TRINITAPOLI: EVALUATION OF THE HUMAN SKELETAL MATERIAL

TRINITAPOLI: A PRELIMINARY EVALUATION OF THE HUMAN SKELETAL MATERIAL RECOVERED FROM A MIDDLE BRONZE AGE BURIAL SITE IN SOUTHERN ITALY.

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Abstract

The *Ipogeo degli Avori* represents an artificially constructed burial cave of the Middle Italian Bronze Age (1600 to 1350 BCE). The site has received recent attention due to the finding of two ivory statues which bear stylistic similarities to Mycenaean Greek art of the era. The presence of these statues has led some to believe that the site may represent one of the first locations of Greek occupation in southern Italy, though others remain skeptical and suggest rather that the artifacts are merely reflective of trade associations. The current analysis provides a preliminary evaluation of a portion of the human skeletal material recovered from the site with a focus on demographic structure, general population health, and evidence of migration inferred from strontium isotope data. The site appears to consist of the fragmentary remains of at least 3 infants, 10 children, and 12 adults, with both sexes represented. The range of age groups represented, along with the presence of both sexes suggests a settled group. Palaeopathological evaluation suggests a population partaking in significant levels of physical activity, showing lesions suggestive of heavy lifting. Skeletal evidence of nutritional deficiencies was also observed, though alternate explanations were provided for the presence of these lesions. Chemical analysis of six individuals revealed two to be local, and four potentially non-local. The conclusions of this analysis are made in acknowledgement of the limitations associated with commingled burials and with material that is generally in a poor state of preservation, and this study shows that anthropologically relevant information can be obtained from the meticulous evaluation of even heavily fragmented material.

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CHAPTER 1: INTRODUCTION

Due to its inviting and temperate climate, southern Italy has been home to a variety of different populations (Caldara et al, 1997). Recently, a new archaeological site has been discovered on the southern portion of the Adriatic coast. The site is called *Madonna di Loreto*, and artifact cross-dating suggests that its use dates to the Middle Italian Bronze Age, approximately 1600 to 1350 BCE. The site consists of two burial caves, or hypogea, that appear to have been used throughout the occupation of the site. This is significant since this site represents the rare occasion where a single population appears to have made concomitant use of two separate hypogea.

More pertinent is the discovery of artifacts in the smaller of the two hypogea, which potentially suggest affiliations with Mycenaean Greek populations. Some researchers believe that the presence of these artifacts may be held as evidence that this site represents a former Greek settlement. The significance of this finding relates to the era in which the site was used. Although this area of southern Italy is considered to have been on the periphery of Mycenaean trading networks as early as the 17^{th} century BCE (Holloway, 1981; Kristiansen, 1998), occupation of sites in southern Italy by Greek populations are not thought to have occurred until the Late Bronze Age, almost three hundred years later (Smith, 1987). In this respect, *Madonna di Loreto* may represent the earliest known site of Greek occupation in southern Italy. The confirmation of the above result may change our understanding of the interactions between populations of the east and west during this period.

Some discussants, however, remain skeptical about the nature of these connections, maintaining that the extensive trade that occurred between different groups during the Middle Bronze Age could be responsible for the finding of Greek artifacts in southern Italy. In an attempt to yield insight into the nature of the interactions between the individuals of this site and those from other areas, analyses are currently being performed on all physical material recovered from the site. The eventual aim of these analyses is to place the individuals of this population in a context of human interactions in the Middle Bronze Age Mediterranean, through consideration of their cultural and biological relationships to other contemporary groups.

One of the essential elements in this effort will be to establish a bio-social representation of the dead individuals. The current analysis provides a preliminary evaluation of the skeletal material recovered from most of the archaeological site, with consideration of demographic structure, general health, and potential residency pattern. The goals of the current analysis are as follows: 1) to determine the age and sex distribution of the individuals represented in the burial chamber to establish if some form of biological selection took place when determining in which hypogeum deceased individuals would be placed; 2) to provide an evaluation of the general health of the individuals of the population in order to obtain an understanding of the physical stresses to which this population was subject; and 3) to comment on the potential residency patterns of the individuals through the analysis of strontium isotope ratio data, by comparing dental enamel values to those obtained from bone.

The eventual goal in this collaborative research effort is to consider the human skeletal analysis alongside the information obtained from the analysis of faunal material and artifacts to develop a comprehensive picture of the population. Equipped with this information, future research will hopefully be able to draw comparisons between this population and other contemporaneous groups, and ultimately comment on the nature of relationships between them, both cultural and biological.

CHAPTER 2: HISTORICAL BACKGROUND

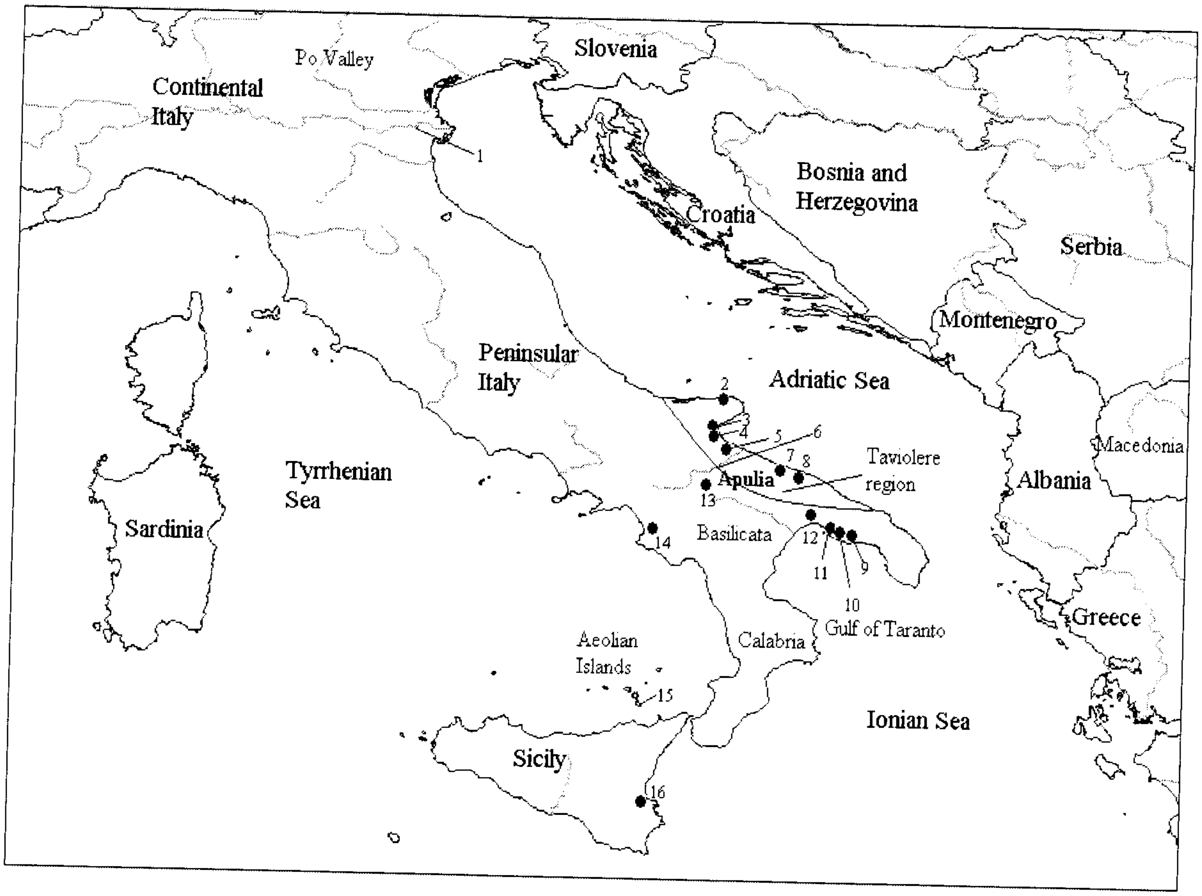
The European Bronze Age is generally characterized as a time of great instability. It is during this period that substantial demographic growth occurred among many populations, the subsistence patterns of agriculturalism and pastoralism were strengthened, and economic allegiances flourished between isolated groups owing to the manufacture and trade of craft items such as metal ware and ceramics (Peroni, 1979). Urbanization was the trend in many areas, especially those to the East, although Italy remained somewhat provincial in its uncharacteristic dependence upon a Neolithic way of life (Barker, 1981; Brown, 1980). Due to its temperate climate and fertile grounds, most of the prehistoric Italian mainland remained inhabited by small farming communities consisting of several families living at near subsistence levels (Barker, 1981), whose populations normally numbered only in the tens (Peroni, 1979). The extensive areas of good soil and pasture contributed to a prolonged period of relative social and economic stability, which remained in place for nearly one thousand years, up until the end of the Bronze Age, at which time invasions from the East introduced a new momentum of life.

The precise range of dates associated with the Bronze Age varies between regions, though the dates for peninsular Italy appear to have reached from 1800 to 900 BCE (Peroni, 1979; Brown, 1980; Smith 1987). Table 2.1 provides a chronology of the main cultural groups that existed in Italy during the Early through Late Bronze Ages. A detailed discussion of all these cultural groups is beyond the scope of the present study, though I have chosen to highlight those most often mentioned in the literature.

<u>Table 2.1</u>: Cultural chronology of the Italian Bronze Age. Table adapted from Smith (1987, p.3); radiocarbon dates for Mycenaean pottery stages corroborated against Warren and Hankey (1989, p.169); cultural sequence for northern Italian populations adapted from Harding (2000, p.16).

Date BCE	Northern Italy	Peninsular Italy	Sicily	Aeolian Islands	Mycenaean Pottery Stages
Early Bronze Age 1800 – 1600 1600 – 1400	Polada *terramare*	Protoapennine	Castelluccio	Capo Graziano	MH LH I – LH II
Middle Bronze Age 1400 – 1325	Peschiera	Apennine	Thapsos	Milazzese	LH IIIA
Late Bronze Age 1325 – 1180	Bronzo finale Proto-golasecca	Subapennine	Pantalica	Ausonian I	LH IIIB
1180 – 1050		Protovillanovan		Ausonian II	LH IIIC

In works addressing the populations of the Italian Bronze Age, scholars often limit their discussion to two main cultural groups, namely the northern-dwelling *terramare* and the south-central Apennines. Little is known about the *terramare*, despite the plentiful,



1. Po River
2. Grotta di Manaccora
3. Manfredonia
4. Coppa Nevigata
5. Trinitapoli (*Madonna di Loreto)*
6. Ofanto River
7. Giovinazzo
8. Bari
9. Torre Castelluccia
10. Satyrion
11. Porto Perone
12. Scoglio del Tonno
13. Toppo Daguzzo
14. Gaudo
15. Lipari
16. Thapsos

<u>Figure 2.1</u>: Map of Italy and surrounding areas. Locations of archaeological sites adapted from Smith (1987, pp.12-17), Holloway (1981, pp.13 and 15), and Guido (1973, pp. 14-15).

though poorly documented, archaeological sites of continental Italy (Coles and Harding, 1979; Peet, 1909). Their occupation appears to have been restricted mainly to the Po Valley of northern Italy (Figure 2.1), (Coles and Harding, 1979; Peet 1909). It is possible that their main attraction to this area related to the abundant supply of metal ores in the valley itself, as well as those in the neighbouring Alpine regions. Evidence from the archaeological record suggests that these populations possessed at least an elementary knowledge of metal casting (Peet, 1909). The hallmark of *terramare* sites appears to be the consistent use of cremation as the burial rite (Coles and Harding, 1979). Peet (1909) discusses the infiltration of this culture into more southern areas, perhaps even as far as Taranto, though the cultural influence that these migrant populations may have had on the southern residents is unclear.

These cultural traditions are in sharp contrast to those of the Apennines, who had limited interest in metals. For these populations, pottery was the main focus, and Apennine sites are fairly easily recognized by their unique and elaborate ceramic decorations (Barker, 1981). The Apennines, who had fully formed as a culture by approximately 1600 BCE (Holloway, 1981), brought cultural unity to the nomadic populations of south-central Italy (Trump, 1966). Cohesiveness appears to have been accomplished peacefully, since there is little evidence of warfare among these groups, and few of their settlements existed in areas with natural or artificial defenses. Barker (1981) has characterized the Apennine groups as subsistence farmers who assumed a common cultural tradition and followed a social organization primarily at the tribal level. He further proposes that the success of the Apennines' social stability was due to the advantageous farming conditions of peninsular Italy. Some popularity exists for the proposal that these groups were primarily pastoralist, taking advantage of the fertile soil and areas of good summer pasture in the mountainous regions of peninsular Italy (Barker, 1981; Trump, 1966), though more recent publications caution against this conclusion (Malone et al, 1994). The geographical conditions of this area likely contributed to poor natural communication, though common cultural traditions may have been obtained through seasonal migrations to the plains. The climate of this region likely consisted of dry summers followed by wet winters (Malone, 1994), and it has been suggested that these populations carried out seasonal occupation of the nearby Taviolere plains and the Adriatic coastal regions, migrating during the winter months when the temperature in the mountains would fall (Trump, 1966; Barker, 1981). These seasonal camps likely served as venues for the exchange of ideas between groups, and thus contributed to their common cultural traditions.

Although these two groups are those most often mentioned in the literature, various other groups appear to have inhabited certain areas further south and to the east along the Adriatic coast. In these regions, a variety of funerary rites have been documented, including rock-cut burials, megalithic tombs, single and multiple inhumations, and even cremation (Coles and Harding, 1979; Malone et al, 1994). The large and impressive megalithic tombs are variably considered to be the norm for south-east Italy in the Bronze Age (Malone et al, 1994), though a large number of rock-cut tombs have been analyzed as well (Whitehouse, 1972). This diversity suggests the presence of several groups of different cultural affinities, though at this time, little is known about the origins of the Bronze Age inhabitants of this area.

The Taviolere plain of Apulia (Figure 2.1) presents an unusual situation for prehistoric Italy in that it appears to have attracted a significant amount of human activity in Neolithic times (Whitehouse, 1986; Peroni, 1979), with some settlements large enough to be considered full villages (Robb and Van Hove, 2003; Malone et al, 1994). By the Bronze Age, much of the Taviolere plain had lost its popularity: sites in this region are nearly absent for this period, with the exception of those in its coastal regions (Rotunno, 1997; Whitehouse, 1986). The unwooded marshlands and temperate climate (Caladara et al, 1997), as well as the availability of fish and wild fowl, were likely to have attracted settlers to this area (Guido, 1973).

The current study involves a site in this very region. The site is located near the modern town of Trinitapoli, in the province of Foggia in the Apulian region of southern Italy. The site is called "*Madonna di Loreto*", and it consists of two underground artificial burial caves, which were created from the calcareous layers of natural bedrock common to most of Apulia (Vanzetti, personal communication, 2003). Tombs of this sort are referred to as "hypogea", or "*ipogeo*" in Italian, and their first use in Italy appears to date back to the fifth millennium BCE (Whitehouse, 1972). The earliest forms of this type of burial were reserved for only a small number of individuals, numbering not more than three. Although the rock-cut tombs did not represent the norm for the Neolithic age, when single burials in earth graves appear to have been most popular (Whitehouse, 1972), their use became more frequent in the Copper Age in Apulia as well as in other areas of the Mediterranean, such as the Iberian peninsula, southern France, Spain, Malta, Greece, Cyprus, and the Balkans (Holloway, 1976). One of the most well-known rock-cut tombs in Italy is that from the Copper Age site of *Gaudo*, on the western side of the peninsula. Although no specific settlement has been identified for this population, the tombs appear to have undergone continued use for a reasonable period. The use and re-use of these burial chambers resulted in the displacement of preceding burials and their associated grave goods, contributing to a disordered commingling of the tombs' contents (Holloway, 1976).

By the Middle Bronze Age, the popularity of the rock-cut chamber tomb had declined, with the Apennines preferring the use of single burials in earth graves (Whitehouse, 1972), though rock-cut tombs from the Bronze Age have been identified in Sicily, where they appear to have been the norm for the Thapsos culture (Harding and Cole, 1979; Holloway, 1981). Several populations of south-east Italy also continued to use the rock-cut tomb (Whitehouse, 1972). Worthy of note is the elaborate Middle Bronze Age tomb of *Toppo Daguzzo* (Repeto et al, 1988; reviewed in Malone et al, 1994). It is believed that this site experienced a relatively long period of occupation dating from the third millennium to the Eighth century BCE, as its advantageous location between the two different environmental zones of the Taviolere and the central foothills likely contributed to a comfortable climate and efficient communication routes. Several burial chambers are associated with this site, though the most impressive consisted of two burial layers, with each layer containing the disarticulated remains of 10 and 11 individuals respectively (reviewed in Malone et al, 1994).

The cave of the current investigation houses a burial chamber composed of multiple inhumations, and as is the case with the multiple inhumations of the great megaliths which are contemporary and plentiful in the region, unintentional disarticulation and commingling has occurred as a natural result of water infiltration, human activity, and animal scavenging (Harding 2000; A. Vanzetti, personal communication, 2003). Funerary items such as bronze daggers and glass beads were included with the burials, and through artifact cross-dating, it has been estimated that this burial site was in use during the Italian Middle Bronze Age, likely within the period of 1600 – 1350 BCE, though these values have not been corroborated against carbon-14 dating since the level of salt contamination from the infiltration of sea water is thought to limit the reliability of the result (A. Vanzetti, personal communication, 2003). Continued use of this burial site for a two hundred and fifty year period could suggest a long occupation of the site, a somewhat atypical situation for the Italian Bronze age (Peroni, 1979).

In addition to its sustained occupation of a single location, it is likely that the population in question was probably larger than most contemporary Italian populations, as it appears that a single community made use of two separate and contemporary hypogea, which could suggest that each tomb was reserved for different segments of the community (A. Vanzetti, personal communication, 2003). The larger of the two, the *Ipogeo dei Bronzo*, so named based on its plentiful supply of bronze artifacts, was excavated in the 1980s. The preliminary analysis of the skeletal material recovered from this tomb has been summarized in two separate publications (Cenni et al, 1999a and

1999b; Minozzi et al, 1999). Similar to the tomb of current investigation, the *Ipogeo dei Bronzo* was used over a span of approximately two hundred and fifty years (Cenni et al, 1999a and 1999b).

The current study concerns the smaller of the two hypogea, which was excavated from 2000 through 2001. Of particular interest in this hypogeum are two small ivory statues that were located at its entrance, or *dromos* (Figure 2.2). On behalf of these unique finds, the cave has been awarded the title the "*Ipogeo degli Avori*". Ivory was not available in this region, so this material was almost certainly obtained through

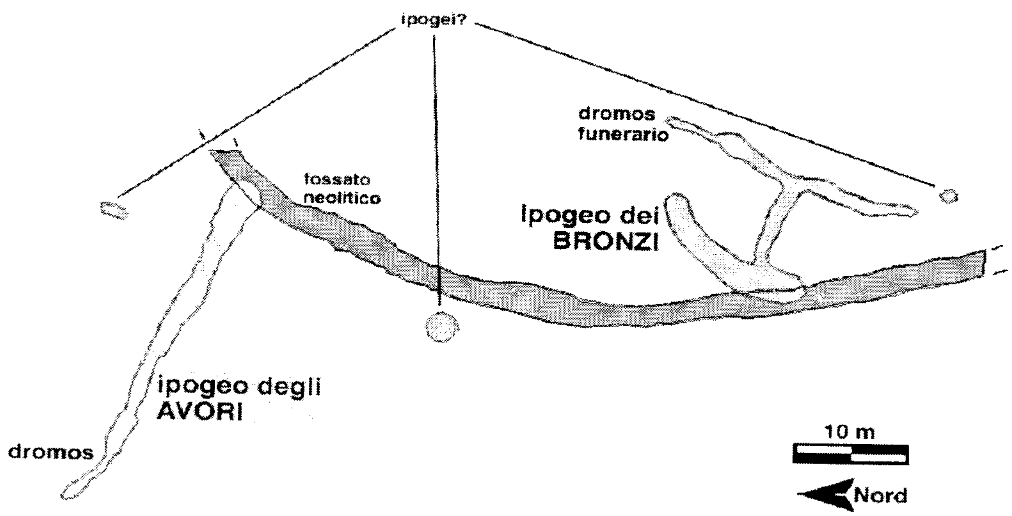
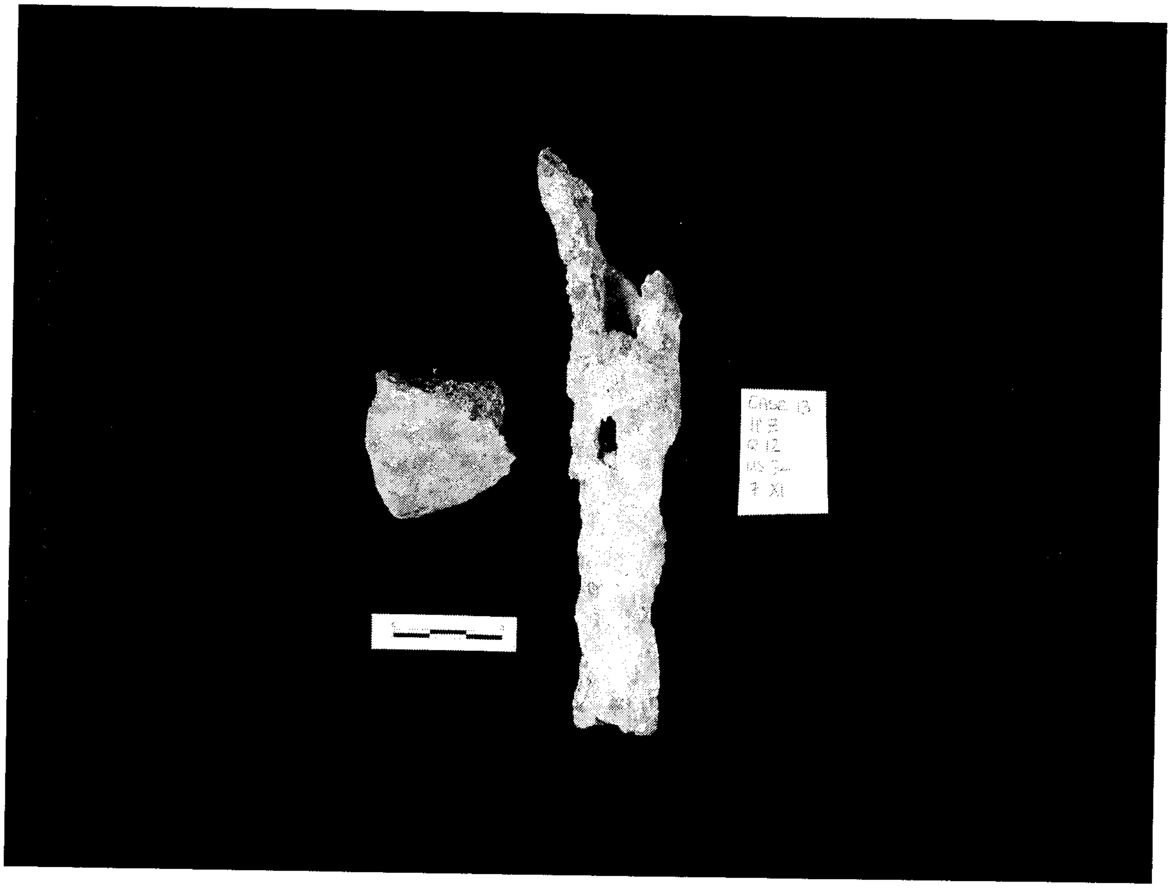


Figure 2.2: The relative positions of the two contemporary Bronze Age hypogea of *Madonna di Loreto* that are thought to have been used by a single community. Both hypogea are examples of rock-cut chamber tombs, created from the calcareous layers of bedrock common to most of Apulia. The "dromos" refers to the entrance of the burial cave. The "fossato neolitico" refers to a depression in the rock that forms a passage between the two burial chambers. Figure adapted, with permission, from A. Vanzetti, July 2003.

trade or through import with human migrations, either as a raw material or as a finished product.

Peroni (1979) has suggested that the Italian Middle Bronze Age was likely dominated by the patriarchal clan model of social organization. Unfortunately, the extent of commingling in collective burials makes the inference of social connections between individuals based on the physical arrangement of burials in the tomb a very difficult task. The *Ipogeo degli Avori* consists of three main strata, though the infiltration of marine waters has contributed to a significant intermixing of these layers. Figure 2.3 shows two different skeletal elements that were found in the same location in the site at the time of excavation, though from the acute differences in erosion, it is evident that they at one time had occupied different areas of the tomb. This demonstrates the limitations in the conclusions that may be drawn concerning the social relationships between individuals based on their placement in the tomb.

