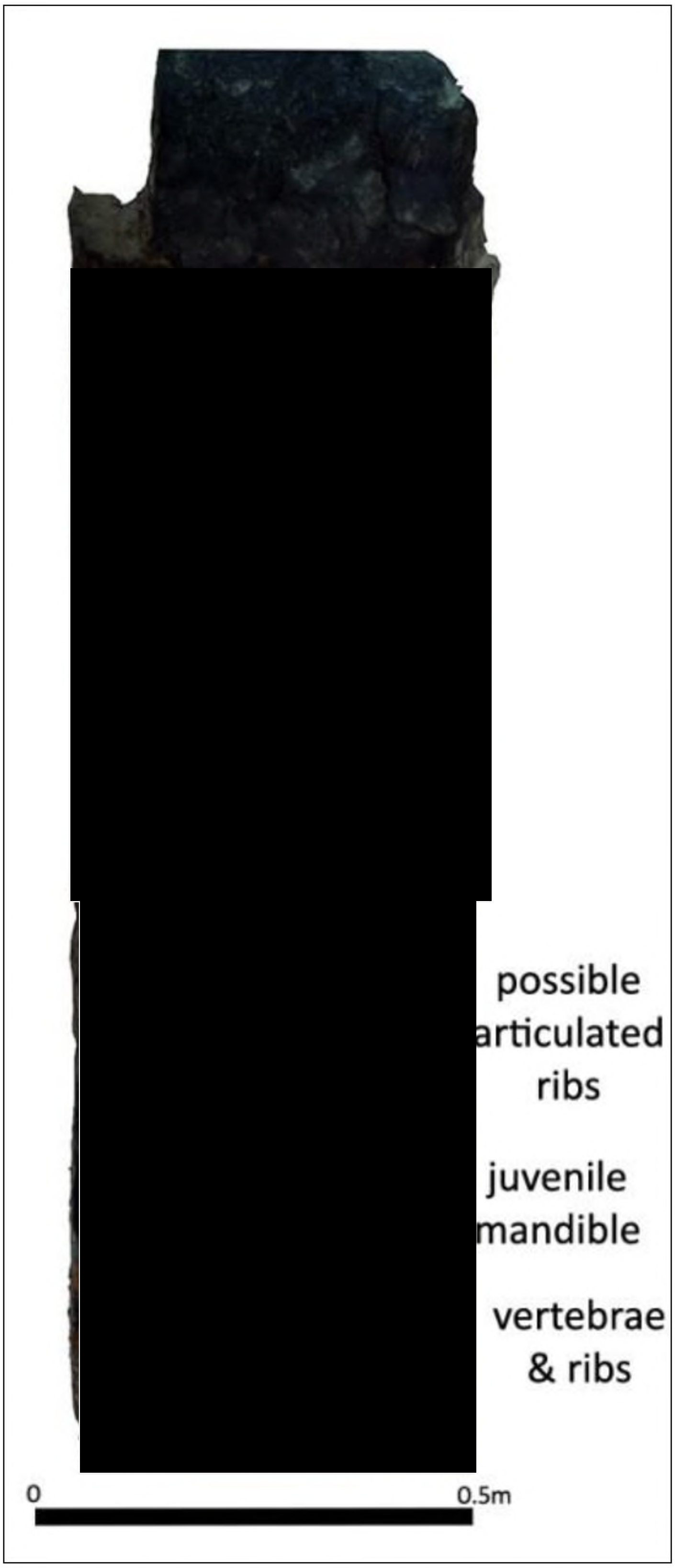

Plate 3.16: C.56/57, locations of identified human remains, see Plates 3.17-3.23

Plate 3.17: C.56/57(a), multiple infant/juvenile cranial bones at north end of tank, see Plate 3.16

Plate 3.18: C.56/57(b), infant/juvenile cranial bone, identified on east side of tank, see Plate 3.16

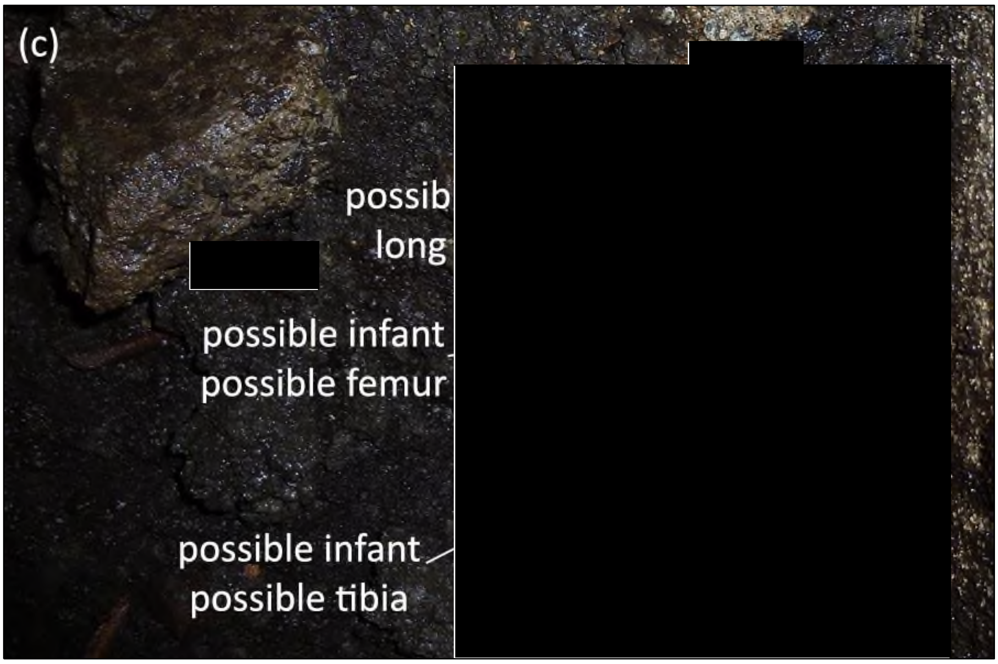

Plate 3.19: C.56/57(c), multiple infant remains, identified near middle of tank, see Plate 3.16

Plate 3.20: C.56/57(d), concentration of primarily young juvenile skeletal remains at southern end of c.56/57, see Plate 3.16


[redacted]

Plate 3.21: C.56/57(d), detail, possible articulated ribs, location indicated in Plate 3.16

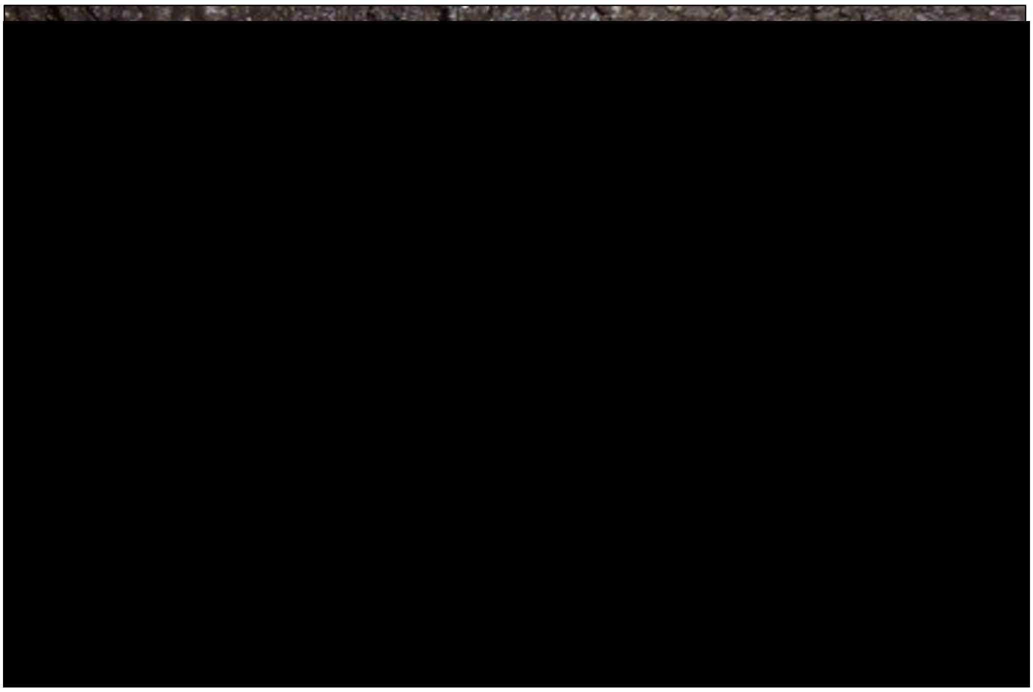
[redacted]

Plate 3.22: C.56/57(d), detail, juvenile mandible (2-4 years) and young juvenile vertebral arch, location indicated in Plate 3.16

Plate 3.23: C.56/57(d), detail, collection of infant/young juvenile vertebral fragments and ribs, suggesting possible articulation, location indicated in Plate 3.16

Plate 3.24: C.58/59, annotated photograph of sections of identified human remains, see Plates 3.25-3.32, with additional feature in Plate 3.33

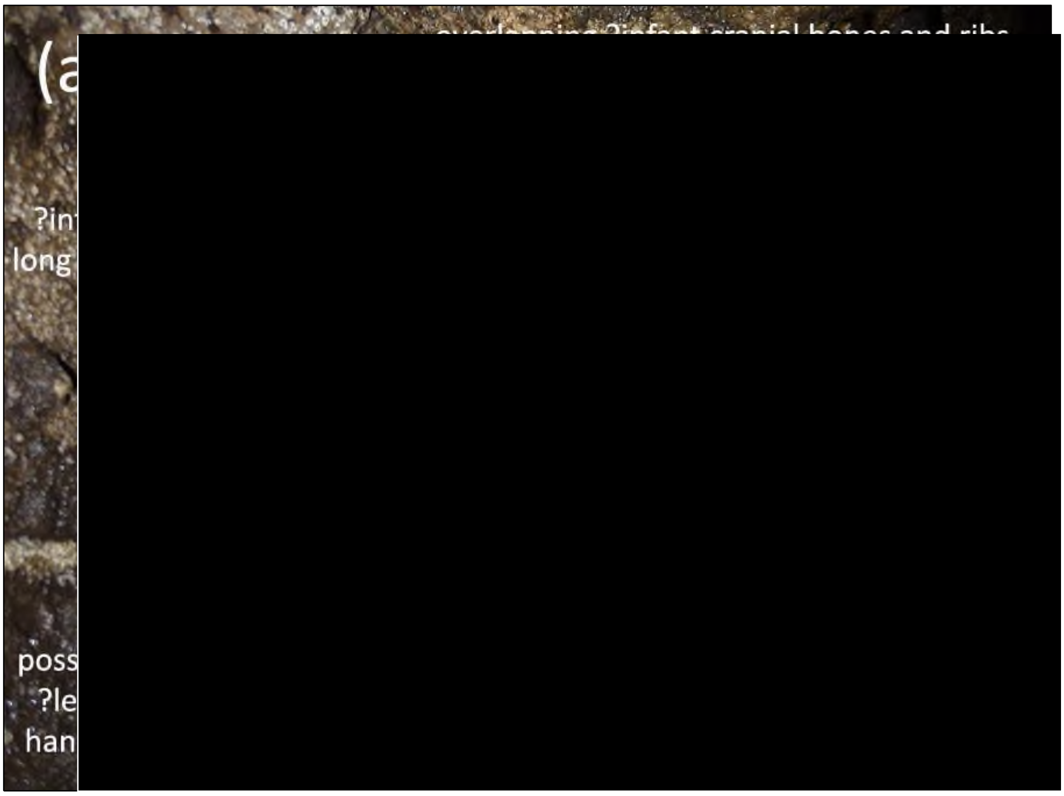
[redacted]

Plate 3.25: C.58/59 (a), multiple infant remains identified at northern end of tank, see Plate 3.24


[redacted]

Plate 3.26: C.58/59 (a) detail, detail of possible infant left ilium, indicated near top right of Plate 3.25


[redacted]

Plate 3.27. C.58/59(a) detail, detail of possible infant ulna and radius, indicated near centre of Plate 3.25

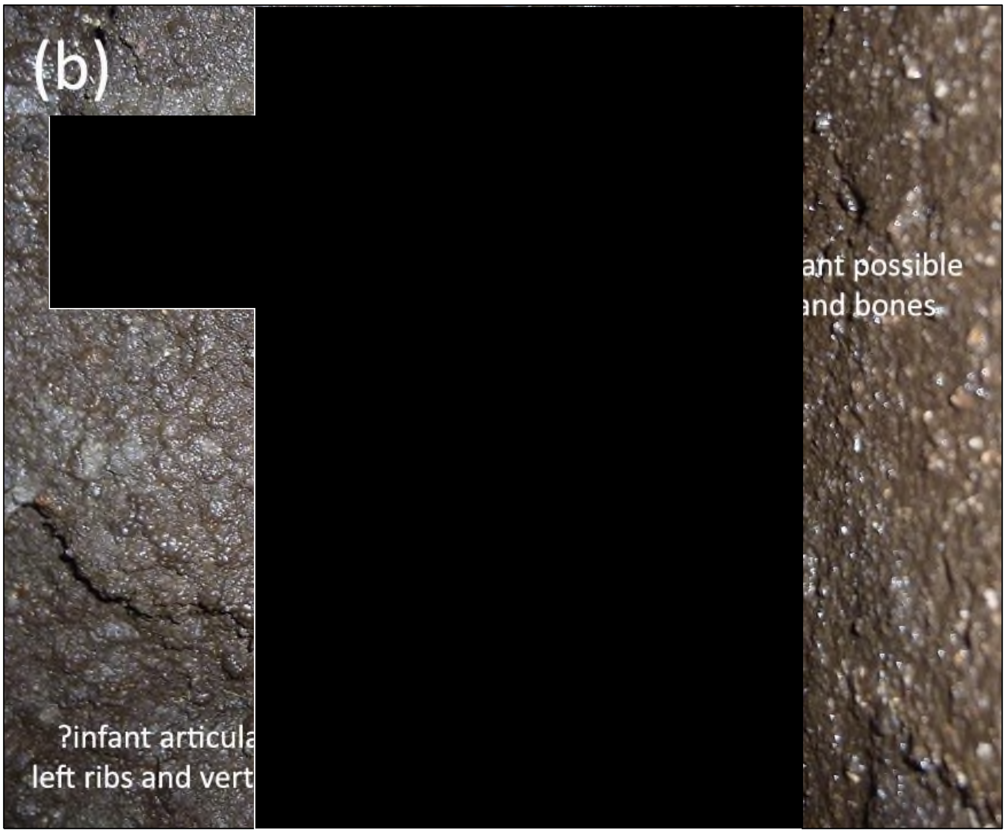

Plate 3.28: C.58/59(b), possible infant/young juvenile remains, see Plate 3.24, detailed in Plates 3.29-3.30

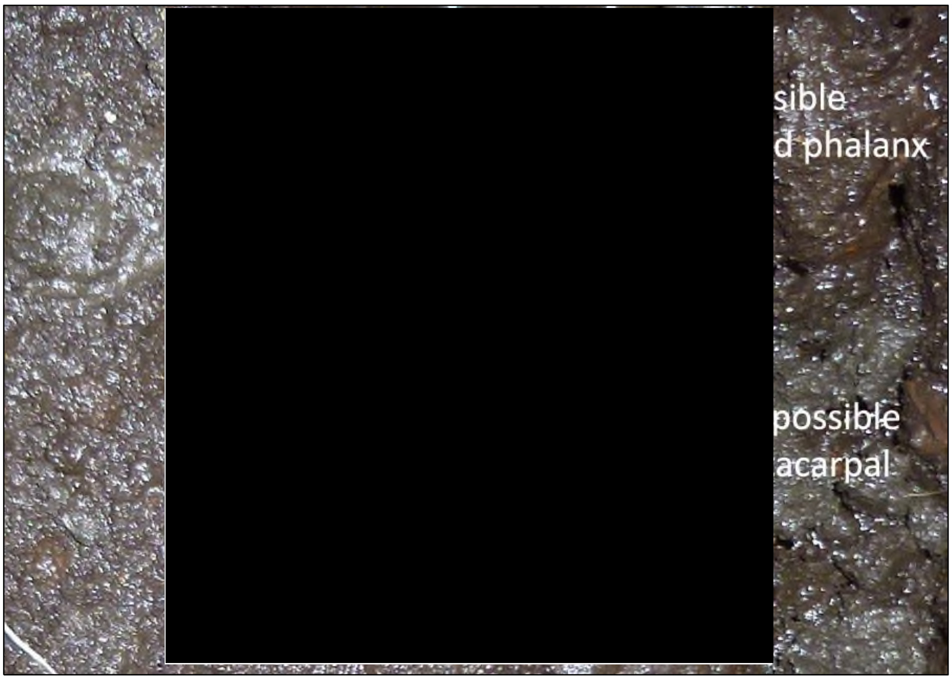

Plate 3.29: C.58/59(b) detail, possible infant hand bones, indicated in top half of Plate 3.28

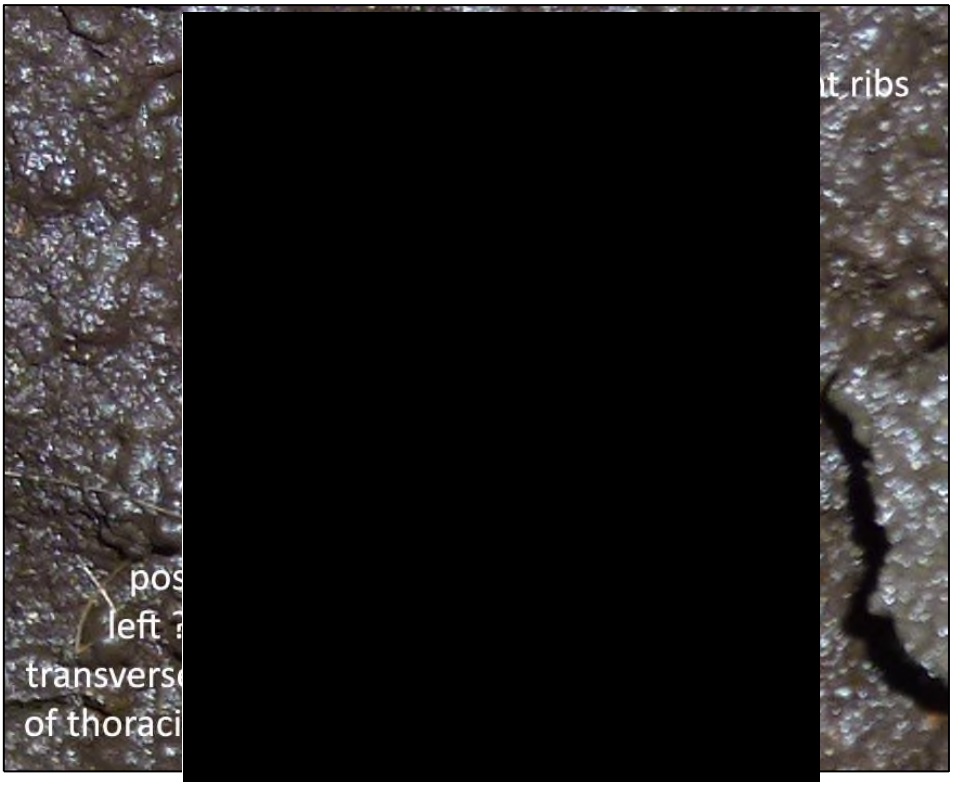

Plate 3.30: C.58/59(b), detail, possible articulated infant/young juvenile left ribs and vertebrae, indicated in bottom half of Plate 3.28

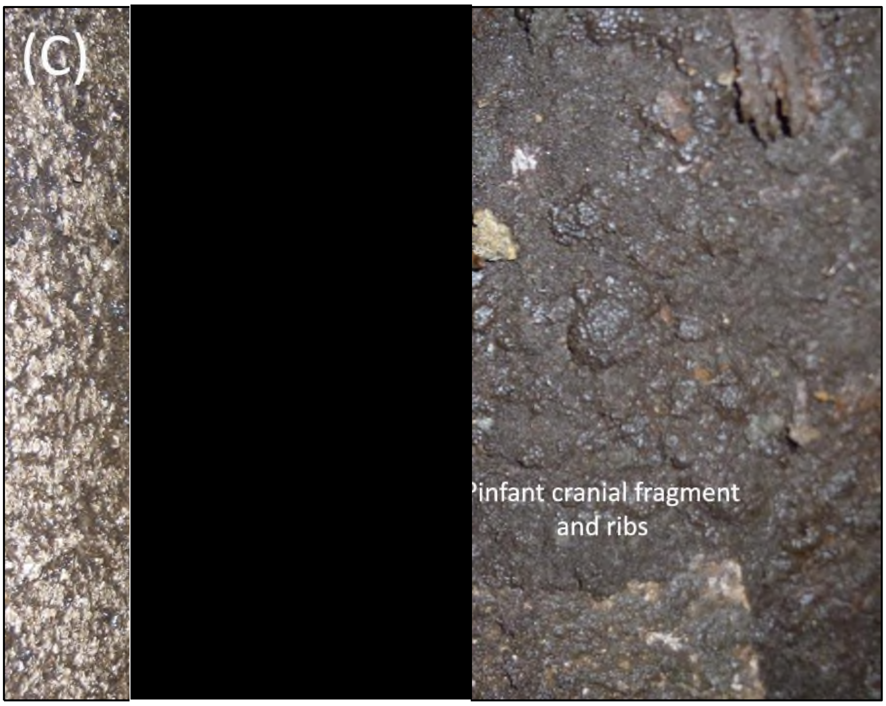

Plate 3.31. C.58/59(c), possible infant remains, see Plate 3.24

Plate 3.32: C.58/59, possible infant/young juvenile hand phalanx attached to wall in northwest corner

Plate 3.33: C.58/59, black plastic comb, see Plate 3.25 for location

Plate 3.34: C.60/61, annotated photograph of sections of identified human remains, see Plates 3.35-3.38

Plate 3.35: C.60/61(a), detail of infant and juvenile bones, see Plate 3.34

Plate 3.36: C.60/61(a), detail, possible infant bones, location indicated by arrow in Plate 3.34

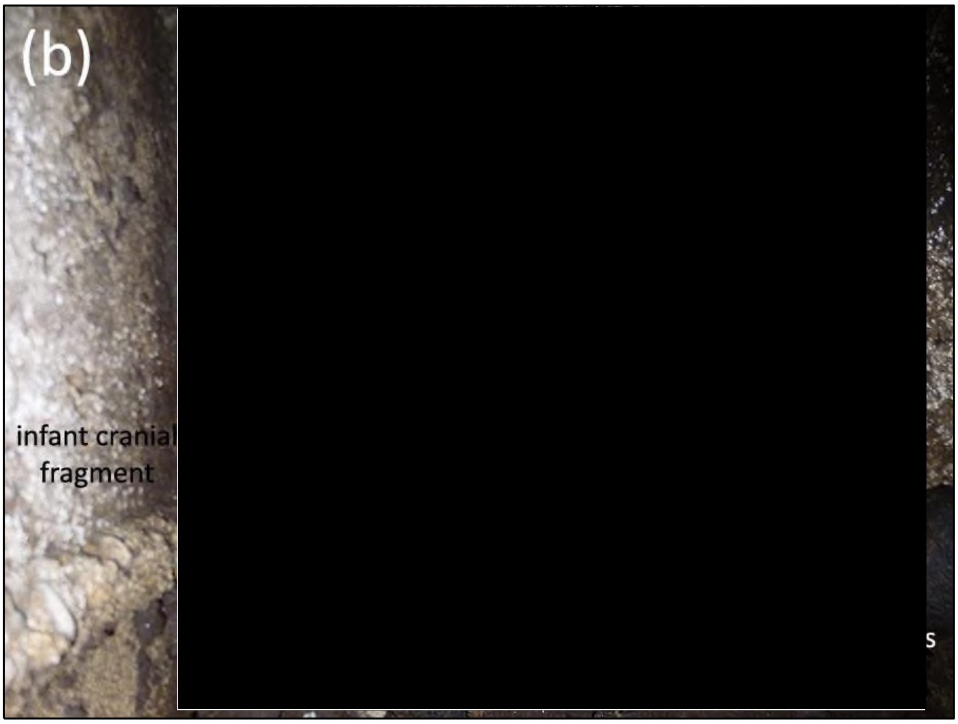

Plate 3.37: C.60/61(b), detail of infant bones, see Plate 3.34

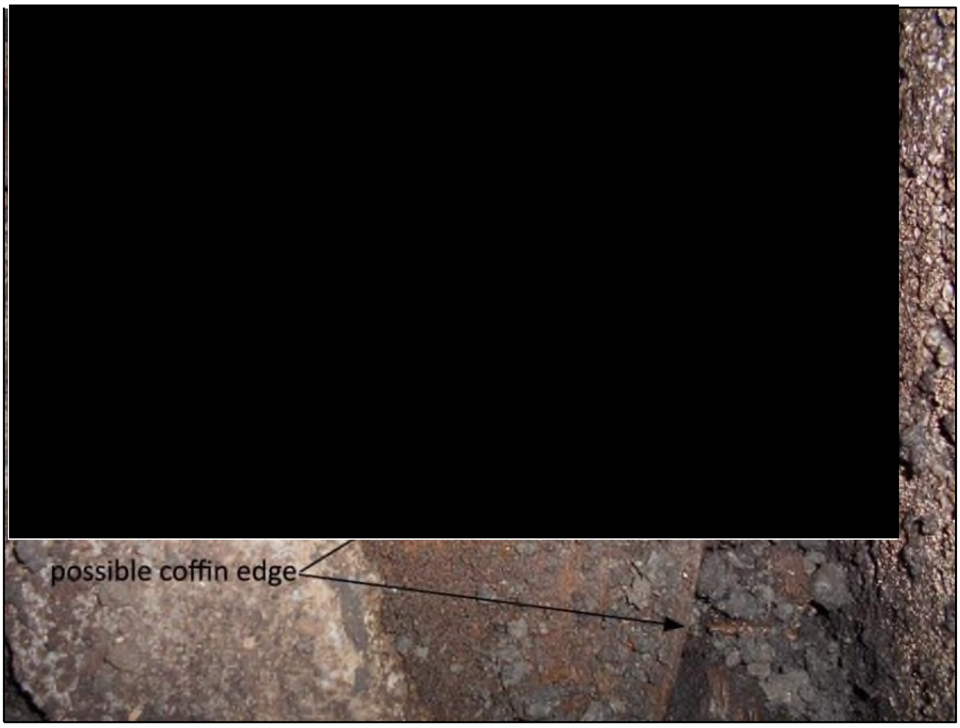

Plate 3.38: C.60/61, unusual edge evident in timber near southern end of tank (north to bottom, detail of inversion of Plate 3.37), which may be the possible edge of a coffin

Plate 3.39: C.62/63, no human skeletal remains identified

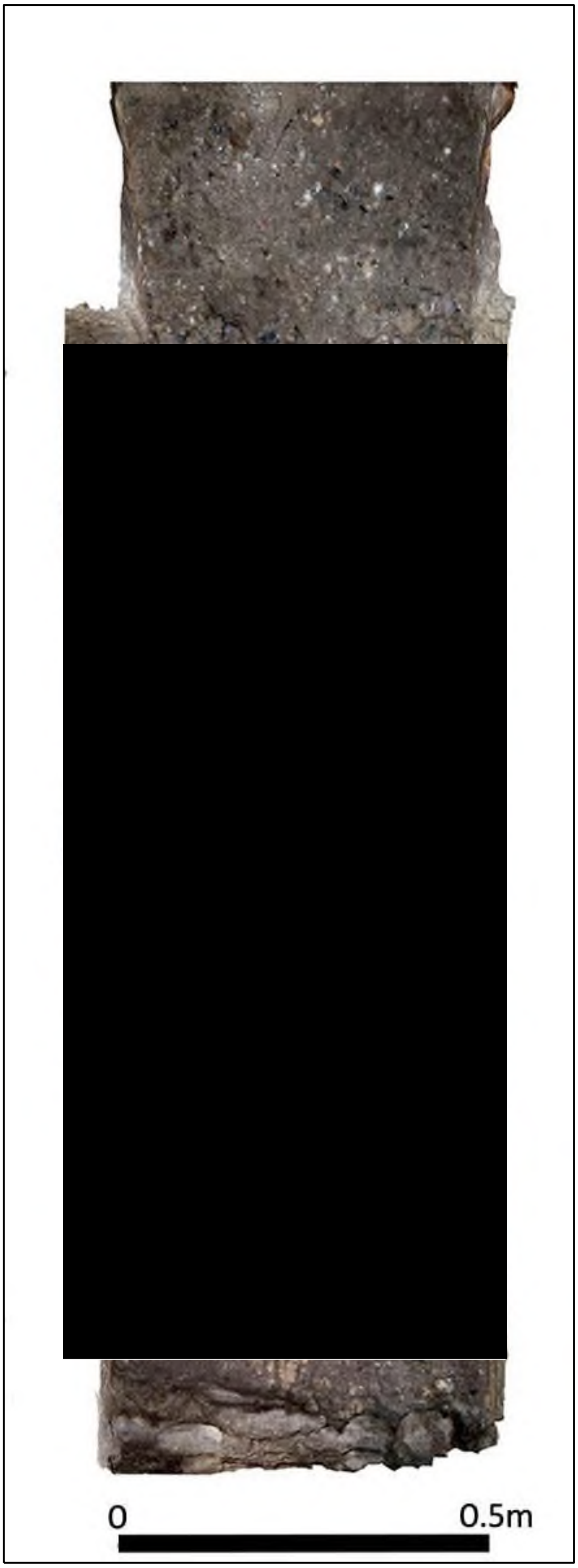

Plate 3.40: C.64/65, annotated photograph of sections with identified human remains, see Plates 3.41-3.42

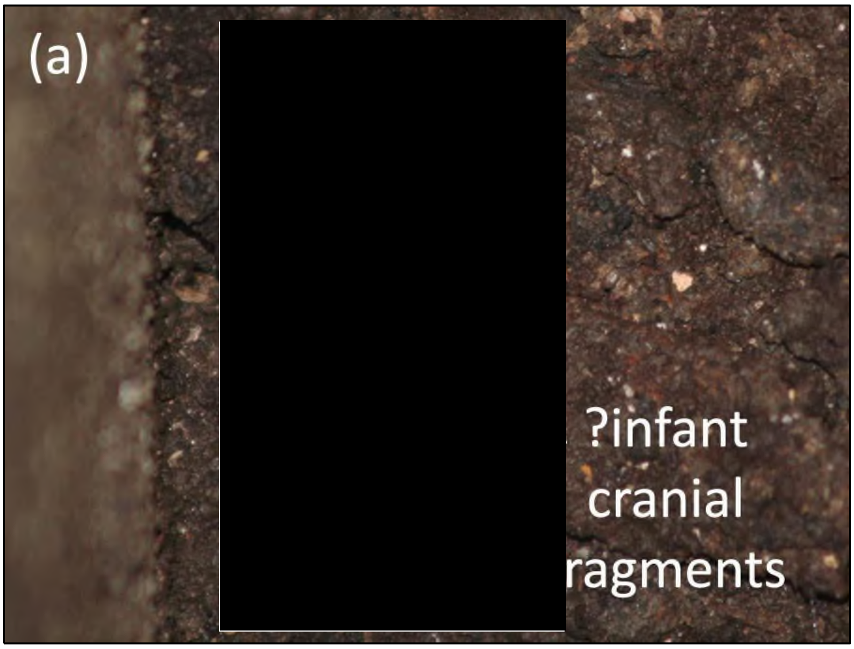

Plate 3.41: C.64/65(a), detail of infant cranial fragments, see Plate 3.40

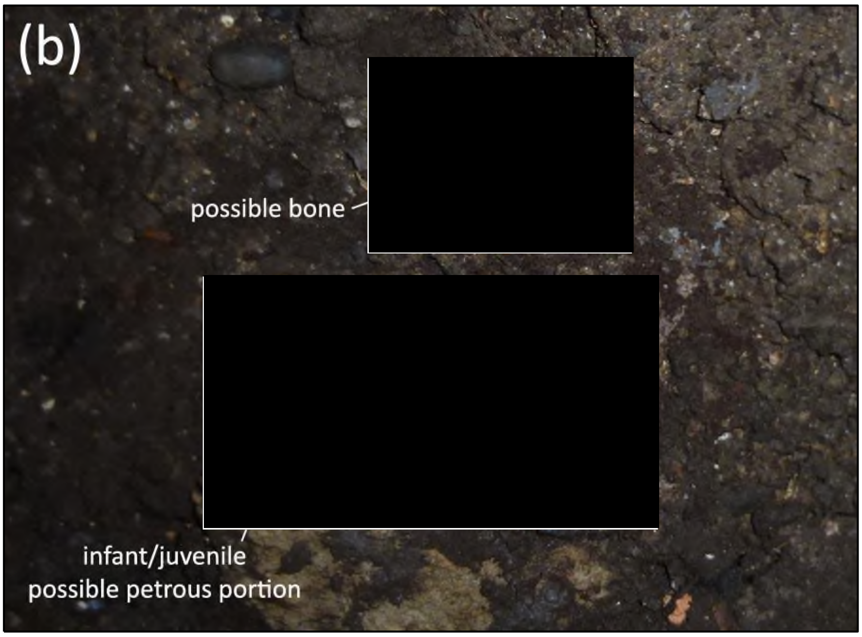

Plate 3.42: C.64/65(b), detail of possible bone and infant/juvenile cranium, see Plate 3.40

Plate 3.43: C.84/85, annotated photograph of sections of identified human remains, see Plates 3.44-3.50

Plate 3.44: C.84/85(a), spread of infant bones, see Plate 3.43 (*n.b.* '?infant petrous portion' refers to the 'infant left temporal' highlighted in Plate 3.45)

Plate 3.45: C.84/85(a), detail, left temporal of infant 0-5 months, see Plate 3.44

Plate 3.46: C.84/85(a), detail, multiple infant bones, including a possibly articulated radius and ulna, see Plate 3.44

Plate 3.47: C.84/85(b), possible infant bones along western edge, see Plate 3.43

Plate 3.48: C.84/85(c), detail of probable infant human bones near south end of tank, see Plate 3.43

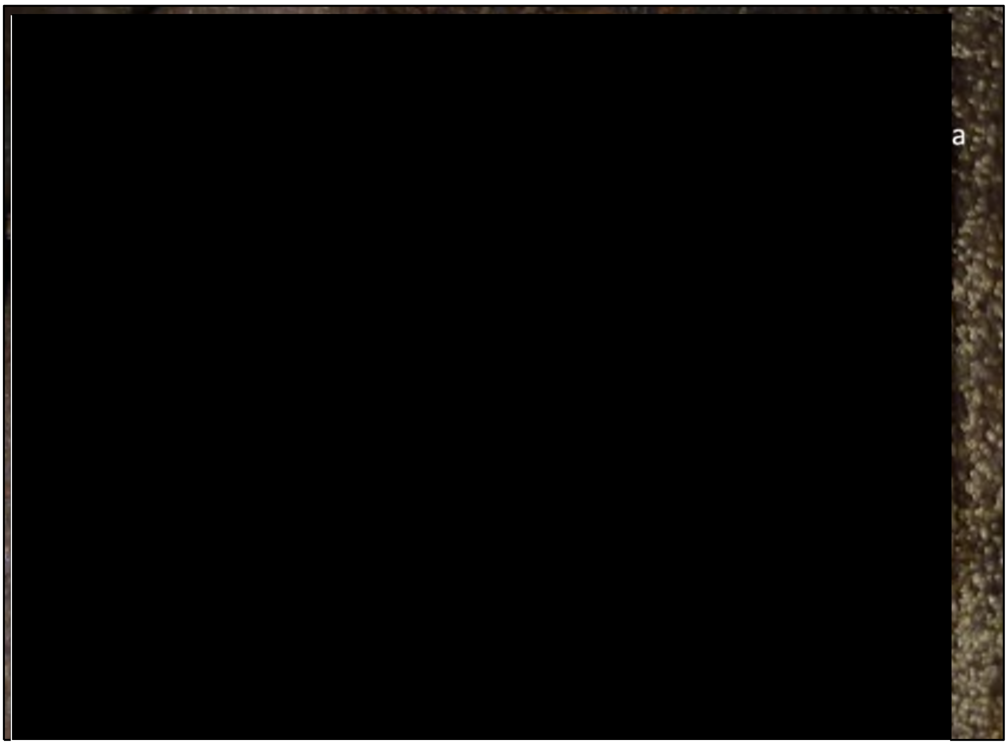

Plate 3.49: C.84/85(c), detail, infant remains with evidence of articulation, see Plate 3.48

Plate 3.50: C.84/85(d), single possible bone fragment adjacent to east wall, see Plate 3.43

Plate 3.51: C.86/87, no human skeletal remains were visible in this tank

Plate 3.52: C.88/89, annotated photograph of sections of identified human remains, see Plates 3.53-3.60

Plate 3.53: C.88/89(a), multiple bones of infants/young juvenile (<6 years), see Plate 3.52

Plate 3.54: C.88/89(b), multiple bones of infants/young juvenile (<6 years), see Plate 3.52

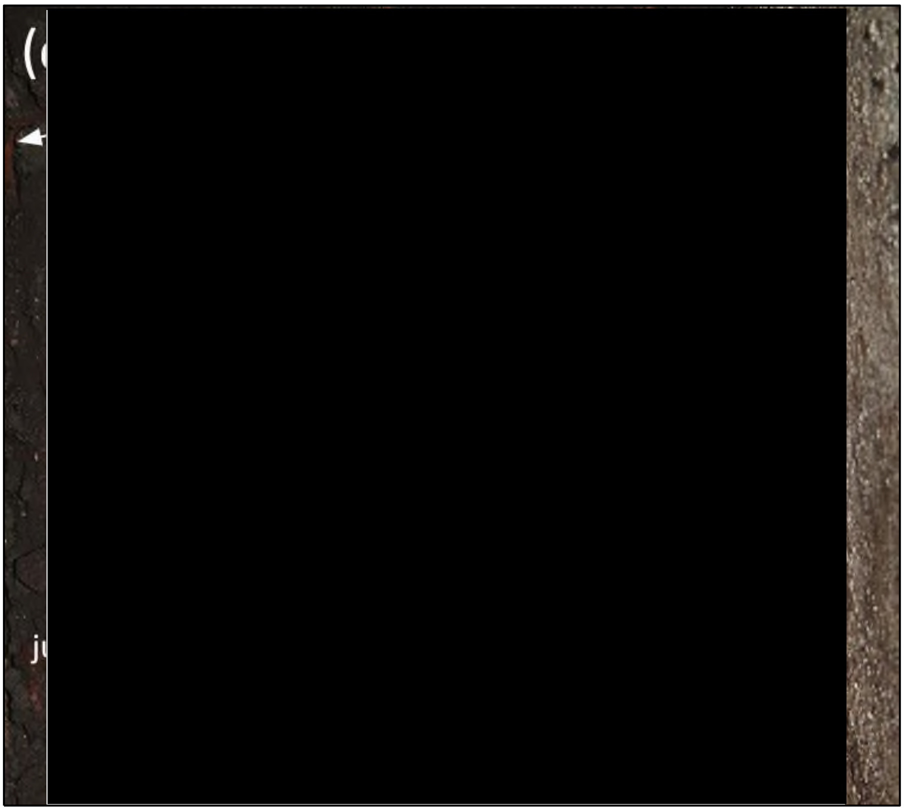

Plate 3.55: C.88/89(c), multiple bones of infants/young juvenile (<6 years), see Plate 3.52

Plate 3.56: C.88/89(d), multiple bones of infants/young juvenile (<6 years), see Plate 3.52

Plate 3.57: C.88/89(e), multiple bones of infants (<1 year) and young juvenile (1.5-2.5 years), see Plate 3.52

Plate 3.58: C.88/89(e), detail, maxillary teeth of disarticulated cranium, with estimated age-at-death of *c.* 1.5-2.5 years, also an infant vertebral arch fragment, north to bottom, see Plate 3.57

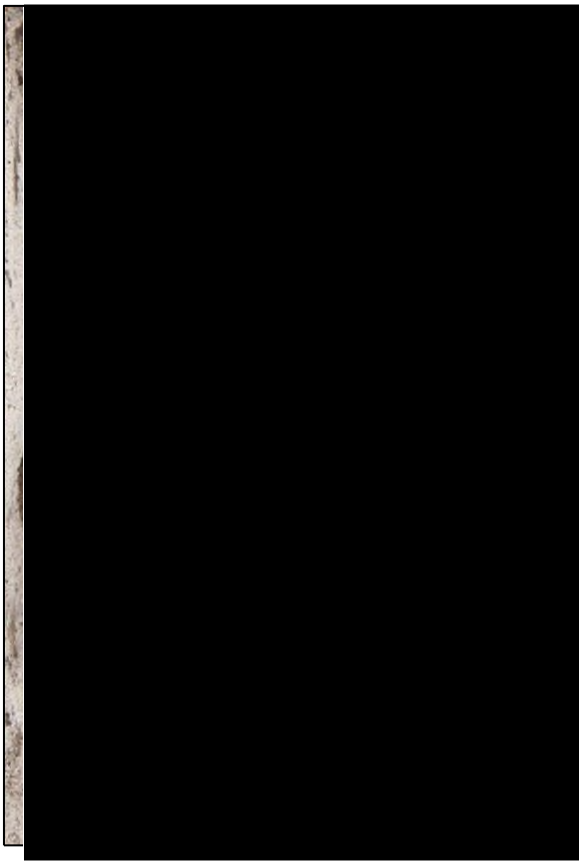

Plate 3.59: C.88/89(e), detail, infant (<1 year) as indicated by humeri, and young juvenile (1-6 years), as indicated by vertebra and cranium, along west side of tank, see Plate 3.57

Plate 3.60: C.88/89(e), detail, infant (<1 year) as indicated by ribs, humerus, and vertebral fragment, and young juvenile (1.5-2.5 years), as indicated by cranium, southwest corner, see Plate 3.57

Plate 3.61: C.90/91, annotated photograph of sections of identified human remains, see Plates 3.62-3.69, and Plate 3.70

Plate 3.62: C.90/91(a), human skeletal remains, see Plate 3.61

Plate 3.63: C.90/91(b), probable infant bones, see Plate 3.61

Plate 3.64: C.90/91(b), detail, showing possible articulation, see Plate 3.61 & 3.63

Plate 3.65: C.90/91(b), detail, showing possible articulation, north to bottom, see Plate 3.61 & 3.63

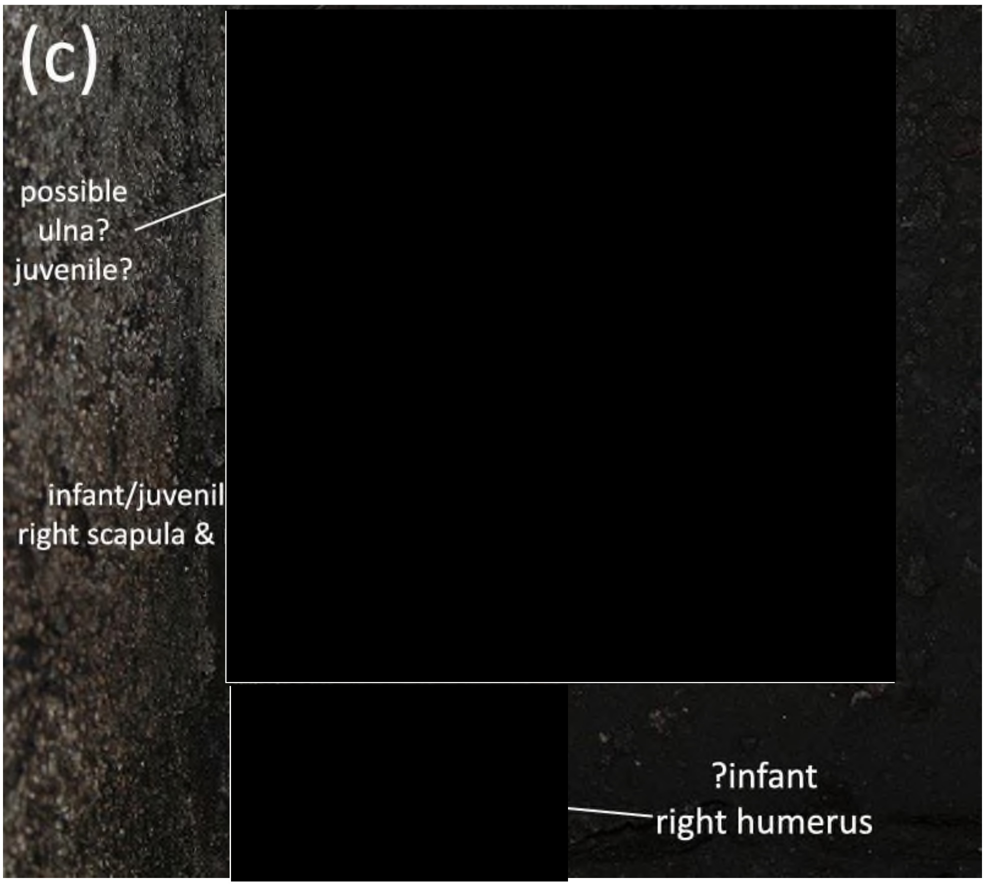

Plate 3.66: C.90/91(c), infant/juvenile remains near southwest corner, see Plate 3.61

Plate 3.67: C.90/91(c), detail, multiple sets of ribs of infant/young juveniles (<6 years), see Plate 3.66

Plate 3.68: C.90/91(c), detail, right ribs and right scapula of infant/young juvenile (<6 years), detail of Plate 3.67

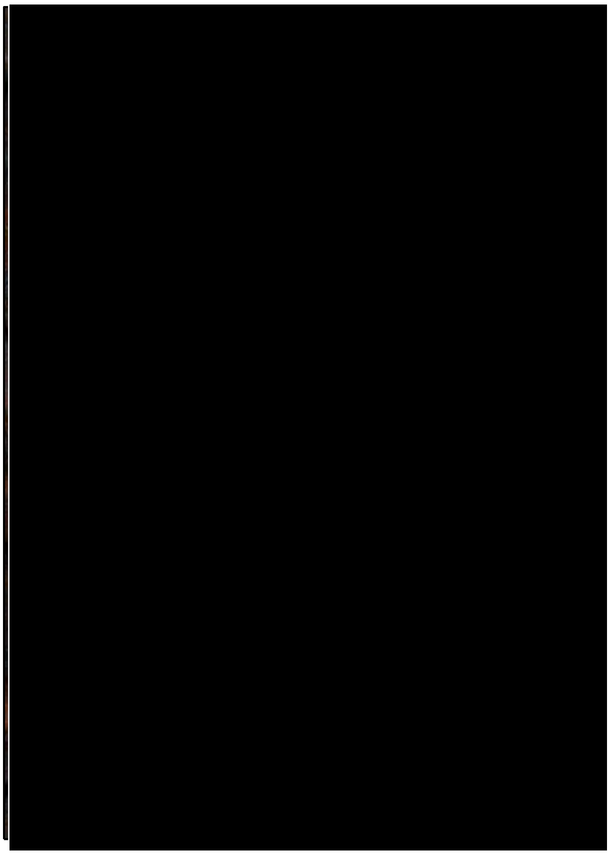

Plate 3.69. C.90/91(c), detail, possibly largely intact cranium of infant/young juvenile (<6 years), detail of Plate 3.67

Plate 3.70: Blue shoe of young juvenile (<6 years), detail from Plate 3.61

Plate 3.71: C.92/93, annotated photograph of sections of identified human remains, see Plates 3.72-3.76

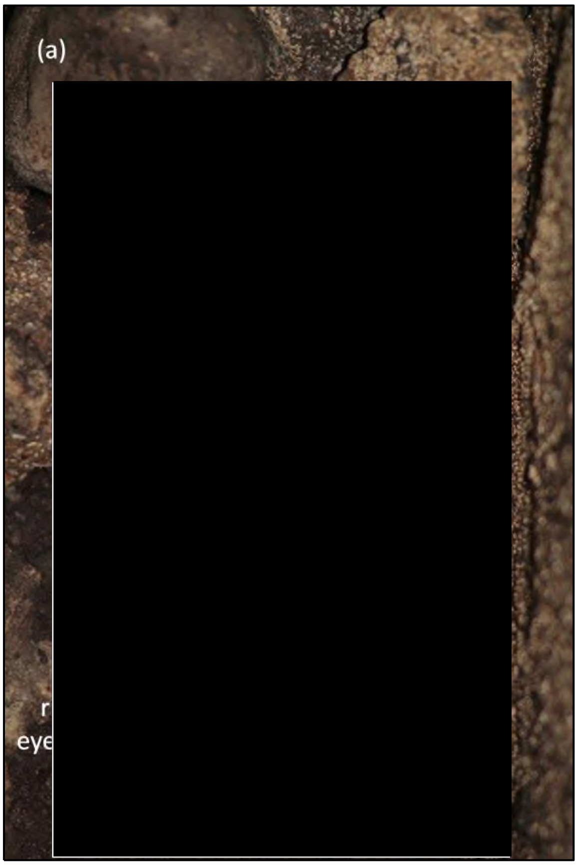

Plate 3.72: C.92/93(a), possibly relatively intact cranium of detail of young juvenile (1-6 years), see Plate 3.71

