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A Radiographic Investigation of Juvenile Scurvy Among the Sub-Adult Remains from Stymphalos and Zaraka, Greece

by

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Abstract

Historically, scurvy has been linked with sailors and famine, seeing only minor investigation in children until the present era. This is also true among archaeological populations where the investigation of juvenile scurvy is a relatively recent development. The development of criteria for assessing juvenile scurvy among archaeological populations has provided a novel means of paleopathological analysis for discussing this disorder among past populations.

In an attempt to further investigate the current criteria for identifying archaeological cases of juvenile scurvy, as proposed by Ortner et al. (2001, 1999; Ortner and Ericksen 1997; Ortner 1984), a combined macroscopic and radiographic study was conducted on the sub-adult individuals from late Roman–Byzantine Stymphalos and Frankish Zaraka, Greece. This study sought to investigate the level or correlation between the proposed macroscopic indicators and clinically employed radiographic indicators of juvenile scurvy. From the research conducted there is clear evidence upon which to suggest a significant level of correlation between the proposed macroscopic and clinically employed radiographic indicators of juvenile scurvy. Such a correlation supports the previously proposed osteoarchaeological criteria for assessing juvenile scurvy among archaeological populations.

Acknowledgments

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Chapter 1–Introduction

This thesis will address the possibility of identifying cases of juvenile scurvy in osteoarchaeological remains through the examination of juvenile skeletal remains from the Greek sites of late Roman–Byzantine Stymphalos and Frankish Zaraka.

Research into the topic of juvenile scurvy in past populations has increased significantly in recent years and has brought into discussion a number of skeletal lesions that had previously been typically attributed to other disorders, particularly anemia (Brickley and Ives 2006; Melikian and Waldron 2003; Ortner et al. 2001, 1999; Ortner and Ericksen 1997; Ortner 1984). The research presented in this thesis seeks to contribute to this relatively recent and growing literature by using radiographic imaging to add clinical standards for assessing cases of juvenile scurvy to the criteria now used to identify this disorder among archaeological populations.

The identification of juvenile scurvy from osteoarchaeological remains is currently assessed based on the presence of a typical suite of porous cranial and long bone lesions. One of the main issues of confusion in the identification of juvenile scurvy in archaeological remains is the exact process of bone formation responsible for these lesions. A review correlating the locations of proposed scorbutic lesions in osteoarchaeological remains with likely sources of hemorrhagic bleeding shows that in remains from many time periods and regions a distinct suite of osteological lesions is seen that strongly correlates with likely sites of scorbutic hemorrhaging and is thus plausibly the result of juvenile scurvy. By examining a series of remains showing these lesions using radiography in conjunction with macroscopic observation, this thesis will seek to provide a more secure basis upon which this diagnosis can be made.

The introduction of radiographic criteria is a novel approach to the complicated topic of identifying juvenile scurvy among archaeological populations. Though there have been previous recommendations for such an approach only limited work to date (e.g. Maxwell et al. 2006) has looked at the correlation between the proposed suite of osteological lesions and the known radiographic indicators of juvenile scurvy used to clinically diagnose this disorder in living children. This is the central rationale of the work to be presented.

The research presented here examined fourteen individuals from the sites of Stymphalos and Zaraka, both of which are located in the valley of Stymphalos in the northeastern Peloponesse, Greece. Nine sub-adult individuals from Stymphalos and five individuals from Zaraka were studied. Both cranial and post-cranial remains were examined.

A second issue examined in this thesis is the connection between infant feeding practices and the development of juvenile scurvy. It is often the case that diagnoses of scurvy in low-latitude countries such as Greece are avoided due to presumed easy access to vitamin C rich foods. However the dietary implications of adult scurvy and those of juvenile scurvy are significantly different as the beliefs and practices surrounding the feeding of children play more of a factor in the development of juvenile scurvy than does the simple access to vitamin C rich foods.

This thesis will show that examination of the sub-adult remains from Stymphalos and Zaraka identified a strong correlation between the proposed macroscopic indicators of juvenile scurvy as identified by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) and clinical radiographic indicators of juvenile scurvy in 21% of the cases examined, with a number of other cases exhibiting possible signs of scurvy. Such correlation between the proposed macroscopic and clinical radiographic indicators provides significant evidence of the presence of juvenile scurvy among the individuals from Stymphalos and Zaraka. The following chapters will examine the level of correlation between the proposed macroscopic and radiographic indicators of juvenile scurvy and the implications that such correlation has regarding the overall ability to identify juvenile scurvy among archaeological populations and sub-adult life in the valley of Stymphalos during the late Roman–Byzantine and Frankish periods.

The material presented in this thesis is arranged and presented as follows:

Chapter 2 examines the medical and osteoarchaeological background to juvenile scurvy. This chapter looks at what causes scurvy and how this disorder affects the structures of the body. Though both skeletal and soft tissue lesions are presented, the main focus is on skeletal alterations caused by this disorder. This chapter also presents a historical background on the discovery and cure of juvenile scurvy. Following this, the chapter reviews the suite of osteological lesions that are believed to be indicative of juvenile scurvy as well as the various reported archaeological cases of juvenile scurvy. This chapter concludes with a discussion of various co-occurring conditions, namely rickets and anemia, and potential methods for differentiating between these disorders.

Chapter 3 presents a background to diet and infant feeding in late Roman–Byzantine and Frankish Greece. This chapter examines the dietary staples that would have provided the majority of nutrition during these periods. Its purpose is to describe the foods that would have been consumed and to look at their nutritional composition with regards to the implication of dietary practices in the development of scurvy. The material on infant feeding presents information on the composition of colostrum and human breast-milk and outlines the importance of these items to the overall health and development of the newborn child. This chapter concludes with an examination of the views of ancient medical authors on infant feeding practices, including the issues of breastfeeding, wet nursing, weaning, and infant diet, as well as the consequences associated with these practices.

Chapter 4 provides a background to the region and specific sites under examination in this thesis. A background to the geography and climate of Greece as a whole is provided before delving into specific material about the valley of Stymphalos. Sections on the individual sites have been broken down so as to provide information about the sites as detailed by ancient authors and original sources, the history of archaeological excavations of the sites and the remains at each site as identified through survey and excavation. This section focuses on the various burials recovered. Chapter 4 concludes with a series of hypotheses regarding the potential for identifying juvenile scurvy among the individuals identified from the sites under examination.

Chapter 5 discusses the results of the osteological and radiographic examinations undertaken. This chapter is utilized for the presentation of results and a short discussion of difficulties identified in assessing the radiographic indicators of juvenile scurvy among osteoarchaeological remains.

Chapter 6 discusses the results and overall implications of the study conducted. This chapter elaborates on the findings presented in Chapter 5 and suggests implications of the results. This chapter also discusses how the findings presented may help to provide a more detailed and clinically correlated method for assessing and identifying cases of juvenile scurvy among osteoarchaeological remains.

Chapter 7 presents the conclusions of the research. This chapter summarizes the hypotheses addressed and discusses cultural implications of diet and deficiency disorders in late Roman–Byzantine Stymphalos and Frankish Zaraka.

Chapter 2–Background to Scurvy

The following chapter will examine the clinical aspects of scurvy, both macroscopic and radiographic, as well as present data on the history and eventual cure of scurvy. Paleopathological methods of investigation and reported archaeological cases of juvenile scurvy will also be presented. The chapter will be concluded with a look at difficulties of diagnosis caused by the co-occurrence of various pathologies that may hinder archaeological observations of juvenile scurvy.

2.1–Scurvy

2.1.1–Definition of Scurvy

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Scurvy, simply put, is a metabolic disorder caused by a lack of vitamin C (ascorbic acid) in the body (Allen et al. 2006; Fain 2005; Fairfield and Fletcher 2002; Weinstein et al. 2001; Hirsch et al. 1976; Paul and Juhl 1972; Jaffe 1972).

Most animals can internally synthesize vitamin C. However, humans, along with other primates, guinea pigs, a fruit-eating bat from India, the red-vented Bulbul of Turkey (*Pycnonotus cafer*), and several species of trout and salmon lack the appropriate enzyme to synthesize vitamin C internally, and thus must obtain this vitamin from external sources (Gaby and Singh 1991; Chatterjee 1990; Stuart-Macadam 1989; Harden and Zilva 1919; Holst and Frölich 1907).

2.1.1.2–Vitamin C in Food

Vitamin C is a relatively abundant dietary element, being most readily obtained from citrus fruits, berries, melons, tomatoes, broccoli, peppers and offal (Allen et al. 2006; Fain 2005; Fairfield and Fletcher 2002; Levine et al. 1999; Johnston 1999; Gabay et al. 1993).

Vitamin C is particularly labile, being lost from foods and liquids in significant quantities (50%–80%) when exposed to heat and during boiling (Combs 2008; Choi et al. 2007: Fain 2005; WHO/FAO 2004; Evans 1983; Whelen et al. 1958; Corkill 1949). Furthermore, exposure of food to oxygen, light, heat, alkaline environments, copper, iron and water can also cause significant loss of vitamin C (Combs 2008; Allen et al. 2006; WHO/FAO 2004; Levine et al. 1999).

2.1.1.3–Daily Requirements of Vitamin C Intake

The recommended daily intake of vitamin C varies by age (Table 2.1).

Table 2.1–Recommended Nutrient Intakes (RNIs) for Vitamin C, by Group

Group	RNI (mg/day)[a]	Group	RNI (mg/day)[a]
0–6 months	25	10–18 years	40[b]
7–12 months	30[b]	19–65 years	45
1–3 years	30[b]	65+	45
4–6 years	30[b]	Pregnant women	55
7–9 years	35[b]	Lactating women	70

Recommended nutrient intakes (RNIs) for vitamin C, by group. [a] Amount required to half saturate body tissues with vitamin C in 97.5% of the population. Larger amounts may often be required to ensure adequate absorption of non-haem iron. [b] Arbitrary values (WHO/FAO 2004: table 7.1).

At tissue saturation the whole-body vitamin C content is approximately 20mg/kg or 1500mg based on a 75 kg. individual (WHO/FAO 2004; Shamsaddini et al. 2001; Gabay et al. 1993). Vitamin C is lost at a rate of approximately 3% of whole body content per day (Fain 2005; WHO/FAO 2004; Basu and Donaldson 2003). If a vitamin C deficient diet were to be introduced, the adult human body at saturation would be able to prevent the onset of scurvy for a period of approximately two to three months, which is the average amount of time it takes for the body reservoir of vitamin C to drop below 350 mg–300 mg, at which point clinical symptoms of scurvy may begin to appear (Fain 2005; WHO/FAO 2004; Basu and Donaldson 2003; Shamsaddini et al. 2001). The daily minimum intake of vitamin C that will prevent scurvy is 6.5 mg–10 mg (WHO/FAO 2004; Shamsaddini et al. 2001). In terms of actual food, the daily required intake for a full vitamin C dose is approximately five servings of fruits and vegetables, though the actual level of vitamin C obtained from any one serving is highly dependent on the quality of the food consumed as it is impossible to equate a particular unit of a given food with a static amount of vitamin C (WHO/FAO 2004).

As Table 2.1 indicates there are different required levels of vitamin C intake for pregnant and lactating women. The increased vitamin C intake for pregnant and lactating women is recommended due to the additional vitamin C needs of the fetus or breastfeeding infant (WHO/FAO 2004).

2.1.1.4–The Function of Vitamin C within the Body

Vitamin C plays an important role in several operations of the body. As a result, when there is a deficiency in vitamin C the function that it serves within the body becomes impaired.

One of the main functions vitamin C is associated with is the production and maintenance of collagen, or more specifically the hydroxylation of proline and lysine, which is necessary for collagen synthesis (Combs 2008; Allen et al. 2006; Fain 2005; De Luna et al 2003; Clemetson 2002; Sloan et al. 1999; Marcove and Arlen 1992; Stuart-Macadam 1989; Kuhlman 1980; Gordon 1977;

Vis 1963; Gould 1960; Follis 1943; Wolbach 1933). Vitamin C also plays an active role in the formation and maintenance of intercellular cement material, particularly in the endothelium of blood vessels, and in supportive tissues throughout the body (Allen et al. 2006; Fain 2005; Basu and Donaldson 2003; De Luna et al 2003; Sloan et al. 1999; Stuart-Macadam 1989; Kuhlman 1980; Jaffe 1972; Vis 1963; Gould 1960; Woodruff 1956; Wolbach 1933). The tendency for hemorrhage so commonly associated with scurvy is believed to be a result of the weakening of the intercellular cement material in the capillaries due to a deficiency of vitamin C (Paul and Juhl 1972; Jaffe 1972; Woodruff 1956).

Dentinogenesis relies on vitamin C. Thus, when there is a deficiency the odontoblasts stop forming new dentin causing an arrest in the growth and development of teeth (Fain 2005; Clemetson 2002; Marcove and Arlen 1992; Chatterjee 1990; Stuart-Macadam 1989; Jaffe 1972; Chazan and Mistilis 1963; Faust 1943; Mann 1943; Follis 1943; Boyle 1941).

Vitamin C is also necessary for osteogenesis, for without appropriate levels of vitamin C the osteoid matrix of bone cannot be properly laid down due to depressed osteoblast activity (Fain 2005; Clemetson 2002; Chatterjee 1990; Stuart-Macadam 1989; Paul and Juhl 1972; Bourne 1971; Bourne 1943; Follis 1943; Bourne 1942). Though impaired osteoid matrix deposition due to scurvy is noticeable in any age group it is particularly noticeable in juveniles due to growth (Fain 2005; Gabay et al. 1993; Chatterjee 1990; Stuart-Macadam 1989; Paul and Juhl 1972; Jaffe 1972). The impairment of bone formation in growing individuals is most noticeable at the growth plates, where endochondral bone growth is normally the most active (Jaffe 1972).

Though there are numerous further functions of vitamin C within the human body, it is those discussed above that are of primary concern to the current study.

2.1.1.5–Symptoms of Scurvy in Adults

The earliest symptoms of scurvy are characterized by fatigue, the so-called "lassitude of scurvy", pallor, muscular weakness, and muscle pain (Fain 2005; Levine et al. 1999; Gabay et al. 1993; Chazan and Mistilis 1963).

Progression to clinical scurvy is relatively rapid, usually taking only a few days. This stage is marked by increased hemorrhaging, including petechial[1], swollen, ulcerated, and bleeding gums in individuals with teeth, mucosal bleeding, bleeding at muscle attachments and under the periosteum, and large bruises both ecchymotic and purpuric.[2] Also seen are abnormalities in keratin formation, impaired wound healing, peripheral edema, and perifollicular hyperkeratosis (Allen et al. 2006; Fain 2005; WHO/FAO 2004; Gabay et al. 1993; Stuart-Macadam 1989; Jaffe 1972; Hodges et al. 1969).

Though there are many symptoms and signs of scurvy medical research has shown that not all manifestations of scurvy are always present. Several studies suggest that petechial hemorrhaging does not appear until the individual has been

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[1] Petechial hemorrhaging refers to the occurrence of localized "pinpoint" hemorrhages along the skin and in cases of scurvy is also frequently seen along the mucosal membrane lining the palate (Jaffe 1972).

[2] Ecchymotic refers to bruises caused by external trauma such as a fall or often in cases of juvenile scurvy the simple stress placed on the skin by an elastic waistband. Purpuric refers to areas of bruising resulting from internal bleeding due to vascular weakness.

deprived of vitamin C for over 100 days, while another study suggested that with appropriate oral hygiene bleeding gums could be avoided, implying that there is a wide range of variability in the manifestation of scurvy (Hodges et al. 1969; Crandon et al. 1940).

Scurvy is easily cured through the intake of as little as 10 mg of vitamin C per day (WHO/FAO 2004; Hodges et al. 1969). The various physical manifestations of scurvy typically improve quickly with the appropriate introduction of vitamin C and a full recovery is associated with the point at which the bodily content of vitamin C rises above 1000 mg (Choi et al. 2007: 447; WHO/FAO 2004:135; Gabay et al. 1993: 280). However, if scurvy goes untreated it will ultimately lead to death, typically due to infection, cachexia and sudden death due to cardiac and myocardial impairment (Choi et al. 2007; Mimasaka et al. 2000; Gabay et al. 1993; Grewar 1965; Follis 1942).

2.1.1.6–Differentiating Adult Scurvy and Juvenile Scurvy

Scurvy is commonly divided into two categories, adult and juvenile scurvy (Jaffe 1972). Though these are the same disease, their manifestation and effects on the body are commonly different due to the stage of physical development of the individual involved. The lesions associated with juvenile scurvy are typically more pronounced than those of adult scurvy due to the incomplete maturity of a juvenile. A large number of the lesions of juvenile scurvy attack the growth plate and other regions of continuing osteoid deposition, while in adults osteoid deposition for the purpose of growth is complete (Jaffe 1972). Adult and juvenile scurvy also show different typical means of occurrence. Adults typically suffer from scurvy due to improper diet, alcoholism, diseases such as diabetes, diet fads, and long standing infections (Basu and Donaldson 2003; Weinstein et al. 2001; Jaffe 1972). In contrast, juvenile scurvy is most often associated with the transition from breastfeeding and accompanying weanling stress (Stuart-Macadam 1989; Jaffe 1972). In several rare instances there have also been documented cases of congenital scurvy (Bhat and Srinivasan 1989; Jaffe 1972; Jackson and Park 1935).

2.1.2–Gross Pathology of Scurvy in Juveniles

The effects of scurvy on the developing body are varied and multiple. Many of the symptoms that appear in adult scurvy are not as readily apparent in juvenile scurvy, and in many cases are not clinically manifested. The symptoms that do manifest are not consistent between individuals, as it is often the case that two individuals with the same extent of vitamin C deficiency may exhibit totally different levels of clinical symptom manifestation. Because of this the symptoms that are outlined below may occur in any combination, and in many cases a large proportion of these symptoms do not occur until scurvy has been present for a long duration, typically several months to a year (Steendijk 1978; Collins 1966; Brailsford 1953; Hess 1917). The symptoms and effects of scurvy presented in this section seek to examine only the gross pathology of the disorder; radiographic signs of scurvy will be presented in a separate section.