There is currently a considerable volume of debate over the cultural origins of the community who made use of these two hypogea. Although limited, the grave goods suggest close and long-term interactions with other cultures of southern Italy. This may suggest that the population was not an immigrant one, but was established and either native to the area or migrant from a nearby land. Furthermore, certain of the grave goods, such as glass beads and metallic tweezers, suggest connections with the ancient Illyrians, though it is not known if these objects were manufactured at the site, or whether they were transported to the region through trade activities (A. Vanzetti, personal communication, 2003).



<u>Figure 2.3</u>: Two skeletal elements retrieved from the same archaeological coordinates in the *Ipogeo degli Avori*. The sharp difference in weathering suggests that these elements at one time occupied different areas of the tomb, and have since been shuffled into adjacent positions from to the mixing of strata. This phenomenon suggests that the extent of shuffling between layers in the tomb may have been considerable, and that the spatial distribution of skeletal elements may provide limited assistance in determining the social relationships between individuals.

A fairly popular school of thought links this population to the Aegean world. The Italian Middle Bronze Age corresponds to an important period of Aegean history where the development of the Mycenaean empire took place. The Mycenaeans were a monarchical population who dominated mainland Greece for the greater part of the

Bronze Age period (Hooker, 1996, Late Helladic Period section, para. 3). Although their main subsistence strategy was agriculture (Diskinson, 1994), the land of mainland Greece was relatively dry and less than ideal for the growth of many crops (Hooker, 1996). Despite these environmental limitations, Mycenaean settlements became very large due to efficient communication and good marine resources (Barker, 1981), and elements of urbanization were witnessed as early as the 16th century BCE (Hooker, 1996). The power of these cultural centers quickly allowed this civilization to assume dominion over a large part of the commercial trade in the Mediterranean during the Bronze Age (Smith, 1987). This control endured for many centuries, but experienced a rapid decline shortly after the Dorian invasion of approximately 1150 BCE (Brown, 1980). The precise reasons for the rapid decline of such a powerful civilization are not clearly understood.

The Mycenaean civilization had experienced its first period of significant cultural activity in the 17th century BCE, a fact that is reflected by their participation in trade with neighbouring areas (Smith, 1987). Trade was a very important part of prehistoric European life, and Greece occupied an advantageous position which permitted relatively easy access to many different territories via marine routes. Trade allegiances with Crete, Asia Minor, and Egypt are known to have existed (Hooker, 1996), and Apulia appears to have been at the periphery of the Mycenaean trading networks (Holloway, 1981). The extent of trade is largely reflected in the sheer abundance of ceramic materials of Mycenaean design that have been found in many Mediterranean areas.

Traditionally, scholars have relied upon ceramic design to establish time lines in the archaeological record, and due to the ubiquitous presence of Mycenaean ceramics in the Aegean, Mycenaean pottery stages are commonly used as convenient chronological references in the literature. The Mycenaean stages are broadly separated into the Early, Middle, and Late Helladic (EH, MH, and LH, respectively), and each is characteristic of a distinct period of historical development. Pottery styles provide the most sensitive available indicator of the passage of time in the Aegean, as their decoration often reflects social changes of the era (Warren and Hankey, 1989); however, the advent of carbon-14 dating has permitted researchers to add a more precise temporal component to the ceramic styles. Table 2.1 (p. 5) provides a summary of the Mycenaean ceramic styles corroborated against radiocarbon estimates for the periods of current interest.

In Italy, Mycenaean pottery is generally concentrated in three main areas: southern Italy (especially Taranto), Sicily, and the Aeolian Islands. These three areas appear to have been subject to a faster social and economic evolution than areas of the central and northern mainlands (Brown, 1980), and this evolution may well have been related to trade connections with the Aegean. Whitehouse (1973) and Malone and colleagues (1994) have stressed the importance of Mycenaean trade in the formation of structural cohesiveness in the communities of prehistoric Italy, and proposed that trade likely precipitated the process of urbanization in these areas. Mycenaean trade appears to have been largely restricted to the three aforementioned areas, and thus discussions of Italian prehistory tend to regard these three areas as a unit, distinct from the north and center (Holloway, 1981; Harding, 2000).

Trade contacts between Italy and the Aegean likely existed as early as the 17th century BCE (Kristiansen, 1998). The earliest Mycenaean pottery finds in southern Italy date to the MH and LH I/II periods (Smith, 1987; Holloway, 1981), though Holloway (1976) has suggested that Mycenaean contacts may have existed at *Gaudo* as far back as the Copper Age. Prior to Mycenaean contact, trade routes had been established between the north and south of Italy, mainly to facilitate the distribution of metal ores (Smith, 1987). The central and southern regions of Italy are completely deficient in metals, so it was necessary to transport raw materials from the north (Trump, 1966; Smith, 1987). This was likely accomplished through marine routes, with Sicily and the Aeolian Islands serving as trading posts for the peninsular regions. It has been suggested that once the Mycenaeans took an interest in trade with Italian populations, they simply integrated themselves into these pre-existing indigenous trade routes (Smith, 1987); it is for this reason that Mycenaean pottery finds are plentiful in the Aeolian Islands and Sicily. Metal was the main material for which the Mycenaeans held any interest, and it is likely that the trading posts established in various areas were for the acquisition of metal sources transported from the north (Smith, 1987). These early contact sites include *Porto Perone* in the Gulf of Taranto, *Lipari* in the Aeolian Islands, and *Thapsos* in Sicily (Holloway, 1981; Smith, 1987).

As far as inland communication is concerned, MH and LHI/II pottery has been found in the large megalithic burial at *Giovinazzo* (Holloway, 1981) on the Adriatic coast, slightly south of the archaeological site of the current investigation. It is not known if these pottery shards were delivered directly by Mycenaean traders or whether they were acquired through the indigenous inland trade network. Holloway (1981) proposed that Apulia received Greek goods directly, and these interactions may have occurred at marine "rest stops" along the Greek trading routes. With regard to Mycenaean trade, Harding (2000:181) suggests "it is likely that long open sea crossings were avoided, and coast hopping was the main type of movement". The voyage between Greece and Apulia would not have been laborious (Holloway, 1981), and some scholars have suggested that certain areas of Apulia may have served as one of these very rest stops for Mycenaean traders en route to Sicily (Smith, 1987).

The Mycenaean empire reached its cultural height at approximately 1300 BCE, at which time its cultural connections with southern Italy are easily discernable (Smith, 1986). This period corresponds to a rise in popularity of metallurgy experienced throughout Europe and the Aegean in the transition between the Middle and Late Bronze Ages (Peroni, 1979; Malone et al, 1994). It is at this time that the coastal regions of southern Italy witnessed the establishment of heavily fortified settlements, and it is generally believed that the sudden popularity of these regions stemmed from their associations with Mycenaean trade (Malone et al, 1994). The populations of the coastal regions appear to have held a greater interest in trade compared to those of the inland regions, though this comes as no great surprise when consideration is given to their ideal location. As previously stated, the marine journey between Greece and Apulia would have been neither lengthy nor laborious (Holloway, 1981), and the many rivers of this region would have facilitated the transport of items of eastern origin into inland areas for further trade with indigenous groups. Though trading sites among the Apennine peoples are few, there is evidence that they made occasional appearances at certain trading nodes via rivers and valleys (Smith, 1986). The Ofanto River, for example, is known to have experienced heavy traffic in prehistoric times (Guido, 1973), and this would have served as an ideal location for a contact point between the coastal populations involved in trade with the East and the inland Apennine populations. In his early monograph, Peet (1909:418) states that in prehistoric times, Apulia was "not an obstacle, but an assistance to commerce".

Although somewhat dated, one of the main sources in English regarding the connections between Italy and the East remains to this day the monograph of Lord William Taylour entitled Mycenaean pottery in Italy and adjacent areas (1958). This publication provides a comprehensive review of the ceramic material of Mycenaean origin that has been identified at Italian sites corresponding to the LH III through sub-Mycenaean periods [1065 through 1015 BCE (Warren and Hankey, 1989)]. In his analysis, Taylour lists 20 important sites where eastern ceramics have been identified, though the more recent literature suggests the number of relevant sites should be increased to more than 60 (Smith, 1987). Taylour considers the archaeological evidence of several different regions, though he devotes a large portion of his analysis exclusively toward the site *Scoglio del Tonno*. This very important site is located on the Gulf of Taranto, and it appears to have experienced a long occupation. As of the Late Bronze Age, this site shows continuous relations with the Mycenaean world (Trump, 1966). Most of the Aegean pottery discovered in Italy thus far comes from *Scoglio del Tonno* (Holloway, 1981), and thus it is most certainly one of the earliest mainland trading posts.

In the ensuing centuries of the Late Bronze Age, the areas adjacent to *Scoglio del Tonno* became popular locations for trading posts. Sites such as *Torre Casteluccia* and

Satyrion assumed a more urban form, and *Porto Perone* continued as an active trading station (Smith, 1986). The locations of these sites are of particular interest in that they are situated in well-fortified areas on coastal promontories to the Ionian Sea, thus making them easily accessible via Mycenaean marine routes. The concomitant development of sites along the Adriatic coastal regions further facilitated trade with the indigenous Italian groups. *Coppa Nevigata*, for example, located on the Gargano promontory, represents yet another exceptionally large settlement for this period. Finds of Mycenaean ceramics and bronzes are plentiful, so it appears that the occupants of this site, along with those mentioned in the south, were in intimate contact with eastern traders (Whitehouse, 1973; Taylour, 1958).

The above trading sites supported relatively large populations, and are thought to represent the beginnings of proto-urban settlements in southern Italy. Whitehouse (1973) provides a discussion of the factors that may have precipitated the process of urbanization in these areas, and suggests, in broad terms, that urbanization can be introduced either through intense commerce with existing urban communities, or by migrants coming from an urban environment. The combination of the contrast in settlement pattern of these sites with the provincial qualities of other contemporary sites in peninsular Italy, and the abundance of Mycenaean ceramics, has led some scholars to theorize that these settlements may have been inhabited by actual Mycenaeans themselves. Evidence of the local production of bronze goods at *Scoglio del Tonno* (Malone et al, 1994) and *Coppa Nevigata* (Whitehouse, 1973) lends further support to this notion. Smith (1987) suggests that Mycenaean traders were likely resident at the major trading nodes to liaise with local traders and to manage the conduct of trade, and this notion of Mycenaean occupation of certain coastal areas in the Late Bronze Age is generally supported in the literature.

Although the majority of the above-mentioned sites experienced their Mycenaean occupation at a time that postdates *Madonna di Loreto*, the preceding discussion does succeed in elucidating the interests the Mycenaeans held for southern Italy, as well as the fact that contacts between the East and West existed at a time contemporary with the use of the *Ipogeo degli Avori*, as evidenced from the MH and early LH Mycenaean ceramic finds at *Porto Perone*, and more importantly those from the neighbouring megalithic tomb of *Giovinazzo*. Some researchers are wedded to the belief that the current population represents some of the earliest Greek settlers in southern Italy, a notion that, if confirmed, would be quite significant. Trump (1966:124) highlights that "it is an important moment in Italian prehistory when Mycenaean ships effected the first direct contact with the civilizations of the east", and the notion that we are currently dealing with a very early potential settlement may invite the opportunity for significant advances in understanding the nature of the contacts between the East and West. More recently, Harding (2000:181-182) put forth that "the chances of finding other major trading stations in south Italy and Sicily must be declining, given the intensive use of the coastline at the present day, [and] the best hope for a new find which will revolutionize understanding of the trade with Greece is a wreck site in the area around Sicily or Sardinia". Though a wreck site would introduce a wealth of new information into the archaeological record, the significance of a newly identified settlement would by far outweigh this yield, and may very well contribute to significant modifications in our current characterization of Italian prehistory.

A large portion of this hypothesis rests upon the presence and design of the two ivory statues. As stated previously, ivory was not available in southern Italy, so the material would have to have been obtained through trade, either as a raw material or as a finished product. Ivory is a material commonly associated with Mycenaean burial sites as a funerary offering (Anderson and Immerwater, 1971; Poursat, 1977). Its mere presence in the *Ipogeo degli Avori* may suggest eastern connections, though its decoration lends even further support to this notion. Most striking are the structural similarities between the wild boar statue and those associated with contemporary populations from Crete (A. Vanzetti, personal communication, 2003).

In addition to the presence of trade items, the location of the site would surely have been advantageous to Mycenaean traders given its close proximity to the Ofanto River, which would have permitted easy contacts with inland populations, and thus presented ample opportunity for trade excursions. Smith (1987:131) proposes that "the [southern Italian] sites which show sustained and intensive contact with the Aegean were all ideally situated to facilitate the movement of raw materials… from inland areas for onward transmission to the Mycenaean world". In this respect, the current site may be positioned so as to infiltrate the indigenous trade routes, and thus allow for the acquisition of metal raw material traded down from northern Italian sources. Furthermore, rock-cut chamber tombs were the norm in the Mycenaean world (Anderson Immerwater, 1971), and when compared to the diversity of burial rites common to southern Italy, the practice of this ritual may once again suggest close Mycenaean contacts.

Despite the evidence that supports the theory of a Mycenaean origin for this population, some researchers remain skeptical concerning this connection. Aside from the two ivory statues, many funerary offerings found within the tomb are suggestive of close associations with areas directly opposite the Adriatic in Albania and the former Yugoslavia, especially Croatia, Bosnia, and Montenegro (A. Vanzetti, personal communication, 2003). Certain of the bronze items, such as the small tweezers and the many glass beads that were recovered from the site, are suggestive of connections with Illyrian populations who inhabited the aforementioned areas in Eastern Europe (A. Vanzetti, personal communication, 2003). The Illyrians did hold a general interest in this area, as is evidenced by their eventual settlement in southern Italy. It is not known when migrations were initiated, though by the commencement of the Iron Age, distinct populations of Illyrian origin, namely the Daunians, the Peucetians, and the Messapians, collectively referred to as the Iapygians, were established in the region (Guido, 1973).

Casting aside the items suggestive of Illyrian associations, several other artifacts recovered from the site are suggestive of a general involvement with contemporary Italian populations of peninsular Italy (A. Vanzetti, personal communication, 2003). In this regard, it is entirely possible that the current population represents an indigenous Italian group who were heavily involved in trade with areas opposite the Adriatic, as facilitated by their coastal position.

Connections between Mediterranean populations are known to have existed during the Bronze Ages, and genetic exchanges between the areas of Apulia, the former Yugoslavia, Albania, Epirus, as well as Western Greece, may hinder our ability to generate conclusions from biomolecular data, if such attempts were made (A. Vanzetti, personal communication, 2003). Furthermore, skeletal samples from the aforementioned regions are scant, and thus it may be difficult to draw tangible conclusions concerning biological relationships based on anthropometric data (A. Vanzetti, personal communication, 2003).

The general picture concerning the biological and cultural origins of this particular population is difficult to draw given the seemingly contradictory nature of the archaeological interpretations. Although the very presence of the ivory figures has been variably accepted as evidence of a Mycenaean connection, the large proportion of material showing associations with populations from the former Yugoslavia and Albania precludes our ability to conclude that the individuals are of Greek origin. Furthermore, the presence of funerary offerings that suggest connections with the indigenous populations of peninsular Italy serves as compelling evidence that we are not, in fact, dealing with an immigrant population at all, but rather one that was either settled in the region, or immigrant from a nearby land.

The analysis of funerary offerings alone cannot reliably provide evidence of cultural affinity when consideration is given to the frequency of trade amongst Mediterranean settlements of the era. If a tangible hypothesis concerning the biological origin of this population is a desirable goal, we may be better equipped to reconcile the existing controversies if we first understand the population as best we can by establishing a bio-social representation of the dead individuals, with consideration to demographic structure and general health. This process represents one of the first vital steps in the characterization of any new skeletal population. The information obtained from the current analysis will eventually be considered alongside the archaeological data for this population, and, in combination, these research efforts will contribute to a better understanding of trade patterns and early human migrations in the Middle Italian Bronze Age.

CHAPTER 3: MATERIALS AND METHODS

3.1 Skeletal Inventory and MNI

The excavation of the *Ipogeo degli Avori* took place between 2000 and 2001. During excavation, great care was taken to record the precise location of each skeletal element. Elements from discrete areas were placed in small plastic bags, each of which was labeled with the pertinent archaeological information relating to the location of the find within the site. Individual bags consisted of anywhere from a single fragment to upwards of 200 fragments. The bags were placed in large gray plastic cases, with each case containing approximately 50 bags. At the time of the current analysis, 17 cases had been made available to the osteologists. It is not known what percentage of total skeletal material from the site that this sample represents.

The current analysis provides an interpretation of the human skeletal material contained within 11 of the 17 cases, thus representing approximately 65% of the total material made available at the time. Information regarding general inventory, age, and sex was recorded in a series of Excel spreadsheets (Microsoft Office XP Professional, 2000), which were largely designed to accord with the inventory criteria outlined in the Inventory Recording Form for Commingled Remains and Isolated Bones, Attachment 2 in Buikstra and Ubelaker's *Standards for Data Collection From Human Skeletal Remains* (1994). Columns entitled "Subadult" and "Palaeopathology" were added to provide a quick representation of the number of subadults and the frequency of pathological specimens in the population. A representation of the general database is included in Appendices A, B, and C.

The first task in the current analysis consisted of a basic inventory of the skeletal elements contained within each bag. The archaeological information displayed on each bag was recorded in detail. The fragments contained within individual bags were placed on a table, and the total number of fragments was recorded. The fragments were then separated into different groups based on anatomical position in the body, and the different skeletal elements represented by the fragments were noted. The number of fragments representing each element was also recorded. For each individual fragment, efforts were made to identify the specific segment of the element represented, its symmetry, and its completeness. The recorded completeness related to the segment of the element listed in the spreadsheet, and it was scored in accordance with the following key: "C" for complete segments; "1" if more than 75% of the segment was present; "2" if the fragment represented between 75 and 25% of the segment; and "3" if under 25% of the segment was present. For example, the well-preserved proximal half of a humerus was listed as "segment = P1/2" and "completeness = C".

Most of the fragments had undergone a cleaning process prior to analysis. Others required minor dirt removal, which was usually done by light tapping of the dirt with a soft wooden chopstick. Calcium carbonate had collected on some of the bones, but removal was not attempted due to concern of incurring damage to the bones. Fragments appeared in many different levels of preservation, though the poor preservation of many elements occasionally precluded the analysts' abilities to identify the skeletal element represented; hence, there was a large proportion of fragments (approximately 30%) which were labeled "unidentified". In addition, symmetry was often difficult to determine due to poor preservation. Non-pathological fragments were occasionally glued to facilitate analysis.

From the general inventory, lists were generated which summarized the number of left, right, and unsided fragments representative of each skeletal element. From these lists, the MNI for each element was calculated based on the individual portion of the element that experienced the greatest recovery.

3.2 Age Estimation

Age estimation was performed on all suitable skeletal elements. Data from this analysis was recorded in a database designed specifically for aging. Due to the fragmentary nature of the material, it was thought advantageous to make use of as many aging methods as possible for both the adult and subadult material.

3.2.1 ***Subadult age estimation***. A variety of methods were used for subadult age estimation due to the great variability in skeletal morphology that occurs at different developmental stages. Dental aging was based on both dental formation and eruption. The formational stages of loose teeth and those *in situ*, though contained within mandibles and maxillae whose preservation was poor enough to permit the observation of developing teeth, were recorded based on the developmental stages outlined in Moorrees and colleagues (1963a and 1963b). Age estimations were made based on the development charts established by these authors. Since sex was unknown, data specific to males and females was averaged based on the mean ages for each developmental stage (by recommendation of Ubelaker, 1987). The stages recorded in the actual spreadsheet match with the developmental stages presented in Buikstra and Ubelaker (1994), which are analogous to those in the Moorrees and colleagues (1963a and 1963b) publications. For all subadult mandibles and maxillae which presented teeth *in situ*, dental eruption was scored as "0" for unerupted teeth, "1" for those in a state of eruption, and "2" for fully erupted teeth. Age estimations were based on the dental eruption chart shown in Buikstra and Ubelaker (1994), as adapted from Ubelaker (1989a). Mean ages along with relevant age ranges were recorded.

Scheuer and Black (2000) provide abundant data on skeletal morphology at different developmental stages. This source was instrumental in the age estimation of many immature skeletal elements. Their text provides a comprehensive summary of the development of many skeletal structures, and the morphological summaries for each element are complemented by tables of measurements, adapted from many different studies on skeletal development. This data was most useful for age estimations involving epiphyseal union and the development of primary ossification centres.

McKern and Stewart (1957) emphasize the importance of considering epiphyseal union as a process rather than an acute event, and for this reason the stages of union were recorded as follows: "0" for unfused epiphyses; "1" for epiphyses for which union has commenced; "2" if union is almost complete; and "3" if fusion has occurred to the extent that the epiphyseal line can no longer be seen based on gross observation. Fused epiphyses were only recorded with a "3" if other epiphyses on the skeletal element had not yet completed the process of fusion. If all epiphyses were fused, the element was considered to be adult, and was not entered in the aging database. In a similar vein, the extent of development of the primary ossification centres was recorded as follows to better evaluate age: "0" for elements which appeared highly underdeveloped; "1" for developing elements that approximated adult morphology; and "2" for elements that had attained adult development. Once again, elements that scored a "2" were only included in the aging database if they possessed an adjacent feature that was underdeveloped.

As with dentition, age estimates for epiphyseal union and extent of ossification of primary centres were based on pooled data for males and females, and age ranges were set to include the minimum and maximum age limits for development as listed for the elements in the Scheuer and Black (2000) text.

Diaphyseal length is often cited as a reliable method of subadult age estimation, though the fragmentary condition of the skeletal elements from this site often precluded the analyst's ability to perform diaphyseal measurements. Only two complete immature diaphyses were encountered, namely one radius and one fetal tibia. Age estimates for these elements were based on the diaphyseal length tables from the Scheuer and Black (2000) text adapted from Gindhart (1973) for radial data, and Trotter and Petersen (1969) for tibial data [pp. 298 and 415 of Scheuer and Black (2000), respectively].

It is important to note that Scheuer and Black (2000) report there to be a trend in the over-estimation of the time of fusion of the spheno-occipital synchondrosis. The skeletal aging chart displayed in Buikstra and Ubelaker (1994) clearly lists this fusion as occurring in the early adult years, though Scheuer and Black caution against this assumption, and state that fusion tends to occur more commonly within the adolescent period. For this reason, the spheno-occipital synchondroses that appeared to be in a state of fusion were considered in the subadult pool of data.

Despite the lack of intact diaphyses, free epiphyses often survived fragmentation, and meticulous measurements were taken from each of these elements. Although the literature on epiphyseal dimensions at different developmental stages is scarce, Sundick (1972) provides metric data for certain epiphyses, as established from his analysis of the Indian Knoll population. In an attempt to better correlate levels of skeletal development with dental age, Sundick (1972) established a set of 18 dental ages, and recorded the level of skeletal development based on measures of epiphyseal width corresponding to each. The epiphyseal dimensions of the following elements were compared to the data presented in Sundick (1972): proximal humerus, capitulum, proximal radius, femoral head, greater trochanter, distal femur, proximal tibia, and the distal tibia. For each of these elements, the appropriate Sundick age stage was selected based on mean width for that element as presented in his dataset. Sundick considered the corresponding dental ages of Schour and Massler (1941) to provide approximate chronological ages for his 18 stages. These age estimates were used as approximate ages represented by the epiphyseal metric data in the current population.

3.2.2 ***Adult age estimation.*** Aging of adult remains was accomplished using the methods of sternal rib assessment (Işcan et al, 1984a and 1984b), pubic symphyseal surface morphology (Todd, 1921; Suchey-Brooks, 1990), and auricular surface morphology (Lovejoy et al, 1985). Due to the fragmentary nature of the skeletal sample, cranial suture closure was not enthusiastically used as an aging method because the relative closure of multiple sutures of the same individual could not be established. Identifiable sutures were only included in age assessments if some level of closure was evident, thus indicating that the cranium represented that of an adult. Age estimates based on dental attrition were not attempted due to time constraints.

Adult age estimates were presented as age ranges based on the age ranges suggested from the above aging references. The fragmentary nature of the skeletal collection often precluded the analyst's abilities to accurately determine the sex of the individual. For this reason, fairly broad age ranges were recorded so as to represent the pooled age ranges of male and female morphological variation for a given age group.

The commingled nature of the remains made it impossible to consider different aging methods for the same skeleton. This necessitated the analysis of the different methods to be done largely in isolation of others.