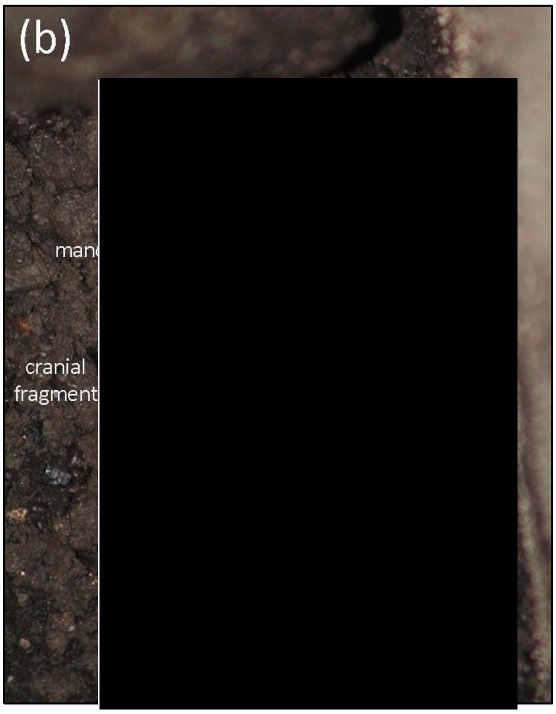

Plate 3.73: C.92/93(b), possible young juvenile (1-6 years) mandible, with cranial fragments and possible hand phalanx, see Plate 3.71

[redacted]

Plate 3.74: C.92/93(c), multiple bones including long bones of juvenile *c.* 2 years, see Plate 3.71

[redacted]

Plate 3.75. C.92/93(d), left ribs and possible scapula of possible young juvenile (1-6 years), see Plate 3.71

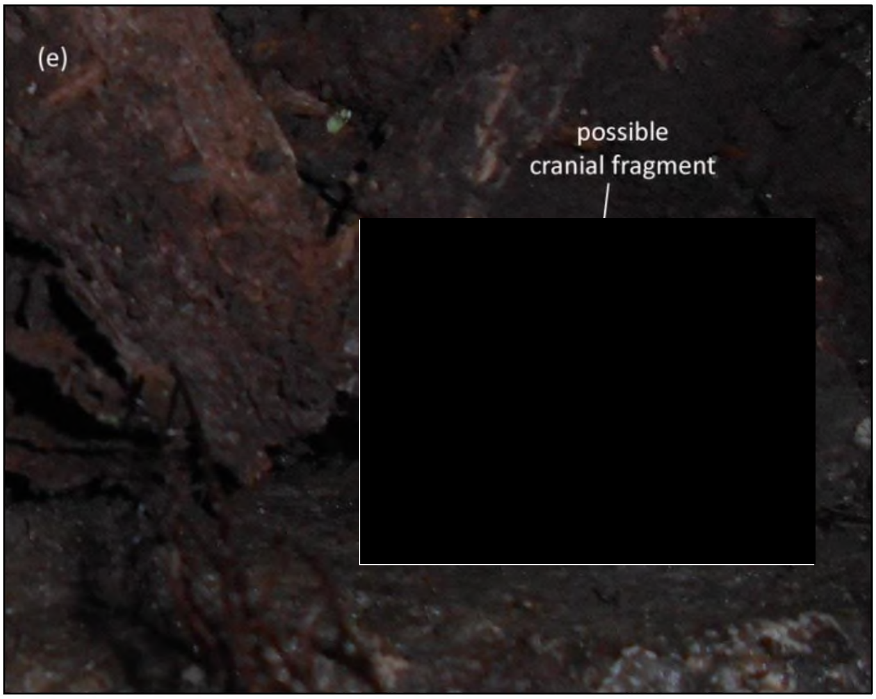

Plate 3.76: C.92/93(e), possible cranial fragment, see Plate 3.71

Plate 3.77: C.94/95, annotated photograph of sections of identified human remains, see Plates 3.78-3.83

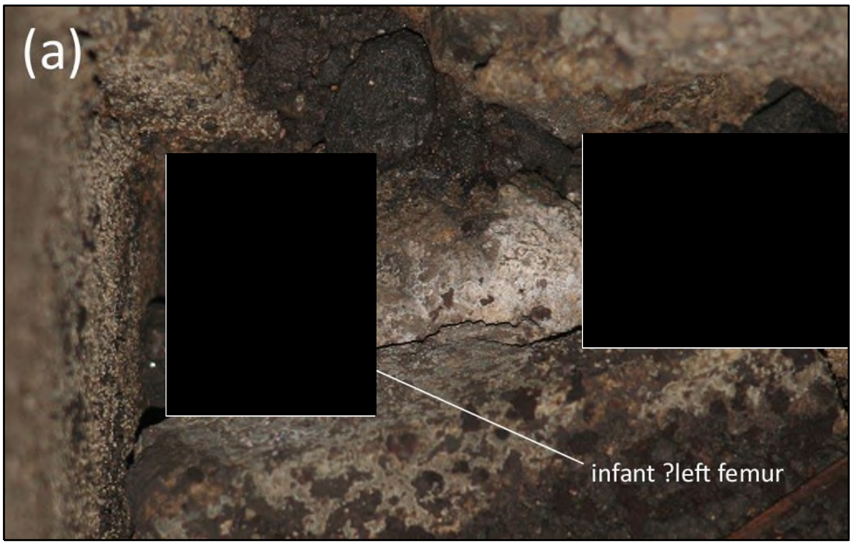

Plate 3.78: C.94/95(a), probable infant left femur, see Plate 3.77

Plate 3.79: C.94/95(b), probable young juvenile (1-6 years) cranium, see Plate 3.77

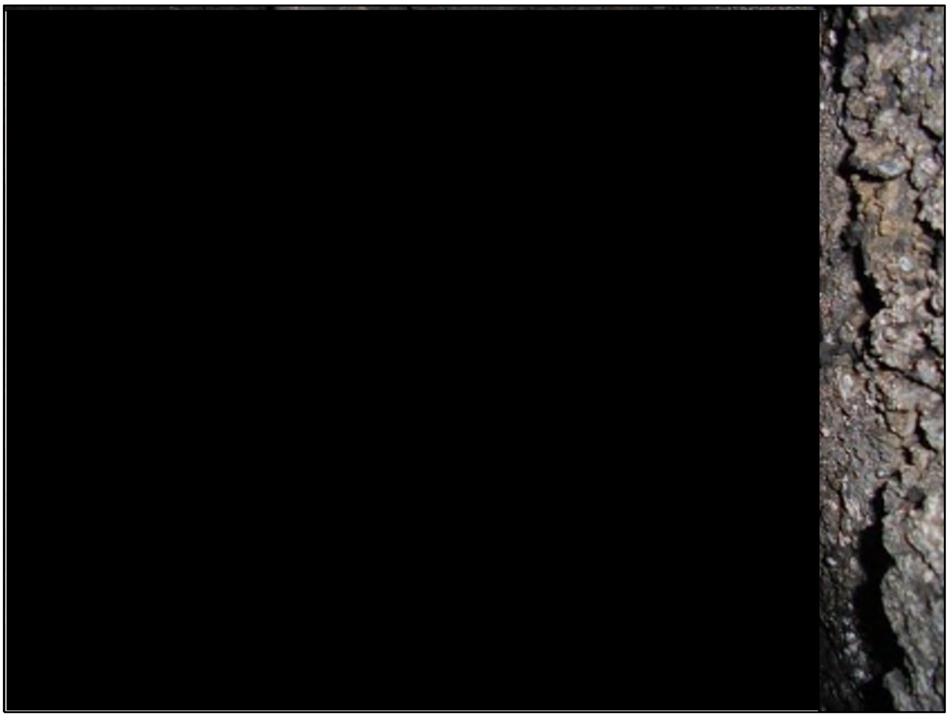

Plate 3.80: C.94/95(c), concentration of probable young juvenile (1-6 years) bones, see Plate 3.77

Plate 3.81: C.94/95(c), detail of unidentified vertebra with at least partial fusion to neural arch, possibly aged 4-6 years, see Plate 3.80

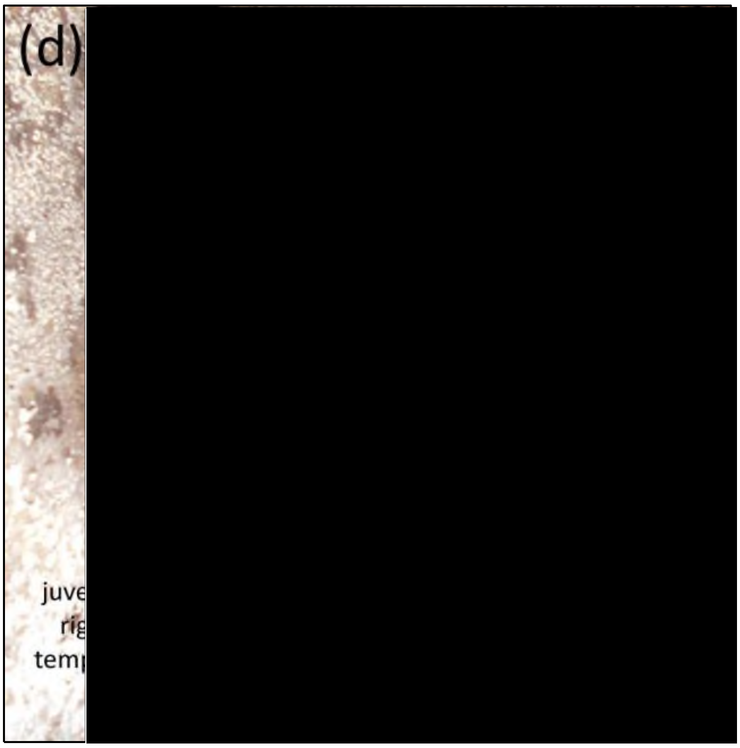

Plate 3.82: C.94/95(d), concentration of young juvenile (1-6 years) cranial bones, see Plate 3.77

Plate 3.83: C.94/95(e), left maxilla of a probable young juvenile (1-6 years), see Plate 3.77


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Plate 3.84: C.96/97, annotated photograph of sections of identified human remains, see Plates 3.85-3.87

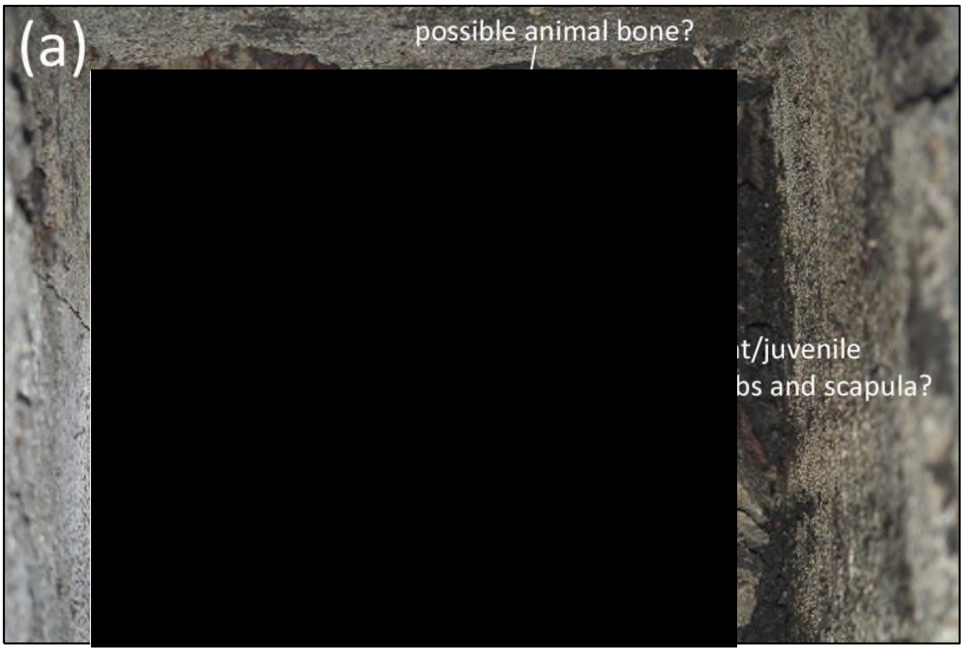

Plate 3.85: C.96/97(a), identified human skeletal remains, see Plate 3.84

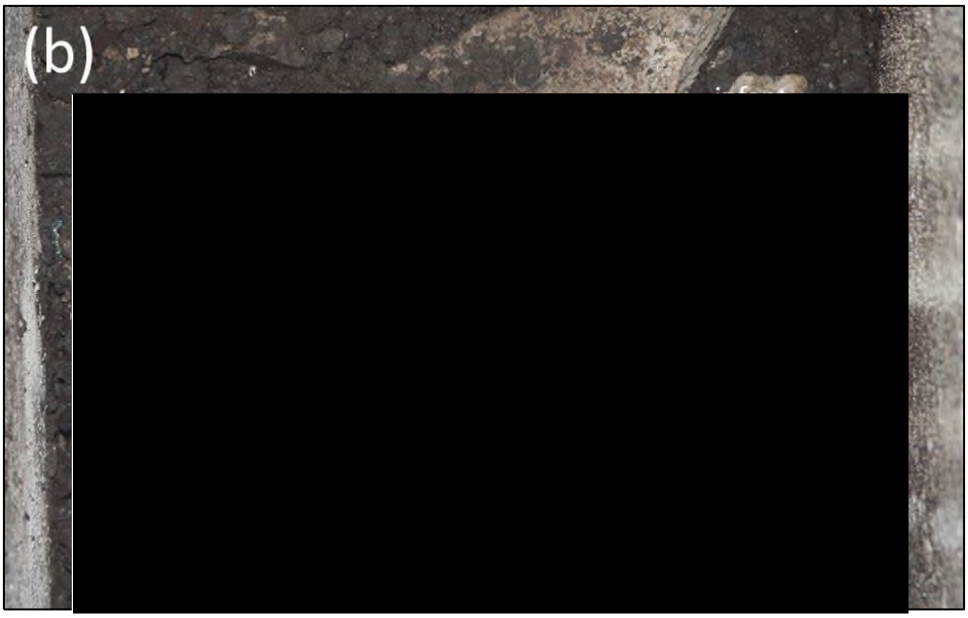

Plate 3.86: C.96/97(b), multiple infant bones at south end of tank, see Plate 3.84

Plate 3.87: C.96/97(b), detail, relatively intact infant cranium with possibly associated vertebrae, see Plate 3.86

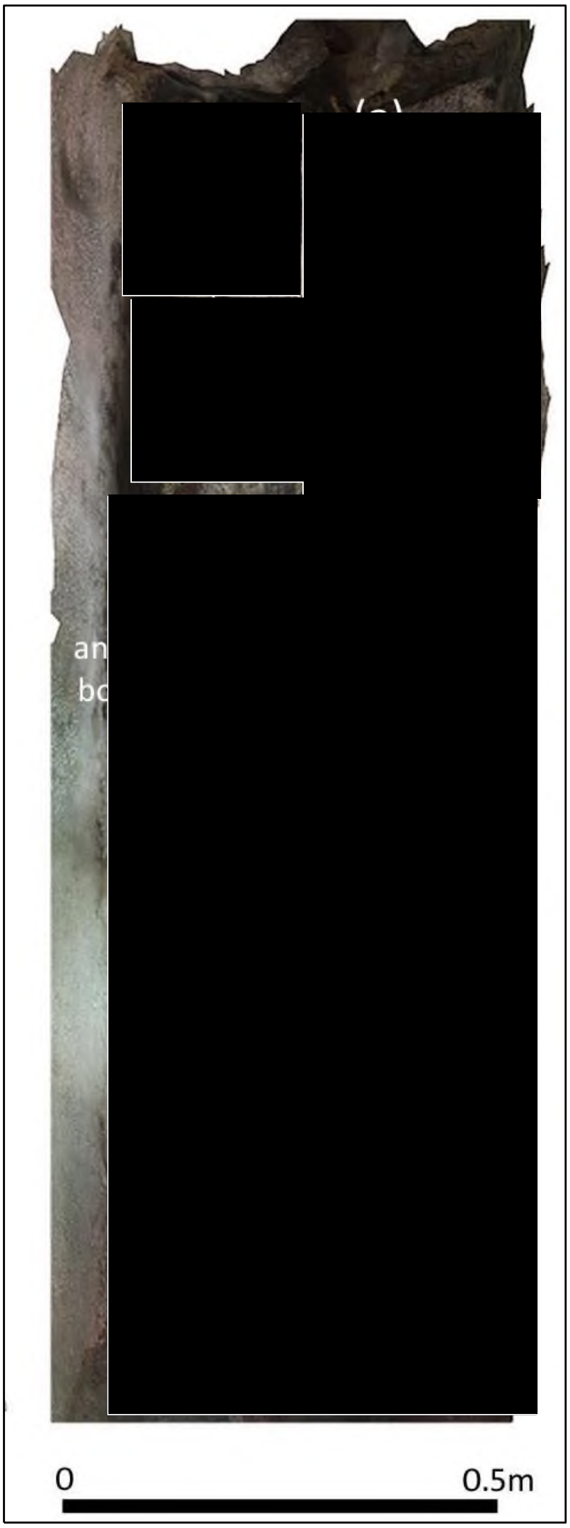

Plate 3.88: C.98/99, annotated photograph of sections of identified human remains, see Plates 3.89-3.91

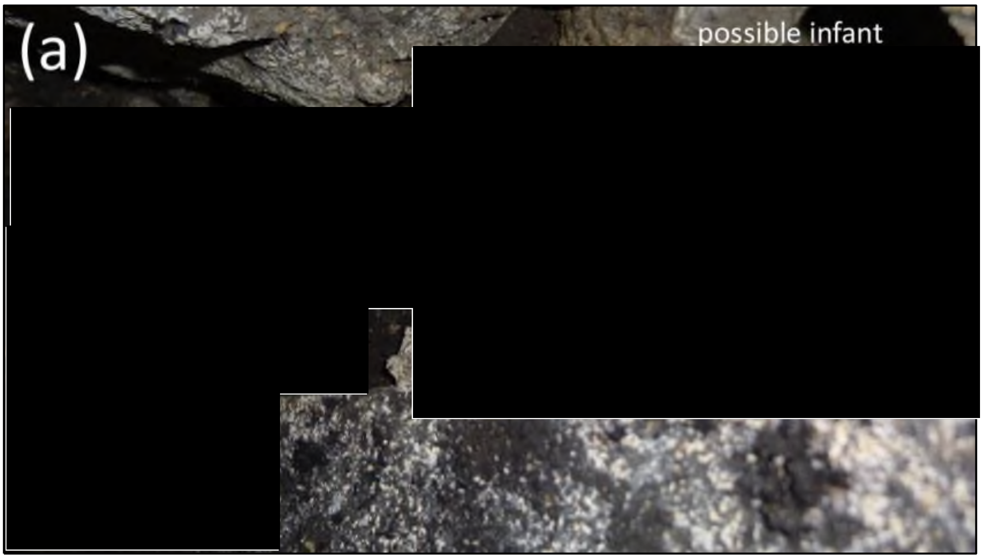

Plate 3.89: C.98/99(a), possible infant cranial remains at northern end, see Plate 3.88

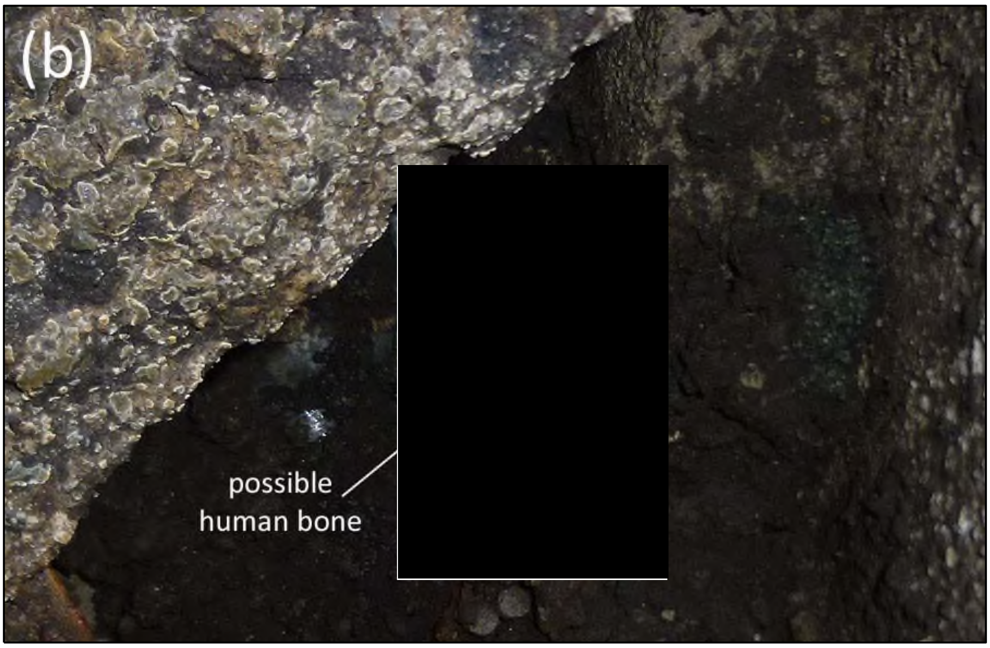

Plate 3.90: C.98/99(b), possible young juvenile vertebral body, see Plate 3.88

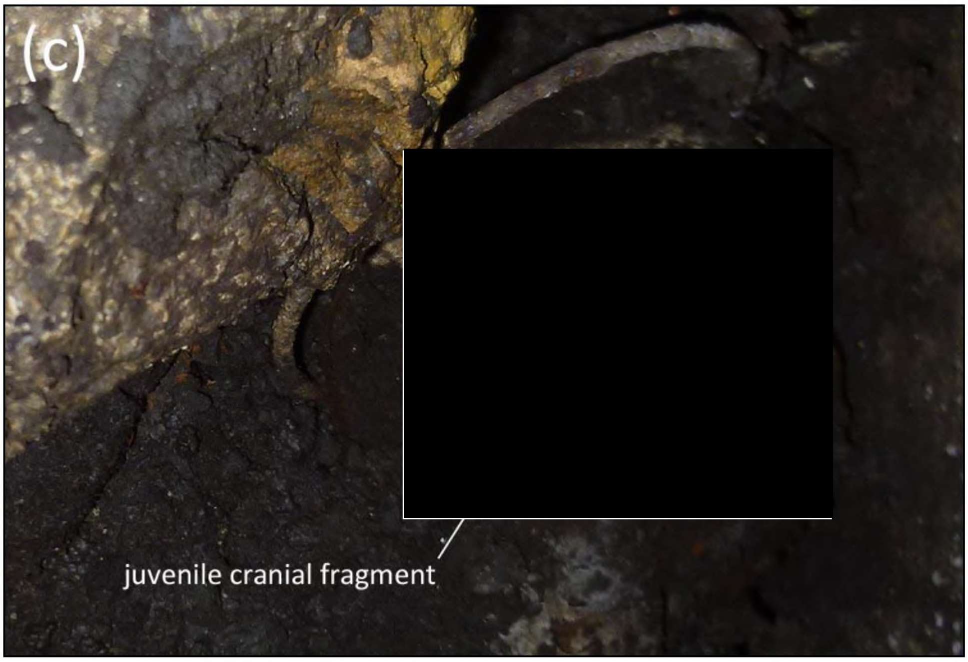

Plate 3.91: C.98/99(c), possible juvenile cranial fragment, see Plate 3.88

Plate 3.92: C.100/101, human remains (a) identified underneath fallen concrete slab, location approximate, see Plates 3.93-3.94

Plate 3.93: C.100/101(a), young juvenile cranial remains underneath collapsed concrete slab, view from north, see Plates 3.92 and 3.94

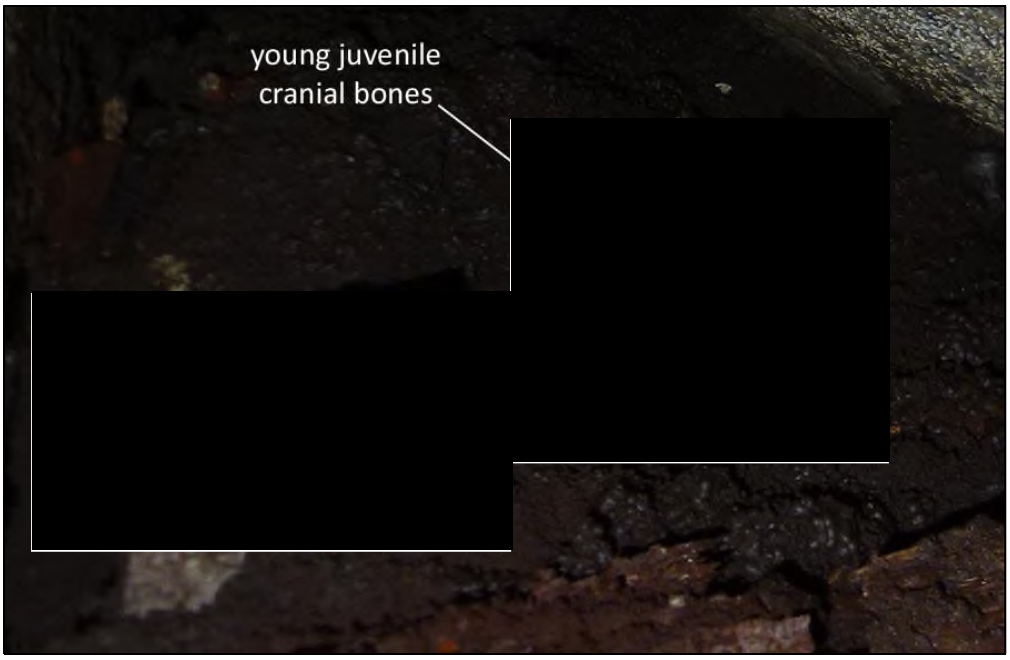

Plate 3.94: C.100/101(a), detail, close up of cranial bones shown in Plate 3.93

Plate 4.1 and 4.2: Castrol Bottle

Plate 4.3: Castrol Logo Chronology, courtesy of BP International

Plate 6.1: Plastic and steel coverings

Plates 6.2: Permeable layer

Plates 6.3: Overburden reinstated

Plates 6.4: Gravel reinstated

Appendix IV: Figures

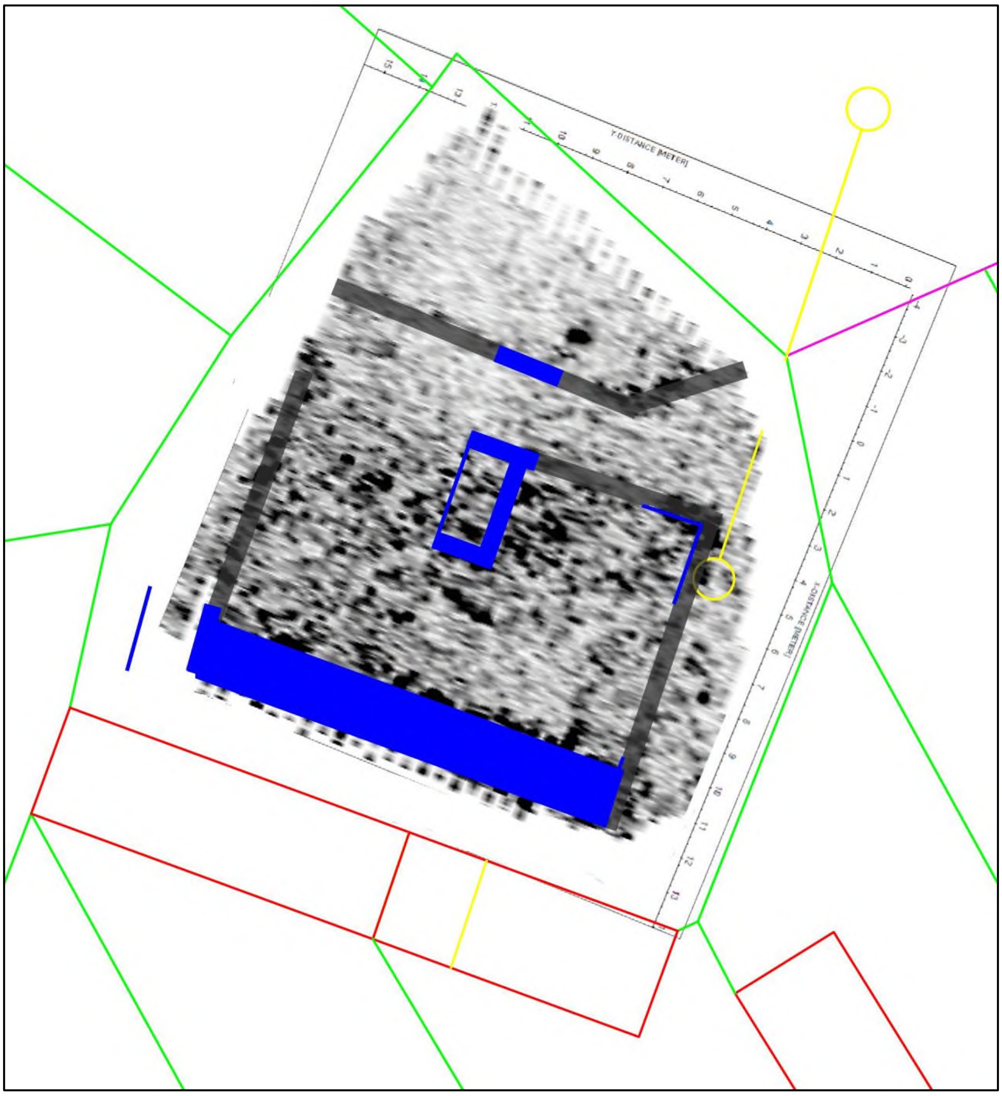

Figure 2.1 Geophysical Survey of the site with the archaeological features identified overlain.

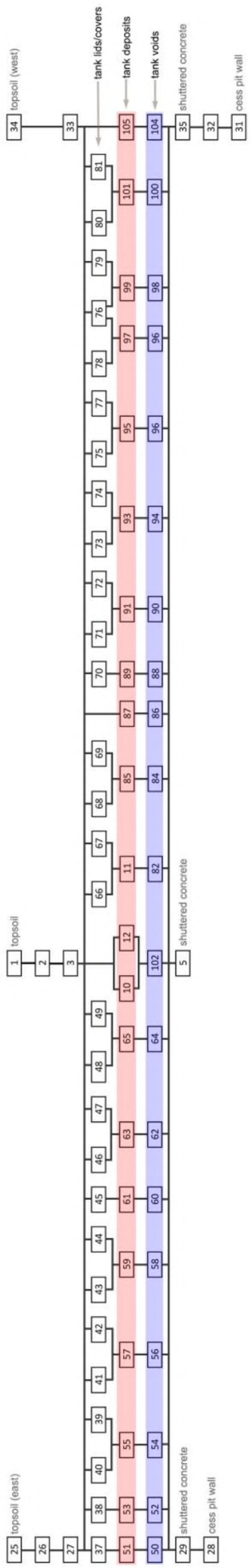

Figure 2.2 Annotated site matrix for Phase IIA

Figure 2.3 and 2.4: Plan and section drawings

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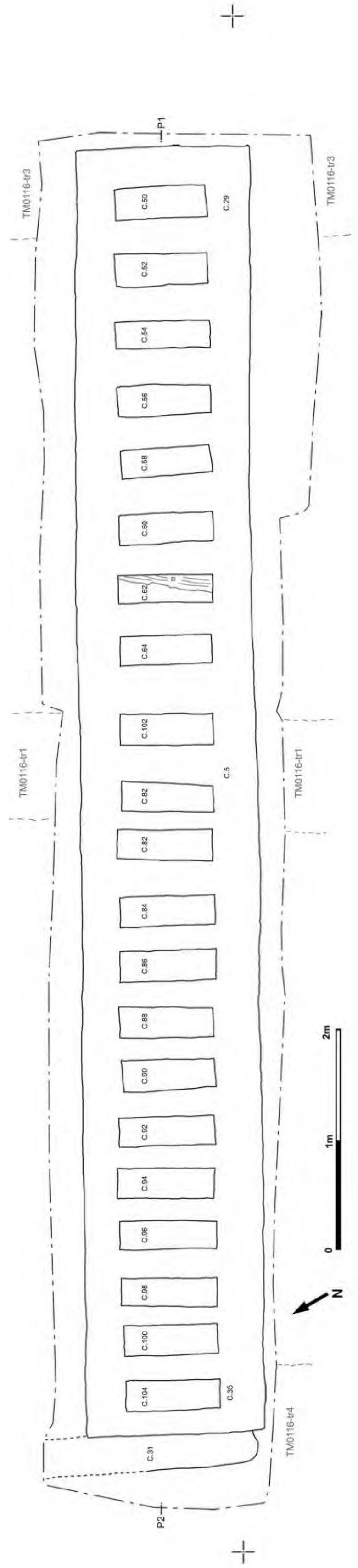


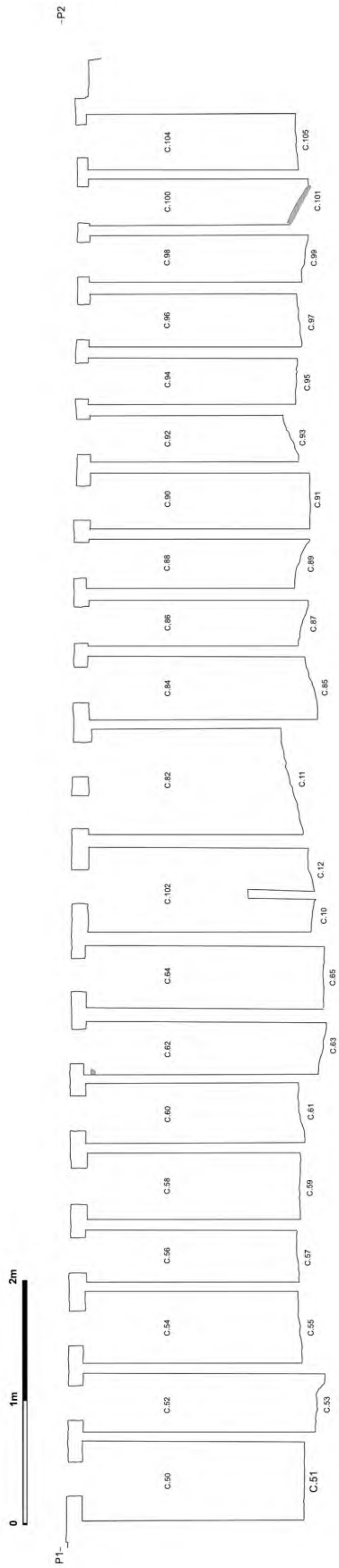


Figure 4.1: C.11/82 illustrating example of debris inserted post deposition of juvenile human remains.

Appendix V: Context Register

MUNSTER ARCHAEOLOGY

Context Register	Sheet No.
Site No.:	1
Site Name: TM1017	

Context No.	Type	Area	Description	Plan No.	Date/ Initials
1	Layer	1	Dark brown silt loam, topsoil	2	AH 03/10/16
2	Layer	1	Disturbed greyish brown gravelly/sandy silt, universal extent	2	AH 03/10/16
3	Layer	1	Dark greyish black silt and stone debris	2	AH 04/10/16
5	Masonry	1A	Stone/concrete structure at S end of trench 1 (Feature 1, where F.1A is the eastern tank and F.1B is the western tank)	1, 2, 8	AH 05/10/16
10	Fill/Deposit	1A	Fill of C.5, F.1A eastern-side (not excavated)	-	NMC 07/10/16
11	Fill/Deposit	1A	Fill of C.5, F.1B (not excavated)	-	NMC 07/10/16
12	Fill/Deposit	1A	Fill of C.5, F.1A western-side (not excavated)	-	NMC 07/10/16
25	Layer	3	Dark brown silt loam, topsoil, same as C.1 and C.24	6	MnC 24/10/16
26	Layer	3	Greyish brown sandy silt layer under C.25, equal to C.2 and C.23	6	MnC 24/10/16
27	Layer	3	Dark brownish black layer over concrete shuttering, same as C.3	6	MnC 24/10/16
28	Masonry	3	Short section of limestone wall at NE of trench 3, poss. same as C.21	4	MnC 24/10/16
29	Masonry	3	Stone/concrete shuttered structure with opening (Feature 1 eastern end)	4, 6	AH 26/10/16
31	Masonry	4	Cess-pit wall, mortared limestone, north-south, same as C.21, C.28, C.8 north	7	AH 26/10/16
32	Fill/Deposit	4	Fill of construction trench along W side of C.31	7	AH 26/10/16
33	Layer	4	Greyish brown overburden/backfill	-	AH 26/10/16

MUNSTER ARCHAEOLOGY

Context Register	Sheet No.
Site No.:	2
Site Name: TM1017	

Context No.	Type	Area	Description	Plan No.	Date/ Initials
34	Layer	4	Dark brown silt loam topsoil	-	AH 26/10/16
35	Masonry	4	Stone/concrete shuttered structure (Feature 1 western end) with opening to tank	7	AH 26/10/16
37	Masonry	-	Pre-cast concrete slab/lid C.50	-	NMC 31/01/17
38	Masonry	-	Fractured pre-cast concrete slab/lid over C.52	-	NMC 31/01/17
39	Masonry	-	Part of fractured pre-cast concrete slab/lid (south) over C.54	-	NMC 31/01/17
40	Masonry	-	Part of concrete slab/lid-repair (north) over C.54	-	NMC 31/01/17
41	Masonry	-	Part of concrete slab/lid-repair (north) over C.56	-	NMC 31/01/17
42	Masonry	-	Part of fractured pre-cast concrete slab/lid (south) over C.56	-	NMC 31/01/17
43	Masonry	-	Part of concrete slab/lid-repair (north) over C.58	-	NMC 31/01/17
44	Masonry	-	Part of fractured pre-cast concrete slab/lid (south) over C.58	-	NMC 31/01/17
45	Masonry	-	Fractured pre-cast concrete slab/lid over C.60	-	NMC 31/01/17
46	Masonry	-	Part of concrete slab/lid-repair (north) over C.62	-	NMC 31/01/17
47	Masonry	-	Part of fractured pre-cast concrete slab/lid (south) over C.62	-	NMC 31/01/17
48	Masonry	-	Part of concrete slab/lid-repair (north) over C.64	-	NMC 31/01/17
49	Masonry	-	Part of fractured pre-cast concrete slab/lid (south) over C.64	-	NMC 31/01/17

MUNSTER ARCHAEOLOGY

Context Register	Sheet No.
Site No.:	3
Site Name: TM1016	

Context No.	Type	Area	Description	Plan No.	Date/ Initials
50	Void	-	Negative space context within chamber containing fill C.51	-	NMC 31/01/17
51	Deposit	-	Deposit within C.50	-	NMC 31/01/17
52	Void	-	Negative space context within chamber containing fill C.53	-	NMC 31/01/17
53	Deposit	-	Deposit within C.52	-	NMC 31/01/17
54	Void	-	Negative space context within chamber containing fill C.55	-	NMC 31/01/17
55	Deposit	-	Deposit within C.54	-	NMC 31/01/17
56	Void	-	Negative space context within chamber containing fill C.57	-	NMC 31/01/17
57	Deposit	-	Deposit within C.56	-	NMC 31/01/17
58	Void	-	Negative space context within chamber containing fill C.59	-	NMC 31/01/17
59	Deposit	-	Deposit within C.58	-	NMC 31/01/17
60	Void	-	Negative space context within chamber containing fill C.61	-	NMC 31/01/17
61	Deposit	-	Deposit within C.60	-	NMC 31/01/17
62	Void	-	Negative space context within chamber containing fill C.63	-	NMC 31/01/17
63	Deposit	-	Deposit within C.62	-	NMC 31/01/17
64	Void	-	Negative space context within chamber containing fill C.65	-	NMC 31/01/17

MUNSTER ARCHAEOLOGY

Context Register

Sheet No. 4

Site No.:

Site Name: TM1017

Context No.	Type	Area	Description	Plan No.	Date/ Initials
65	Deposit	-	Deposit within C.64	-	NMC 31/01/17
66	Masonry	-	Part of fractured pre-cast concrete slab/lid (north) over C.82	-	NMC 02/02/17
67	Masonry	-	Part of fractured pre-cast concrete slab/lid (south) over C.82	-	NMC 02/02/17
68	Masonry	-	Part of concrete slab/lid-repair (north) over C.84	-	NMC 02/02/17
69	Masonry	-	Part of fractured pre-cast concrete slab/lid (south) over C.84	-	NMC 02/02/17
70	Masonry	-	Fractured pre-cast concrete slab/lid over C.88	-	NMC 02/02/17
71	Masonry	-	Part of fractured pre-cast concrete slab/lid (north) over C.90	-	NMC 02/02/17
72	Masonry	-	Part of heavily fractured pre-cast concrete slab/lid (south) over C.90	-	NMC 02/02/17
73	Masonry	-	Part of fractured pre-cast concrete slab/lid (north) over C.92	-	NMC 02/02/17
74	Masonry	-	Part of fractured pre-cast concrete slab/lid (south) over C.92	-	NMC 02/02/17
75	Masonry	-	Concrete slab/lid-repair (north) aligned east-west, over C.94, C.96, C.98 and C.100	-	NMC 02/02/17
76	Metal	-	Corrugated sheeting over C.75	-	NMC 02/02/17
77	Masonry	-	Part of fractured pre-cast concrete slab/lid (south) over C.94	-	NMC 02/02/17
78	Masonry	-	Part of fractured pre-cast concrete slab/lid (south) over C.96	-	NMC 02/02/17
79	Masonry	-	Part of fractured pre-cast concrete slab/lid (south) over C.98	-	NMC 02/02/17

MUNSTER ARCHAEOLOGY

Context Register

Sheet No. **5**

Site No.:
Site Name: TM1017

Context No.	Type	Area	Description	Plan No.	Date/ Initials
80	Masonry	-	Concrete slab/lid-repair (north), over C.100	-	NMC 02/02/17
81	Masonry	-	Part of fractured pre-cast concrete slab/lid (south) over C.92	-	NMC 02/02/17
82	Void	-	Negative space context within chamber containing fill C.11	-	NMC 02/02/17
83	Deposit	-	Deposit within C.82, equal to C.11	-	NMC 02/02/17
84	Void	-	Negative space context within chamber containing fill C.85	-	NMC 02/02/17
85	Deposit	-	Deposit within C.84	-	NMC 02/02/17
86	Void	-	Negative space context within chamber containing fill C.87	-	NMC 02/02/17
87	Deposit	-	Deposit within C.86	-	NMC 02/02/17
88	Void	-	Negative space context within chamber containing fill C.89	-	NMC 02/02/17
89	Deposit	-	Deposit within C.88	-	NMC 02/02/17
90	Void	-	Negative space context within chamber containing fill C.91	-	NMC 02/02/17
91	Deposit	-	Deposit within C.90	-	NMC 02/02/17
92	Void	-	Negative space context within chamber containing fill C.93	-	NMC 02/02/17
93	Deposit	-	Deposit within C.92	-	NMC 02/02/17

MUNSTER ARCHAEOLOGY

Context Register

Sheet No. 6

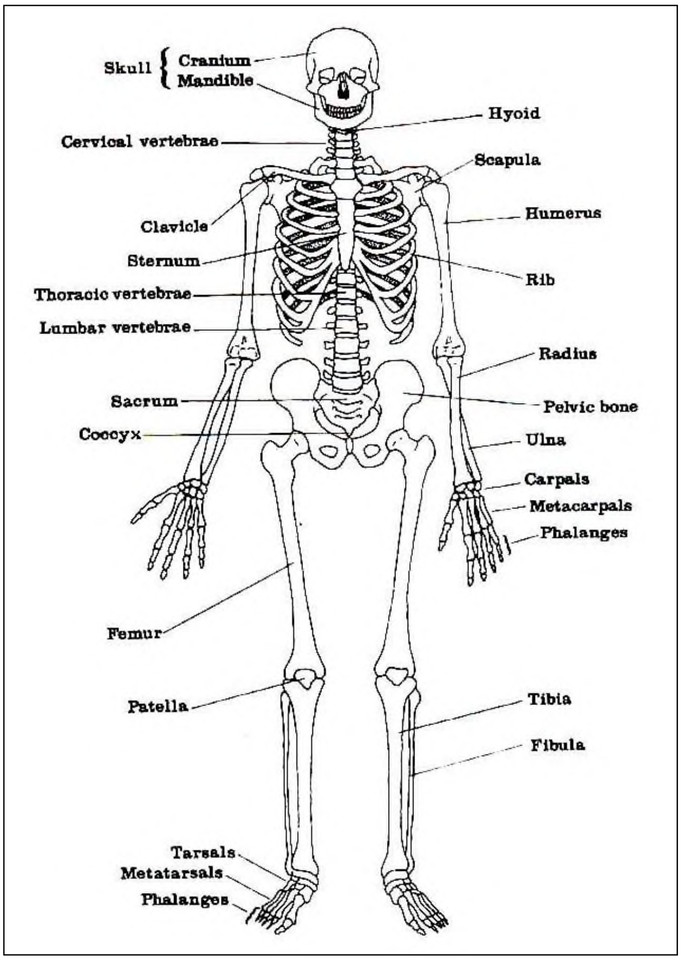
Site No.:

Site Name: TM1016

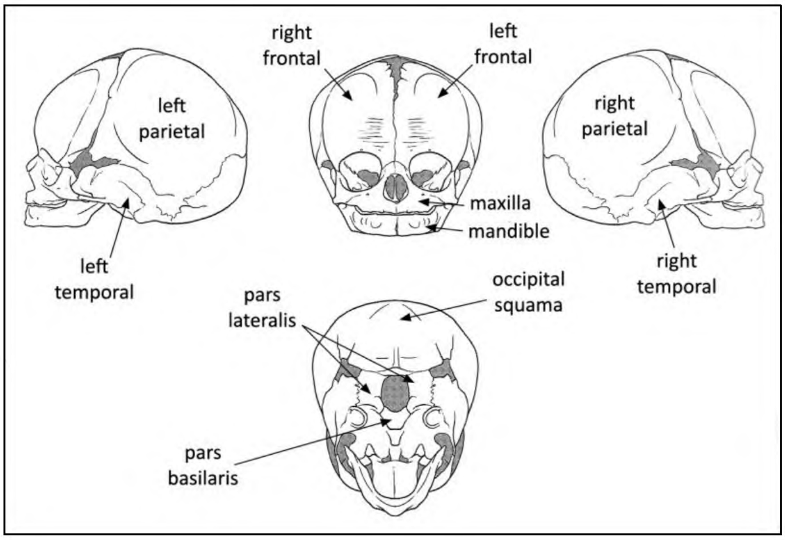
Context No.	Type	Area	Description	Plan No.	Date/ Initials
94	Void	-	Negative space context within chamber containing fill C.95	-	NMC 02/02/17
95	Deposit	-	Deposit within C.94	-	NMC 02/02/17
96	Void	-	Negative space context within chamber containing fill C.97	-	NMC 02/02/17
97	Deposit	-	Deposit within C.96	-	NMC 02/02/17
98	Void	-	Negative space context within chamber containing fill C.99	-	NMC 02/02/17
99	Deposit	-	Deposit within C.98	-	NMC 02/02/17
100	Void	-	Negative space context within chamber containing fill C.101	-	NMC 02/02/17
101	Deposit	-	Deposit within C.100	-	NMC 02/02/17
102	Void	-	Negative space context within chamber containing fills C.10 and C.12	-	NMC 02/02/17
104	Void	-	Negative space context within chamber containing fill C.105	-	NMC 02/02/17
105	Deposit	-	Deposit within C.104	-	NMC 02/02/17

Appendix VI: Osteological Appendices

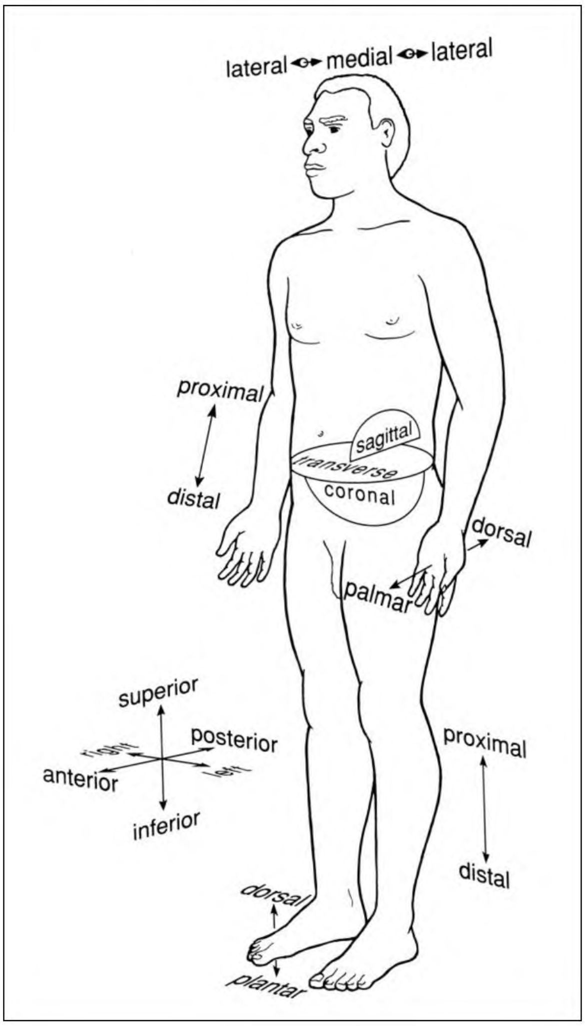
A. Annotated diagram showing main skeletal elements (after Mays 1998, 2, fig. 1.1)



B. Annotated diagram showing main elements of infant cranium (adapted from Schaefer et al. 2009, 360)



C. Anatomical directions(from White and Folkens 1991, 29, fig. 3.1)



D. Osteological Terms Used (after White and Folkens 1991, 28-35; Bass 1995, 319-321)

Directions - General

Superior	toward the head of the body.
Inferior	opposite of superior, body parts away from the head.
Anterior	toward the front of the body.
Posterior	opposite of anterior, toward the back of the individual.
Medial	toward the midline of the body.
Lateral	opposite of medial, away from the midline of the body.
Proximal	nearest the axial skeleton, usually used for long bones.
Distal	opposite of proximal, furthest from the axial skeleton.
Palmar	relating to the hand, the palm side
Plantar	relating to the foot, towards the sole of the foot
Dorsal	relating to the hand/foot, back of the hand, top side of the foot
External	outer.
Internal	opposite of external, inside.
Endocranial	inner surface of the cranial vault.
Ectocranial	outer surface of the cranial vault.