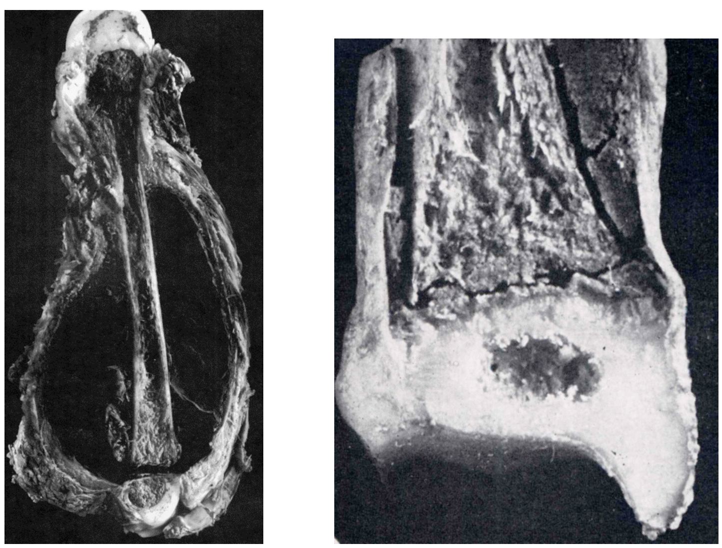
2.1.2.1–Early Symptoms of Scurvy

The early symptoms of juvenile scurvy are non-specific and are not clinically diagnostic from a gross pathological perspective. Early symptoms of juvenile scurvy include lassitude, fatigue, weakness, muscle and joint pain, pallor, failure to gain weight, loss of weight, general discomfort and irritability (Combs 2008; Fain 2005; WHO 1999; Levine et al. 1999; Gabay et al. 1993; Cornatzer 1989; Collins 1966; Grewar 1965; Chazan and Mistilis 1963; Warkany 1959; Youmans 1941). In young children many of these early symptoms may be overlooked as simple irritability; thus, scurvy in juvenile individuals is not typically documented before gross pathological indicators appear. The symptoms discussed below are clinically indicative of scurvy. However, no one particular symptom is diagnostic of scurvy as many of the symptoms presented are common in various other disorders and diseases. Thus, further testing must be undertaken to secure a confident diagnosis of juvenile scurvy.

2.1.2.2–Hemorrhage

The occurrence of multiple hemorrhages, including capillary hemorrhages, is a relatively common clinical symptom observed in scorbutic juveniles. One of the more common types is of subperiosteal hemorrhages, which commonly manifest at the ends and along the shaft of the long bones leading to the elevation of the periosteum from the bone and giving the limb a swollen appearance (Janssens et al. 1993; Cornatzer 1989; Steendijk 1978; Collins 1966; Shopfner 1966; Youmans 1941; Fig. 2.1). These subperiosteal hemorrhages may also be observed at the ossification centres of the flat bones, though this type of hemorrhage is less common than those observed along the long bones (Youmans 1941). The severity of hemorrhage in the limbs seems to be associated with use and trauma; the legs typically exhibit greater hemorrhaging than the arms and torso, often due to the fact that the legs are used more extensively and bear more weight than the other limbs and are more often exposed to trauma such as falls or collision (van der Merwe et al. 2009; Youmans 1941).

Purpuric hemorrhages are also known to occur in connection with scurvy; however these particular types of hemorrhages are observed much less frequently and are commonly associated with areas of increased trauma and pressure such as the buttocks, face, and neck (Youmans 1941). Nose bleeds as well as bloody fecal matter, bloody vomit, and bleeding from the genitourinary tract have also been observed in cases of juvenile scurvy, though these types of hemorrhagic bleeding are rare (Youmans 1941).



a.) b.)

Fig. 2.1– a.) Prepared specimen of a right bisected femur exhibiting subperiosteal hemorrhage and subsequent hematoma formation. Also note the presence of a fracture in close proximity to the distal growth plate (Ortner 2003: figure 15-2), b). Subperisoteal hemorrhaging causing hematoma, as well as the presence of a transverse fracture in the region of the growth plate, can also be clearly observed in this less severe example (Jaffe 1972: fig. 114a).

2.1.2.3–Bleeding Gums and Tooth Loss

Bleeding gums and tooth loss are associated with scurvy, and occur at varying rates and to varying degrees. Historically many researchers have shown that bleeding gums and tooth loss occur frequently in cases of scurvy (Garvie-Lok 2006; Gaby and Singh 1991; Barlow 1883). Though bleeding gums and tooth loss are a common occurrence in cases of scurvy there have also been reported cases where scurvy was present yet bleeding gums and tooth loss were absent (Crandon et al. 1940; Jaffe 1972; Hodges et al. 1969). Bleeding of the gums is only seen in instances where the individual has teeth, including when the teeth are beginning to erupt through the gums (Fain 2005; McLaren 1992; Stuart-Macadam 1989; Grewar 1965). Lack of vitamin C eventually leads to a weakening and hemorrhage of the capillaries in the gums resulting in reddening and swelling, causing progressively worse bleeding and potential thromboses as long as the case of scurvy persists (McLaren 1992). Though the level of bleeding can be highly variable this particular symptom is commonly listed as one of the most apparent and consistently present clinical manifestations of scurvy (WHO 1999). Swelling with tiny hemorrhages in the ends of the interdental papillae is commonly observed, which over time can lead to infection and necrosis of the region (Cornatzer 1989; McLaren and Meguid 1988). Ulceration and infection of the gums can lead to loosening and eventual loss of the teeth if scurvy goes untreated for an extended period of time (Fain 2005; Chatterjee 1990; Stuart-Macadam 1989; Di Cyan 1974; Jaffe 1972; Chazan and Mistilis 1963; Boyle 1941; Youmans 1941).

2.1.2.4–Petechial Hemorrhages

The occurrence of petechial hemorrhages is pathognomonic of scurvy, often being identified as one of the earliest clinical signs of vitamin C deficiency (Shamsaddini et al. 2001; Gabay et al. 1993: 279; McLaren 1992: 176; Cornatzer 1989: 353; Stuart-Macadam 1989: 202; Fig. 2.2).

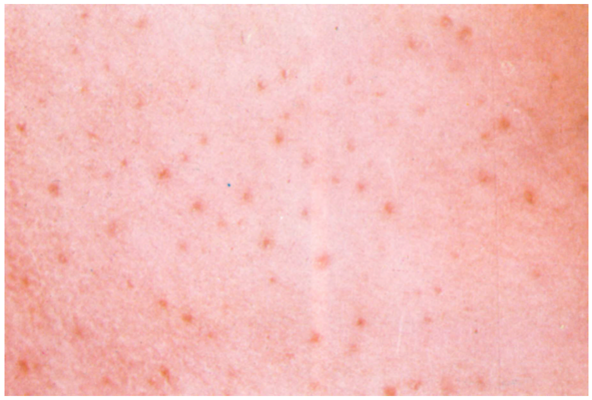


Fig. 2.2– Example of perifollicular petechial hemorraghing (McLaren 1992: fig. 354).

Such hemorrhages are most commonly observable along the limbs, but examples of this type of hemorrhaging can also be observed elsewhere on the body including the mucosal membrane of the palate and the eye (Gabay et al. 1993; Jaffe 1972; Hood and Hodges 1969). According to the World Health Organization this particular symptom occurs in approximately 10%–15% of children with scurvy, indicating that though pathognomonic this particular symptom may not always manifest to a significant degree (WHO 1999).

2.1.2.5–Crepitus

Crepitus, being a cracking or grating of the joints or presence of air in the soft tissues where it is not supposed to be, though not commonly described as a symptom of scurvy, was observed by Barlow (1883: 167) in two very severe cases of scurvy. Barlow goes on to state that crepitus may actually occur quite frequently in cases of scurvy, particularly at the hip, knee, and shoulder joints, however due to the excessive tenderness and pain of movement in scurvy, which often prohibits full examination of a child, crepitus is often very difficult to observe and thus commonly overlooked (Barlow 1883: 167).

2.1.2.6–Ecchymosis

Ecchymosis, a skin discolouration due to bleeding below the skin commonly caused by bruising, is typically associated with advanced stages of scurvy, and can be observed anywhere on the skin due to bruising and bleeding typically caused by decreased cellular strength (Fairfield and Fletcher 2002; Shamsaddini et al. 2001; Cornatzer 1989; Di Cyan 1974; Fig. 2.3).

Fig. 2.3– Example of ecchymosis on the knee (McLaren 1992: fig. 356).

2.1.2.7–Edema

Edema may be observed in cases of juvenile scurvy due to weakening of the capillaries (Youmans 1941). Such edema typically manifests along with pallor and can be most noticeably observed along the legs (Silverman et al. 1993; Youmans 1941). Edema may be present even in cases of mild scurvy (Youmans 1941).

2.1.2.8–Proptosis

Proptosis, or protuberance of the eyes, is an infrequently observed clinical symptom of scurvy, usually occurring unilaterally (McLaren 1992; Jaffe 1972; Barlow 1883: 170). Proptosis due to scurvy is typically observed in connection with hemorrhaging and infraorbital hematomas, which commonly manifest in the form of large ecchymotic regions on the eyelids and along the orbital plate, thus placing pressure on the eye leading to subsequent displacement (Shore 2008; Jaffe 1972; Fig. 2.4).

Fig. 2.4– Example of bilateral orbital hemorrhaging, with more prominent hemorrhaging observable in the left eye (McLaren 1992: fig. 341).

2.1.2.9–Frog Position

The ‘frog position’ is a bodily position typically associated with pseudo-paralysis in scorbutic infants where the child lies on its back with the upper and lower limbs semi-flexed and externally rotated, thus removing pressure from the joints (WHO 1999; McLaren 1992; McLaren and Meguid 1988; Steendijk 1978; Fig. 2.5).

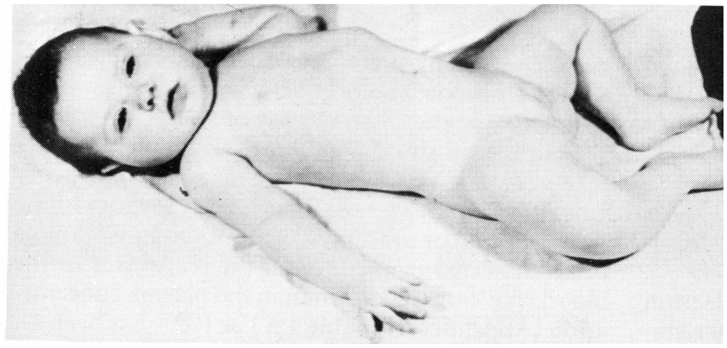


Fig. 2.5– Example of the "frog position" adopted by scorbutic children in an attempt to remove pressure from the limbs (McLaren 1992: fig. 340).

This position is adopted by the scorbutic child due to the pain of hemorrhaging and associated swelling, particularly at the joints (Fain 2005; WHO 1999; Stuart-Macadam 1989; McLaren and Meguid 1988; Evans 1983; Steendijk 1978; Jaffe 1972; Grewar 1965; Woodruff 1956; Park et al. 1935). By adopting this position the infant appears to remove stress and tension from the limbs. This is supported by reports that when the child is moved from this position it leads to crying and extreme discomfort (Jaffe 1972; Stuart-Macadam 1989).

2.1.2.10–Scorbutic Rosary

The scorbutic rosary effect refers to an enlargement of the costochondral junction of the ribs due to irregular calcification causing infraction and fracture (Riepe et al. 2001; Jaffe 1972; Grewar 1965; Warkany 1959; Fig. 2.6).

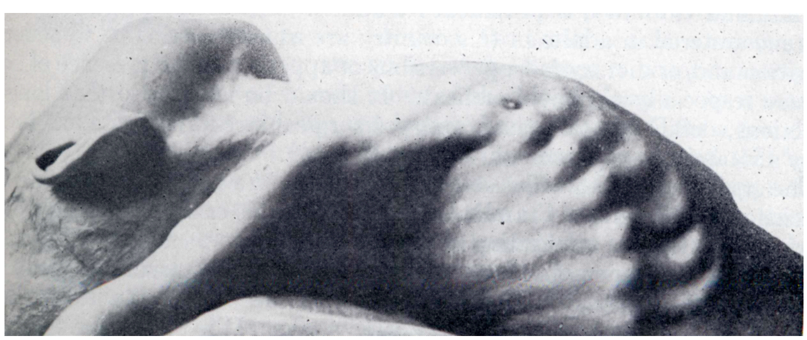


Fig. 2.6– Depiction of a sub-adult individual with pronounced enlargement at the costo-chondral junctions of the ribs (scorbutic rosary) (Jaffe 1972: fig. 113b).

This causes an externally visible rounded protruberance, which when considering all the ribs together forms what researchers have felt looks similar to a row of rosary beads, hence a scorbutic rosary (McLaren 1992; McLaren and Meguid 1988; Steendijk 1978). Such costochondral enlargement is the result of subperiosteal hemorrhage at the sternal ends of the ribs causing disruption of the costochondral junctions. This suppresses endochondral bone formation and causes disordered bone formation (Riepe et al. 2001; Jaffe 1972). This effect is one of the most common and visibly identifiable signs of infantile scurvy being observed in approximately 80% of cases (WHO 1999).

2.1.2.11–Splinter Hemorrhages

Splinter hemorrhages refer to semicircular hemorrhages that occur under the fingernails involving the nail beds (McLaren 1992; Fig. 2.7). This type of hemorrhage, though pathognomonic of scurvy, is highly uncommon (McLaren 1992).

Fig. 2.7– Example of splinter hemorrhages (McLaren 1992: fig. 348).

2.1.2.12–Impaired Wound Healing

As vitamin C is partially responsible for the production and maintenance of the endothelial lining of cells, it is common to observe impaired wound healing in cases of scurvy due to the weakened state of cellular linings, thus impairing the rate at which the cells can repair themselves due to inhibited collagen formation (Myllyharju 2004; McLaren 1992; Gaby and Singh 1991; Di Cyan 1974; Collins 1966; Wolfer et al. 1947; Lund and Crandon 1941; Crandon et al. 1940; Fig. 2.8). Such impaired wound healing has been shown to occur at variable rates between individuals depending on the store of vitamin C already in the body before the episode of scurvy.

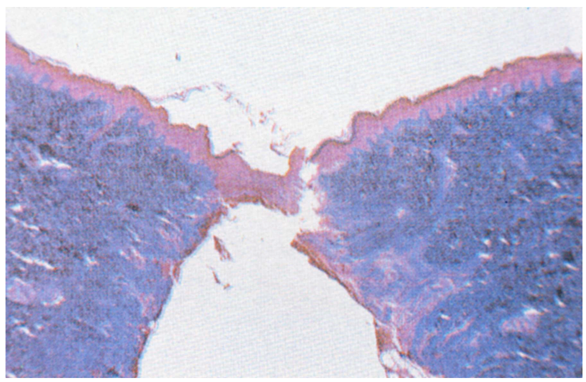


Fig. 2.8– Example of a wound made after six months on a diet devoid of vitamin C. No healing is evident except for the epithelium (McLaren 1992: fig. 350).

Thus though this symptom is commonly identified with scurvy it can occur at varying rates and to varying degrees of severity (McLaren 1992; Di Cyan 1974; Collins 1966; Lund and Crandon 1941; Crandon et al. 1940).

2.1.3–Radiological Identification of Scurvy in Juveniles

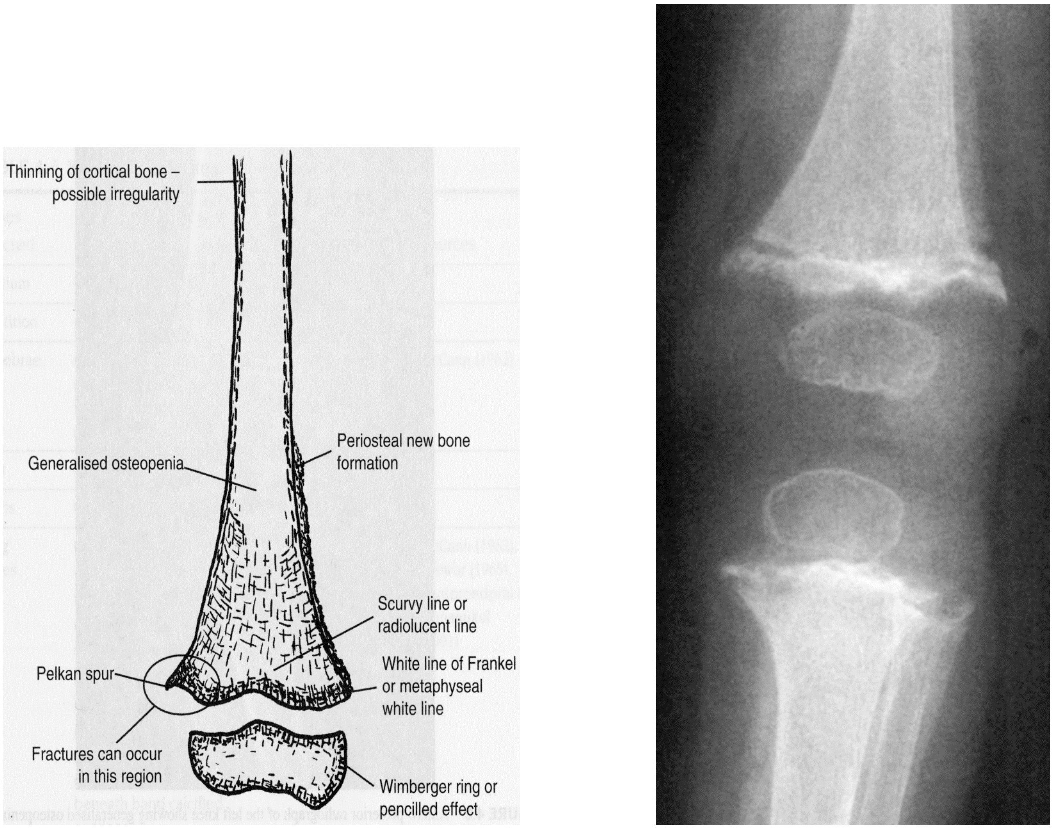
2.1.3.1–Benefits of Using Radiography to Assess for Juvenile Scurvy

The clinical identification of scurvy typically relies on two methods to make an effective diagnosis of juvenile scurvy, these being blood and serum vitamin C levels and radiographic analysis. For the purpose of examining archaeological remains it is impossible to assess blood or serum levels, however with adequate preservation radiographic testing, one of the most practical and efficient means of identifying scurvy, is possible (Edeiken 1981; McCann 1962). As scurvy causes a depression in osteoblastic activity it is at the sites of bone growth where clinical radiology has identified the most diagnostically pathognomonic signs of this disorder (Marcove and Arlen 1992; Jaffe 1972). Focusing particularly on the development of the metaphyseal-epiphyseal region, physicians have been able to isolate a series of diagnostic indicators associated with juvenile scurvy. The following sections will discuss these.

2.1.3.2–Radiopaque Metaphyseal Line (White Line of Scurvy)

One of the earliest changes observed due to scurvy is an increased density of the metaphyseal region associated with active endochondral bone formation, particularly at the sternal ends of the ribs, the proximal end of the humerus, the distal end of the femur, at both ends of the tibia and fibula, and the distal ends of the radius and ulna (Shore 2008; Silverman et al. 1993; Greenfield 1990; Jaffe 1972; Follis 1958). This zone, accompanied by increased density in the region of provisional calcification, appears as a radiopaque line located at the end of the metaphysis, which is commonly referred to as the "white line of scurvy" or the "line of Fränkel", in reference to the physician who first described this feature (Greenfield 1990; Oestreich 1984; Netter et al. 1965; Follis 1958; Fränkel 1908, 1903/04; Fig. 2.9). This effect is caused by demineralization due to failure of matrix formation with preservation of the zone of provisional calcification. Essentially an atrophic layer forms between the sclerotic provisional zone and the heavier deeper spongiosa of the shaft, thus casting a transverse band of diminished density on radiographs (Silverman et al. 1993; Oestreich 1984;

Gordon and Ross 1977; Jaffe 1972). This feature, though diagnostic of scurvy, is non-specific if in isolation as it has also been observed in cases of lead and phosphorus poisoning as well as in cases of healing rickets (Edeiken 1981).



a.) b.)