3.2.3 ***Age Categorization***. Once age ranges had been established for the relevant elements, each was assigned to an age category. There is a large discrepancy in the terms used to denote different stages of subadult development (discussed in Scheuer and Black, 2000). For the purposes of the current analysis, age categories were established as follows:

Infant: 0 to 0.9 yr.

Juvenile: 1 to 11.9 yrs. (childhood period before puberty)

Adolescent: 12 to 19.9 yrs. (period of most epiphyseal fusions)

Subadult: >20 yrs. (all immature elements for which a discrete age range could not be determined)

Adult: 20 and older.

Ubelaker (1989a) states that most of the features of the subadult skeleton have reached maturity by the age of 20; that is, dental eruption is mostly complete, the majority of the body's epiphyses have united, and long bone growth has largely ceased. Due to the relative timing of these morphological changes, Ubelaker (1989a) suggests that an individual can be said to be biologically "adult" by the age of 20. For this reason, an age estimate of less than 20 years was set as the uppermost boundary for a fragment to represent that of an immature individual.

There were many immature elements for which narrow age ranges could not be established. For example, a small fragment of a proximal humeral diaphysis which exhibited an unfused humeral head could only be said to be under the age of 20 years, the maximum age at which the proximal humerus is said to fuse to the diaphysis according to the data presented in Scheuer and Black (2000). Skeletal elements subject to this situation were labeled as "subadult", because although they were undeniably immature, a discrete age category could not be established.

Given the upper boundary of 19 years of age in the subadult category, it was necessary to re-evaluate some of the aging methods that applied to the adult remains. The Işcan and colleagues (1984a and 1984b) method of aging based on the sternal ends of the ribs, for example, includes age categories in the younger phases of the system that would fall within the adolescent phase, as defined in this analysis. For this reason, elements identified in phases "0" or "1", corresponding to ages 13 and younger and 14 to 19 respectively (for pooled male and female data), were considered in the adolescent category. Similarly, the youngest stages of the Todd (from Buikstra and Ubelaker, 1994) and Suchey-Brooks (1990) data for the symphyseal surface incorporate age ranges of 18 to 19 and 15 to 24, respectively. The adolescent development of the change from the pre-epiphyseal stage, as described in Scheuer and Black (2000), was not well-documented for the pubes considered in this analysis. Given this limitation, it is entirely likely that pubic symphyseal fragments labeled as stage "1" in the Todd and Suchey-Brooks systems represented pubic bones of immature individuals. For this reason, all pubic fragments labeled as stage "1" for the Todd and Suchey-Brooks methods were considered in the subadult pool of data. Fragments which were scored in the youngest phase of the Suchey-

Brooks system, corresponding to an age range of 20 to 24 years, were considered in the adult pool of data.

3.3 Sex Determination

The methods of sex determination followed those outlined in the Buikstra and Ubelaker (1994) standards guide. Both cranial traits and pelvic traits were considered in this analysis. Cranial traits were scored on a five point system, with 1 representing highly feminine traits, and 5 representing highly masculine traits. The morphology of the greater sciatic notch was subject to a similar five point system. The presence of the preauricular sulcus was scored according to a four-point system when appropriate. The sexing methods of the subpubic region suggested by Phenice (1969) were also considered in the determination of sex, and the scoring of the ventral arc was performed based on the three point system defined in Phenice (1969). Due to the fragmentary nature of the sample, not a single pubic bone was intact enough to afford scoring of the subpubic concavity or the ishiopubic ramus ridge.

Unfortunately, the suggestion to consider cranial and pelvic traits as a constellation of sex indicators (Buikstra and Ubelaker, 1994) was not possible for most of the elements subject to sexing in this study due to the extent of commingling and fragmentation of the remains. The sample did miraculously include the beautifully intact cranium of one individual, for whom each of the cranial indicators were considered as elements of the sex determination.

3.4 Palaeopathology

Most of the palaeopathological analysis was performed based on meticulous gross morphological assessment of the remains. Pathological fragments were rarely glued since there was concern that the slightest misalignment of skeletal structures might influence the analysis of lesions. A total of 25 elements exhibited pathological lesions. Lesions were described using non-diagnostic terms, and were measured whenever possible. Elements were placed in the following tentative categories based on the suspected nature of the lesion:

Trauma

Infection

Occupational stress markers

Neoplasia

Haematological disorders

If infection appeared to be associated with a traumatic lesion, the element was considered in the category of trauma. X rays were performed on 8 of the 25 fragments to evaluate bone density and internal morphology. Dental pathology was not considered in the current analysis due to time constraints.

3.5 Soil pH

A small portion of soil removed from one of the skeletal fragments was prepared for pH analysis. Following the methods of Gordon and Buikstra (1981), the soil was suspended in a solution containing one part soil and two parts deionized water by volume. The pH was measured with an ultraBASIC pH meter (Denver Instruments). Calibration of the meter was accomplished by use of the appropriate buffers. The pH of the deionized water was measured prior to the addition of soil. The soil was later removed from the aqueous solution by centrifugation.

Methods followed for the chemical analysis are discussed in Chapter 6, pages 111 through 115.

CHAPTER 4: DEMOGRAPHIC ANALYSIS

4.1 Archaeological description

4.1.1 ***Skeletal subset of the hypogeum subject to the current analysis.*** The following analysis is restricted to the skeletal material contained within cases 1, 2, 3, 4, 5, 7, 8, 9, 11, 12, and 13. Many of the cases contained remains that had been retrieved from several different areas of the hypogeum. For this reason, it was not possible to restrict analysis to an individual area, nor was it possible to analyze the skeletal material from specific locations of the hypogeum in their entirety.

Figure 4.1 displays the areas of the hypogeum represented by the skeletal material contained within each case of current interest. At the time of excavation, great care was taken to create an accurate GIS representation of the site, and meticulous efforts were made to document the three-dimensional coordinates of every skeletal element recovered. The coordinates of the horizontal plane were represented by letters for the "X" dimension and numbers for the "Y" dimension, and collectively these coordinates were recorded under the field "Q" (for "*quadrati*") in the general database. These coordinates proved most useful when attempts were made to represent the spatial distribution of the analyzed skeletal material within the hypogeum.

The depth of the site was considered in three main phases, each of which corresponding to a different period of the hypogeum's use. The deepest phase, "Fase 1", represents the earliest use of the cave, and "Fase 3" represents the latest. Each phase was in turn considered in different stratigraphical units, recorded in the spreadsheet in the field "US" (for "*uniti stratificati*"). Due to the extent of intermixing between layers that occurred at the site, the individual layers represented by US numbers were not always uniformly restricted to a single phase; that is, some layers infiltrated two different phases. This created the complication of having certain US numbers being representative of two different phases. Table 4.1 provides a summary of the phases that were represented in the cases studied in this analysis. Most of the bones represented phases 1 and 2, which suggests that the current analysis was concentrated on some of the older sections of the hypogeum. It should be noted, however, that several US numbers did not appear to accord with a specific phase in the GIS. Since it is not known which phases these US numbers represent, it would be naïve to dismiss phase 3 as having been largely excluded from this analysis.

Figure 4.2 provides a diagrammatic representation of the spatial distribution of the skeletal elements contained in the site. These images were obtained directly from the GIS. Comparison of different phases shows that exploitation of different areas of the

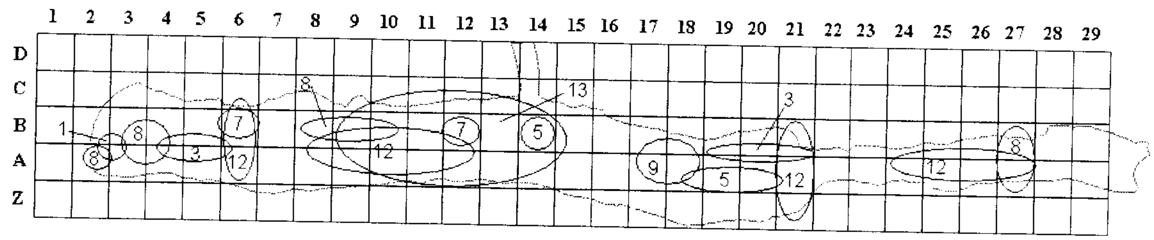


Figure 4.1. Distribution of the relevant skeletal material within the hypogeum, as identified by the "Q" coordinates represented within each case. Numerical values represent case numbers, though "Q" coordinates for case 11 were not available, and thus its skeletal complement is not included in the above diagram. The size of the circled areas signifies distribution only, and has no bearing on the number of fragments analyzed from each area.

hypogeum occurred at different times, with an occasional overlap. The entrance and the end of the cave appear to be the areas most frequently used. Fase 2 appears to house the greatest amount of skeletal material, followed by Fase 1. Fewer bones were recovered from Fase 3.

Table 4.1. Phases of the hypogeum represented by the skeletal contents of each case.

Case Number	*Fase 1 US*	*Fase 2 US*	*Fase 3 US*	*US of unknown Fase*
1	51	51	0	0
2	213	0	0	109
3	213	220, 51B	0	202
4	213	0	34B	0
5	56B	48B	0	103
7	0	55	34, 59	104, 107, 123, 100
8	0	220	0	114
9	0	214	0	0
11	56	54, 220	0	107, 240
12	56, 225	220, 48	0	202, 19, 130, 23, 8
13	51	48, 51, 55	34, 50	3, 4, 6, 31, 37, 39, 43, 44, 45, 107

Figure 4.2 provides a diagrammatic representation of the spatial distribution of the skeletal elements contained in the site. These images were obtained directly from the GIS. Comparison of different phases shows that exploitation of different areas of the hypogeum occurred at different times, with an occasional overlap. The entrance and the end of the cave appear to be the areas most frequently used. Fase 2 appears to house the greatest amount of skeletal material, followed by Fase 1. Fewer bones were recovered from Fase 3.

4.1.2 ***Condition of the skeletal material.*** A representation of a GIS image taken from one of the more skeletally dense areas of the hypogeum can be found in Figure 4.3. Through the consideration of GIS images such as these, it is evident that the skeletal remains are disarticulated and heavily commingled to the extent that identification of elements from the same individual would be a very difficult, if not impossible, task. In this regard, the *Ipogeo degli Avori* may be regarded as analogous to the many ossuary burial sites common to North American aboriginal populations. Although the term "ossuary" has been loosely employed to refer to burial sites which contain the disarticulated and commingled remains of a large number of individuals, Ubelaker (1974) affirms that the term should be restricted to the description of sites that represent "a collective secondary deposit of skeletal material representing individuals initially buried elsewhere," (Ubelaker, 1974:8). Furthermore, ossuary burials are often characterized by the intentional shuffling of individual skeletal elements by men sporting long poles, resulting in a commingled orientation of all skeletal material in the burial pit (Ubelaker, 1974). For the current burial site, such a formal process of shuffling cannot be assumed, and it is more likely that the displacement of skeletal elements was a natural consequence of soil movement due to faunal activity, root infiltration, and the dissolution of soil due to sea water from the adjacent Adriatic coast. In this respect, it is unlikely that the *Ipogeo degli Avori* represents an ossuary burial per se.

One of the most puzzling features of the *Ipogeo degli Avori* skeletal material relates to its consistent level of fragmentation. Scarcely few long bones survived to the extent where useful measurements could be taken. Nearly every skeletal element was subject to some level of breakage, though those that appeared to be most resistant to fragmentation tended to be the relatively small irregular bones such as the talus and the patella.

Fragmentation is a fairly common occurrence in ancient cemeteries, and several different theories have been proposed to describe the factors that influence it. Some authors relate degree of fragmentation to general bone fragility. Boddington and colleagues (1987) discuss the notion that cremation and burning can do much to reduce the integrity of bone, and thus contribute to its disintegration. A very small number of skeletal elements within the analyzed set displayed evidence of burning, and thus it is possible that fires made a contribution to the level of fragmentation observed. Figure 4.4 shows a subadult humerus which displays an area of the shaft that appears to have been exposed to flames either naturally occurring or set intentionally, perhaps as a rite of cremation. It is important to note, however, that the surface area showing evidence of

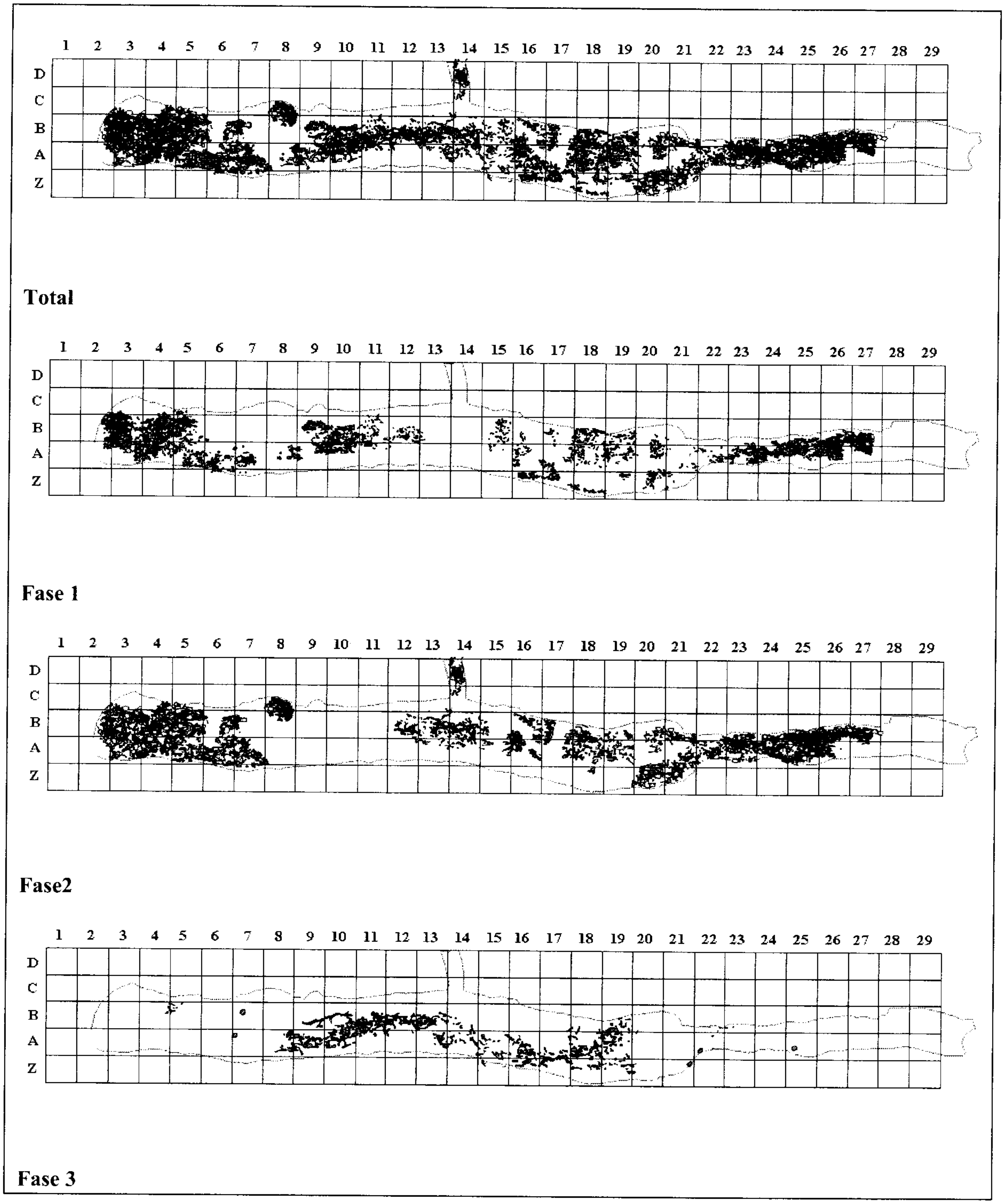
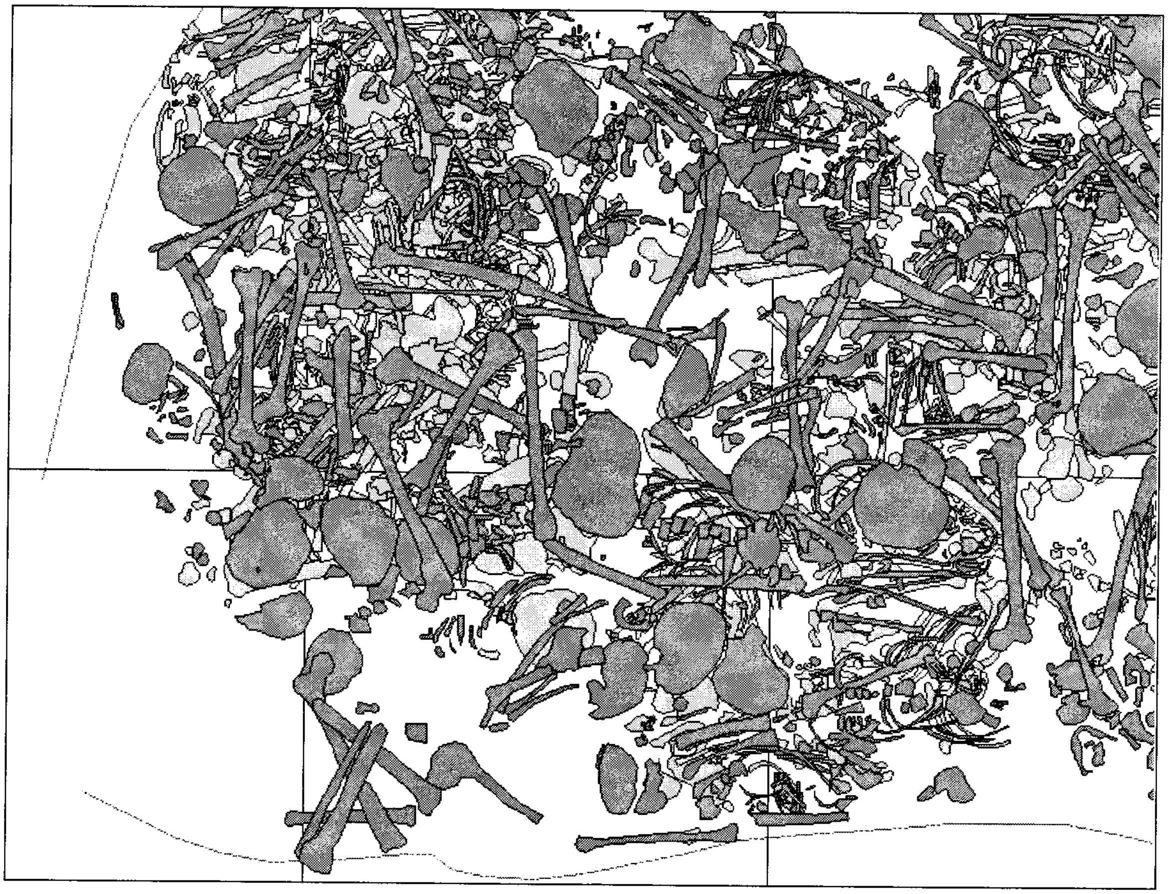


Figure 4.2. Distribution of the skeletal material contained within the hypogeum, represented by the combined fragments of all phases [*Total*] and by individual phase [*Fases 1, 2, and 3*]. This figure shows all the skeletal material recorded in the GIS, and is not restricted to the elements subject to the current analysis.



<u>Figure 4.3</u>. Enlarged view of the GIS image of the entrance of the cave, showing the density of the skeletal material, its fragmentation as recorded at the time of excavation, and the extent of commingling that has occurred. This diagram shows the skeletal material of Fase 2 superimposed over that of Fase 1. Skeletal elements from Fase 1 are shown in light grey, and those from Fase 2 are shown in dark grey. Material from Fase 3 is absent in this area of the hypogeum.

burning transcends the cross-sectional area of the fractured cortical bone, therefore suggesting that the bone had achieved its fragmented state prior to its exposure to fire.

The skeletal elements that display evidence of burning appear to be concentrated in the more densely used areas of the hypogeum. Given the skeletal density in these areas, it is conceivable that burning was used as a means of clearing interred remains

(a)

(b)

<u>Figure 4.4</u>. Evidence of burning shown on a subadult humerus *(a)*. Note that the bone surface area that has been exposed to fire includes the inner cortical bone that was exposed during fragmentation *(b)*, thus suggesting that this element was fragmentary at the time of burning.

from these areas to afford space for new burials. Although this notion cannot be entirely dismissed, I consider it an unlikely occurrence due to the extremely small number of bones that show evidence of exposure to fire, and the lack of recovery of heavily burned bone that one would expect to find in such a situation.

In his analysis of the highly fragmented remains recovered from the Romano-British site at West Trenter Street in London, Waldron (1987) suggests that fragmentation was the result of damage incurred by skeletal material during the digging of adjacent burials. This situation is entirely possible for the material of the *Ipogeo degli Avori*, when consideration is given to density of burials in certain sections of the hypogeum. However, the fragmented state of the skeletal elements recovered from the more sparse areas of the tomb suggests that additional factors have exerted influences on preservation.

It would be advantageous to now turn our attention to the physical qualities of the burial environment to yield insight into the forces behind fragmentation. Gordon and Buikstra (1981) relate bone preservation to the level of acidity in the soil. A small sample of soil yielded a pH value of 9.31, thus suggesting that soil acidity was not a factor. Although soil acidity can be influenced by the dissolution of atmospheric CO_2 into water to produce carbonic acid, it is entirely likely that the pH of the soil remained basic due to the buffering action provided by the cave bedrock's limestone content.

Boddington (1987a) introduces the notion that burials contained within soils high in clay content are usually subject to fragmentation "presumably caused by the expansion and contraction… with changes of moisture and temperature," (Boddington, 1987a:30). Although the clay content of the soil contained within the hypogeum is not known, the infiltration of sea water is a likely event given the site's proximity to the coast.

Of the above factors mentioned, it is likely that the infiltration of water, which contributed to the contraction of soils and the displacement of soil layers within the cave, was the main factor that contributed to the level of observed fragmentation. It is unlikely that specific cultural practices were employed to intentionally fragment the remains because, although not included in the current analysis, the faunal material associated with the site, both domestic and feral, had undergone a similar level of fragmentation.

On a final note, there is an unquantified level of disparity in the preservation of the bones contained within the cases as compared to those represented in the GIS analysis. The GIS analysis was created before the bones were removed from the soil, and the possibility exists that some elements became fragmentary upon removal. In this description of the excavation of the Tide Water Potomac, Ubelaker (1974) describes certain infant bones as crumbling upon removal, so it is possible that the skeletal elements appeared intact at the time the GIS was created, were removed as fragments, and the fragments were placed in different cases. Despite this possibility, it is conceivable that the skeletal elements subject to the current analysis just happened to be those which were represented as fragments in the GIS analysis.

Regardless of its cause, the extent of fragmentation introduced many limitations on the demographic analysis. There is a certain level of pessimism in the literature as to whether fragmented remains can provide important information regarding population demography (discussed in Hoppa and Gruspier, 1996), though the following analysis attempts to illustrate that with close attention to detail and an acknowledgement of the inherent limitations and various margins of error, fragmentary remains can yield a wealth of anthropologically relevant information. Excluding them from demographic analysis may, therefore, significantly limit the complement of information that can be gathered from the analysis of a skeletal population.

4.2 Age Estimation, Sex Determination and MNI

"The fully preserved, gleaming white skeleton is a thing which survives only in the minds of writers of fiction; the reality is quite likely to be something which resembles a well chewed digestive biscuit and which may be about as easy to deal with," (Waldron, 1994:14).

An accurate determination of demographically relevant data from the individuals in a skeletal sample is dependent upon obtaining a complete inventory of the remains, and providing an appropriate representation of the remains through aging and sexing techniques. Some difficulties were encountered in the identification of certain elements due to poor preservation represented as either extensive fragmentation or cortical bone erosion, and thus a proportion of the analyzed fragments had to be labeled as "unidentified". In full recognition that this represents a loss of data that might be useful in an anthropological context, meticulous attention was paid to accurately document all identifiable material.

4.2.1 ***Subadult skeletal inventory and MNI.*** The inventory of the subadult remains is summarized in Table 4.2. Given the extensive level of fragmentation, it was thought useful to represent the inventory of different skeletal elements by the minimum number of elements (MNE) that could be deduced. From these estimates, a minimum number of individuals (MNI) of 7 was determined based on the data from the sacrum and the right radius; however, this is most certainly a conservative estimate since the remains had not yet been subject to aging.

4.2.2 ***Subadult age distribution and age-adjusted MNI.*** Subadult aging methods included dental formation and eruption, diaphyseal length, epiphyseal size, epiphyseal fusion, and development of the primary centres of ossification. When aging subadult material, many authors recommend that the analyst bear in mind the level of accuracy of each method utilized. In addition to the confidence limits that exist within the published aging methods, one should also keep in mind that significant differences

Table 4.2. Skeletal inventory of the subadult material showing the minimum number of elements (MNE) and in turn the minimum number of individuals (MNI) represented by each element. Note that the MNI calculations have not been corrected by age estimates for the elements in question.