Directions - Teeth

Mesial	toward the point on the midline where the central incisors meet.
Distal	opposite of mesial.
Lingual -	toward the tongue.
Labial	opposite of lingual, toward the lips.
Buccal	opposite of lingual, toward the cheeks.
Incisal	the biting surface of the tooth.
Occlusal	the chewing surface of the tooth.

General bone features/terms

Process	a bony eminence.
Eminence	a bony projection, usually not as prominent as a process.
Spine	generally a long, thinner, sharper process than an eminence.
Tuberosity	a large, usually roughened eminence of variable shape, often the site of a ligament attachment.
Tubercle	a small, usually roughened eminence, often a site of a ligament attachment.
Trochanters	two large, prominent, blunt, rugose processes found on the distal femur.
Malleolus	a rounded protuberance adjacent to the ankle joint.
Articulation	an area in which adjacent bones are in contact at a joint.
Condyle	a rounded articular process.
Epicondyle	a non-articular projection adjacent to a condyle.
Head	a large, rounded, usually articular end of a bone.
Shaft/diaphysis	the long, straight section between the ends of a long bone.
Epiphysis	usually the end portion or extremity of a long bone which is expanded for articulation.

Neck	the section of a bone between the head and the shaft.
Torus -	a bony thickening.
Ridge	a linear bony elevation, often roughened.
Crest	a prominent, usually sharp and thin ridge of bone.
Line	a raised linear surface, not as thick as a torus or as sharp as a crest.
Facet	a small articular surface, or tooth contact.
Metaphysis	a line of junction between epiphysis and diaphysis.
Osteoblastic	process of bone formation
Osteoclastic	process of bone resorption

Other osteological terms/abbreviations

C1-C7	cervical vertebrae (neck) numbered from 1-7.
CEJ	cemento-enamel junction, junction of crown of tooth and root.
DJD	degenerative joint disease.
T1-T12	thoracic vertebrae (torso) numbered 1-12.
TMJ	tempromandibular joint, joint of lower jaw.
L1-L5	lumbar vertebrae (lower back) numbered 1-5.
S1-S5	sacral vertebrae (in between left and right pelvis) numbered 1-5.
MC-	metacarpal (bones of the palm of the hand), may be numbered 1-5.
MT	metatarsal (bones of the arch of the foot), may be numbered 1-5.
IAM	Internal Auditory Meatus in temporal bone of cranium.
EAM	External Auditory Meatus in temporal bone of cranium.
MN	Minimum Number of Individuals.
CPR	Crude Prevalence Rate.
TPR	True Prevalence Rate.
SN/s	Schmorl's nodes, depression defects in the vertebral bodies, associated with herniation of intervertebral disk.

Appendix VII: Environmental Sampling Report

Joint Report
The Characterisation of Samples
For Niamh McCullagh and
The Mother and Baby Homes Commission of Investigation

(Criminal Procedure Rules [2015] Parts 16 and 19; Criminal Justice Act 1967, s. 9)

Report of Professor Lorna DAWSON, Dr Tom SHEPHERD and Dr Bob MAYES

Qualifications
BSc, PhD, C.Sci, F.I.Soil Sci, FRSA (LD);
BSc, PhD (TS);
BSc, MSc, PhD (BM),

Age Over 18

Occupations Soil Scientist, Volatile Organic Chemist and Organic Chemist

Address James Hutton Institute
Craigiebuckler
Aberdeen
AB15 8QH

I (Lorna DAWSON, Tom SHEPHERD and Bob MAYES) DECLARE THAT:

1. I understand that my duty is to help the court to achieve the overriding objective by giving independent assistance by way of objective, unbiased opinion on matters within my expertise, both in preparing reports and giving oral evidence. I understand that this duty overrides any obligation to the party by whom I am engaged or the person who has paid or is liable to pay me. I confirm that I have complied with and will continue to comply with that duty.

2. I confirm that I have not entered into any arrangement where the amount or payment of my fees is in any way dependent on the outcome of the case.

3. I know of no conflict of interest of any kind, other than any which I have disclosed in my report.

4. I do not consider that any interest which I have disclosed affects my suitability as an expert witness on any issues on which I have given evidence.

5. I will advise the party by whom I am instructed if, between the date of my report and the trial, there is any change in circumstances which affect my answers to points 3 and 4 above.

6. I have shown the sources of all information I have used.

7. I have exercised reasonable care and skill in order to be accurate and complete in preparing this report.

8. I have endeavoured to include in my report those matters, of which I have knowledge or of which I have been made aware, that might adversely affect the validity of my opinion. I have clearly stated any qualifications to my opinion.

9. I have not, without forming an independent view, included or excluded anything which has been suggested to me by others including my instructing lawyers.

10. I will notify those instructing me immediately and confirm in writing if for any reason my existing report requires any correction or qualification.

11. I understand that:

    (a) my report will form the evidence to be given under oath or affirmation;

    (b) the court may at any stage direct a discussion to take place between experts;

    (c) the court may direct that, following a discussion between the experts, a statement should be prepared showing those issues which are agreed and those issues which are not agreed, together with the reasons;

    (d) I may be required to attend court to be cross-examined on my report by a cross-examiner assisted by an expert.

    (e) I am likely to be the subject of public adverse criticism by the judge if the Court concludes that I have not taken reasonable care in trying to meet the standards set out above.

12. I have read Part 19 of the Criminal Procedure Rules and I have complied with its requirements.

13. I confirm that my discipline does not have a material code to adhere to.

14. I confirm that I have read guidance contained in a booklet known as *Disclosure: Experts' Evidence and Unused Material* which details my role and documents my responsibilities, in relation to revelation as an expert witness. I have followed the guidance and recognise the continuing nature of my responsibilities of disclosure. In accordance with my duties of disclosure, as documented in the guidance booklet, I confirm that:

    (a) I have complied with my duties to record, retain and reveal material in accordance with the Criminal Procedure and Investigations Act 1996, as amended;

    (b) I have compiled an Index of all material. I will ensure that the Index is updated in the event I am provided with or generate additional material;

    (c) in the event my opinion changes on any material issue, I will inform the investigating officer, as soon as reasonably practicable and give reasons.

I confirm that the contents of this report are true to the best of my knowledge and belief and that I make this report knowing that, if it is tendered in evidence, I would be liable to prosecution if I have wilfully stated anything which I know to be false or that I do not believe to be true.

Signed lorna Dawson Dated the 23rd May 2017

Signed Tom Shepherd. Dated the 23rd May 2017

Signed R.N. Mayes Dated the 23rd May 2017

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1. Qualifications and Experience

Prof. Lorna DAWSON

I am employed as a principal research scientist at the James Hutton Institute, Aberdeen, Scotland, where I am Head of the Soil Forensics Section and hold the qualifications of BSc (Honours) Geography (Edinburgh University, 1979), and a PhD in Soil Science (Aberdeen University, 1984). I am a visiting Professor in Forensic Science at the Robert Gordon University. I am a Fellow of the British Society of Soil Science, a Fellow of the Royal Society of the Arts, a Chartered Scientist and hold an Expert Witness certificate in both Criminal and Civil Law (Cardiff University, 2011, 2012). I have published widely on the subject of forensic soil science; published over 80 refereed publications, books and book chapters. I am an Expert Advisor with the National Crime Agency, have worked with numerous police forces in Scotland, England, Wales, Ireland & Australia over the last 12 years and have advised on over 100 cases, written over 70 Expert Witness reports, and presented evidence in 10, in the UK and overseas. During the past 12 years I have encountered the evidence type involved in this case on several occasions.

Dr Tom SHEPHERD

I am a senior research chemist employed at the James Hutton Institute, Dundee, Scotland holding the qualifications of BSc (Honours) Chemistry (University of St Andrews, 1980) and a PhD in Synthetic Organic Chemistry (University of St Andrews, 1983). I am an expert in the use of techniques such as automated thermal desorption (ATD) and solid-phase micro-extraction (SPME), coupled with GC-MS, for entrainment and analysis of volatiles. A main element of my research is the analysis of volatile chemicals, compiling an extensive database of chromatographic characteristics from a wide range of different matrices. During the past two years I have encountered the evidence type involved in this case on several occasions.

Dr Bob MAYES

I am a Research Associate at the James Hutton Institute where I was previously head of the Ecological Sciences GC and GC-MS laboratories, and hold the qualifications PhD from Queen's University of Belfast, MSc in Animal Nutrition from the University of Aberdeen and BSc in Physiology and Biochemistry of Farm Animals from Reading University. I am an expert in the analysis of wax markers and my research interests revolve around the application of this biomarker technology to measuring dietary intake, digestibility and plant species composition in grazing herbivores and to the chemical characterisation of soil organic matter as applied in criminal investigations. I have worked with a number of police forces in Scotland, England, Wales & Ireland over the last 6 years, have written over 16 Expert Witness reports, and presented evidence in court with two of them. During the past 6 years I have encountered the evidence type involved in this case on several occasions.

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2. Summary of findings

- It can be confirmed from our examination that there is evidence that the site *had* previously been used as a sewage facility.
- The results of this series of tests cannot establish categorically whether the sewage facility was being used at the time when the human remains were deposited. It is a matter of historic record to establish when and how long the facility was used.
- The results of this series of tests cannot establish categorically whether the non-decomposed human remains had been deposited in the chambers, or whether the bodies have previously been stored (and decomposed) elsewhere, with mainly bones being placed in the chambers.

It does appear that the volatile organic profiles are characteristic of decomposition of mammalian tissue *or* waste and probably human. It is not possible to determine the extent to which the deposited human infant remains which are known to be present may have contributed to this, or to what extent human faecal material may also have done so. The presence of hotspots within the northern and western boundary samples but not the southern and eastern boundary samples is of note. A number of the hotspots for compounds characteristic of bone decomposition, particularly ketones, but also aliphatic alcohols and *n*-aldehydes, are found at locations with high bone densities.

However, the concentrations of the solid organic biomarkers in the analysed samples were very low, much lower than would be expected if the analysed material had entirely originated from human sewage waste. The samples collected from the site boundaries (negative control samples; samples 55 and 57) had generally lower biomarker concentrations than the samples collected from within the chambers where remains were located. 10-Hydroxy stearic acid, cholesterol and the faecal stanols, coprostanol and epicoprostanol have been recognised as being products of the decomposition of mammalian remains (including human), and their concentration patterns generally differ from those of human sewage material. The presence of these compounds in the samples collected from the chambers could, at least in part, have come from decomposed human bodies.

The reasons for the low biomarker concentrations found in the samples are not easy to assess. If the chambers represented a closed cesspit or a number of cesspits, it is possible that the collected sewage had been removed before depositing the human cadaver material; soil may have been added at the same time, or soil may have seeped in from the roof area of the chambers. If there were one or more piped out flows (i.e. the facility was a septic tank, or was connected to a sewer outflow), it would be expected that little sewage would be left behind.

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Samples 55 and 57 (west boundary and east boundary locations respectively) and sample 14 (no visible human remains) have different isotopic profiles to the other samples examined, reflecting likely a lesser influence from either sewage or human remains.

It is likely that some signature due to faecal material is present, but it is also likely that the human remains have also contributed to the signatures observed, and the presence of compounds associated with decomposition of bone at locations of high bone density in the samples is suggestive of this.

3. Information/Circumstances of Case

We examined a single sample of soil (DAWSON & MAYES Report dated 6th December 2016) and ascertained that that sample was not a typical soil but was shown to contain faecal markers and potential indications of human decomposition markers.

I, Lorna DAWSON, later received a phone call from Donal GUINNESS, Counsel to the Mother and Baby Home Commission of Investigation, on 7th February, 2017 to enquire if we could carry out a set of Volatile Organic Compound (VOC) analyses of 20 soil samples, followed by an independent alkane/sterol/alcohol analysis on the interesting samples as identified from the initial VOC analysis. After discussion with Niamh McCULLAGH, forensic archaeologist, and representing the Counsel to the Mother and Baby Home Commission of Investigation, a tender with agreed costs for VOC screening of 32 samples, followed by detailed VOC interpretation and alkane/sterol/alcohol analysis of 6 interesting samples was sent on 13th February 2017, the work having been commissioned on the 12th February 2017.

The conclusions we have drawn in this case are based on information provided by Niamh McCULLAGH. Should this information change it may be necessary for us to reconsider our interpretation and conclusions.

4. Items Received

A scanned copy of the list of samples collected at the site under investigation is in Appendix 1. Samples were taken from several locations in a rectangular facility with several concrete cells within that outer structure (and is described in a separate report by McCULLAGH) Appendix 10. Two samples were taken at each location, one of which was retained by the client. All samples not marked as retained were delivered by DHL couriers to the James Hutton Institute, Aberdeen on the 15th February 2017 in a sealed box. Inside the sealed box was a second box securely sealed on all edges containing 2 sealed evidence bags MRHC01 – bags 1 & 2.

5. Request or Purpose of Examination

Human remains have been found within a structure at a site that, in general terms, has been used previously as a sewage treatment facility. The investigative questions relevant to the sample submissions are:

a) Can it be determined if the structure from which human remains were recovered was or ever had been used as a sewage treatment facility?
b) Can it be determined if this structure was in use at the time remains were deposited?

c) Can it be determined if these remains decomposed in situ? If so, what degree of certainty can be applied to the result?

6. Assumptions

It is assumed the samples were collected in a rigorous manner and that the sampling was carried out with due care and by adhering to established forensic sampling protocols.

7. Use of Assistants

In undertaking the work in this case I, Lorna DAWSON was assisted by other members of the Soil Forensic Unit Laboratory staff. Their involvement is described in the forensic case files and I have taken their contributions into account when we prepared this report. The involvement of other staff is fully recorded in case notes available for inspection at the laboratory if necessary. Mrs Jasmine ROSS, forensic laboratory manager, assisted myself in examining the samples, captured photographs, analysed the samples for organic markers and prepared the audit trail (Appendix 2). Dr Tom SHEPHERD analysed the samples for VOCs by Solid Phase Microextraction - Gas Chromatography – Mass Spectrometry (SPME-GC-MS) and interpreted the VOC data. Dr Bob MAYES interpreted the organic marker chromatograms for markers of sewage and or human decomposition. Mrs Maureen PROCEE analysed the samples for isotopic C and N. Mr Gareth NEWMAN, Service Delivery Manager, James Hutton Limited, carried out a stage 1 review of this report. Prof. Colin CAMPBELL, CEO, James Hutton Institute, reviewed this report.

8. Nature of Examination

Soil is a mixture of both inorganic and organic material (Dawson and Hillier, 2010: Dawson and Mayes, 2014). The organic material reflects the plant and animal material having been deposited or decomposed within that soil and also human organic inputs to the soil (Dawson and Mayes, 2014). A combination of gas chromatography (GC) and gas chromatography-mass spectrometry (GCMS) can be used to characterise and identify many organic compounds in soils, both volatile and physical which helps ascertain what those inputs likely were.

Comparison of the distribution of the volatile compounds found in the samples with published data describing the range of volatile compounds produced during decomposition of mammalian tissues, including that of humans (Vaas et al., 2004, 2008; Vaas, 2012) allows the interpretation of contact with human decomposition products to be made. This use of the examination of the odour of decomposition is relatively recent and is considered an experimental technique for intelligence and is still under development.

This report describes the sample examination, the VOC analysis, the organic analysis and the isotope analysis of the samples received on the 15th February 2017.

A full record of the work done in this case is available for inspection at Laboratory 234, the James Hutton Institute, Aberdeen.

An audit trail is in Appendix 2. A list of references used is in Appendix 3. Materials and methods for VOCs, low volatility organic compounds and isotope analysis are in Appendices 4, 5 and 6.

9. Results

Selection of the eight most interesting samples for further analysis

From the phase 1 VOC analysis results, interesting samples were selected for examination for non-volatile organic marker analysis (Table 1, page 10). In addition to the samples identified by the VOC analysis a further 3 samples were chosen for analysis. These were: sample 18 (C.65) where no human remains were seen, sample 35 (C.91) where a fragment of bone was seen when the sample was taken, and sample 57 (east boundary) as a negative control that contained low levels of VOCs.

For every sample, the abundances of individual components in each of the 16 different compound classes were combined to give a compound class sum. Compound class sums for each sample were combined to give a compound class total across all samples.

The compound class sums for each sample were then expressed as a percentage of the compound class total across all samples. This is the scaled abundance. For an individual compound class the sum of the scaled abundances across all samples is 100 (rows in the table).The scaled abundances for the individual compound classes in each individual sample were then combined (columns in the table) to give a combined scale abundance score for the sample

Samples were ranked according to their combined scale abundance scores (in the line below main table), and the eight samples with the highest scores were identified (in grey on right hand side of table): (samples 055, 049, 007, 001, 011, 014, 005 and 045).

Table 1. Compound class analysis for identification of samples with interesting profiles for further analysis based on amounts of classes of compounds of interest. First key refers to individual abundances within main table and second key refers to sum of compound classes.

Compound Class	Sample Numbers (Context Numbers) 1 (51)	3 (53)	5 (55)	7 (57)	9 (59)	11 (61)	13 (63)	14 (63)	15 (63)	17 (65)	18 (65)	19 (65)	21 (10)	23 (12)	25 (11)	27 (85)	29 (87)	30 (87)	31 (87)	33 (89)	35 (91)	37 (93)	39 (95)	43 (97)	45 (99)	47 (101)	49 (105)	Baulk 51 (2)	Boundary Controls 53 N	55 W	57 E	59 S
Aliphatic Alcohols	3.18	1.02	1.81	3.54	4.10	2.83	2.75	6.60	2.81	0.73	0.70	0.90	0.36	5.77	0.36	1.97	0.93	0.97	0.91	1.82	0.39	0.46	0.79	0.67	2.73	0.45	8.63	0.69	0.65	39.05	0.70	0.66
Aromatic Alcohols	2.92	2.10	3.32	5.81	4.01	4.90	1.10	2.26	2.50	0.64	0.71	0.63	0.72	3.86	0.57	3.27	0.72	0.56	0.73	4.68	0.65	1.64	1.52	0.92	2.69	0.49	8.10	0.29	0.71	32.82	1.33	0.84
Phenols	7.62	3.10	3.92	4.15	7.22	5.60	4.54	8.08	4.95	1.50	0.88	1.00	0.58	3.67	1.44	1.41	1.83	0.84	1.20	6.44	1.83	1.25	3.04	3.40	4.68	2.85	4.04	0.61	1.01	4.54	1.25	1.36
Sulfur compounds	0.60	0.55	0.83	1.13	0.64	2.69	2.33	3.37	1.45	0.56	0.84	1.37	0.67	0.66	1.12	11.11	5.06	3.68	3.77	2.83	3.79	6.96	3.85	6.03	6.40	7.35	3.00	8.15	3.79	3.36	0.43	0.73
Aliphatic Ketones	10.41	10.21	6.70	12.12	2.37	7.22	2.68	2.23	2.04	0.74	0.70	0.56	0.53	5.79	0.38	2.36	0.64	0.39	0.63	3.24	0.38	0.76	0.56	0.42	7.93	0.31	7.73	0.52	0.82	6.99	1.20	0.41
Aromatic Ketones	6.80	8.04	10.25	10.91	8.60	9.62	2.44	7.33	5.31	0.84	0.29	0.52	0.33	2.30	0.68	1.39	0.73	0.32	0.39	3.56	0.59	0.21	0.94	0.80	1.74	0.60	8.19	0.19	0.42	3.84	0.66	0.36
Halocarbons	2.29	2.06	2.82	7.69	1.98	5.98	2.40	2.19	2.09	1.16	2.97	0.83	2.86	1.02	0.64	1.20	2.49	0.89	1.45	0.82	1.16	0.56	3.55	2.43	4.04	2.02	4.72	5.79	[illegible]	4.81	3.21	1.99
Furans	6.03	3.09	4.30	6.69	2.26	4.71	2.48	3.52	2.51	1.17	1.37	1.10	0.94	5.80	0.70	3.50	1.15	0.70	0.65	3.24	2.58	2.15	1.51	1.50	4.24	0.98	10.41	2.36	3.92	13.29	0.73	0.40
Branched Aldehydes	2.91	2.33	4.79	4.80	2.42	7.31	1.92	4.55	2.02	1.64	2.79	2.44	1.57	1.24	1.83	1.12	0.84	0.71	0.59	2.90	0.65	1.26	2.23	0.60	14.10	0.38	6.45	1.18	3.53	13.89	2.89	1.97
Aromatic Aldehydes	[illegible]	3.53	6.11	7.42	3.14	7.68	6.49	4.32	2.06	0.60	0.45	1.16	1.33	5.60	0.58	3.57	0.76	0.42	0.52	3.70	0.31	0.52	0.73	0.83	1.57	0.57	5.81	0.28	0.66	12.10	1.00	0.59
n-Aldehydes	6.94	6.06	5.72	10.35	3.88	6.39	4.34	4.73	2.63	1.08	0.89	0.95	0.65	7.19	0.38	2.48	0.74	0.85	0.94	2.76	0.57	0.99	1.09	0.49	2.82	0.24	10.93	0.82	0.99	9.29	1.17	0.63
Aromatic Hydrocarbons	3.20	2.60	9.29	9.91	1.27	3.38	2.83	1.11	0.74	0.32	0.55	0.22	0.27	2.79	0.25	4.78	0.52	0.42	0.81	1.53	0.43	0.71	3.39	[illegible]	5.20	3.79	5.66	3.02	6.46	4.31	0.40	0.56
Aliphatic Acids	5.16	1.78	3.92	5.66	7.86	10.30	2.11	7.43	4.81	2.43	2.27	1.04	0.73	4.03	2.79	2.60	2.33	1.30	0.95	4.07	2.42	1.19	1.95	2.49	5.29	2.07	4.60	0.82	2.01	1.61	0.58	1.37
Aromatic Acids	2.99	0.49	1.46	1.41	10.21	3.75	2.05	[illegible]	13.24	1.37	0.51	0.43	0.19	1.46	0.45	1.15	0.41	0.14	0.32	9.09	1.47	0.60	2.91	2.01	5.95	1.16	6.03	0.29	0.96	3.78	3.64	1.04
Unsaturated Aldehydes	5.08	4.55	4.16	6.86	3.66	4.88	6.54	5.16	3.78	1.36	1.66	1.23	0.64	7.42	0.58	2.89	1.47	1.46	1.16	3.63	0.84	1.25	0.90	0.59	1.80	0.46	13.25	0.53	1.00	9.46	0.85	0.70
Alkanes	19.31	7.54	5.28	8.10	2.43	6.26	2.87	3.63	2.79	0.84	1.00	0.62	1.08	2.14	0.37	1.31	0.79	0.19	1.02	3.25	0.45	0.35	0.50	0.32	0.29	0.18	3.20	0.27	13.57	7.78	2.37	0.29
	101.02	59.06	74.70	106.56	69.06	93.49	49.88	82.55	55.74	16.95	18.57	15.17	13.45	60.74	13.13	46.21	22.20	13.85	15.83	59.65	18.51	20.96	29.44	43.15	72.37	23.88	110.76	25.80	59.18	171.02	22.42	13.91
	101.02	59.06	74.70	106.56	69.06	93.49	49.88	82.55	55.74	16.95	18.57	15.17	13.45	60.74	13.13	46.21	22.20	13.85	15.83	59.65	18.51	20.96	29.44	43.15	72.37	23.88	110.76	25.80	59.18	171.02	22.42	13.91

0-3
3-6
6-9
9-12
12-15
15 - 20
20 - 40

Distribution of individual compound classes across all samples expressed as a percentage of their combined total abundance for each compound class

(sum of horizontal rows = 100)

Scaled Abundance Scores For Individual Compound Classes

10-20
20-40
40-60
60-100
100 - 150
150+

Combined scaled abundance scores per sample for all compound classes

(sum of vertical columns)

Samples (n = 8) with the highestcombined scores

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Soil description

Sub-samples of the 11 selected interesting samples were taken and dried overnight at 40° C before being photographed under a Nikon SMZ1500 binocular microscope at either times 10 or times 20 magnification. Images are in Appendix 9.The sub-samples were then hand ground with an agate mortar and pestle before weighing for organic biomarker analysis by GC and GCMS.

Table 2. Description of samples examined.

Exhibit/Item Number	**Location**	**Context**	**Mineral Composition**	**Organic material and other fragments**	**Density of remains** (from osteologist's report as provided by Niamh McCULLAGH)
Sample 1	C.50 Z1 20cm to 'gravel'.	C.51	No stones. Small white grains.	No discrete vegetation. White/yellow material.	High
Sample 5	C.54 Z6 25cm to 'gravel'.	C.55	Few medium stones. White stones, quartz grains.	Highly organic. Reddish/orange organic material. Material which could be bone seen at X10 magnification.	Medium, animal bone also visible.
Sample 7	C.56 Z1	C.57	No stones. White quartz grains.	Highly organic. Orange/white material. Material which could be bone seen at X10 magnification.	High
Sample 11	C.60 Z6 12cm to 'gravel'.	C.61	Fine textured. Very small stones and quartz grains. Crystallized material.	Highly organic. Material which could be bone seen at X10 magnification.	Medium

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Sample 14	C.62 Z7 No HR visible 4cm to 'gravel'.	C.63	Fine textured. Quartz grains and spherical clear particles.	Highly organic. Yellow/white material.	No HR visible.
Sample 18	C.64 Z7 14cm to 'gravel'.	C.65	Fine textured. Quartz grains and very small stones. Brick. Black coal type material.	Highly organic.	Low
Sample 35	C.90 Z5 25cm to 'gravel' includes bone.	C.91	Fine textured. Small stones and quartz grains.	Flaky orange/brown material (bone?). Material which could be bone seen at X10 magnification.	High
Sample 45	C.98 Z7 12cm to 'gravel'.	C.99	Wet, fine textured. Quartz, opaque very small stones.	Spongy material with a parallel structure.	Low
Sample 49	C.104	C.105	Fine textured. Quartz, White very small stones.	Deposit similar to spongy material in sample 45.	Low
Sample 55	West boundary 50cm depth.	Negative control	Fine textured. Quartz grains. Coal type material. Small stones.	Dark organic. Conifer needle. Small roots and plant material.	No HR visible.
Sample 57	East boundary 50cm depth.	Negative control	Small stones and quartz grains.	Dried leaf and stem material. Long thin white worm (not identified).	No HR visible.

In this report we shall refer to samples using the terms in column 1 above (exhibit/item number).

VOC Analysis

Details of the sample preparation, materials and methods of analysis and results are in appendix 4.

Summary of VOC observations

The distribution of VOC hotspots is represented by the abundance of compound classes in each sample and are presented as a matrix of rows (VOC compound class) and columns (sample number) in Figure 1 which can be read with Appendix 10 as a spatial gradient across the facility sampled. For the majority of compound classes these are concentrated in samples 7, 8, 9, 14, 23, 27, 33, 46, 49 and in the Western boundary sample 55.

Individual sampling locations 1 – 49 were categorised by an osteologist as having high, medium, low or no visible densities of human remains, and this scoring is indicated in Table 2.

For some compound classes the hotspots are more widely spread across cells towards the eastern end of the alignment of cells (low sample numbers, high – medium bone density), and to a lesser extent towards the western end (high sample numbers, high – low bone density).

Of the two cells characterised as having no visible human remains, which were each sampled at several locations, one shows hotspots for most compound classes (samples 13, 14, 15; context 63) while the other only has low abundances of volatiles (samples 29, 30, 31; context 87). A third cell which was sampled at several locations also has low abundances of volatiles and low bone densities (samples 17, 18, 19; context 65).

With the exception of samples 29 – 31, cells in the central region of the cellular array are of high - medium bone density. For some of these samples abundances of volatiles are high (23, 27 and 33; context 12, 85 and 89), while for others abundances are low (21, 25, 35; context 10, 83/11 and 91).

A number of compound hotspots for different compound classes are concentrated in the Northern boundary sample rather than the Western boundary sample.

Similar compound classes, for example the various types of aldehyde, share a high degree of commonality in the location of their hotspots. However there are also examples of differentiation within a compound class according to structure and chain length (aromatic hydrocarbons; sulphur compounds DMS and DMDS; aliphatic acids).

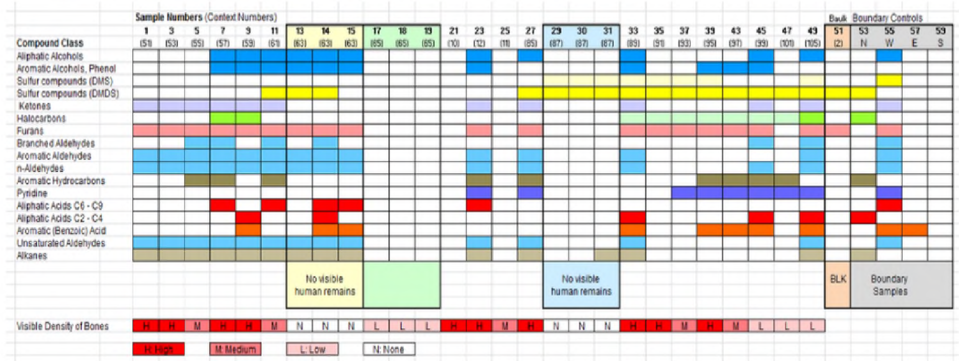
Many of the compound classes show compound distributions consistent with known patterns of volatile emission during decomposition of mammalian tissue. These include compounds known to be produced during bone decomposition (ketones, alcohols and aldehydes). The isomer ratios for 3- and 2-methyl butanal (3-/2-) are > 1, which is a specific characteristic of human decomposition. The distribution of compound classes and of individual members within compound classes are very similar to those measured for human adult and baby positive control samples, analysed under identical conditions. There is a slightly closer similarity with the volatile profiles obtained from the human baby positive control samples.

Although all compounds detected were found in samples collected from every sampling location, there is clearly a significant concentration effect within specific cells of the cellular alignment. There does not appear to be a significant background level of volatiles of interest within those cells without distinct hotspots. The extent to which there may have been mixing and redistribution of cellular contents between cells is unknown. The concentration of volatile hotspots at specific regions within the cellular array could indicate where the highest concentration of material deposition has occurred with limited intra-cell mixing. However the apparent concentration of some of the hotspots towards the eastern and western ends of the cellular array may indicate redistribution of cellular content away from the central regions. There are hotspots within the northern and western boundary samples but not in the southern and eastern boundary samples. Whether this may represent leaching of cellular contents out of the structure is unclear and will depend on the local topography, drainage patterns and distance of the boundary sampling locations from the array.

A number of the hotspots for compounds characteristic of bone decomposition, particularly ketones, but also aliphatic alcohols and *n*-aldehydes, are found at locations with high bone densities (Table 2).

It is possible that some of the volatiles detected could have originated from the decomposition of legacy human faecal matter deposited within the cells if the structure has been used historically for treatment of human waste. For example, it is highly likely that 3- and 2-methyl butanal are present in faecal residue with the characteristic isomer ratio (Shepherd and Dawson, unpublished observations). However it is unclear whether the compounds specifically associated with decomposition of bone are similarly present in faecal residue. Limited evidence we have for soils known to be contaminated with human faeces (Shepherd and Dawson, unpublished data) suggests that these markers of bone decomposition, particularly the ketones, may indeed be present but at lower relative abundances than found in this investigation. However, there is currently insufficient experimental data regarding the persistence and characterisation of human faecal decomposition volatiles to comment further.

Figure 1. Distribution of volatiles by compound class across the cellular array.



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Solid organic compound analysis

Details of the sample preparation, materials and methods of analysis and results are in appendix 5.

Summary of low-volatility lipid biomarkers observations

Biomarkers compatible with human sewage (cholesterol, faecal stanols, faecal bile acids) were detected in in all analysed samples.

10-Hydroxy stearic acid, which has been used as an indicator of cadaver decomposition was also detected, but this compound has also been found to be present at relatively high concentrations in (human) sewage sludge.

The biomarker patterns (i.e. relative concentrations of individual biomarkers) were compatible with having originated from human sewage and not from farm animal waste.

The concentrations of the solid organic biomarkers in the analysed samples were much lower than would be expected if the analysed material had entirely originated from human sewage.

The two samples collected from the site boundaries had generally lower biomarker concentrations than the samples collected from within the chambers. 10-Hydroxy stearic acid, cholesterol and the faecal stanols, coprostanol and epicoprostanol have been recognised as being products of the decomposition of mammalian remains (including human), and their concentration patterns generally differ from those of human sewage material. The presence of these compounds in the samples collected from the chambers could, at least in part, have come from decomposed human bodies.

However, because of the low levels of biomarkers found in the samples from the chambers, it was not possible to assess the relative contributions from human sewage and from human body decomposition.

Total carbon and nitrogen, and stable isotope (13C and 15N) content

Details of the sample preparation, materials and methods of analysis and results are in appendix 6.

Table 3 Isotope values of the analysed samples

Context Number	Sample Number	C (%, w/w)	δ13C (‰)	N (%, w/w)	δ15N (‰)
C.51	1	18.6	-22.45	0.79	12.3
C.55	5	21.5	-23.21	0.86	11.7
C.57	7	35.7	-25.00	2.05	16.2
C.61	11	21.4	-22.63	0.88	12.3
C.63	14	12.6	-18.01	0.58	5.31
C.65	18	17.5	-22.54	0.53	5.26
C.91	35	15.9	-18.68	0.70	11.1
C.99	45	15.3	-21.56	0.71	6.14
C.105	49	25.6	-24.65	1.24	13.5
west boundary control	55	8.30	-15.16	0.33	4.44
east boundary control	57	8.82	-15.56	0.33	4.40
	bone picked out from sample 7	**13.8**	**-22.81**	2.22	10.0
Figures in bold did not contain enough material for accurate analysis.					

Sample numbers 14, 18, 45, 55 and 57 have lower carbon and nitrogen concentrations relative to the other samples collected. 14, 35, 55 and 57 also have higher C isotope ratio values, in particular the two boundary control samples (55 and 57).

10. Interpretation

Statistical analysis of the data was carried out using Primer software with square root transformation of the data (Appendix 8). The isotope plots show a clear separation of samples 55 and 57 (west boundary and east boundary locations respectively) from the other samples. Sample 14 (Context 63) is also positioned close to these two samples (no human remains observed (Table 2)). Sample 7 (context 57) which registered as a high density of human remains was furthest removed from the control boundary samples on this plot.

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The sterol and stanol and the bile acids also show clear separation of samples 55 and 57. The bile acid data also shows sample 45 (Context 99) to be similar to the boundary samples. The VOC data shows less of a clear distinction between samples, possibly as a result of the mobility of these compounds and that there had been movement of water through the chambers over time The depth of the deposits from which samples were recovered were such that it is highly likely that ground water has influenced the dispersal of remains within the context (sampling submission form, page 2, Niamh McCULLAGH).

11. Conclusions

It can be confirmed from this series of analyses that there is evidence that the site *had* previously been used as a sewage facility in the past.

The results of these tests however cannot establish categorically whether the sewage facility was being used at the time when the human remains were deposited.

The results of these tests cannot establish categorically whether the non-decomposed human remains had been deposited in the chambers, or whether the bodies have previously been stored (and decomposed) elsewhere, with mainly the bones being placed in the chambers.

It does appear that the volatile organic profiles are characteristic of decomposition of mammalian tissue *or* waste, probably human. It is not possible to determine the extent to which the deposited human infant remains which are known to be present may have contributed to this, or to what extent human faecal material may also have done so. The presence of hotspots within the northern and western boundary samples but not the southern and eastern boundary samples is of note. A number of the hotspots for compounds characteristic of bone decomposition, particularly ketones, but also aliphatic alcohols and *n*-aldehydes, are found at locations with high bone densities.

The concentrations of the solid organic biomarkers in the analysed samples were very low, much lower than would be expected if the analysed material had entirely originated from human sewage waste. The samples collected from the site boundaries (samples 55, west boundary and 57, east boundary) had generally lower biomarker concentrations than the samples collected from within the chambers where remains were located. 10-Hydroxy stearic acid, cholesterol and the faecal stanols, coprostanol and epicoprostanol have been recognised as being products of the decomposition of mammalian remains (including human), and their concentration patterns generally differ from those of human sewage material. The presence of these compounds in the samples collected from the chambers could, at least in part, have come from decomposed human bodies.

The reasons for the low biomarker concentrations found in the samples are not easy to assess. If the chambers represented a closed cesspit or a number of cesspits, it is possible that the collected sewage had been removed before depositing the human cadaver material; soil may have been added at the same time, or soil may have seeped in from the roofs of the chambers. If there were one or more pipe outflows (i.e. the facility was a septic tank, or was connected to a sewer outflow), it would be expected that little sewage would be left behind).

Samples 55 and 57 (west boundary and east boundary locations respectively) and sample 14 (no visible human remains) have different isotopic profiles to the other samples examined, likely reflecting no influence from human remains or sewage.

It is likely that some analytical signature due to faecal material is present, but it is also likely that the human remains have also contributed to the analytical signatures observed, and the presence of compounds associated with decomposition of bone at locations of high bone density in the samples is suggestive of this.

Appendices

Appendix 1

Table 1 Samples received at James Hutton Institute on 15th February 2017

Case Code	MBHCOI_TM0117_		NMcC	Niamh McCullagh
GPS Location	544,086,751,178		AH	Aidan Harte
	Mother and Baby Home		LL	Linda Lynch
Client	Commission of Investigation			

Z4	Z8
Z3	Z7
Z2	Z6
Z1	Z5

N ↑

Sample number	Date	Time	Location	Context number	Collected by	Witnessed by	
001	8_2_2017		13:49 C.50 Z1: 20cm to 'gravel'	C.51	NMcC	AH, LL	
002	8_2_2017		13:49 C.50 Z1: Control of 001	C.51	NMcC	AH, LL	RETAINED
003	8_2_2017		14:04 C.52 Z6: 15cm to 'gravel'	C.53	NMcC	AH, LL	
004	8_2_2017		14:04 C.52 Z6: Control of 003	C.53	NMcC	AH, LL	RETAINED
005	8_2_2017		14:19 C.54 Z6: 25cm to 'gravel'	C.55	NMcC	AH, LL	
006	8_2_2017		14:19 C.54 Z6: Control of 005	C.55	NMcC	AH, LL	RETAINED
007	8_2_2017		14:38 C.56 Z1:	C.57	NMcC	AH, LL	
008	8_2_2017		14:38 C.56 Z1: Control of 007	C.57	NMcC	AH, LL	RETAINED
009	8_2_2017		14:50 C.58 Z7: 30cm to 'gravel'	C.59	NMcC	AH, LL	
010	8_2_2017		14:50 C.58 Z7: Control of 009	C.59	NMcC	AH, LL	RETAINED
011	8_2_2017		16:37 C.60 Z6: 12cm to 'gravel'	C.61	NMcC	AH, LL	
012	8_2_2017		16:37 C.60 Z6: Control of 011	C.61	NMcC	AH, LL	RETAINED
013	8_2_2017		16:48 C.62 Z4: No HR visible 4cm to 'gravel'	C.63	NMcC	AH, LL	
014	8_2_2017		16:45 C.62 Z7: No HR visible 4cm to 'gravel'	C.63	NMcC	AH, LL	
015	8_2_2017		16:49 C.62 Z1: No HR visible 2cm to 'gravel'	C.63	NMcC	AH, LL	
016	8_2_2017		16:53 C.62 Z8: Control of 013-015	C.63	NMcC	AH, LL	RETAINED
017	8_2_2017		16:59 C.64 Z4: No HR visible 15cm to 'gravel'	C.65	NMcC	AH, LL	
018	8_2_2017		17:00 C.64 Z7: No HR visible 14cm to 'gravel'	C.65	NMcC	AH, LL	
019	8_2_2017		17:02 C.64 Z2: No HR visible 12cm to 'gravel'	C.65	NMcC	AH, LL	
020	8_2_2017		17:04 C.64 Z5: Control of 017-019	C.65	NMcC	AH, LL	RETAINED
021	8_2_2017		17:04 C.102 Z8: 20cm to 'gravel'	C.10	NMcC	AH, LL	
022	8_2_2017		17:04 C.102 Z8: Control of 021	C.10	NMcC	AH, LL	RETAINED
023	8_2_2017		17:25 C.102 Z7: 25cm to 'gravel'	C.12	NMcC	AH, LL	
024	8_2_2017		17:25 C.102 Z7: Control of 023	C.12	NMcC	AH, LL	RETAINED
025	8_2_2017		17:33 C.11/82 Z8: 30cm to 'gravel'	C.83/11	NMcC	AH, LL	
026	8_2_2017		17:33 C.11/82 Z8: Control of 025	C.83/11	NMcC	AH, LL	RETAINED
027	8_2_2017		17:40 C.84 Z2: 21cm to 'gravel'	C.85	NMcC	AH, LL	
028	8_2_2017		17:40 C.84 Z2: Control of 027	C.85	NMcC	AH, LL	RETAINED
029	8_2_2017		16:49 C.86 Z4: 14cm to 'gravel'	C.87	NMcC	AH, LL	
030	8_2_2017		17:50 C.86 Z7: 21cm to 'gravel'	C.87	NMcC	AH, LL	
031	8_2_2017		17:52 C.86 Z2: 25cm to 'gravel'	C.87	NMcC	AH, LL	
032	8_2_2017		17:55 C.86 Z5: Control of 029-031	C.87	NMcC	AH, LL	RETAINED
033	8_2_2017		18:01 C.88 Z6: 6cm to resistance	C.89	NMcC	AH, LL	
034	8_2_2017		18:01 C.88 Z6: Control of 033	C.89	NMcC	AH, LL	RETAINED
035	8_2_2017		18:08 C.90 Z5: 25cm to 'gravel' includes bone	C.91	NMcC	AH, LL	
036	8_2_2017		18:08 C.90 Z7: Control of 035	C.91	NMcC	AH, LL	RETAINED
037	8_2_2017		18:11 C.92 Z7: 25cm to 'gravel'	C.93	NMcC	AH, LL	
038	8_2_2017		18:11 C.92 Z7: Control of 037	C.93	NMcC	AH, LL	RETAINED
039	9_2_2017		10:46 C.94 Z3 35cm to 'gravel'	C.95	NMcC	AH, LL	
040	9_2_2017		10:48 C.94 Z3 Control to 039	C.95	NMcC	AH, LL	RETAINED
041	9_2_2017		10:48 C.92 Atmospheric inside chamber		NMcC	AH, LL	
042	9_2_2017		10:48 C.92 Atmospheric inside chamber Control		NMcC	AH, LL	RETAINED
043	9_2_2017		10:54 C.96 Z6 23cm to 'gravel'	C.97	NMcC	AH, LL	
044	9_2_2017		10:54 C.96 Z6 Control to 043	C.97	NMcC	AH, LL	RETAINED
045	9_2_2017		11:00 C.98 Z7: 12cm to 'gravel'	C.99	NMcC	AH, LL	
046	9_2_2017		11:00 C.98 Z7: Control to 045	C.99	NMcC	AH, LL	RETAINED
047	9_2_2017		11:06 C.100 Z8 15cm to 'gravel'	C.101	NMcC	AH, LL	
048	9_2_2017		11:06 C.100 Z8: Control to 047	C.101	NMcC	AH, LL	RETAINED
049	9_2_2017		11:15 C.104	C.105	NMcC	AH, LL	
050	9_2_2017		11:15 C.104 Control	C.105	NMcC	AH, LL	RETAINED
051	9_2_2017		11:21 Baulk in T6	C.2	NMcC	AH, LL	
052	9_2_2017		11:21 Baulk in T6 Control	C.2	NMcC	AH, LL	RETAINED
053	9_2_2017		11:27 North boundary 60cm depth		NMcC	AH, LL	
054	9_2_2017		11:27 North boundary 60cm depth Control		NMcC	AH, LL	RETAINED
055	9_2_2017		11:30 West boundary 50cm depth		NMcC	AH, LL	
056	9_2_2017		11:30 West boundary 50cm depth Control		NMcC	AH, LL	RETAINED
057	9_2_2017		11:33 East boundary 50cm depth		NMcC	AH, LL	
058	9_2_2017		11:33 East boundary 50cm depth Control		NMcC	AH, LL	RETAINED
059	9_2_2017		11:35 South boundary 50cm depth		NMcC	AH, LL	
060	9_2_2017		11:35 South boundary 50cm depth Control		NMcC	AH, LL	RETAINED
061	9_2_2017		12:30 Atmospheric outside tank		NMcC	AH, LL	
062	9_2_2017		12:30 Atmospheric outside tank Control		NMcC	AH, LL	RETAINED
063	9_2_2017	NA	Blank unopened type I		NMcC	AH, LL	
064	9_2_2017	NA	Blank unopened type I Control		NMcC	AH, LL	RETAINED

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065	9_2_2017	NA	Blank unopened type II	NMcC	AH, LL	
066	9_2_2017	NA	Blank unopened type II Control	NMcC	AH, LL	RETAINED

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Appendix 2

Audit Trail

MBHCOI_TM0117_					
NOTE: All sample examination, description and preparation for analysis carried out in secure lab 234.					
Date	Analyst	Sample ID	Method	Type	Hutton ID
15/02/2017			Samples received from DHL Couriers. One large box containing 2 sealed evidence bags		
15/02/2017	L. Dawson, J. Ross		The bags were opened, samples checked, then bags resealed.		
16/02/2017	L. Dawson		Samples taken to Tom Shepherd at Dundee site who signed a record of receipt.		
06/04/2017	H. Watson, C. Taylor		Samples brought back to Aberdeen in sealed container.		
17/04/2017	L. Dawson, J. Ross	1, 5, 7, 11, 14, 18, 35, 45, 49, 55, 57	These samples were chosen for biomarker analysis		
17/04/2017	L. Dawson, J. Ross	1	The sample pot was opened, a sub-sample taken to a petri dish, described and placed in an oven @ 40 degrees C overnight.	Soil	
17/04/2017	L. Dawson, J. Ross	5	The sample pot was opened, a sub-sample taken to a petri dish, described and placed in an oven @ 40 degrees C overnight.	Soil	
17/04/2017	L. Dawson, J. Ross	7	The sample pot was opened, a sub-sample taken to a petri dish, described and placed in an oven @ 40 degrees C overnight.	Soil	

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17/04/2017	L. Dawson, J. Ross	11	The sample pot was opened, a sub-sample taken to a petri dish, described, crystallized material was taken to a vial labelled LD1, then the vial and sub-sample placed in an oven @ 40 degrees C overnight.	Soil LD1 crystallized material	
17/04/2017	L. Dawson, J. Ross	14	The sample pot was opened, a sub-sample taken to a petri dish, described and placed in an oven @ 40 degrees C overnight.	Soil	
17/04/2017	L. Dawson, J. Ross	18	The sample pot was opened, a sub-sample taken to a petri dish, described and placed in an oven @ 40 degrees C overnight.	Soil	
17/04/2017	L. Dawson, J. Ross	35	The sample pot was opened, a sub-sample taken to a petri dish, described,a flake of material (query bone) was taken to a vial labelled LD2, then the vial and sub-sample placed in an oven @ 40 degrees C overnight.	Soil LD2 possible bone	
17/04/2017	L. Dawson, J. Ross	45	The sample pot was opened, a sub-sample taken to a petri dish, described and placed in an oven @ 40 degrees C overnight.	Soil	
17/04/2017	L. Dawson, J. Ross	49	The sample pot was opened, a sub-sample taken to a petri dish, described and placed in an oven @ 40 degrees C overnight.	Soil	
17/04/2017	L. Dawson, J. Ross	55	The sample pot was opened, a sub-sample taken to a petri dish, described and placed in an oven @ 40 degrees C overnight.	Soil	
17/04/2017	L. Dawson, J. Ross	57	The sample pot was opened, a sub-sample taken to a petri dish, described and placed in an oven @ 40 degrees C overnight.	Soil	
18/04/2017	L. Dawson, J. Ross	1	Sample given a Hutton ID code, photographed, hand ground and weighed for biomarker analysis.		1259284

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18/04/2017	L. Dawson, J. Ross	5	Sample given a Hutton ID code, photographed and pieces of material which could be bone picked out to a petri dish. The sample was then hand ground and weighed for biomarker analysis.		1259285
18/04/2017	L. Dawson, J. Ross	7	Sample photographed and pieces of material which could be bone picked out to a petri dish. The sample was then hand ground and weighed for biomarker analysis.		1259286
18/04/2017	L. Dawson, J. Ross	11	Sample given a Hutton ID code, photographed, hand ground and weighed for biomarker analysis.		1259287
18/04/2017	L. Dawson, J. Ross	14	Sample given a Hutton ID code, photographed, hand ground and weighed for biomarker analysis.		1259288
18/04/2017	L. Dawson, J. Ross	18	Sample given a Hutton ID code, photographed, hand ground and weighed for biomarker analysis.		1259289
18/04/2017	L. Dawson, J. Ross	35	Sample given a Hutton ID code, photographed and pieces of material which could be bone picked out to a petri dish. The sample was then hand ground and weighed for biomarker analysis.		1259290
18/04/2017	L. Dawson, J. Ross	45	Sample given a Hutton ID code, photographed, hand ground and weighed for biomarker analysis.		1259291
18/04/2017	L. Dawson, J. Ross	49	Sample given a Hutton ID code, photographed, hand ground and weighed for biomarker analysis.		1259292
18/04/2017	L. Dawson, J. Ross	55	Sample given a Hutton ID code, photographed, hand ground and weighed for biomarker analysis.		1259293

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18/04/2017	L. Dawson, J. Ross	57	Sample given a Hutton ID code, photographed, hand ground and weighed for biomarker analysis.		1259294
19/04/2017	L. Dawson, J. Ross	7	A small piece of the material which could be bone was hand ground and given a Hutton ID code.		1259295
19/04/2017	J. Ross, G Martin		Samples 1259284-1259295 were given to Gillian Martin for 13C and 15N analysis.		
21/04/2017	J. Ross, G Martin		Samples 1259284-1259295 were returned to lab 234 by Gillian Martin.		