Fig. 2.9– a.) diagram outlining the radiographic indicators used to diagnose juvenile scurvy (Brickley and Ives 2008: fig. 4.7), b.) radiograph exhibiting typical signs of juvenile scurvy (Burgener 2006a: fig. 1.4a).

2.1.3.3–Atrophic Scurvy Line (Trummerfeld Zone)

The atrophic scurvy line, or Trummerfeld zone, is a transverse band of diminished density, commonly referred to as a zone of detritus, on the shaftward border of the provisional zone of calcification (Shore 2008; Silverman et al. 1993; Greenfield 1990; Jaffe 1972; Follis 1943; Fig. 2.9). This zone is defined by a region of matrix that has not converted into bone (Shore 2008; Edeiken 1981). Radiographically the atrophic scurvy line is observed as a radiolucent zone on the shaft side of the scurvy line (Edeiken 1981).

2.1.3.4–Ground Glass Appearance

Atrophy of the spongiosa is responsible for creating what is referred to as a ground glass textured appearance of the bone (Silverman et al. 1993; Netter et al. 1965). This ground-glass appearance manifests at the end of the long bone shaft and is associated with a blurring or disappearance of trabecular markings (Marcove and Arlen 1992; Edeiken 1981; Jaffe 1972; Fig. 2.9).

2.1.3.5–Radiopaque Epiphyseal Ring or Halo (Wimberger's Ring)

This particular feature is one of the most common radiographic findings associated with active juvenile scurvy (Shore 2008; Silverman et al. 1993). Due to peripheral mineral deposition the edges of the epiphyses, as well as the carpal and tarsal bones, can exhibit a ring or halo of dense calcification, commonly referred to as Wimberger ring after the physician who descried this effect (Greenfield 1990; Oestreich 1984; Gordon and Ross 1977; Wimberger 1925, 1923). The exterior ring will appear radiopaque while the centre of the epiphysis will appear radiolucent (Edeiken 1981; Fig. 2.9). Though a heavy transverse shadow is cast by this effect giving the perception of density this is not actually the case as the region is actually brittle and often presents with fissures and fractures (Silverman et al. 1993). The cause of this effect is the same as that of the dense metaphyseal line, in that thickening of the provisional zone of calcification produces a thickened outer shell of calcified cartilage around the ossification centre, while atrophy of the spongiosa is the cause of central rarefaction, leading to the heightened contrast between the outer ring and the centre of the bone element in question (Silverman et al. 1993). This ring effect is typically more intense in the epiphyses than in the carpals and tarsals (Silverman et al. 1993).

2.1.3.6–Cortical Thinning

Radiographs of scorbutic juvenile individuals typically exhibit thinning of the cortices of the long bones (Marcove and Arlen 1992; Jaffe 1972; Netter et al. 1965). According to Edeiken (1981) such thinning can be observed by comparing the diameter of the cortices to the diameter of the medullary cavity, noting that in the normal individual the diameters of the two are equal or nearly so.

2.1.3.7–Corner Sign

Defects in the spongiosa and cortex below the provisional zone of calcification may permit incomplete separation of the plate from the shaft, causing subepiphyseal marginal clefts which are commonly referred to as the corner or angle sign of scurvy (Shore 2008; Silverman et al. 1993; Fig. 2.9). Also associated with this effect is a comminution of the epiphysis resulting in a mushrooming effect; in some cases where comminution is greater in the centre of the end of the bone a cupping effect may be produced (Edeiken 1981; Jaffe 1972). Though indicative of scurvy a similar effect has also been observed with cases of syphilitic osteochondritis (Edeiken 1981).

2.1.3.8–Lateral Spurs (Pelkan Spurs)

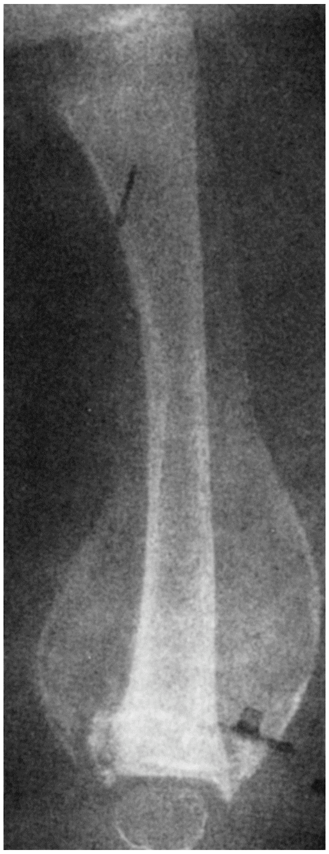
Lateral spurs, or Pelkan spurs as they are commonly called, refer to the formation of marginal bone spurs that typically occur at right angles to the axis of the shaft (Shore 2008: 2740; Edeiken 1981: 846; Fig. 2-9). Such spur formation has been linked to abnormal brittleness, which creates microfractures and thus leads to metaphyseal spurs and the mushrooming of the epiphysis on the metaphysis, as was noted under the description of the corner sign. Alternatively some have suggested that these spurs form as one of the earliest stages of calcification of the elevated periosteum, which is caused by subperiosteal hemorrhaging (Silverman et al. 1993; Edeiken 1981; Jaffe 1972). Spurs are observed radiographically when the heavy provisional zones of calcification project peripherally beyond the typical limits of the shaft (Silverman et al. 1993; Gordon and Ross 1977). Radiographically spurs are one of the most diagnostic indicators of juvenile scurvy (Shore 2008; Silverman et al. 1993; Gordon and Ross 1977).

2.1.3.9–Metaphyseal Fractures

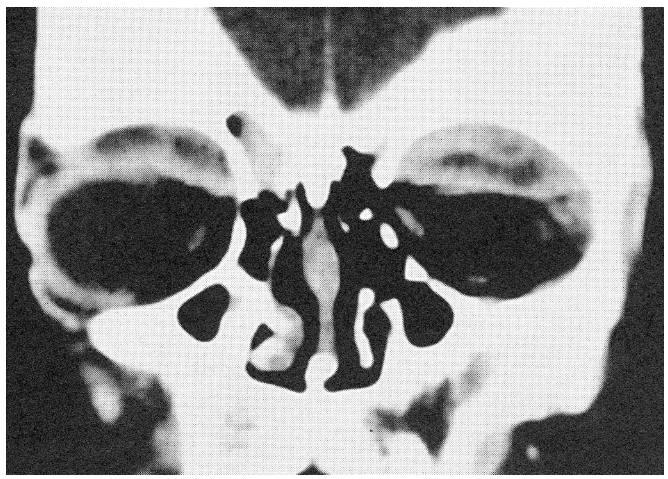
Metaphyseal fractures occur when the calcified cartilaginous trabeculae beneath the thickened zone become irregular in size and are oriented in a random network, with significant loss of the original longitudinal parallel pattern (Shore 2008; Silverman et al. 1993; Fig. 2.9). These trabeculae are bare of endosteal bony coating and are brittle allowing for easy fracture (Silverman et al. 1993). Such fractures are commonly comminuted and are most often located at the ends of the long bones, typically extending only partially through the width of the bone and may give rise to epiphyseal displacement and separation (Silverman et al. 1993; Edeiken 1981). Metaphyseal fractures are relatively rare and are said to be diagnostic of scurvy when syphilis can be excluded (Silverman et al. 1993).

2.1.3.10–Subperiosteal Hemorrhaging

In the later stages of scurvy it is common to observe subperiosteal hemorrhages (Greenfield 1990; Netter et al. 1965; Fig. 2.10).



a.)



b.)

Fig. 2.10– a.) Radiographic example of a healing subperisoteal hemorrhage can be clearly seen along the distal extent of the tibia (Burgener 2006b: fig. 3.10), b.) Bilateral subperiosteal hemorrhaging and hematomas along the orbital roofs can be clearly observed from this coronal CT scan of a child with scurvy (Brickley and Ives 2008: figure 4.5).

The relatively rapid calcification of subperiosteal hematomas around the shafts of the long bones creates an observable shadow on radiographs due to increased density (Shore 2008; Silverman et al. 1993; Gordon and Ross 1977). Subperiosteal hematomas typically occur at the ends of the long bones; however, cases have been documented where such hematomas have spread the length of the shaft (Silverman et al. 1993). Such hemorrhages may not become visible radiographically until weeks after the onset of clinical scurvy (Edeiken 1981). In observing subperiosteal hemorrhages it is not the hemorrhage that calcifies but rather the elevated periosteum (Marcove and Arlen 1992; Edeiken 1981; Jaffe 1972). Such hemorrhages are most commonly observed in the larger long bones, such as the femur, tibia, and humerus, however examples of subperiosteal hematomas have also been documented as occurring on the flat bones of the vault, orbits, and shoulder girdle (Silverman et al. 1993). Subperiosteal hemorrhages gradually resorb once scurvy has been treated (Edeiken 1981).

2.1.3.11–Spinal Changes

Spinal changes associated with scurvy are extremely rare, especially in infants under 12 months of age (Edeiken 1981). Spinal changes that can occur with scurvy typically involve generalized osteopenia and flattening and biconcavity of the vertebral bodies, particularly in older children and adults (Brickley and Ives 2008; Gordon and Ross 1977; Joffe 1961; Fig. 2.11). However in most cases scurvy is diagnosed and treated before spinal changes manifest (Edeiken 1981).

Fig. 2.11– Radiograph of the lateral aspect of the lumbar region of the spine of a scorbutic adult male exhibiting generalized osteopenia accompanied by compression induced bi-concavity of the vertebral bodies (Brickley and Ives 2008: fig. 4.10).

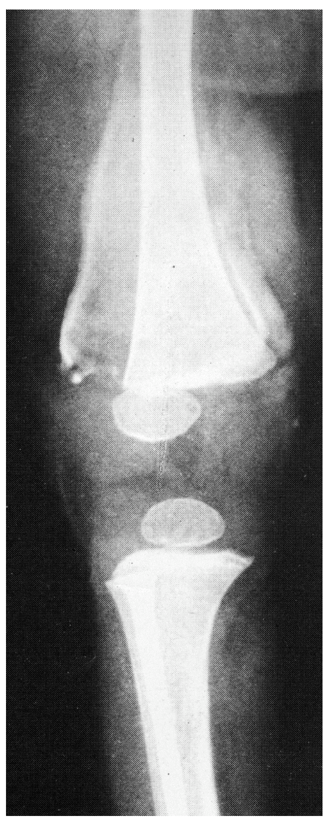


Fig. 2.12– Subluxation of the femoral epiphysis (McLaren 1992: fig. 344).

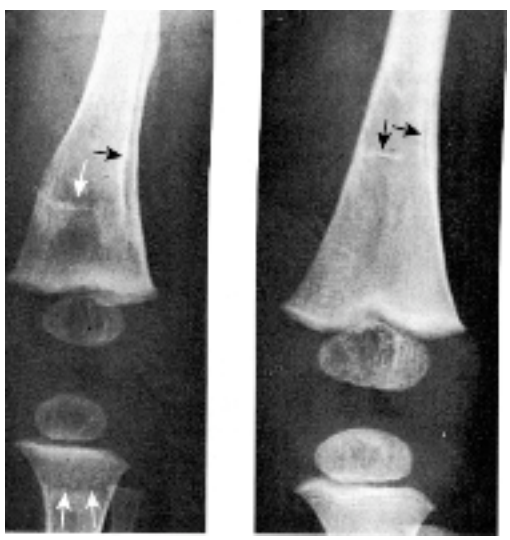
2.1.3.12–Subluxation of the Epiphyses

Subluxation of the epiphyses is commonly identified in cases of scurvy (Oestreich 1984; Fig. 2.12). In healed scurvy, though, it does not commonly cause severe deformity (Silverman et al. 1993; McLaren 1992; Edeiken 1981).

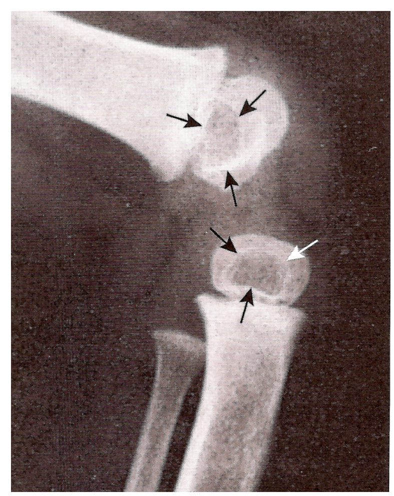
2.1.3.13–Radiographic Signs of Healing Scurvy

One of the earliest and easiest observed signs of healing scurvy is extensive deposition of new bone under the elevated periosteum which will form the new cortex, residues of which may persist for years, as well as progressive settling of the periosteum as the hemorrhage is resorbed (Shore 2008; Silverman et al. 1993; Greenfield 1990; Sprague 1976; Jaffe 1972; Fig. 2.13). This process is taken to be the surest radiographic sign of healing scurvy (Edeiken 1981). With healing the cortices become thicker and the trabeculae of the spongiosa become more clearly defined, reappearing rather quickly in the metaphyses with the healing of fractures and the disappearance of the scurvy line, while this process is typically slower in the epiphyses seeing an increase in the prominence of the Wimberger ring during the early stages of healing (Silverman et al. 1993; Greenfield 1990; Edeiken 1981; Jaffe 1972). In the case of epiphyseal displacement, subepiphyseal separations are reduced and the shaft is realigned to the epiphyseal centre adapting to the new longitudinal axis of growth, typically without complication (Silverman et al. 1993; Edeiken 1981). The healed epiphysis may exhibit a central rarefaction that is identical in size and contour to that seen in the period of active scurvy, which may last for years after healing (Shore 2008; Silverman et al. 1993; Fig. 2.13). As the bone continues to grow the thickened metaphyseal plate becomes progressively further buried in the shaft continuing to appear as a radiopaque band similar to a Harris line (Edeiken 1981; Edeiken and Hodes 1967; Harris 1933; Fig. 2.13).

Permanent skeletal deformity due to scurvy almost never occurs (Edeiken 1981). The time it takes for the skeleton to heal and regenerate after the presence of scurvy varies by element and overall health; however on a general level bone healing typically requires one to two months to fully manifest (McLaren 1992). Despite relatively quick recovery, radiological evidence of the presence of scurvy can remain observable in the skeleton for years (Shore 2008; McLaren 1992; Brailsford 1953).



a.)



b.)

Fig. 2.13– a.) Example of healed scurvy. Notice how radiopaque transverse lines, indicating previous assault to the bone structure, remain visible, progressively moving or being "buried" further into the shaft as the bone continues to grow (Shore 2008: fig. 167-19), b.) Depiction of healed scurvy, 20 months after active stage, showing a "buried" epiphysis, where the original rarefied scorbutic epiphysis is preserved (arrows) and can still be seen within the larger epiphysis, which has regenerated and continued to grow (Shore 2008: fig. 167-24b).

2.1.3.14–Possible Confusion

Though many of the radiographic signs presented are specific to scurvy, some are also commonly observed in other diseases and disorders, so no one radiographic sign is pathognomonic of scurvy. Rather a firm diagnosis of scurvy relies on the presence of two or more radiographic indicators (Grewar 1965). This must be kept in mind when attempting to make a proper diagnosis. The corner sign as observed in scurvy can also be observed in syphilitic osteochondritis, however in the case of syphilitic osteochondritis the individual in question would exhibit chronic marrow and subperiosteal white cell inflammation (Marcove and Arlen 1992; Edeiken 1981; Jaffe 1972). Epiphyseal fractures similar to those observed in scurvy may also be preset in osteogenesis imperfecta, though in the case of osteogenesis imperfecta subperiosteal hemorrhage as seen in scurvy would not be present (Marcove and Arlen 1992). Several of the indicators of juvenile scurvy, particularly metaphyseal fractures and subperiosteal hematoma, can be confused with child abuse (Schumacher 1999). Thus it is important to establish that the various skeletal aberrations observed are the result of scurvy and not trauma. Such a distinction is relatively easily made as cases of child abuse lack many of the radiological signs of scurvy and often involve other aspects of skeletal trauma, such as rib and vertebral fractures, which are not associated with scurvy (Schumacher 1999).

2.1.3.15–Multifactorial Elements of Diagnosis

Though many radiographic texts dealing with scurvy present the characteristic signs to look for, it is important to remember that scurvy typically does not occur in isolation, but rather commonly occurs in conjunction with other disorders, such as anemia and rickets, among others (Silverman et al. 1993). The presence of several disorders in conjunction with scurvy may alter what can be observed on radiographs, possibly leading to confusion or improper diagnosis (Silverman et al. 1993). Thus caution should always be used when examining radiographs for signs of juvenile scurvy.

2.2–Historical Causes of Juvenile Scurvy

2.2.1–Ancient Authors on Scurvy

Scurvy is rarely mentioned among the ancient authors; however there are three ancient authors, namely Hippocrates, Pliny the Elder and Galen, who make reference to a series of physical symptoms that are likely a result of scurvy.

One of the earliest references to what was most likely a case of scurvy can be found in the works of Hippocrates of Cos (ca. 460–370 BCE), who is commonly identified as the father of medicine (Harvie 2002; O'Dowd 2001; Jouanna 1999; Brothwell and Brothwell 1998; Sauberlich 1997; Jackson 1988). Hippocrates describes observing individuals who had foetid breath, lax gums, and hemorrhaging from the nose (Harvie 2002: 11). Hippocrates proposed a cure for this disorder; however the cure was typically ineffective and often fatal (Harvie 2002: 11).