Element	*L MNE*	*R MNE*	*Unsided MNE*	*MNI*	*Element*	*L MNE*	*R MNE*	*Unsided MNE*	*MNI*
Occipital			3	3	Scapula	0	0	1	1
Vertebra			4 (C) 2 (T) 4 (L) 12 (?)	N/A	Maxilla	0	0	2	2
Sacrum			5	5	Mandible	1	4	0	4
Metacarpal	1	0	1	1	Ilium	1	0	3	3
Metatarsal	2	2	9	2	Pubis	0	3	9	6
Fibula	2	1		2	Patella	0	0	0	0
Femur	4	4	2	5	Ischium	0	3	1	3
Tibia	3	3	2	5	Talus	0	0	0	0
Ulna	2	1	2	3	Calcaneus	0	0	0	0
Radius	2	4	5	6	Tarsal (other)	0	0	0	0
Humerus	3	4	5	6	Clavicle	0	0	0	0
Infant (complete)	1			1	Phalanx			15	N/A

Subadult MNI, unadjusted for age: *7*

may exist between the study population and those from which the standards were developed. Discrepancies may exist, for example, between modern and archaeological populations (Hoppa, 1992). Angel (1971) and Sundick (1977) both highlight the notion that a secular trend has occurred with regard to skeletal development throughout human history, with modern populations experiencing maturation at earlier times as compared to those from antiquity. Furthermore, Sundick (1977) mentions that significant differences in skeletal development may occur between contemporary populations, and variations in development between different individuals of the same population may confound aging estimates. In addition to these theoretical shortcomings, the difference in maturational rates between males and females is difficult to accommodate in skeletal aging estimates, considering the difficulty in sexing immature remains.

Given the above limitations, establishing precise chronological ages for subadult skeletal material from this site is unfortunately not a realistic endeavour at present. To minimize the extent of error inherent in skeletal aging, it has been suggested that standards be chosen that will yield the most reliable results for a given population (Saunders, 1992). Unfortunately, limiting oneself to standards that have been derived from genetically similar and roughly contemporary groups potentially limits the complement of aging estimates that can be applied to a given population. With a fragmented sample, it is imperative to use as many age indicators as possible, and to represent all age estimates with the appropriate margin of error. For this reason, skeletal ages were considered in broad age ranges. The resulting MNI values, along with the aging methods applied to the remains in each age group, are summarized in Table 4.3.

The reliability of the MNI estimate is greatly dependent upon the accuracy of the applied aging methods. There appears to be consensus in the reviewed literature that dental formation serves as the most reliable method for determining the chronological age from a subadult skeleton (Sundick, 1977; Ubelaker 1989; Ubelaker 1987; Saunders 1992; Hoppa, 1992), since this process is under strong genetic control (Falkner and Tanner, 1986), and is thus largely unaffected by environmental conditions (Brauer et al, 1942; Falkner and Tanner, 1986). The dental formation charts of Moorrees and colleagues (1963a and 1963b) have shown promise for yielding the most accurate age estimates for

Table 4.3. Distribution of subadult skeletal material used in the calculation of the age-adjusted MNI.

Age range	*MNI*	*Bones considered*	*Aging references*
0 – 0.9 (infant)	3	Dental formation Long bone diaphyseal length	MFH (1963a) S and B (2000)
1 – 5.9 (juvenile)	3	Frontal bone (showing metopic suture) Dental formation	S and B (2000) MFH (1963b)
6 – 11.9 (juvenile)	2	Mandible showing dental eruption	U (1989a)
12 – 15.9 (adolescent)	1	Dimensions of radial proximal epiphysis Morphology of ischium	S (1972) S and B (2000)
16 – 19.9 (adolescent)	4	Pubic symphyseal surfaces	S and B (1990) and T (adapted, 1994)

Total age-adjusted subadult MNI: 13

The overall MNI estimate of 13, as compared to the previous estimate of 7 based on skeletal data not corrected for by age, demonstrates the importance of skeletal aging on the MNI. Aging references followed the following key: MFH (1963a, 1963b) = Moorrees, Fanning, and Hunt, 1963a and 1963b; S and B (2000) = Scheuer and Black 2000; U (1989a) = Ubelaker, 1989; S (1972) = Sundick, 1972; S and B (1990) = Brooks and Suchey, 1990; and T (adapted, 1994) = Todd stages as adapted in Buikstra and Ubelaker, 1994.

populations of European descent (Saunders et al, 1993), and hence these estimates were used for the current population. Variability in age accuracy has been reported for different teeth (Owsley and Jantz, 1983), though due to low rates of recovery, all loose teeth were used for age evaluations.

Due to the unavailability of radiographs in the field, the aging of immature mandibles and maxillae which contained teeth *in situ* relied upon dental eruption charts, unless the level of cortical bone erosion permitted evaluation of an unerupted tooth. Although explicitly designed for aging North American Aboriginal populations, the eruption chart of Ubelaker (1989) was used. Studies have suggested that North American

Aboriginals show slightly earlier dental eruption schedules when compared to populations of European descent (Ubelaker, 1989), though it was thought that this discrepancy could be minimized by the use of large age intervals.

Only two subadult long bones, namely one neonatal tibia and one juvenile radius, remained sufficiently intact to warrant metric analysis. The age estimates were determined from the data in Scheuer and Black (2000), and were corroborated against age-specific measurements from archaeological populations [Saunders and Spence (1986) for the tibia data; and Merchant and Ubelaker (1977) for the radius data] to account for problems associated with using standards from modern populations to age archaeological samples (Merchant and Ubelaker, 1977; Hoppa 1992). The archaeological references showed results comparable to those from the modern data.

There appeared to be significant pessimism in the reviewed literature regarding the utility of unfused epiphyses as sensitive measures of age. The reasons provided mostly relate to the fact that epiphyses tend to experience poor recovery from archaeological sites given their small size (Johnston and Zimmer, 1989). Furthermore, variations in the thickness of the epiphyseal cartilage eliminates the possibility of including epiphyses in long bone length calculations (Saunders, 1992; Johnston and Zimmer, 1989). At the current site, a large number of unfused epiphyses were recovered, and it was thought that considering these as merely representative of "subadults", or under the age at which fusion occurs, would potentially exclude a large portion of anthropologically relevant data. For this reason, approximate ages were determined based on the data provided in Sundick's (1972) metric evaluation of the subadult skeletal material of the Indian Knoll population.

Although Sundick's dataset provided a wealth of information relating to skeletal development, it is important to take note of its inherent limitations. First, he provided approximate chronological ages for the individuals in his analysis by comparing their level of dental development against the developmental stages reported in Schour and Massler (1942). Ubelaker (1989) cautions against the utility of evaluating skeletal development based on dental age estimates because the skeletal ages will therefore incorporate the error inherent in the dental data. Futhermore, the Schour and Massler data sets have been criticized for providing estimates that are consistently higher than those based on the data of Moorrees and colleagues (1963a and 1963b) (Ubelaker 1974; Merchant and Ubelaker, 1977); however, the previous observation that North American Aboriginal populations experience earlier dental eruption schedules may potentially limit this margin of error. The second limitation of this dataset relates to the fact that developmental standards of a North American population were used to provide age estimates for a European population, which contributes to an undetermined amount of error. In light of the above limitations, it was thought that at the very least, the categorization of an element as representing either a juvenile or an adolescent could be accomplished based on metric data.

Unfortunately, to the knowledge of the author, a similar standard for the metric evaluation of the ends of long bones displaying unfused epiphyses does not exist;

therefore, all long bone with unfused epiphyses yielded information that could only be considered in the subadult inventory table that had not been corrected for age.

The stage of epiphyseal fusion was dutifully recorded by the suggestion of McKern and Stewart (1957), and this pool of data was useful for the assessment of individuals in the adolescent category.

Applying these different age estimates did, in the end, have a significant effect on the MNI calculation. Based on inventory alone, the MNI estimate of 7 is significantly lower than the MNI estimate of 13, derived from age-adjusted inventory counts. Even with the application of a variety of age methods, however, this estimate likely remains conservative. One obvious potential error in the data relates to the small number of infants represented in the sample. Infant mortality is known to have been high amongst ancient populations, though the underepresentation of infant material in ancient cemeteries is a common occurrence. Most of this underepresentation has been attributed to the loss of infant material due to taphonomic processes. Infant bone is known to be less dense than adult bone (Currey and Butler, 1975), and thus is thought to be more susceptible to damage. Despite this fragility, Saunders et al (1994), in their evaluation of the St. Thomas Anglican Church Cemetery of Belleville, Ontario, report a preservation of subadult material that approximates that of robust adult bone, and thus caution against the assumption that a low recovery of subadult material is a result of preservation. Saunders (1992) suggests that a low recovery of subadult material is more likely to be an artifact of differential burial practices or inexperience on the part of the excavators. Acsádi and Nemeskéri (1970) describe the effect of the practice of infant exposure as contributing to low numbers of infant skeletons in archaeological sites. Furthermore, Saunders and Spence (1986) highlight the observation of burying infants away from the common burial ground for cultural reasons.

Although cultural practices such as these cannot be ignored for the current population, I believe it to be more likely that the low recovery of infant remains relates largely to the fragmentary nature of the skeletal material. The consistent fragmentation of nearly every bone in this population suggests that the small and fragile bones of the infant skeleton simply did not survive to excavation. This notion could be supported by the recovery of one nearly intact infant skeleton, which was likely housed in an area of the hypogeum less affected by bone tumble and damage due to water infiltration. The loss of additional subadult bones due to a similar process of disintegration cannot be overruled, and thus an accurate measure of the minimum number of individuals in this population will, at best, be an approximation based on the meticulous evaluation of all the subadult material retrieved from the site, as opposed to that based on the current subset of the population.

4.2.3 ***Adult skeletal inventory and MNI.*** Unfortunately, aging estimates for adult skeletal material are not subject to the same degree of accuracy as those which can be applied to immature remains. Furthermore, the bones commonly used to age adult skeletons, namely the innominate and the ribs, are known to be rather fragile, and, therefore, tend to experience low levels of recovery (Walker, 1994; Kelley, 1979; Katzenberg and White, 1979). It was thought that a comprehensive inventory of the adult material would provide the best measure of the MNI. Skeletal elements experience different success in preservation, and thus all elements were considered for this purpose so as to avoid "the fallacy of relying upon counts of a single skeletal part for reconstruction of the number of individuals," for a commingled burial (Ubelaker, 1974:36).

Preservation appears to vary directly with skeletal density, with the more dense elements, such as the petrous portion of the temporal bone, often yielding the best recovery (Ubelaker, 1974; Waldron, 1994). Size has also been cited as a contributing factor to preservation, since larger bones have been reported to experience better levels of recovery than smaller ones (Waldron, 1994). In addition, anatomical position has been observed to affect recovery, with bones from the posterior of the body often being better represented (Waldron, 1994), though this is likely an artifact of the position in which the individual was buried.

Waldron's (1994) analysis of the fragmented remains from the 2nd to 4th century population from the Romano-British site at West Trenter Street, London serves as a useful documentation of the comparative survival of different skeletal elements. The level of preservation of the cemetery allowed for the identification of structural components of individual graves, which was used to provide an estimate of the minimum number of individuals expected from the site. Waldron anticipated a minimum number of 88 individuals, though the actual value revealed through skeletal inventory reached only 62, based on recovery of the left greater sciatic notch. No fragment yielded a 100% recovery, though Waldron reports those which experienced the best preservation (of

Table 4.4. Skeletal inventory of the adult material showing the minimum number of elements (MNE) and in turn the minimum number of individuals (MNI) represented by each element. Note that the MNI calculations have not been corrected by age estimates for the relative elements in question.

Element	*L MNE*	*R MNE*	*Unsided MNE*	*MNI*	*Element*	*L MNE*	*R MNE*	*Unsided MNE*	*MNI*
Occipital	3	2	6	6	Scapula	2	5	2	5
Vertebra			23 (C) 15 (T) 22 (L) 31 (?)		Petrous temporal	2	10	2	10
Atlas			11	11	Tibia	8	9	1	9
Axis			7	7	Maxilla	4	3	3	8
Sacrum			5	5	Mandible	5	2	3	5
Metacarpal	2	2	4	3	Os coxa				7
Metatarsal	11	7		N/A	Patella	4	9	0	9
Fibula	10	5	1	10	Calcaneus	10	7	4	11
Femur	12	3		12	Other tarsal	31	23	14	12 (navicular)
Ulna	5	7	0	7	Talus	11	10	0	11
Radius	3	3	0	3	Cubiod	6	8	3	9
Humerus	3	5	0	5	Clavicle	3	4	2	5
cranium (complete)	1			1	Phalanx				

MNI = 12

greater than approximately 60%, based on an expected value of 88) included the petrous temporal, the mastoid process, the right hemi-mandible, the acetabulum, the greater sciatic notch, the proximal ulna, and the proximal femur. Waldron cautions against assuming that these results are typical, though comparison with the material from the current analysis shows some level of similarity.

Table 4.4 lists the basic inventory of each adult element recovered, and provides a MNI estimate of 12. Of the bones Waldron reports as experiencing good recovery, the proximal femur and the petrous temporal show good yields; however, other bones showed recovery equally as good, and this likely relates to the factors which influenced fragmentation and preservation. The MNI estimate of 12 was based on the recovery of the proximal femur and the navicular. Close behind were the estimates for the calcaneus, talus, atlas, fibula (distal physis), tibia (proximal physis), and patella. The degree of fragmentation was the largest obstacle which limited the MNI calculation, as small fragments of the shafts of long bones could yield little information of demographic relevance. With the exception of the atlas, tibia, and fibula, the bones that were recovered in appreciable amounts tended to be relatively small and compact, and were thus likely more resistant to fragmentation. Furthermore, the morphology of these bones allowed for even fragmentary portions to be sided accurately with confidence. In this respect, it appears that shape and density may have been the main factors that contributed to good preservation in the current sample; however, it is important to caution against this conclusion based on this data, since one must keep in mind that we are only dealing with a subset of the skeletal material recovered from the site. More intact elements may exist in cases that were not considered in the current analysis.

4.2.4 ***Age estimation of adult material.*** Aging of adult material was attempted on all suitable skeletal material, which included the pubic symphysis (Buikstra and Ubelaker, 1994; Brooks and Suchey 1990), the auricular surface (Lovejoy et al, 1985) and the sternal ends of the ribs (Işcan et al, 1984a and 1984b). Data obtained from cranial suture closure was not considered in this analysis due to its reported high degree of variability

(Lovejoy et al, 1985b; Ubelaker, 1989) and its reliance upon the comparison of different sutures in the same skull (Meindl and Lovejoy, 1985; Buikstra and Ubelaker, 1994). There is consensus in the literature that the limitations of adult aging methods can be partially accommodated by the comparison of different methods on the same individual; however, such an endeavour is rarely possible on heavily fragmented material.

Table 4.5 and Figure 4.5 provide a distribution of the age ranges represented by the different aging methods. Skeletal data for the pubic symphysis and the ribs that was considered in the subadult category (20 or under) was included in these representations only to illustrate the disparity in age distribution represented by the different methods. The most obvious difference relates to the lack of older ages represented by the rib aging method. Tests of this method have shown promising results (Işcan and Loth, 1986a and 1986b), though the limitation in this sample likely relates to the poor preservation of the fragile bones that characterize the older stages. The skeletal material of older individuals tends to be more porous, and thus is more susceptible to disintegration in the soil. The large proportion of ribs recovered in the 19 and under age category may support this notion.

Relative consensus was reported for the Suchey-Brooks and Todd methods of aging, though it is important to note that sexing of pubes was rarely possible, and hence a margin of error may exist in the assignment of Suchey-Brooks stages. In their analysis of the fragmentary os coxae from the Huron Ossossane ossuary, Katzenberg and White (1979) relied on estimates from the Todd method when sex was unknown. For the

Table 4.5. Distribution of the relative ages represented by the adult skeletal material according to the different methods applied.

Age Range	*Suchey-Brooks/Tood*			*Lovejoy et al*			*Işcan et al*	
	No. fragments	*%*	*MNI*	*No. fragments*	*%*	*MNI*	*No. fragments*	*%*
<20	13	61.9	7	0	0	0	20	76.9
20-24	2	9.5	2	2	15.4	2	4	15.4
25-29	1	4.8	1	2	15.4	2	2	7.7
30-34	1	4.8	1	6	46.2	3	0	0
35-39	3	14.3	2	2	15.4	1	0	0
40-44	0	0	0	1	7.8	1	0	0
45-49	1	4.8	1	0	0	0	0	0
50+	0	0	0	0	0	0	0	0
Avg. age (adult)	32.0			30.3			N/A	

Skeletal fragments that technically fall in the subadult category, < 19, have been included in this table for comparison of the distribution of age estimates based on the different methods traditionally applied to adult skeletal material. One pubis aged 35-39 is from the same individual as the auricular surface aged 40-44. Adult (> 20) age averages were calculated by taking the midpoint age from each age range and considering the minimum number of individuals in that age range.

current analysis, age estimates based on both methods were attempted, merely as a method of affirming that large errors in age estimation were not made. Some fragments displayed significant erosion on their surfaces, and the yielding of similar ages based on the different criteria of Suchey-Brooks and Todd was held as evidence that the age estimate was an appropriate approximation.

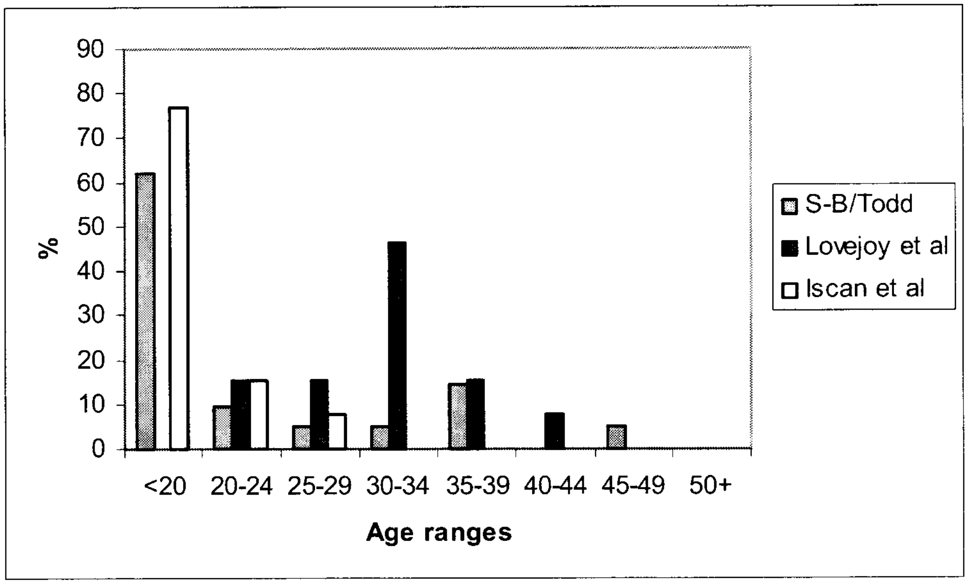


Figure 4.5. Graphical representation of the distribution of ages represented by the different methods applied to the aging of adult material, based on percentages of the total number of fragments considered for each method.

The auricular surface technique has been criticized for over-aging young adults and under-aging older adults (Rogers, 1991). This is an important limitation to keep in mind when dealing with fragmentary remains because the auricular surface often experiences better preservation than the fragile pubis (Kelley, 1979; Katzenberg and White, 1979). For the study population, this phenomenon could explain the high proportion of material aged in the 30 to 34 yrs. range. Furthermore, the only fragment intact enough to permit age estimation based on both pubic symphysis and auricular surface morphology yielded a higher estimate with the Lovejoy and colleagues method (35 to 39 for Suchey Brooks/Todd and 40 to 44 for Lovejoy et al).

The average age estimate for the pubic symphysis method is higher than that for the auricular surface. The lower average age estimate reported for the Lovejoy and colleagues method, however, does not necessarily preclude the notion that this method is prone to under-aging. It may simply be the case that fragments of younger individuals became subject to this analysis. Alternatively, it is possible that the one individual aged 45-49 for the pubic symphysis method significantly raised the average adult age at death for the Suchey-Brooks estimate; when dealing with a small N size, single individuals can greatly influence averages. Removing this individual from the pool of ages for the sypmphysis pubis method produces an adult age at death estimate of 29.5 yrs., which is lower than the calculated 30.3 yrs. for the Lovejoy and colleagues method. It is important, however, to bear in mind that we are dealing with only a subset of the skeletal material recovered from a commingled burial, and hence a more accurate reflection of the age at death distribution of the population will likely be obtained from an analysis of the entire population.

4.2.5 ***Adult sex determination.*** Of the sexually dimorphic features evident on the skeleton that are considered for sex determination, pelvic traits are generally held as superior to those of the cranium (reviewed in Milner et al, 2000). The pelvic traits described by Phenice (1969) appear to yield the most accurate results, with the ventral arc being favoured over the subpubic concavity and the ischiopubic ramus (Phenice, 1969; supported further in Rogers, 1991). Phenice (1969) stresses the importance of considering all traits, and maintains that accuracy is greatest when at least two traits are analyzed. Unfortunately, the fragility of the pubis in this sample did not permit the preservation of a single element to the extent where the three traits described by Phenice

(1969) could be considered in concert. In fact, only one fragment was found which displayed a ventral arc which could be analyzed, and it was considered to be representative of a female.

The more robust greater sciatic notch proved to preserve in more plentiful amounts, though Meindl and Russel (1998) suggest that this feature is not generally held as being a good indicator of sex, and recommend that it be used only for elements exhibiting extreme morphology, either very open or very closed. Five fragments were subject to this analysis: four of which were deemed feminine in morphology, and one masculine. All pelvic traits considered, the material appeared to represent a minimum of one male and two females. The reliability of this estimate certainly remains in question due to the fragmentary nature of the hip bones subject to analysis, and the general observation that female remains do not tend to preserve as well as male remains due to their decreased bone density (Pfeiffer, 1983).

Cranial traits were also considered. Although thought to yield less accurate results, Meindl and Russel (1998) suggest that some cranial features, namely the supra-orbital margin and the nuchal crest, may be under hormonal control, and therefore would be the most reliable features to consider. Walker (1994) cautions that cranial morphology may produce misleading results because the reliability of the method is heavily influenced by the age of the individual in question. There is a trend in the cranial traits of females to appear more masculine in the older stages of adulthood. Furthermore, male cranial development appears to be a continuous process until age 30, with younger males exhibiting more feminine traits (Walker, 1994). With an acknowledgement of these theoretical shortcomings, and with consideration given to the young age estimates provided by the aging data, it is likely that the higher observance of feminine features is an artifact of young male crania which display feminine features. A summary of the cranial sexing data is provided in Table 4.6 below.

Table 4.6. Inventory of sexually dimorphic cranial features.

Skeletal feature	*Male*		*Female*		*Undetermined Sex*
	No. of fragments	*MNI*	*No. of fragments*	*MNI*	
Mental eminence	0	0	1	1	0
Glabella	0	0	1	1	0
Supra-orbital margin	1	1	5	2	0
Mastoid process	2	1	2	1	1
Nuchal crest	0	0	3	3	0
Complete cranium	1	1	0	0	0

Scoring of features was performed in accordance with the scoring key provided in Buikstra and Ubelaker (1994), with traits scoring "1" or "2" considered female, and traits scoring "4" and "5" considered male. Undetermined sex included only those traits scoring "3".

Sex-specific MNI: 2 males, 3 females.

The value of "3" for the female MNI is likely accurate as it was based upon the morphology of the nuchal crest, which Meindl and Russel (1998) suggest to be reasonably accurate. The value of "2" for the male MNI is also likely accurate: one individual is represented by an intact cranium for which all traits could be scored and compared, whereas the other is represented by a very male supra-orbital margin, the other trait noted by Meindl and Russel (1998) as being prone to the highest accuracy.

4.2.6 ***Approximation of the maximum number of adult individuals.*** The MNI estimate obtained from the adult inventory alone is likely to be conservative due to the fact that the age-adjusted MNI value of the subadult material increased this number by nearly half, from 7 to 13 individuals. Evidently, the accuracy of the adult MNI value could not be improved by either aging or sexing, as each of these analyses yielded numbers lower than that of the basic inventory. It may not be accurate to assume that a difference as great as that which was observed for the subadult data would occur if aging and sexing methods were more sensitive, since it is likely that the adult material was subject to a better recovery as compared to the immature remains (Walker, 1994). Some level of discrepancy, however, is still likely to have occurred, especially when one considers Waldron's analysis of the fragmentary remains at West Trenter Street, for which no skeletal element was reported to yield a 100% recovery; in fact, the highest yields he reported approximated only 70%. It is likely that elements from the current population have been lost either to extensive fragmentation or erosion in the soil, and thus it may be useful to extrapolate a *maximum number of individuals* based on the information available. To the knowledge of the author, a literature reference does not exist for an extrapolation such as this, though an attempt will be made to provide the most logical estimate.