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Appendix 3

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Appendix 4

VOC analysis

Solid Phase Microextraction (SPME)

In the SPME technique, a short (1 cm) fibre coated with a thin film of polymeric adsorbant is exposed in the headspace above the sample, which is sealed in a glass vial and heated within a temperature controlled incubator. During the exposure period volatiles released from the sample are entrained and concentrated *in-situ* within the fibre film. After a defined period, the fibre is withdrawn into a protective sheath and removed from the sample vial. The fibre is subsequently re-exposed within the injector of a GC-MS instrument, and the entrained volatiles are desorbed directly into the gas chromatography column, where they are separated into individual constituents and passed to the mass spectrometer for characterisation and identification. The methodology used was based on SPME techniques developed in our laboratories for analysis of cooked potato flavour volatiles (Decreux et al., 2008), for analysis of plant leaf derived volatiles (McMenemy et al., 2012) and for analysis of plant root-derived volatiles collected in situ (Deasy et al., 2016a, b).

GC -MS

During the gas chromatographic phase of the analysis, analytes are separated by passage through the GC column, a long length of narrow bore silica glass tubing, the inside of which is coated in very thin layer of a polymeric material, the stationary phase. The complex mixture of analytes is carried onto one end of the GC column by a flow of inert helium gas which flows continuously through the column. Individual analytes interact differentially with the stationary phase, migrating along the column at different rates. In addition, the GC column, which is located within a temperature controlled oven, is heated at a predetermined rate to accelerate analyte migration. Analytes then pass from the GC into the mass spectrometer via a heated transfer line, where they undergo mass spectrometric analysis.

During mass spectral analysis, analytes under high vacuum are ionized by high energy electrons with a set energy of 70eV. An electron is knocked out from the electronic structure of the analyte, to form ions carrying a single positive charge (electron ionization EI). Each ion formed has a specific mass to charge ratio (*m/z*) which is effectively the mass of the ion since the charge is unity. The initial product of ionization is an ionized intact molecule, the molecular ion (M). However the EI process transfers a lot of excess energy to the molecular ion, which is lost or redistributed by the break-up (fragmentation) of the ion. Depending on the structure of the ion (and hence of the intact analyte), a whole range of fragments with different atomic compositions and different masses (*m/z*) are generated, and in turn some of the fragment ions will themselves fragment further. At the end of the process, each analyte generates a range of fragment ions, often including some intact molecular ions, each of which has a relative abundance unique to the analyte. This is the mass spectrum which is usually depicted graphically as a series of vertical lines showing ions of increasing mass (x-axis) against their abundance (z-axis). Use of EI at 70 eV is an accepted international standard, and all GC-MS systems are generally operated in this way. Consequently, MS analyses of the same analytes will generate broadly similar mass spectra Irrespective of instrument manufacturer, location or operator. This has led to compilation of large databases of EI (70 eV) mass spectra which can be searched using computerized data systems to aid in the identification of analytes.

The mass spectrometer analyses the content of the GC effluent as it passes into the instrument by sampling the ions present over a pre-set mass range (one scan, 30-400 amu) repeatedly and rapidly (6 scans/sec) for the duration of the analysis. One scan constitutes a single mass spectrum, and 6 mass spectra are generated each second. Each mass spectrum incorporates abundance data for each ion detected. If the ion abundances for all ions in a scan are summed and then are displayed for separate scans along a time (x) axis against abundance (y axis), a chromatographic trace is generated, the Total Ion Chromatogram (TIC).

Individual compounds have a compound-specific mass spectrum which is often unique to the compound or has unique compound class-related characteristics. In addition individual compounds generally have a unique retention time on chromatographic separation by GC. Both of these attributes are used to characterize each compound. However, for a complex mixture of compounds, it is usually the case that not all of the individual components present will be chromatographically resolved in the TIC traces, ie there will be overlap to various degrees with different compounds co-eluting. The mass spectra of individual co-eluting compounds usually contain some ions or ion groups, with different masses which are unique to each compound in the mixture and are not common to the other compounds present. This property is used In order to de-convolute overlapping and co-eluting peaks. Using the software packages such as Xcalibur™, selected ion chromatograms (SIC) for these ions unique to each component can be extracted from the raw data. SIC traces show how the abundance of the chosen ion(s) change with time, and overlapping and co-eluting peaks can usually be resolved into their individual constituents. A measure of the abundance of the compounds present is made by integrating the SIC traces.

Materials and Methods

Sample preparation

Sample numbers were inscribed onto the side of clean, empty 20 mL screw top headspace vials (Supelco, UK) using an indelible marker pen, and the vials were flushed out with dry filtered nitrogen at > 500 mL/minute for 30 seconds and then capped. The vials were weighed and placed in the fume cupboard prior to transfer of soil samples.

Soil samples were allowed to warm to room temperature, then the large sample vial and weighed headspace vial were both opened, and a subsample of soil was transferred to the weighed vial using a clean spatula until it was approximately 1/4 to 1/3 full. Care was taken to ensure there was no sample adhering to the neck of the vial which would interfere with insertion of the SPME fibre assembly through the vial cap septum. Both vials were capped and sealed. The weighed vial containing the transferred sample was reweighed and then transferred to a cold room at -20°C for storage overnight.

Individual samples were loaded onto a CombiPal autosampler (CTC Analytics, Switzerland) for automated sampling using solid phase micro extraction (SPME) for trapping of volatiles and analysis by gas chromatography-mass spectrometry (GC-MS). A sample blank containing a mixture of laboratory and fume cupboard air was prepared by leaving an empty uncapped vial exposed within the fume cupboard for 5 minutes before the vial was capped. A sampling schedule for preparation and analysis of all samples is shown in Appendix 1, Table 1.

Analysis of soil volatiles by SPME-GC-MS

Samples were analysed using a Trace DSQII GC-MS (Thermo Scientific, Hemel Hempstead, U.K.) fitted with a CombiPal autosampler configured for use with SPME fibers. Volatiles were trapped using a polydimethylsiloxane/divinylbenzene (PDMS/DVB) SPME fibre (23 gauge, 65mm film, Supelco, UK) at 75°C for 30 minutes. During entrainment the vial was maintained at the appropriate temperature in a heated incubator which formed part of the autosampler assembly. Volatiles were desorbed from the SPME fibre isothermally at 250°C for 2 minutes within a programmable temperature vapourising (PTV) injector operating in splitless mode and fitted with a Merlin Microseal™ high pressure septum (Agilent Technologies, UK). Compounds were separated on a DB 1701 GC column (30m x 0.25 mm i.d x 0.25 □m, Agilent Technologies, UK) using helium at 1.5 mL/min in constant flow mode. The GC oven temperature was held for 2.0 min at 40°C followed by a 10°C/min temperature increase up to 240°C with a further 10 minute isothermal hold at that temperature. The GC-MS interface temperature was 250°C and the MS was used in electron ionisation (EI) mode at 70 eV over a mass range of 25-400 amu with a source temperature of 200°C. Data was acquired at 6 scans/sec and analysed using the Xcalibur™ software package V. 2.07 (ThermoFisher, UK). Immediately following the desorbtion of volatiles from the fibre into the PTV injector, the fibre was automatically reconditioned at 250°C for 30 minutes, under a flow of dry nitrogen, using a reconditioning station attachment for the GC-MS autosampler. At the end of this time, and following a short period for re-equlibration of the GC, the instrumentation was ready for loading and analysis of the next soil sample.

The sample methodology normally ensures that the same individual SPME fibre was used for entrainment and analysis of each sample. However, during the course of the analysis two separate fibres from the same manufacturing batch were used. Fibre 2 was used for trapping volatiles from a laboratory control air blank and samples 001 - 013 and 049 – 059. Fibre 3 was used for samples 013 – 047.

VOC results

Although an attempt was made to ensure that the samples from which volatiles were trapped were visually of a similar size by volume, sample weights ranged from 0.971 - 4.205 g probably due to variation in moisture content, particle size and density. Initially, abundance data was generated as total abundance of each compound per sample, from which the abundance per gram of sample was calculated. The proportional abundance for each analyte in each sample taken from individual cells (samples 001 – 049) was calculated as a percentage of the combined total abundance of the analyte for all these cells. Proportional abundances for compounds in the Baulk sample (051) and in the north, west, east and south boundary samples (053, 055, 057, 059) were also calculated relative to their combined total abundance for samples 001 – 049. The data in Appendix 2, Table 3, ordered according to analyte class, is presented both as abundance per gram of sample and as the proportional abundances of individual compounds in each sample (sum for samples 001 – 049 = 100). In addition, for each analyte class, these two abundance values for constituent compounds are also plotted graphically in sample order in order to provide a means of visualizing their spatial distribution.

Among the structural analyte classes present, most are aliphatic compounds consisting of chains of methylene units (CH_2) with various attached functional groups and substituents which define the compound class. Some compound classes consist of ring structures, incorporating benzene (aromatic compounds) or furan, to which functional groups and other substituents may be attached. Eleven groupings are defined:
(1) Aliphatic alcohols, aromatic alcohols and phenol; (2) Sulfur compounds; (3) Ketones; (4) Halocarbons (halogenated compounds); (5) Furans; (6) Branched chain (*br*-) aldehydes and aromatic aldehydes; (7) Saturated straight chain (*n*-) aldehydes; (8) Aromatic hydrocarbons (benzene derivatives and pyridine); (9) Carboxylic acids; (10) Unsaturated *n*-aldehydes; (11) Alkanes (aliphatic *n*- saturated hydrocarbons)

All listed compounds were found to be present in virtually all samples at varying abundances, and at abundances considerably greater than measured in laboratory air controls (data not shown in tables). A single sample was taken from most cells; however there were three instances where three samples were taken from the same cell. These are highlighted by yellow, green and blue colour bands in Appendix 2, Table 3, . Of these there was no visible evidence of human remains in two of the groupings (samples 013, 014, 015, yellow background; samples 029, 030, 031, blue background). The baulk sample (051) is highlighted pink and the four boundary samples (053, 055, 057 and 059) in grey. The same colour scheme is used to delineate the location of the same sample groups in the accompanying graphical plots. In the following interpretation of the results both measurements of abundance were used in combination to assess if compounds were present at a particular location at significantly elevated levels.

Interpretation of the data was based on comparison of the distribution of the volatile compounds found in the samples with published data describing the range of volatile compounds produced during decomposition of mammalian tissues, including that of humans (Vaas et al., 2004, 2008; Vaas, 2012). The use of VOC analysis in this way to characterize the odour of decomposition is relatively recent and is considered an experimental technique still under development. The data compiled by Vass was largely based on use of polymer entrainment techniques for recovery of volatiles from burials within body farms within the USA. Use of SPME for trapping of volatiles is a recent modification of the polymer entrainment methods, and lacks the equivalent range of positive control data. However we have recently analysed the volatile profiles from two positive control samples (soil from the grave of an adult female buried for 15 years and residue (possibly adipocere) from the burial of a full term baby for 6 months) under identical conditions as used in this investigation (Shepherd and Dawson, unpublished data). This data is also used for comparison with that generated in this investigation.

Aliphatic alcohols, aromatic alcohols and phenol

The aliphatic alcohols ethanol (C_2), 1-pentanol (C_5), 1-hexanol (C_6), 1-heptanol (C_7) and the aromatic compound phenol are known non-specific markers of bone decomposition in mammals. Although not usually a major product of decomposition in humans, they may be significant in decomposition of other animals such as dogs or pigs (Vaas et al., 2004, 2008; Vaas, 2012). Ethanol, 1-pentanol, 1-heptanol, 1-octanol (C_8), 1-octen-3-ol (C_8) were present in the positive human control SPME samples in the abundance order octanol > heptanol > pentanol > ethanol along with the aromatic alcohol phenylmethanol and phenol (Shepherd and Dawson, unpublished data). Ethanol, hexanol, heptanol, octanol, 1-octen-3-ol phenylmethanol and phenol were found in the samples.

In terms of abundance per g of sample and proportional abundance, hotspots are found for phenol and phenylmethanol in samples 7 – 15, 23, 33, and 39-45. Collectively for ethanol, 1-hexanol and 1-heptanol, hotspots are found for samples 7, 9, 11, 23, 27, 33, 45 and 49. Hotspots for 1-octanol and 1-octen-3-ol were found for samples 7-15, 23, 45 and 49.
High abundances of these compounds, particularly phenyl methanol and the C_8 alcohols were also found for the West boundary control sample (55).
Abundances of these compounds were low in one of the cells with no visible human remains (samples 29 – 31), but showed a peak for some components in the other (samples 13 – 15).

Sulfur compounds

Sulfur compounds, including carbon disulfide, carbon oxide sulfide (COS), dimethyl sulfide (DMS), dimethyl disulfide (DMDS), dimethyl trisulfide, and dimethyl tetrasulfide (DMTS) are non-specific markers of mammalian decomposition (Vaas et al., 2004, 2008; Vaas, 2012). DMS, DMDS and

DMTS may be associated with late, mid and early stages of decomposition respectively. In the SPME positive controls, DMS was only detected in the adult control samples, whereas DMDS and DMTS were only detected in the baby control (DMTS > DMDS), consistent with decomposition stage differences as described by Vaas (Shepherd and Dawson, unpublished data).
Only dimethylsulfide and dimethyldisulfide were detected in the samples.

Proportional abundance and abundance per g for DMS is fairly uniform across the samples with perhaps an indication of an increase for cells located towards the west (higher sample number). The abundance for this compound is significantly greater for the West boundary control sample (55). The abundance profiles for DMDS show maxima for samples 11-14, the west tending samples 27-49, the Baulk sample (51) and to a lesser extent North boundary control (53). The abundances of DMDS in the other boundary samples, including the West boundary sample (55) are relatively low in comparison.

Ketones

Several ketones have been associated with human and other mammalian decomposition, particularly of bone, and these include acetone (2-propanone), 2-butanone (methyl ethyl ketone, MEK), 2-nonanone and 2-decanone (Vaas et al., 2004, 2008; Vaas, 2012). In all these compounds the carbonyl functional group is located at C-2 of the carbon chain. There were high abundances of ketones in the range C_3-C_{15} in the SPME positive control baby residue and adult soil samples, with the chain length distribution peaking at 2-Decanone (C_{10}) (Shepherd and Dawson, unpublished data).
Thirteen ketones of this type were detected in the samples of increasing size from C_3 up to C_{13}. These include 2-propanone (acetone, C_3), 2-pentanone (C_5), 2-hexanone (C_6), 2-heptanone (C_7), 2-octanone (C_8), 2-nonanone (C_9), 2-decanone (C_{10}), 2-undecanone (C_{11}), 2-dodecanone (C_{12}) and 2-tridecanone (C_{13}). In addition the branched saturated and unsaturated C_8 homologues of this series, 6-methyl-2-heptanone and 6-methyl-5-hepten-2-one, were also found along with the C_8 compound 3-octanone, which has the keto group at C-3. A C_4 diketo compound, 2,3-butanedione and an aromatic ketone acetophenone were also present.
Abundance hotspots for the C-2 ketones were found for samples 1-11, 23, 27, 33, 45 and 49, particularly for the 2-decanone (C_{10}), 2-undecanone (C_{11}), and to a lesser extent for 2-pentanone (C_5), 2-octanone (C_8) and 2-nonanone (C_9). Higher levels of the C-3 ketone 3-octanone (C_8) were associated with samples 23 and 45.
The western control also showed appreciable abundances of some of these compounds, particularly 2-hexanone (C_6) and the branched C_8 compounds 6-methyl-2-heptanone and 6-methyl-5-hepten-2-one.
Ketones were generally of lower abundance in one of the samples from cells with no visible human remains (29-31), but were of higher abundance for some components in the other (samples 13 – 15).

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Halocarbons

A number of halogenated compounds such as chloroform, carbon tetrachloride, di- or trichloroethylene and various chloro-fluorocarbons are associated with mammalian decomposition (Vaas et al., 2004, 2008; Vaas, 2012). Of these, carbon tetrachloride has been identified as a specific marker of human decomposition, produced during the early phase of decomposition. Chlorofluorocarbons are not expected to be found for children under 4 years old, and would also not be expected for any burials in the period prior to the fluoridation of water. Chloroform and dichloromethane (DCM) were found in the positive SPME controls (chloroform > DCM), however carbon tetrachloride was not detected (Shepherd and Dawson, unpublished data).
Detailed examination of the data failed to show any evidence for the presence of carbon tetrachloride or chlorofluorocarbons, and dichloromethane and chloroform were the only halocarbons detected in the samples.

Abundance profiles for dichloromethane and chloroform were broadly similar across the samples, with abundance maxima for samples 7, 9 and an increase towards the western cells (higher sample numbers) and baulk sample (51) culminating with maximum abundance for the Northern boundary sample (53).

Furans

Furans, including 2-methyl furan and furans with other substituents, are found in adult human and animal decomposition, but may not be expected (2-methyl furan) for children under 4 years old (Vaas et al., 2004, 2008; Vaas, 2012). Most of these components, in particular furfural and 2-pentyl furan, were present in the SPME positive control samples (Shepherd and Dawson, unpublished data).
A series of four alkyl substituted furans was found in the samples. Most of the compounds present were substituted at C-2 in the furan ring (2-methyl-, 2-ethyl- and 2-pentylfuran) and one at C-3 (3-methylfuran). Reduced (hydrogenated) furan derivatives, 2,3-dihydrofuran and tetrahydrofuran (THF) were also detected along with the aldehyde furfural (furan-2-carboxaldehyde).
The most abundant furan derivatives were 2-pentyl furan with hotspots at samples 1-7, 11, 23, 27, 49 and the western boundary sample (55) and THF with hotspots at samples 1-15, 33-45, 49, baulk sample 51 and the Northern (53) and Western boundary samples (55). The distribution of the other furans follows a broadly similar pattern to a combination of those for 2-pentylfuran and tetrahydrofuran.

Branched chain (br-) aldehydes and aromatic aldehydes

Branched (*br*-) short chain aldehydes 2-methyl propanal, 3-methyl butanal and 2-methyl butanal are considered to be key indicators of mammalian decomposition. The ratio of 3-methyl butanal to 2-methyl butanal (3-/2-) is considered a key factor distinguishing human remains from those of other animals. A greater abundance of the 3- isomer relative to the 2- isomer (ratio of 3-/2- > 1) being indicative of human decomposition, whereas for other mammals, the 2- isomer is more abundant (ratio of 3-/2- < 1) (Vaas, 2012). These aldehydes were present in the SPME positive control samples, and the methylbutanal isomer ratios (3-/2-) were 2.6-3.3 for the adult control and 7.0 for the baby control (Shepherd and Dawson, unpublished data).

The three short chain branched aldehydes, 2-methylpropanal, 3-methylbutanal and 2-methyl butanal were detected in all samples with 3-/2- isomer ratios in the range of 1.27 – 3.07 for all but one sample (5) which had an isomer ratio 1.01. These isomer ratios are consistent with a human decomposition process.

The *br*-aldehydes were most abundant for samples 5, 7, 11, 14, 45 and 49, and for the Western boundary sample (55).

The presence of the benzenoid aldehyde benzaldehyde and the related compound phenylacetaldehyde may be associated with decomposition (Vaas et al., 2004, 2008; Vaas, 2012). Both were present in the SPME positive control samples (benzaldehyde > phenylacetaldehyde)

Benzaldehyde and phenylacetaldehyde were found in the samples, with broadly similar abundance profiles. Abundance maxima were seen for samples 1-9, 11-15, 23, 27, 33, 49, and for the Western boundary sample (55).

n-Aldehydes

Straight chain aldehydes in the range C_5 to C_{11} are among the interesting marker compounds associated with mammalian and in particular bone decomposition. Increased abundance of the longer homologues is associated with the later stages of decomposition. Of these nonanal (C_9) and decanal (C_{10}) are considered of significance for burial decomposition (Vaas et al., 2004, 2008; Vaas, 2012). Aldehydes in the range C_5 to C_{11} and C_{15} were found in the SPME positive control adult and baby samples with similar chain length distributions ($C_9 > C_8 = C_{10} = C_7$) (Shepherd and Dawson, unpublished data).

Ten aldehydes of this type were detected in the samples including butanal (C_4), pentanal (C_5), hexanal (C_6), heptanal (C_7), octanal (C_8), nonanal (C_9), decanal (C_{10}), undecanal (C_{11}), dodecanal (C_{12}) and pentadecanal (C_{15}).

Of these the C_8-C_{11} aldehydes, octanal, nonanal, decanal, and unecanal were the most abundant homologues with abundance maxima for samples 1-15, 23, 27, 33, 45 and 49, and for the Western boundary sample (55).

Aromatic hydrocarbons

Several aromatic hydrocarbons including benzene, toluene (methyl benzene), isomers of dimethyl benzene (xylenes), ethyl methyl benzene and styrene (ethenyl benzene) are associated with mammalian decomposition but are considered to be non-specific. Most of the aromatic compounds are produced during all phases of decomposition, although the more substituted forms and styrene may be more prevalent in the earlier stages (Vaas et al., 2004, 2008; Vaas, 2012). These compounds were also found extensively in the SPME positive control adult and baby samples (Shepherd and Dawson, unpublished data). The aromatic nitrogen heterocycle, pyridine, was found in the SPME positive baby control, but not in the adult control (Shepherd and Dawson, unpublished data).

Eleven members of this class of compound, including benzene, toluene, ethyl benzene, ethylmethyl benzene, styrene, dimethyl styrene (or ethyl styrene), and multiple isomers of dimethyl benzene and methylisopropy benzene (or diethyl benzene) were detected in the samples. In addition the aromatic nitrogen-containing heterocyclic compound pyridine was detected.

Abundance maxima for aromatic compounds were seen for samples 5, 7, 11, 13, 13, 27, 39 - 45 and 49, and for the Northern boundary sample (53). Interestingly, there is a shift in the dominant aromatics present in the samples when moving from eastern to western cells (low to high sample numbers). The methylisopropylbenzenes and one of the dimethylbenzenes (or ethylbenzene) dominate the distribution for samples 5 and 7, whereas the methylethyl/ethymethyl benzenes dominate for samples 11, 13, 23 and 27. Styrene and ethylbenzene (or dimethylbenzene) dominate at sample 43 and toluene and ethylbenzene (or dimethylbenzene) dominate at sample 49. The dimethylbenzenes/ethylbenzene and toluene dominate in the Northern boundary sample (53). Pyridine shows abundance maxima at samples 23, 27, 37-49 and the Western boundary sample (55).

Carboxylic acids

The methyl ester of hexadecanoic acid (C_{16}) is associated with early stage decomposition (Vaas et al., 2004, 2008; Vaas, 2012). Free hexadecanoic (C_{16}) and the unsaturated hexadecenoic (C_{16}) acids were detected in the SPME positive control baby sample but not the adult samples. Shorter chain acids in the range C_2 - C_9 were detected in the positive control samples with much higher abundances for the baby control. The homolog distributions were also different for the baby ($C_9 > C_8 > C_6 > C_7 = C_2 > C_3 > C_4 = C_5$) and adult ($C_8 > C_2 > C_6 = C_9 = C_3 > C_7 = C_5 = C_4$) samples. The aromatic compound, benzoic acid, was detected in the adult and baby positive control samples (Shepherd & Dawson, unpublished data).

Long chain C_{16} fatty acids were not found in the samples, however, seven shorter chain free fatty acids in the range C_2 - C_9, acetic (C_2), propanoic (C_3), butanoic (C_4), hexanoic (C_6), heptanoic (C_7), octanoic (C_8) and nonanoic (C_9) acids were detected in the samples. In addition the aromatic compound benzoic acid was also present.

There is a sample location difference in the distribution of the C_2-C_9 acids which is related to acid chain length. The longer C_6-C_9 (hexanoic, heptanoic, octanoic and nonanoic) acids predominate at sample locations 7, 11, 14, 15 and 23, whereas the shorter C_2-C_4 (acetic, propanoic and butanoic)

acids predominate for samples 9, 14, 33, 45 and 49. Acetic and propanoic acids dominate the Northern boundary sample (53).
The aromatic benzoic acid has abundance maxima for samples 9, 14, 15, 33, 39 – 49 and for the Western (55) and Eastern (57) boundary samples.

Unsaturated aldehydes

Unsaturated straight chain aldehydes, the 2-alkenals, have a double bond located between C2 and C3 of the alkyl chain. Six members of this series in the range C_6 – C_{11} were found in the SPME positive control samples. These were in the general order of abundance $C_{10} > C_9 = C_8 > C_{11} > C_7 > C_6$, although the C_7 and C_9 homologues were not detected in the adult control samples. In addition, 2,4-nonadienal (C_9) with double bonds located between C2 and C3 and between C4 and C5, was also present in the adult and baby controls at abundance level intermediate between the C_{11} and C_6 2-alkenals (Shepherd & Dawson, unpublished data). The significance of the 2-alkenals with respect to mammalian decomposition is uncertain; however, their homologue distribution closely follows that of the equivalent saturated C_6 to C_{11} compounds, suggesting a common origin.

2-Alkenals in the range C_6 –C_{10} were detected in the samples, consisting of 2-hexenal (C_6), 2-heptenal (C_7), 2-octenal (C_8), 2-nonenal (C_9) and 2-decenal (C_{10}). In addition, 2,4-nonadienal (C_9) was also present.

The C_8-C_{10} unsaturated aldehydes 2-octenal, 2-nonenal and 2-decenal were most abundant, followed by the C_6 and C_7 compounds 2-hexenal and 2-heptenal and the C_9 2,4-nonadienal. This order of abundance is similar to that seen for the positive controls.
Abundance maxima were observed for samples 1-15, 23, 27, 33, 49, and for the Western boundary sample (55). This distribution profile is very similar to that seen for the saturated C_8-C_{10} *n*-aldehydes octanal, nonanal and decanal, providing further evidence for a common origin for both classes of compound.

Alkanes

Straight chain (*n*-) alkanes in the range C_5-C_{11} are associated with mammalian decomposition and the longer homologues are particularly associated with human decomposition, for which the presence of undecane (C_{11}) is considered to be a marker (Vaas et al., 2004, 2008; Vaas, 2012).
Alkanes in the range C_7, C_9-C_{19} were found in the SPME positive control adult and baby samples with different abundance distributions for adult ($C_{12} > C_{10} = C_{13} = C_{14} > C_{16} = C_{15} > C_{17} > C_{11} = C_{18} = C_{19} > C_7 = C_9$) and baby ($C_{15} > C_{16} = C_{17} = C_{12} = C_{13} = C_{14} > C_{18} = C_{19} > C_{10} > C_{11} > C_7 = C_9$).
The C_{10}-C_{18} alkane homologues decane (C_{10}), Undecane (C_{11}), dodecane (C_{10}), tridecane (C_{13}), tetradecane (C_{14}), pentadecane (C_{15}), hexadecane (C_{16}) heptadecane (C_{17}) and octadecane (C_{18}) were found in the samples.

For most alkane homologues there is a broad abundance maxima profile over samples 1 – 15 and also at samples 23, 27, 31, 33 and 49, and at the Northern (53) and to a lesser extent the Western (55) boundary samples.

Maximum alkane abundances were seen for the longest C_{15}-C_{18} homologues, pentadecane, hexadecane, heptadecane and octadecane at the most easterly cell (sample 1), similar to the distribution seen for the positive control baby sample, and for tetradecane, hexadecane and octadecane at the Northern (53) boundary sample.

Undecane (C11) was generally of low abundance in all samples, but the abundance maxima for this compound were for samples 1-14, 23, 27, 31, 49, and for the boundary samples 53 and 55.

Data analysis

Analyte lists and analyte characterization

The first stage of data analysis was to create a master list of analytes of interest. This was based in part on published data describing volatiles associated with mammalian and human decomposition processes (Vaas et al., 2004, 2008; Vaas, 2012). In addition, further similar compounds were added following qualitative inspection of the data.

A composite sample analysis sequence was created using the Xcalibur™ software which allowed sequential qualitative inspection of all raw data files for all samples. Using this approach, combined selected ion chromatograms (SIC) for ion groups characteristic of specific target compounds were extracted and the SIC traces examined to assess for the presence of the target compounds in the sample. Ion groups for compound identification were selected by examination of reference MS data for the analytes in question which included published data, entries in commercial MS libraries and our own extensive databases. Selection criteria were that the ions should be of high relative abundance and where possible unique to the analyte, and should take into account possible contributions from overlapping and co-eluting analytes. In some instances it was necessary to modify the ion groups initially selected to provide optimal chromatographic resolution.

The master analyte list is shown in Table 2 and incorporates the following data:

(1) Name of analyte, and possible alternative identification(s);

(2) Retention time (R_t) (in minutes) and relative retention index (RRI);

(3) Molecular formula; molecular weight and the masses of the selected ions used for indentification and subsequent quantitation.

Relative retention index (RRI) describes the elution characteristics of analytes in a manner that is independent of the absolute retention times. It uses homologues of a specific class of compound, in this case straight chain saturated hydrocarbons (*n*-alkanes), as retention markers. Each alkane is assigned a RRI value of 100n where n is the number of carbon atoms in the alkane (e.g. octane, C_8, RRI = 800). Ideally a range of such alkanes differing in chain length by one carbon increments should be present in the analytical samples, or a mixture of such alkanes can be prepared, sampled and analysed separately under identical conditions. Each analyte is then assigned a calculated RRI value based on linear interpolation of the retention time differences between it and the two nearest adjacent alkane RRI markers of longer and shorter R_t. RRI values are therefore of greater utility when comparing retention data with that in pre-existing lists of metabolites previously analysed under similar conditions.

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Automated data processing

An automated data processing method was created in Xcalibur™ using the data from the master metabolite list. This was used with the composite sample analysis sequence to extract then integrate the combined SIC trace of the diagnostic ions for each analyte within an analyte-specific defined time window, centered on the SIC peak apex. The output from the initial data processing was reviewed, checked for misidentification of peaks, and corrected where necessary. The results were then output to an excel workbook, with individual spreadsheets for each analyte in which the SIC peak areas were listed for each sample. This data was copied into a single spreadsheet listing analyte abundances against sample number. By comparison with the sample blanks many components present in each sample were shown to be sampling artifacts related to the SPME fiber chemistry and these were excluded from Tables 2 and 3. Compounds were identified by comparison of their mass spectra with entries in MS spectral libraries (NIST, Wiley and Pal600K), by comparison of mass spectral data and retention behavior with authentic standards and by extrapolation from data for known compounds. Where exact identities could not be given (e.g positional isomers with different substitution patterns) the general identity by compound family or class is given.

Table 1 Sampling Schedule

Sample Name	Context Number	Sample Weight (g)	Analysis Date	Analysis Time	Fibre No.	File Name
Lab control	Blank		11-Apr-17	09:47 AM	2	110417_IRS_SPME_PD_F2_blank_001
001	C.51	1.401	04-Apr-17	11.32 AM	2	040417_IRS_SPME_PD_F2_001_001_170404115644
003	C.53	2.019	04-Apr-17	12:49 PM	2	040417_IRS_SPME_PD_F2_003_001
005	C.55	2.447	04-Apr-17	14:02 PM	2	040417_IRS_SPME_PD_F2_005_001
007	C.57	1.667	04-Apr-17	15:15 PM	2	040417_IRS_SPME_PD_F2_007_001
009	C.59	3.220	04-Apr-17	16:28 AM	2	040417_IRS_SPME_PD_F2_009_001
011	C.61	1.855	04-Apr-17	17:40 PM	2	040417_IRS_SPME_PD_F2_011_001
013	C.63	1.734	05-Apr-17	10:01AM	3	050417_IRS_SPME_PD_F3_013_001
014	C.63	1.872	05-Apr-17	12:00 AM	3	050417_IRS_SPME_PD_F3_014_001
015	C.63	2.642	05-Apr-17	13:15 PM	3	050417_IRS_SPME_PD_F3_014_001_170405133831
017	C.65	3.090	05-Apr-17	14:27 PM	3	050417_IRS_SPME_PD_F3_014_001_170405145042
018	C.65	2.712	05-Apr-17	15:35 PM	3	050417_IRS_SPME_PD_F3_018_001
019	C.65	2.251	05-Apr-17	16:51 PM	3	050417_IRS_SPME_PD_F3_019_001
021	C.10	2.134	05-Apr-17	18:04 PM	3	050417_IRS_SPME_PD_F3_021_001
023	C.12	2.139	06-Apr-17	09:09 AM	3	060417_IRS_SPME_PD_F3_023_001
025	C.11	2.595	06-Apr-17	10:20 AM	3	060417_IRS_SPME_PD_F3_025_001
027	C.85	2.070	06-Apr-17	11:34 AM	3	060417_IRS_SPME_PD_F3_027_001
029	C.87	2.146	06-Apr-17	12:45 PM	3	060417_IRS_SPME_PD_F3_029_001
030	C.87	3.532	06-Apr-17	13:59 PM	3	060417_IRS_SPME_PD_F3_030_001
031	C.87	4.205	06-Apr-17	15:10 PM	3	060417_IRS_SPME_PD_F3_031_001
033	C.89	0.971	06-Apr-17	16:21 PM	3	060417_IRS_SPME_PD_F3_033_001
035	C.91	2.607	06-Apr-17	17:32 PM	3	060417_IRS_SPME_PD_F3_035_001
037	C.93	2.091	07-Apr-17	09:16 AM	3	070417_IRS_SPME_PD_F3_037_001
039	C.95	2.460	07-Apr-17	10:30 AM	3	070417_IRS_SPME_PD_F3_039_001
043	C.97	2.673	07-Apr-17	11:40 AM	3	070417_IRS_SPME_PD_F3_043_001
045	C.99	1.223	07-Apr-17	12:51 PM	3	070417_IRS_SPME_PD_F3_045_001
047	C.101	2.986	07-Apr-17	14:05 PM	3	070417_IRS_SPME_PD_F3_047_001
049	C.105	1.735	07-Apr-17	16:26 PM	2	070417_IRS_SPME_PD_F3_049b_001
051	C.2	3.523	07-Apr-17	17:39 PM	2	070417_IRS_SPME_PD_F2_051_001
053	N Boundary	2.608	07-Apr-17	18:50 PM	2	070417_IRS_SPME_PD_F2_053_001
055	W Boundary	2.277	10-Apr-17	12:04 PM	2	100417_IRS_SPME_PD_F2_055_001

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057	E Boundary	2.949	10-Apr-17	14:28 PM	2	100417_IRS_SPME_PD_F2_057_001
059	S Boundary	3.186	10-Apr-17	15:46 PM	2	100417_IRS_SPME_PD_F2_059_001

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Table 2. Compounds detected in soil samples

Best match(es)	Diagnostic ions	Formula	Mwt	Rt	RRI
Ethanol	45.1, 46.1	C_2H_6O	46	1.59	590
Dimethylsulfide	47.1, 62.1	C_2H_6S	62	1.60	591
Acetone	43.1, 58.1	C_3H_6O	58	1.68	601
Dichloromethane	49.1, 84.1, 86.1, 88.1	CH_2Cl_2	84	1.75	610
2,3-dihydrofuran[a]	39.1, 41.1, 69.1, 70.1	C_4H_6O	70	1.90	628
2-Methylpropanal	43.1, 72.1	C_4H_8O	72	1.94	633
2- or 3-Methylfuran	53.1, 81.1, 82.1	C_5H_6O	82	2.02	643
3- or 2-Methylfuran	53.1, 81.1, 82.1	C_5H_6O	82	2.13	657
Butanal	57.1, 72.1	C_4H_8O	72	2.24	670
2,3-Butanedione	43.1, 86.1	$C_4H_6O_2$	86	2.36	685
Tetrahydrofuran	42.1, 71.1, 72.1	C_4H_8O	72	2.38	686
Chloroform	83.1, 85.1, 87.1	$CHCl_3$	118	2.43	694
Benzene	51.1, 52.1, 78.1	C_6H_6	78	2.63	719
3-Methylbutanal	41.1, 43.1, 44.1, 57.1, 58.1, 71.1, 86.1	$C_5H_{10}O$	86	2.90	731
2-Methylbutanal	41.1, 43.1, 44.1, 57.1, 58.1, 71.1, 86.1	$C_5H_{10}O$	86	2.98	737
2-Ethylfuran	53.1, 81.1, 96.1	C_6H_8O	96	2.99	738
2-Pentanone[b]	43.1, 57.1, 71.1, 86.1	$C_5H_{10}O$	86	3.05	742
Pentanal	55.1, 57.1, 58.1	$C_5H_{10}O$	86	3.51	777
Acetic acid	43.1, 45.1, 60.1	$C_2H_4O_2$	60	3.74	794
Dimethyl disulfide	79.1, 94.1	$C_2H_6S_2$	94	3.97	809
Toluene	63.1, 65.1, 91.1, 92.1	C_7H_8	92	4.09	816
Pyridine	52.1, 79.1	C_5H_5N	79	4.40	834
2-Hexanone	43.1, 58.1, 71.1, 85.1, 100.1	$C_6H_{12}O$	100	5.17	880
Hexanal[c]	43.1, 44.1, 56.1, 57.1, 72.1, 82.1	$C_6H_{12}O$	100	5.21	883
Propanoic acid	45.1, 56.1, 57.1, 73.1, 74.1	$C_3H_6O_2$	74	5.25	885
Ethylbenzene[d]	65.1, 77.1, 91.1, 106.1	C_8H_{10}	106	5.70	912
Dimethylbenzene (1)[e]	65.1, 77.1, 91.1, 106.1	C_8H_{10}	106	5.83	919
Dimethylbenzene (2)[e]	65.1, 77.1, 91.1, 106.1	C_8H_{10}	106	6.33	948
Styrene	54.1, 78.1, 103.1, 104.1	C_8H_8	104	6.48	957
2-Hexenal	41.1, 55.1, 69.1, 83.1, 98.1	$C_6H_{10}O$	98	6.57	963
Butanoic acid	45.1, 60.1, 73.1, 88.1	$C_4H_8O_2$	88	6.70	970

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Table 2 (continued). Compounds detected in soil samples

Best match(es)	Diagnostic ions	Formula	Mwt	Rt	RRI
Furfural	39.1,67.1, 95.1, 96.1	$C_5H_4O_2$	96	6.72	971
1-hexanol[f]	41.1, 43.12, 56.1, 69.1, 84.1	$C_6H_{14}O_3$	102	6.85	979
2-Heptanone (MPK)	43.1, 58.1, 71.1, 85.1, 99.1, 114.1	$C_7H_{14}O$	114	6.92	983
Heptanal	43.1, 44.1, 57.1, 70.1, 71.1, 86.1, 96.1	$C_7H_{14}O$	114	6.98	987
Decane	43.1, 57.1, 71.1, 85.1, 99.1, 113.1, 142.2	$C_{10}H_{22}$	142	7.21	1000
Methylisopropylbenzene (1)	91.1, 119.1, 134.1	$C_{10}H_{14}$	134	7.33	1007
Methylethylbenzene[g]	91.1, 105.1, 120.1	C_9H_{12}	120	7.43	1013
2-Pentylfuran	53.1, 81.1,120.1, 138.1	$C_9H_{14}O$	138	7.78	1035
6-Methyl-2-heptanone	43.1, 58.1, 71.1, 95..1, 110.1, 128.1	$C_8H_{16}O$	128	7.99	1048
Ethylmethylbenzene[g]	91.1, 105.1, 120.1	C_9H_{12}	120	8.03	1050
2-Heptenal	41.1, 55.1, 70.1, 83.1, 97.1, 112.1	$C_7H_{12}O$	112	8.35	1070
Methylisopropylbenzene (2)	91.1, 119.1, 134.1	$C_{10}H_{14}$	134	8.42	1074
3-Octanone	43.1, 57.1, 71.1, 72.1, 99.1, 128.1	$C_8H_{16}O$	128	8.43	1075
Heptanol	55.1, 56.1, 69.1, 70.1, 83.1	$C_7H_{16}O$	116	8.52	1080
1-Octen-3-ol	43.1, 57.1, 72.1, 85.1, 99.1, 110.1, 128.1	$C_8H_{16}O$	128	8.53	1081
Benzaldehyde	51.1, 77.1, 105.1, 106.1	C_7H_6O	106	8.59	1085
2-Octanone	43.1, 55.1, 58.1, 71.1, 85.1, 113.1, 128.1	$C_8H_{16}O$	128	8.60	1085
6-Methyl-5-hepten-2-one	41.1, 43.1, 55.1, 58.1, 69.1, 93.1, 108.1, 111.1,126.1	$C_8H_{14}O$	126	8.61	1086
Octanal	43.1, 44.1, 57.1, 69.1, 84.1, 100.1, 110.1	$C_8H_{16}O$	128	8.69	1091
Undecane	43.1, 57.1, 71.1, 85.1, 99.1, 113.1, 156.2	$C_{11}H_{24}$	156	8.84	1100
Dimethylstyrene (2)[h]	91.1, 115.1, 117.1, 132.1	$C_{10}H_{20}O$	132	9.68	1155
Hexanoic acid	41.1, 60.1, 73.1, 87.1, 98.1	$C_6H_{12}O_2$	116	9.78	1162
2-Octenal	5.1, 69.1, 70.1, 83.1, 97.1, 108.1, 111.1, 126.1	$C_8H_{14}O$	126	9.99	1175
1-Octanol	55.1, 56.1, 69.1, 70.1, 83.1, 84.1, 97.1, 112.1	$C_8H_{18}O$	130	10.06	1180
Phenylacetaldehyde	65.1, 91.1, 120.1	C_8H_8O	120	10.13	1184
2-Nonanone	43.1, 58.1, 71.1, 142.1	$C_9H_{18}O$	142	10.19	1188
Nonanal	43.1, 55.1, 57.1, 67.1, 70.1, 82.1, 95.1, 98.1, 114.1	$C_9H_{18}O$	142	10.28	1194
Dodecane	43.1, 57.1, 71.1, 85.1, 99.1, 113.1, 156.2	$C_{12}H_{26}$	170	10.37	1200
Acetophenone	77.1, 105.1, 120.1	C_8H_8O	120	10.43	1204
Phenol	65.1, 66.1, 94.1	C_6H_6O	94	10.68	1222
Heptanoic acid	60.1, 73.1, 87.1, 101.1, 113.1	$C_7H_{14}O_2$	130	11.16	1255

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Table 2 (continued). Compounds detected in soil samples

Best match(es)	Diagnostic ions	Formula	Mwt	Rt	RRI
2-Nonenal	41.1, 55.1, 70.1, 83.1, 97.1, 111.1, 127.1	$C_9H_{16}O$	140	11.52	1280
Phenylmethanol	91.1, 92.1, 122.1	$C_8H_{10}O$	122	11.56	1283
2-Decanone	43.1, 58.1, 96.1, 98.1, 113.1, 141.1, 156.2	$C_{10}H_{20}O$	156	11.68	1292
Decanal	43.1, 55.1, 57.1, 67.1, 70.1, 82.1, 95.1, 112.1, 128.1	$C_{10}H_{20}O$	156	11.77	1298
Tridecane	57.1, 71.1, 85.1, 99.1, 113.1, 184.1	$C_{13}H_{28}$	184	11.80	1300
Octanoic acid	60.1, 73.1, 85.1, 101.1, 115.1, 129.1, 144.1	$C_8H_{16}O_2$	144	12.51	1352
2, 4-Nonadienal	67.10, 81.10, 95.10, 138.10	$C_9H_{14}O$	138	12.55	1355
2-Decenal	41.1, 43.1, 55.1, 70.1, 83.1, 98.1, 110.1, 121.1, 136.1	$C_{10}H_{18}O$	154	12.96	1385
2-Undecanone	43.1, 58.1, 71.1, 85.1, 113.1, 155.1, 170.2	$C_{11}H_{22}O$	170	13.07	1394
Tetradecane	43.1, 57.1, 71.1, 85.1, 99.1, 113.1, 127.1, 141.1	$C_{14}H_{30}$	198	13.17	1400
Undecanal	43.1, 55.1, 57.1, 69.1, 70.1, 82.1, 96.1, 11.1, 126.1, 142.1, 152.1	$C_{11}H_{22}O$	170	13.19	1402
Benzoic acid	77.1, 105.1, 122.1	$C_7H_6O_2$	122	13.27	1408
Nonanoic acid	60.1, 73.1, 85.1, 98.1, 115.1, 129.1, 158.2	$C_9H_{18}O_2$	158	13.80	1449
2-Dodecanone	43.1, 58.1, 71.1, 85.1, 110.1, 169.1, 184.2	$C_{12}H_{24}O$	184	13.92	1459
Dodecanal (b)	43.1, 55.1, 57.1, 69.1, 70.1, 82.1, 96.1, 110.1, 126.1, 140.1, 156.1	$C_{12}H_{24}O$	184	14.03	1467
Pentadecane	57.1, 71.1, 85.1, 99.1, 113.1, 127.1, 141.1, 226.2	$C_{15}H_{32}$	212	14.44	1500
Hexadecane	57.1, 71.1, 85.1, 99.1, 113.1, 127.1, 141.1, 226.3	$C_{16}H_{34}$	226	15.64	1600
2-Tridecanone	43.10, 58.10, 71.10, 85.10, 96.1, 110.10, 140.10, 183.20, 198.2	$C_{13}H_{26}O$	198	15.65	1601
Heptadecane	57.1, 71.1, 85.1, 99.1, 113.1, 127.1, 141.1, 240.3	$C_{17}H_{36}$	240	16.79	1700
Pentadecanal	43.10, 55.10, 57.10, 69.10, 70.10, 82.10, 96.10, 110.10, 124.10, 137.10, 152.10	$C_{15}H_{30}O$	226	17.64	1779
Octadecane	57.1, 71.1, 85.1, 99.1, 113.1, 127.1, 141.1, 254.3	$C_{18}H_{38}$	254	17.87	1800

Alternative matches: [a]2- or 3-Butenal; [b]3-Me-2-butanone; [c]1-hexen-3-ol; [d]Dimethylbenzene; [e]Ethylbenzene; [f]4-Methyl-1-pentanol; [g]Trimethylbenzene or Propylbenzene; [h]Methyl propenylbenzene.