Though Hippocrates does not refer to the disease described outright as scurvy it is quite probable that these are cases of scurvy, as combine occurrence of the ailments mentioned are common symptoms of scurvy. Where ulceration and bleeding of the gums would create foul breath, while hemorrhaging of the nose can be understood as a result of scurvy in the context that hemorrhaging in general is one of the primary symptoms of scurvy. However nosebleeds in the absence of the other symptoms mentioned should not be interpreted as evidence of scurvy due to the fact that there are a countless number of causes for nosebleeds.[4]

Pliny the Elder, (ca. 23–79 CE) also details a disorder that is likely scurvy. In his *Historia Naturalis*, Pliny discusses the effects of what he called *stomacace* (*στομακακη* from the Greek *stoma* for mouth and *kakos* for bad) and *scelotyrbe* (*σκελοτυρβη* from the Greek *skelos* for leg and *tyrbe* for disorder), on the troops of Germanicus Caesar while campaigning along the Rhine (Pliny 1938: 25.6.20–21; O'Dowd 2001; Prioreschi 1991; Townsend 1964; Pliny 1964). Pliny details that such a problem as that which befell Germanicus' troops if prolonged would result in the loss of teeth and the failure of the knee joints (Pliny 1938: 25.6.20). Pliny proposes the cause of such symptoms as being the result of consuming disagreeable water in the region, however considering the area of the Rhine and the extended duration of military campaigns it was undoubtedly absence of fresh fruit and vegetable supplies that lead to the development of the symptoms described by Pliny (Pliny 1938: 25.6.20; Prioreschi 1991). It can be seen that the words Pliny has chosen are both descriptive of symptoms of scurvy, where

[4] Celsus (1935) in *De Medicina* and Avicenna in *The Canon of Medicine* also note the frequency of nosebleeds among youths, the occurrence of which is proposed as being due to the abundance and thickness of the blood, which may suggest that the association of bleeding with youth may have a basis in humoral medicine and thus may not be of any real clinical significance (Garvie-Lok 2009: pers. comm.; Gruner 1930: 69).

stomacace refers to the ulcerations and hemorrhagic bleeding of the gums commonly seen in scurvy, while *sclerotyrbe* refers to limb and joint pain, which was likely a result of hemorrhaging and bleeding into the joints (Prioreschi 1991; Jackson 1988; Pliny 1964; Pliny 1938: 25.6.20–21). In the same writings Pliny also suggests that the Roman army under Germanicus was shown a cure for this unknown disease by the Frisians in ca. 16 CE, who suggested that the use of the flowers of the *Britannica* plant, called *vibones*, if eaten would cure the scurvy-like ailments (Pliny 1964; Pliny 1938: 25.6.20–21). Though this cure is described by Pliny there is no reference to it in later medical works of the era suggesting that knowledge of this cure may have been lost over time or that it may have been ineffective (Prioreschi 1991; Pliny 1964).

Galen of Pergamum (ca. 129–200 CE) recorded as series of adverse affects on the skin and mouth that he attributed to a disease state consistent with scurvy (O'Dowd 2001; Siegel 1968). Upon observing the affects of a great famine that had lasted for many years, Galen noted adverse changes in the humors of individuals, where inflammation and ulceration became common among individuals affected by the famine (Siegel 1968: 307). Galen attributes these adverse changes to the fact that people were malnourished and starving, thus linking the development of the lesions he observed during the famine with an aetiology related to dietary insufficiency (Siegel 1968). An interesting statement presented by Galen in his treatise *On Matters of Health* is the observation of a child that broke out in ulcers after being continually breastfed by a malnourished wet nurse (Mattern 2008: 109). This is interesting as this observation describes a circumstance in which scurvy might develop despite relying on breastfeeding. The possibility, however, is difficult to substantiate given the antiquity of the text and the inability to definitely identify scurvy as the disorder from which the child in question suffered. It can be seen again from the work of Galen, as was also the case with Pliny the Elder, that even in the Roman era in certain instances a link was made between the occurrence of oral ulcers, hemorrhaging and skin lesions and dietary insufficiency that would have ultimately lead to the onset of scurvy.

It is not unlikely that further ancient authors described symptoms that are consistent with scurvy; however it is mainly Hippocrates, Pliny the Elder and Galen who provide information linking a combination of symptoms to situations of famine during which scurvy would be likely to develop.

2.2.2–History of the Identification of Juvenile Scurvy in the Modern Era

One of the earliest recorded instances of juvenile scurvy is found in the work of Glisson (1651) who noted the association of scurvy with rickets (Pimentel 2003; Rajakumar 2001; Carpenter 1986; Evans 1983; Hess 1920). After the work of Glisson it was over two hundred years before any further significant work on the topic of juvenile scurvy was presented.

In 19th century Europe, particularly England, an increasing number of cases of juvenile scurvy began to appear (Pimentel 2003; Rajakumar 2001). At the time when these cases were occurring scurvy was still considered a disease of sailors, soldiers, and crop failure and as such there was no reason for a direct association of the increasing cases of this new and unknown disease in children with scurvy (Maat 2004; Pimentel 2003; Rajakumar 2001; Maat 1982; Zivanovic 1982; Major 1945).

In 1859 Moeller was one of the first to describe this new disease, which he equated with acute rickets, though his descriptions agree with juvenile scurvy (Carli-Thiele 1996; Carpenter 1986; Evans 1983; Moeller 1859). It was in 1873 that Jalland commented on the abnormality he had observed in a young patient, noting that the symptoms seemed to be consistent with scurvy (Carpenter 1986; Jalland 1873). It was Cheadle (1882, 1878), looking at the almost epidemic spread of juvenile scurvy in 1870's suburban London, who was one of the first to describe the symptoms of juvenile scurvy in English. However, his analysis intrinsically linked the symptoms identified with the presence of rickets (Evans 1983). As a result it was not until 1883 with the work of Sir Thomas Barlow that the aetiology of this new disorder was recognized as being scurvy in juveniles, for it was Barlow who was the first to successfully distinguish the symptoms present in these children as being due to scurvy and not predominantly rickets (Evans 1983; Barlow 1883). It is due to the identification of juvenile scurvy by Barlow that the disease is still frequently referred to as Barlow's disease today.

The purpose of this work is not to examine the history of juvenile scurvy at length. The material presented in this section has provided a necessarily brief introduction to the history of juvenile scurvy and is not intended to be exhaustive. The problem of juvenile scurvy persisted for years and a multitude of medical investigators contributed to the eventual identification and cure of scurvy. A more thorough background on the subject is provided by Hess (1920) and Carpenter (1986).

2.2.3–Historical Causes of Juvenile Scurvy

The near epidemic outbreak of juvenile scurvy among European children of the 1800's coincides with the rise of industry and new abilities to produce food as well as increase the sanitation and sterilization of foods (Carpenter 1986). The rise of juvenile scurvy was a curious instance in that the majority of cases were observed as occurring in the children of the wealthier classes of society (Evans 1983). The eventual explanation as to why the children of the wealthy became ill with scurvy and not the children of the poor lies in the simple access to prestige items. It was observed that the children of the wealthy were often weaned early and given sterilized milk and proprietary foods, often of a grain-based nature, in place of fresh foods (Rajakumar 2001; Wilson 1975; Barlow 1883). The substitution of sterilized milk and processed foods for fresh foods essentially ensured that the children were receiving little to no vitamin C in their diets due to the processing of such foods during production, which effectively diminishes vitamin C content to an insignificant amount due to heating (Pimentel 2003; Carpenter 1986; Evans 1983). This use of processed prestige foods provides a firm basis for understanding the development of juvenile scurvy among the children of the wealthy. Conversely poorer families did not often have access to processed foods and as such typically breastfed their children for longer durations (Carpenter 1986; Evans 1983). Furthermore after a child was weaned it would typically be fed on a diet of root vegetables and local produce, a significant portion of which would have been potatoes, a naturally high source of vitamin C (Basu and Donaldson 2003; Carpenter 1986; Barlow 1883). Thus, due to extended periods of breastfeeding and the use of fresh foods, the children of the poor typically avoided any significant encounters with juvenile scurvy (Carpenter 1986).

Recognizing that the children of the wealthy were becoming ill with juvenile scurvy due to a reliance on heavily processed proprietary foods, physicians implemented a series of medicinal treatments in an attempt to cure the disorder. By this time physicians were aware of the success of citrus treatments of scurvy in long distance sailors; however, there was a seeming reluctance to rely solely on citrus juices for the cure of juvenile scurvy. Rather, a mix of food products was prescribed for the scorbutic juvenile. Though each physician likely prescribed a series of different items for treating this disorder many of the elements remain the same: oranges, raw meat juice, fresh milk, mashed potatoes, fresh vegetables, and a number of herbs (Rajakumar 2001; Carpenter 1986; Wilson 1975). This method of treatment of early cases of juvenile scurvy seems to be a cover-all technique in that the intention was to prescribe a wide variety of foodstuffs in the hope that one of the given materials would sufficiently cure scurvy.

Despite the brevity of this section the key point of the association between juvenile diet and juvenile scurvy is clear. Though this section has examined the British example of the rise of juvenile scurvy in the 1800's, childhood feeding practices, especially those relying on well cook grains, undoubtedly have caused many cases of juvenile scurvy worldwide throughout history.

Chapter three of the present work will examine more thoroughly the nature of childhood feeding practices in late Roman-Byzantine Greece and how the use of certain foods prescribed by cultural practice for feeding children potentially contributed to the development of juvenile scurvy within the populations in question. It must be kept in mind that despite access to appropriate anti-scorbutic foods it is often cultural views and prescribed childhood feeding practices that lead to the presence of juvenile scurvy rather than a lack of access to anti-scorbutic foods.

2.3–The Proposed Ortner et al. Suite of Lesions

The following sections will examine the suite of lesions proposed as being representative of the presence of juvenile scurvy. Further use of the lesions described below will be noted as the Ortner et al. suite of lesions in reference to the research that originally identified such lesions with a probable diagnosis of juvenile scurvy.

2.3.1–Assessment of Skull Lesions

2.3.1.1–Porosity of Lesions

Lesions believed to be associated with scurvy are of a porous variety and are proposed as conforming to a specific distribution on the skull. Scurvy cannot be successfully identified from a singular lesion rather a confident diagnosis relies on a combination of lesions at specific locations (Brickley and Ives 2006: 170; Ortner et al. 2007: 188). Ortner and Ericksen (1997) who originally proposed the criteria for identifying scurvy from porous cranial lesions detail the type of porosity involved as being of localized porosity which is typically visible with the unaided eye consisting of pores less than 1 mm in diameter that penetrate a lamellar bone surface of which the lamellar surface can be normal or hypertrophic (Ortner et al. 1999: 323). Such porosity it proposed as being the result of chronic inflammation in the affected areas (Ortner and Ericksen 1997: 212). In order for the porosity to be considered indicative of scurvy the pores must consistently penetrate through cortical bone (Ortner et al. 1999: 323).

It is important when investigating juvenile remains that normal porosity be separated from abnormal porosity. Normal cranial porosity is commonly seen in juvenile bone due to continued growth, however normal porosity does not penetrate through the entire cortex and is thus an important distinction from porosity caused by inflammation (Ortner et al. 2001: 344). The following material documents the proposed distribution of scorbutic lesions on the skull.

2.3.1.2–Greater Wing of the Sphenoid

Lesions located along the greater wing of the sphenoid have been identified by Ortner and Ericksen (1997) as the cranial lesion location most pathognomonic of scurvy (Brickley 2000: 185; Buckley 2000: 495; Ortner et al. 1999: 322; Fig. 2.14). Lesions on the greater wing of the sphenoid are porous and typically occur bilaterally, being the most common archaeologically identifiable lesion indicative of scurvy (Ortner and Ericksen 1997). Using Scanning electron microscopy (SEM) Ortner et al. (2001) observed vascular holes resulting from complete penetration of the cortex of the greater wing of the sphenoid by pathological pores. The severity of lesions identified on the greater wing of the sphenoid varies and it has been stated that though less likely it remains possible that an individual could have scurvy and not exhibit porous lesions on the greater wing of the sphenoid (Ortner et al. 2007, 2001).

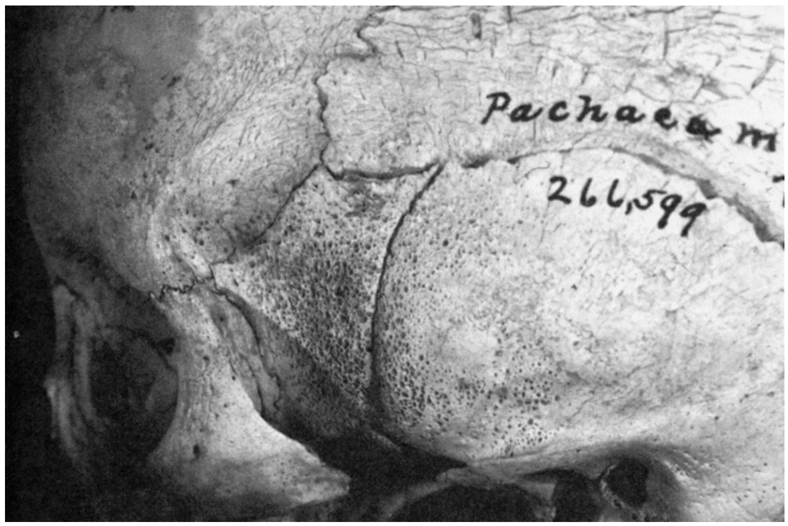


Fig. 2.14– Extensive porosity and hypertrophic bone formation are observable along the greater wing of the sphenoid. Such porosity and bone formation are believed to be pathognomonic of juvenile scurvy (Ortner 2003: figure 15-6b).

2.3.1.3–Lesser Wing and Body of the Sphenoid

Brickley and Ives (2006: 168) identified a series of spicules of disorganized new bone on the lesser wing and part of the body of the sphenoid from an individual at St. Martin's Church, England, which they believe may have been caused by scurvy. Significantly less data exists about the identification of porous lesions on the lesser wing and body of the sphenoid.

2.3.1.4–Parietals

Lesions associated with scurvy are less common on the parietals however Brickley and Ives (2006: 168) have suggested that porosity of the ectocranial surface with increased vascularization and porosity of irregular size and shape that penetrates through the cortex may be indicative of scurvy, particularly in combination with the presence of porous lesions in the orbits and along the greater wing of the sphenoid (Fig. 2.15).

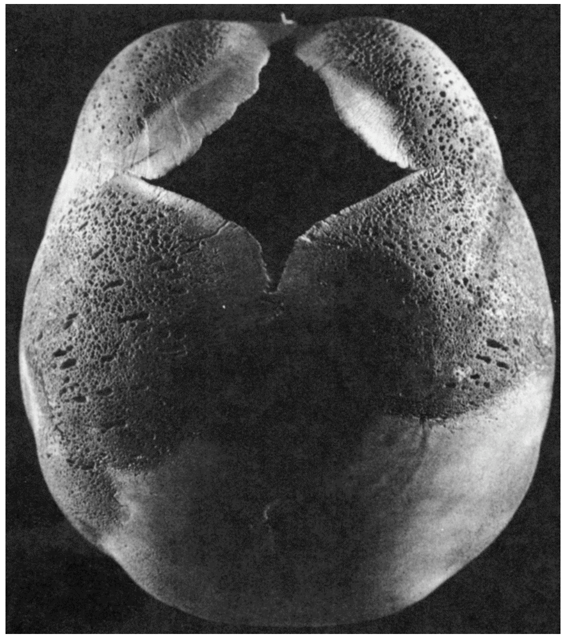


Fig. 2.15– Subadult skull identified with juvenile scurvy exhibiting extensive porosity along the frontal and parietals (Ortner 2003: figure 15-3).

From the analysis of sub-adult individuals from excavations in Tonga Buckley identified endocranial lesions on a right parietal that were proposed as being caused by the presence of scurvy (Buckley 2000: 484).

2.3.1.5–Temporals

At the present time there is little documented archaeological evidence of porous lesions associated with scurvy identifiable on the temporal bones, excluding the zygomatic arch. Often such porosity is only marginally observed along the anterior aspect of the bone directly adjacent to the greater wing of the sphenoid (Ortner 2003; Barlow 1883). Though there is limited evidence of porosity associated with scurvy along the temporal bones it remains highly possible that porous lesions similar to those identified on the other cranial bones could also be present on the temporal bones, based on the extent of the temporalis muscle (McMinn and Hutchings 1985: 12, 38).

2.3.1.6–Occipital

Based on their St. Martin's Church study Brickley and Ives (2006) suggested that several endocranial bone changes observed within three young infants may be attributed to scurvy. Such a diagnosis was made based on localized vascularization with holes penetrating the cortex as well as several irregular plaques of new bone formation on top of the endocranial surface.

2.3.1.7–Orbital Aspect of the Frontal and Zygomatics

Looking at the orbits it is typically the roof and lateral margins of the orbits that display porous lesions identified with scurvy (Ortner et al. 2001: 344; Roberts 1987). Intensely vascular regions with spiculation and substantial holes penetrating the cortex are proposed as being indicative of abnormal porosity (Brickley and Ives 2006). Though some porosity is normal in juvenile bone it is the increased vascularity within the thickened layers of new bone in the orbital roof that is proposed as being the most helpful in establishing a diagnosis of scurvy (Brickley and Ives 2006; Fig. 2.16).

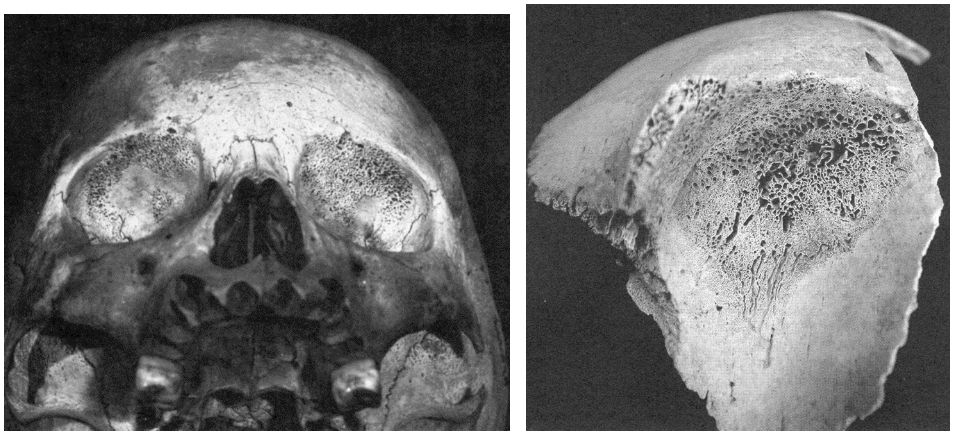


Fig. 2.16– a.) Extensive porous lesions visible along the extent of the orbital plate (Ortner 2003: figure 15-6a), b.) Close up view of extensive orbital porosity and associated new bone formation (Brickley and Ives 2008: figure 4.6).

2.3.1.8–Zygomatic

When looking at the zygomatic it is typically the interior surface where the temporalis muscle abuts the bone that exhibits porous lesions that have been taken to be indicative of scurvy (Ortner et al. 2001).

2.3.1.9–Maxilla

Lesions due to scurvy identified on the maxilla usually occur bilaterally and are typically identified as porous and hypertrophic lesions on the posterior surface and along the alveolar process (Ortner et al. 2001; Ortner and Ericksen 1997; Fig. 2.17). Porous lesions due to scurvy are also often identified around the infraorbital foramen (Ortner et al. 2001; Fig. 2.17).

Fig. 2.17– Diffuse porosity is visible along the maxilla, alveolar process, and around the infraorbital foramen (Ortner 2003: figure 15-7c).