For this purpose, the data on relative preservation of different elements reported in Waldron (1987) will serve as a useful measure of bone survival. Waldron does explicitly state that skeletal preservation is specific to the burial environment, and that his results should be considered far from typical; however, the survival of the petrous temporal and the proximal femur from the excavations at West Trenter Street and the current site was likely due to skeletal density in both cases, and thus it is conceivable that the recovery levels of these elements may have been similar. The current analysis suggests MNI values of 10 and 12 respectively for the petrous temporal and femur data. Waldron reports recovery of these elements to be approximately 60%. If this approximate level of recovery is applied to the MNI values for the current population, we obtain values of 17 for the petrous pyramid and 20 for the proximal femur. Although this estimate is highly speculative, it is important to consider as it provides a possible level of error in the adult MNI estimate. This is very important for skeletal populations that experience poor recovery such as that demonstrated in the study population. Regardless, a certain level of error is likely to exist for any approximation of population size, justly put in Henderson's (1987) comment that the MNI "is an elusive figure at the best of times, and may be even more so where the remains are poorly preserved," (Henderson, 1987:43).

4.2.7 *Interpretation of pooled subadult and adult data.* The main purpose of performing demographic analyses on skeletal material is, in the end, to yield insight into the demographic parameters of the living population. Traditionally, this extrapolation has been accomplished through life table analyses, though this measure has met with theoretical objections in recent years (reviewed in Meindl and Russel, 1999 and Milner, Wood and Boldsen, 2000). The construction of an accurate life table rests upon the assumption that 1) the skeletal samples are complete, 2) that the ages at death are considered to be accurate, and 3) that the size of the living population remained constant during the period of use of the cemetery; that is, fertility levels remained constant, and no appreciable changes were introduced by migrations (Ubelaker, 1974). Skeletal populations, however, are by nature subject to a degree of selectivity (Ubelaker, 1974; Boddington, 1987b); it is naïve to assume that all individuals in a given community were laid to rest in cemeteries and, furthermore, that all skeletal material survived in its entirety, was fully recovered at excavation, and reached the eyes of the skeletal analyst fully intact. The current skeletal population represents a subset of the skeletal material from the *Ipogeo degli Avori*, that is itself likely incomplete due to issues of preservation. In combination with the fact that the site was used over a long period, the results generated from a life table analysis would likely not provide an accurate extrapolation of the living group (Jackes 1986, Meindl and Russel, 1998), and hence this was not attempted.

With the current limitations, it would be best to limit demographic analysis to the descriptive basics of number, age, and sex (Pfeiffer, 1983). The population appears to be comprised of 13 subadults and 12 adults, of which at least two are male and three are female. Figure 4.6 provides a graphical representation of the distribution of the ages at death for this population. From observation of this chart, it is evident that certain expected qualities are absent. Waldron (1994) suggests that mortality profiles for pre-industrial societies should exhibit a U-shaped pattern, displaying characteristic levels of infant death and mortality at mature ages. The current chart, however, shows nearly an

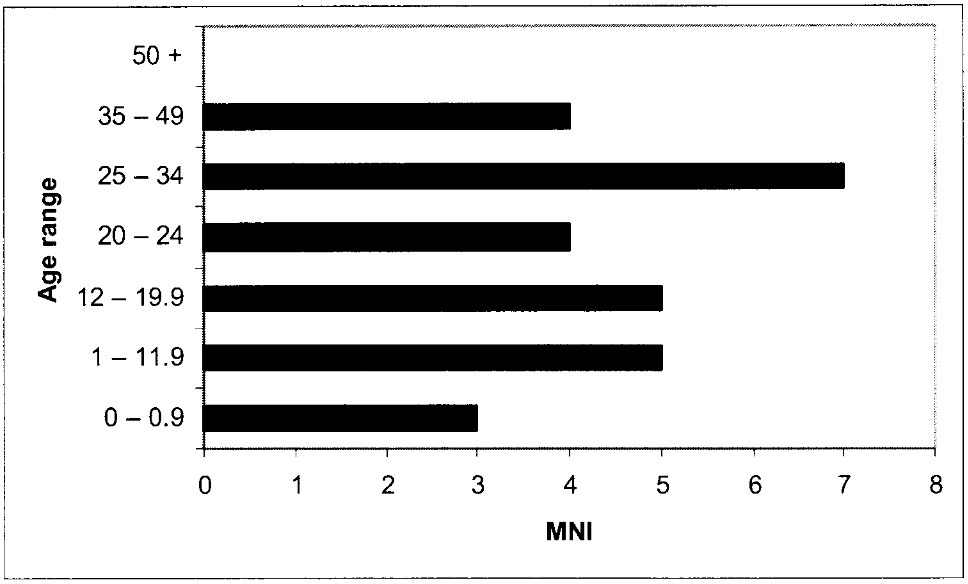


Figure 4.6. Age distribution as represented by the MNI in each age category based on the age-adjusted subadult MNI and the adult MNI obtained from the inventory data.

opposite distribution, with fewer infant and mature deaths, and the greatest observed mortality occurring in the young adult years. The absence of skeletal material aged above 50 years, however, should not be interpreted as evidence that members of this population unanimously passed away before reaching their 50th birthday. Howell (1986) maintains that there are usually some individuals in archaeological populations that survive to 80 years; it is likely, however, that the absence of individuals in this age category, as well infants, are indicators of poor preservation and recovery of skeletal material from the site (Walker, 1994).

To account for limitations in selectivity, Milner and colleagues (2000) recommend that skeletal populations be compared against a plausible model of some sort. Table 4.7

Table 4.7. Comparison of the demographic data for the current population with that obtained from other roughly contemporary European populations.

Authors	*Site*	*Approx. period*	*Burial type*	*Less than one year*	*1 to 19*	*20+*	*S/A*	*Male*	*Female*	*M/F*	*Total MNI*
Current	Ipogeo degli Avori	1600 to 1350 BC	Rock-cut burials	3	10	12	0.83	3	2	1.5	25
Cenni et al (1999a and 1999b)	Ipogeo del Bronzo	1600 to 1350 BC	Rock-cut burials	10	17	71	0.24	48	17	2.8	98
Minozzi et al (1999)	Ipogeo del Bronzo	1600 to 1350 BC	Rock-cut burials	37		126	0.29	80	35	2.3	163
Angel (1971)	Lerna, Greece	Middle Bronze Age	Earth graves, under houses	84	56	104	0.54	54	40	1.35	234
Ortner (1979)	Bab edh-Dhra, Jordan	Early Bronze Age, 3150 - 2200	Underground shaft tomb chambers	8	28	56	0.5	N/A	N/A	N/A	92

- **"S/A" refers to the subadult to adult ratio; infant deaths were not considered in this calculation due to the high number of infant deaths known to characterize prehistoric populations.**
- **"M/F" refers to the male to female ratio for adults.**

presents the demographic data obtained from the *Ipogeo degli Avori* population in a context of roughly contemporary European groups. Most important is the comparison against data obtained from the related *Ipogeo del Bronzo* site. The disparity in the MNI estimates for these two populations is certainly expected because, on the one hand, analysis of the skeletal material from the *Bronzo* site is complete, and on the other hand, the site is substantially larger than the *Avori* site.

Comparisons between different populations are likely to be far more informative through consideration of ratio estimates. Most striking is the high proportion of subadults in this sample compared to the other populations, though this is likely a consequence of a low MNI count for the adult material; however, the low proportion of subadult material in the *Bronzo* hypogeum, as compared to both Lerna and Bab edh-Dhra collections could suggest that children were preferentially buried in the *Avori* hypogeum, provided that child mortality levels were roughly similar between populations. Furthermore, the lower proportion of male burials in the *Avori* hypogeum could suggest that adult males were preferentially buried in the *Bronzo* site; however, the poor preservation of sexable skeletal material in the current collection makes conclusions such as these elusive at best.

4.3 Future directions

The largest limitations with the current data set relate to the incompleteness of the population and the likely unrepresentative demographic parameters derived from the adult skeletal material. The importance of basing future analyses on the complete population cannot be stressed enough, for this will allow for more accurate estimates of MNI and age structure for the collection. Since the remains are commingled, it is important to consider the skeletal material from all sections of the burial site in order to provide reliable estimates for the MNI. Furthermore, reliance upon dense skeletal elements such as the petrous temporal, and those more resistant to fragmentation such as the talus would likely contribute to the accuracy of this calculation. It may also be useful to document the relative survival of different elements through evaluation of both level of fragmentation and degree of surface erosion. A determination of the amount of clay in the soil may also assist in elucidating the factors that influenced the consistent level of fragmentation observed.

Adult age estimations can be improved if elements specific to an aging method are considered as a continuum of variation. Lovejoy et al (1985b) recommend that seriation, or the arrangement of skeletal elements in a sequence of increasing age prior to the assignment of age, be attempted when aging adult material to overcome the issues of intraobserver error. This would be best accomplished with a complete skeletal sample. Furthermore, on behalf of its reported accuracy (Lovejoy et al, 1985b), it may be beneficial to include dental wear as an aging method. With regard to subadult material, Hoppa and Gruspier (1996) suggest that a wealth of anthropologically relevant information relating to age structure is lost when certain immature remains are used only for MNI estimates. Many of the fragments encountered in the current collection were nothing more than long bone fragments; in the absence of an unfused epiphysis, long bone fragments could not be aged accurately, and thus can only be said to represent a subadult. Hoppa and Gruspier, however, have proposed a method whereby diaphyseal length is extrapolated from long bone fragments through regression analysis. Applying this technique could contribute to more accurate age at death data for the subadult sample. In addition, it would be beneficial to take radiographs of all subadult mandibles and maxillae to assist in providing age at death estimates through dental development (Saunders, 2000).

If more reliable estimates for the MNI and age at death profile can be derived, the population may show promise for further demographic evaluations. Limitations would remain plentiful, though the application of the maximum likelihood method that is gaining popularity in palaeodemography (reviewed in Milner et al, 2000) may succeed in producing additional reliable data. Through consideration of age-at-death distributions alone, maximum likelihood methods are designed to accommodate errors inherent in aging skeletal material, and the confounding effects of non-stationarity, while yielding reliable estimates for the parameters of interest. The model has only recently been introduced in this context, though Milner and colleagues recommend that it be the preferred way to introduce mortality models into future analyses.

CHAPTER 5: PALAEOPATHOLOGY

5.1 Theoretical Orientation

In recent decades, the field of palaeopathology has enjoyed the application of new analytical methods consisting of histological evaluations, chemical analyses, and more recently molecular analyses that have served to increase the yield of information that can be obtained from skeletal material. In light of these methods, however, and especially in consideration of their fundamentally destructive nature, the value of the traditional gross morphological assessment of skeletal lesions should not be minimized. Skeletal biologists must keep in mind that we have the privilege of viewing the defleshed skeletal element upon which to base our observations, a situation that does not exist in clinical practice. Even with radiographic analyses, there is consensus that a change in skeletal density of at least 40% is required before skeletal changes can be detected on conventional radiographs (Ortner, 1991). Clearly, with regard to the assessment of certain aspects of skeletal pathology, there is no substitute for the actual intact element. This concept is central to Ortner and Putschar's (1981:29) suggestion that the fundamental objective of palaeopathology is "to obtain as much background information about the skeleton as possible and take maximum advantage of one's ability to evaluate the skeletal lesion by itself by direct observation". For this reason, it is important to provide meticulous documentation and evaluation of all skeletal elements in a population as a preliminary step in the analysis of any skeletal population, before the execution of more destructive analytical methods.

The aforementioned advantages of relying upon gross observation of skeletal lesions, however, are certainly met with their share of concomitant limitations. One of the most difficult theoretical issues in palaeopathology relates to the fact that bone is limited in the number of ways in which it can react to physical insults, and hence the analysts' abilities to provide differential diagnoses are complicated by the fact that lesions from different causes may result in similar skeletal manifestations. Furthermore, skeletal tissue tends to be slow in its reaction to stress, and hence acute events in the life of the individual may not be evident in the skeletal remains based on observation alone.

In more general terms, it is also important to recognize the limitations inherent in the analysis of skeletal populations. The ultimate goal of any palaeopathological analysis is to provide plausible conclusions concerning the health status of the population from which the skeletal sample originated. Waldron (1994:12) reminds us that a "burial assemblage is a social or cultural sample, not a biological one, and to that extent may not in any way be typical of the population from which it was once part". In addition to this level of cultural selectivity, the differential survival of skeletal elements within the site introduces yet another limitation in the data upon which we base our conclusions.

In light of these restrictions introduced by the use of skeletal data, some have concluded that palaeopatholgical analysis alone is insufficient to reconstruct a meaningful picture of the health status of a population (Jimenez, 1991). This notion was further explored in Wood and colleagues' 1992 publication on the so-called "osteological paradox", wherein the authors claim that it may not be possible to predict the health of an individual in a population based on aggregate-level data, and that sound mathematical models based on probability functions demonstrate that a given frequency of skeletal lesions can be produced by a myriad of different theoretical models. The above sentiments may be accurate, though some of the discussants feel strongly that pathological data can provide important clues about general population health when it is considered in a context of the interactions between culture, environment, and disease status, and when multiple indicators of health status are considered in evaluations (eg., Goodman, 1993; Ortner, 1991).

In any palaeopathological analysis, it is important to be well aware of the limitations that are inherent in the data set of interest, and to interpret data accordingly (Waldron, 1994). A good portion of these limitations can be minimized if meticulous consideration is given to all skeletal elements, and if careful and objective descriptions of all abnormal bones are compiled, with the avoidance of applying diagnostic labels (Buikstra and Cook, 1980). The discussion that follows provides a thorough attempt at differential diagnosis of those skeletal elements which showed evidence of pathological changes, first with consideration given to the literature addressing the biomedical explanations for bone responses to different insults. The frequency of pathological changes observed in the skeletal material is then interpreted in a context of cultural influences and the population's demographic structure.

5.2 Description of Skeletal Lesions

5.2.1 ***Infection.*** Osteological manifestations of infection can result from two broad categories, namely specific infections and non-specific infections. Specific infections relate to skeletal changes that appear to be pathognomonic of a specific agent, such as Pott's disease in tuberculosis or caries sicca in syphilis (Aufderheide and Rodriguez-Martin, 1998). Although the diagnosis of a specific etiologic agent is most reliable when analysis is based upon the distribution of lesions within the entire skeleton, each specific infection is generally attributed to have certain hallmark features (see Steinbock 1976, Ortner and Putschar 1981, or Aufderheide and Rodriguez-Martin 1998 for discussions of specific diseases). None of these hallmark skeletal lesions were identified in the skeletal sample from the *Ipogeo degli Avori*. Although this does not preclude their existence in the population, especially considering that Cenni and colleagues (1999a and 1999b) reported several cases of tuberculosis in the *Ipogeo dei Bronzo* population, no indepth description of these skeletal features will be provided in the current discussion.

Far more ubiquitous amongst skeletal populations are the lesions of non-specific origin, or those for which the responsible pathogens cannot be identified by gross observation alone. Although lesions of this type can be caused by a myriad of pathogens to which humans can gain exposure, Ortner and Putschar (1981) suggest that approximately 90% of these lesions are due to infections of the pus-forming bacteria *Staphylococcus aureus*. Skeletal lesions are classified based on the extent of involvement of different skeletal structures, where periostitis refers to periosteal involvement, osteitis refers to cortical bone response, and osteomyelitis relates to involvement of both the cortical bone and the medullary cavity (Aufderheide and Rodriguez-Martin, 1998).

Invasion of the pathogen into bone can occur either by direct contact, as through a localized soft tissue trauma or bone fracture referred to as a secondary osteomyelitis, or by the haematogenous route if the infection has reached the bloodstream, constituting haematogenous osteomyelitis (McCarthy and Frassica, 1998). The different paths of entry can result in somewhat different manifestations in the skeleton. In the event of soft tissue trauma, skeletal involvement is sometimes limited to the periosteum, where the invasion of the microorganism results in a raising of the periosteum, characteristic of periostitis (Ortner and Putschar, 1981). It should be noted that periostitis resulting from factors other than infection alone will be discussed in later sections of this work.

In the case of haematogenous dissemination, the lesions usually have their origin in the marrow cavity. Penetration of the cortical bone occurs via enlarged Volkmann's and Haversian canals, and eventually the pathogens may reach the periosteum (McCarthy and Frassica, 1998). In young individuals, it is most common for infections to begin in the metaphyses of long bones, as the fenestrated capillaries in these regions allow for easy passage of the pathogen into the marrow tissue (Steinbock, 1976). The periosteum of younger individuals is not as tightly bound to the cortical bone as is the case in adults, and the collection of pathogens and inflammatory tissue in the subperiosteal area will cause the periosteum to lift, showing the formation of a subperiosteal abscess. The periosteum can remain reasonably healthy in this state thanks to its external blood supply. Pressure produced by the subperiosteal abscess, however, can lead to a reduced blood supply and an eventual avascular necrosis of the underlying cortical bone, thus producing sequestra, or areas of necrotic bone (Steinbock, 1976). In adults, the formation of subperiosteal abscesses tends to be less common, and involvement of the diaphysis can occur as commonly as that of the metaphysis (Aufderheide and Rodriguez-Martin).

The large collection of pus both in the marrow cavity and the subperiosteal abscess (if present) is eventually drained through the formation of large drainage channels called cloacae. The presence of these drainage channels and sequestra are often held as hallmark features of osteomyelitis, and many scholars may refrain from making a diagnosis of infection without the presence of these diagnostic features (Ortner and Putschar, 1981). Sequestra can be visualized in conventional radiographs as areas of radiodensity, whereas the replacement of bone marrow with inflammatory tissue will result in areas of radiolucency (McCarthy and Frassica, 1998). It is important to keep in mind in this discussion that inflammation is not synonymous with infection, but rather may also be seen in healing fractures, osteoarthritis, inflammatory arthritis, or neoplasms (McCarthy and Frassica, 1998).

In the study skeletal collection, most of the lesions that appear to be associated with skeletal infection are manifest as mild periosteal responses, with little or no changes apparent in the medullary cavity, and no apparent evidence of skeletal trauma (though some of the fragments are small, and thus such skeletal changes on adjacent parts of the elements cannot be excluded). Two unidentified long bone fragments show an accumulation of woven bone on the external surface. One benefit of working with fragmentary remains is that one can evaluate the structure of the cortical bone without having to impart damage to the elements. The enlarged canals traveling through the cortex suggest that involvement may have originated from the marrow cavity, or perhaps from an adjacent infected area of the bone. Another cranial fragment shows a distribution of small lytic lesions along a cranial sulcus (tranverse?) that resemble the "maze-like" lesions reported in Hershkovitz and colleagues' (2002) publication on cranial lesions purportedly associated with intrathoracic diseases. Such a precise diagnosis is too specific for the current fragment, though it is possible that the lesions resulted from a focal resorption of necrotic bone produced by an avascular necrosis, which may have had its origins in a systemic infection. This fragment is shown in figure 5.1.

Of the skeletal material that was intact enough to afford identification, bones showing evidence of possible infection are concentrated in the lower extremities. Two metatarsal bones show evidence of periosteal reactions with no associated skeletal trauma. Poor preservation of the reactive bone, perhaps a result of cleaning damage, makes identification of the size of the lesion difficult to assess. In the event of a haematogenous dissemination of a pathogen, the slow blood flow to the feet may have led

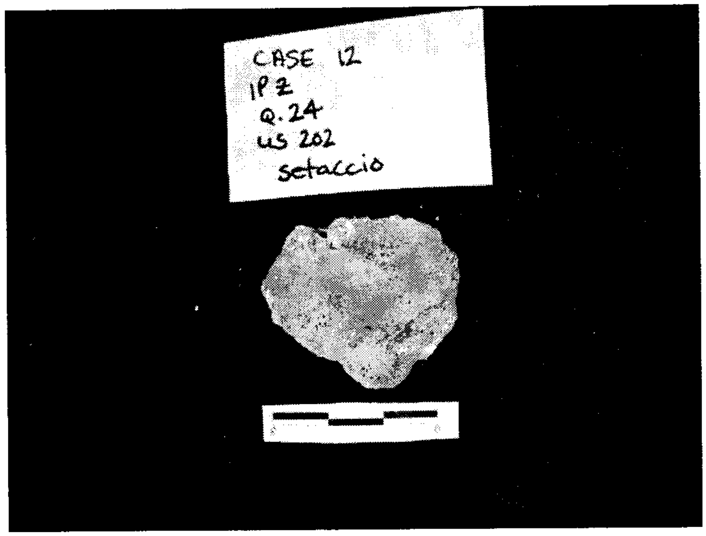


Figure 5.1. Cranial fragment, likely occipital at the level of the transverse sulcus, showing lytic lesions which may be due to an avascular necrosis, stemming from a localized infection of haematogenous origin.

to its accumulation in these areas; however, the possibility of an overlying soft tissue injury cannot be ruled out. A distal fibula fragment, shown in Figure 5.2, also appears to show evidence of bony changes that may be interpreted as stemming from an infection. Radiographic analysis showed no evidence of skeletal trauma. The lesion measures 4.0 centimeters in length, and consists entirely of woven bone. A tentative diagnosis of haematogenous osteomyelitis is supported by the fact that the lesion consists of a subperiosteal abscess located at the metaphysis of a long bone, and the Haverisan canals of the cortical bone appear to be quite large; however, this lesion is close to the area of attachment of the interosseous ligament, and thus it may be possible that the lesion resulted from a sharp pull to the periosteum, as can occur in myostitis ossificans.

Figure 5.2. A distal fibula showing evidence of periosteal reaction on the medial surface below the area of attachment of the interosseous ligament.

Three tibia fragments, two subadult and one potentially adult (physes missing) show evidence of periosteal reactions on their surfaces, which may be attributable to infection. The lesions on the two subadult fragments are very small, and one shows evidence of healing (shown in figure 5.3). The larger adult (?) fragment exhibits extensive erosion of the periosteum, though radiographic analysis showed evidence of a large subperiosteal lesion along the anterior crest, composed of woven bone and measuring approximately 9.5 cm in diameter. The lack of lesions apparent in the medullary cavity and cortical bone suggest that if infection is the cause of the lesion, it must be due to an overlying soft tissue injury. Such a situation would not be so unusual considering the proximity of the anterior crest of the tibia to the skin. These three elements provide the most sensitive measure of infection prevalence, and based on the survival of subadult and adult tibiae, these fragments suggest an infection prevalence estimate of 12% for the subadult sample, and 16.7% for the adult.

A discussion of the pathology of the tibia fragments is not complete without consideration afforded to scurvy, for which the hallmark skeletal manifestation consists of subperiosteal haemorrhages, most notably in the tibia (Steinbock, 1976); however, it is difficult to address the possibility of scurvy in this population through analysis of skeletal features alone.

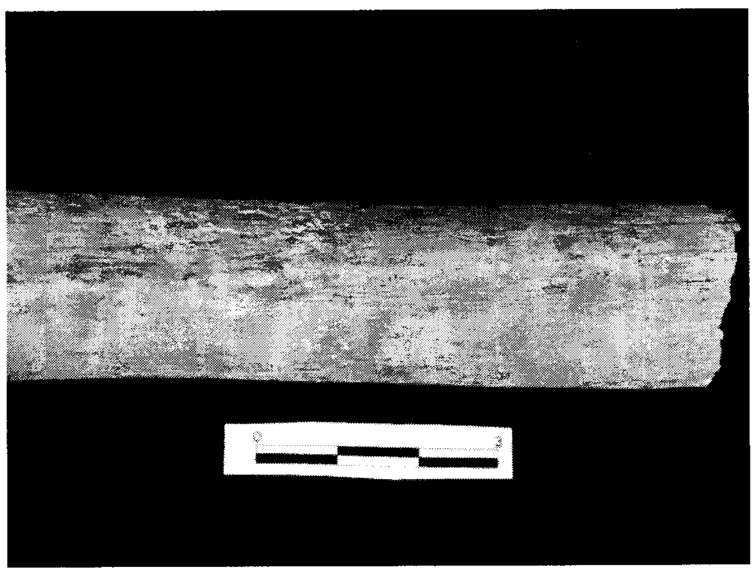


Figure 5.3. Evidence of a healing periosteal reaction on a tibia fragment.