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Table 3. Aliphatic and aromatic alcohols and phenol (abundance per g of sample)

Sample Number	Context Number	Ethanol	1-Hexanol	Heptanol	1-Octanol	1-Octen-3-ol	Phenylmethanol	Phenol
1	(51)	198,670	703,414	2,435,359	15,072,734	500,870	2,890,023	12,652,247
3	(53)	47,039	157,565	787,779	4,765,593	305,024	2,076,204	5,144,687
5	(55)	97,628	293,782	1,029,402	8,611,450	732,524	3,286,628	6,518,920
7	(57)	57,367	1,017,750	3,535,050	15,273,293	1,193,822	5,741,048	6,897,038
9	(59)	404,758	378,720	693,027	22,504,285	423,291	3,962,574	11,998,630
11	(61)	348,562	524,074	1,444,249	13,634,439	881,672	4,839,229	9,311,035
13	(63)	201,494	449,703	977,558	14,420,911	341,998	1,082,631	7,535,976
14	(63)	278,573	955,249	1,437,090	35,848,721	774,904	2,233,083	13,421,475
15	(63)	249,220	479,322	848,084	14,772,564	376,081	2,474,044	8,219,573
17	(65)	79,043	192,859	259,078	3,700,087	97,097	634,726	2,494,860
18	(65)	79,623	181,444	213,636	3,502,572	178,801	701,236	1,459,157
19	(65)	174,491	328,381	372,207	4,802,356	140,965	623,082	1,792,469
21	(10)	117,115	267,194	245,153	1,445,056	71,945	709,530	969,474
23	(12)	67,734	1,499,760	3,862,984	25,578,365	3,347,538	3,814,853	6,096,523
25	(11)	154,956	318,930	203,404	1,376,694	77,850	564,491	2,396,508
27	(85)	314,107	1,480,057	2,466,496	6,646,140	847,603	3,232,333	2,337,360
29	(87)	31,177	774,536	534,531	4,027,042	177,924	711,106	3,038,751
30	(87)	69,811	563,101	462,600	4,499,845	183,983	557,571	1,397,721
31	(87)	115,302	502,337	720,825	3,826,475	228,312	724,305	1,988,092
33	(89)	597,583	688,283	1,692,819	7,364,441	476,733	6,605,938	10,701,694
35	(91)	255,992	288,208	175,741	1,519,009	80,275	644,244	3,048,106
37	(93)	115,216	587,962	252,831	1,647,019	152,280	1,616,733	2,080,170
39	(95)	181,804	718,208	352,547	3,349,474	129,800	1,498,134	5,054,480
43	(97)	204,454	582,146	425,037	2,546,382	229,112	914,131	5,778,725
45	(99)	475,411	1,588,703	2,032,689	5,591,446	6,568,733	2,661,251	7,775,907
47	(101)	152,738	393,344	375,867	1,686,852	67,687	482,232	4,728,181
49	(105)	127,411	2,920,256	5,771,715	40,861,478	1,739,462	8,007,205	6,710,151
51	(2)	109,442	623,633	478,944	2,772,282	151,552	272,727	1,019,412
53	N	183,122	611,058	433,148	2,189,154	467,925	702,129	1,681,833
55	W	341,425	4,619,546	4,723,958	216,504,404	6,369,702	32,442,630	7,535,615
57	E	113,964	337,642	376,163	3,023,754	299,964	1,315,988	2,074,368
59	S	129,726	435,731	284,182	2,952,449	122,458	825,944	2,266,941

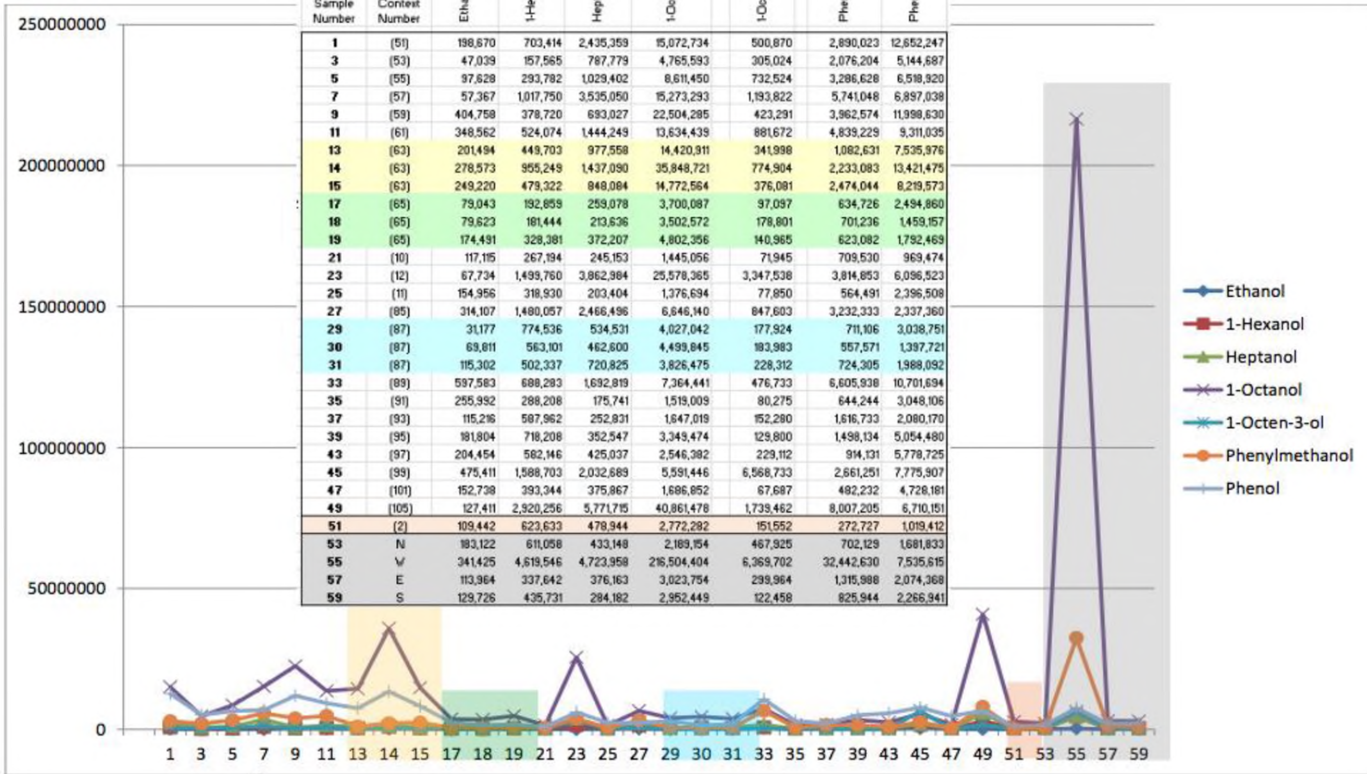

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Table 3 (continued). Aliphatic and aromatic alcohols and phenol (abundance per sample as a percentage of the total abundance for samples 1 – 49)

Sample Number	Contest Number	Ethanol	1-Hexanol	Heptanol	1-Octanol	1-Octen-3-ol	Phenylmethanol	Phenol
1	(51)	3.82	3.73	7.25	5.61	2.46	4.57	8.35
3	(53)	0.91	0.84	2.34	1.77	1.50	3.28	3.39
5	(55)	1.88	1.56	3.06	3.20	3.60	5.19	4.30
7	(57)	1.10	5.40	10.52	5.68	5.87	9.07	4.55
9	(59)	7.79	2.01	2.06	8.37	2.08	6.26	7.92
11	(61)	6.71	2.78	4.30	5.07	4.34	7.65	6.14
13	(63)	3.88	2.39	2.91	5.36	1.68	1.71	4.97
14	(63)	5.36	5.07	4.28	13.33	3.81	3.53	8.86
15	(63)	4.80	2.54	2.52	5.49	1.85	3.91	5.42
17	(65)	1.52	1.02	0.77	1.38	0.48	1.00	1.65
18	(65)	1.53	0.96	0.64	1.30	0.88	1.11	0.96
19	(65)	3.36	1.74	1.11	1.79	0.69	0.98	1.18
21	(10)	2.25	1.42	0.73	0.54	0.35	1.12	0.64
23	(12)	1.30	7.96	11.49	9.51	16.47	6.03	4.02
25	(11)	2.98	1.69	0.61	0.51	0.38	0.89	1.58
27	(85)	6.04	7.86	7.34	2.47	4.17	5.11	1.54
29	(87)	0.60	4.11	1.59	1.50	0.88	1.12	2.01
30	(87)	1.34	2.99	1.38	1.67	0.91	0.88	0.92
31	(87)	2.22	2.67	2.14	1.42	1.12	1.14	1.31
33	(89)	11.50	3.65	5.04	2.74	2.35	10.44	7.06
35	(91)	4.93	1.53	0.52	0.56	0.39	1.02	2.01
37	(93)	2.22	3.12	0.75	0.61	0.75	2.55	1.37
39	(95)	3.50	3.81	1.05	1.25	0.64	2.37	3.34
43	(97)	3.93	3.09	1.26	0.95	1.13	1.44	3.81
45	(99)	9.15	8.43	6.05	2.08	32.32	4.20	5.13
47	(101)	2.94	2.09	1.12	0.63	0.33	0.76	3.12
49	(105)	2.45	15.50	17.17	15.20	8.56	12.65	4.43
51	(2)	2.11	3.31	1.43	1.03	0.75	0.43	0.67
53	N	3.52	3.24	1.29	0.81	2.30	1.11	1.11
55	V	6.57	24.53	14.06	80.52	31.34	51.26	4.97
57	E	2.19	1.79	1.12	1.12	1.48	2.08	1.37
59	S	2.50	2.31	0.85	1.10	0.60	1.31	1.50

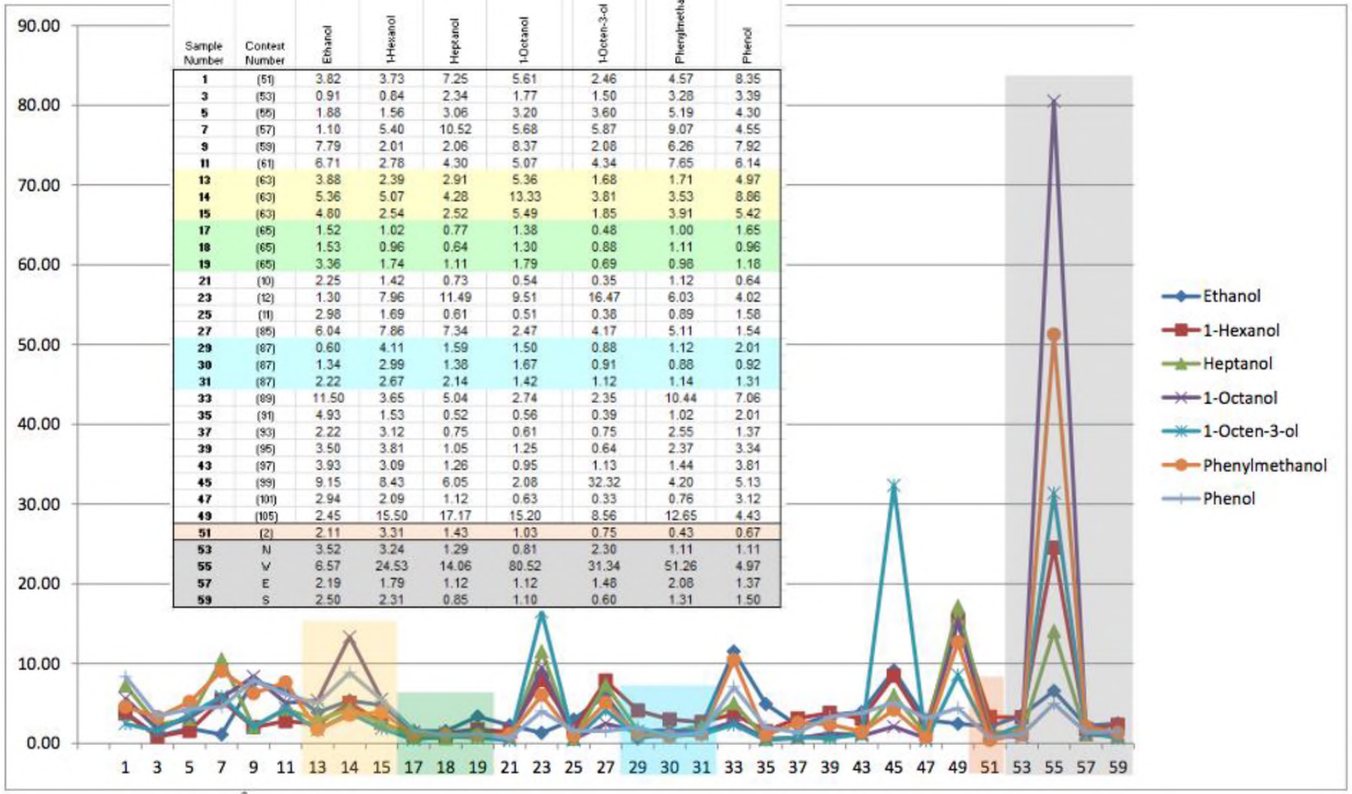

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Table 3 (continued). Aliphatic and aromatic alcohols and phenol

- The aliphatic alcohols ethanol (C_2), 1-hexanol (C_6), 1-heptanol (C_7) and the aromatic compound phenol were found in the samples, along with the C_8 alcohols 1-octanol and 1-octen-3-ol, and the aromatic alcohol phenyl methanol.

- In terms of abundance per g of sample and proportional abundance, hotspots are found for phenol and phenylmethanol in samples 7 – 15, 23, 33, and 39-45. Collectively for ethanol, 1-hexanol and 1-heptanol, hotspots are found for samples 7, 9, 11, 23, 27, 33, 45 and 49. Hotspots for 1-octanol and 1-octen-3-ol were found for samples 7-15, 23, 45 and 49.

- High abundances of these compounds, particularly phenyl methanol and the C_8 alcohols were also found for the West boundary control sample (55).

- Abundances of these compounds were low in one of the cells with no visible human remains (samples 17 – 19), but showed a peak for some components in the other (samples 13 – 15).

- Ethanol, 1-pentanol, 1-hexanol, 1-heptanol and phenol are known non-specific markers of bone decomposition in mammals

Table 3 (continued). Sulfur Compounds (abundance per g of sample)

Sample Number	Context Number	Dimethylsulfide	Dimethyldisulfide
1	(51)	3,638	93,267
3	(53)	16,246	72,412
5	(55)	13,040	120,593
7	(57)	26,275	154,340
9	(59)	2,907	100,140
11	(61)	30,029	400,844
13	(63)	10,443	362,774
14	(63)	28,270	512,032
15	(63)	25,156	207,361
17	(65)	18,051	71,579
18	(65)	16,695	117,872
19	(65)	27,893	191,455
21	(10)	12,292	95,414
23	(12)	17,245	89,163
25	(11)	11,891	167,281
27	(85)	3,571	1,776,833
29	(87)	23,825	915,527
30	(87)	39,049	549,678
31	(87)	42,696	560,757
33	(89)	10,251	443,193
35	(91)	37,924	569,534
37	(93)	42,352	1,073,272
39	(95)	41,839	574,319
43	(97)	5,127	961,453
45	(99)	28,330	1,009,742
47	(101)	3,524	1,174,156
49	(105)	69,721	410,148
51	(2)	23,591	1,281,182
53	N	51,075	555,638
55	W	239,037	299,634
57	E	39,314	29,568
59	S	24,550	91,815

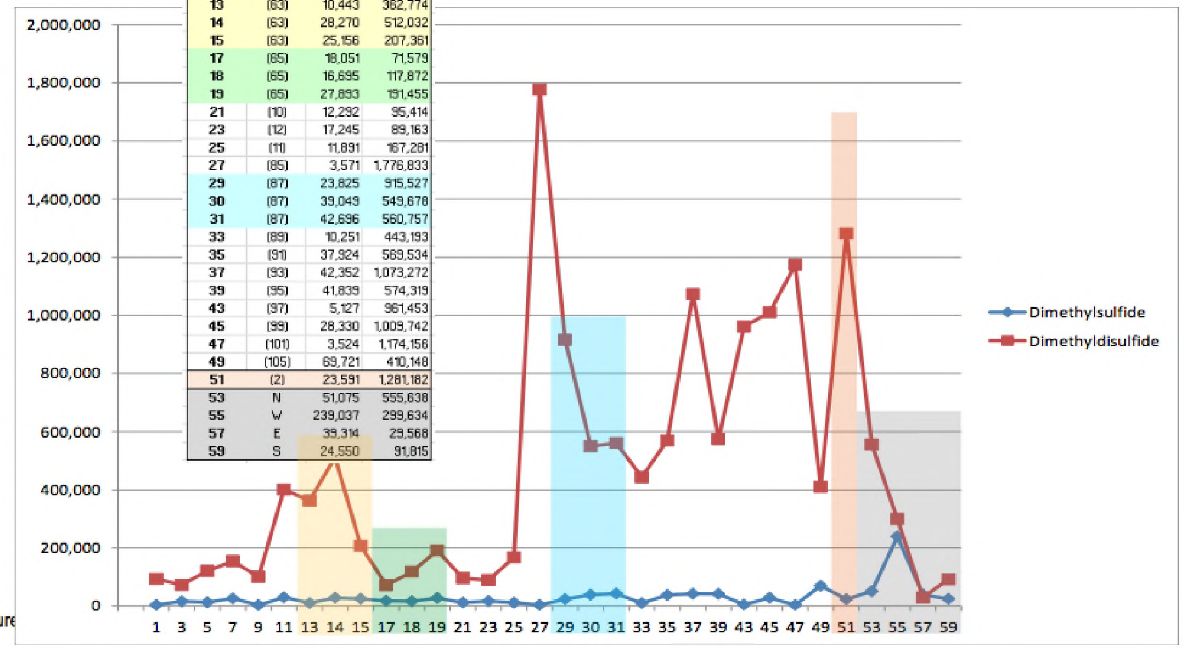

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Table 3 (continued). Sulfur Compounds (abundance per sample a percentage of the total abundance for samples 1 – 49)

Sample Number	Context Number	Dimethylsulfide	Dimethyldisulfide
1	(51)	0.60	0.73
3	(53)	2.67	0.57
5	(55)	2.14	0.94
7	(57)	4.32	1.21
9	(59)	0.48	0.78
11	(61)	4.94	3.14
13	(63)	1.72	2.84
14	(63)	4.65	4.01
15	(63)	4.14	1.62
17	(65)	2.97	0.56
18	(65)	2.74	0.92
19	(65)	4.59	1.50
21	(10)	2.02	0.75
23	(12)	2.84	0.70
25	(11)	1.95	1.31
27	(85)	0.59	13.91
29	(87)	3.92	7.17
30	(87)	6.42	4.30
31	(87)	7.02	4.39
33	(89)	1.69	3.47
35	(91)	6.23	4.46
37	(93)	6.96	8.40
39	(95)	6.88	4.50
43	(97)	0.84	7.53
45	(99)	4.66	7.90
47	(101)	0.58	9.19
49	(105)	11.46	3.21
51	(2)	3.88	10.03
53	N	8.40	4.35
55	W	39.30	2.35
57	E	6.46	0.23
59	S	4.04	0.72

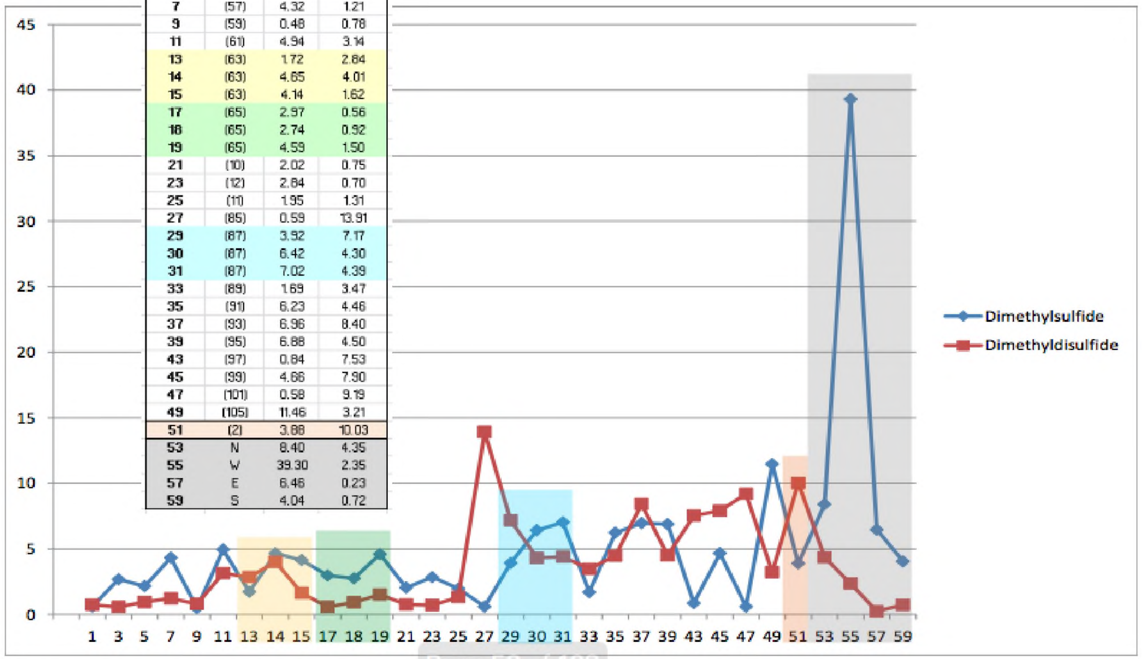

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Table 3 (continued). Sulfur Compounds

- Dimethylsulfide (DMS) and dimethyldisulfide (DMDS) were the only sulfur compounds detected in the samples. These compounds are non-specific markers of mammalian decomposition.
- Proportional abundance and abundance per g for DMS is fairly uniform across the samples with perhaps an indication of an increase for cells located towards the west (higher sample number). The abundance for this compound is significantly greater for the West boundary sample (55).
- The abundance profiles for DMDS show maxima for samples 11-14, the west tending samples 27-49, the Baulk sample (51) and to a lesser extent North boundary control (53). The abundances of DMDS in the other boundary samples, including the West boundary sample (55) are relatively low in comparison.
- Abundances of DMDS compounds were low in one of the cells with no visible human remains (samples 17 – 19), but showed a peak in the other (samples 13 – 15).

Table 3 (continued). Ketones (abundance per g of sample)

Sample Number	Context Number	Acetone	2-Pentanone	2-Hexanone	2-Heptanone	6-Methyl-2-heptanone	3-Octanone	2-Octanone	2-Nonanone	2-Decanone	2-Undecanone	2-Dodecanone	2-Tridecanone	2,3-Butanedione	6-Methyl-5-hepten-2-one	Acetophenone
1	[51]	1,870,360	372,203	855,951	5,947,551	12,645,800	2,632,180	30,241,629	14,438,808	75,979,660	17,943,975	85,726,580	18,568,544	34,320	2,592,651	34,552,743
3	[53]	686,744	601,281	655,937	3,918,304	3,787,312	817,146	9,903,138	9,477,006	86,353,429	15,859,018	107,524,623	23,893,510	78,976	1,096,780	44,951,164
5	[55]	1,064,193	498,050	621,718	4,273,981	7,852,481	1,264,130	11,815,082	11,940,728	60,438,793	12,648,662	49,038,373	10,483,608	35,973	1,610,550	52,076,126
7	[57]	2,099,956	849,544	1,086,201	8,827,971	14,167,259	2,353,913	19,627,215	17,492,118	132,501,086	20,574,067	72,861,215	18,803,213	75,858	2,809,026	55,440,289
9	[59]	240,254	225,511	470,372	2,549,047	3,786,668	2,575,505	6,356,083	6,368,953	22,101,142	3,942,459	8,709,159	3,143,546	30,060	1,016,837	43,730,224
11	[61]	1,318,244	798,588	1,160,981	6,392,556	7,091,725	2,091,827	14,507,531	12,391,933	77,508,475	10,197,226	42,658,697	9,145,642	67,903	1,857,245	48,906,075
13	[63]	1,935,191	200,527	399,906	3,114,641	5,863,772	1,703,481	5,687,533	7,147,211	19,921,642	5,442,133	12,938,979	4,193,558	46,812	804,023	12,393,612
14	[63]	1,521,573	460,075	608,535	1,862,594	5,220,519	913,730	4,988,352	7,581,940	14,821,462	4,569,503	10,741,560	3,765,962	43,416	645,910	37,240,387
15	[63]	1,139,590	234,025	465,012	1,399,973	3,166,242	592,010	3,011,329	4,741,812	18,942,404	3,741,927	11,943,093	2,949,121	46,060	425,186	27,009,585
17	[65]	806,372	169,633	172,562	619,942	1,742,795	214,998	1,498,191	1,219,368	5,853,652	883,026	4,869,787	1,023,938	25,231	193,090	4,253,434
18	[65]	1,475,090	314,982	244,699	1,403,600	2,001,179	353,254	1,780,740	1,138,000	4,636,880	676,864	3,066,600	737,093	42,610	235,650	1,462,488
19	[65]	1,624,731	218,762	263,374	887,584	1,812,688	199,873	1,611,195	1,249,005	3,015,395	629,235	2,270,059	533,717	43,650	243,947	2,653,818
21	[10]	1,269,391	252,442	171,042	727,143	1,069,236	219,415	1,834,340	918,386	3,771,837	543,680	2,130,066	724,108	40,233	179,950	1,653,966
23	[12]	1,589,156	491,720	1,215,148	6,249,031	13,694,058	51,722,675	17,112,663	12,722,578	26,023,768	5,835,632	7,615,238	2,772,029	65,939	2,717,333	11,708,801
25	[11]	657,209	156,318	235,439	885,144	1,036,482	219,506	1,155,248	662,025	2,393,396	387,220	1,628,284	319,996	29,003	125,041	3,474,688
27	[85]	131,717	321,465	480,825	3,568,589	5,303,446	2,529,323	10,248,745	4,487,053	18,908,058	3,890,572	7,696,778	2,151,905	12,039	1,501,722	7,064,693
29	[87]	1,033,638	226,268	297,819	1,517,496	2,192,428	469,551	2,059,511	1,500,167	2,570,017	817,224	3,110,223	444,264	57,410	213,890	3,700,372
30	[87]	554,836	103,448	211,753	995,717	1,601,812	148,742	1,538,807	1,633,107	1,888,427	362,225	677,092	132,878	32,377	208,209	1,620,178
31	[87]	272,156	108,280	225,440	841,601	3,862,875	348,527	1,981,958	1,759,359	2,691,332	405,725	3,124,742	478,844	14,436	298,904	2,006,469
33	[89]	1,976,955	996,032	242,668	2,407,555	1,571,614	243,410	4,305,965	3,658,487	34,094,464	5,425,416	23,306,975	4,943,593	101,308	561,710	18,118,044
35	[91]	901,610	219,061	95,167	885,520	604,781	106,872	585,338	530,108	3,274,147	527,816	1,590,038	475,035	71,210	90,882	2,979,790
37	[93]	948,221	175,652	252,462	1,263,228	1,017,481	410,889	1,124,375	1,002,718	8,311,753	1,549,205	2,402,526	887,486	60,534	195,561	1,091,195
39	[95]	1,007,151	150,251	245,225	1,071,317	1,629,823	114,397	1,306,267	1,440,380	4,428,593	754,786	1,629,520	630,913	25,739	164,005	4,756,023
43	[97]	835,368	220,454	166,911	1,318,843	1,715,897	221,099	1,243,455	879,689	2,427,595	316,358	924,892	300,998	21,642	265,598	4,051,178
45	[99]	3,954,063	3,615,161	404,896	2,905,124	2,364,567	170,415,316	3,354,755	2,203,498	5,278,920	6,342,879	2,500,887	1,349,191	172,533	694,779	8,865,141
47	[101]	660,138	90,312	73,750	707,457	695,581	91,779	702,907	391,590	2,512,552	401,891	1,125,925	369,060	13,242	109,046	3,040,413
49	[105]	3,969,537	743,732	941,505	9,584,978	9,010,425	4,240,477	8,612,480	20,134,204	78,572,557	24,747,645	25,276,427	12,880,381	187,469	1,353,983	41,627,252
51	[2]	520,522	183,467	279,575	1,346,315	3,535,801	352,746	1,573,439	826,431	2,743,088	633,262	918,032	365,219	52,870	202,454	981,207
53	N	1,063,998	270,862	525,462	1,068,203	3,403,871	504,452	1,160,025	617,839	3,142,298	1,188,041	4,061,976	4,087,375	44,831	230,600	2,139,919
55	W	2,487,958	807,758	3,341,613	7,075,530	21,970,113	2,971,933	7,980,899	9,137,500	37,660,106	20,687,217	41,037,989	17,523,022	48,984	8,449,828	19,513,766
57	E	482,756	174,534	604,310	556,323	1,245,718	256,472	1,067,149	1,389,038	5,749,472	3,726,375	4,917,454	10,640,520	19,405	305,911	3,376,633
59	S	594,628	194,897	365,127	701,215	1,672,530	94,110	725,037	817,636	2,366,627	865,824	1,436,579	597,950	24,420	135,495	1,817,673

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Table 3 (continued). Ketones (abundance per g of sample)

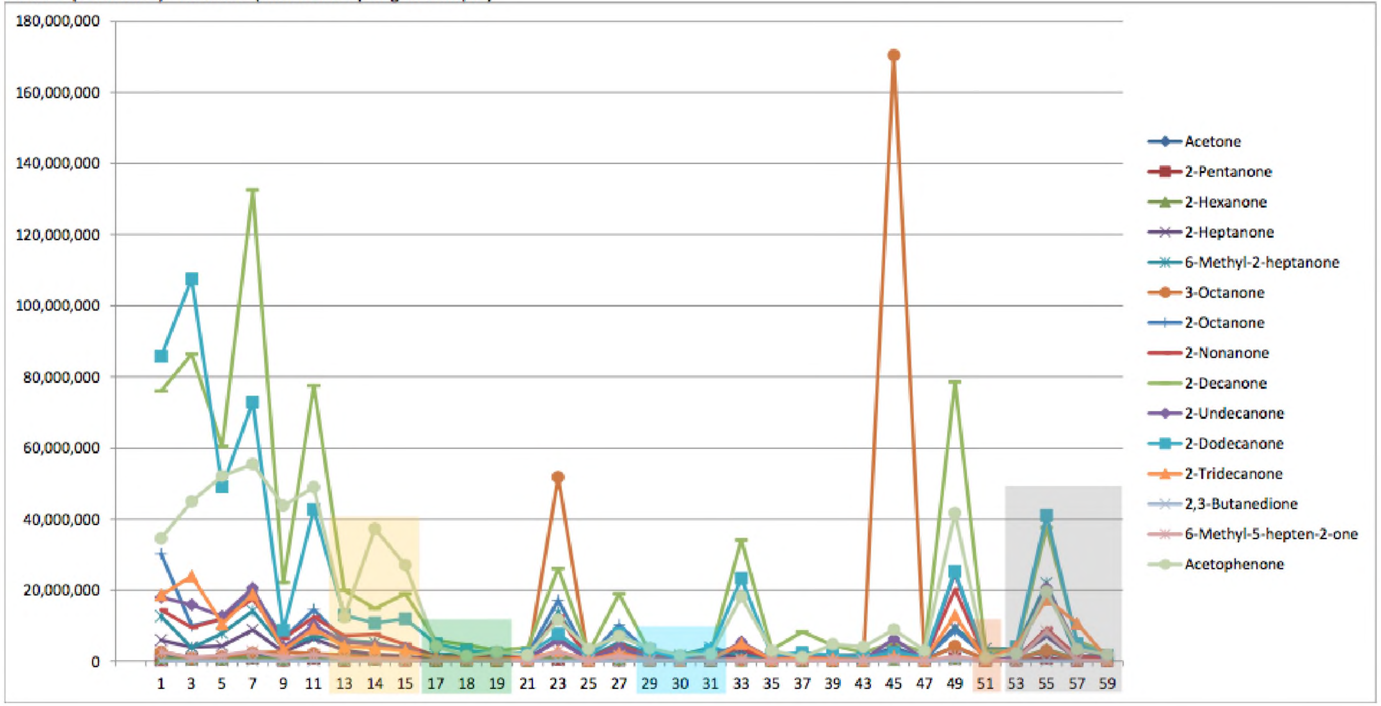

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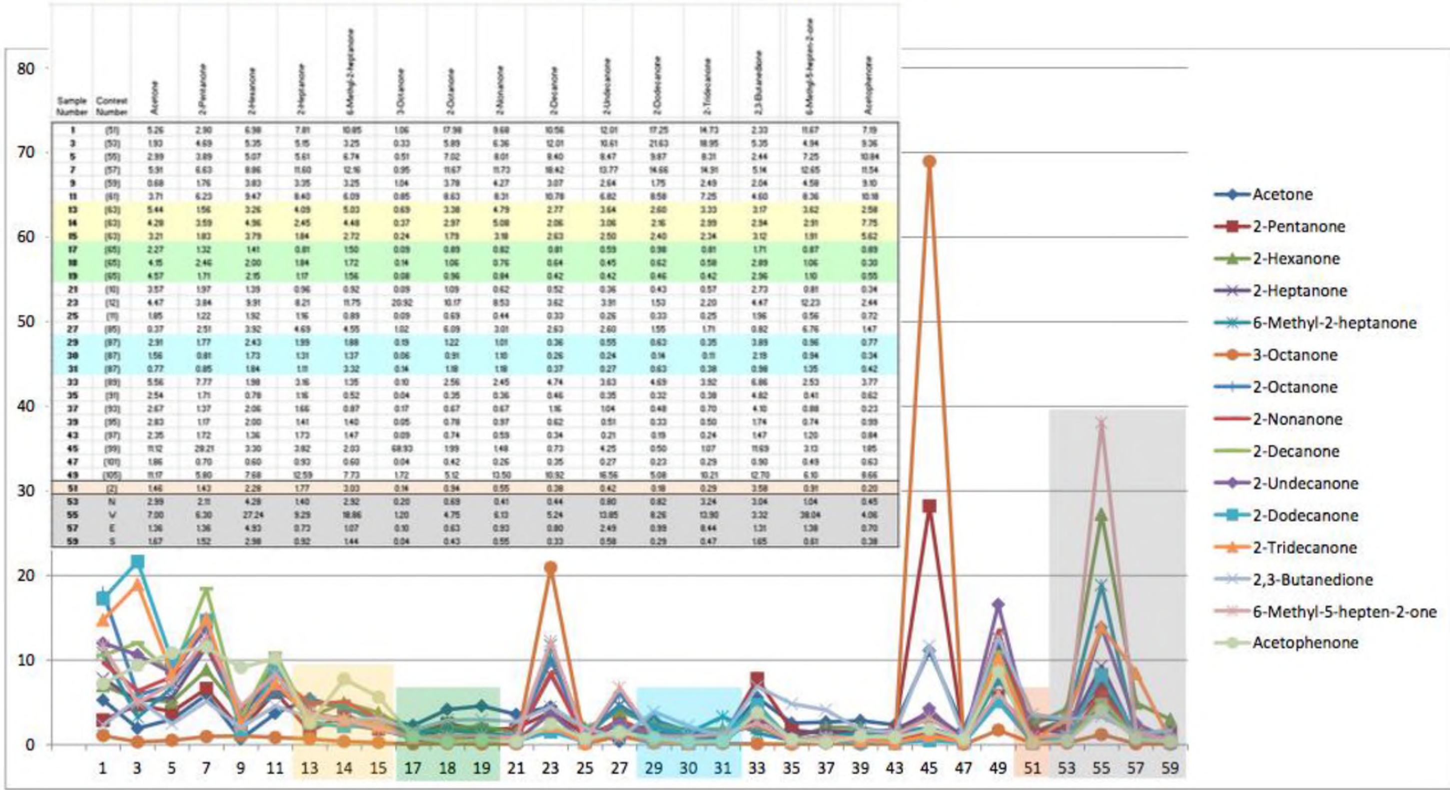
Table 3 (continued). Ketones (abundance per sample as a percentage of the total abundance for samples 1 – 49)



Sample Number	Context Number	Acetone	2-Pentanone	2-Hexanone	2-Heptanone	6-Methyl-2-heptanone	3-Octanone	2-Octanone	2-Nonanone	2-Decanone	2-Undecanone	2-Dodecanone	2-Tridecanone	2,3-Butanedione	6-Methyl-5-hepten-2-one	Acetophenone
1	(51)	5.26	2.90	6.98	7.81	10.85	1.06	17.98	9.68	10.56	12.01	17.25	14.73	2.33	11.67	7.19
3	(53)	1.93	4.69	5.35	5.15	3.25	0.33	5.89	6.36	12.01	10.61	21.63	18.95	5.35	4.94	9.36
5	(55)	2.99	3.89	5.07	5.61	6.74	0.51	7.02	8.01	8.40	8.47	9.87	8.31	2.44	7.25	10.84
7	(57)	5.31	6.63	8.86	11.60	12.16	0.95	11.67	11.73	18.42	13.77	14.66	14.91	5.14	12.65	11.54
9	(59)	0.68	1.76	3.83	3.35	3.25	1.04	3.79	4.27	3.07	2.64	1.75	2.49	2.04	4.58	9.10
11	(61)	3.71	6.23	9.47	8.40	6.09	0.85	8.63	8.31	10.78	6.82	8.58	7.25	4.60	8.36	10.18
13	(63)	5.44	1.56	3.26	4.09	5.03	0.63	3.38	4.79	2.77	3.64	2.60	3.33	3.17	3.62	2.58
14	(63)	4.29	3.59	4.96	2.45	4.48	0.37	2.97	5.08	2.06	3.06	2.16	2.99	2.94	2.91	7.75
15	(63)	3.21	1.83	3.79	1.84	2.72	0.24	1.79	3.18	2.63	2.50	2.40	2.34	3.12	1.91	5.62
17	(65)	2.27	1.32	1.41	0.81	1.50	0.09	0.89	0.82	0.81	0.59	0.98	0.81	1.71	0.87	0.89
18	(65)	4.15	2.46	2.00	1.84	1.72	0.14	1.06	0.76	0.64	0.45	0.62	0.58	2.89	1.06	0.30
19	(65)	4.57	1.71	2.15	1.17	1.56	0.08	0.96	0.84	0.42	0.42	0.46	0.42	2.96	1.10	0.55
21	(10)	3.57	1.97	1.39	0.96	0.92	0.09	1.09	0.62	0.52	0.36	0.43	0.57	2.73	0.81	0.34
23	(12)	4.47	3.84	9.91	8.21	11.75	20.92	10.17	8.53	3.62	3.91	1.53	2.20	4.47	12.23	2.44
25	(11)	1.85	1.22	1.92	1.16	0.89	0.09	0.69	0.44	0.33	0.26	0.33	0.25	1.96	0.56	0.72
27	(85)	0.37	2.51	3.92	4.63	4.55	1.02	6.09	3.01	2.63	2.60	1.55	1.71	0.82	6.76	1.47
29	(87)	2.91	1.77	2.43	1.99	1.88	0.19	1.22	1.01	0.36	0.55	0.63	0.35	3.89	0.96	0.77
30	(87)	1.56	0.81	1.73	1.31	1.37	0.06	0.91	1.10	0.26	0.24	0.14	0.11	2.19	0.94	0.34
31	(87)	0.77	0.85	1.84	1.11	3.32	0.14	1.18	1.18	0.37	0.27	0.63	0.38	0.98	1.35	0.42
33	(89)	5.56	7.77	1.98	3.16	1.35	0.10	2.56	2.45	4.74	3.63	4.69	3.92	6.86	2.53	3.77
35	(91)	2.54	1.71	0.78	1.16	0.52	0.04	0.35	0.36	0.46	0.35	0.32	0.38	4.82	0.41	0.62
37	(93)	2.67	1.37	2.06	1.66	0.87	0.17	0.67	0.67	1.16	1.04	0.48	0.70	4.10	0.88	0.23
39	(95)	2.83	1.17	2.00	1.41	1.40	0.05	0.78	0.97	0.62	0.51	0.33	0.50	1.74	0.74	0.99
43	(97)	2.35	1.72	1.36	1.73	1.47	0.09	0.74	0.59	0.34	0.21	0.19	0.24	1.47	1.20	0.84
45	(99)	11.12	28.21	3.30	3.82	2.03	68.93	1.99	1.48	0.73	4.25	0.50	1.07	11.69	3.13	1.85
47	(101)	1.86	0.70	0.60	0.93	0.60	0.04	0.42	0.26	0.35	0.27	0.23	0.29	0.90	0.49	0.63
49	(105)	11.17	5.80	7.68	12.59	7.73	1.72	5.12	13.50	10.92	16.56	5.08	10.21	12.70	6.10	8.66
51	(2)	1.46	1.43	2.29	1.77	3.03	0.16	0.94	0.55	0.38	0.42	0.18	0.29	3.58	0.91	0.20
53	N	2.99	2.11	4.29	1.40	2.92	0.20	0.69	0.41	0.44	0.80	0.82	3.24	3.04	1.04	0.45
55	V	7.00	6.30	27.24	9.29	18.86	1.20	4.75	6.13	5.24	13.85	8.26	13.90	3.32	38.04	4.06
57	E	1.36	1.36	4.93	0.73	1.07	0.10	0.63	0.93	0.80	2.49	0.99	8.44	1.31	1.38	0.70
59	S	1.67	1.52	2.98	0.92	1.44	0.04	0.43	0.55	0.33	0.58	0.29	0.47	1.65	0.61	0.38

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Table 3 (continued). Ketones

- A range of aliphatic ketones in the range C_3-C_{13} with the keto group at the C-2 position in the alkyl chain were detected in the samples. These include 2-propanone (acetone, C_3), 2-pentanone (C_5), 2-hexanone (C_6), 2-heptanone (C_7), 2-octanone (C_8), 2-nonanone (C_9), 2-decanone (C_{10}), 2-undecanone (C_{11}), 2-dodecanone (C_{12}) and 2-tridecanone (C_{13}). In addition the branched saturated and unsaturated C_8 homologues of this series, 6-methyl-2-heptanone and 6-methyl-5-hepten-2-one, were also found along with the C_8 compound 3-octanone, which has the keto group at C-3. A C_4 diketo compound, 2,3-butanedione and an aromatic ketone acetophenone were also present.

- Abundance hotspots for the C-2 ketones were found for samples 1-11, 23, 27, 33, 45 and 49, particularly for 2-decanone (C_{10}), 2-undecanone (C_{11}), and to a lesser extent for 2-pentanone (C_5), 2-octanone (C_8) and 2-nonanone (C_9). Higher levels of the C-3 ketone 3-octanone (C_8) were associated with samples 23 and 45.

- The western control also showed appreciable abundances of some of these compounds, particularly 2-hexanone (C_6) and the branched C_8 compounds 6-methyl-2-heptanone and 6-methyl-5-hepten-2-one.

- Ketones were generally of lower abundance in one of the samples from cells with no visible human remains (17-19), but were of higher abundance for some components in the other (samples 13 – 15).

- Acetone 2-nonanone and 2-decanone are associated with human and other mammalian decomposition, particularly of bone.

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Table 3 (continued). Halocarbons (abundance per g of sample)

Sample Number	Context Number	Dicholoromethane	Chloroform
1	(51)	73,249	265,283
3	(53)	54,178	250,053
5	(55)	70,656	346,800
7	(57)	174,623	963,576
9	(59)	67,784	224,673
11	(61)	126,619	757,598
13	(63)	53,895	301,068
14	(63)	62,014	261,651
15	(63)	72,199	237,282
17	(65)	31,407	136,617
18	(65)	103,277	335,492
19	(65)	49,710	73,513
21	(10)	119,533	303,437
23	(12)	40,700	109,916
25	(11)	37,113	58,009
27	(85)	7,979	169,440
29	(87)	78,626	289,021
30	(87)	28,258	103,110
31	(87)	58,401	155,584
33	(89)	26,455	94,572
35	(91)	31,609	137,167
37	(93)	22,993	60,046
39	(95)	129,161	395,501
43	(97)	85,758	283,045
45	(99)	167,829	548,493
47	(101)	76,822	222,646
49	(105)	159,626	538,679
51	(2)	143,169	713,753
53	N	443,751	2,379,336
55	W	58,453	652,514
57	E	38,865	436,665
59	S	26,275	268,382

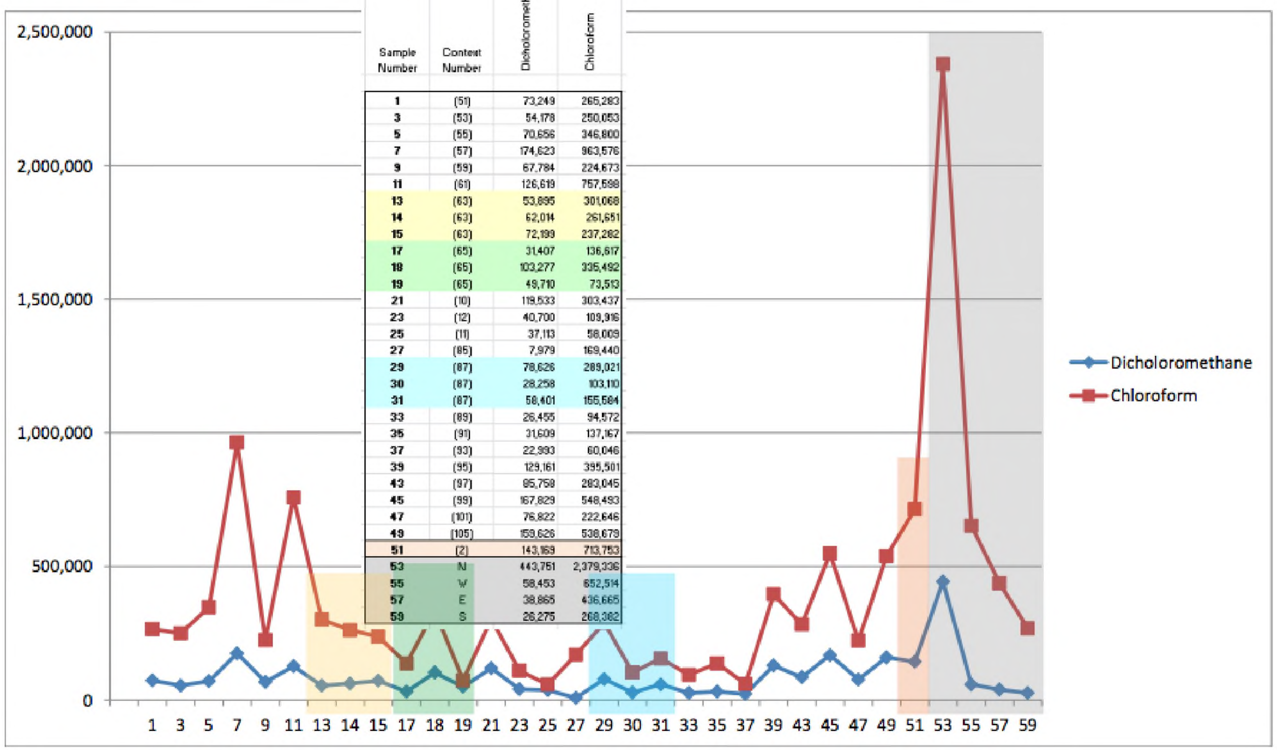

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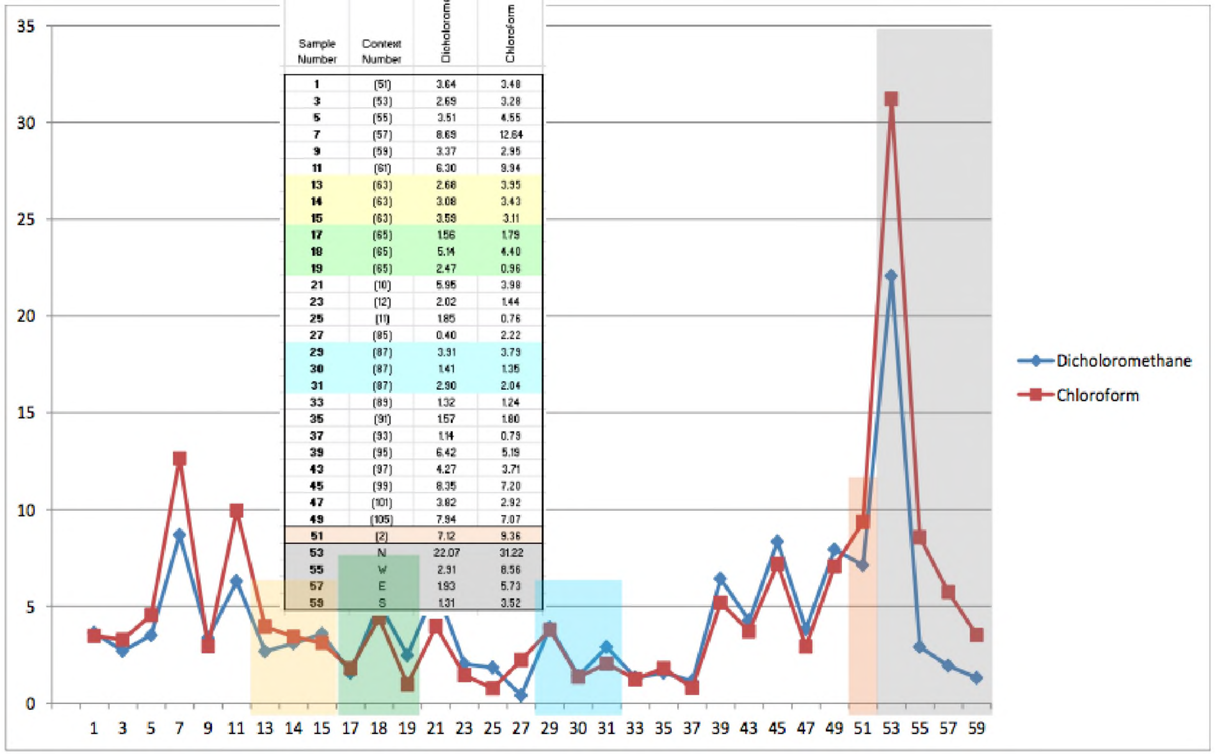
Table 3 (continued). Halocarbons (abundance per sample as a percentage of the total abundance for samples 1 – 49)



Sample Number	Context Number	Dicholoromethane	Chloroform
1	(51)	3.64	3.48
3	(53)	2.69	3.28
5	(55)	3.51	4.55
7	(57)	8.69	12.64
9	(59)	3.37	2.95
11	(61)	6.30	9.94
13	(63)	2.68	3.95
14	(63)	3.08	3.43
15	(63)	3.59	3.11
17	(65)	1.56	1.79
18	(65)	5.14	4.40
19	(65)	2.47	0.96
21	(10)	5.96	3.98
23	(12)	2.02	1.44
25	(11)	1.85	0.76
27	(85)	0.40	2.22
29	(87)	3.91	3.79
30	(87)	1.41	1.35
31	(87)	2.90	2.04
33	(89)	1.32	1.24
35	(91)	1.57	1.80
37	(93)	1.14	0.79
39	(95)	6.42	5.19
43	(97)	4.27	3.71
45	(99)	8.35	7.20
47	(101)	3.82	2.92
49	(105)	7.94	7.07
51	(2)	7.12	9.36
53	N	22.07	31.22
55	W	2.91	8.56
57	E	1.93	5.73
59	S	1.31	3.52

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Table 3 (continued). Halocarbons.

- Dichloromethane and chloroform were the only halocarbons detected in the samples.
- Abundance profiles for dichloromethane and chloroform were broadly similar across the samples, with abundance maxima for samples 7, 9 and an increase towards the western cells (higher sample numbers) and baulk sample (51) culminating with maximum abundance for the Northern boundary sample (53).
- Chloroform is a non-specific mammalian decomposition marker.