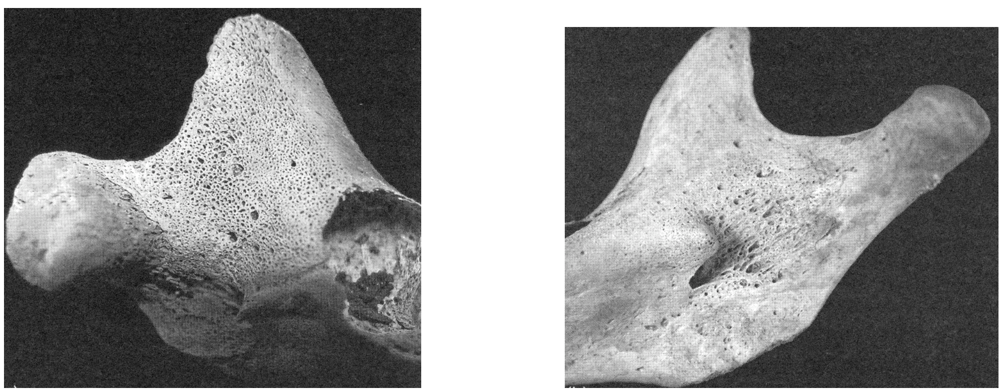
When examining the maxilla for porosity it is important to keep in mind that there is a significant degree of normal porosity in the juvenile maxilla, particularly along the alveolar around developing molars. As such when assessing porosity for evidence of scurvy it is important to be sure that the porosity extends significantly above the alveolar margin so as not to confuse normal porosity with abnormal porosity (Brickley and Ives 2006; Ortner et al. 1999; Roberts 1987).

2.3.1.10–Palate

Some porosity of the palate is normal (Ortner and Ericksen 1997). Normal palate porosity is distributed in a U-shaped arch roughly corresponding to the arch of the alveolar process with the porosity typically becoming denser along the anterior portion of the palate (Brickley and Ives 2006; Ortner et al. 1999). As such when observing porosity along the palate diffuse porosity may potentially be indicative of scurvy.

2.3.1.11–Mandible

Lesions associated with scurvy are typically identified around the coronoid process of the rami (Brickley and Ives 2006; Ortner et al. 2001; Roberts 1987). Brickley and Ives (2006) identified large holes towards the pterygoid fovea as well as porosity covering the region of the lingua and surrounding mandibular foramen, however the porosity did not continue significantly beyond the mandibular foramen (Brickley and Ives 2006: 166; Fig. 2.18).



a.) b.)

Fig. 2.18– a.) Porosity along the coronoid process and surrounding region (Brickley and Ives 2008: figure 4.3a), b.) Porosity along the medial surface of the mandible in the region of the mandibular foramen (Brickley and Ives 2008: figure 4.3b).

2.3.1.12–Hemorrhage

The underlying cause of the porous lesions outlined above has been proposed as being due to hemorrhage. Ortner and Ericksen (1997: 215) propose that the maxillary artery, the deep temporal arteries, mainly the anterior and the posterior, and the middle temporal artery can be understood as the likely sources of hemorrhage for causing such porous lesions. Such an assertion is based on the fact that the deep temporal arteries are located between the muscle and the periosteum which covers the temporal and the greater wing of the sphenoid (Ortner et al.

2001: 344; Ortner and Ericksen 1997: 215). It is due to the close proximity of these blood vessels to the underlying bone that Ortner and Ericksen (1997: 215) identify these particular vessels as the cause of the observed cranial lesions.

Hemorrhage due to a lack of vitamin C would lead to bleeding directly onto the underlying bone surface, which if occurring continually could lead to the observed porotic lesions. Further supporting this notion is the fact that the deep temporal arteries, which have been shown as the likely cause of the porous lesions on the parietal and greater wing of the sphenoid, also anastomose with the lacrimal branch of the ophthalmic artery which enters high within the orbit and as such is proposed as the likely candidate for causing the orbital lesions presented above (Ortner and Ericksen 1997: 215).

Looking at the palate and the surrounding alveolar region the third part of the maxillary artery supplies the soft tissue and gingival, as well as the mucous membrane of the hard palate (Ortner and Ericksen 1997: 215). Hemorrhaging of this blood vessel can clearly be understood as a highly likely mechanism contributing to the porous lesions identified with scurvy.

Understanding the distribution of significant blood sources in the cranial region provides a clear mechanism for interpreting the porous lesions proposed as being indicative of scurvy. It is possible that due to the involvement of the temporalis muscle in chewing that mechanical stress in this area in a vitamin C deficient individual could easily lead to hemorrhage, which if occurring repeatedly within an individual for a significant period of time could lead to porous lesions along the extent of the temporalis muscle (Ortner and Ericksen

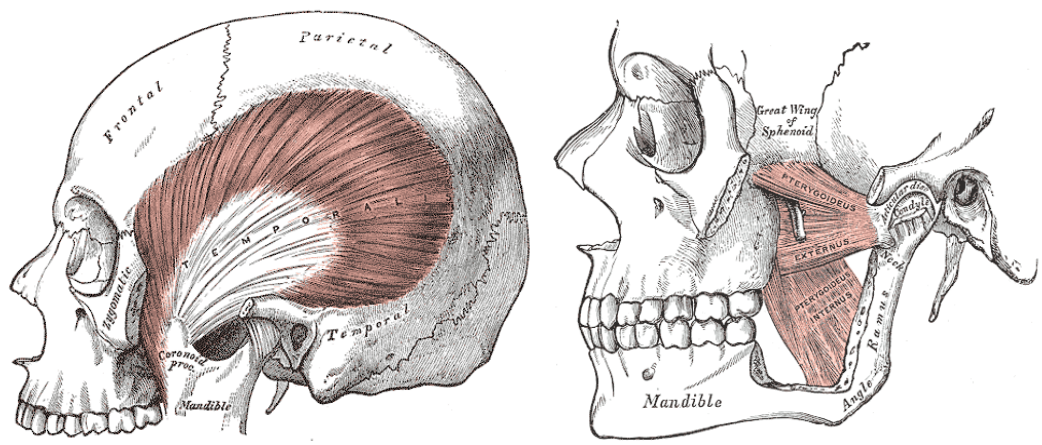
1997: 215; Fig. 2.20). Brickely and Ives (2006: 165) have suggested that in the case of individuals too young to be consuming solid foods such hemorrhaging in the cranial region might be induced from the action of the child sucking during breastfeeding (Stirland 2000: 92). Both chewing and sucking remain likely options for such hemorrhaging for if the child is deprived of vitamin C to such a significant degree to induce scurvy it can be argued that any mechanical stress of the muscles may lead to hemorrhaging, which even if mild, may over an extended period of time result in the type of porous cranial lesions herein discussed.

In the orbits, much as in the long bones, subperiosteal hemorrhage along the inferior surface of the orbital plate of the frontal bone may lead to increased blood in the area which as a result may lead to chronic inflammation that ultimately could account for the porous lesions observed in the orbits (Ortner and Ericksen 1997: 214, 217). Brickley and Ives (2006: 168) have suggested that regular eye movement in an individual with a lack of vitamin C may be significant enough to lead to hemorrhaging along the orbits.

Looking at endocranial lesions, Buckley proposed that a weakening of the endosteal layer, which is essentially the periosteum of the endocranium, may lead to the porous lesions identified on the endocranial surface (Buckley 2000: 484).

Ortner and Ericksen (1997) have proposed that porous lesions may potentially also be found along the masseter muscle, one of the four chief muscles of mastication, however the masseter muscle seems to be significantly less involved in the pattern of porous lesions identified with scurvy than that of the temporalis muscle and possible the pterygodei (Gray 1973: 386–390; McMinn and Hutchings 1985: 12; Fig. 2.19). It remains possible that porous lesions due to mechanical activity during chewing may be identified along the lateral portion of the zygomatic arch, the posterio-inferior area of the zygomatic, as well as along the ascending ramus of the mandible, though at this time such lesions have not been documented in proposed paleopathological cases of scurvy (McMinn and Hutchings 1985: 12).

The overall justification for identifying the proposed porous lesion pattern with a diagnosis of scurvy is based on a strong correlation with the musculature involved in chewing and motion of the mouth and eyes. This suggests that mechanical, and undoubtedly traumatic, stress in this region would have had an adverse effect on the increasingly fragile vascular system, which would have caused repeated hemorrhaging in the area potentially leading to the distinct pattern of porous lesions here identified with scurvy.



a.) b.)

Fig. 2.19– Depiction showing the extent and attachment points of the muscles of mastication, a.) showing the extent of the temporalis (Gray 1973: fig. 6–5), b.) showing the attachment points and extent of the of the pterygoidei muscles (Gray 1973: fig. 6–6).

2.3.2–Assessment of Long Bone and Scapular Lesions

Notable attention has been given to the assessment of lesions along the long bones in connection with scurvy. However there has been significantly less attention given to the examination of scapular lesions in connection with scurvy in archaeological remains.

2.3.2.1–Lesions of the Long Bones

During growth the metaphyseal region of the long bones is porous due to the reduction of the metaphysis diameter to form the diaphysis as the bones grow in length (Goldring and Goldring 1990; Siffert 1966: 546–547). Such normal porosity is due to osteoclast action, which removes the cortex of the metaphyses thus exposing vascular canals, which subsequently causes the bone to appear porous (Ortner 2003: 15). Such porosity can be easily mistaken as pathological, particularly with regards to juvenile scurvy, as it is along the metaphyses where abnormal porosity due to juvenile scurvy can be observed (Ortner 2003: 15). Thus it is important to distinguish pathological porosity from that of developmental porosity when examining osteoarchaeological remains.

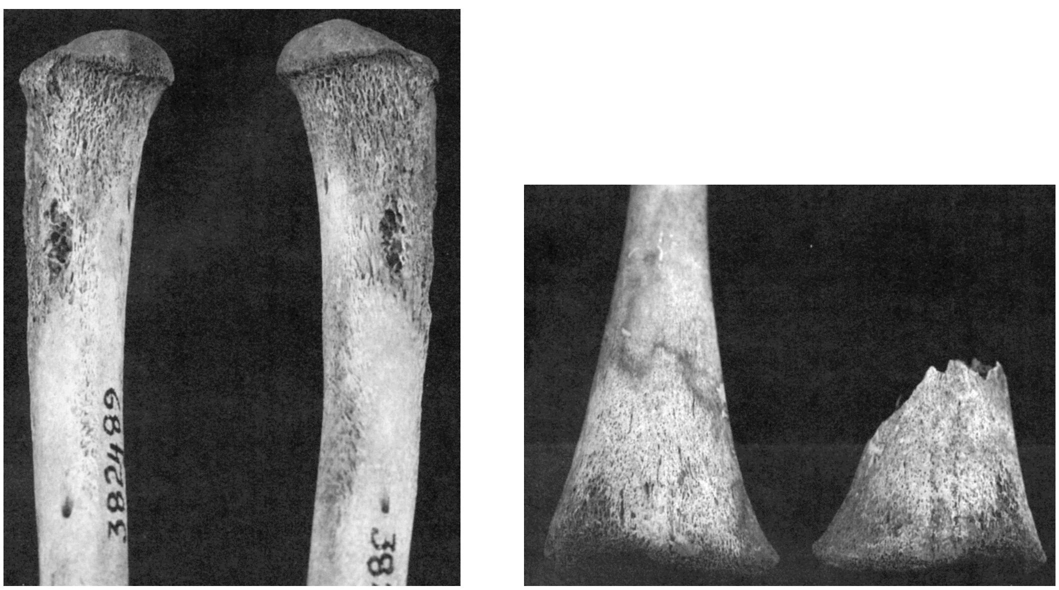
Looking at the long bones of the juvenile individual it is periosteal new bone formation, which can be as thick as 1 cm, that is most common in probable cases of juvenile scurvy (Ortner 2003: 386). Along with such periosteal new bone formation is porosity and fractures in the metaphyseal region, which are commonly identified with cases of scurvy due to hemorrhage and weakening of the growth plate attachment (Brickley and Ives 2006; Roberts and Manchester 2005; Ortner et al. 2001; Stuart-Macadam 1989; Fig. 2.20). Further focusing on the metaphyseal region Ortner (2003) notes that in severe cases of juvenile scurvy the proximal metaphysis of the femur may exhibit a depressed neck angle due to the amount of weight placed on this joint.

Another common occurrence observed in the long bones of scorbutic individuals is subluxation of the epiphyses (Ortner 2003; Fig. 2.12). Though this is common the degree of deformity which subluxation causes is typically minimal and often self resolving once scurvy is cured (Ortner 2003: 387). The weakening of the long bones due to scurvy also manifests in the form of osteopenia, osteoporosis and cortical thinning (Brickley and Ives 2006; Ortner 2003).

A common lesion due to scurvy observed among the long bones within archaeological individuals is the presence of ossified subperiosteal hemorrhages, hematomas, and periosteum, forming what is essentially a shell of bone (Ortner and Ericksen 1997; Huss-Ashmore et al. 1982; Steinbock 1976; Saul 1972). Though such ossified hemorrhages are unlikely to preserve it is often possible to observe the extent of such hemorrhaging based on increased porosity of the affected bone surface as well as discolouration of the bone demarcating where the periosteum ceased to be raised by hemorrhaging (Roberts and Manchester 2005; Ortner 2003; Stirland 2000; Maat and Uytterschaut 1984; Fig. 2.21).

Cupping of the weakened metaphyses and invagination of the epiphyses may also occur in scorbutic individuals, though this type of deformation is relatively uncommon and typically returns to normal after the cessation of scurvy, however it is nonetheless possible to observe such cupped metaphyses archaeologically (Stuart-Macadam 1989; Sprague 1976).

It is important to remember that porosity of the growing juvenile long bones is normal, however such porosity is limited and typically does not extend more than 5–10 mm beyond the end of the metaphysis (Ortner et al. 2001: 348). Furthermore lesions associated with osteological alteration due to hemorrhaging are more commonly observed in the bones of the lower limbs, which is attributed to the fact that the lower limbs bare significantly more weight than the upper limbs and as such hemorrhaging in scorbutic individuals occurs more frequently among these bones (Jaffe 1972: 455). Despite the significant hemorrhaging associated with scurvy Jaffe (1972) notes that bleeding into the joints is rarely found in cases of juvenile scurvy, as such it is proposed as being less likely that lesions associated with juvenile scurvy will be present in the joints.

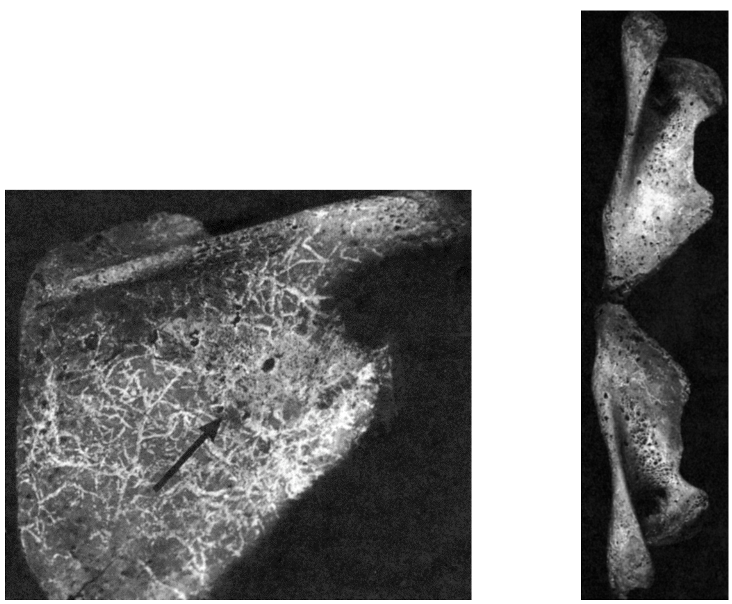


a.) b.)

Fig. 2.20– a.) Extensive porosity along the anteromedial aspect of the proximal tibiae (Ortner 2003: figure 15-8a), b.) Extensive porosity observed along the anterior surface of the distal femora. Note the “stain line” along the proximal aspect of the distal femur on the left of the image. Such staining is believed to indicate the extent of subperiosteal hemorrhaging in this individual (Ortner 2003: figure 15-8b). Though porosity is normal in growing juvenile bones, the extent of porosity observed in these bones, a.) and b.), is abnormal due to the proposed presence of scurvy.

2.3.2.2–Lesions of the Scapulae

The identification of scapular lesions associated with juvenile scurvy from archaeological individuals is based on the original identification of hematoma and an osseous shell over the scapula of a child by Barlow in his seminal 1883 publication (Barlow 1883). Based on the identification of an osseous shell along the scapulae Ortner and Ericksen (1997) made a preliminary association of possible porosity along the scapula with the presence of juvenile scurvy among archaeological individuals. In their 2001 work Ortner et al. provided further documentation of porous scapular lesions believed to be associated with scurvy. The abnormal scapular porosity identified by Ortner et al. (2001) as being likely caused by the presence of juvenile scurvy was located along the supraspinous and infraspinous region of the scapula (Brickley ad Ives 2006; Fig. 2.21).



a.) b.)

Fig. 2.21– a.) Porosity can be clearly observed along the infraspinous fossa (Ortner 2003: figure 15-7e), b.) Porosity can be clearly observed along the supraspinous fossa (Ortner 2003: figure 15-7f).

Brickley and Ives in their 2006 study identified five individuals who exhibited similar porous scapular lesions, thus further affirming the identification of such lesions with the probable presence of juvenile scurvy.

The cause of such scapular lesions is proposed by Ortner and Ericksen (1997: 218) as being a result of hemorrhaging of predominantly the subscapular and circumflex branches of the subscapular artery. The subscapular and circumflex branches of the subscapular artery enter the supra- and infraspinous fossae lying in close proximity to the bone (Ortner and Ericksen 1997: 218; Gray 1973: 613; Fig. 2.22). It is proposed as being due to contraction and mechanical tension as well as potential trauma to the shoulder area that inflammation and hemorrhaging in this region would occur leaving the type of porous lesions identified from the osteoarchaeological remains examined (Ortner et al. 2001: 347).

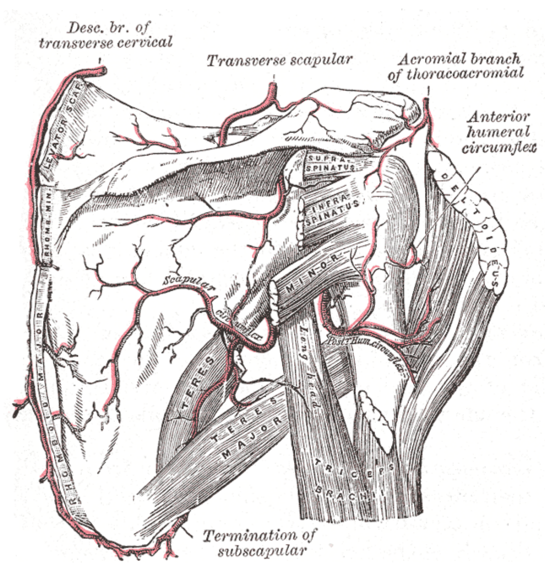


Fig. 2.22– Depiction of the distribution of arteries along the scapula (Gray 1973: fig. 8-34).