5.2.2 ***Trauma***. Next to degenerative joint diseases, traumatic lesions are regarded as the most prevalent type of pathological manifestation of the skeleton in archaeological remains (Ortner and Putschar, 1981). Traumatic lesions are considered in four different classifications, namely the breakage of a bone, a dislocation, a disruption in either nerve or blood supply, or an artificially-induced change in shape (Ortner and Putschar, 1981). Although the skeletal changes that result from these insults can be quite different, it is often confusion with other forms of insult such as advanced infection or neoplasia that can introduce ambiguities in differential diagnosis. As such, the lack of evidence of a clear fractured area may preclude one's ability to provide an evaluation with confidence (Ortner and Putschar, 1981).

Fractures may occur due to acute traumatic events, as a consequence of a weakening pathological condition such as neoplasia, or by a repeated activity where they are referred to as stress fractures (Steinbock, 1976). Although the etiologies of these fracture types differ, they are subject to the same sequence of bony response. A skeletal fracture is immediately followed by the formation of a haematoma between the broken elements. This forms mainly from the clotting of blood that has been released from broken blood vessels. This clot soon becomes infiltrated by fibrous connective tissue containing pluripotent cells, which later differentiate into chodroblasts and osteoblasts (McCarthy and Frassica, 1998). The fibrous tissues within the haematoma provide the framework over which the chondroblasts and osteoblasts lay down cartilage and woven bone (Steinbock, 1976). This rigid mixture of different cell types and connective tissue is referred to as the bony callus.

The periosteal periphery of the callus may resemble the bony changes associated with subperiosteal lesions observed in infections. Radiographs may be used to display evidence of fracture in the cortical bone, with fractured areas being represented by areas of radiolucency (Ortner and Putschar, 1981; McCarthy and Frassica, 1998). The callus increases in size as union between the fractured elements is achieved. Once healing has completed, the callus is normally resorbed. If union occurs in the proper orientation, there can be a complete obliteration of evidence of the fracture (McCarthy and Frassica, 1998), though skeletal analysts have the benefit of evaluating bones through gross assessment, as even the smallest fractures which may not be detectable on radiographs can be observed on the elements themselves (Merbs, 1989b).

Two likely fractures have been identified in the current collection, both of which occur in the fibula. The first consists of a suggested fracture in the distal end of the bone. The fracture appears to have been caused by a medial torsional injury, with the apparent medial displacement of several skeletal structures. The groove for the peroneal tendons appears to be angled more posteriorly, and there are pronounced areas of insertion for the superior extensor retinaculum and the interosseous ligament, suggesting biomechanical alterations. Evidence of the fracture site is absent on this element, either suggesting complete healing or that the fracture occurred in a more superior location which is not represented in this fragment. The second fibula displays evidence of a well-healed spiral fracture, completely absent on the radiographic image, approximately one third of the shaft length from the distal epiphysis. The fracture appears to have resulted in a rearticulation of the origin of the peroneous brevis muscle.

A slightly more difficult interpretation is required for a left adult innominate which exhibits a periosteal lesion on the pubis, just superior to the acetabulum. Radiographs show this lesion to be in the process of advanced healing, as it is composed of lamellar

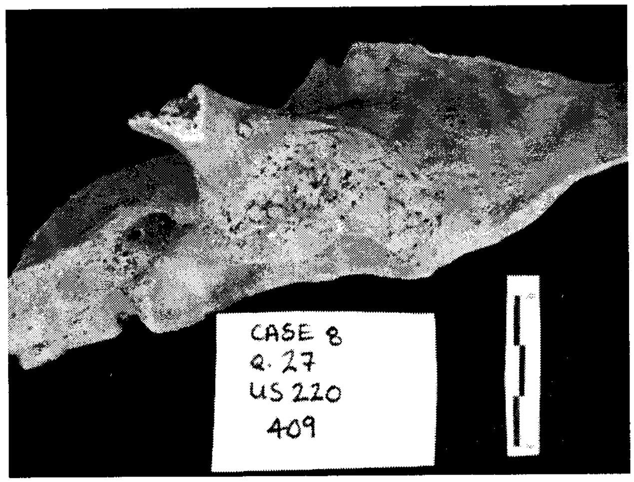
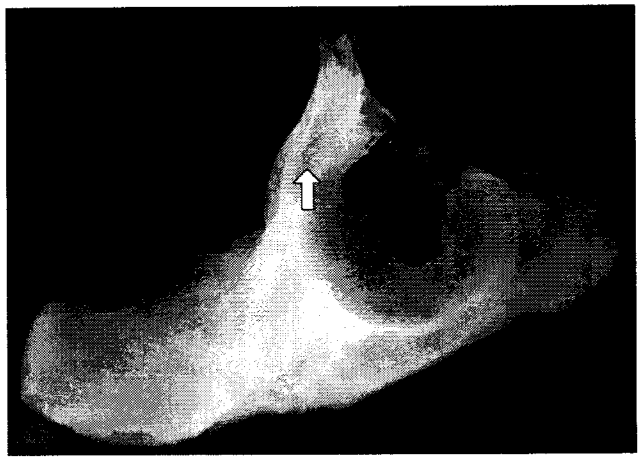


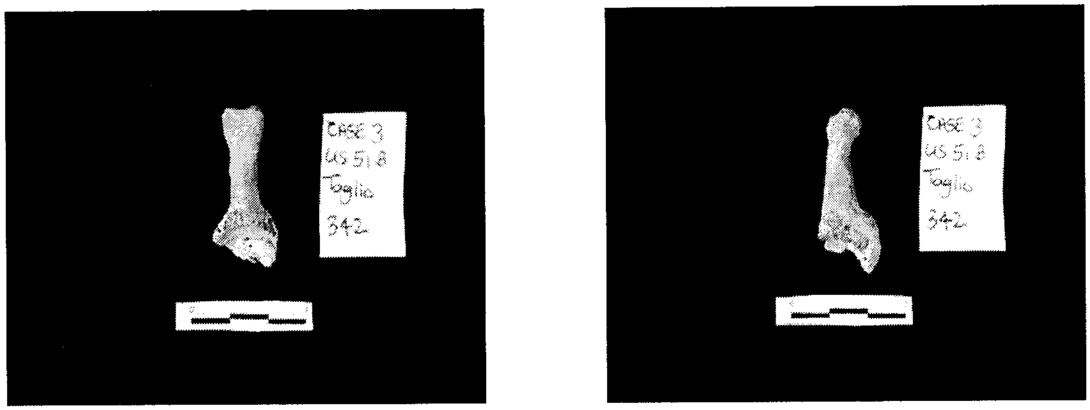
Figure 5.4. Bony callus formation as a result of a healing fracture.

bone. Surface texture shows healing, though an adjacent, more recent proliferative lesion of woven bone appears to be forming along the anterior surface of the pubis, contiguous with the acetabulum (Figure 5.4). This is likely in the area of the attachment of the joint capsule, and may suggest a biomechanical change due to the injury, though if this is indeed the case, it is odd that there is no evidence of altered biomechanics in the acetabulum. Radiographic analysis shows subtle evidence of a possible healed fracture of the pubis at a right angle to the bony callus (Figure 5.5). No evidence of this fracture is apparent in the acetabulum. Features that might assist in identifying the sex or age of this individual unfortunately did not survive, though a subjective observation of the degree of flaring of the iliac pillar suggests that this individual is female.



<u>Figure 5.5</u>. Radiographic image of the above hip fragment showing the location of the fracture and the development of a mature bone callus.

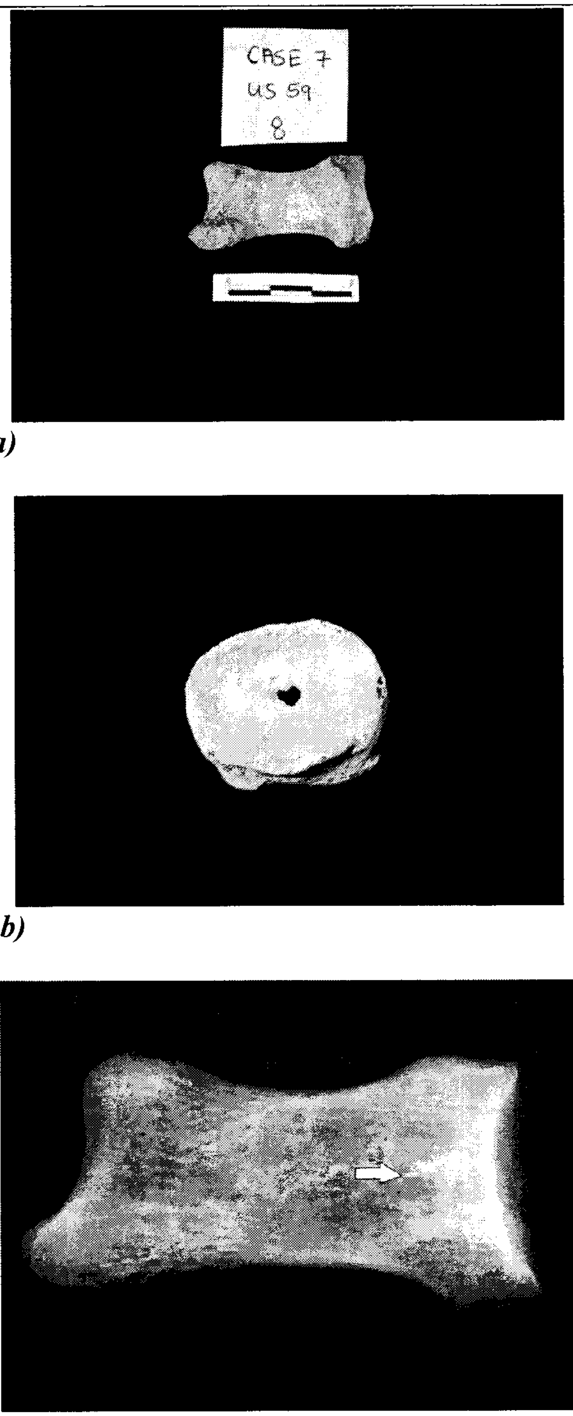
Two bones of the feet display pronounced proliferative growth, which may be a manifestation of trauma. One proximal phalanx, perhaps from the second digit, has a large lesion on its proximal plantar surface, which extends over the metatarsophalangeal joint [Figures 5.6 *a)* and *b)* below]. This lesion would certainly have rendered the joint immobile, and may potentially have resulted in a frozen hammertoe for this individual (Beito and Lavery, 1990). Such a skeletal manifestation has likely arisen due to an infraction. The proximal articular surface appears normal. Unfortunately this element was not radiographed, though it is likely that a fracture has occurred somewhere on the proximal plantar surface.



a) *b)*

Figure 5.6. A proximal foot phalanx showing a large lesion on its plantar surface, having occurred perhaps as the result of an infraction; *a)* dorsal view, and *b)* lateral view. The articular surface appears normal.

A first proximal phalanx [Figures 5.7 *a)*, *b)*, and *c)*] shows a peculiar addition of bone to the plantar surface of the medial condyle of the distal articular surface, which may have occurred in response to an infraction. In addition to the change, a small portion of bone is absent in the centre of the concave surface of the proximal articular surface. The lesion [Figure 5.7 *b)*] is nearly circular, and it measures a maximum of 2.8 mm in diameter. This lesion is likely related to avascular necrosis of a portion of subchondral bone which occurs in osteochondritis dissecans (Zimmerman and Kelley, 1982). The condition may result from low-grade microtrauma to a joint. Areas of radiodensity, suggesting necrotic bone (McCarthy and Frassica, 1998), are evident on the radiograph just anterior to the lesion [Figure 5.7 *c)*], which suggests that the circulation to this element had been significantly compromised, perhaps as a biomechanical consequence of



a)

b)

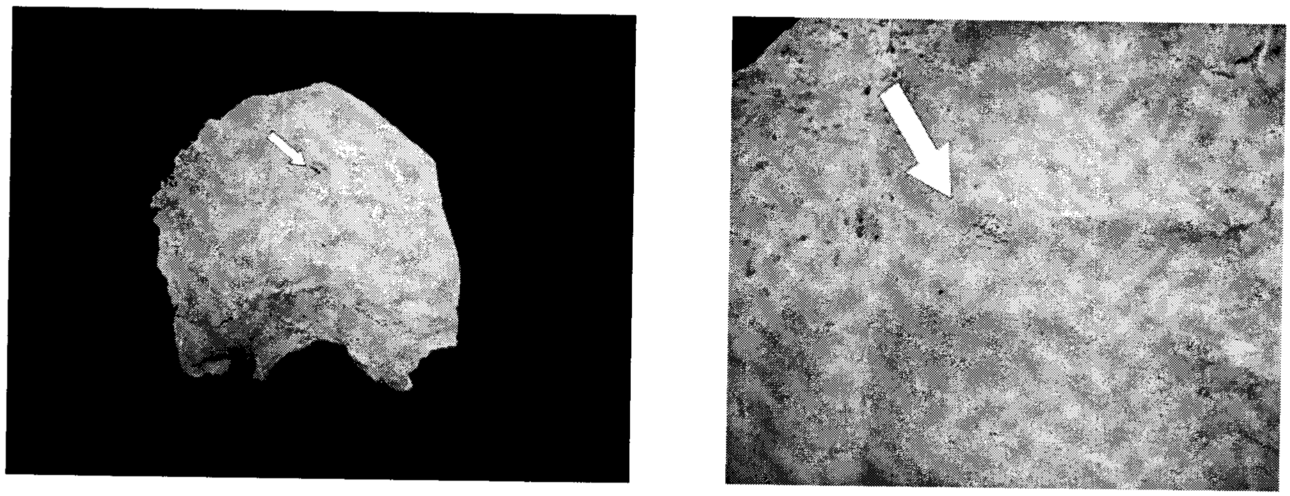
c)

Figure 5.7. A first proximal foot phalanx showing ossteochondritis dissecans. a) the full element; b) area of necrotic bone absorption on the proximal articular surface; c) radiographic image showing areas of radiodensity, and necrotic bone (arrow).

<u>Figure 5.8</u>. Proximal third of an adult radius, showing changes suggestive of altered biomechanical forces, perhaps the result of carrying heavy loads with the forearm flexed.

element had been significantly compromised, perhaps as a biomechanical consequence of the changes in the distal part of the element.

Figure 5.8 shows a fragment of the proximal third of an adult radius, which displays changes potentially attributable to altered biomechanical forces, most likely due to an adjacent fracture, perhaps on the ulna. The bone shows a pronounced outgrowth of woven bone along the surface of the interosseous crest at an angle of approximately 20 degrees to the shaft. A skeletal change such as this may have occurred as a result of altered biomechanical forces on the interosseous membrane, perhaps caused by the flexor



(a) *(b)*

<u>Figure 5.9</u>. Subadult occipital bone showing evidence of a lesion of unknown origin *(a)* and the resulting periosteal reaction on the endocranial surface *(b)*.

digitorum profundus muscle. The radial tuberosity on this element is very large, which could suggest that these pathological changes are the result of carrying heavy loads, perhaps in a supinated position with the forearm flexed.

Perhaps the most difficult element to interpret which displays evidence of trauma is an occipital fragment from a juvenile (determined by the underdeveloped state of the occipital condyles). This fragment shows a small, roughly circular lesion with sharp edges on the external surface, as shown in Figure 5.9 *(a)*. If this lesion was caused by a puncture wound of some sort, the puncture did not result in any adjacent fractures to the bone, and nor did it penetrate through to the inner table. It did, however, give rise to an infection [Figure 5.9 *(b)*], which can clearly be seen as a collection of periosteal new bone on the complementary location of the endocranial surface, at the level of the right transverse sulcus. It is not known with certainty if the lesion on the outer surface was caused by a wound from an object. Another possibility may be a focal lytic neoplasm on the external surface of the occipital bone, which may have become infected. It is difficult to offer conclusions about this case without the rest of the skeleton.

5.2.3 *Markers of Occupational Stress*. Although not always considered to be relevant to discussions of palaeopathology, the following evaluation will provide an explanation of certain markers of occupational stress that may be misinterpreted for pathological conditions, or may be the result of stress fractures associated with habitual activities. The notion that bone is responsive to mechanical loading is a central tenet in skeletal biology (Rafferty, 1998), and there is a suggested mathematical relationship between the force imparted to a bone and the extent of lamellar and cortical remodeling (Frost, 1990). Remodeling is regarded as a slow process, most likely the result of accumulated responses to microfractures (Frost, 1990), as can be the result of habitual pulling or pushing on an element with a force that is not great enough to exceed the elasticity of bone and cause an acute fracture (Kennedy, 1989).

A common type of occupationally related skeletal manifestation is a change in the area of muscle, tendon, or ligament attachment to bone. With a hypertrophy in a given muscle, bone will respond by increasing its attachment area by the extension of Sharpey's fibres which extend from the connective tissue. These fibres become ossified, and result in the appearance of rough patches, irregularities, and osteophytes (Kennedy, 1989). Several bones in the current collection exhibit extensive changes in areas of muscle or ligament attachment. Most notable are several fragments of distal fibulae that show pronounced areas of insertion of the interosseous ligament, though with less proliferation than may occur from infection. Changes appear as areas of roughening or porosity, with some sharp osteophytes. The interosseous ligament is largely responsible for the stability of the tibiofibular joint (Snedden and Shea, 2001), and the suggestion that this joint may be subject to a greater amount of motion than previously thought on account of its qualities as a synovial joint (Bartonicek, 2003), may suggest that the interosseous ligament is under great stress in certain ranges of motion. There has been little report on lesions of this nature in the archaeological record. Even in Kennedy's (1990) extensive review of the literature on occupational stresses, no mention is made of reported stress of the interosseous ligament of the fibula.

Although there is some level of discrepancy concerning the etiology of spondylolysis (Taillard, 1976), one lumbar vertebra did display this pathological change, and it is possible that this resulted from a stress fracture in the lower back (Manchester, 1982; Merbs, 1989a). The skeletal changes involve bilateral spondylolysis, accompanied by spondylolisthesis. Merbs (1989b) suggests that the forward slippage can create a gap ranging from several millimeters to greater than one centimeter, and this space may prevent the formation of the bony callus. In the archaeological record, this lesion has been observed to afflict primarily adults aged 30 to 50 (Arriaza, 1997). A familial pattern of this pathological change has been established (Taillard, 1976), though Merbs (1989b) believes that inheritance of the predisposing anatomy is likely the related factor, and that occupational stresses are still required for the manifestation to develop.

Two long bone fragments, one tibia shaft and one proximal femur, exhibit skeletal changes of flattening that may even approach the morphology associated with nutritional deficiencies such as rickets or osteomalacia (Ortner and Putschar, 1981, Buxton, 1938). An alternative explanation might be that these changes occurred due to the pressure of adjacent muscles as the result of strenuous activities which may have placed demanding physical stress on the muscles of the legs. Angel has observed anterio-posterior shaft flattening of the upper femur, or platymeria, and medio-lateral flattening of the upper tibia, or platycnemia in the New World (1966) and Old World (1971), and in both occasions he has attributed the changes to arduous travel in areas of rough terrain. Evidence of both platymeria and platycnemia are present in the current population, and considering the relative survival of femora and tibiae, this suggests an overall prevalence of 8.3% and 11.1% for platymeria and platycnemia respectively.

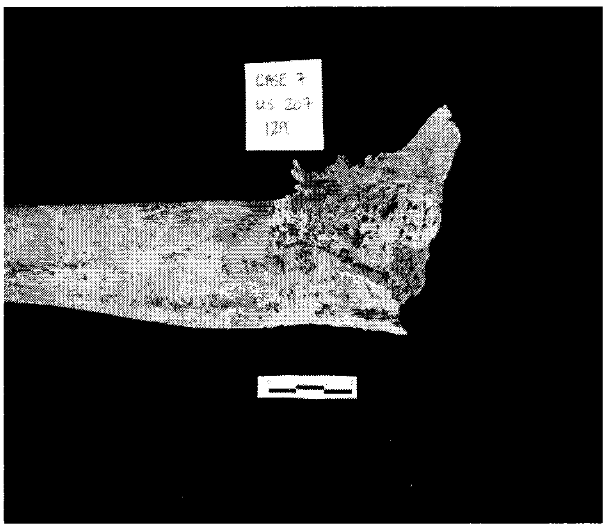
The large origin of the soleus muscle on the tibia fragment suggests that perhaps muscle contraction alone may have been the cause of the skeletal flattening, though such a finding may be considered unusual in a population which inhabits an area of smooth terrain such as that of the Taviolere region. The extent of biomechanical changes reflective of mechanical loading in the lower limb might relate to both the strenuousness of daily activities and the roughness of the terrain, though in Ruff's (2000) extensive review of lower limb biomechanics, he concludes that subsistence strategy does not have a consistent effect on overall mechanical loading, but rather that physical terrain provides a greater influence. Contrary to his conclusion, it appears that for this population daily activities, and hence subsistence strategy, did provide a greater influence than terrain on the level of platymeria and platycnemia. A possible reason for this may be an underlying level of vitamin D deficiency in the population which may have made these individuals more susceptible to changes of this sort, though it is difficult to substantiate this claim with the limited number of bones subject to this analysis. The finding of skeletal elements that show changes suggestive of vitamin D deficiency in the subset of the skeletal material awaiting analysis might lend support to this hypothesis, though such a finding might be unusual considering the high levels of solar radiation that occur in southern Italy.

5.2.4 ***Neoplasia***. The most difficult skeletal lesions to identify in archaeological specimens are neoplastic lesions because most of the associated skeletal changes mimic those apparent in chronic infection and in callus formation from fractures. In addition, the skeleton is susceptible to many different forms of tumours, and it can be very difficult to distinguish the different types in the analysis of skeletal tissue alone (Ortner and Putschar, 1981). Skeletal tumours fall into two main categories, namely primary tumours which originate in bone and are either benign or malignant, and secondary tumours comprised of malignant tissue that originated in another area of the body and was carried to the bone in either the blood or lymph. There is consensus in the literature that factors such as age, sex, location, distribution throughout the body, and morphology may assist in the differentiation between types of lesions (Ortner and Putschar, 1981; Steinbock, 1976;

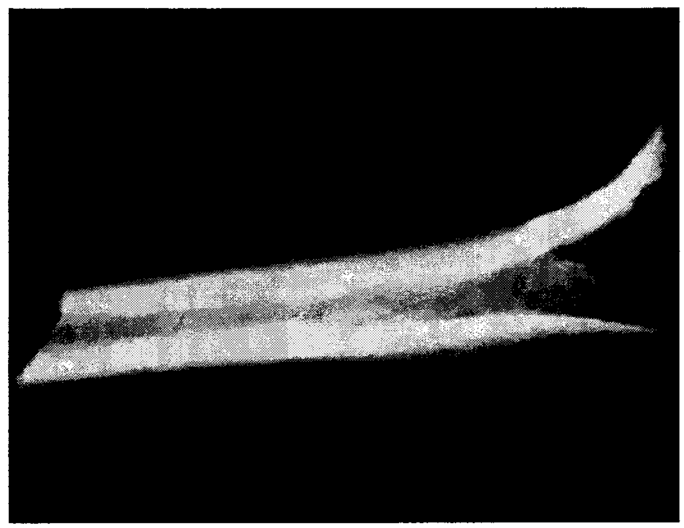
McCarthy and Frassica, 1998). Steinbock (1976) states that secondary metastases are more common in bone than primary lesions; however, Ortner and Putschar (1981) and Manchester (1989) remind us that skeletal populations are usually comprised of individuals with a life expectancy of only half that of modern populations, and the predilection of secondary metastases in older individuals should be kept in mind when evaluating archaeological material.

Two skeletal elements in the current collection exhibit lesions that may be suggestive of neoplastic origins. The first is the proximal half of a right femur which shows a lesion with an apparent mixture of proliferative and lytic activity in the posterior proximal end. Slightly inferior to this lesion is a periosteal reaction 7.8 cm in length along the lateral surface of the shaft (Figures 5.10 and 5.11). It cannot be said with certainty that the more prominent of the two lesions represents a tumour, though a differential diagnosis of chondrosarcoma is supported by the fact that the individual is adult, the proximal femur is a common location for this anomaly, and the lesion is characterized by both lytic and proliferative changes with a periosteal involvement evidenced by the radiation of bony spicules (Aufderheide and Rodriguez-Martin, 1998). Endosteal scalloping is also often observed in this condition, though the poor preservation of the trabecular bone in the marrow cavity makes this assessment difficult. Many of these features may be descriptive measures for osteosarcoma as well, though these lesions tend to be more common amongst younger individuals.