Table 3 (continued). Furans (abundance per g of sample)

Sample Number	Context Number	2,3-Dihydrofuran	2- or 3- Methylfuran	3- or 2- Methylfuran	Tetrahydrofuran	2-Ethylfuran	2-Pentylfuran	Furfural
1	(51)	288,592	155,496	48,906	3,719,482	21,677	4,550,141	2,185,563
3	(53)	270,860	140,241	50,897	1,824,967	36,429	2,363,064	944,200
5	(55)	290,260	69,999	29,315	2,054,782	58,265	4,786,625	534,534
7	(57)	245,171	68,889	28,157	2,403,880	47,551	8,358,903	1,019,374
9	(59)	799,620	26,231	17,516	2,029,268	24,941	1,008,343	203,673
11	(61)	731,868	100,981	20,293	3,633,090	114,077	3,058,884	912,742
13	(63)	215,930	134,194	15,987	1,822,136	19,221	1,457,231	856,072
14	(63)	2,023,583	165,340	88,715	2,788,230	67,589	1,047,524	217,682
15	(63)	1,614,248	62,914	28,289	1,444,939	85,423	1,132,652	193,502
17	(65)	647,873	93,534	53,385	875,088	35,539	338,449	82,111
18	(65)	377,568	85,297	27,514	1,090,671	61,171	648,572	201,127
19	(65)	536,092	84,237	18,480	861,625	27,165	378,055	103,802
21	(10)	403,861	21,322	11,888	732,884	30,846	391,989	120,175
23	(12)	102,680	31,135	13,995	702,125	49,345	8,242,337	1,415,124
25	(11)	259,069	24,004	31,062	565,404	21,569	229,400	144,109
27	(85)	183,440	0	35,490	460,265	49,787	4,679,686	964,882
29	(87)	240,413	34,714	18,308	1,007,528	17,623	348,899	432,944
30	(87)	104,629	21,810	18,273	414,501	16,290	538,215	166,818
31	(87)	89,014	12,447	16,289	146,000	12,765	814,730	88,866
33	(89)	632,193	70,629	43,300	2,683,212	71,326	1,872,179	529,104
35	(91)	686,501	62,979	25,636	3,203,905	27,010	483,851	198,098
37	(93)	407,684	84,927	17,128	2,258,439	15,278	789,990	337,945
39	(95)	456,315	29,631	14,478	1,662,278	17,239	356,204	204,137
43	(97)	284,907	33,910	16,968	1,433,063	17,195	443,553	505,107
45	(99)	528,193	115,082	36,694	3,637,091	68,550	2,032,095	1,297,643
47	(101)	158,073	21,193	16,912	608,892	12,721	306,523	656,824
49	(105)	903,491	220,074	74,227	5,330,329	60,083	10,056,635	2,299,799
51	(2)	384,100	33,344	16,127	3,364,463	19,201	431,271	53,600
53	N	728,054	50,690	23,179	5,420,177	47,457	802,369	57,388
55	W	777,980	77,890	40,968	12,849,976	112,156	9,947,694	369,780
57	E	234,662	22,817	14,780	270,592	26,479	726,062	27,671
59	S	107,586	16,949	7,533	296,644	19,862	238,194	44,801

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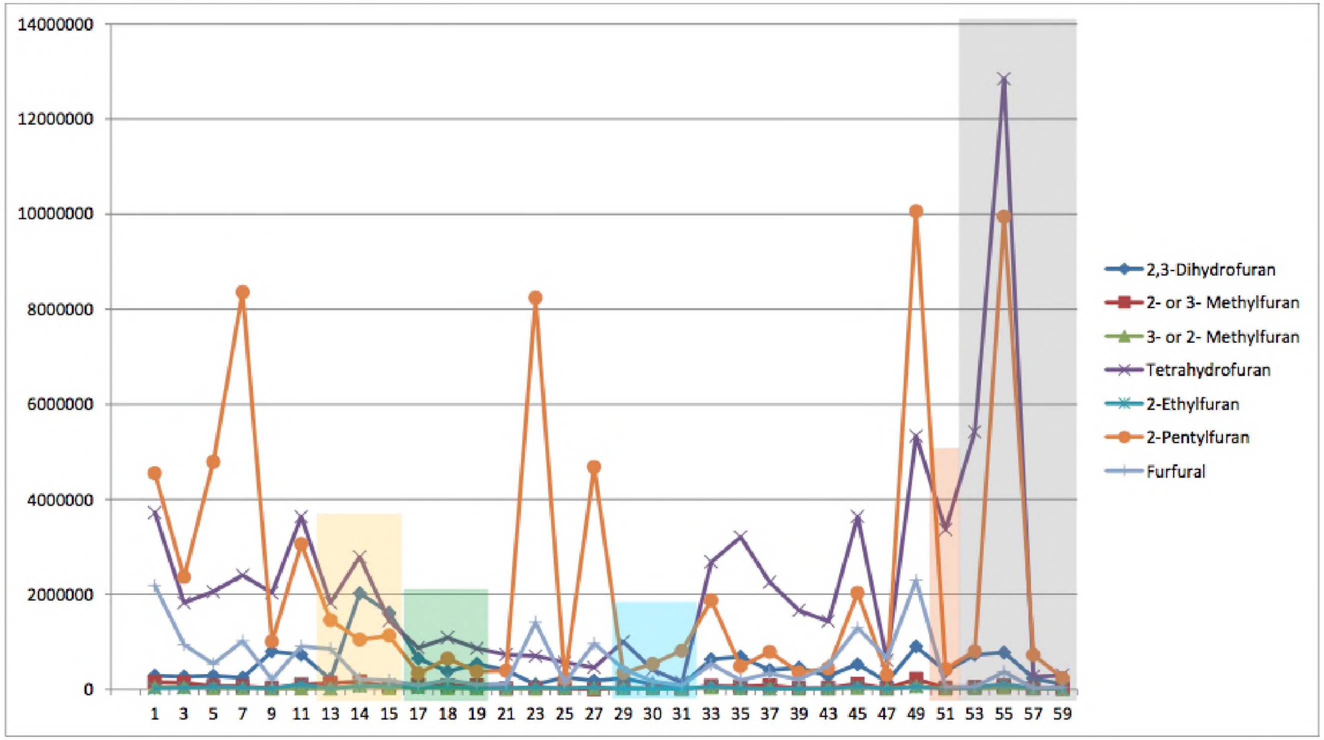
Table 3 (continued). Furans (abundance per g of sample)



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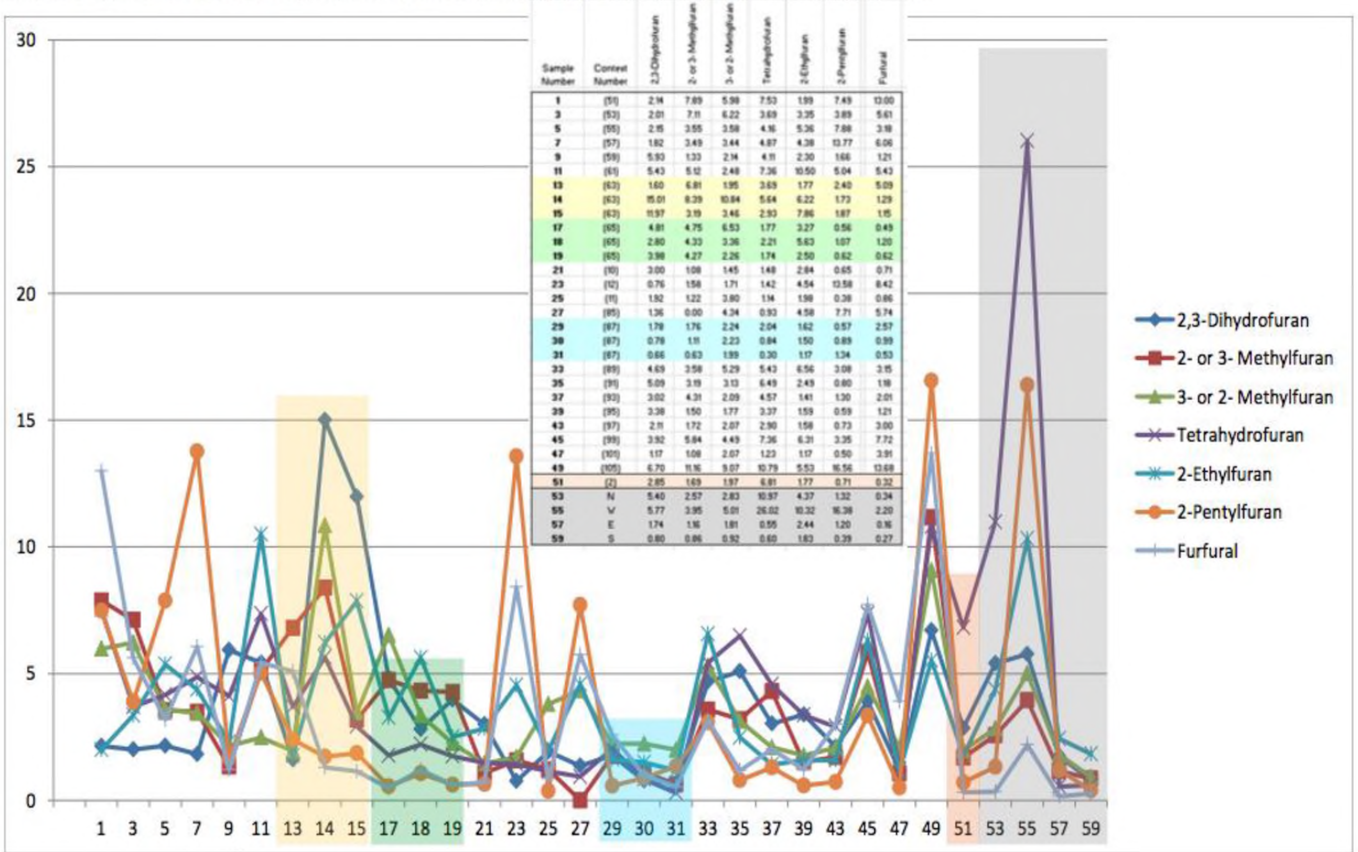
Continuation of Report by Lorna DAWSON

Table 3 (continued). Furans (abundance per sample as a percentage of the total abundance for samples 1 – 49)



Sample Number	Context Number	2,3-Dihydrofuran	2- or 3- Methylfuran	3- or 2- Methylfuran	Tetrahydrofuran	2-Ethylfuran	2-Pentylfuran	Furfural
1	(51)	2.14	7.89	5.98	7.53	1.99	7.49	13.00
3	(53)	2.01	7.11	6.22	3.69	3.35	3.89	5.61
5	(55)	2.15	3.55	3.58	4.16	5.36	7.88	3.18
7	(57)	1.82	3.49	3.44	4.87	4.38	13.77	6.06
9	(59)	5.93	1.33	2.14	4.11	2.30	1.66	1.21
11	(61)	5.43	5.12	2.48	7.36	10.50	5.04	5.43
13	(63)	1.60	6.81	1.95	3.69	1.77	2.40	5.09
14	(63)	15.01	8.39	10.84	5.64	6.22	1.73	1.29
15	(63)	11.97	3.19	3.46	2.93	7.86	1.87	1.15
17	(65)	4.81	4.75	6.53	1.77	3.27	0.56	0.49
18	(65)	2.80	4.33	3.36	2.21	5.63	1.07	1.20
19	(65)	3.98	4.27	2.26	1.74	2.50	0.62	0.62
21	(10)	3.00	1.08	1.45	1.48	2.84	0.65	0.71
23	(12)	0.76	1.58	1.71	1.42	4.54	13.58	8.42
25	(11)	1.92	1.22	3.80	1.14	1.98	0.38	0.86
27	(85)	1.36	0.00	4.34	0.93	4.58	7.71	5.74
29	(87)	1.78	1.76	2.24	2.04	1.62	0.57	2.57
30	(87)	0.78	1.11	2.23	0.84	1.50	0.89	0.99
31	(87)	0.66	0.63	1.99	0.30	1.17	1.34	0.53
33	(89)	4.69	3.58	5.29	5.43	6.56	3.08	3.15
35	(91)	5.09	3.19	3.13	6.49	2.49	0.80	1.18
37	(93)	3.02	4.31	2.09	4.57	1.41	1.30	2.01
39	(95)	3.38	1.50	1.77	3.37	1.59	0.59	1.21
43	(97)	2.11	1.72	2.07	2.90	1.58	0.73	3.00
45	(99)	3.92	5.84	4.49	7.36	6.31	3.35	7.72
47	(101)	1.17	1.08	2.07	1.23	1.17	0.50	3.91
49	(105)	6.70	11.16	9.07	10.79	5.53	16.56	13.68
51	(2)	2.85	1.69	1.97	6.81	1.77	0.71	0.32
53	N	5.40	2.57	2.83	10.97	4.37	1.32	0.34
55	V	5.77	3.95	5.01	26.02	10.32	16.38	2.20
57	E	1.74	1.16	1.81	0.55	2.44	1.20	0.16
59	S	0.80	0.86	0.92	0.60	1.83	0.39	0.27

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Table 3 (continued). Furans

- A series of four alkyl substituted furans was found in the samples. Most of the compounds present were substituted at C-2 in the furan ring (2-methyl-, 2-ethyl- and 2-pentylfuran) and one at C-3 (3-methylfuran). Reduced (hydrogenated) furan derivatives, 2,3-dihydrofuran and tetrahydrofuran (THF) were also detected along with the aldehyde furfural (furan-2-carboxaldehyde).

- The most abundant furan derivatives were 2-pentyl furan with hotspots at samples 1-7, 11, 23, 27, 49 and the western boundary sample (55) and THF with hotspots at samples 1-15, 33-45, 49, baulk sample 51 and the Northern (53) and Western boundary samples (55). The distribution of the other furans follows a broadly similar pattern to a combination of those for 2-pentylfuran and THF.

- Furans, including 2-methyl furan and furans with other substituents are found in adult human and animal decomposition, but may not be expected (2-methyl furan) for children under 4 years old.

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Table 3 (continued). Branched and aromatic aldehydes (abundance per g of sample)

Sample Number	Context Number	2-Methylpropanal	3-Methylbutanal	2-Methylbutanal	Ratio 3-/2-	Adj Ratio 3-/2- (x 1.34)	Benzaldehyde	Phenylacetaldehyde
1	(51)	1,467,038	6,674,214	5,074,201	1.32	1.76	580,814,529	84,138,690
3	(53)	1,148,326	4,606,119	4,794,775	0.96	1.29	106,528,454	44,096,743
5	(55)	1,871,998	8,549,722	11,297,239	0.76	1.01	184,072,492	77,017,673
7	(57)	1,990,740	9,635,800	10,148,585	0.95	1.27	220,773,861	96,246,059
9	(59)	1,034,273	5,838,385	4,082,414	1.43	1.92	73,219,428	61,032,610
11	(61)	2,389,682	17,543,359	13,187,274	1.33	1.78	232,848,316	94,970,852
13	(63)	1,145,336	4,816,782	2,722,279	1.77	2.37	249,085,301	28,063,618
14	(63)	1,903,116	11,990,863	6,719,057	1.78	2.39	152,457,833	31,863,158
15	(63)	1,142,708	5,008,900	3,005,432	1.67	2.23	75,453,023	12,640,207
17	(65)	890,057	4,258,400	2,274,713	1.87	2.51	21,456,463	4,167,587
18	(65)	1,914,239	6,773,714	3,926,484	1.73	2.31	15,881,718	3,371,807
19	(65)	1,615,393	6,239,095	3,209,977	1.94	2.60	41,812,398	7,694,522
21	(10)	1,386,572	3,747,935	1,993,056	1.88	2.52	52,157,000	4,682,060
23	(12)	581,226	3,358,611	1,668,712	2.01	2.70	204,663,578	34,490,013
25	(11)	1,172,539	4,245,380	2,865,224	1.48	1.99	20,857,654	4,098,908
27	(85)	765,376	2,486,089	1,823,327	1.36	1.83	140,345,649	11,916,922
29	(87)	681,642	2,068,182	1,036,059	2.00	2.67	27,372,465	5,065,033
30	(87)	440,155	1,961,847	818,264	2.40	3.21	13,881,475	3,946,482
31	(87)	494,971	1,484,062	707,194	2.10	2.81	19,095,215	3,316,053
33	(89)	1,828,799	7,289,088	4,386,321	1.66	2.23	141,232,462	16,804,134
35	(91)	463,078	1,735,056	763,872	2.27	3.04	9,546,641	3,875,501
37	(93)	754,921	3,357,516	1,577,377	2.13	2.85	15,191,405	7,209,132
39	(95)	1,157,189	5,619,563	3,317,918	1.69	2.27	24,649,483	6,384,596
43	(97)	592,419	1,357,333	765,455	1.77	2.38	30,867,231	4,601,653
45	(99)	6,631,496	32,387,847	24,924,865	1.30	1.74	55,426,995	11,818,340
47	(101)	273,607	907,140	521,399	1.74	2.33	20,302,701	3,853,546
49	(105)	3,828,297	19,024,827	6,387,672	2.98	3.99	183,534,439	64,365,042
51	(2)	548,679	3,346,776	1,462,249	2.29	3.07	9,996,769	2,144,375
53	N	2,789,357	8,953,700	4,264,770	2.10	2.81	22,922,029	5,276,776
55	W	4,914,489	34,686,630	23,827,013	1.46	1.95	248,182,671	268,359,249
57	E	1,385,854	6,994,299	4,731,258	1.48	1.98	30,927,716	11,572,219
59	S	640,913	5,248,099	3,036,338	1.73	2.32	18,330,022	6,883,378

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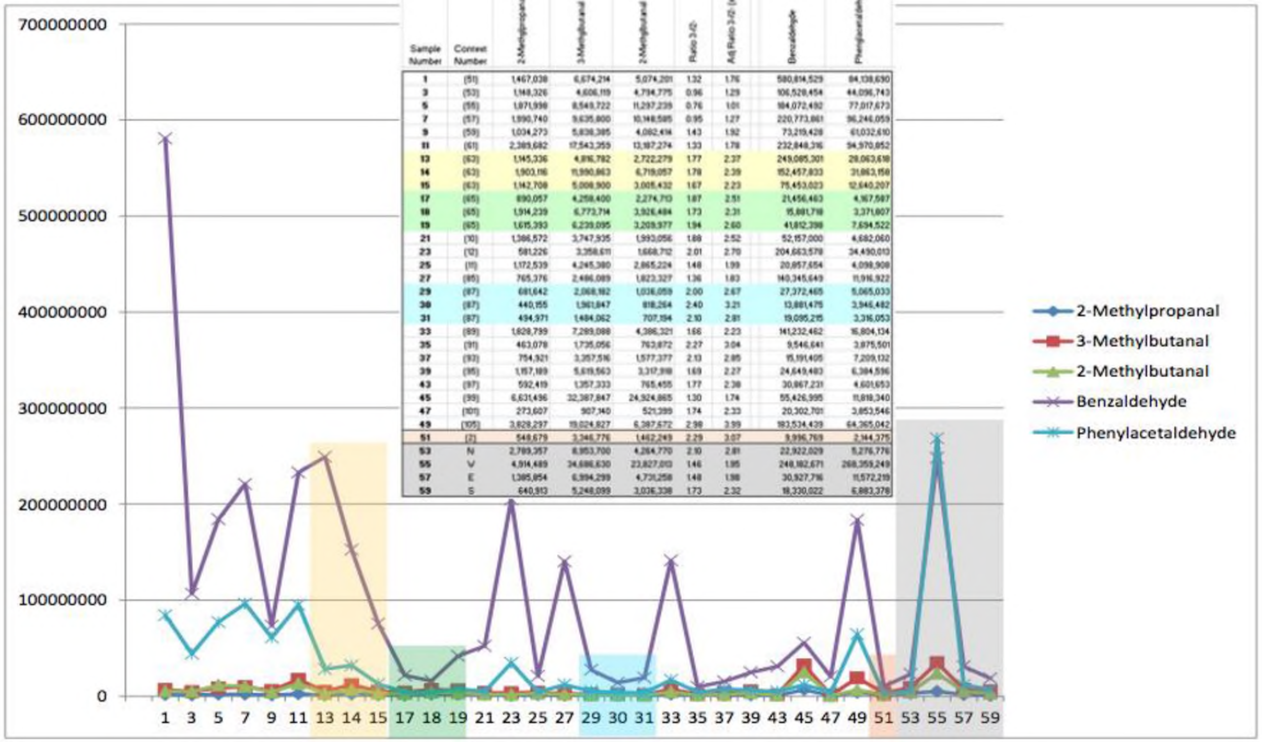
Table 3 (continued). Branched and aromatic aldehydes (abundance per g of sample)



Sample Number	Context Number	2-Methylpropanal	3-Methylbutanal	2-Methylbutanal	Ratio 3/2	Adj Ratio 3/2 (x1.34)	Benzaldehyde	Phenylacetaldehyde
1	(51)	1,467,038	6,674,214	5,074,201	1.32	1.76	580,814,529	84,138,690
3	(53)	1,148,326	4,606,119	4,794,775	0.96	1.29	106,528,454	44,096,743
5	(55)	1,871,998	8,549,722	11,297,239	0.76	1.01	184,072,492	77,017,673
7	(57)	1,990,740	9,635,800	10,148,585	0.95	1.27	220,773,861	96,246,059
9	(59)	1,034,273	5,838,385	4,082,414	1.43	1.92	73,219,428	61,032,610
11	(61)	2,389,682	17,543,359	13,187,274	1.33	1.78	232,848,316	94,970,852
13	(63)	1,145,336	4,816,782	2,722,279	1.77	2.37	249,085,301	28,063,618
14	(63)	1,903,116	11,990,863	6,719,057	1.78	2.39	152,457,833	31,863,158
15	(63)	1,142,708	5,008,900	3,005,432	1.67	2.23	75,453,023	12,640,207
17	(65)	890,057	4,258,400	2,274,710	1.87	2.51	21,456,463	4,167,587
18	(65)	1,914,239	6,773,714	3,926,484	1.73	2.31	15,881,718	3,371,807
19	(65)	1,615,393	6,239,095	3,209,977	1.94	2.60	41,812,398	7,694,522
21	(10)	1,386,572	3,747,935	1,993,056	1.88	2.52	52,157,000	4,682,060
23	(12)	581,226	3,358,611	1,668,712	2.01	2.70	204,663,579	34,490,013
25	(11)	1,172,539	4,245,380	2,865,224	1.48	1.99	20,857,654	4,098,908
27	(85)	765,376	2,486,089	1,823,327	1.36	1.83	140,345,649	11,916,922
29	(87)	681,642	2,068,182	1,036,059	2.00	2.67	27,372,465	5,065,033
30	(87)	440,155	1,961,847	818,264	2.40	3.21	13,881,475	3,946,482
31	(87)	494,971	1,484,062	707,194	2.10	2.81	19,095,215	3,316,053
33	(89)	1,628,799	7,289,088	4,386,321	1.66	2.23	141,232,462	16,804,134
35	(91)	463,078	1,735,056	763,872	2.27	3.04	9,546,641	3,875,501
37	(93)	754,921	3,357,516	1,577,377	2.13	2.85	15,191,405	7,209,132
39	(95)	1,157,189	5,619,563	3,317,918	1.69	2.27	24,649,483	6,384,596
43	(97)	592,419	1,357,333	765,455	1.77	2.38	30,867,231	4,601,653
45	(99)	6,631,496	32,387,847	24,924,865	1.30	1.74	55,426,995	11,818,340
47	(101)	273,607	907,140	521,399	1.74	2.33	20,302,701	3,853,546
49	(105)	3,828,297	19,024,827	6,387,672	2.98	3.99	183,534,439	64,365,042
51	(2)	548,679	3,346,776	1,462,249	2.29	3.07	9,996,769	2,144,375
53	N	2,789,357	8,953,700	4,264,770	2.10	2.81	22,922,029	5,276,776
55	V	4,914,489	34,686,630	23,827,013	1.46	1.95	248,182,671	268,359,249
57	E	1,385,854	6,994,299	4,731,258	1.48	1.98	30,927,716	11,572,219
59	S	640,913	5,248,099	3,036,338	1.73	2.32	18,330,022	6,883,378

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Table 3 (continued). Branched and aromatic aldehydes (abundance per sample expressed as a percentage of the total abundance for samples 1 – 49)

Sample Number	Context Number	2-Methylpropanal	3-Methylbutanal	2-Methylbutanal	Benzaldehyde	Phenylacetaldehyde
1	(51)	3.71	3.65	4.09	19.94	11.50
3	(53)	2.90	2.52	3.87	3.66	6.03
5	(55)	4.73	4.67	9.11	6.32	10.53
7	(57)	5.03	5.27	8.18	7.58	13.15
9	(59)	2.61	3.19	3.29	2.51	8.34
11	(61)	6.04	9.59	10.63	7.99	12.98
13	(63)	2.89	2.63	2.20	8.55	3.84
14	(63)	4.81	6.55	5.42	5.23	4.35
15	(63)	2.89	2.74	2.42	2.59	1.73
17	(65)	2.25	2.33	1.83	0.74	0.57
18	(65)	4.84	3.70	3.17	0.55	0.46
19	(65)	4.08	3.41	2.59	1.44	1.05
21	(10)	3.50	2.05	1.61	1.79	0.64
23	(12)	1.47	1.84	1.35	7.02	4.71
25	(11)	2.96	2.32	2.31	0.72	0.56
27	(85)	1.93	1.36	1.47	4.82	1.63
29	(87)	1.72	1.13	0.84	0.94	0.69
30	(87)	1.11	1.07	0.66	0.48	0.54
31	(87)	1.25	0.81	0.57	0.66	0.45
33	(89)	4.62	3.98	3.54	4.85	2.30
35	(91)	1.17	0.95	0.62	0.33	0.53
37	(93)	1.91	1.84	1.27	0.52	0.99
39	(95)	2.92	3.07	2.68	0.85	0.87
43	(97)	1.50	0.74	0.62	1.06	0.63
45	(99)	16.76	17.70	20.10	1.90	1.62
47	(101)	0.69	0.50	0.42	0.70	0.53
49	(105)	9.68	10.40	5.15	6.30	8.80
51	(2)	1.39	1.83	1.18	0.34	0.29
53	N	7.05	4.89	3.44	0.79	0.72
55	W	12.42	18.96	19.22	8.52	36.67
57	E	3.50	3.82	3.82	1.06	1.58
59	S	1.62	2.87	2.45	0.63	0.94

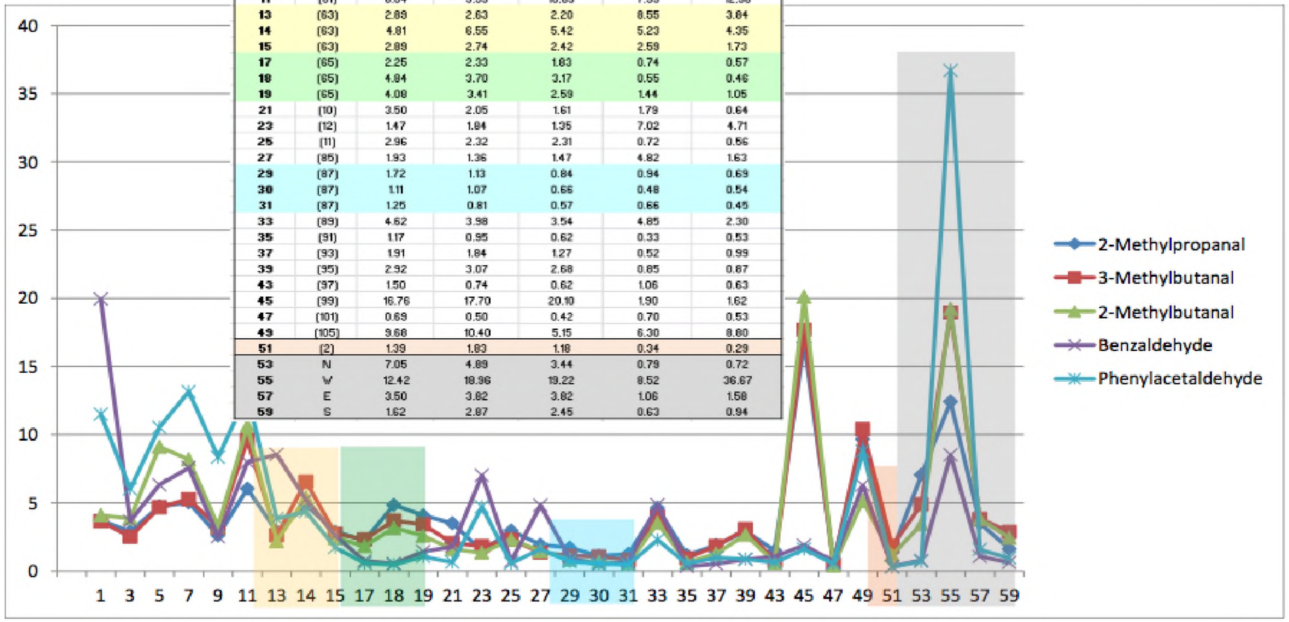

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Table 3 (continued). Branched and aromatic aldehydes

- The three short chain branched aldehydes, 2-methylpropanal, 3-methylbutanal and 2-methyl butanal were detected in all samples with 3-/2- isomer ratios in the range of 1.27 – 3.07 for all but one sample (5) which had an isomer ratio 1.01. These isomer ratios are consistent with a human decomposition process.

- The br-aldehydes were most abundant for samples 5, 7, 11, 14, 45 and 49, and for the Western boundary sample (55).

- Benzaldehyde and phenylacetaldehyde were found in the samples, with broadly similar abundance profiles. Abundance maxima were seen for samples 1-9, 11-15, 23, 27, 33, 49, and for the Western boundary sample (55).

Table 3 (continued). *n*-Aldehydes (abundance per g of sample)

Sample Number	Context Number	Butanal	Pentanal	Hexanal	Heptanal	Octanal	Nonanal	Decanal	Undecanal	Dodecanal	Pentadecanal
1	(51)	715,924	117,323	5,138,056	7,837,787	22,580,981	123,418,467	80,195,249	125,432,951	59,222,029	89,622,683
3	(53)	690,399	213,551	2,611,780	2,863,722	12,298,452	72,121,668	83,117,050	95,929,277	44,138,752	135,224,895
5	(55)	316,920	259,478	2,819,138	4,665,118	18,063,540	104,296,128	90,766,921	91,244,182	27,563,649	83,988,562
7	(57)	396,977	433,690	8,983,526	13,886,887	56,086,838	192,378,078	177,449,617	167,807,913	55,184,025	94,249,323
9	(59)	85,586	72,103	3,124,577	6,079,850	21,544,332	104,321,020	46,821,768	59,577,522	13,375,748	32,556,574
11	(61)	150,408	417,738	9,181,875	9,925,577	40,440,765	140,117,841	80,065,707	70,125,143	31,611,556	91,087,884
13	(63)	877,606	153,597	4,360,025	18,997,692	38,894,665	115,346,020	38,925,991	63,586,177	19,397,591	21,119,826
14	(63)	199,430	545,832	5,365,876	14,252,609	42,400,034	132,500,370	40,427,460	68,275,277	16,423,793	30,338,107
15	(63)	124,636	325,316	3,284,389	6,301,824	21,357,680	61,554,210	28,415,716	35,160,131	15,813,979	22,682,596
17	(65)	46,930	108,684	999,406	2,700,385	7,179,363	25,395,321	11,879,387	14,004,080	5,042,933	12,345,600
18	(65)	87,203	141,807	3,370,522	5,596,668	6,919,517	21,473,207	8,247,266	7,916,270	2,615,599	9,228,779
19	(65)	59,121	191,168	2,089,612	4,045,703	11,850,805	26,493,968	9,378,193	10,475,393	1,726,204	3,844,191
21	(10)	43,568	81,397	1,062,049	1,609,046	5,601,585	11,631,482	13,064,051	8,643,993	2,306,295	4,320,568
23	(12)	75,588	197,345	11,726,772	26,525,456	85,080,418	187,918,791	114,248,567	90,071,848	8,720,722	8,160,172
25	(11)	56,768	212,013	2,053,503	1,977,905	3,339,016	8,313,037	6,633,023	2,824,213	1,190,403	1,879,166
27	(85)	32,928	62,371	5,076,219	5,414,064	23,214,813	32,814,383	72,719,125	32,044,350	5,903,247	6,172,155
29	(87)	43,805	267,346	2,745,241	7,686,293	14,230,910	15,930,785	4,958,924	5,155,947	1,434,719	2,152,801
30	(87)	41,640	231,121	2,605,441	9,974,221	20,941,170	18,776,716	4,661,034	4,596,873	660,765	619,067
31	(87)	19,762	49,015	2,002,685	7,889,740	20,087,818	19,837,284	5,960,185	6,625,722	1,563,805	5,401,508
33	(89)	119,087	130,188	1,045,775	2,819,649	12,132,813	28,705,826	81,596,059	47,808,056	11,765,070	18,530,505
35	(91)	69,177	98,760	1,801,181	1,933,560	3,897,570	7,813,656	13,023,561	8,731,389	1,492,435	3,454,110
37	(93)	49,826	189,899	4,036,468	2,730,595	6,651,817	13,761,003	24,757,507	16,051,252	2,584,172	2,200,233
39	(95)	49,417	204,176	2,049,490	5,630,551	15,916,435	17,947,754	13,622,577	18,583,441	2,754,632	3,948,959
43	(97)	34,031	67,413	1,872,070	3,251,635	6,992,009	8,883,262	5,595,300	6,685,251	966,186	2,290,577
45	(99)	157,452	1,037,408	16,761,305	16,354,642	39,241,253	46,719,433	30,209,594	49,681,958	3,304,265	5,627,983
47	(101)	17,816	25,455	929,031	1,996,274	3,864,720	3,777,380	2,386,851	2,307,533	741,766	2,034,229
49	(105)	171,364	1,425,338	24,696,123	48,772,361	89,632,901	176,524,823	207,419,703	214,380,446	31,023,271	15,761,048
51	(2)	93,467	152,751	2,004,420	4,697,941	10,196,998	22,681,178	8,376,895	9,348,190	1,314,602	1,878,519
53	N	96,224	299,690	3,351,362	4,930,283	13,087,197	16,381,648	8,111,499	21,444,678	2,789,613	2,623,005
55	W	77,121	1,039,213	11,890,520	26,131,432	28,917,033	227,814,185	108,560,980	163,651,432	56,483,900	63,595,020
57	E	32,844	68,889	907,892	1,274,898	11,267,385	14,525,581	7,752,250	23,157,259	5,917,621	21,908,928
59	S	34,754	53,929	688,385	2,236,629	13,644,687	10,229,449	5,152,875	9,269,047	2,167,451	3,274,050

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Table 3 (continued). *n*-Aldehydes (abundance per g of sample)

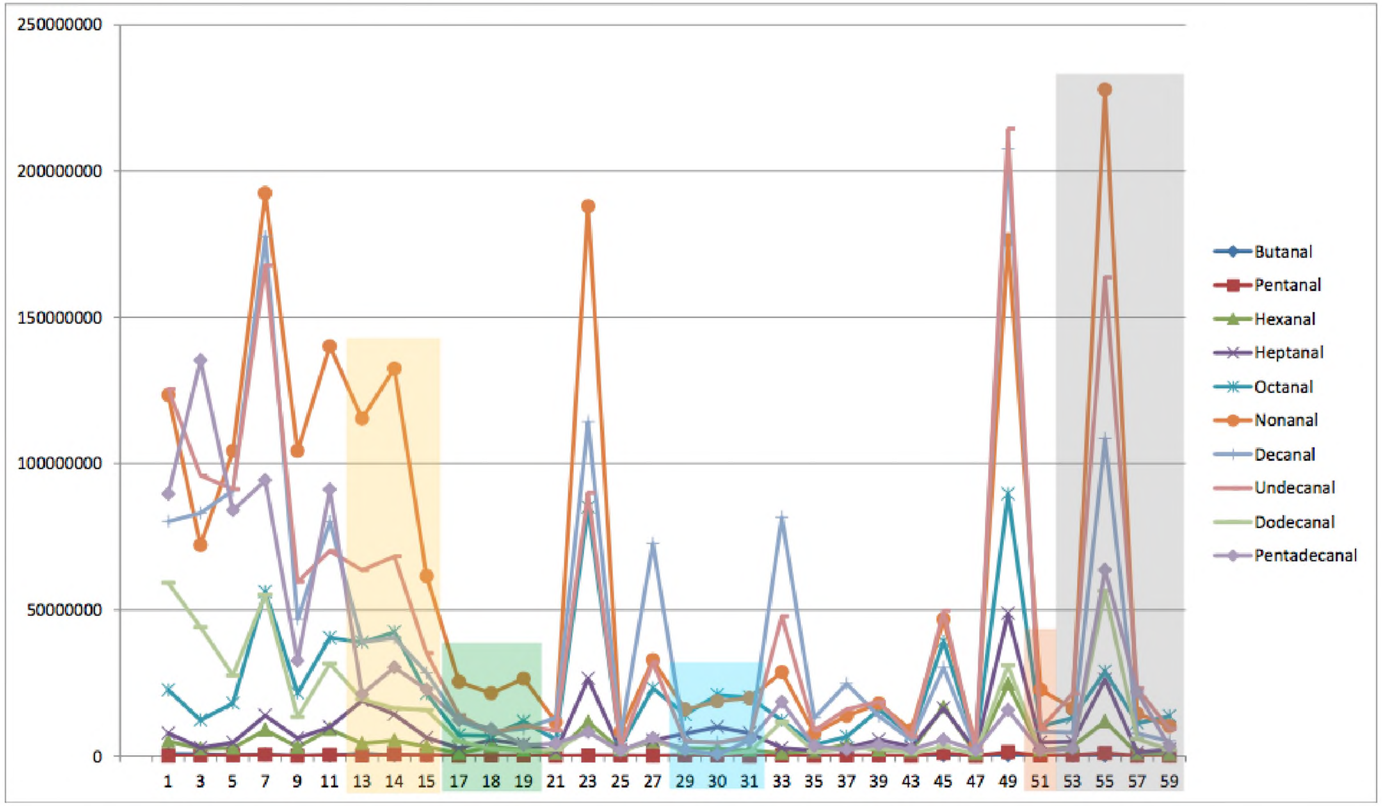

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Table 3 (continued). *n*-Aldehydes (abundance per sample as a percentage of the total abundance for samples 1 – 49)

Sample Number	Context Number	Butanal	Pentanal	Hexanal	Heptanal	Octanal	Nonanal	Decanal	Undecanal	Dodecanal	Pentadecanal
1	(51)	15.13	1.62	3.90	3.24	3.47	7.18	6.19	9.48	16.07	12.64
3	(53)	14.59	2.94	1.98	1.18	1.69	4.20	6.41	7.25	11.98	19.08
5	(55)	6.70	3.57	2.14	1.93	2.78	6.07	7.00	6.89	7.48	11.85
7	(57)	8.39	5.97	6.82	5.75	8.62	11.19	13.69	12.68	14.97	13.30
9	(59)	1.81	0.99	2.37	2.52	3.31	6.07	3.61	4.50	3.63	4.59
11	(61)	3.18	5.75	6.97	4.11	6.22	8.15	6.18	5.30	8.58	12.85
13	(63)	18.54	2.12	3.31	7.86	5.98	6.71	3.00	4.80	5.26	2.98
14	(63)	4.21	7.52	4.07	5.90	6.52	7.71	3.12	5.16	4.46	4.28
15	(63)	2.63	4.48	2.49	2.61	3.28	3.58	2.19	2.66	4.29	3.20
17	(65)	0.99	1.50	0.76	1.12	1.10	1.48	0.92	1.06	1.37	1.74
18	(65)	1.84	1.95	2.56	2.32	1.06	1.25	0.64	0.60	0.71	1.30
19	(65)	1.25	2.63	1.59	1.67	1.82	1.54	0.72	0.79	0.47	0.54
21	(10)	0.92	1.12	0.81	0.67	0.86	0.68	1.01	0.65	0.63	0.61
23	(12)	1.60	2.72	8.90	10.97	13.08	10.93	8.81	6.80	2.37	1.15
25	(11)	1.20	2.92	1.56	0.82	0.51	0.48	0.51	0.21	0.32	0.27
27	(85)	0.70	0.86	3.85	2.24	3.57	1.91	5.61	2.42	1.60	0.87
29	(87)	0.93	3.68	2.08	3.18	2.19	0.93	0.38	0.39	0.39	0.30
30	(87)	0.88	3.18	1.98	4.13	3.22	1.09	0.36	0.35	0.18	0.09
31	(87)	0.42	0.68	1.52	3.26	3.09	1.15	0.46	0.50	0.42	0.76
33	(89)	2.52	1.79	0.79	1.17	1.87	1.67	6.29	3.61	3.19	2.61
35	(91)	1.46	1.36	1.37	0.80	0.60	0.45	1.00	0.66	0.40	0.49
37	(93)	1.05	2.62	3.06	1.13	1.02	0.80	1.91	1.21	0.70	0.31
39	(95)	1.04	2.81	1.56	2.33	2.45	1.04	1.05	1.40	0.75	0.56
43	(97)	0.72	0.93	1.42	1.35	1.07	0.52	0.43	0.51	0.26	0.32
45	(99)	3.33	14.29	12.72	6.77	6.03	2.72	2.33	3.75	0.90	0.79
47	(101)	0.38	0.35	0.70	0.83	0.59	0.22	0.18	0.17	0.20	0.29
49	(105)	3.62	19.63	18.74	20.18	13.78	10.27	16.00	16.20	8.42	2.22
51	(2)	1.97	2.10	1.52	1.94	1.57	1.32	0.65	0.71	0.36	0.27
53	N	2.03	4.13	2.54	2.04	2.01	0.95	0.63	1.62	0.76	0.37
55	W	1.63	14.32	9.02	10.81	4.45	13.25	8.37	12.36	15.33	8.97
57	E	0.69	0.95	0.69	0.53	1.73	0.85	0.60	1.75	1.61	3.09
59	S	0.73	0.74	0.52	0.93	2.10	0.60	0.40	0.70	0.59	0.46

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Table 3 (continued). *n*-Aldehydes (abundance per sample as a percentage of the total abundance for samples 1 – 49)

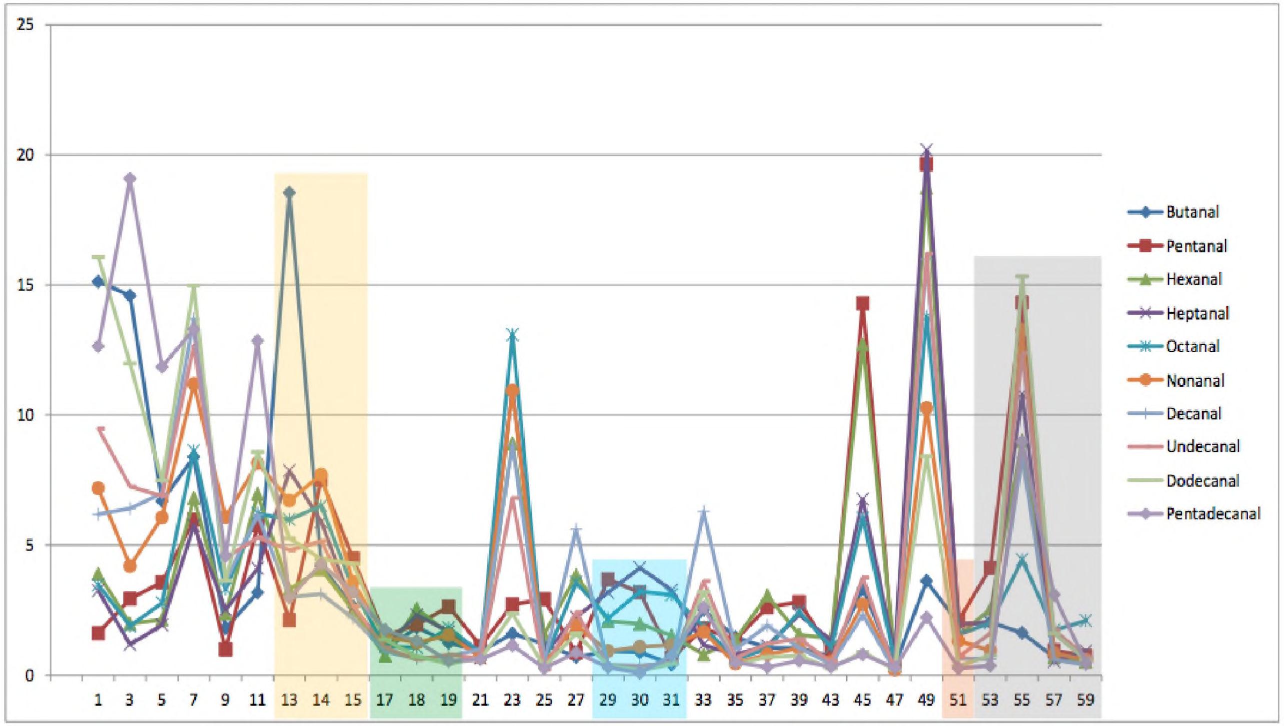

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Table 3 (continued). *n*-Aldehydes

- Ten aldehydes of this type were detected in the samples including butanal (C_4), pentanal (C_5), hexanal (C_6), heptanal (C_7), octanal (C_8), nonanal (C_9), decanal (C_{10}) undecanal (C_{11}) and pentadecanal (C_{15}).
- Of these the C_8-C_{11} aldehydes, octanal, nonanal, decanal, and unecanal were the most abundant homologues with abundance maxima for samples 1-15, 23, 27, 33, 45 and 49, and for the Western boundary sample (55).
- Nonanal (C_9) and decanal (C_{10}) are considered of significance for burial decomposition of bone.