2.4–Review of Reported Archaeological Cases of Juvenile Scurvy

Until recently the study of juvenile scurvy among archaeological populations has been relatively rare in the literature. Instances in which porous lesions, such as those discussed in the previous section, were observed on the skull and long bones were commonly attributed to anemia with little consideration of a differential diagnosis. However in recent years there has been a significant increase in the research conducted on identifying juvenile scurvy among archaeological populations. The paleopathological criteria for identifying probable case of juvenile scurvy has predominantly been developed by Ortner et al. (2001, 1999; Ortner and Ericksen 1997; Ortner 1984). The following sections on archaeological cases of juvenile scurvy begins with a review of the Ortner et al. (2001, 1999; Ortner and Ericksen 1997; Ortner 1984) research before moving on to other reported archaeological cases of this disorder.

2.4.1–Discussing the Ortner et al. Suite of Lesions

In 1984 Ortner published research discussing the likely evidence of juvenile scurvy identified from the well preserved skull and mandible of an approximately eight year old individual recovered in Alaska dating to the 19^{th}–20^{th} century C.E. Ortner (1984) identified mound shaped cribriform lesions on the orbital roofs which also exhibited abnormally pronounced blood vessel channels. Non-expansive porous lesions were also noted along the anterior and posterior maxilla, the inferior nasal aperture and the alveolae of the anterior mandible (Ortner 1984). Of significant identification from this study was Ortner's observation of porous non-expansive lesions along the greater wing of the sphenoid and to a lesser extent along the squamous portion of the temporal (Ortner 1984). Concluding his observations of the porous lesions identified Ortner noted that it is important to establish whether missing teeth were lost antemortem or postmortem, as tooth loss is a well-established sequela of scurvy and as such could prove increasingly significant in facilitating a paleopathological diagnosis (Ortner 1984: 80).

In 1997 Ortner and Ericksen published what remains the seminal study discussing a particular pattern of lesions believed to be strongly indicative of juvenile scurvy within archaeological remains. To conduct this study six skulls from various time periods and archaeological contexts were utilized (Ortner and Ericksen 1997: table 1). The skulls in question exhibited varying degrees of bilateral porous lesions on the greater wing of the sphenoid, which is believed to be the most pathognomonic lesion of juvenile scurvy among archaeological remains, as well as along the posterior maxilla, the palate, and the roofs of the orbits (Ortner and Ericksen 1997). Ortner and Ericksen (1997) proposed that porous and hypertrophic lesions at these specific anatomical locations agree with the location of a major muscle of mastication, the temporalis, which overlies the vascular system of the skull and thus constriction of the underlying blood vessels in cases of scurvy by the movement of the temporalis may result in hemorrhaging leading to inflammation potentially resulting in the type of porous cranial lesions presented. Based on this Ortner and Ericsken (1997) proposed that the location and extent of the lesions observed could be correlated with hemorrhaging and inflammation of scorbutically weakened blood vessels. The hemorrhaging was attributed to trauma and the mechanical stress of mastication (Ortner and Ericksen

1997: 218). Ortner and Ericksen (1997) suggest that further research into the topic is needed, and that archeological evidence of porous scapular lesions, such as what might be expected from the "blood clots" described by Barlow (1883), in connection with the proposed cranial lesions would provide an even stronger basis for a probable diagnosis of juvenile scurvy (Ortner and Ericksen 1997: 219; See Table 2.2).

Expanding on the research presented in Ortner and Ericksen (1997), Ortner et al. (1999) examined a sample of 363 Peruvian sub-adult skulls from the Smithsonian Museum. Of the 363 skulls studied, 38 individuals exhibited lesions consistent with the proposed scurvy pattern presented in Ortner and Ericksen (1997). In almost all of the cases where porous lesions of the greater wing of the sphenoid were present so too were porous and hypertrophic lesions of the orbits further suggesting a possible link between the lesions represented at these two locations (Ortner et al. 1999). The highest frequency of changes believed to be due to scurvy was identified in individuals two years old or younger (Ortner et al. 1999: 322). Porosity along the internal surface of the zygomatic, along the palate, in the lambdoid region and along the posterior surface of the maxilla and alveolae was also discussed (Ortner et al. 1999). One of the main concerns presented in this article is that greater care should be taken to distinguish orbital lesions that have been caused by anemia from those that could have been caused by scurvy. Orbital lesions of anemia involve marrow hyperplasia, which is not observed in cases of scurvy, and as such this criterion should be used as a distinguishing factor when attempting to identify archaeological cases of juvenile scurvy

(Roberts and Manchester 2005: 236). One of the major difficulties in diagnosing juvenile scurvy from archaeological remains that Ortner et al. (1999) point out is the lack of supporting clinical data for the lesions in question. This must be a future direction of research in order to help increase successful and well document diagnoses of juvenile scurvy from archaeological remains.

A study examining 557 sub-adult skeletons from across North America, dating from ca. 950 C.E. to the historic period, was conducted by Ortner et al. (2001). From this group 22 individuals were identified as exhibiting signs of probable juvenile scurvy (Ortner et al. 2001: table 1). Of the individuals exhibiting signs of scurvy 87% were below the age of 7 years (Ortner et al. 2001: 346). From the sample examined porous lesions were identified along the posterior maxilla, internal zygomatic, the medial coronoid processes of the mandible, the metaphyseal regions of the humerus and femur, the posterior supraspinatus region of the scapulae, as well as along the orbital roofs and the greater wing of the sphenoid extending onto the temporal and frontal bones (Ortner et al. 2001). Scanning electron microscopy (SEM) was employed to aid in illustrating the vascular holes observed as well as the complete penetration of the cortex of the greater wing of the sphenoid by the pores (Ortner et al. 2001). The lesions identified from the sample of North American sub-adult remains strongly conform to the pattern of lesions proposed by Ortner et al. (1999; Ortner and Ericksen 1997; Ortner 1984) as being indicative of juvenile scurvy among archaeological remains.

Brickley and Ives (2006) examined the skeletal remains of 164 juvenile individuals dating from the 18th–19th centuries C.E., recovered from the burial ground at St. Martin's Church, England. From this sample six infants aged birth to three years were identified as having lesions consistent with a diagnosis of probable juvenile scurvy based on the criteria presented in Ortner and Ericksen (1997). Several sections of orbit and scapula were examined under SEM in an attempt to better clarify the nature and extent of observed porous lesions, both to better define such lesions and to aid in the distinction between porous lesions observed in scurvy and porous lesions observed in other diseases such as anemia and rickets (Brickley and Ives 2006). The SEM images confirm the previous assessment of Ortner et al. (2001), in that the margins of the new deposited bone are spiculated and irregular in shape, being highly vascular. Such an appearance is likely due to the rapid formation of new bone in a response to inflammation, with the pores penetrating through the cortex being significantly different from the normal porosity observed in the growing bones of juveniles in which the pores present are often few and randomly distributed and do not penetrate the cortex (Brickley and Ives 2006: 166–167). The work of Brickley and Ives (2006) serves as another thorough study helping to better define the pattern of porous lesions originally proposed by Ortner and Ericksen (1997) as being strongly indicative of probable juvenile scurvy among the examined archaeological individuals.

Examining several Early Bronze Age burials from the site of Bab edh-Dhra in Jordan, Ortner et al. (2007) identified four sub-adult individuals who exhibited signs of juvenile scurvy. Of these four individuals only two had enough skeletal elements preserved to provide a confident diagnosis (Ortner et al. 2007). The best example of potential juvenile scurvy was an individual who exhibited orbital porosity, as well as porosity along the alveolar bone of the maxilla, the infraorbital foramen region and along the metaphyseal region of several long bones (Ortner et al. 2007: 188). An interesting result from the study of this individual was the absence of porosity along the greater wing of the sphenoid, which is proposed as being the most pathognomonic lesion of juvenile scurvy (Ortner et al 2007: 188). The absence of porosity along the greater wing of the sphenoid stresses the need for compiling a series of lesions for diagnosing juvenile scurvy and not just depending on one singular lesion as an indicator of the presence or absence of juvenile scurvy, as it remains clear that scurvy can be highly varied in its skeletal manifestations (Ortner et al. 2007).

Investigations into archaeologically identifiable cases of juvenile scurvy have largely utilized the pattern of lesions identified here as the Ortner et al. suite of lesions (Ortner et al. 2001, 1999; Ortner and Ericksen 1997; Ortner 1984). The following sections will present a variety of cases that have employed the Ortner et al. suite of lesions for identifying probable archaeological cases of juvenile scurvy.

Table 2.2–Macroscopic Lesions Proposed as Indicative of Juvenile Scurvy

Skeletal Location	Lesion Description	Associated Soft Tissue
Mandible	Porosity is observed along the coronoid process and ramus.	Hemorrhaging at the temporalis and masseter muscle attachment points, as well as the pterygoid muscles.

Greater Wing of the Sphenoid (GWS)	Porous non-expansive lesions along the greater wing of the sphenoid are believed to be the most pathognomonic lesion of juvenile scurvy.	Hemorrhaging of the deep temporal arteries under the temporalis and pterygoid muscles is the likely source of such porous lesions.
Orbits (frontal and lateral zygomatic)	Involves the lateral aspect of the zygomatic as well as the frontal. Mound shaped cribriform lesions, commonly observed with pronounced vessel channels. Can be porous and hypertrophic. Caused by hemorrhage and inflammation along the inferior surface of the orbital plate. Orbital porosity associated with scurvy is due to new bone formation, not hyperplasia of the marrow cavity. Orbital lesions may be unilateral or bilateral.	The anterior deep temporal artery anastomoses with the lacrimal branch of the ophthalmic artery high within the orbit. Hemorrhaging of these vessels is believed to be the source of the porous lesions observed in the orbits in cases of scurvy.
Maxilla	Porous non-expansive lesions occur on the posterior and anterior maxilla as well as to a lesser extent around the inferior portion of the nasal aperture. Porosity is also commonly observed around the infraorbital foramen.	Hemorrhaging of the deep temporal arteries and maxillary arteries are primarily involved in the lesions observed, as well as the pterygoid muscles.
Temporals	Porous lesions are occasionally observed along the squamous portion of the temporal. These lesions typically occur in association with porous lesions on the GWS.	Hemorrhaging of the deep temporal arteries is the likely source of such porous lesions.
Parietals	Porous lesions are often observed along the inferior aspect of the parietals. These lesions typically occur in association with porous lesions on the GWS.	Hemorrhaging of the deep temporal arteries is the likely source of such porous lesions.
Zygomatic (internal/posterior aspect)	Thickening and porosity of the zygomatic due to scurvy may be observed along the internal/posterior aspect.	Proximity to the temporalis muscle likely causes such porous lesions due to hemorrhaging and inflammation of underlying blood vessels.

Palatine	Abnormal porosity along the palatine bones may be observed.	Hemorrhaging of the palatine and alveolar branches of the third maxillary artery is the likely cause of such lesions.
Alveolar border*	Porosity due to scurvy is often observed along the alveolar border. Weakening of the periodontal ligament may lead to loss of teeth, particularly single rooted teeth. As such porosity and bone resorption may potentially be observed in the tooth socket.	Hemorrhaging of the alveolar branches of the third maxillary artery is likely responsible for such lesions.
Scapula	Porosity along the supraspinous and infraspinous fossa of the scapula may be caused by scurvy.	Hemorrhaging of the subscapular, circumflex and thoracodorsal arteries along the supraspinatus and infraspinatus muscles is likely responsible for such lesions.
Metaphyses (long bones)	Porosity at the metaphyseal region of the long bones may be observed in cases of scurvy.	Hemorrhaging, hematoma formation and inflammation of the periosteum is believed to produce such lesions.

Data utilized in this table were compiled from Ortner et al. (2001, 1999; Ortner and Ericksen 1997; Ortner 1984), Gray (1973) and McMinn and Hutchings (1985). The porosity detailed as being indicative of potential cases of scurvy is defined as: a localized, abnormal condition in which fine holes visible without magnification, but typically less then 1mm in diameter, penetrate a lamellar bone surface. The lamellar bone may be normal or the result of hypertrophic bone formation (Ortner et al. 1999: 323). *Regarding porosity and resorption in the tooth sockets Ortner et al. (1999) were unable to establish a baseline for differentiating normal porosity due to growth from pathological porosity and as such did not include this criteria in their study, but rather stated that it could potentially be observed in cases of scurvy.

2.4.2–Examining Reported Archaeological Cases of Juvenile Scurvy

The material presented in the following section examines reported archaeological cases of juvenile scurvy. The cases presented below, aside from those that predate 1984, predominantly employ the criteria established by Ortner et al. (2001, 1999; Ortner and Ericksen 1997; Ortner 1984) to provide a probable diagnosis of juvenile scurvy showing the significant impact the development of the Ortner et al. suite of lesions has had on the ability to archaeologically identify juvenile scurvy.

Hooton (1930) in his work on the Pecos Pueblo natives discusses several cases of osteoporosis among the sub-adult remains, which show characteristic porosity along the orbital roofs, which Hooton attributes to a probable diagnosis of scurvy (1930: 317). In discussing scurvy Hooton suggests that it is not unlikely that the children at this sight would have suffered from such a disorder, particularly during the phase directly after weaning, considering the reliance of the Pecos Pueblo peoples on a diet predominantly consisting of maize (Hooton 1930: 317).

Møller-Christensen examined a series of 800 burials from the monastic site of Æbelholt kloster dating to ca. 750–1550 AD (Brickley and Ives 2008; Wells 1975; Møller-Christensen 1958). From these burials Møller-Christensen identified six juvenile individuals who exhibited osteological lesions believed to be consistent with the presence of juvenile scurvy (Møller-Christensen 1958: 190). However only limited information regarding the diagnostic criteria employed is provided.

Though not focusing specifically on juveniles, the osteoarchaeological publication of Saul (1972) discusses the presence of scurvy among individuals from excavations at the Mayan site of Altar de Sacrificios in Guatemala (Saul 1972). Saul presents a brief discussion on the identification of subperiosteal hemorrhages and periodontal degeneration, which he suggests when found together may be evidence of the presence of scurvy (Saul 1972: 56). Saul makes this association based on the increased fragility of the vascular system identified with scurvy, which is known to lead to easy hemorrhaging, typically due to mechanical stress and trauma (Saul 1972: 56).

In 1984 Holk published a short research statement suggesting that during the Middle Ages scurvy would have been the most frequently occurring disorder among Scandinavian populations. Holk states that signs of scurvy have often been observed from skeletal remains of this time period; however no method or criteria for identification is provided.

In 1987 Roberts was one of the first researchers to employ the criteria suggested by Ortner (1984) for investigating possible cases of juvenile scurvy among archaeological populations. Examining the skull of a 3–4 year old individual from the Late Iron age/Early Roman period (ca. 100 B.C.–43 A.D.) site of Beckford in Worcestershire, England, Roberts (1987) identified a series of lesions correlating with a probable diagnosis of juvenile scurvy. The individual in question exhibited subperiosteal new bone which had formed in an irregular trabecular pattern predominantly along the anterior portion of the orbital roofs (Roberts 1987: 14). Porosity was also observed around the pyriform aperture on the medial aspect of both mandibular rami, close to the mandibular foramina (Roberts 1987: 14). Two small lesions of new bone formation were also identified above rdm^2 and on the medial aspect of the mid-shaft on the left tibia (Roberts 1987: 14). The lesions identified by Roberts (1987) correlate strongly with those identified by Ortner (1984).

Schultz (1989) presents data on sub-adult pathologies identified among the populations of five Bronze Age sites from Central Europe and Anatolia (modern day Turkey). Of these five sites the infants from Ikiztepe (ca. 2500–2300 BCE) in Anatolia and Franzhausen I (ca. 2200–1900 BCE) in Lower Austria are of the most value to the current study. From the Ikiztepe population Schultz identified that 13.8% (17/123) of infants examined exhibited signs consistent with the presence of scurvy, though Schultz provides no criteria for how scurvy was identified, while 6.4% (7/110) of infants examined from Franzhausen I exhibited signs of scurvy (Schultz 1989: 178). Schultz also noted that 79.5% (31/39) of the children at Ikiztepe and 40.0% (4/10) of the children from Franzhausen I exhibited transverse radiopaque bands (Schultz 1989: 178). Though not necessarily a direct result of scurvy, as radiopaque transverse bands have highly varied aetiologies, it is not unlikely that the formation of such radiopaque transverse bands could have been associated with scurvy. Schultz further discusses the identification of stomatitis[5] among the populations examined, identifying 15.6% (10/64) of the infants from Ikiztepe and 10.5% (6/57) of infants from Franzhausen I as having had stomatitis (Schultz 1989: 178–179). Schultz details that in general stomatitis is caused by either scurvy or parodontopathy[6], and that considering the level of scurvy observed among the individuals of these two populations it is probable that scurvy was the cause of the stomatitis observed (Schutz 1989: 179).

Mogle and Zias (1995) provide an interesting investigation of what they believe was the use of trephination as a mechanism for treating scurvy. The skull in question is of an 8–9 year old individual from the Bronze Age (ca. 2200 BCE),

[5] Stomatitis refers to an inflammation of the oral tissues.

[6] Parodontopathy refers to a periodontal disorder characterized by inflammation of the gums, alveolar resorption and degeneration of the periodontal membrane.

the context of recovery is unspecified but is believed to be from somewhere in Israel (Mogle and Zias 1995: 77). The skull exhibits multiple penetrating cortical defects and cavitating destructive bilateral lesions along the orbital roofs, which are more commonly associated with cases of anemia than juvenile scurvy (Mogle and Zias 1995: 77). The proposed basis of using trephination to treat scurvy is that trepanning the skull would allow for the excess build up of blood in the region to drain and thus hopefully relieve the pain of scurvy (Mogle and Zias 1995: 80). Mogle and Zias (1995) also propose that juvenile scurvy was present in the individual in question based on the edentulous nature of the mandible. However it is not clear that the mandible in question actually belongs with the skull under investigation, for it appears, based on the illustration used, to belong to an older individual than that of the trepanned skull. Though dental changes associated with scurvy are well known tooth loss to the extent proposed by Mogle and Zias (1995), where complete resorption has occurred in what is proposed as the mandible of an 8–9 year old individual, is not commonly observed.

The claimed trephination in question was elliptical in shape and was located essentially at bregma, crossing the sagittal suture and abutting the coronal suture (Mogle and Zias 1995: 77). The trephination in question is not smooth or complete having jagged edges with a flat edge termination at the coronal suture (Mogle and Zias 1995: 78, fig. 1). The trephination shows no signs of healing, either macroscopically or radiographically. It is likely that the individual in question did not survive more than a few days after the trephination was attempted (Mogle and Zias 1995). Mogle and Zias suggest that with the placement of the trephination at bregma crossing the sagittal suture it is unlikely that an individual would survive very long as there is high potential for great blood lose due to the close proximity of the meningeal arteries in this area and a high likelihood of puncturing through into the sagittal sinus, which would likely lead to infection and subsequently death (1995: 79). Though it is possible that this is a trephination used to treat scurvy there also remains the potential differential diagnosis of a developmental error such as meningocoele (Garvie-Lok 2008: pers. comm.; Webb and Thorne 1985; Warkany 1971). Such a differential diagnosis may be further suggested by the noticeable lack of scratch marks on the "trepanned" skull in question (Mogle and Zias 1995: fig. 1). Though Mogle and Zias make an interesting argument, the data presented seem questionable with regards to a diagnosis of scurvy.