Infection must also be considered for this element. If infection were the sole cause, it would be reasonably simple to suggest a relationship between the two lesions, the less advanced being caused by a subperiosteal accumulation of granulation tissue in response to an infection in the medullary cavity; however, the lack of sequestra and cloaca make it difficult to offer this conclusion with certainty. Another possibility might be that the less advanced lesion is reflective of a change in biomechanics at the joint, due perhaps to the increased pressure placed on the lateral quadriceps muscle in order to perpetuate mobility in the joint.



<u>Figure 5.10</u>. Mixed proliferative and lytic lesion on a proximal femur, possibly representing a case of neoplasia.



<u>Figure 5.11</u>. Radiographic image of the femur.

The second fragment is an adult innominate that displays a mixed lytic and proliferative lesion on the medial surface of the ilium at the level of the greater sciatic notch. A large lytic area in the element likely corresponds to the location of the nidus, the location where the soft tissue tumour multiplies. The pelvis is a common site of metastases, and hence it is possible that this lesion represents a secondary carcinoma. Metastases can occur from different primary origins, though those from the prostate tend to be proliferative, those from the kidney, lung, and thyroid tend to be lytic, and those from the breast tend to involve a mixture of both proliferative and lytic lesions. Unfortunately the areas of the innominate which are informative of sex did not survive, though the greater sciatic notch suggests that the individual is female. This, in concert with the mixed lesion, may be accepted as evidence that this element displays a metastasis of breast cancer. Regardless, an interpretation of haematological osteomyelitis cannot be ruled out, because the large lytic lesions may have been the result of an avascular necrosis, with the channel through the marrow region representing a drainage channel. The lack of sequestra, however, makes this distinction difficult.

Since the two skeletal elements suggestive of neoplasia likely represent different forms of cancer, it is likely that they are from two separate individuals.

5.2.5 *Haematological disorders*. Cribra orbitalia and porotic hyperostosis are two relatively common conditions that have been observed in the archaeological record. The skeletal changes are thought to be the result of iron-deficiency anaemia. The lesions likely result from a hypertrophy in the red marrow in response to low levels of serum iron. This hypertrophy is most noticeable in areas where the cortical bone is relatively thin, such as in the orbital plate (Steinbock, 1976). Lesions tend to develop only in childhood, though evidence may persist into the adult years.

Figure 5.12. An example of active cribra orbitalia in the right orbit of a juvenile.

Figure 5.13. An example of a remodeled lesion associated with cribra orbitalia.

Three examples of cribra orbitalia were found in the current collection, one active manifestation in the right orbit of a juvenile (Figure 5.12), and two lesions in the orbits of two different adult individuals, one in the process of healing (Figure 5.13) and another completely healed. Devising frequencies of the lesions based on this data is difficult because only one juvenile is represented by the number of frontal bone fragments, and it would be erroneous to assume a 100% distribution of the trait in the subadult sample. Conversely, eight adults are represented by frontal bone fragments which have an intact orbital plate, and this corresponds to a frequency of 25% in the adult sample.

5.3 Discussion

Generally, the subset of this population which has been subject to the current analysis has shown a low level of subtle pathological changes as manifest on the skeleton, though this does not necessarily imply that we are dealing with a relatively healthy population. One must keep in mind that significant limitations have been introduced by the poor state of preservation of the material, as elements were often not complete, and recovery of pathological elements was likely not 100%. Waldron (1991) reminds us that osteoarthritis is considered to be the single most prevalent pathological change observed in archaeological material, and its absence suggests that the sample is in some way unusual. Its absence in this sample likely relates to the low recovery of elements with intact articular surfaces. In addition, bone that may have experienced extensive degenerative changes is less likely to survive to recovery, especially when taphonomic conditions are as destructive as those for this skeletal collection.

Perhaps more telling than the observed pathological lesions is the age structure of the population. Longevity is regarded as the single most informative measure of population health (Goodman et al, 1984; Angel, 1984; Ortner and Putschar, 1981), and the high proportion of subadult material in the site suggests that health status was likely problematic. The lack of lesions in much of the subadult material could be held as evidence of individuals succumbing to infections while still in the acute stages. If this were indeed the case, however, one might expect some to have survived the insults and survived to adulthood with evidence of chronic infections on their skeletal remains. This seemingly paradoxical result could be reconciled by a lack of skeletal preservation of these elements, or at least of the fragile features that can be held suggestive of pathological changes due to chronic infection. Alternatively, it may be possible that infections only reached great severity in the fragile proportion of the population, and hence those who survive to adulthood appear skeletally healthy. Furthermore, there is no evidence to suggest that the site was used for interment with any particular frequency, and thus it may be possible that individuals with chronic infections were not laid to rest in this hypogeum.

Of the observed skeletal lesions, the most informative indicator of population health is the reasonably high frequency of cribra orbitalia, reported at a level of 25% for this population based on remodeled lesions in the adult sample, and the MNI value obtained from recovered orbits. The most simplistic interpretation of these lesions may be one of poor nutrition, perhaps the result of seasonal shortages of dietary iron. This notion might be supported by the observation of ossified periosteal lesions on the three tibia fragments which may be indicative of vitamin C deficiency. It has been established that the uptake of dietary iron can be improved with high levels of vitamin C (Haschke et al, 1988), and hence limited amounts of both in the diet may have deleterious effects on iron absorption. Regardless, the presence of scurvy in this population is highly unlikely as the condition does not tend to be common amongst populations from temperate regions (Aufderheide and Rodriguez-Martin, 1998), and it has not been reported in skeletal populations from adjacent areas (Angel, 1971; Brasili et al, 1997).

An alternative interpretation might be to relate the level of iron-deficiency to the parasitic load of the population. Over the past several decades, growing evidence has been presented which shows a relationship between the level of iron deficiency and infectious episodes, and this correlation has prompted some authors to consider cribra orbitalia and porotic hyperostosis as evidence of endemic infections (Angel, 1971; Keenleyside, 1998; Pietrusewsky, 1997; Powell, 1988; Stuart-Macadam, 1992). It is important to consider this possibility in the current population, especially in light of the high proportion of subadult fatalities that may have occurred as a result of infection.

In his evaluation of the Bronze Age population of Lerna, Angel (1971) argues that the observed high level of porotic hyperostosis was intimately related to endemic malaria of the region. Angel suggests that thalassemia was likely high in this population, as individuals heterozygous for the condition would have held an advantage during a malarial episode. The high proportion of cribra-orbitalia in the subadult sample was viewed as evidence of thalassemia in the population, a condition that is fatal to the homozygote. Malaria is known to have existed in many areas of the Mediterranean (Angel, 1971), and the individuals of the *Iopgeo degli Avori* were likely not exempt from its effects. However, if thalassemia was present in the current population, one might expect that skeletal changes other than those on the cranium would be recorded, thus suggesting severe anaemia in childhood. As these were not present, an alternative hypothesis may be that the level of iron-deficiency is evidence of the iron-withholding mechanism, whereby endogenous iron is chelated in the liver and spleen in order to deprive an invading pathogen of a supply of iron (reviewed in Weinberg, 1992). Iron-withholding itself is not a sufficient cause for pathological levels of iron deficiency, but other factors such as growth demands, poor dietary intake, or blood loss could tip the scale into the hazardous zone (Stuart-Macadam, 1992). In such a situation, an underlying infection, perhaps the result of urban living, accompanied by a seasonal shortage of iron may be enough to produce the observed lesions (Rathbun, 1984). In addition, some authors support the notion that social stresses may be responsible for certain indications of physiological stress in the skeleton (Powell, 1988; Manzi et al, 1999; Hummert and Van Gerven, 1983), and hence lesions such as those of cribra orbitalia may be suggestive of generalized stresses in the community.

Aside from cribra orbitalia, the frequency of other pathological lesions is difficult to express due to the poor preservation and incomplete nature of the skeletal elements. Although the eventual aim of palaeopathological analyses is to propose models for overall population health, such a task will be difficult for the study population at this time. In addition to the issues of selectivity that have been discussed as they relate to the differential survival of skeletal elements, a reliable analysis of pathological lesions cannot be accomplished without a consideration of the cultural practices of the population and the environment of the region which they inhabited (Goodman et al, 1984; Pfeiffer 1984). Comparisons with other populations may be problematic as some studies have revealed that different frequencies of skeletal lesions can be observed amongst populations from similar regions who practice similar subsistence strategies (Keenleyside, 1998; Pietrusewsky, 1997). Ortner (1991) cautions that "[w]hile enlightened speculation may be helpful, it is very easy to careen down scientifically blind alleys because of ignorance or because we have overextended our data". In light of the above concerns, it may be best to restrict the interpretation of the skeletal lesions to a more general discussion.

The current population likely represents a settled group. The mode of subsistence will be better understood once an evaluation of the archaeological artifacts and faunal material of this site is complete, though it is likely that the population generally relied upon agriculture and domestic livestock to meet their nutritional requirements. Given their proximity to the ocean, fish likely also made a large contribution to the diet. Robb (1994) suggests that early pastoralist groups might be skeletally represented by traits associated with high mobility, and Angel (1971) describes adaptations that favour greater joint flexibility and muscular strength below the thorax in his evaluation of the Bronze Age horticulturalist community of Lerna. By extension, it is not surprising that a great deal of pathological changes were observed in elements of the lower limb. These may also serve as evidence that the individuals in this group engaged in travel by foot, perhaps while on trade routes to the adjacent mountainous Apennine regions, though archaeological evidence will be required to substantiate this hypothesis. Furthermore, the evidence of occupational markers suggests intense physical labour in some individuals, which likely involved heavy lifting of some sort and stress on the lower back. Such activities may be regarded as a part of the normal life in an early farming group.

5.4 Future directions

Without a more complete representation of the age and sex distribution of the skeletal traits, it would likely be erroneous to offer additional interpretations of the pathological findings. Goodman and colleagues (1984) suggest that the health of past human populations is best evaluated when several different indicators of stress are incorporated in the analysis. Evidence of stressful events in childhood can be detected through the analysis of linear enamel hypoplasias and Harris lines, and these may serve as important indicators of quality of life in the childhood years. Due to time constraints, dental lesions were not evaluated, and the prevalence of these may assist in either supporting or dismissing the suggestion that scurvy was absent in the population, as Steinbock (1976) suggests that dental lesions are a common consequence of vitamin C deficiency. Above all, more information about the settlement is required before a reliable interpretation of palaeopathology can be provided. A collaborative evaluation of the population which includes the involvement of skeletal biologists, faunal analysts, and archaeologists would be beneficial in creating a comprehensive picture of the population, upon which inferences about daily life and health can be proposed.

CHAPTER 6: CHEMICAL ANALYSIS

6.1 Background

Over the past several decades, chemical analysis has gained popularity as a method of harnessing additional information that would be unattainable through traditional means of gross observation of skeletal remains. Since its introduction to anthropological study nearly twenty years ago (Ericson, 1985), strontium (Sr) has shown promise as an informative chemical indicator of residential mobility amongst prehistoric human populations. Other elements have been used for analyses of this nature (examples in Müller *et al*, 2003), though strontium appears to make the best candidate (Price *et al*, 2002) due to the extremely sensitive differences in Sr isotope values that occur in distinct areas of the earth's crust, which in turn affect the biological composition of tissues that relied upon food and water sources in a certain area during their formation. With the comparison of strontium isotope levels against an appropriate standard, sensitive methods can be employed to suggest precisely the location where an individual resided at the time that the tissue of interest matured (Ezzo et al, 1997; Beard and Johnson, 2000; Muller et al, 2003; Bentley et al, 2004).

Of interest in this analysis is the relative level of the radiogenic isotope ^{87}Sr as compared to the non-radiogenic variant ^{86}Sr. ^{87}Sr is produced by the spontaneous beta decay of ^{87}Rb, which obeys a decay half life of 48.8×10^9 yrs. (Beard and Johnson, 2000). Radiogenic strontium levels are normalized against the non-radiogenic isotope, since their near equal levels on the earth allow for very high accuracy in detected differences (Beard and Johnson, 2000). Variations in earth values for $^{87}Sr/^{86}Sr$ tend to occur between 0.700 and 0.750, with regional diversities attributable to the relative levels of rubidium and strontium in rock (Price et al, 2002). Age of the rock is also a significant factor, with older rocks (>100 million years), having significantly higher ratios (Price et al, 2002). Variations in strontium ratios tend to seem rather small, though they are quite substantial from a geological perspective, and are frequently far in excess of values reported for analytical error (usually 0.00003) (Price et al, 1994; Beard and Johnson, 2000).

Beard and Johnson (2000) provide a map detailing the variability of strontium isotope ratios for the United States. They report a high degree of heterogeneity between close geographic regions, which suggests a diverse worldwide variability in strontium isotopic levels. Price and colleagues (2002) report that even a single rock can contain different strontium signatures. Differences largely relate to the time period in which rocks of a given region formed, with very old rocks having experienced a higher level of ^{87}Rb decay.

Strontium, like calcium, is an alkaline earth element, and thus the two hold certain chemical properties in common. Consequently, strontium may substitute for calcium in trace amounts in the carbonated hydroxyapatite of bone and dental enamel (Driessen and Verbeeck, 1990). Crystallization of these tissues does not appear to follow tight stoichiometric parameters, and thus small amounts of strontium can become incorporated with relative ease (Boivin and Meunier, 2003). This heteroionic exchange does not introduce any major changes at the crystal level (Biovin and Meunier, 2003), and thus its incorporation appears to occur with no physiological consequence to biological systems.

Strontium concentration is known to differ between trophic levels (Price et al, 1994), though it appears that the $^{87}Sr/^{86}Sr$ ratio passes through the food chain relatively unchanged (Ericson, 1985). Fractionation of different isotopes does not appear to occur as a result of biological processes, likely due to the fact that 1) strontium is of no known nutritional or biochemical value (Price et al, 1992), and 2) the differences in atomic weight between ^{87}Sr and ^{86}Sr are negligible, considering it is a high mass element (Price 1994; Beard and Johnson, 2000). As such, strontium ratios are viewed as being largely independent of concentration, and will, therefore, provide a reflection of the geology of the area inhabited by the individual at the time the structure of interest formed, regardless of the trophic level of the organism (Price et al, 1994).

Of interest in an anthropological context is the manner in which strontium isotope analysis can assist us in determining the residential history of an individual. This determination is made possible due to certain physiological features of skeletal elements. Bones remain as living tissue throughout the life of the individual, and undergo a continuous process of remodeling. New bone that is formed will, therefore, contain elements that reflect the diet of the individual at the time that remodeling occurred. It has been suggested that the Sr values for bone will represent the diet over the last six years of the life of the individual (Ericson, 1985), though others suggest that the time period represented may be as high as ten years (Lowenstram and Weiner, 1989). By contrast, mature enamel is not infiltrated by organic structures (Steele and Bramblett, 1988), and thus does not undergo recrystallization, and by extension chemical changes, after its formation is complete. Taken together, the above information suggests that the chemical constituents of bone will yield values suggestive of the diet of the individual at the time of death, whereas dental enamel will be more useful as an indicator of dietary Sr ratios during the developmental years. Considering the high levels of variation in strontium isotope ratios observed between different geographic regions, evidence of migration is thought to be represented by significant differences in the $^{87}Sr/^{86}Sr$ of bone and dental enamel in the same individual. Brought to a population level, migration can be considered as having occurred if the values for dental enamel show a higher variability than those of bone (Price et al, 1994). It should be noted that the adjacent dentin continues to remodel throughout the life of the individual (Tolstykh et al, 2003), and thus care must be taken during the removal of enamel so as to avoid contamination with remodeled tissue.

For analyses of this nature, the first permanent molar is preferred since its early mineralization makes it the best candidate of any permanent tooth to provide the most sensitive measure of migrations early in life (Ezzo et al, 1997). Bentley and colleagues

(2004) stress the importance of considering possible changes in Sr isotope ratios of past populations as resulting from cultural factors such as significant changes in diet or food sources throughout life, and further recommend use of the terms "local" versus "non-local" as opposed to "local" versus "migrant" to eliminate possible false assumptions about residency. In Sr isotope analysis, it is also important to bear in mind that the strontium ratios measured from preserved tissue represent the average of the ratios from all food sources consumed during its period of development, and thus small fluctuations in isotopic values can be expected from a region which may have a varied food source.

In addition to the above considerations, the major theoretical limitation of any chemical analysis of skeletal tissue involves diagenetic changes that occur due to the burial environment. After decomposition of the organic component of bone, changes in bone mineral content are accelerated (Price et al, 1992). The extent of diagenetic changes will vary depending on the burial environment and type of skeletal element, with thicker tissue having more protection (Price et al, 1992).

Diagenesis occurs via two processes: infiltration of environmental carbonate via pores of the element, or by recrystallization. Both of these processes result in the incorporation of diagenetic Sr, whether it is contained within a carbonate molecule housed inside the bone, or by ionic exchange with biogenic calcium or strontium. The primary source of diagenetic strontium is carbonate (Price et al, 1994). Bone is particularly susceptible to carbonate contamination because it is relatively porous (Driessen and Verbeeck, 1990). In addition, bone possesses fairly small apatite crystals (Boivin and Meunier, 2003; Driessen and Verbeeck, 1990), and the resulting large surface area facilitates interaction with groundwater, and thus increases its likelihood of experiencing ionic exchanges. By contrast, dental enamel is a denser, harder, and more inert tissue (Price, 2002); its conservative porosity limits its susceptibility to water infiltration. Its larger apatite crystals also restrict the surface area which could gain exposure to diagenetic fluids, which further protects it against ionic exchanges (Driessen and Verbeeck, 1990). Furthermore, the process of recrystallization poses complications relating to chemical alterations. Local dissolution and reprecipitation of apatite crystals results in the consolidation and growth of crystallites (reviewed in Koch et al, 1992), with new crystals being susceptible to incorporating diagenetic Sr from the surrounding fluid media.

Differences in the solubility profiles of original and newly formed crystals have allowed for the development of a purported purification technique of archaeological skeletal tissue. Price and colleagues (1992, 1994) suggest that soaking the powdered sample in acetic acid (pH ~2) for 24 hours not only removes diagenetic carbonate, but also is sufficient for dissolving the external layer of the recrystallized interior of the element.

Despite the limitations of diagenesis, strontium isotopic ratios have been used in many analyses of prehistoric migrations (Ericson, 1985; Price et al, 1994; Ezzo et al, 1997; Price et al, 2002; Bentely et al, 2003; Bentley et al, 2004), modern cases of forensic interest (Beard and Johnson, 2000), and even as a refinement of the location where the Alpine Iceman spent his youth (Muller et al, 2003). It is hoped that the following analysis may yield some insight into the migrational patterns of the individuals of Trinitapoli.

6.2 Methods

Strontium signatures were evaluated for human bone and enamel, as well as three faunal samples to determine the local strontium ratios. For human samples, the relative $^{86}Sr/^{87}Sr$ ratios for dental enamel and bone were compared in four mandibles and three maxillae. Two of the maxillary samples came from the same individual (one from the left and one from the right) to provide a control. The external surfaces of the bones and teeth were manually cleaned with a soft tooth brush and a soft wooden chopstick to remove surface dirt. A fine grit diamond saw was used to pulverize the bone and dental enamel into a fine powder. Approximately 200 mg of bone was obtained from each sample. Attempts were made to obtain 100 mg of dental enamel, though due to the extent of dental wear, this yield was not always met. Whenever possible, teeth were removed from the bone for easier manipulation with the saw. The first molar was used whenever it was present, since it experiences the earliest formation and thus is thought to provide the most accurate measure of chemical differences that exist between the earlier and later stages of an individual's life (Ezzo et al, 1997). Table 6.1 provides a summary of the archaeological information and a description of each element used in the strontium analysis.

<u>Table 6.1</u>: Summary of the seven human samples used for chemical analyses. Bone and dental enamel samples were obtained from each fragment.

Case	Archaeological Label	Bone	Side	Tooth	Sample Identification
2	Q US 109 Taglio 13	mandible	L	M_2	109 T M2 109 B
7	US 107 142	mandible	L	M_1	142 T 142 B
13	Q9 US 31	mandible	R	M_2	31 T M2 31B
13	IPZ Q 14A US 48 23 XI	mandible (midline portion)		C (right)	48 B 48 T
5	R 202 T 201 N-S Q 18A/19A Buco animale	maxilla	L	M^1	202 B 202 T
9	US 214 3	maxilla	L	M^1	214A T 214A B
9	US 214 3	maxilla (same individual as above)	R	M^1	214B T 214B B

- **"B" refers to bone samples**
- **"T" refers to tooth samples; in some cases the enamel identification title also included the tooth number.**

The resulting 14 biological samples were placed in small beakers, each having been triple rinsed with dH_2O. A 1:1 bleach (NaOCl, or sodium hypochlorite) to dH_2O solution was added to each of the bone and enamel samples in the amount of 0.04 ml of solution for every 1 mg of biological material. Beakers were covered with a parafilm wax cover and the samples were allowed to soak for three days.

Samples were removed from the beakers and transferred to 15 ml centrifuge tubes, with dH_2O added to liberate the biological material that had collected on the sides of the glass. The bleach solution was removed by centrifugation at 700*g* for five minutes, followed by aspiration. To ensure removal of all the bleach solution, rinsing with dH_2O, followed by centrifugation at 700*g* for five minutes and aspiration of the aqueous phase, was carried out three times.

The recommended protocol of one 24 hour acetic acid soak (Price et al, 1992, 1994) was followed in the current analysis in hopes of eliminating the influence of diagenetic strontium. In addition to the acid soak, Price and colleagues (1992) suggest mechanical abrasion of the external surface of the preserved element prior to the acid soak as an additional purification method, though this was not done in the present study due to the limited amounts of dental enamel remaining on the teeth. The rinsed samples were exposed to a buffered acetic acid ($C_2H_4O_2$) solution, in the amounts of 0.04 ml of solution for every 1 mg of biological material. Centrifuge tubes were capped, and the samples were allowed to soak for 24 hrs. The acid solution was removed by centrifugation at 700*g* for five minutes, followed by aspiration. Once again, the samples were thoroughly rinsed with three suspensions in dH_2O. Purified samples were placed on an oven rack to dry, loosely covered by a thin layer of aluminum foil. After one week, the final weights were determined. Yields for strontium analysis of the human material are summarized in Table 6.2. Strontium analysis was performed by the thermal ionization mass spectrometry (TIMS) technique in the School of Geography and Geology at McMaster University.

Table 6.2: Weights obtained for Strontium analysis. Sample identifications accord with those described in Table 2.

Sample identification	**Original weight (g)**	**Yield after purification (g)**	**Loss (g)**
109 B	0.2091	0.1839	0.0252
142 B	0.2000	0.1504	0.0496
31 B	0.2015	0.1720	0.0295
48 B	0.1998	0.1673	0.0325
202 B	0.2009	0.1690	0.0319
214_A B	0.1999	0.1637	0.0362
214_B B	0.2000	0.1584	0.0416
109 T M_2	0.0579	0.0481	0.0098
142 T	0.0415	0.0329	0.0086
31 T M_2	0.0506	0.0359	0.0147
48 T	0.0395	0.0140	0.0255
202 T	0.0637	0.0517	0.0120
$214_{A\ T}$	0.0317	0.0248	0.0069
$214_{B\ T}$	0.0724	0.0635	0.0089

Three faunal bone fragments, representing the genus *bos* (cow), *ovis/capri* (sheep/goat), and *vulpes* (fox), were also used for strontium analysis to determine the relationship between the Sr signatures of human bone to faunal material. The preparation of the faunal material followed the same protocol as that for the human fragments above. Table 6.3 provides a summary of the weights yielded for this analysis.

Table 6.3. Summary for the three faunal bone samples used for Sr isotope analysis.

Archaeological Label	**Bone**	**Sample Identification**	**Original Weight**	**Weight after Purification**	**Loss**
US 56 B 295	Metatarsal, *Bos*	295	0.2757	0.2040	0.0717
Q 14 B US 56 B Ossa Sparse	Ulna, *Vulpes*	Ossa Sparse	0.2024	0.1085	0.0939
US B 14	Metatarsal, *Ovis/capra*	14	0.3442	0.2819	0.0623

Strontium quantitation was also performed by means of TIMS analysis. A small sample of dirt from the site was also removed from the faunal bones. This sample has been reserved for future analysis if the need arises to study the soil.