Table 3 (continued). Aromatic hydrocarbons (abundance per g of sample)

Sample Number	Context Number	Benzene	Toluene	Ethylbenzene	Dimethylbenzene 1	Dimethylbenzene 2	Styrene	Methylisopropylbenzene	MethylethylBenzene	Ethylmethylbenzene	Methylisopropylbenzene 2	Dimethylstyrene 2	Pyridine
1	(51)	1,379,904	794,807	694,651	2,183,004	4,501,037	6,770,490	340,248	1,810,344	19,643,838	3,931,496	9,645,829	1,309,062
3	(53)	886,228	903,799	139,667	334,353	6,503,919	1,930,046	2,790,522	217,472	667,811	15,893,677	12,224,672	539,389
5	(55)	497,354	2,470,647	323,916	1,339,885	30,550,189	4,145,072	10,070,766	4,412,653	33,840,686	35,072,772	30,556,340	636,994
7	(57)	624,340	2,333,537	451,654	1,308,763	58,374,271	2,262,532	24,832,746	2,724,560	13,927,778	37,183,632	19,549,618	560,112
9	(59)	456,956	2,960,555	600,328	1,288,154	1,512,272	1,040,637	370,373	1,089,619	4,657,560	532,823	5,643,835	821,141
11	(61)	780,329	5,245,809	555,703	1,784,867	4,624,230	2,230,804	312,932	4,641,780	25,199,118	3,054,757	6,215,151	1,294,263
13	(63)	1,069,732	3,143,054	625,293	1,082,155	2,691,259	3,522,688	227,496	6,817,960	23,989,654	595,706	2,385,894	730,795
14	(63)	470,445	2,712,388	480,671	917,140	999,259	794,611	83,930	1,349,418	6,490,990	532,516	2,963,620	586,877
15	(63)	288,554	1,456,995	293,408	629,414	747,220	575,851	192,165	486,062	1,346,348	2,093,886	3,893,365	322,264
17	(65)	128,323	439,029	274,754	542,505	472,704	268,910	19,270	577,175	1,525,816	188,598	513,240	335,293
18	(65)	247,599	490,852	234,231	285,332	307,156	1,902,029	140,898	1,221,670	2,807,770	329,580	760,849	362,558
19	(65)	136,450	413,422	109,924	109,630	156,518	162,187	45,980	221,850	1,074,290	180,218	418,050	616,503
21	(10)	225,977	426,626	152,073	282,956	573,183	218,112	45,482	236,717	1,044,482	237,445	303,169	728,814
23	(12)	109,777	443,060	586,217	1,353,334	593,599	505,213	95,557	4,242,738	28,166,863	5,873,978	2,526,459	1,778,992
25	(11)	170,370	723,197	246,548	211,486	446,649	211,581	48,834	236,758	828,713	115,096	378,748	514,194
27	(85)	161,268	3,182,096	897,366	2,111,309	2,391,884	3,353,911	771,862	5,869,178	40,710,471	12,573,825	3,276,724	3,847,113
29	(87)	222,835	1,137,945	192,334	532,654	1,750,623	595,033	104,908	677,072	1,729,915	183,947	470,163	1,085,993
30	(87)	118,239	838,107	148,372	354,192	1,782,135	535,694	66,988	430,876	1,040,263	206,064	300,259	1,128,684
31	(87)	157,796	1,647,393	370,612	767,557	1,425,589	800,845	43,855	555,909	1,757,085	613,864	512,591	1,476,788
33	(89)	813,823	1,770,348	201,721	1,516,156	3,827,757	3,362,882	384,866	1,238,072	5,411,213	1,309,759	4,074,948	1,423,798
35	(91)	307,690	439,796	150,556	463,250	1,512,480	1,028,863	113,431	558,111	991,778	147,469	492,450	940,155
37	(93)	86,269	614,596	144,917	306,295	789,814	818,634	127,643	785,139	1,920,924	1,038,990	3,044,104	2,033,316
39	(95)	256,784	1,809,172	2,305,643	968,031	3,548,264	41,473,766	99,077	963,049	603,815	700,969	1,103,157	2,342,118
43	(97)	144,261	2,299,301	2,750,270	914,576	3,504,511	307,535,307	117,768	1,066,959	732,156	323,099	1,019,990	2,508,091
45	(99)	245,844	1,125,668	1,861,073	614,922	7,461,869	68,219,544	168,844	1,137,612	762,409	923,779	561,913	3,088,643
47	(101)	52,259	563,053	909,305	206,972	2,262,730	53,482,112	293,166	465,312	270,534	1,168,845	1,351,608	1,701,649
49	(105)	583,020	9,628,505	2,670,651	2,406,824	12,439,864	34,727,305	1,159,286	5,799,122	6,860,301	8,767,554	6,448,715	2,245,288
51	(2)	262,433	1,071,871	1,775,783	784,180	10,965,454	30,863,922	82,730	1,257,730	1,200,615	672,881	511,122	554,164
53	N	627,676	4,468,157	3,258,347	7,911,844	33,254,455	43,586,573	205,642	4,285,951	6,761,542	767,019	759,664	1,069,933
55	W	446,705	2,417,655	1,382,050	1,514,261	14,055,564	18,741,592	663,307	1,089,439	3,245,907	12,990,592	12,891,354	2,035,972
57	E	136,354	163,403	332,761	259,534	217,480	3,055,338	15,498	97,917	220,165	779,374	727,670	702,792
59	S	117,908	275,714	222,640	170,672	1,865,821	5,132,505	62,031	196,157	290,699	83,628	312,034	585,048

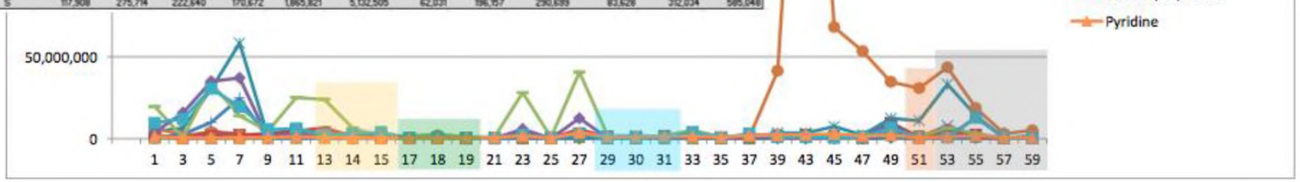

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Table 3 (continued). Aromatic hydrocarbons (abundance per sample as a percentage of the total abundance for samples 1 – 49)

Sample Number	Context Number	Benzene	Toluene	Ethylbenzene	Dimethylbenzene 1	Dimethylbenzene 2	Styrene	Methylisopropylbenzene	MethylethylBenzene	Ethylmethylbenzene	Methylisopropylbenzene 2	Dimethylstyrene 2	Pyridine
1	(51)	12.99	1.59	3.78	8.80	2.89	1.25	0.79	3.63	8.62	2.94	8.00	3.74
3	(53)	8.34	1.81	0.76	1.35	4.18	0.36	6.48	0.44	0.29	11.88	10.13	1.54
5	(55)	4.68	4.94	1.76	5.40	19.61	0.76	23.38	8.85	14.84	26.22	25.33	1.82
7	(57)	5.88	4.67	2.46	5.27	37.48	0.42	57.66	5.47	6.11	27.80	16.21	1.60
9	(59)	4.30	5.92	3.27	5.19	0.97	0.19	0.86	2.19	2.04	0.40	4.68	2.35
11	(61)	7.35	10.49	3.02	7.19	2.97	0.41	0.73	9.31	11.05	2.28	5.15	3.70
13	(63)	10.07	6.28	3.40	4.36	1.73	0.65	0.53	13.68	10.52	0.45	1.98	2.09
14	(63)	4.43	5.42	2.62	3.70	0.64	0.15	0.19	2.71	2.85	0.40	2.46	1.68
15	(63)	2.72	2.91	1.60	2.54	0.48	0.11	0.45	0.98	0.59	1.57	3.23	0.92
17	(65)	1.21	0.88	1.50	2.19	0.30	0.05	0.04	1.16	0.67	0.14	0.43	0.96
18	(65)	2.33	0.98	1.27	1.15	0.20	0.35	0.33	2.45	1.23	0.25	0.63	1.04
19	(65)	1.28	0.83	0.60	0.44	0.10	0.03	0.11	0.45	0.47	0.13	0.35	1.76
21	(10)	2.13	0.85	0.83	1.14	0.37	0.04	0.11	0.48	0.46	0.18	0.25	2.08
23	(12)	1.03	0.89	3.19	5.45	0.38	0.09	0.22	8.51	12.35	4.39	2.09	5.09
25	(11)	1.60	1.45	1.34	0.85	0.29	0.04	0.11	0.48	0.36	0.09	0.31	1.47
27	(85)	1.52	6.36	4.88	8.51	1.54	0.62	1.79	11.78	17.86	9.40	2.72	11.00
29	(87)	2.10	2.28	1.05	2.15	1.12	0.11	0.24	1.36	0.76	0.14	0.39	3.11
30	(87)	1.11	1.68	0.81	1.43	1.14	0.10	0.16	0.86	0.46	0.15	0.25	3.23
31	(87)	1.49	3.29	2.02	3.09	0.92	0.15	0.10	1.12	0.77	0.46	0.42	4.22
33	(89)	7.66	3.54	1.10	6.11	2.46	0.62	0.89	2.48	2.37	0.98	3.38	4.07
35	(91)	2.90	0.88	0.82	1.87	0.97	0.19	0.26	1.12	0.43	0.11	0.41	2.69
37	(93)	0.81	1.23	0.79	1.23	0.51	0.15	0.30	1.58	0.84	0.78	2.52	5.82
39	(95)	2.42	3.62	12.55	3.90	2.28	7.65	0.23	1.93	0.26	0.52	0.91	6.70
43	(97)	1.36	4.60	14.97	3.69	2.25	56.69	0.27	2.14	0.32	0.24	0.85	7.17
45	(99)	2.31	2.25	10.13	2.48	4.79	12.58	0.39	2.28	0.33	0.69	0.47	8.84
47	(101)	0.49	1.13	4.95	0.83	1.45	9.86	0.68	0.93	0.12	0.87	1.12	4.87
49	(105)	5.49	19.25	14.54	9.70	7.99	6.40	2.69	11.64	3.01	6.55	5.35	6.42
51	(2)	2.47	2.14	9.67	3.16	7.04	5.69	0.19	2.52	0.53	0.50	0.42	1.59
53	N	5.91	8.93	17.79	31.88	21.35	8.03	0.48	8.60	2.97	0.57	0.63	3.06
55	W	4.21	4.83	7.52	6.10	9.02	3.45	1.54	2.19	1.42	9.71	10.69	5.82
57	E	1.28	0.33	1.81	1.05	0.14	0.56	0.04	0.20	0.10	0.58	0.60	2.01
59	S	1.11	0.55	1.21	0.69	1.20	0.95	0.14	0.39	0.13	0.06	0.26	1.67

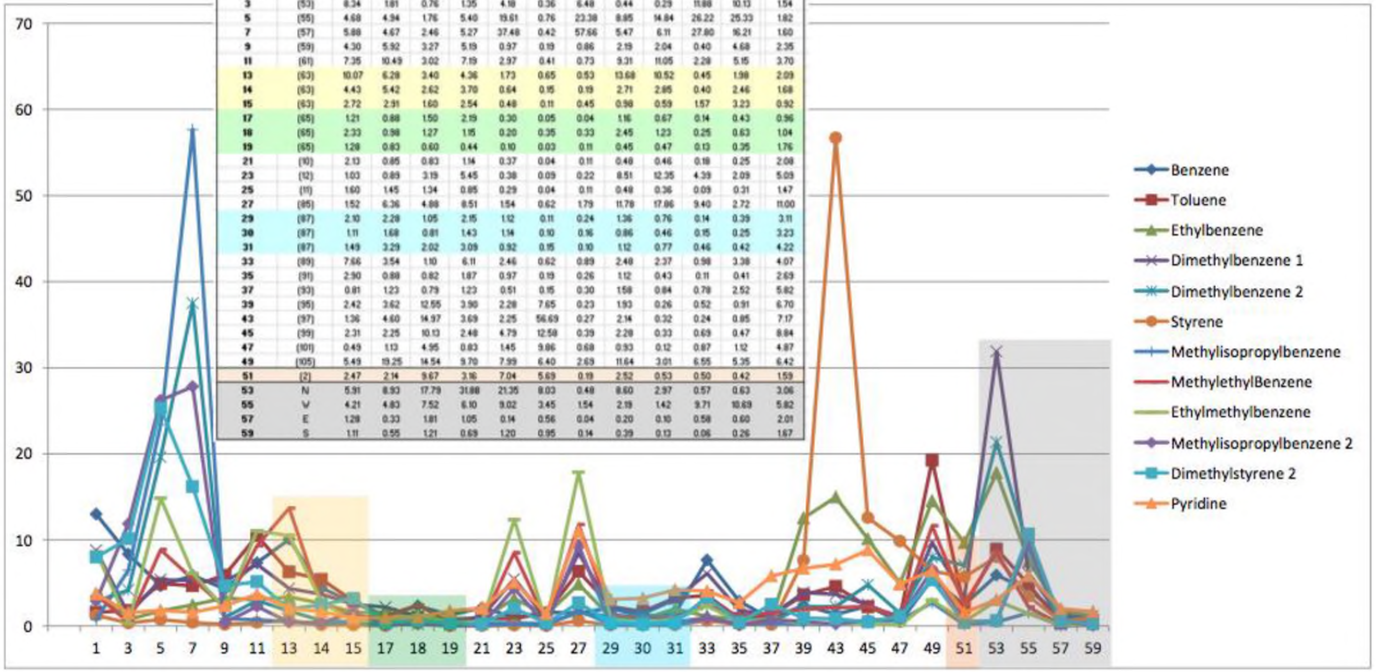

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Table 3 (continued). Aromatic hydrocarbons

- Eleven members of this class of compound, including benzene, toluene, ethyl benzene, ethylmethyl benzene, styrene, dimethyl styrene (or ethyl styrene), and multiple isomers of dimethyl benzene and methylisopropy benzene (or diethyl benzene) were detected in the samples. In addition the aromatic nitrogen-containing heterocyclic compound pyridine was detected.
- Abundance maxima for aromatic compounds were seen for samples 5, 7, 11, 13, 23, 27, 39 - 45 and 49, and for the Northern boundary sample (53). Interestingly, there is a shift in the dominant aromatics present in the samples when moving from eastern to western cells (low to high sample numbers). The methylisopropylbenzenes and one of the dimethylbenzenes (or ethylbenzene) dominate the distribution for samples 5 and 7, whereas the methylethyl/ethymethyl benzenes dominate for samples 11, 13, 23 and 27. Styrene and ethylbenzene (or dimethylbenzene) dominate at sample 43 and toluene and ethylbenzene (or dimethylbenzene) dominate at sample 49. The dimethylbenzenes/ethylbenzene and toluene dominate in the Northern boundary sample (53).
- Pyridine shows abundance maxima at samples 23, 27, 37-49 and the Western boundary sample (55).
- Benzene, toluene (methyl benzene), isomers of dimethyl benzene (xylenes), ethy methyl benzene and styrene (ethenyl benzene) are associated with mammalian decomposition but are considered to be non-specific.

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Table 3 (continued). Carboxylic acids (abundance per g of sample)

Sample Number	Context Number	Acetic acid	Propanoic acid	Butanoic acid	Hexanoic acid	Heptanoic acid	Octanoic acid	Nonanoic acid	Benzoic acid
1	(51)	8,937,494	7,760	756,142	1,869,551	177,471	428,638	921,240	17,362,324
3	(53)	1,999,910	138,908	154,856	529,794	169,974	743,913	786,832	2,870,596
5	(55)	4,633,242	448,250	299,481	2,135,468	372,098	1,161,697	915,992	8,469,679
7	(57)	1,802,712	249,776	254,078	5,008,234	944,633	3,137,320	2,973,155	8,177,246
9	(59)	15,745,250	1,277,384	798,542	535,596	94,170	843,977	668,439	76,741,082
11	(61)	9,174,871	545,007	560,415	9,332,082	1,194,590	2,848,836	2,496,009	21,811,004
13	(63)	2,206,678	305,377	140,098	612,268	136,622	674,835	1,289,670	11,937,252
14	(63)	9,887,800	1,211,751	1,154,537	1,511,788	401,032	2,293,019	2,421,921	93,231,155
15	(63)	3,976,633	422,703	469,494	2,581,301	408,633	2,302,480	2,063,014	76,894,246
17	(65)	2,212,370	117,413	181,395	1,777,832	205,642	1,116,482	556,404	7,957,084
18	(65)	1,839,005	120,449	27,824	2,316,704	232,937	751,339	485,572	2,981,965
19	(65)	1,253,897	69,428	114,180	606,345	83,558	299,487	222,008	2,505,143
21	(10)	638,872	28,941	53,585	539,625	66,657	283,283	243,268	1,075,913
23	(12)	2,208,386	42,935	51,632	4,483,024	476,719	1,767,729	1,212,956	8,468,929
25	(11)	5,311,160	194,065	185,661	551,477	69,443	381,020	383,730	2,634,635
27	(85)	4,102,629	296,102	209,508	1,090,792	129,155	422,472	343,924	6,675,525
29	(87)	4,925,247	292,126	226,355	186,448	26,005	133,509	126,128	2,366,340
30	(87)	2,020,864	133,787	9,928	617,824	66,731	233,738	226,958	827,752
31	(87)	1,239,264	71,091	51,413	576,747	52,796	160,891	262,212	1,856,343
33	(89)	7,365,444	307,694	374,808	891,061	119,890	666,233	604,096	52,823,218
35	(91)	4,597,194	125,299	223,531	488,950	62,430	310,847	326,683	8,534,539
37	(93)	1,921,945	144,675	132,153	250,350	7,270	496,204	80,407	3,507,830
39	(95)	4,228,542	235,701	292,156	46,610	3,114	113,931	34,791	16,889,180
43	(97)	5,969,684	43,124	73,985	114,900	23,999	61,481	44,383	11,685,813
45	(99)	11,792,570	559,363	887,775	51,372	11,543	78,128	59,055	34,550,973
47	(101)	4,425,529	286,400	416,161	77,795	10,339	31,619	16,762	6,716,089
49	(105)	8,787,335	488,231	510,432	536,891	116,027	465,352	786,762	35,031,294
51	(2)	1,826,128	73,691	43,855	31,910	2,862	73,123	23,393	1,638,418
53	N	4,531,531	255,294	103,962	67,097	8,514	102,423	32,283	5,569,396
55	W	2,812,990	145,885	157,894	624,291	68,871	140,607	149,762	21,956,810
57	E	1,198,194	47,963	52,320	39,422	7,169	67,800	60,281	21,163,871
59	S	3,122,917	117,318	136,931	33,675	11,471	51,964	16,734	6,045,775

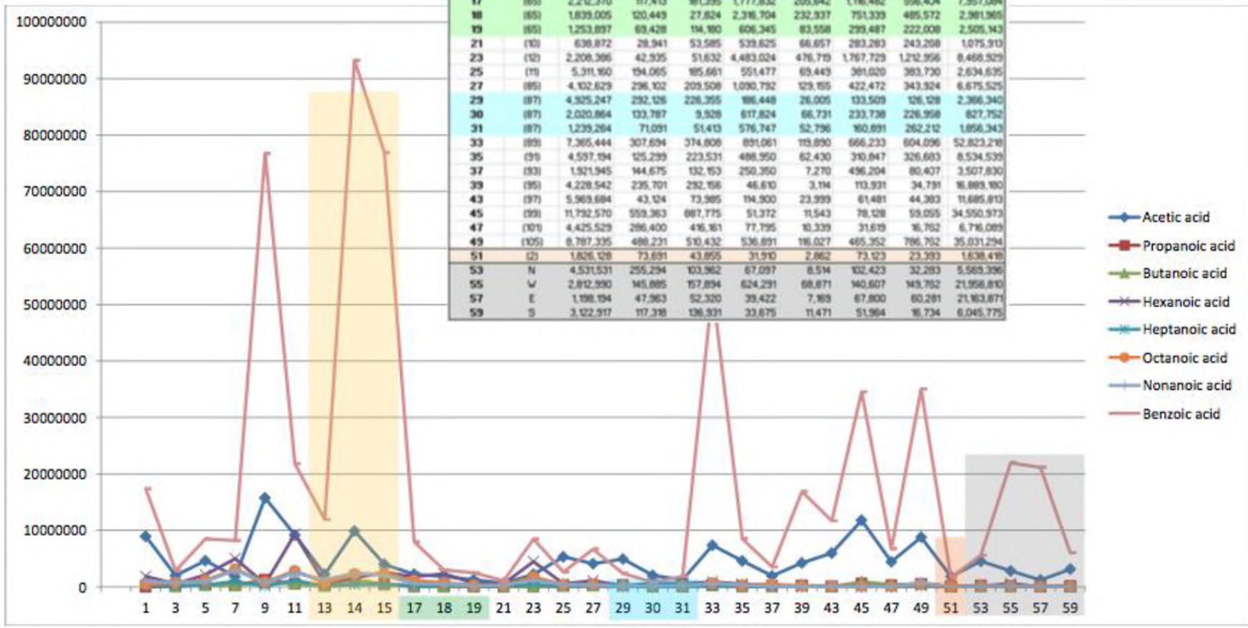

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Table 3 (continued). Carboxylic acids (abundance per sample as a percentage of the total abundance for samples 1 – 49)

Sample Number	Content Number	Acetic acid	Propanoic acid	Butanoic acid	Hexanoic acid	Heptanoic acid	Octanoic acid	Nonanoic acid	Benzoic acid
1	(51)	6.71	0.10	8.78	4.75	3.13	1.93	4.48	3.31
3	(53)	1.50	1.70	1.80	1.35	3.00	3.35	3.83	0.55
5	(55)	3.48	5.49	3.48	5.43	6.57	5.23	4.46	1.61
7	(57)	1.35	3.06	2.95	12.74	16.68	14.13	14.47	1.56
9	(59)	11.82	15.65	9.27	1.36	1.66	3.80	3.25	14.63
11	(61)	6.89	6.68	6.51	23.73	21.09	12.83	12.14	4.16
13	(63)	1.66	3.74	1.63	1.56	2.41	3.04	6.28	2.28
14	(63)	7.42	14.84	13.41	3.84	7.08	10.32	11.78	17.77
15	(63)	2.99	5.18	5.45	6.56	7.22	10.37	10.04	14.66
17	(65)	1.66	1.44	2.11	4.52	3.63	5.03	2.71	1.52
18	(65)	1.38	1.48	0.32	5.89	4.11	3.38	2.36	0.57
19	(65)	0.94	0.85	1.33	1.54	1.48	1.35	1.08	0.48
21	(10)	0.48	0.35	0.62	1.37	1.18	1.28	1.18	0.21
23	(12)	1.66	0.53	0.60	11.40	8.42	7.96	5.90	1.61
25	(11)	3.99	2.38	2.16	1.40	1.23	1.72	1.87	0.50
27	(85)	3.08	3.63	2.43	2.77	2.28	1.90	1.67	1.27
29	(87)	3.70	3.58	2.63	0.47	0.46	0.60	0.61	0.45
30	(87)	1.52	1.64	0.12	1.57	1.18	1.05	1.10	0.16
31	(87)	0.93	0.87	0.60	1.47	0.93	0.72	1.28	0.35
33	(89)	5.53	3.77	4.35	2.27	2.12	3.00	2.94	10.07
35	(91)	3.45	1.53	2.60	1.24	1.10	1.40	1.59	1.63
37	(93)	1.44	1.77	1.53	0.64	0.13	2.23	0.39	0.67
39	(95)	3.17	2.89	3.39	0.12	0.05	0.51	0.17	3.22
43	(97)	4.48	0.53	0.86	0.29	0.42	0.28	0.22	2.23
45	(99)	8.85	6.85	10.31	0.13	0.20	0.35	0.29	6.59
47	(101)	3.32	3.51	4.83	0.20	0.18	0.14	0.08	1.28
49	(105)	6.60	5.98	5.93	1.37	2.05	2.10	3.83	6.68
51	(2)	1.37	0.90	0.51	0.08	0.05	0.33	0.11	0.31
53	N	3.40	3.13	1.21	0.17	0.15	0.46	0.16	1.06
55	W	2.11	1.79	1.83	1.59	1.22	0.63	0.73	4.19
57	E	0.90	0.59	0.61	0.10	0.13	0.31	0.29	4.03
59	S	2.34	1.44	1.59	0.09	0.20	0.23	0.08	1.15

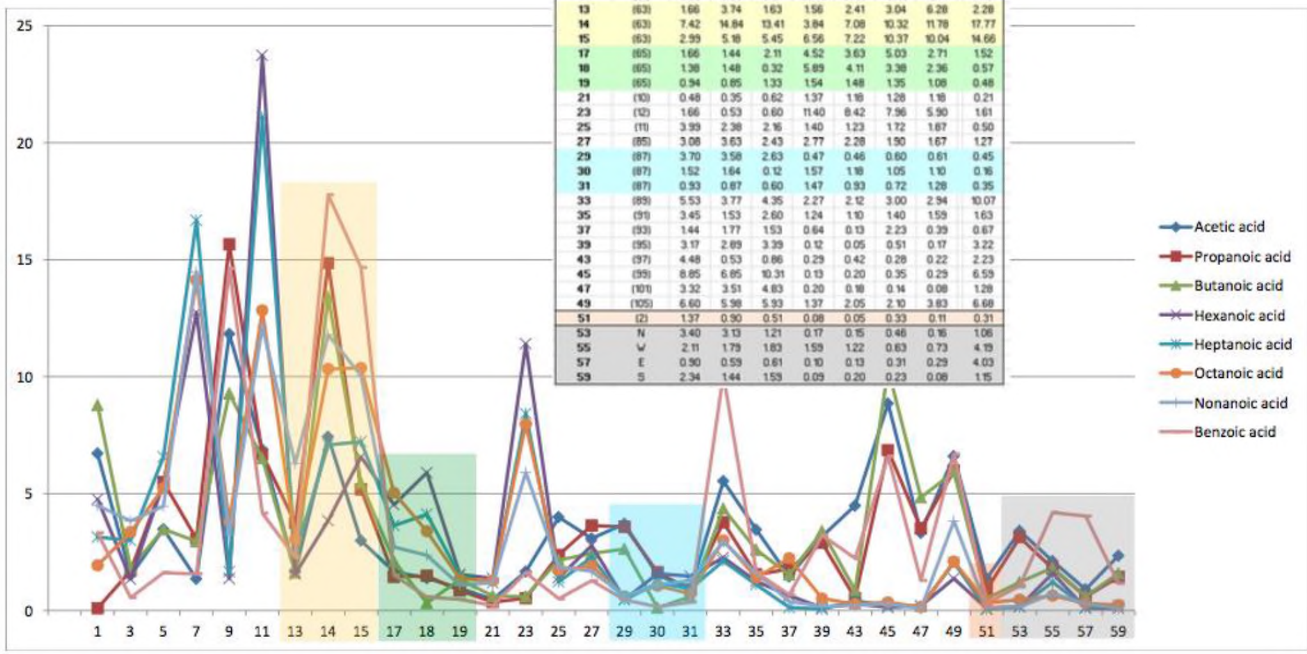

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Table 3 (continued). Carboxylic acids

- The methyl ester of hexadecanoic acid (C_{16}) is associated with early stage decomposition.

- Long chain C_{16} fatty acids were not found in the samples, however, seven shorter chain free fatty acids in the range C_2 - C_9, acetic (C_2), propanoic (C_3), butanoic (C_4), hexanoic (C_6), heptanoic (C_7), octanoic (C_8) and nonanoic (C_9) acids were detected in the samples. In addition the aromatic compound benzoic acid was also present.

- There is a sample location difference in the distribution of the C_2-C_9 acids which is related to acid chain length. The longer C_6-C_9 (hexanoic, heptanoic, octanoic and nonanoic) acids predominate at sample locations 7, 11, 14, 15 and 23, whereas the shorter C_2-C_4 (acetic, propanoic and butanoic) acids predominate for samples 9, 14, 33, 45 and 49. Acetic and propanoic acids dominate the Northern boundary sample (53).

- The aromatic benzoic acid has abundance maxima for samples 9, 14, 15, 33, 39 – 49 and for the Western (55) and Eastern (57) boundary samples.

Table 3 (continued). Unsaturated aldehydes (abundance per g of sample)

Sample Number	Context Number	2-Hexenal	2-Heptenal	2-Octenal	2-Nonenal	2-Decenal	2,4-Nonadienal
1	(51)	524,962	2,189,826	14,755,975	31,302,445	35,133,365	1,991,880
3	(53)	123,288	1,146,607	18,541,108	21,605,178	33,683,089	1,859,656
5	(55)	349,007	2,262,592	21,879,631	17,511,436	26,395,186	1,939,782
7	(57)	455,187	3,585,456	18,895,448	41,854,316	48,452,930	2,847,919
9	(59)	323,311	1,361,161	23,876,301	22,634,910	12,991,901	759,407
11	(61)	603,520	3,391,797	25,866,008	27,212,070	22,919,132	2,560,125
13	(63)	792,967	1,562,802	59,699,903	20,942,872	26,704,236	923,994
14	(63)	446,313	983,995	37,655,149	20,072,808	27,246,178	857,356
15	(63)	357,999	834,384	27,927,206	18,289,683	15,411,939	1,137,571
17	(65)	195,170	295,179	12,619,443	6,518,301	3,201,033	220,218
18	(65)	609,511	588,609	14,990,214	9,618,882	2,115,373	187,525
19	(65)	242,295	392,945	10,001,785	7,094,764	2,910,982	190,676
21	(10)	158,162	364,201	2,171,879	5,906,652	2,043,875	149,184
23	(12)	1,818,458	7,215,438	32,275,774	60,855,601	21,665,472	1,695,202
25	(11)	131,197	258,796	2,663,495	5,543,910	1,127,203	85,518
27	(85)	436,691	2,237,696	10,940,523	29,850,341	6,571,054	518,046
29	(87)	316,621	626,685	8,234,087	13,385,495	2,232,027	85,445
30	(87)	285,071	531,903	7,852,657	13,843,806	2,101,881	69,841
31	(87)	217,002	613,871	2,921,877	13,302,384	2,175,694	106,464
33	(89)	362,565	853,448	4,770,023	45,884,916	8,788,940	696,674
35	(91)	175,376	321,318	4,873,376	7,366,702	1,356,236	130,875
37	(93)	271,955	691,044	2,258,398	17,054,828	2,245,837	286,381
39	(95)	412,259	315,721	1,097,893	10,007,920	3,214,935	129,142
43	(97)	427,059	393,303	1,504,223	6,513,523	1,047,344	82,089
45	(99)	1,750,075	3,149,017	4,790,909	11,406,565	8,376,028	1,042,941
47	(101)	142,229	271,849	1,301,780	5,357,205	598,979	79,165
49	(105)	1,737,670	4,840,230	61,520,916	93,791,309	58,512,788	3,732,470
51	(2)	327,256	514,394	940,867	5,645,595	1,406,962	111,404
53	N	888,294	1,828,254	1,231,033	11,340,654	1,293,901	333,613
55	W	1,408,249	14,025,693	33,035,738	70,603,367	37,758,743	3,093,335
57	E	174,311	1,521,281	696,346	8,678,295	2,950,879	287,798
59	S	173,741	646,113	530,445	9,268,297	1,118,240	83,971

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Table 3 (continued). Unsaturated aldehydes (abundance per g of sample)

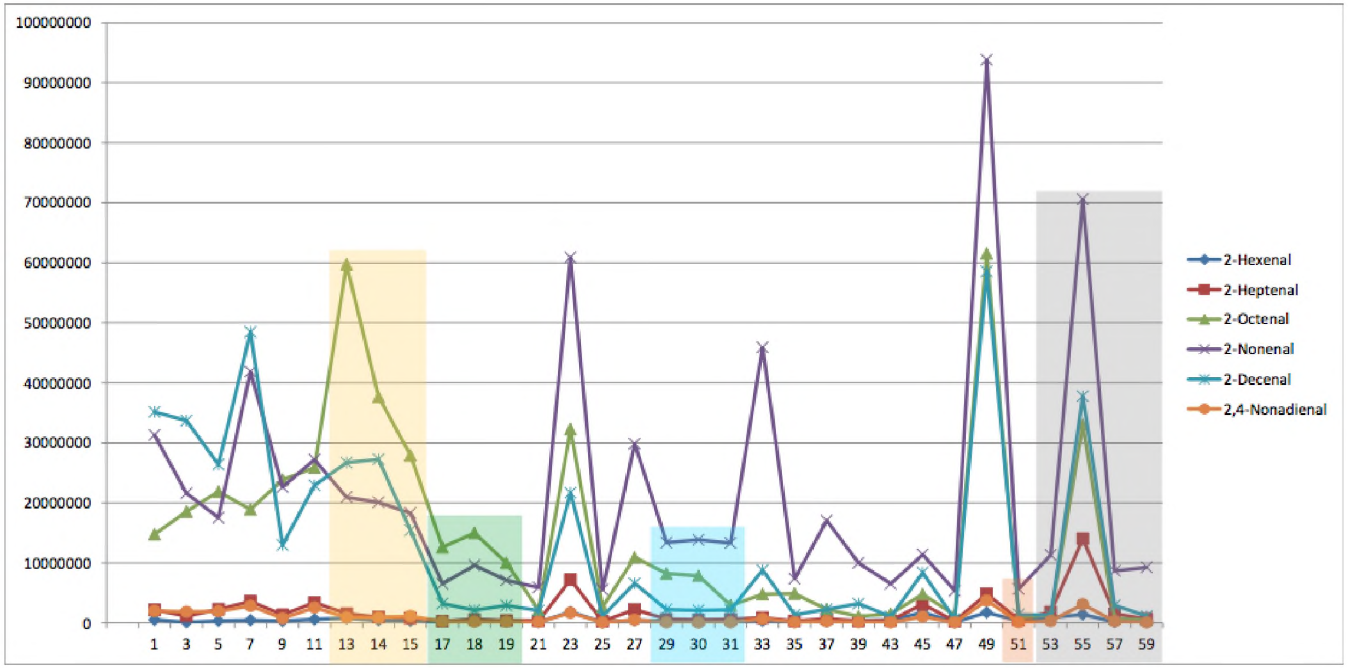

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Table 3 (continued). Unsaturated aldehydes (abundance per sample as a percentage of the total abundance for samples 1 – 49)

Sample Number	Context Number	2-Hexenal	2-Heptenal	2-Octenal	2-Nonenal	2-Decenal	2,4-Nonadienal
1	(51)	3.84	5.30	3.39	5.35	9.26	8.17
3	(53)	0.90	2.78	4.25	3.69	8.88	7.63
5	(55)	2.55	5.48	5.02	2.99	6.96	7.96
7	(57)	3.33	8.69	4.33	7.16	12.78	11.69
9	(59)	2.37	3.30	5.48	3.87	3.43	3.12
11	(61)	4.42	8.22	5.93	4.65	6.04	10.51
13	(63)	5.80	3.79	13.70	3.58	7.04	3.79
14	(63)	3.27	2.38	8.64	3.43	7.18	3.52
15	(63)	2.62	2.02	6.41	3.13	4.06	4.67
17	(65)	1.43	0.72	2.90	1.11	0.84	0.90
18	(65)	4.46	1.43	3.44	1.65	0.56	0.77
19	(65)	1.77	0.95	2.29	1.21	0.77	0.78
21	(10)	1.16	0.88	0.50	1.01	0.54	0.61
23	(12)	13.31	17.48	7.40	10.41	5.71	6.96
25	(11)	0.96	0.63	0.61	0.95	0.30	0.35
27	(85)	3.20	5.42	2.51	5.10	1.73	2.13
29	(87)	2.32	1.52	1.89	2.29	0.59	0.35
30	(87)	2.09	1.29	1.80	2.37	0.55	0.29
31	(87)	1.59	1.49	0.67	2.27	0.57	0.44
33	(89)	2.65	2.07	1.09	7.85	2.32	2.86
35	(91)	1.28	0.78	1.12	1.26	0.36	0.54
37	(93)	1.99	1.67	0.52	2.92	0.59	1.18
39	(95)	3.02	0.76	0.25	1.71	0.85	0.53
43	(97)	3.12	0.95	0.35	1.11	0.28	0.34
45	(99)	12.81	7.63	1.10	1.95	2.21	4.28
47	(101)	1.04	0.66	0.30	0.92	0.16	0.32
49	(105)	12.72	11.73	14.11	16.04	15.43	15.32
51	(2)	2.39	1.25	0.22	0.97	0.37	0.46
53	N	6.50	4.43	0.28	1.94	0.34	1.37
55	W	10.30	33.98	7.58	12.07	9.96	12.70
57	E	1.28	3.69	0.16	1.48	0.78	1.18
59	S	1.27	1.57	0.12	1.59	0.29	0.34

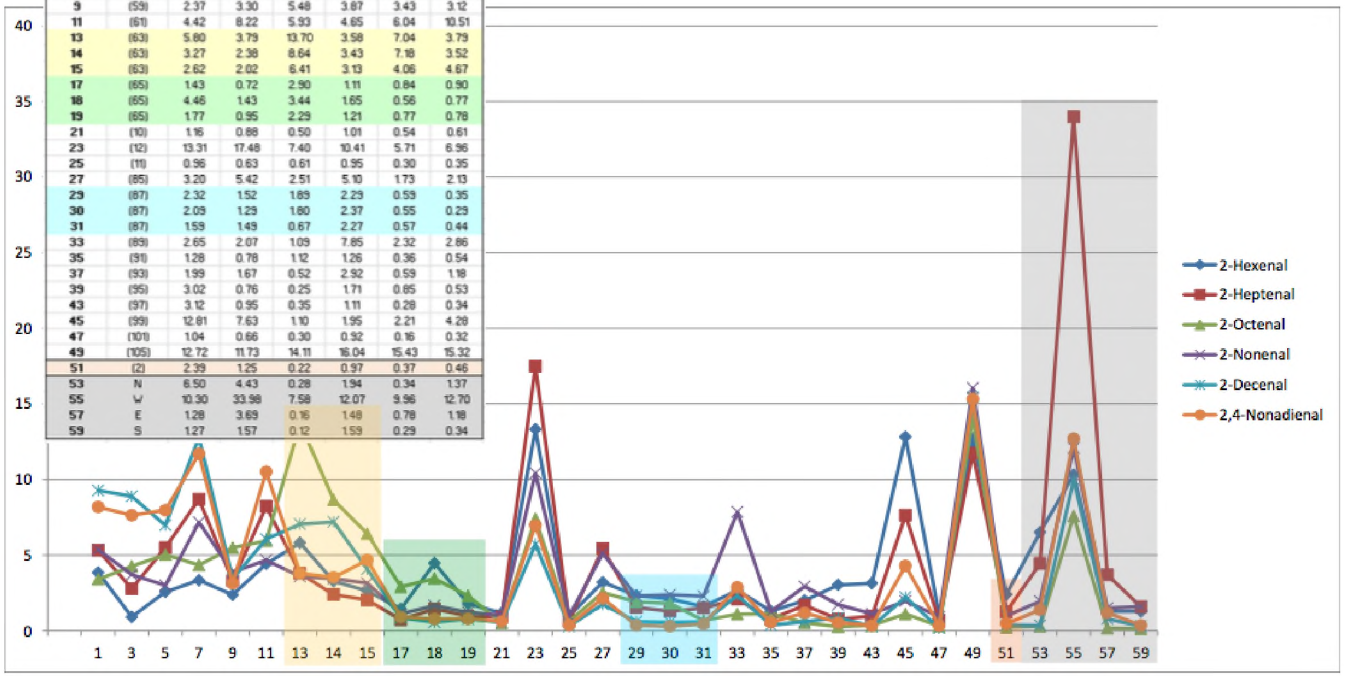

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Table 3 (continued). Unsaturated aldehydes

- 2-Alkenals in the range C_6 –C_{10} were detected in the samples, consisting of 2-hexenal (C_6), 2-heptenal (C_7), 2-octenal (C_8), 2-nonenal (C_9) and 2-decenal (C_{10}). In addition, 2,4-nonadienal (C_9) was also present.
- The C_8-C_{10} unsaturated aldehydes 2-octenal, 2-nonenal and 2-decenal were most abundant, followed by the C_6 and C_7 compounds 2-hexenal and 2-heptenal and the C_9 2,4-nonadienal.
- Abundance maxima were observed for samples 1-15, 23, 27, 33, 49, and for the Western boundary sample (55). This distribution profile is very similar to that seen for the saturated C_8-C_{10} *n*-aldehydes octanal, nonanal and decanal, providing further evidence for a common origin for both classes of compound.

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Table 3 (continued). Alkanes (abundance per g of sample)

Sample Number	Context Number	Decane	Undecane	Dodecane	Tridecane	Tetradecane	Pentadecane	Hexadecane	Heptadecane	Octadecane
1	(51)	1,336,268	1,745,987	22,625,379	40,137,565	49,174,757	100,007,654	175,559,678	280,640,026	214,489,965
3	(53)	382,922	1,091,996	15,789,842	103,089,456	35,383,818	22,399,324	71,679,916	42,960,783	53,096,919
5	(55)	771,112	1,580,031	18,055,897	51,181,635	28,936,076	12,699,247	50,764,428	43,135,198	35,157,299
7	(57)	1,459,060	1,760,400	29,320,548	92,203,183	41,737,856	26,040,811	60,442,437	55,756,768	63,001,922
9	(59)	438,164	1,760,334	16,232,505	15,224,787	6,910,887	7,930,298	18,508,006	28,971,630	15,600,473
11	(61)	853,553	1,522,162	17,996,658	64,356,602	15,395,909	28,686,307	43,292,585	67,010,913	47,809,640
13	(63)	760,062	1,083,810	12,464,591	42,899,269	13,254,391	13,220,358	25,933,663	12,430,006	9,806,387
14	(63)	262,854	1,106,559	14,616,181	22,108,962	6,010,381	14,543,178	14,011,030	84,484,243	9,448,905
15	(63)	240,149	407,581	11,453,918	39,755,401	9,780,206	13,207,348	19,800,409	24,099,337	9,221,686
17	(65)	177,215	204,524	3,398,963	9,280,758	2,078,226	3,788,514	4,867,259	9,700,820	4,855,939
18	(65)	815,062	583,087	3,870,034	8,495,340	2,814,427	6,204,875	6,571,761	11,366,559	5,191,782
19	(65)	218,663	137,910	2,163,584	3,369,164	1,069,421	2,637,432	4,139,923	8,910,402	5,619,523
21	(10)	211,555	249,276	2,821,609	18,611,803	3,032,100	5,793,355	6,419,195	8,404,868	3,792,845
23	(12)	1,778,864	1,312,402	9,847,380	42,030,231	6,268,042	5,595,192	9,771,973	16,133,047	5,228,300
25	(11)	217,913	198,705	1,458,848	5,524,505	816,401	1,522,059	1,808,899	4,038,417	1,323,179
27	(85)	986,726	786,136	3,205,460	22,524,085	2,548,173	3,562,635	5,505,961	16,880,192	4,133,472
29	(87)	360,553	329,277	2,305,549	4,648,834	2,839,815	13,061,799	4,865,992	5,964,492	1,660,078
30	(87)	397,877	225,084	1,423,624	1,581,840	409,364	793,420	981,909	2,223,701	892,688
31	(87)	1,054,419	2,233,704	3,930,483	7,475,341	1,467,832	3,009,432	6,893,677	13,103,463	7,795,581
33	(89)	570,944	417,100	2,425,138	49,658,493	4,296,660	15,827,014	14,129,756	51,054,483	10,838,483
35	(91)	188,596	155,425	638,620	3,777,265	459,808	1,764,276	2,955,439	8,398,807	2,512,650
37	(93)	210,477	228,164	504,213	5,638,969	371,098	1,527,155	2,644,107	3,590,695	1,136,595
39	(95)	274,257	138,797	1,132,913	1,757,617	1,149,372	1,444,236	6,144,245	6,630,328	4,321,404
43	(97)	394,975	158,201	988,785	972,298	474,008	1,006,914	2,204,315	5,293,557	3,300,100
45	(99)	391,678	224,426	907,617	1,942,868	1,217,016	1,318,597	3,001,863	2,783,234	1,209,738
47	(101)	0	140,416	534,298	845,329	282,897	653,739	1,169,326	3,070,078	1,405,600
49	(105)	1,780,076	1,518,387	30,563,060	46,756,145	15,471,724	9,422,783	23,502,418	14,514,210	3,294,866
51	(2)	701,414	728,570	2,407,565	1,578,771	869,090	1,010,773	1,353,218	2,790,669	888,985
53	N	4,046,904	2,793,863	17,359,299	7,007,534	82,204,056	15,431,762	327,187,421	20,352,242	127,803,694
55	W	3,271,639	2,253,833	17,317,994	19,548,465	14,752,589	87,357,516	82,488,515	80,623,107	49,216,348
57	E	493,334	136,242	1,507,996	1,359,129	2,064,225	12,691,793	48,326,542	24,119,163	17,982,621
59	S	251,802	196,522	1,493,740	3,322,341	564,456	846,247	1,861,430	4,001,855	973,601

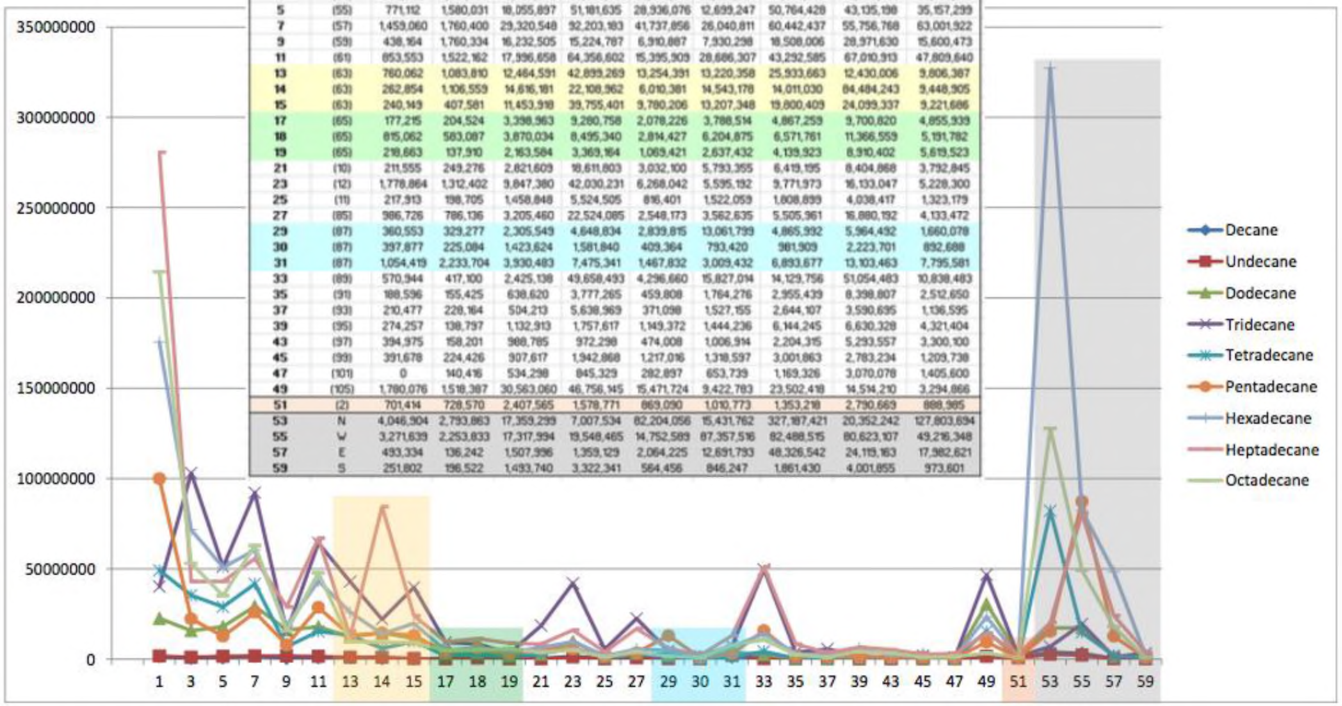

Table 3 (continued). Alkanes (abundance per sample as a percentage of the total abundance for samples 1 – 49)

Sample Number	Context Number	Decane	Undecane	Dodecane	Tridecane	Tetradecane	Pentadecane	Hexadecane	Heptadecane	Octadecane
1	(51)	8.08	8.20	9.81	5.69	19.39	31.48	29.88	33.75	40.77
3	(53)	2.32	5.13	6.85	14.61	13.95	7.05	12.20	5.17	10.09
5	(55)	4.66	7.42	7.83	7.25	11.41	4.00	8.64	5.19	6.68
7	(57)	8.82	8.26	12.71	13.06	16.45	8.20	10.29	6.71	11.97
9	(59)	2.65	8.26	7.04	2.16	2.72	2.50	3.15	3.48	2.97
11	(61)	5.16	7.15	7.80	9.12	6.07	9.03	7.37	8.06	9.09
13	(63)	4.60	5.09	5.40	6.08	5.23	4.16	4.41	1.49	1.86
14	(63)	1.59	5.20	6.34	3.13	2.37	4.58	2.38	10.16	1.80
15	(63)	1.45	1.91	4.97	5.63	3.86	4.16	3.37	2.90	1.75
17	(65)	1.07	0.96	1.47	1.31	0.82	1.19	0.83	1.17	0.92
18	(65)	4.93	2.74	1.68	1.20	1.11	1.95	1.12	1.37	0.99
19	(65)	1.32	0.65	0.94	0.48	0.42	0.83	0.70	1.07	1.07
21	(10)	1.28	1.17	1.22	2.64	1.20	1.82	1.09	1.01	0.72
23	(12)	10.76	6.16	4.27	5.95	2.47	1.76	1.66	1.94	0.99
25	(11)	1.32	0.93	0.63	0.78	0.32	0.48	0.31	0.49	0.25
27	(85)	5.97	3.69	1.39	3.19	1.00	1.12	0.94	2.03	0.79
29	(87)	2.18	1.55	1.00	0.66	1.12	4.11	0.83	0.72	0.32
30	(87)	2.41	1.06	0.62	0.22	0.16	0.25	0.17	0.27	0.17
31	(87)	6.38	10.49	1.70	1.06	0.58	0.95	1.17	1.58	1.48
33	(89)	3.45	1.96	1.05	7.04	1.69	4.98	2.40	6.14	2.06
35	(91)	1.14	0.73	0.28	0.54	0.18	0.56	0.50	1.01	0.48
37	(93)	1.27	1.07	0.22	0.80	0.15	0.48	0.45	0.43	0.22
39	(95)	1.66	0.65	0.49	0.25	0.45	0.45	1.05	0.80	0.82
43	(97)	2.39	0.74	0.43	0.14	0.19	0.32	0.38	0.64	0.63
45	(99)	2.37	1.05	0.39	0.28	0.48	0.42	0.51	0.33	0.23
47	(101)	0.00	0.66	0.23	0.12	0.11	0.21	0.20	0.37	0.27
49	(105)	10.77	7.13	13.25	6.62	6.10	2.97	4.00	1.75	0.63
51	(2)	4.24	3.42	1.04	0.22	0.34	0.32	0.23	0.34	0.17
53	N	24.48	13.12	7.53	0.99	32.41	4.86	55.68	2.45	24.29
55	W	19.79	10.58	7.51	2.77	5.82	27.50	14.04	9.70	9.35
57	E	2.98	0.64	0.65	0.19	0.81	4.00	8.22	2.90	3.42
59	S	1.52	0.92	0.65	0.47	0.22	0.27	0.32	0.48	0.19

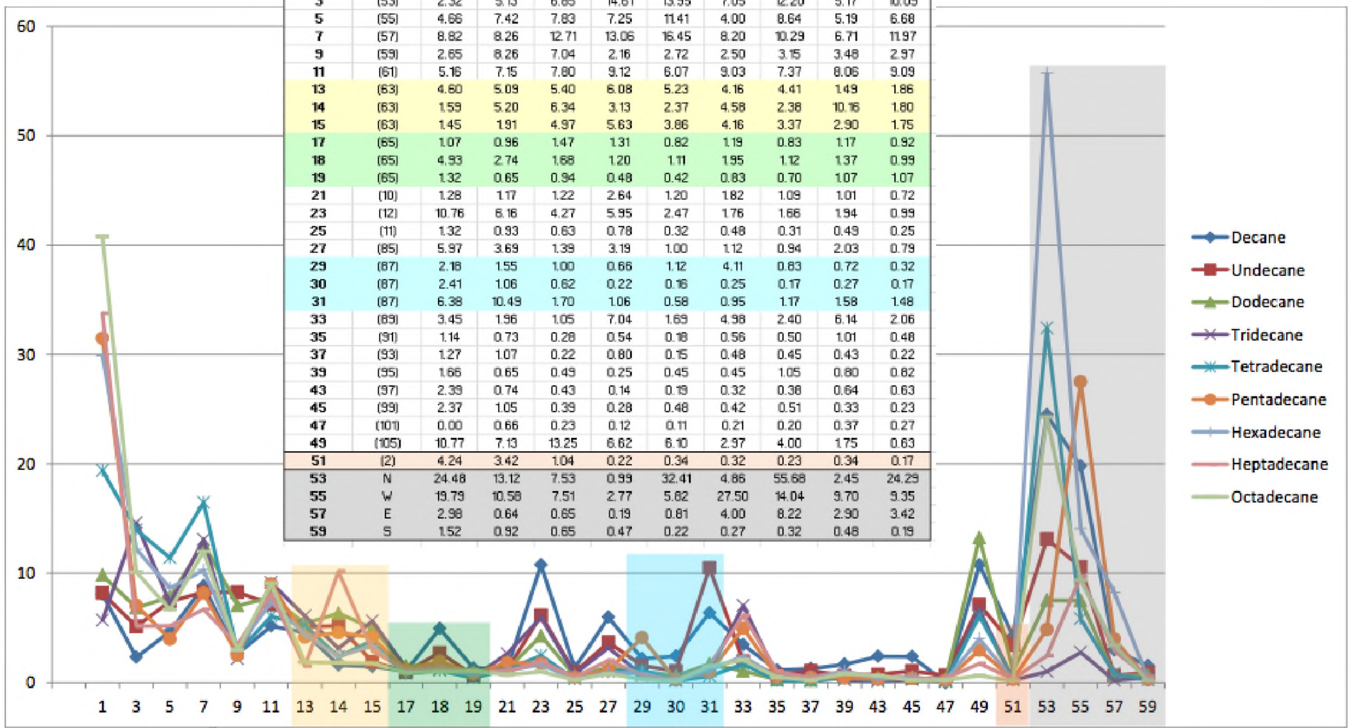

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Table 3 (continued). Alkanes

- Straight chain (*n*-) alkanes in the range C_5-C_{11} are associated with mammalian decomposition and the longer homologues are particularly associated with human decomposition, for which the presence of undecane (C_{11}) is considered to be a marker.
- The C_{10}-C_{18} alkane homologues decane (C_{10}), Undecane (C_{11}), dodecane (C_{10}), tridecane (C_{13}), tetradecane (C_{14}), pentadecane (C_{15}), hexadecane (C_{16}) heptadecane (C_{17}) and octadecane (C_{18}) were found in the samples.
- For most alkane homologues there is a broad abundance maxima profile over samples 1 – 15 and also at samples 23, 27, 31, 33 and 49, and at the Northerly (53) and to a lesser extent the Westerly (55) boundary samples.
- Maximum alkane abundances were seen for the longest C_{15}-C_{18} homologues, pentadecane, hexadecane, heptadecane and octadecane at the most easterly cell (sample 1), and for tetradecane, hexadecane and octadecane at the Northerly (53) boundary sample.
- Undecane (C11) was generally of low abundance in all samples, but the abundance maxima for this compound were for samples 1-14, 23, 27, 31, 49, and for the boundary samples 53 and 55.