A small number of juvenile individuals from two Neolithic period excavations in Germany were identified, based on the material of Schultz (1988a, 1990), as having lesions consistent with juvenile scurvy. The individuals examined were from Aiterhofen, where 6.7% of the study sample exhibited lesions consistent with juvenile scurvy, and Wandersleben, where 40% of the study sample exhibited lesions consistent with scurvy (Carli-Thiele 1996: 195; Carli-Thiele 1995: 88). Of the individuals examined at Wandersleben 85% exhibited inflammatory changes in the nasal cavity, paranasal sinuses, middle ear, hard palate, and/or venous sinuses of the brain (Carli–Thiele 1996: 195–196). Subperiosteal hemorrhages along the femur, tibia, and humerus were also represented, with such hemorrhages being more frequently observed in the lower limb bones, likely due to the increased weight placed on these bones compared to the upper limb bones (Carli-Thiele 1996: 195). Hemorrhagic processes in conjunction with inflammatory processes within the middle cranial fossa region were also observed (Carli-Thiele 1996: 196). Assessment of the state of scurvy was somewhat hindered in this particular analysis due to the poor state of skeletal preservation (Carli-Thiele 1996: 195).

Malgosa et al. (1996) examined the remains of four pathological skeletal elements belonging to at least two newborn children, 0–6 months of age, from 16th century A.D. Huelva, Spain. Malgosa et al. (1996) noted several bones that exhibited a raised cortical surface that potentially could indicate the presence of scurvy. However specific criteria for assessing scurvy is not provided. Though scurvy does not usually manifest in children under the age of 6 months the lesions identified in the metaphyseal region of the individual in question suggested a possible diagnosis as such (Malgosa et al. 1996). To account for the young age of the individual Malgosa suggests that if this were to have been a case of scurvy it could have occurred in conjunction with the presence of some other sort of pathology, which may account for the relatively early age of onset (Malgosa et al. 1996: 393).

From excavations at the ca. 1100–1250 C.E. site of ‘Atele, Tonga Buckley (2000) identified a number of sub-adults that exhibited signs of juvenile scurvy based on the identification of the Ortner et al. suite of lesions. Both active and healing examples of proposed juvenile scurvy were identified with the most common lesions identified being woven new bone formation, hypervascular subperiosteal new bone with diffuse pitting, cortical thinning, as observed radiographically, and enlarged foramina on the limbs of one individual, which may suggest hemorrhaging due to scurvy (Buckley 2000: table 8). Cribra orbitalia was also identified. However there was no accompanying porotic hyperostosis of the cranial vault (Buckley 2000: 483). Several individuals also exhibited new bone formation on the endocranial surface of the parietals, frontal, and temporals (Buckley 2000: 484). Buckley suggests that such lesions are a result of hemorrhaging due to trauma, mechanical stress, and movement of the eyes, all of which may be associated with the presence of juvenile scurvy (Buckley 2000: 495).

In discussing the various pathologies identified among the crew of the *Mary Rose* Stirland (2000:93) suggests that the presence of orbital porosity as well as ossified hemorrhages along the shaft of the long bones may be evidence that several of the adult crew suffered from scurvy as children. An important point that Stirland makes is the difficulty of distinguishing metabolic disorders, stressing that it is unlikely that scurvy occurred in isolation. Rather it is likely that scurvy occurred along with other metabolic disorders such as rickets and anemia, as well as pathologies such as infection (2000: 95).

From a 4th c. C.E. ossuary recovered inside a basilica at the Roman villa site of Monte da Cegonha in Vidigueira, Portugal Ferreira (2002) identified one sub-adult individual approximately 1 year ± 4 months of age who exhibited porous lesions proposed as being characteristic of juvenile scurvy in accordance with the data presented by Ortner and Ericksen (1997). The individual in question exhibited cranial and scapular porosity consistent with the Ortner et al. suite of lesions, while no further post-cranial lesions consistent with scurvy were identified (Ferreira 2002). Ferreira goes on to discuss the likelihood of other pathologies such as anemia and rickets being present with scurvy, explaining how despite the common occurrence of all three of these pathologies the specific lesions identified from the sub-adult in question are highly indicative of juvenile scurvy, while evidence of anemia and rickets in this particular case is lacking (Ferreira 2002: 62).

Bourbou (2003a, 2003b) discusses two potential cases of juvenile scurvy identified among the burials from the proto-Byzantine Basilica (ca. 430–668 AD), at Eleutherna, Crete. These were identified from organized periosteal lesions on the cranium, mandible, and long bones in accordance with the Ortner et al. suite of lesions (Bourbou 2003: 306; Ortner et al. 2001, 1999; Ortner and Ericksen 1997; Ortner 1984). One individual, approximately four years old, exhibited porous new bone on the anterior aspect of the orbits, as well as along the frontal, and to a lesser extent along the temporals, occipital, and the medial surface of the coronoid process of the mandible, while the left tibia exhibited signs of hematoma in the metaphyseal region, which may or may not have been due to scurvy (Bourbou 2003b: 108). Bourbou (2003a: 306) suggests that if anemia, infection, rickets, and other inflammatory disorders can be excluded the likely cause of the lesions observed is juvenile scurvy. Despite the relative abundance of high content vitamin C foods on Crete Bourbou (2003b: 111) explains how frequent natural disasters, particularly earthquakes, may have caused site abandonment and crop failure, which subsequently may have lead to the development of scurvy within this population.

Melikian and Waldron (2003) examined 123 well preserved sub-adult skeletons from Romano-British Poundbury and Medieval Abingdon cemetery as well 19 sub-adult skulls of unknown provenance from the Natural History Museum, London in an attempt to compare observations with the suite of scorbutic lesions proposed by Ortner et al. (1999). To compare findings Melikian and Waldron (2003) used four curated skulls of children known to have suffered from scurvy during their lifetime. From their observations Melikian and Waldron (2003) assert that the roof of the orbit, the cranial vault, and the greater wing of the sphenoid are the most important sites of porous cranial lesion formation for identifying potential cases of juvenile scurvy. However Melikian and Waldron (2003) remain skeptical of the potential ability to identify archaeological cases of scurvy, largely dismissing the viability of the Ortner et al. suite of lesions, as the authors note that the porous lesions observed from the control individuals who were known to have suffered from scurvy do not correspond in any significant way to the proposed Ortner et al. suite of lesions. Melikian and Waldron stress that future investigations of archaeological cases of juvenile scurvy should seek to provide a more clinically validated basis of diagnosis.

Lewis (2004) presents a series of possible aetiologies for the presence of endocranial lesions, one possibility being that of vitamin C deficiency. The research presented was based on a study of 528 sub-adult individuals from four sites in England dating to the Medieval and post-Medieval period being Anglo-

Saxon Raunds Furnells, St. Helen-on-the-Walls, Wharram Percy, and Christ Church Spitalfields (Lewis 2004). From the 528 individuals examined 64 presented with endocranial lesions (Lewis 2004: 93). From this sample only 6% (4/64) of the individuals examined presented endocranial lesions in connection with osteological evidence of rickets or scurvy (Lewis 2004: 93). While this suggests that endocranial lesions are a relatively rare occurrence in vitamin deficiencies, the presence of such lesions among proposed scorbutic individuals does attest to the possibility of endocranial lesions being associated with scurvy (Lewis 2004).

The Final Greek Neolithic phase site of Alepotrypa Cave (ca. 5000–3200 B.C.E) yielded a series of sub-adult skeletal remains that exhibit porotic orbital lesions indicative of juvenile scurvy based on macroscopic examination (Papathanasiou 2005; Papathanassopoulos 1996). Several of the proposed cases of juvenile scurvy were observed in conjunction with similar porotic lesions and diploic expansion of the marrow cavity suggesting the possible co-occurrence of anemia in several of the potential juvenile scurvy cases. (Papathanasiou 2005). Unfortunately due to damage it was impossible to observe the greater wing of the sphenoid for porosity, thus one of classic Ortner et al. suite lesions of juvenile scurvy could not be confirmed or denied (Papathanasiou 2005: 387). Papathanasiou proposes that the increased development of juvenile scurvy, among various other pathologies, in the Alepotrypa Cave population corresponds with the transition to agriculture and thus the likely adoption of a nutritionally deficient diet, an occurrence that is commonly observed at the transition to agriculture in various world populations (Papathanasiou 2005: 388).

From the Postclassical/Historic Mayan sites of Marco Gonzalez and San Pedro in northern Belize, White et al. (2006: 37) examined 143 individuals, 97 of which were from Marco Gonzalez and 46 from San Pedro. From the sample examined White et al. (2006) identified a high incidence of cases of juvenile scurvy among these populations, ca. 58% based on the Ortner et al. criteria. Of the individuals examined 47% exhibited juvenile scurvy in combination with anemia (White et al. 2006: 37).

At the Bronze Age site of Barrow Clump in Wiltshire, England Mays (2008a) identified a two-year old child that he diagnosed as having juvenile scurvy based on the observation of abnormal cranial porosity consistent with the Ortner et al. suite of lesions as well as deposits of endocranial new bone (Lewis 2004; Ortner et al. 2001, 1999; Ortner and Ericksen 1997; Ortner 1984) Postcranial preservation of this individual was poor with the only evidence of abnormality being the deposition of woven bone on the medial surface of the shaft of the left tibia (Mays 2008a: 180).

From the pre-Columbian site of Grasshopper Pueblo in Arizona Schultz et al. (2007) examined the skeletons of 369 infants and children. Macroscopic investigation of 260 suitable individuals identified 84 (32.3%) cases of sub-adult scurvy. Scurvy was identified based on porosity of the cranial vault, orbital roof, zygomaxillary area, and ramus and body of the mandible (Schultz et al. 2007: 372; Schultz 2001). Post-cranial remains were not examined. Schultz et al. (2007:

373) elaborate that in other pre-Columbian populations evidence of scurvy is not commonly observed to such a significant degree as that seen among the individuals from Grasshopper Pueblo. Regarding other pre-Columbian populations Schultz et al. (2007) state that scurvy was observed in only 7% (7/100) of individuals examined from Mogollon pueblo of Paa-ko, New Mexico, 6.7% (2/30) from the pre-Columbian North American Piedmont of the southeastern Mississippian culture, and 7.5% (3/40) from La Ventilla-B, an area of Teotihuacan, Mexico (Schultz and Schmidt-Schultz, in press). Schultz et al. (2007: 376) suggest that the high rate of scurvy observed at Grasshopper Pueblo was likely due to climate and political changes, namely migrations, which would have resulted in a lack of appropriate food resources.

From the Middle Byzantine (ca. 10th–11th c. C.E.) site of Xironomi in Boeotia, Greece Tritsaroli (2007) presents data on a series of sub-adult remains, ranging in age from birth to 12 years, that are proposed as having suffered from a nutritional deficiency such as scurvy or rickets or a combination of both based on the presence of abnormal bone formation. Tritsaroli (2007: 30) suggests that the sub-adults in question may have developed a disorder such as scurvy due to weaning stress and seasonal variability in crops. The concept of seasonal variability provides an excellent means for understanding potential cases of juvenile scurvy. Tritsaroli (2007: 30) discusses how in 927–928 C.E. there was 120 consecutive days of snow, while in 1037 C.E. there was unending rain. Both episodes are connected with crop failure and as Tritsaroli (2007: 30) suggests can be understood as likely mechanisms for causing nutritional disorders such as scurvy.

From the Medieval cemetery at Giecz, Poland Agnew et al (2008) describe a 5–6 year old individual whom they identified as exhibiting porous cranial and scapular lesions consistent with the Ortner et al. suite of lesions suggesting a probable diagnosis of juvenile scurvy. Agnew et al. (2008) also imply a connection between the presence of juvenile scurvy and the ante-mortem loss of both first deciduous mandibular molars. Agnew et al. (2008) propose that the case of juvenile scurvy presented was not likely severe in nature as only mild periostitis was identified among the post-cranial remains. The authors discuss the possibility that the sub-adult in question may have also suffered from other nutritional deficiencies though no specific evidence of other such deficiencies was identified.

From the post-medieval historic cemetery of St. James church in Clerkenwell, London Ives and Melikian (2009: 19) identified several juveniles who exhibited evidence of having suffered from scurvy. However Ives and Melikian (2009) do not provide any further specific information about the scorbutic lesions identified among the sub-adults from this particular site.

Conducting research as part of the Global History of Health Project, which was established as a large-scale project to investigate human health among European populations from between the late Paleolithic to the early 20th century CE, Brickley et al. (2009) identified a number of individuals who exhibited osteological evidence consistent with the Ortner et al. suite of lesions suggesting that the individuals in question suffered from scurvy. Of the sample examined 1.37% (147/10,724) of individuals exhibited evidence of having suffered from scurvy at some point in their lifetime. Of the sample examined 29 individuals exhibited evidence of having had both rickets and scurvy at some point in their lifetime. An interesting observation noted by this study is the steady increase of scorbutic indicators from the time of Classical Antiquity until the High Middle Ages after which time there is a noticeable decline in scorbutic symptoms during the Late Middle Ages (Brickley et al. 2009: 98).

2.4.3–Identifying Probable Cases of Juvenile Scurvy from Published Data

The research presented by Ortner et al. (2001, 1999; Ortner and Ericksen 1997; Ortner 1984) has drastically modified the ability to identify probable cases of juvenile scurvy among osteoarchaeological remains. Using the Ortner et al. suite of lesions it is possible to examine previously documented osteoarchaeological material for evidence of juvenile scurvy. The use of the Ortner et al. suite of lesions to identify probable cases of juvenile scurvy from previously published material is well illustrated by the cases of Anderson (1968) and Tyson and Alcauskas (1980).

Of the remains in the Hrdlicka palaeopathology collection curated at the San Diego Museum of Man, being predominantly from Peru and other South American regions and to a lesser extent from the United States, Europe, Africa and Asia, there are a number of sub-adult skulls, ranging in age from infant to ~12 years old that exhibit the distribution of porous lesions discussed by Ortner et al. (2001, 1999; Ortner and Ericksen 1997; Ortner 1984). Several skulls exhibit bilateral orbital porosity as well as marked porosity along the surface of the greater wing of the sphenoid (Tyson and Alcauskas 1980: 38–48). One individual of approximately 12 years of age exhibited endocranial lesions consistent with those presented by Lewis (2004). The assessments presented by Tyson and Alcauskas provide only limited diagnoses for the individuals described above, suggesting in most cases that the observation of cribra orbitalia and cribra cranii was most consistent with an aetiology of anemia. Though anemia may have been involved in the formation of the lesions observed there is also significant evidence to suggest a probable diagnosis of juvenile scurvy for several of these individuals based on the observation of the Ortner et al. suite of lesions.

A further example of how the Ortner et al. suite of lesions can be employed to identify probable cases of juvenile scurvy from previously published material is well illustrated by the work presented in Anderson (1968). From the osteoarchaeological remains of the Serpent Mounds site in Ontario, Canada Anderson (1968) identified a number of sub-adult individuals, ranging in age from ~2 years old to adolescent, who presented with areas of swollen porous spongy bone along the orbital roofs as well as porosity along the maxilla and greater wings of the sphenoid. Anderson (1968) attributes such pathological lesions to an aetiology of anemia. However considering the nature of these lesions in light of the Ortner et al. suite of lesions there is strong evidence to suggest a probable diagnosis of juvenile scurvy.

The skeletal material documented by Tyson and Alcauskas (1980) and Anderson (1968) provide excellent examples for demonstrating how the Ortner et al. suite of lesions can be employed to assess for the probable presence of juvenile scurvy among osteoarchaeological remains that were documented and published before it was common to examine for evidence of juvenile scurvy.

2.4.4–Assessing the Ortner et al. Suite of Lesions

Considering the cases of probable juvenile scurvy identified from archaeological remains a clear pattern can be observed. Regardless of location or time period the same pattern of porous lesions is continually represented in the individuals discussed. Such a similar pattern of lesions strongly indicates a common pathology among the individuals examined. The anatomical evidence correlating the muscles of mastication and the cranial vascular system with the causation of the noted lesions due to inflammation and hemorrhage provides an excellent mechanism for understanding the lesions observed as being the result of juvenile scurvy (see Section 2.3).

Observation of the noted porous cranial lesions in connection with evidence of subperiosteal hemorrhage and new bone formation further supports a diagnosis of juvenile scurvy based on the fact that subperiosteal hemorrhage along the juvenile long bones is a classic symptom of juvenile scurvy (Marcove and Arlen 1992: 92; Jaffe 1972: 458; Barlow 1894, 1893). Thus considering the lesions in question there is a significant basis on which to propose that such lesions are strongly indicative of an aetiology of scurvy. Further research and continued vigilance is undoubtedly the key to gaining more accurate and better insights into the presence of juvenile scurvy among osteoarchaeological remains.

2.5–The Difficulty of Assessing Archaeological Cases of Scurvy

Until relatively recently the investigation of juvenile scurvy from archaeological remains had been negligible, with the majority of human remains which exhibited porous lesions, particularly in the orbits, being attributed to anemia, predominantly iron deficiency anemia. Though anemia likely occurred frequently among individuals of the past it is not necessarily the sole disease that leaves porous lesions in the orbits and elsewhere on the skull. It was with the publication of Ortner (1984) that one of the fist attempts to identify juvenile scurvy from an archaeological individual was made. However it was not until the publication of Ortner and Ericksen (1997) that the true need for a more thorough scrutiny of porous lesions was presented. It was the impetus of this 1997 work that asserted the need to establish and be able to distinguish between the aetiologies of porous lesions. The following material will seek to briefly outline a basis for differentiating the porous lesions observed in cases of rickets and anemia from those observed in probable cases of juvenile scurvy.

2.5.1–Differentiating the Osteological Signs of Scurvy, Anemia and Rickets

2.5.1.1–Co-Occurrence of Pathologies

One of the main concerns in establishing a paleopathological diagnosis is the issue of co-morbidity. Investigations have shown that deficiency disorders typically do not occur in isolation, but rather often involve a combination of co-occurring disorders (Shamsaddini et al. 2001; Buckley 2000; Ortner et al. 1999; Gestsdottir 1998). This is to say that an individual is not likely to have a diet devoid of simply one vitamin or mineral leading to a singular deficiency disorder, but rather the individual with a deficient diet is likely to have several vitamins and minerals missing leading to the onset of more than one deficiency disorder (Brickley et al. 2009; Buckley 2000; Ortner et al. 1999; Ortner and Mays 1998; Carli-Thiele 1996; Carli-Thiele 1995). In the case of juvenile scurvy it is not uncommon for anemia to co-occur based on the need of ascorbic acid for effective absorption of iron (Allen et al. 2006; Fain 2005; Pimentel 2003; Carli-Thiele 1996; Gabay et al. 1993; Baynes and Brothwell 1990; Hallberg et al. 1989; Chazan and Mistilis 1963). Several researchers have indicated that in as many as 75% of cases of scurvy anemia co-occurs, typically normochromic-normocytic anemia due to blood loss from hemorrhaging (Ho et al. 2007; Fain 2005; Shamsaddini et al. 2001; Gabay 1993; Chazan and Mistilis 1963). It is not only iron deficiency anemia that may occur with juvenile scurvy but rather several varieties including megaloblastic and post-hemorrhagic anemia, among others, may also occur due to the effect of vitamin C on blood formation as well as potentially due to hemorrhaging and infection (Walker et al. 2009; Paine et al. 2007; Wapler et al. 2004; Schultz 2001; WHO 1999; Baynes and Brothwell 1990; Palkovich 1987; Walker 1986; Mensforth et al. 1978; Lallo et al. 1977; El-Najjar and Robertson 1976; El-Najjar et al. 1975; Carlson et al. 1974; Angel 1966).