6.3 Results

Values obtained from the TIMS analysis of bone-enamel pairs are presented in Table 6.4. There is a trend in the literature to express these values in $\varepsilon^{87}Sr$ (DePaolo and Wasserberg, 1976 and 1977; Price et al, 1994; Ezzo et al, 1997; Beard and Johnson, 2000), which is defined as:

$$\boldsymbol{\varepsilon^{87}Sr = ([^{87}Sr/^{86}Sr]_{SAMPLE} / [^{87}Sr/^{86}Sr]_{BULK\ EARTH} - 1) \times 10^4}$$

where ($[^{87}Sr/^{86}Sr]_{SAMPLE}$ refers to the measured value, and $[^{87}Sr/^{86}Sr]_{BULK\ EARTH}$ is equal to 0.7045. This parameter facilitates the comparison of numerically small differences that occur in Sr ratios. The results show only a small difference in the average values of bone and teeth; however, as stressed by Bentley and colleagues (2004), when averages are similar, one should also pay close attention to variation to determine heterogeneity of Sr ratios. Dental enamel data shows much more variability than bone, having a standard deviation ten fold larger (0.00019078 and 0.000023100 for enamel and bone respectively); this, therefore, suggests that the individuals in this analysis represent a pool that experienced diets with different levels of Sr ratios during development. Noteworthy is the level of discrepancy that exists between the two enamel values for individual 214. For this individual, bone-enamel pairs were analyzed from both the right and left sides of the maxilla, and thus should theoretically yield similar values. Bone data produced consistent results; however, dental enamel showed a 1% discrepancy (0.70822 vs

0.70842). Although this may seem a very small level of error, one must bear in mind that small numerical changes in ratio values are meaningful on a geological scale. Consequently, this discrepancy suggests a level of experimental error in addition to that reported as measured analytical error.

Table 6.4. Bone and enamel values obtained from the TIMS analysis of Sr^{87}/Sr^{86}, expressed both as unaltered ratio and $\varepsilon^{87}Sr$. Fase refers to the geological stratum in which the element was found, provided that information could be deciphered from the associated archaeological data.

Sample	Bone		Enamel		Fase
	$^{87}Sr/^{86}Sr$	$\varepsilon^{87}Sr$	$^{87}Sr/^{86}Sr$	$\varepsilon^{87}Sr$	
31	0.70854 ±7	57.346	0.70854 ±5	57.346	?
48	0.70855 ±4	57.486	0.70812 ±10	51.384	2
109	0.70855 ±2	57.486	0.70856 ±4	57.629	?
142	0.70860 ±2	58.197	0.70846 ±12	56.210	?
202	0.70854 ±2	57.346	0.70865 ±4	58.907	?
214_A	0.70857 ±2	57.771	0.70822 ±6	52.803	2
214_B	0.70857 ±7	57.771	0.70842 ±4	55.642	2
Average	0.70856	57.629	0.70842	55.642	
Std. deviation	0.000023100		0.00019078		

Although data from faunal bone are not presented in the above table, the values appeared similar to those reported for human bone.

The issue of residency is understood only if a proper calibration of what determines a local value is presented. Price and colleagues (1994) suggest that the most appropriate limits for local values be set as the mean measured variation in the tissue purportedly exhibiting local values (in the current case human bone) ± 2 SD. The bone average value of 0.70856 ± 2 SD of 0.000023100 each provides "local" limits of 0.70851 and 0.70860. With these boundaries, all reported bone values fall within the "local" range. Dental enamel shows greater variation: of the six individuals subject to analysis, two fell within "local" values, and four appear as "non-locals". These results are shown in Figure 6.1 below.

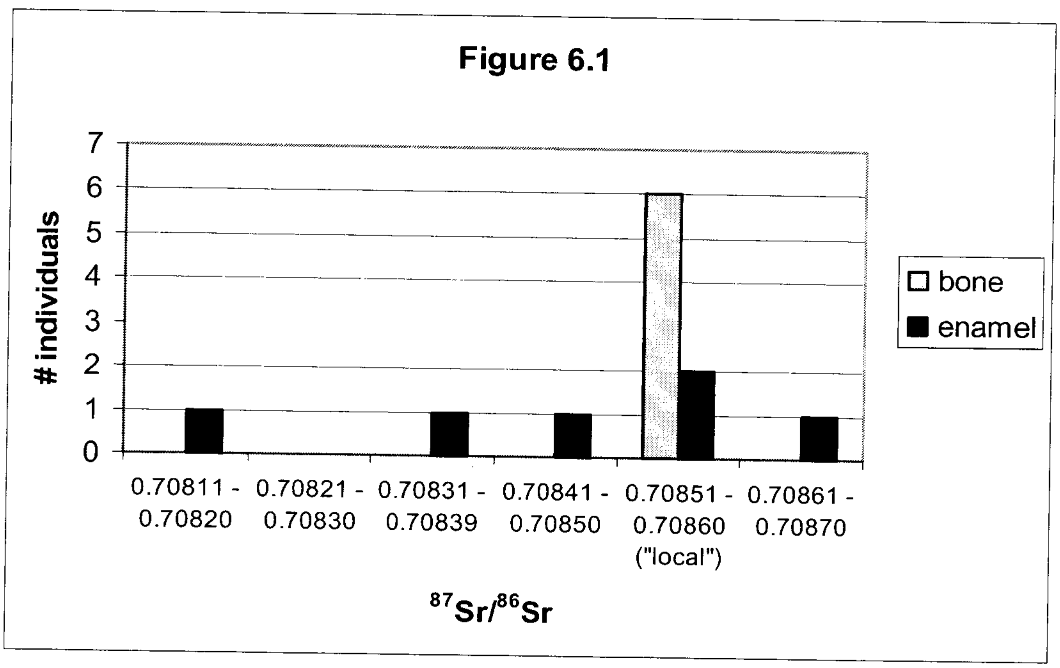
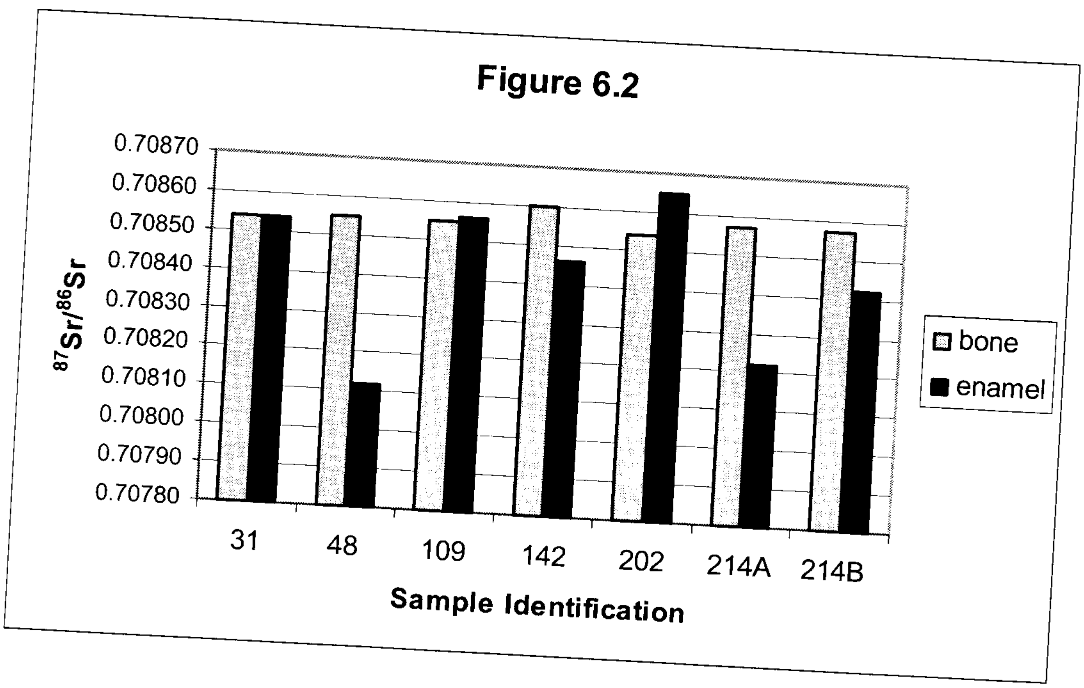


Figure 6.1. Bar graph displaying the number of individuals representing "local" and "non-local" status. Local values are defined as mean bone value ±2 SD, which corresponds to 0.70851 and 0.70860. Of the six individuals subject to this analysis, two appeared as "local" and four appeared to be of "non-local" origins. The enamel value for individual 214 was determined by averaging the different values obtained for the left and right first maxillary molars. As a note of caution, these results are subject to the accuracy of the bone values.

Figure 6.2 below displays the relative values of the bone-enamel pairs for the individuals studied. From this graph, it is evident that individuals 31 and 109 are identified as "local", whereas individuals 48, 142, 202, and 214 fall under the "non-local" criteria. These results are under the provision that the "local" ranges were defined by appropriate parameters, and that bone values do indeed reflect biogenic Sr ratios.



<u>Figure 6.2</u>. Bar graph showing the relative differences in Sr^{87}/Sr^{86} ratios for bone and enamel pairs. Values between 0.70851 and 0.70860 were considered "local", based on the criteria explained in Figure 6.1. From the above graph, "local" individuals are sample numbers 31 and 109. "Non-locals" are sample numbers 48, 142, 202, and 214.

6.4 Discussion

Price and colleagues (1994) remind us that if migration had occurred in a population, the strontium data should reflect at least two modes, one showing the local values, and the other the values common to a different region. Based on the suggestion of calibrating "local" values as the local mean ± 2 SD, two of the six individuals appear as "local"; however, it is imperative that an acknowledgement be made concerning the effect of the homogeneity of the bone Sr ratios on this calibration. The similar Sr ratios obtained for the bone samples result in a very small standard deviation, and consequently a narrow range for the "local" values. The assignment of an individual to "local" status was based on a local range 0.70851 to 0.70860, with a corresponding difference of only 0.00009. Other reports list differences in local values of 0.0009 for an early Neolithic settlement in Germany (Bentley et al, 2003) and 0.001127 for the Southwestern United States Grasshopper Pueblo (data presented in Price et al, 1994; Ezzo et al, 1997; and Beard and Johnson, 2000), thus suggesting a higher level of local variation than that observed in the current data set. The homogeneity in bone samples of this study may be an artifact of small sample size, or it could have resulted from additional complications from bone diagenesis (discussed in detail below). The differences between the bone and enamel values for individuals 142 and 202 are not terribly large, and had the "local" range been greater, they may have appeared as "locals". By contrast, individuals 48 and 214 show larger discrepancies between bone and enamel values, and are hence more likely to represent "non-locals".

It is unfortunate that the location in the hypogeum could not be established for all the individuals subject to this analysis. One might expect to see a high number of immigrants in fase 1, which corresponds to the earliest occupation of the site. Of the four individuals identified as "non-locals", two were from fase 2, which could potentially suggest that there was a level of migratory activity into this area after the settlement had been established.

One factor that potentially complicates the ability to draw conclusions from the above data concerning residency relates to the level of error reported between the two enamel samples from individual 214. Since the two samples were obtained from the left and right first maxillary molars from the same mouth, one would expect to observe the same ratios from analysis. The difference of 0.0002 between the left and right molars is larger than the 2 SD "local" range (0.0000462); therefore, a discrepancy such as this is large enough to influence the residential status of an individual. Price and colleagues (2002) report a level of error that occurs in prehistoric populations beyond that introduced by migration relating to length of residency, changes in diet, and multiple movements, though for any of these factors to influence the strontium signatures between different teeth from the same mouth, it would be necessary to have analyzed teeth that experience enamel crown completions at different times during development. According to the information presented in the Moorrees, Fanning, and Hunt charts (1963b), the first maxillary molar completes its enamel development within a narrow range, and thus it may be unlikely that biological variation alone contributed to the recorded difference. The significance of this discrepancy may be better understood once the reasons for the homogeneity in bone samples, and hence the narrow "local" range, are elucidated.

An additional source of potential inconsistency in the above data relates to the fact that a variety of different teeth were used in the analysis. Although the first molar would provide the best estimate of early changes in residency, it was often not present, and other teeth had to be used. For the two individuals identified as "local", the second molar was sacrificed for analysis, whereas the analysis of the other individuals relied upon the first molar (142, 214, 202) and the canine (48). In interpreting Sr ratios, one must bear in mind that the change to a "local" signal will be affected by diet and length of residency (Price et al, 2002; Bentley et al, 2004). The crown development of the second molar occurs at a later time than for these other teeth, with formation complete as late as 8 years of age in the male (Moorrees, Fanning, and Hunt, 1963b). It is conceivable that changes in residency or diet may have occurred before this time, and thus a homogenous bone to enamel ratio value with the second molar may lead an author to the erroneous conclusion that no change in residency had occurred. It is for this reason that Ezzo and colleagues (1997), in their analysis of prehistoric migrations in Arizona, exclude all individuals for whom the first molar is missing. Given the small sample size of *in situ* dental material from the *Ipogeo degli Avori*, observing the same criterion would have limited the sample size to only three individuals. For this reason, other teeth were used in the absence of the first molar.

Another potential source of discrepancy in the consistency of the dental enamel values relates to the known differences in strontium concentrations between different teeth (Tolstykh et al 2003). Experimental evidence has shown there to be different degrees of strontium retention in bone and enamel that change as a function of age and sex (Shagina et al, 2003). Although there seems to be consensus in the archaeological literature that Sr ratios are largely independent of concentration, the physiological reasons for retention are poorly understood, and thus the elucidation of this concept may influence the interpretation of Sr ratios obtained from tissues that formed during different stages of development. Furthermore, the physiological reasons for retention may provide an explanation for why different residential signatures can be observed in the same mouth.

Quite possibly the largest limitation to the above data relates to the possibility of diagenetic changes, not accommodated by treatment methods, as influencing the results. Price and colleagues (2002) suggest that the overnight soak in acetic acid is successful in removing diagenetic carbonate, as well as the surface of recrystallized apatite; however, other authors have reported varied levels of success when these protocols were followed. Beard and Johnson (2000), in their analysis of human material from the Vietnam Conflict, observed two different pools of Sr in their samples, one of which they attribute to the biogenic sources, and the other to diagenetic sources. Despite their use of the acid soaks, they conclude that for bones "not in pristine condition", leaching has variable effects, and that diagenetic changes in bone occurring in uncontained burials in warm, humid climates may preclude the use of bone-enamel pairs as providing information regarding geographical mobility. Furthermore, Hoppe and colleagues (2003) report that pretreatment with acid was unsuccessful in removing 15 to 80% of diagenetic Sr from bone. Considering that the range of "local" values was established based on data from bone, the possibility of diagenetic Sr remaining in the tissue after acid treatment suggests that this range may be obscured. The persistence of diagenetic Sr in bone may account for the high level of homogeneity observed in the human and faunal skeletal material. Such a suggestion would seem likely given the very small standard deviation obtained from the data: one might expect to observe a slightly larger level of variation in values, to accommodate for changes in diet that may have occurred during the 250 year period of use of the hypogeum. Conversely, it may be possible that the population experienced relative stability with regard to food sources throughout the use of the burial site, which could result in homogeneous Sr values in bone. Without reliable data on the subsistence strategy and food sources for this population, it is difficult to resolve this issue. We will be better equipped to address the issue of population stability once the archaeological analysis of the site is complete. At this time, however, the lack of variation in the bone samples suggests that diagenetic Sr may have infiltrated the bone and affected natural Sr signatures. This potentially removes the possibility of ascribing "local" vs "non-local" status to individuals subject to the current analysis.

The observation that human and animal bone tend to yield similar values has been observed in other studies (Price et al, 2002), and many authors support the use of faunal enamel to establish the range of values that can be considered "local" for a site. Given its decreased susceptibility to diagenesis, faunal enamel appears to be the best preserved indicator of prehistoric local Sr ratios (Bentley et al, 2004). There appears to be consensus in the literature that "local" should be set as the mean variation in faunal dental enamel ± 2 SD. Bentley and colleagues (2003) stress the importance of testing the ratios of several different species to determine which should be used to set the local values. Ancient livestock may have grazed over many different pastures, and thus it is necessary to assess the ratios obtained from several different species to determine which yields the most consistent, and therefore accurate, results (Bentley et al, 2003). In the absence of faunal material, some authors suggest the use of modern faunal material as an alternative (Bentley et al, 2003), though Price and colleagues (2002) stress the possibility of contamination of local Sr values by fertilizers and other imported food pollutants

6.5 Future Directions

In order to properly establish the residency patterns of the individuals of the *Ipogeo degli Avori*, it will be necessary to expand upon the above analysis with the inclusion of more individuals for whom the location in the hypogeum is known, as this will facilitate the interpretation of the results. Whenever possible, the first molar should be used, possibly with the exclusion of individuals for whom this tooth is absent. The establishment of appropriate local values will best be accomplished with a calibration based on archaeological faunal data. If possible, several different species should be used to accurately determine these values. This essential step will permit the assessment of whether or not the bone data is reliable, and in turn will confirm if indeed the four individuals currently identified as "non-local" represent Sr signatures from another area. Once confidence has been established in the "local" criteria, it may be possible to compare the signatures of the "non-local" individuals to known values for different areas of the Eastern Mediterranean to infer origin. The above suggestions are appropriate only if the chemical data is interpreted alongside information obtained from the archaeological analysis of the site. In an analysis as sensitive as Sr ratios, adequate knowledge of the possible changes in diet and subsistence patterns is essential, especially for a site that has observed a reasonably long occupation such as that suggested by the artifacts in the *Ipogeo degli Avori*.

CHAPTER 7: CONCLUSIONS

The goal of this analysis is to provide a bio-social representation of the dead from the *Ipogeo degli Avori*. The eventual goals of studying this population are to determine how the individuals of *Madonna di Loreto* fit into the web of human activity that existed in the Middle Bronze Age Mediterranean world. The analyses performed in the current work are not sufficient to afford an interpretation of the biological origins of the population and its cultural associations, though they do succeed in providing an important first step in the analysis of the skeletal population regarding demography, general health, and possible residency.

Regardless of the many limitations that were discussed relating to the interpretation of the demographic data, it can be said with certainty that the burial site consists of at least three infants (under one year), 10 children (aged 1 to 18 years), and 12 adults, with both sexes represented. A child to adult ratio of 0.83 was calculated, and this value is much higher than those reported for demographic analyses of contemporary populations [Cenni (1999a and 1999b) 0.24, Angel (1971) 0.54, and Ortner (1979) 0.5; see Table 4.7, p.69]. This ratio is likely obscured due to the more accurate MNI value for the subadult material, whose accuracy relates to the more sensitive aging methods that apply to immature remains. The adult MNI is likely a conservative estimate, owing to low recovery, especially of those elements which can assist in aging and sexing. To accommodate for this, a maximum number of adults was estimated based on Waldron's (1994) reported recovery of skeletal elements in the commingled burial of West Trenter Street, London; however, this estimate of 20 adults provides a child to adult ratio of 0.65, which is still significantly higher than those reported in other studies. At this time, it is difficult to establish the accuracy of these estimates, though this analysis does succeed in telling us that the burial site does not appear to have been restricted to a specific group based on age and sex. Social status, cultural origin, or perhaps time of death may have been more instrumental in determining in which hypogeum an individual was laid to rest.

The observed pathological changes consist mostly of mild periosteal reactions, with the lower limb showing the greatest susceptibility. Lesions are among those that one might expect to find amongst an early farming community, with non-specific infection, and upper limb and vertebral lesions suggestive of heavy lifting. There is no evidence of interpersonal violence found on the remains subject to this analysis, though the lack of this finding may be due to poor recovery. Potential evidence of nutritional deficiencies, such as cribra orbitalia (remodeled lesions in 25% of the adult sample) and subperiosteal haemorrhages on the anterior crest of the tibia are observed, though alternate interpretations were provided for each lesion, and hence one should observe caution in assuming that the population suffered from a poor diet.

The most informative parameter of population health is the age distribution represented in the hypogeum, showing a high proportion of subadult deaths. Longevity has been touted as the most informative indicator of population health (Goodman et al, 1984; Angel, 1984; Ortner and Putschar, 1981), and the high proportion of subadult deaths suggests that the population was subject to arduous physiological stresses. The near absence of lesions on the subadult material was suggested as evidence of individuals succumbing to infections while in their acute phases, though it may be best to refrain from making this conclusion until all the skeletal material from the site has been analysed.

Data on residential patterns are difficult to interpret without the proper calibration of the local strontium levels based on archaeological faunal enamel samples. A provisional interpretation suggests that of the six individuals analysed, two appear to be "local", while four may potentially be "non-local". This finding could suggest a high level of migration to the site, and hence a great deal of interaction with communities from other areas. Such a finding would come as no surprise considering the ideal location of the site. Its coastal position would invite communication with populations opposite the Adriatic, such as those from Albania, the former Yugoslavia, and most notably, Mycenaean Greece. Furthermore, its proximity to the Ofanto River would facilitate communication with inland Italian populations. Of more pertinent interest would be to eventually correlate the non-local strontium signatures with their areas of origin. This task would be best attempted once the local strontium ratios for this site have been established through analysis of faunal dental enamel.

Overall, the analysis presented in this work provides an important piece of the puzzle concerning the characterization of the Trinitapoli population, but the results will be more easily interpreted once the analysis of the entire skeletal sample is complete. A complete skeletal inventory will allow for a better estimate of the MNI, a more comprehensive understanding of population health, and it may also allow us to evaluate the extent that taphonomic processes affected recovery. After the analysis is complete, consideration of the anthropological data alongside the archaeological and faunal data will be possible, and a better picture of the history of this population relating to the factors that influenced health, their interactions with other groups, and perhaps their cultural origins will be possible. In addition, comparison of the data from the *Ipogeo degli Avori* with that from the *Ipogeo del Bronzo* may assist us in speculating on what selective measures were used to determine in which hypogeum the individuals were laid to rest.

At the completion of the current study, the two general possibilities concerning the origins of this population remain: it may represent a population of immigrant individuals who gained interest in this region to integrate into established trade routes, or it may represent a local group. Based on skeletal material alone, biological relationships with other groups would best be established through a comparison of non-metric traits with contemporary populations, coupled by a comparison of stable and radiogenic isotope ratios. However, it would be imperative to consider this biological information in a context of the information obtained from the on-going archaeological analysis.

Although the current study was merely provisional, it did succeed in revealing important information concerning the population's demographic profile. The finding of individuals who represent a wide range of age groups and the presence of both sexes suggest that we are dealing with a settled group as opposed to a small trading post established by a foreign group to facilitate communication between mainland Italy and populations across the Adriatic. This conclusion seems consistent with the suggestion that the site experienced continued use over a 250 year period.

On a final note, the current analysis was performed with an acknowledgement of the extensive limitations that exist concerning the use of commingled and heavily fragmented material, which likely experienced poor recovery. Incomplete skeletal samples can contribute to frustration during analysis, and general pessimism exists in the literature regarding the utility of fragment analysis in the characterization of skeletal populations. However, the preceding analysis demonstrated that with close attention to detail and an acknowledgement of the various margins of error, fragmentary remains can yield a wealth of anthropologically relevant information. Excluding them from population analyses may, therefore, significantly limit the complement of anthropologically relevant information that can be obtained from the analysis of a skeletal population.

APPENDICES

Box number	Archaeological label				Bag description	Number of fragments	Element	Number of fragments	Segment	Side
	MDL	IP	Q	US						

Completeness	Denititon		Age	Sex	Subadult	Pathology	Comments
	mandibular	maxillary					

APPENDIX A - Recording form for general inventory of skeletal elements

Case | Archaeological Identification: MDL, IP, Q, US | Bag Descrption | Bone | Segme...

Adult age estimate

Os Coxa: Suchey-Brooks, Todd, auricular surface

Rib: Işcan

Skull closure: suture

age category

Subadult age estimate

Dentition: tooth, formation, dental eruption, Ubelaker stage

Epiphyseal Fusion: epiphysis, stage of union

Ossification centres: primary centre, extent

Subadult Age Estimate

Measurements: Max width, Max Height, Max length

age estimate

age category

Summary

Comments

Age estimate reference

APPENDIX B - Recording form for skeletal aging

Case	Archaeological Identification			US	Bag Descrption	Bone	Segment	Side
	MDL	IP	O					

	Os Coxa		Adult age estimate				
			Rib		Skull		
Suchey-Brooks	Todd	auricular surface	Işcan	suture	closure	age category	

		Dentition	Subadult age estimate				
				Epiphyseal Fusion		Ossification centres	
tooth	formation	dental eruption	Ubelaker stage	epiphysis	stage of union	primary centre	extent

Subadult Age Estimate			Summary			
Measurements						
Max width	Max Height	Max length	age estimate	age category	Comments	Age estimate reference

APPENDIX B - Recording form for skeletal aging

Case	Archaeological label				Bag Description	Bone	Side
	MDL	IP	O	US			

Skull traits				
nuchal crest	mastoid process	supra-orbital margin	glabella	mental eminence

Pelvic traits						
ventral arc	subpubic concavity	ischiopubic ramus	greater sciatic notch	preauricular sulcus	Estimated Sex	Comments

APPENDIX C - Recording form for skeletal sex determination

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