Appendix 5

Solid organic compound analysis

***Derivatisation of compounds of interest prior to analysis by gas chromatography*:**

The use of **BSTFA** reagent to convert any alcohol species present in the soil 'alcohol' fractions to **trimethylsilyl (TMS) ethers** not only improves gas-chromatographic separations, but with **GCMS** allows direct identification of peaks appearing on the gas chromatogram, since the individual **TMS** compounds have distinct characteristic mass spectra. Similarly, methylation of the carboxyl groups of organic acids improves improves gas-chromatographic separations; for hydroxyacids, such as the faecal bile acids and 10-hydroxystearic acid, to get good separations and distinct mass spectra, it is necessary to both methylate the carboxyl group and silylate the hydroxyl groups on the compounds.

***Gas chromatography (GC)*:** This is a method of separating and quantifying individual components (compounds) from complex mixtures, based on differences in relative affinities for a stationary phase (usually an immobilised liquid) and remaining in a vapour phase. The sample is introduced to a column (long tube) as a vapour, which is swept along the column by flow of an inert **carrier gas** (commonly nitrogen, helium or hydrogen). In the past, most gas chromatography was carried out using *packed columns* in which the stationary phase was supported by inert particles held throughout the length of the column. Most present-day applications involve the use of *capillary columns*, in which the stationary phase coats the inside of long, narrow silica, glass or metal tubing; capillary columns have much higher resolutions. As the sample vapour passes along the column, different components travel at differing rates, leading to separation of the components into individual peaks leaving the distal end of the column. The speed of passage and degree of separation is affected by the amount of stationary phase, carrier gas flow rate and column temperature. The instrument containing the column, the **gas chromatograph**, consists primarily of a temperature-programmable oven which encloses the column. Unless the sample is a gaseous mixture, samples to be analysed are usually dissolved in a volatile solvent, and introduced by means of a syringe, either directly onto the column (e.g. *cold on-column injection*), or an injection system, heated to vaporise the sample; the sample vapours are swept on to the column by the carrier gas. The separated sample component peaks reaching the lower end of the column are sensed by a *detector*, which gives an electrical response dependent on the size of the component peak. There are a number of different types of detector, dependent upon the components being analysed. For routine analysis of organic compounds the *flame ionisation detector* is most widely used. Some modern gas chromatography columns have been designed to allow compounds of relatively low volatility to be analysed, by running at high temperatures. The plant wax compounds and sterols/stanols described in the present report come under this category.

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Gas chromatography-mass spectrometry (GCMS): This is essentially conventional gas chromatography fitted with a mass-selective detector, primarily for resolution of organic analytes. The separated compound molecules eluting from the chromatography column are transferred to a vacuum chamber, where they are ionised and separated and detected according to ion mass. In the most widely used configuration (as used in the work described in this report), the analyte molecules are ionised by bombardment with an electron beam (*electron ionisation*), which breaks up the molecules to produce a number of fragment ions. By using a fixed standard electron energy (conventionally 70eV), the relative percentages of the different fragment ions result in a reproducible *mass spectrum* which, being characteristic for different individual compounds, enables the compounds to be directly identified. Since the number of ions produced for a particular compound is dependent on the amounts of compound eluting from the GC column, quantitative analysis can be carried out. Counting all of the ions produced (*total ion count*, TIC) results in a gas chromatogram which is very similar to that obtained from a conventional gas chromatograph fitted with a flame ionisation detector.

Interpretation of gas chromatograms and quantification: In conventional gas chromatography, compound peaks can be identified from the *retention time*, which is the time after injecting the sample that the summit of the peak occurs; standard mixtures containing compounds of interest also need to be run under identical conditions (temperature, gas flow rate etc.) of the gas chromatograph. Peak sizes are usually determined in terms of peak areas, determined with specialist software built into a computing integrator or computer attached to the gas chromatograph. The accurate assessment of peak area is very much dependent on the correct positioning of baselines executed by the software; this is particularly important in situations where peaks may not be fully resolved.

The *n*-alkanes, fatty alcohols, sterols and stanols in the samples analysed in this report could be quantified by adding a known amount of relevant *internal standard* compound to the sample prior to extraction, purification and analysis. Ideally, a suitable internal standard compound should not be present in the samples, but have the same physical and chemical properties as the compounds being quantified. It has been shown that the concentrations of the chosen internal standards for *n*-alkanes and for fatty alcohols can be considered as having negligible concentrations in plant and soil samples. The internal standard used to quantify *n*-alkanes was tetratriacontane (C34).The fatty alcohol internal standard was1-heptacosanol (C27-ol), the fatty acid standard was hentriacontanoic acid (C31) and 5β-cholan-24-ol was added as the internal standard for the sterols and stanols.

A mixture of standards of some of the main alcohols and sterols expected to be found in the samples were run on the GC-MS to corroborate retention times and identification.

ORGANIC MARKERS RELEVANT TO THIS REPORT

Plant wax compounds: Lipid (hydrophobic) compounds found in the surface wax of plants. These can be complex mixtures. The plant wax compounds mentioned in this report are listed as follows:
***n*-Alkanes**: straight-chain, C_{21}-C_{37}, with odd-chain compounds predominating

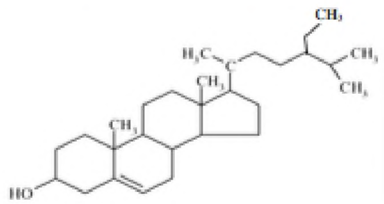
Primary long-chain fatty alcohols: straight-chain, C_{20}-ol - C_{34}-ol, predominantly even-chain

Sterols and stanols:

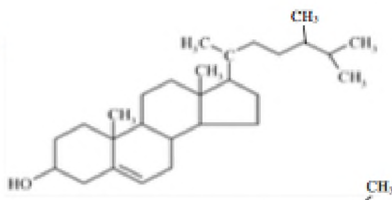
These, if present, occur in the 'alcohol' fraction eluted from silica-gel columns. Sterols are unsaturated (i.e. containing one or more double bonds) steroidal alcohols; stanols are saturated steroidal alcohols.

Sterols:

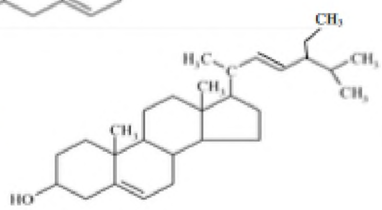
β-Sitosterol (24-ethyl cholest-5-en-3β-ol):
main sterol found in plants



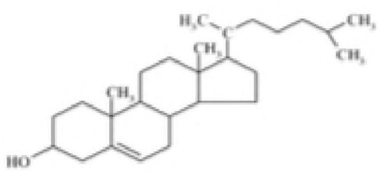
Campesterol (24-methyl cholest-5-en-3β-ol):
common plant sterol



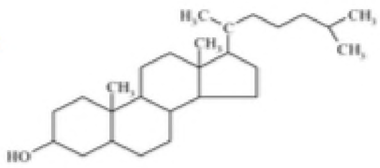
Stigmasterol (24-ethyl 5,22-dien-cholestan-3β-ol)
common plant sterol



Cholesterol (cholest-5-en-3β-ol):
main sterol found in animals



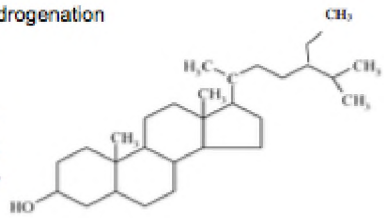
Stanols:



Coprostanol (5β-cholestan-3β-ol): hydrogenation product of cholesterol occurring in mammalian faeces; main stanol in human and pig faeces

Epicoprostanol (5β-cholestan-3α-ol): isomer produced from coprostanol by microbes under anaerobic conditions (e.g. septic tank)

Cholestanol (5α-cholestan-3β-ol): another isomer produced by hydrogenation of cholesterol under anaerobic conditions in the environment (not in the mammalian gut).



24-Ethylcoprostanol (24-ethyl 5β-cholestan-3-β-ol): hydrogenation product of β-Sitosterol; main stanol in herbivore faeces

24-Ethyl epicoprostanol (24-ethyl 5β-cholestan-3α-ol): isomer produced from 24-ethylcoprostanol by microbes under anaerobic conditions (e.g. farm slurry tank); minor stanol in fresh faeces

Stigmastanol (24-ethyl 5α-cholestan-3β-ol):
another isomer produced by hydrogenation of β-sitosterol under anaerobic conditions in the environment (not in the mammalian gut:

Campestanol (24-methyl 5α-cholestan-3β-ol): hydrogenation product produced by hydrogenation of campesterol under anaerobic conditions in the environment (not in the mammalian gut).

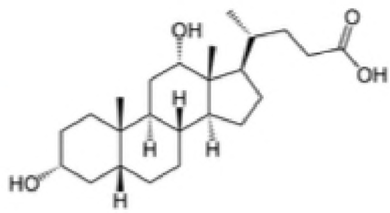
NB: The structural diagrams of the above stanols and isomers are generic. The numbers refer to the individual carbon atoms within the steroidal structure and the Greek letters (α and β) refer to whether the side group (e.g. the 'OH' group) is in a position above or below the ring structure. The same applies to 24-ethylcoprostanol, campestanol and their isomers.

Faecal bile acids:

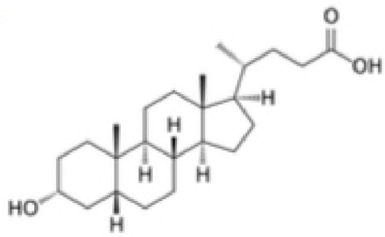
Bile acids are steroidal hydroxyl acids. The compounds of interest as markers found in faeces are secondary bile acids, which have been transformed by gut bacteria from primary bile acids (cholic acid and chenodeoxycholic acid) which had been secreted into the gut from bile.

Lithocholic acid (3α-hydroxy-5β-cholan-24-oic acid):

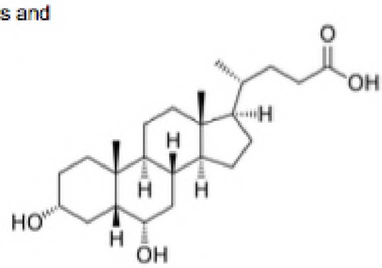
found in faeces of most mammals, including faeces from humans, pigs, ruminants and other herbivores.



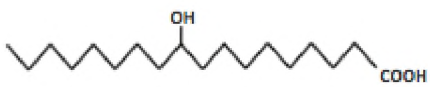
Deoxycholic acid (3α,12α-dihydroxy-5β-cholan-24-oic acid):
found in faeces of humans, ruminants and other herbivores, but not in pig faeces



Hyodeoxycholic acid (3α,6α-dihydroxy-5β-cholan-24-oic acid):
found in pig faeces, but not in faeces of humans, ruminants and other herbivores



10-Hydroxy stearic acid:



Produced from oleic acid by microbes under wet anaerobic conditions. It is a major constituent of adipocere, which is a white soapy substance originating from body fat and found in cadavers which had decomposed in a waterlogged environment. 10-Hydroxystearate is thus a useful body decomposition marker and has also been found in human faeces.

Summary of procedure for the analysis of soil samples for organic lipid markers

High-purity solvents are re-distilled (*n*-heptane, ethanol and ethyl acetate) before being used.

The air-dried soil samples were hand milled in an agate mortar and pestle. Duplicate sub-samples of each soil (about 100mg) were weighed with alkane, fatty alcohol, fatty acid and sterol internal standard compounds from separate solutions of known concentration (C22 and C34 *n*-alkanes, C27 alcohol, C31 acid and 5β-cholan 24ol, respectively) into screw capped tubes with PTFE cap-liners, and heated overnight in sealed screw-cap vials with 1M ethanolic KOH at 90°C.

After cooling to 50°C and the addition of water, any hydrocarbons (including *n*-alkanes) and alcohols present were extracted twice with *n*-heptane. After removing the solvent, the heptane extracts were re-dissolved in heptane prior to being transferred to a small glass solid-phase extraction column packed with about 50mg of silica-gel. The hydrocarbons were eluted from the column with *n*-heptane. The solvent was then changed to 20% ethyl acetate/ 80% *n*-heptane (v/v) in order to elute any fatty alcohols, sterols and triterpenols (crude alcohol extract). The hydrocarbon extract was dried and redissolved in dodecane prior to analysis by GC. The crude alcohol extract was derivitised with a mixture of BSTFA and pyridine before drying and redissolving in dodecane prior to analysis by GC-MS.

The residue remaining after alkane and alcohol extraction was acidified and extracted with chloroform. The extracted compounds were added to an SPE column containing aminopropyl packing. The organic acids were eluted with a mixture of diethyl ether and glacial acetic acid. After drying the acids were converted to their methyl esters, by heating with acidified methanol and then further treated with BSTFA to silylate the hydroxyl groups (as trimethylsilyl ethers on hydroxy acids). The derivatised extracts were analysed by GCMS in TIC mode.

Appendix 6

Isotope analysis

The method used was according to the James Hutton Institute - 1917 Schedule, AM002. The carbon and nitrogen concentrations (%) along with $\delta^{13}C$ and $\delta^{15}N$ natural abundance isotope ratios of the milled dried soil were determined using a Flash EA 1112 Series Elemental Analyser connected via a Conflo III to a Delta^{Plus} XP isotope ratio mass spectrometer (all Thermo, Bremen, Germany). The $\delta^{13}C_{VPDB}$ and $\delta^{15}N_{Air\text{-}N2}$ values were normalized to their respective scales using International Atomic Energy Agency reference materials USGS40 and USGS41a (both L-glutamic acid). Additionally the USGS40 was used as a reference material for both carbon and nitrogen concentrations, measured using the area output of the mass spectrometer (JHI – UKAS Accreditation Schedule 1917, Method AM002). Long term precisions for a quality control standard (dried milled topsoil) were: total carbon 3.80 ± 0.15 %, $\delta^{13}C$ -27.79 ± 0.20 ‰, total nitrogen 0.28 ± 0.02 % and $\delta^{15}N$ 4.63 ± 0.60 ‰ (mean ± sd). Data processing was performed using Isodat 2.0 (Thermo Fisher Scientific, Bremen, Germany) and exported into Excel.

Appendix 7

Glossary

Isotope- Atoms of an element with the normal number of protons and electrons, but different numbers of neutrons. The different isotopes of an element have identical chemical properties.

Mineral - A mineral is a naturally occurring solid chemical substance, formed through geological processes, which has a characteristic chemical composition, a highly ordered atomic structure, and specific physical properties consequent upon its structure and chemistry.

Organic - Pertaining to a class of chemical compound that exist in or have been derived from plants or animals.

VOC – Volatile organic compound is an organic chemical which is emitted as gas from certain solids or liquids.

Appendix 8

Statistical analysis

Multidimensional scaling analysis (MDS) plots analysed with Primer 6 software

Figure 2. MDS plot of VOC data.

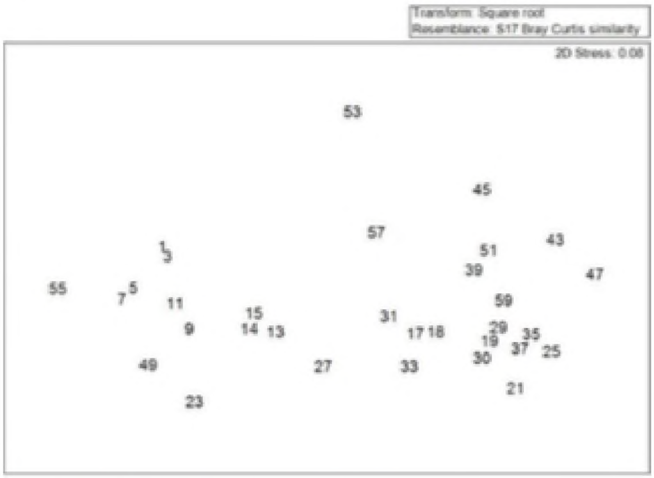


Figure 3. MDS plot of sterol and stanol data.

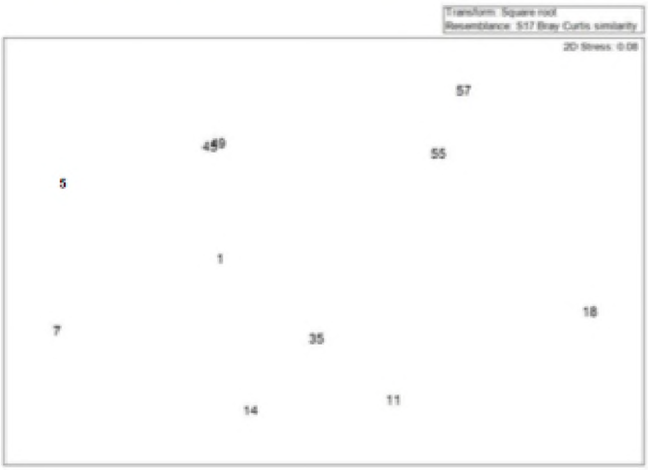


Figure 4 MDS plot of bile acid data.

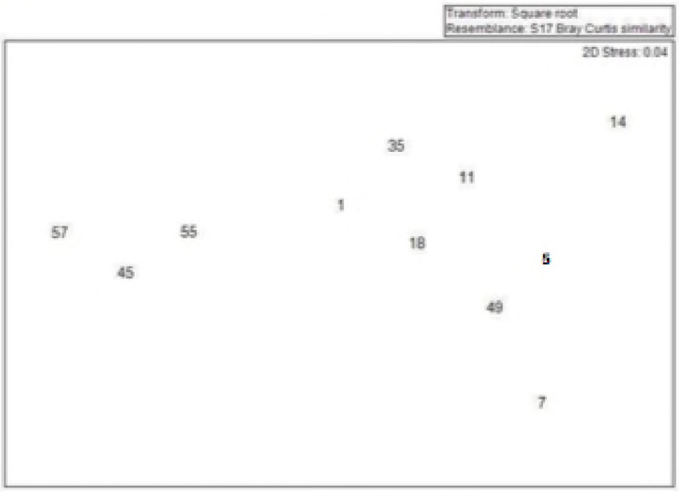
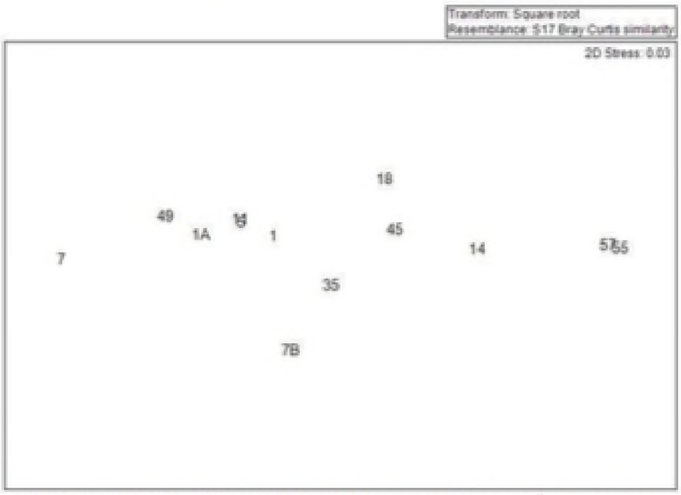


Figure 5. MDS plot of isotope data.



Note: Sample 1A is EXHIB –LL016 which we received on 4th Nov 2016.
Sample 7B is a fragment picked out from sample 7 which was thought to be bone.

Appendix 9

Images of soil examined

Photographs of soil sample examined. (Scale = mm)

Plate 1. Sample 1

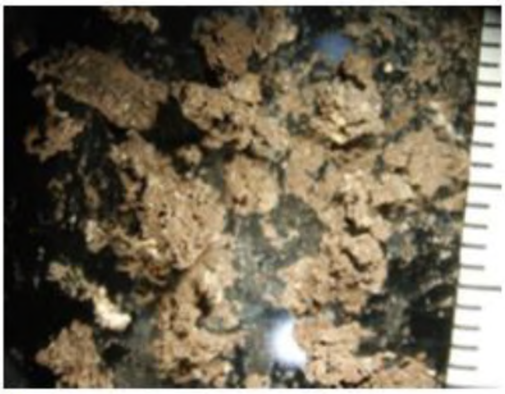


Plate 2. Sample 5

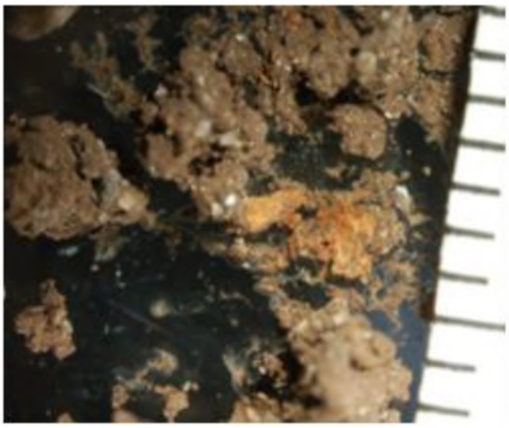


Plate 3. Sample 7

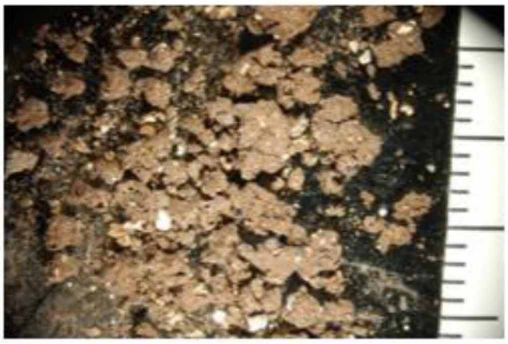


Plate 4. Sample 11

Plate 5. Sample 14

Plate 6. Sample 18

Plate 7. Sample 35

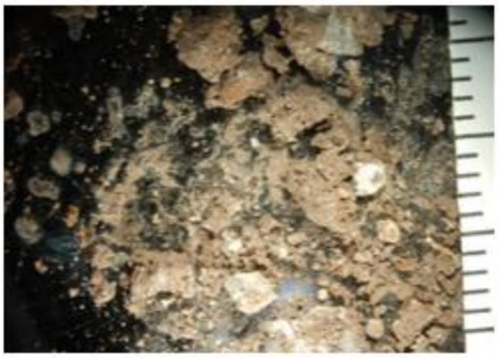


Plate 8. Sample 45

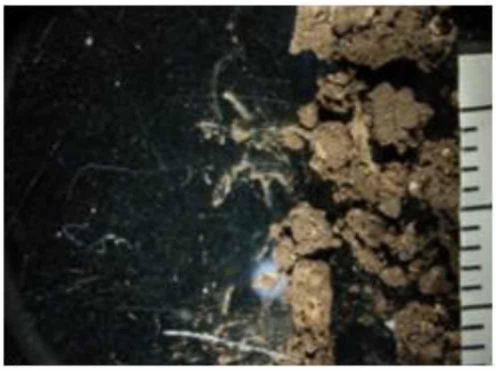


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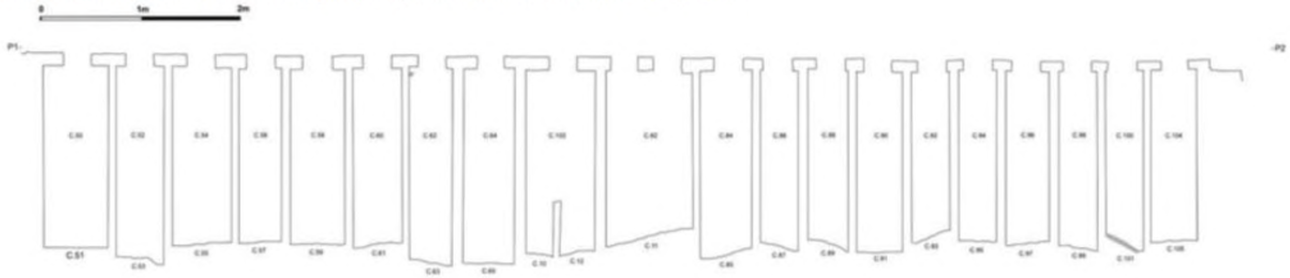
Plate 9. Sample 49

Plate 10. Sample 55

Plate 11. Sample 57

Appendix 10

Section drawing of cell locations as provide by Niamh McCULLAGH on 7 May 2017.



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Appendix 11

Declaration

If you have any queries in relation to this report or any of the work that we have performed then please contact the laboratory.

Report provided by: Prof Lorna DAWSON, Dr Tom SHEPHERD and Dr Bob MAYES
Mrs Jasmine ROSS has quality checked this report.

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Signature:

Signature:

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Dated the 23rd May 2017

Appendix VIII: References

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For Niamh McCullagh and
The Mother and Baby Homes Commission of Investigation

(Criminal Procedure Rules [2015] Parts 16 and 19; Criminal Justice Act 1967, s. 9)

Professor Lorna DAWSON, Dr Tom SHEPHERD and Dr Bob MAYES

BSc, PhD, C.Sci, F.I.Soil Sci, FRSA (LD);
BSc, PhD (TS);
BSc, MSc, PhD (BM),

Over 18

Soil Scientist, Volatile Organic Chemist and Organic Chemist

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I (Lorna DAWSON, Tom SHEPHERD and Bob MAYES) DECLARE THAT:

1. I understand that my duty is to help the court to achieve the overriding objective by giving independent assistance by way of objective, unbiased opinion on matters within my expertise, both in preparing reports and giving oral evidence. I understand that this duty overrides any obligation to the party by whom I am engaged or the person who has paid or is liable to pay me. I confirm that I have complied with and will continue to comply with that duty.

2. I confirm that I have not entered into any arrangement where the amount or payment of my fees is in any way dependent on the outcome of the case.

3. I know of no conflict of interest of any kind, other than any which I have disclosed in my report.

4. I do not consider that any interest which I have disclosed affects my suitability as an expert witness on any issues on which I have given evidence.

5. I will advise the party by whom I am instructed if, between the date of my report and the trial, there is any change in circumstances which affect my answers to points 3 and 4 above.

6. I have shown the sources of all information I have used.

7. I have exercised reasonable care and skill in order to be accurate and complete in preparing this report.

8. I have endeavoured to include in my report those matters, of which I have knowledge or of which I have been made aware, that might adversely affect the validity of my opinion. I have clearly stated any qualifications to my opinion.

9. I have not, without forming an independent view, included or excluded anything which has been suggested to me by others including my instructing lawyers.

10. I will notify those instructing me immediately and confirm in writing if for any reason my existing report requires any correction or qualification.

11. I understand that:

    (a) my report will form the evidence to be given under oath or affirmation;

    (b) the court may at any stage direct a discussion to take place between experts;

    (c) the court may direct that, following a discussion between the experts, a statement should be prepared showing those issues which are agreed and those issues which are not agreed, together with the reasons;

    (d) I may be required to attend court to be cross-examined on my report by a cross-examiner assisted by an expert.

    (e) I am likely to be the subject of public adverse criticism by the judge if the Court concludes that I have not taken reasonable care in trying to meet the standards set out above.

12. I have read Part 19 of the Criminal Procedure Rules and I have complied with its requirements.

13. I confirm that my discipline does not have a material code to adhere to.

14. I confirm that I have read guidance contained in a booklet known as *Disclosure: Experts' Evidence and Unused Material* which details my role and documents my responsibilities, in relation to revelation as an expert witness. I have followed the guidance and recognise the continuing nature of my responsibilities of disclosure. In accordance with my duties of disclosure, as documented in the guidance booklet, I confirm that:

    (a) I have complied with my duties to record, retain and reveal material in accordance with the Criminal Procedure and Investigations Act 1996, as amended;

    (b) I have compiled an Index of all material. I will ensure that the Index is updated in the event I am provided with or generate additional material;

    (c) in the event my opinion changes on any material issue, I will inform the investigating officer, as soon as reasonably practicable and give reasons.

I confirm that the contents of this report are true to the best of my knowledge and belief and that I make this report knowing that, if it is tendered in evidence, I would be liable to prosecution if I have wilfully stated anything which I know to be false or that I do not believe to be true.

Signed Dated the 26th June 2017

Signed Tom Shepherd. Dated the 26th June 2017

Signed R.N. Mayes Dated the 26th June 2017

Prof. Lorna DAWSON

I am employed as a principal research scientist at the James Hutton Institute, Aberdeen, Scotland, where I am Head of the Soil Forensics Section and hold the qualifications of BSc (Honours) Geography (Edinburgh University, 1979), and a PhD in Soil Science (Aberdeen University, 1984). I am a visiting Professor in Forensic Science at the Robert Gordon University. I am a Fellow of the British Society of Soil Science, a Fellow of the Royal Society of the Arts, a Chartered Scientist and hold an Expert Witness certificate in both Criminal and Civil Law (Cardiff University, 2011, 2012). I have published widely on the subject of forensic soil science; published over 80 refereed publications, books and book chapters. I am an Expert Advisor with the National Crime Agency, have worked with numerous police forces in Scotland, England, Wales, Ireland & Australia over the last 12 years and have advised on over 100 cases, written over 70 Expert Witness reports, and presented evidence in 10, in the UK and overseas. During the past 12 years I have encountered the evidence type involved in this case on several occasions.

Dr Tom SHEPHERD

I am a senior research chemist employed at the James Hutton Institute, Dundee, Scotland holding the qualifications of BSc (Honours) Chemistry (University of St Andrews, 1980) and a PhD in Synthetic Organic Chemistry (University of St Andrews, 1983). I am an expert in the use of techniques such as automated thermal desorption (ATD) and solid-phase micro-extraction (SPME), coupled with GC-MS, for entrainment and analysis of volatiles. A main element of my research is the analysis of volatile chemicals, compiling an extensive database of chromatographic characteristics from a wide range of different matrices. During the past two years I have encountered the evidence type involved in this case on several occasions.

Dr Bob MAYES

I am a Research Associate at the James Hutton Institute where I was previously head of the Ecological Sciences GC and GC-MS laboratories, and hold the qualifications PhD from Queen's University of Belfast, MSc in Animal Nutrition from the University of Aberdeen and BSc in Physiology and Biochemistry of Farm Animals from Reading University. I am an expert in the analysis of wax markers and my research interests revolve around the application of this biomarker technology to measuring dietary intake, digestibility and plant species composition in grazing herbivores and to the chemical characterisation of soil organic matter as applied in criminal investigations. I have worked with a number of police forces in Scotland, England, Wales & Ireland over the last 6 years, have written over 16 Expert Witness reports, and presented evidence in court with two of them. During the past 6 years I have encountered the evidence type involved in this case on several occasions.

1.1 The sample examined was not a typical soil. It was shown from GC-MS analysis that there are markers of faeces (cholesterol, faecal stanols and faecal bile acids) in the sample.

1.2 The observed patterns of these individual markers were typical of human faeces, and not of faeces from any herbivore (e.g. sheep, cattle, horses or rabbits), pigs or dogs.

1.3 However, despite the high organic matter content of the sample, the concentrations of faecal markers were extremely low, compared with levels expected from decomposed faecal material (such as sewage sludge, septic tank sludge or manure). Thus either the faecal material had been considerably diluted by the presence of non-faecal organic matter, or the faecal markers had come from another source.

1.4 The possibility that the faecal markers found in the sample had originated from decomposing cadavers is a possibility.

1.5 The fatty acid, 10-hydroxy stearic acid, which is a recognised body decomposition marker, was found in the sample at low levels, but its origin in this case was not clear, because it is also found in human faeces. Any association of cadaver decomposition with the presence of faecal bile acids has yet to be established.

1.6 An unusual feature about the *n*-alkane/alcohol/sterol results of the sample examined was the exceptionally high levels of the plant sterols, β-sitosterol and campesterol, together with low (but detectable) concentrations of plant-wax *n*-alkanes and fatty alcohols. The observed *n*-alkane and long-chain fatty alcohol patterns were typical of those found in grasses and other higher plants, but their low concentrations relative to the plant sterol levels in the sample suggest that decomposed plant material was unlikely to be the source of these compounds in this sample.

1.7 There is the possibility that it was infant matter that was in the sample (including infant faecal matter) and that the high levels of plant sterols we detected in the sample could be as a result of infants being fed with formula milk containing vegetable oils. (Nearly all formula milks contain vegetable oils). The relative levels of plant sterols, *n*-alkanes and fatty alcohols in vegetable oils are similar to those found in the current analysed sample. Furthermore, although the patterns of *n*-alkanes and fatty alcohols can vary according to the type of vegetable oil, the patterns found in the sample examined were compatible with certain individual oils, or mixtures of oils.

1.8 The concentration patterns of stanols and sterols and hydrocarbons found in the sample are not compatible with that of sewage from human adults or from individuals eating solid food.

1.9 The alcohol/sterol fraction and hydrocarbon fraction profiles suggest that the sample examined is not material originating from a sewage treatment plant, septic tank or cesspit. It is unlikely that the specific location of the questioned case sample was a receptacle for sewage.

1.10 The sample does contain indicators which suggest that human faeces are present. However, the markers present are not compatible with that of sewage from human adults or children eating solid food. It has not originated wholly from a sewage treatment plant or wholly from adult faeces.

- 2.1 It can be confirmed from our examination that there is evidence that the site *had* previously been used as a sewage facility. Cholesterol, faecal stanols (coprostanol, epicoprostanol, 24-ethyl coprostanol and 24-ethyl epicoprostanol) and faecal bile acids (biomarkers found in human sewage) were detected in all samples analysed for solid organic compounds. However, during decomposition of animal (including human) bodies large quantities of cholesterol are released; coprostanol and epicoprostanol have also been found in association with body decomposition. Whilst these biomarkers are found both in sewage and in decomposing bodies, the relative concentration patterns would be expected to differ greatly between faecal (sewage) and body decomposition origins – in faeces and sewage, cholesterol concentrations are much lower than those of coprostanol + epicoprostanol, whereas cholesterol concentrations in body decomposition material would be expected to be considerably higher than these stanol concentrations. The high stanol: cholesterol ratio (Figure 2) found in sample 11 suggests that for this sample, the solid biomarkers had originated from predominantly sewage; the lower ratios observed in the other samples from the chambers suggest mixed origins from sewage and from decomposed bodies. Whilst the presence of faecal bile acids suggests that sewage had at some time in the past been present in all of the chambers providing the analysed samples, the possibility that faecal bile acids can be released during body decomposition cannot be categorically ruled out;

currently, there does not appear to be any published evidence that faecal bile acids are produced during the process of human or animal body decomposition.

Other points:

- Coprostanol and epicoprostanol are produced in the guts of most mammals by microbial hydrogenation of cholesterol (endogenous and from dietary animal products). 24-Ethyl coprostanol and 24-ethyl epicoprostanol are produced in the gut from β-sitosterol (from dietary plant products).
- In human sewage coprostanol+epicoprostanol concentrations are normally one to three times the concentrations of 24-ethyl coprostanol+24-ethyl epicoprostanol. If much of the coprostanol and epicoprostanol found from body decomposition originates from released cholesterol rather than from the gut contents (not yet confirmed to be the case), it would be expected that human body decomposition coprostanol+epicoprostanol concentrations would be very much higher (>3 times) than 24-ethyl coprostanol+24-ethyl epicoprostanol concentrations. However, β-sitosterol concentrations were relatively high in some of the analysed samples (notably in sample 2). Because this compound is the source of 24-ethyl coprostanol and 24-ethyl epicoprostanol, bodies with high levels of β-sitosterol in the gut contents (suggested as coming from baby formula milk) could result in lower than expected coprostanol+epicoprostanol:24-ethyl coprostanol+24-ethyl epicoprostanol concentration ratios.

- The results of this series of tests cannot establish categorically whether the sewage facility was being used at the time when the human remains were deposited. It is a matter of historic record to establish when and how long the facility was used.
- The results of this series of tests cannot establish categorically whether the non-decomposed human remains had been deposited in the chambers, or whether the bodies have previously been stored (and decomposed) elsewhere, with mainly bones being placed in the chambers.

2.2 It is not possible to determine the extent to which the deposited human infant remains which are known to be present may have contributed to this, or to what extent human faecal material may also have done so.

2.3 The presence of VOC hotspots within the northern and western boundary samples but not the southern and eastern boundary samples is of note. A number of the hotspots for compounds characteristic of bone decomposition, particularly ketones, but also aliphatic alcohols and *n*-aldehydes, are found at locations with high bone densities.

2.4 However, the concentrations of the solid organic biomarkers in the analysed samples were very low, much lower than would be expected if the analysed material had entirely originated from human sewage waste.

2.5 The samples collected from the site boundaries (negative control samples; samples 55 and 57) had generally lower biomarker concentrations than the samples collected from within the chambers where remains were located.

2.6 10-Hydroxy stearic acid, cholesterol and the faecal stanols, coprostanol and epicoprostanol have been recognised as being products of the decomposition of mammalian remains (including human), and their concentration patterns generally differ from those of human sewage material. The presence of these compounds in the samples collected from the chambers could, at least in part, have come from decomposed human bodies.

2.7 The reasons for the low biomarker concentrations found in the samples are not easy to assess. If the chambers represented a closed cesspit or a number of cesspits, it is possible that the collected sewage had been removed before depositing the human cadaver material; soil may have been added at the same time, or soil may have seeped in from the roof area of the chambers. If there were one or more piped out flows (i.e. the facility was a septic tank, or was connected to a sewer outflow), it would be expected that little sewage would be left behind.

2.8 Samples 55 and 57 (west boundary and east boundary locations respectively) and sample 14 (no visible human remains) have different isotopic profiles to the other samples examined, reflecting possibly a lesser influence from human remains (or human sewage).

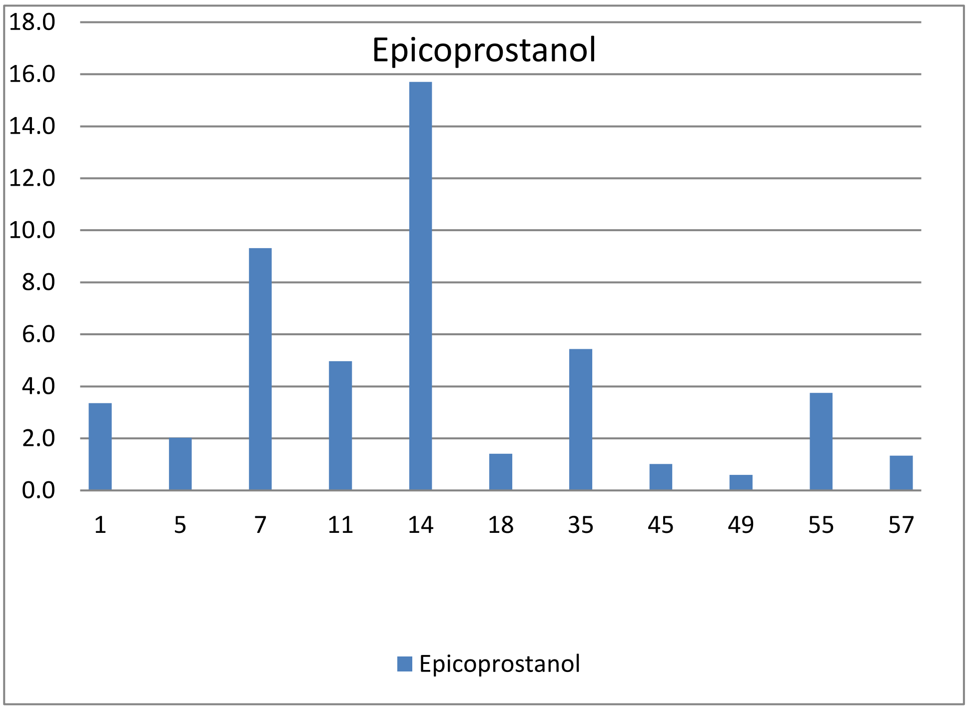
2.9 It is likely that some signature due to faecal material is present, but it is also likely that the human remains have also contributed to the signatures observed, and the presence of compounds associated with decomposition of bone at locations of high bone density in the samples is suggestive of this.

3.1 Relative proportions of sterols and stanols (cholesterol, β-sitosterol, coprostanol, 24-ethylcoprostanol) indicate the faecal source (e.g. herbivores, omnivores, birds).

Coprostanol, epicoprostanol, 24-ethylcoprostanol and 24-ethyl-epicoprostanol originate from faeces cadaver decomposition.

3.2 High levels of cholesterol, coprostanol and epicoprostanol are found in soils adjacent to, or underlying decomposing cadavers.

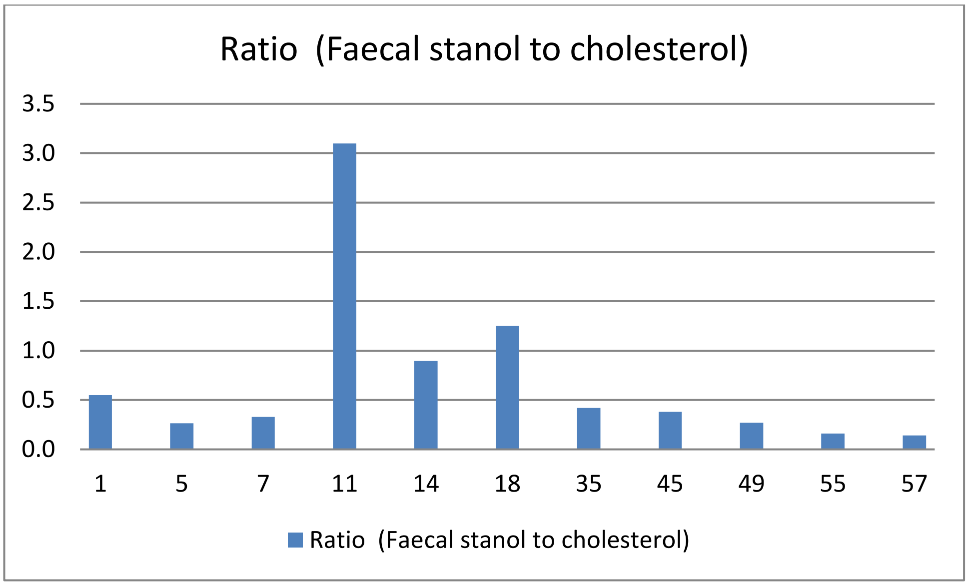
Figure 1 Concentration (mg/kg) of epicoprostanol in samples analysed for solid organic markers



3.3 Fresh faecal material typically has low levels of epicoprostanol and 24-ethylepicoprostanol compared with their respective isomers, coprostanol and 24-ethylcoprostanol, while old faecal sources have relatively high levels of the former compounds (epicoprostanol and 24-ethylepicoprostanol). It is not known whether cadaver decomposition over time has similarly changing levels of these compounds

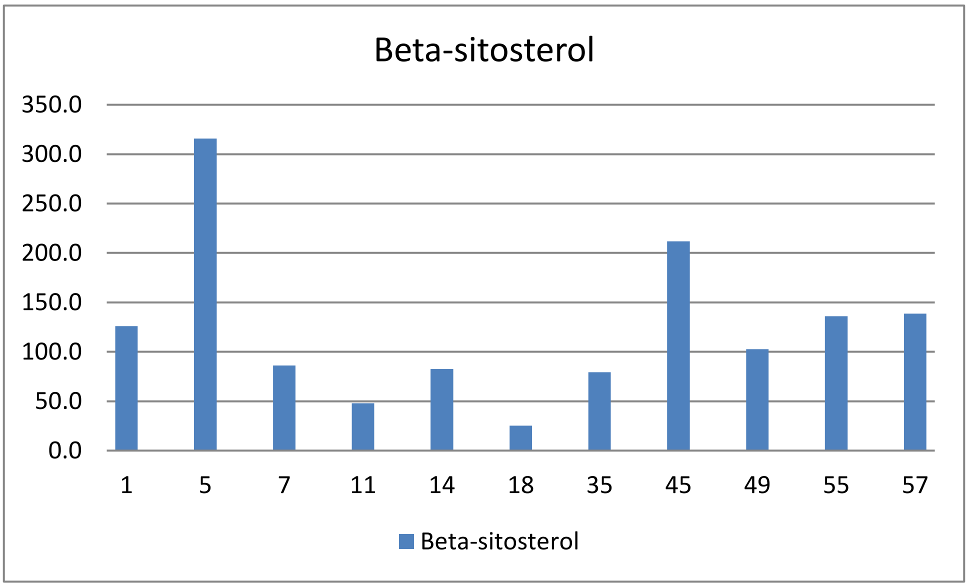
3.4 24-Ethylcoprostanol originates from sitosterol, whereas the 'epis' are associated with faecal age.

Figure 2. Ratio of faecal stanols (coprostanol and epicoprostanol) to cholesterol in samples analysed for solid organic markers.



3.5 Most of the analysed samples had relatively high concentrations of beta-sitosterol- higher than expected from cadaver decomposition, and higher than expected from human adults or children eating solid food. The reason for the relatively high betasitosterol concentrations are not clear, but it is possible that the source was faeces, or cadaver gut contents from infants receiving formula milk containing vegetable oils. However, the two external control samples also had relatively high values for beta-sitosterol, although this may have come from vegetation associated with these samples.

Figure 3. Beta-sitosterol concentration (mg/kg) in samples analysed for solid organic markers.



3.6 Possible strategy for initial further work would be:

1. to complete the analysis of all the samples for organics and isotopes to accompany the VOCs.

2. Select some appropriate sewage samples of different ages for VOC and isotope analysis.

Comments:

4.1 There are currently several issues which hamper detailed interpretation.

4.2 One is the considerable passage of the time since the potential use of the facility for storage of sewage, potential leaks into surrounding areas, and that so little is known of the history of use of that site.

4.3 A sampling issue is that the solid organics are very spatially distributed, and grab sampling may have introduced a high level of heterogeneity to the results. On direct contact sampling, samples can be collected at points directly under the torso of the skeleton to increase chances of obtaining compounds which are indicative of human decomposition. Previous research has shown that cholesterol can be recovered from soil directly underneath the torso, while none can be detected at the feet for example.

4.4 The other issue is that both the sewage storage and the decomposition has taken place more than 60 years ago and there is no direct experimental data (neither pig surrogate nor human decomposition studies) to predict what happens to compounds over that period of time.

4.5 Another issue is that not much knowledge is known about the actual history of these sites to give time lines of potential usage.

4.6 In addition, the negative control samples do not appear to represent no contact with sewage (e.g. Site 55 may have been in contact with sewage which had leaked at one point in time (per comm Niamh McC)).

4.7 In addition, some of the sites (e.g. Site 14) which had been reported not to have any visible remains may contain human sewage or remains.

4.8 The recovery of the human remains, quantification of numbers and age, along with careful spatial sampling with subsequent analysis of VOC, Organics and stable isotopic data of all collected samples, along with carefully selected and collected reference samples, would allow much improved interpretation.

If you have any queries in relation to this report or any of the work that we have performed then please contact the laboratory.

Report provided by: Prof Lorna DAWSON, Dr Tom SHEPHERD and Dr Bob MAYES
Mrs Jasmine ROSS has quality checked this report.

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Dated the 26 June 2017