A further deficiency disorder that is commonly observed with cases of juvenile scurvy is that of rickets, which is a disorder caused by a deficiency of vitamin D (Brickley et al. 2009; Fain 2005; Ortner et al. 1999).

Along with deficiency disorders alternate pathologies such as the presence of infection must also be considered (Schultz 2001; Brickley 2008). It is often highly difficult to predict the type of pathological lesions that will be left by any combination of illnesses (Waldron 2007; Hengen 1970). As a result of the relatively high rate of co-occurring disorders examination and thorough description of all skeletal elements in a paleopathological assessment is of great importance. One method of differentiating lesions that has been increasingly useful in recent years is that of histology. By examining the cross-section of a skeletal element it is significantly easier to provide a distinction between different deficiency disorders based on lesion formation and affects on the bone (Wapler et al. 2004; Schultz 2001). Though histology will not be addressed in the present work it is nonetheless a method of analysis that has excellent potential for providing increasingly accurate diagnoses of paleopathologies

2.5.1.2–Anemia

One of the main concerns in distinguishing scurvy from anemia is the proper identification of the mechanism that lead to the formation of porous lesions in the orbits. In cases of scurvy the bony lesions identified in the orbits are the result of hemorrhaging leading to osteoblastic reaction and thus irregular new bone formation (Brickley and Ives 2006: 166). In the case of anemia where cribra orbitalia and associated porotic hyperostosis are present it is resorptive action that is the key to understanding these lesions (Salvadei et al. 2001; Huss-Ashmore et al. 1982; Hengen 1970). In anemia hyperplasia of the marrow cavity leads to an expansion of the diploë of the skull which causes progressive diminution of the outer table of the skull resulting in exposure of the underlying trabecular bone (Ortner 2003: 375; Nathan 1966).

Looking at the distribution of porotic hyperostosis along the skull the lesions of anemia typically affect different areas from those proposed as being due to the presence of scurvy. Porotic hyperostosis along the skull usually occurs to the most significant degree along the superior portion of the orbits, the forehead portion of the frontal, and above the temporal line along the parietals (Huss-Ashmore et al. 1982: 414). Whereas lesions proposed as being the result of scurvy are due to inflammation and hemorrhage along the cranial bones likely as a result of mechanical stress and trauma (Ortner et al. 2001, 1999; Ortner and Ericksen 1997; Brickley and Ives 2006). As such when examining paleopathological remains based on cranial lesions caution must be exercised and the mechanisms of lesion formation as well as lesion distribution must always be considered. One particularly useful mechanism that can help to distinguish the lesions of anemia from scurvy is that of radiography. Anemia can be identified radiographically from a series of pathognomonic skeletal alterations, namely the "hair-on-end" appearance, noticeable depletion of the outer table, and expansion of the marrow cavity of the diploë, all of which are strongly indicative of anemia, particularly in combination with one another, but are absent in scurvy (Stuart-Macadam 1987, 1989; El-Najjar and Robertson 1976; Moseley 1974, 1963).

Manifestations of anemia in the postcranial remains are typically limited and relatively none diagnostic, with osteoporosis and coarse trabeculae striations being potential indicators (Stuart-Macadam 1989). It is important that the lesions of anemia be properly diagnosed so as not to bias the representation of one disorder over another among osteoarchaeological remains.

2.5.1.3–Rickets

Osteological changes due to rickets can be easily identified from the long bones of the skeleton where unmineralized osteoid leads to a mechanical weakening of the bones which often leads to subsequent bowing of the limbs, a symptom that is pathognomonic of rickets (Brickley et al. 2009; Ortner and Mays 1998). However in the instance where postcranial remains are not present there remains a series of porous cranial lesions that potentially could be confused with scurvy, as such it is important that a proper distinction be made.

Unmineralized osteoid does not preserve archaeologically, however the presence of unmineralized osteoid leads to pores and other defects in the bone that will preserve archaeologically (Ortner and Mays 1998: 52–53). Porous lesions are commonly identifiable along the orbital roofs and outer table of the cranium, including the zygomatic and temporal bones (Ortner and Mays 1998). Further examining the orbital lesions it is apparent that such lesions in rickets are typically superficially porous, unlike the porous lesions observed in juvenile scurvy (Mays 2008a; Brickley and Ives 2006; Ortner and Mays 1998).

One mechanism that can be used to separate rickets from scurvy in juvenile individuals is the presence of craniotabes (Ortner 2003). Craniotabes is essentially an underformation or softening of the cranial bones of the juvenile, which is most commonly noticeable along the posterio-lateral segments of the parietals and along the squama of the occipital (Ortner 2003: 394). Craniotabes is caused by the rapid growth of the juvenile where mineralized bone is replaced by osteoid, which in a rachitic individual fails to mineralize thus accounting for the thinness and soft nature of the bones (Ortner 2003). In the developing juvenile rickets tends to lead to obliteration of the tables of the skull, both inner and outer, with the outer typically being more severe (Ortner 2003). This obliteration of the cranial tables leads to a porous diploë like appearance of the cranial bones that often appears similar to the cranial changes observed in anemia, except for the obliteration of the inner table of the skull, which is not commonly seen in cases of anemia (Ortner 2003).

Furthermore with relation to ageing and cranial development, the presence of rickets tends to delay the closure of the fontanelles (Ortner 2003). Though delayed fontanelle closure can occur for a number of reasons if present with the type of lesions discussed this may aid in establishing a diagnosis of rickets over another disorder (Ortner 2003).

A last alteration to the skull that may be present in cases of rickets is the inward angling of the skull around the foramen magnum due to the weight of the skull and the weakness of the rachitic bone (Ortner 2003).

The cranial changes observed in cases of rickets manifest several porous lesions that may be mistaken for juvenile scurvy, however with careful examination and proper identification of the distribution and type of lesions it should be possible to distinguish the lesions associated with juvenile scurvy from those of rickets (Brickley et al. 2009).

2.6–Summary

Chapter 2 has examined the clinical, both macroscopic and radiographic, material regarding the development and effects of scurvy on the body. Utilizing this clinical research this chapter has also addressed the proposed osteological lesion criteria presented by Ortner et al. (2001, 1999; Ortner and Ericksen 1997; Ortner 1984), herein referred to as the Ortner et al. suite of lesions, for diagnosing probable cases of juvenile scurvy among archaeological populations. This chapter also examined how the introduction of the Ortner et al. suite of lesions has drastically altered the investigation of juvenile scurvy among archaeological populations, developing from a relative dearth before the work of Ortner (1984) and increasing steadily in investigation into the present day. The final section of this chapter examined the difficulty and means of distinguishing between cases of juvenile scurvy, rickets and anemia and the possible co-occurrence of these disorders. Chapter 2 has thus established the clinical and osteoarchaeological basis upon which juvenile scurvy can and has been investigated archaeologically.

Chapter 3–Cultural Background to Diet

Scurvy is a direct result of diet and the provision of foodstuffs. The role of diet in scurvy is particularly important when considering the development of this disorder among children who are dependent on others to provide appropriate nourishment. The following sections will examine how diet, staple foods and prescribed infant feeding practices during the late Roman-Byzantine period would have been significant factors in the development of juvenile scurvy among sub-adults of this era.

3.1–History of the Late Roman-Byzantine Empire

By the 3rd century CE, Rome's power over its extensive territory was beginning to falter as it came under increasingly frequent attacks from rival groups, leading to a power struggle for territory (Mackay 2004; Garnsey 1999; Grant 1998; Ostrogosky 1969; Thorndike 1956). As a result of the difficulty of maintaining the large territory held under Roman control, Diocletian in the late 3rd century CE divided the Empire into east and west, appointing Maximian as co-emperor in 285 CE to maintain the western half of the empire, while Diocletian would maintain the eastern part of the Empire (Mackay 2004; Hussey 1957). This division of power was one of the first signs of the Roman Empire's inability to maintain itself, ultimately leading to the demise of the western Roman Empire in 476 CE (Grant 1998). Though the western Empire fell the eastern Empire continued to grow in strength and would ultimately be transformed into the Byzantine Empire, seeing the Roman capital moved from Rome to Byzantium.[1] The Byzantine Empire thrived, adopting Christianity as its credo, and over time developed into one of the main centers of trade and culture in the ancient world (Gregory 2005; Bintliff 1996; Foss 1995; Thorndike 1956).

Despite the relative prosperity of the Byzantine Empire there continued to be highs and lows throughout its history. Continual efforts to expand the Empire eventually resulted in weakness and instability of the frontier territories. Greece was one such Byzantine territory that was weakened by the growing size of the Empire. During the 6th century CE rising Slavic powers began to capture and hold Byzantine territory in Greece, including the Peloponesse where Nemea, in a valley adjacent to Stymphalos, is known to have been significantly damaged and ultimately abandoned (Miller et al. 2001; Charanis 1973).

By the 8th century CE Byzantine products were in high demand and Byzantium had become a major transshipment location, leading to increasing contact with western European (Frankish) groups (Bass and van Doornick 1978; Kazhdan and Epstein 1985). Byzantine prosperity continued to increase to the point that Byzantium was the richest and most cultured state of the West by 1000 CE (Lock 1995: 2; Charanis 1973). At this high point of the Empire Byzantine territory extended from the Araxes River in eastern Turkey to the river Volturno near Capua, Italy, and from the Crimea to the river Yarmuk south of the sea of Galilee, including the islands of Crete and Cyprus (Lock 1995: 3). Despite such prosperity the power of the Empire continued to decline, leading to ever

[1] Byzantium was renamed Constantinople after the death of Constantine I and was again renamed Istanbul after the Ottoman conquest of Constantinople in 1453 CE (Lock 1995; Babinger 1978).

increasing reliance on the Frankish groups for both trade and support. This decline eventually resulted in the staging of the Fourth Crusade, which saw the siege of Constantinople under the Franks in 1204 CE (Lock 2006; Angold 1997; Lock 1995; Ostrogosky 1969; Thorndike 1956). Following the siege of Constantinople in 1204 CE the Byzantine Empire continued to decline, to such an extent that Lock (1995: 3) refers to the Byzantine empire in the 13th century CE as the "sick man of Europe."

Prior to the Fourth Crusade the majority of Greek territory had been under Byzantine control (Miller 1908). Following the conquest of Constantinople in 1204 CE the victorious Crusaders established guidelines for partitioning Byzantine territory into various dominions to be ruled by Frankish feudal lords as part of what would come to be known as the Latin Empire (Lock 1995; Miller 1908).

Despite the advent of Frankish dominion regions formerly controlled by the Byzantine Empire did not automatically submit to Frankish control. The Peloponesse was one such area. Beginning in 1205 CE a combine Frankish force under the leadership of Geoffrey de Villehardouin and Guillaume de Champlitte, who would become the Prince of Achaia, captured the northern part of the Peloponesse in what is commonly referred to as the conquest of the Morea (Lock 1995; Schmitt 1967; Miller 1908). This conquest placed the region of Arcadia, in which Stymphalos and Zaraka are located, under Frankish control (Lock 1995; Schmitt 1967; Miller 1908). Frankish control of Greece continued to be heavily contested by various factions, both Greek and foreign, making Frankish rule of this region highly volatile and fragmented.

The Latin Empire of Constantinople continued to claim control over all of Romania,[2] however this control was largely theoretical seeing many of the Aegean states maintain autonomous rule (Lock 1995). The Latin Empire of Constantinople was weakened due to continual conflict with Greek and Bulgarian states and eventually fell to the Empire of Nicaea on July 25, 1261 CE during the reign of the Byzantine Emperor Michael VIII Palaiologos. (Lock 1995: 6; Panagopoulos 1979; Ostrogorsky 1969; Brown 1958; Hussey 1957). In the Peloponesse from 1316–1321 CE Greeks from Mistra took the castle of Akova, occupied and destroyed lands in the Morea, and laid siege to the castle of St. George in Skorta (Lock 1995: 6). In 1388 CE the castles at Nauplia and Argos in the Frankish principality of Achaia were lost to the Greeks of Mistra, while Patras, the last outpost of the Frankish Morea, remained under Frankish control until it was taken by the Greek despot of the Morea in 1430 C.E. (Lock 1995). The lands of the Morea continued to be contested after 1430 C.E. by Catalan, Greek and Turkish raiders, placing the territories of the Peloponesse in a weakened state (Lock 1995).

The final demise of the Byzantine Empire was realized in 1453 CE when, under the leadership of the Ottoman Sultan Mehmed II, Constantinople was invaded and captured, effectively ending the reign of the Byzantine Empire and ushering in the new Ottoman Empire (Babinger 1978).

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[2] Romania was a geographical term used to refer to the regions of the Aegean during the 13th and 14th centuries (Lock 1995: 6).

3.2–Late Roman-Byzantine Diet

The foods that were most frequently consumed during the late Roman-Byzantine period often reflect choices that would have been low in vitamin C content, such as grains. Individuals consuming such foods as dietary staples would run the risk of developing scurvy, particularly in the case of children. It is with regards to food choices that the investigation of late Roman-Byzantine dietary practices provided below is important for understanding the occurrence of cases of juvenile scurvy during this time period in Greece.

3.2.1–Primary Elements of the Late Roman–Byzantine Diet

Staple foods during the Late Roman–Byzantine period consisted of a variety of grains, legumes, vegetables, olives and olive products, wild greens, fruits, and to a lesser extent marine and animal resources (Bourbou and Richards 2007; Rautman 2006; Garnsey 1999).

Based on the ancient works of authors such as Pliny (1938), Galen (Powell 2003), Cato (1934), Varro (1934) and Columella (1941), among others, it is apparent that the diet consisted predominantly of grain based products, namely various types of bread, porridge, *trachanas*[3], and legumes, while marine and meat resources were eaten on a less frequent basis, particularly by non-elite classes of society (Bourbou and Richards 2007; Rautman 2006; Garnsey 1999).

Regarding the recording of dietary practices it is somewhat difficult to assess the diets of non-elite individuals as written texts of the period typically reflect the practices of the elite classes (Nielsen 1998). Though text based

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[3] According to Bourbou and Richards (2007: 65) *trachanas* was produced by stirring milk, cheese, and grain together in hot water. This food is noted as being particularly important to shepards and soldiers.

descriptions of diets for the period in question typically focus on the elite, modern isotopic research has helped to provide insights to the diets of non-elite and rural archaeological populations (Pennycook 2008b; Bourbou and Richards 2007; Garvie-Lok 2001).

The following sections will discuss in detail the various foodstuffs that comprised the predominant dietary items of the late Roman–Byzantine period. These sections will seek to provide the relative vitamin C content of the foods consumed and will provide evidence to suggest that the foods consumed were typically poor in vitamin C content and would have posed a dietary risk to the individual of developing scurvy.

3.2.2–Grains

Grains were by far the most widely utilized dietary element during the late Roman–Byzantine period. Grains acted as a staple food for all elements of society, though reliance on grains was even more pronounced among rural groups and the poor. Grains typically would have been consumed as bread (*psomi/sitos*), flat cakes and porridge, seeing use in some form during almost every meal (Megaloudi 2006; Braun 1996; Garnsey 1999; Foxhall and Forbes 1982; Teall 1959). By the Medieval period in Greece the reliance on grain-based foods represented approximately 20%–45% of the average diet, which could have provided as much as 70%–75% of caloric intake (Foxhall and Forbes 1982).

3.2.2.1–Types of Grains

Looking at the types of grains utilized in Greece in antiquity there are four main varieties, being wheat, barley, millet and emmer/einkorn, and to a significantly lesser extent rice (Adamson 2004; Braun 1996; Powell 2003: 57, 1.17; Garnsey 1999; Dalby 1996; Garnsey 1988; Teall 1959).

Historical evidence indicates that it was wheat and barley that were the two predominantly consumed grains, while the role of millet and emmer/einkorn remains largely ambiguous. Regardless of preference there is significant evidence supporting the use of all of these varieties of grains in antiquity (Faas 2003; Pliny 1938: 18.14; Celsus 1935: 2.18.4).

3.2.2.2–Ancient Authors on the Use of Grains

Attitudes towards the use of grains in antiquity can be ascertained from the works of ancient authors. It is clear from many of the ancient authors that grain based foods, bread in particular, were esteemed as one of the best sources of nutrition. Celsus (1935: 2.18.4) in *De Medicina* claims that there is more nutriment in bread than in anything else, further explaining that wheat is better than millet, while millet is better than barley, essentially establishing a hierarchy of value for various types of grain.

This notion of the superiority of wheat over barley is supported by many of the ancient authors. In Columella (1941: 2.6–7) and Pliny (1938: 18.14–19) there is discussion of how wheat is the highest of grains, typically seeing fine wheat bread being eaten only by the upper classes, while barley is described as being best suited for animal fodder, only to be used by humans when wheat is not available (Braun 1996; Garnsey 1988; Varro 1934: 2.2.13). Despite such claims it is also known that due to the increased cost of wheat over barely many of the lower classes of society, as well as soldiers, would have consumed barley on a regular basis (Powell 2003: 47, 1.9; Choniates 1984: 264, 305; Leutsch and Schneidewin 1839: *Zenobius* 1.12). Both the Prodromic Poems (Prodromic Poem II: 147–197, cited in Garvie-Lok 2001) and the work of Niketas Choniates (Choniates 1984: 452, 495, 635) note that bread was a necessity of life and the basic food of the humble and poor. Hippocrates, in *Regimen in Acute Disease* (Chadwick and Mann 1950: 14), says that barley gruel is smooth, consistent and soothing, being slippery and soft, thirst quenching and easily expelled, in cases where expulsion is necessary, further noting that barley gruel does not cause constipation nor does it swell the stomach, making barley a well-suited food (Chadwick and Mann 1950: 130).

The use of millet in antiquity remains largely ambiguous. From the work of Cato (1934: 1.6–7), Columella (1941: 2.9.17–19), Theophrastus (1916) and Pliny (1938: 18: 24–26), among other authors, it is clear that millet was cultivated and depended upon as a food source to a significant degree in the Eastern Mediterranean, however both Galen and Simeon Seth suggest that millet should only be consumed when more satisfactory grains are not available (Powell 2003: 57, I.15; Teall 1959: 99). Though it is possible that millet was frequently used in late Roman-Byzantine Greece the isotopic research presented by Pennycook (2008b: 176) suggests that millet did not contribute significantly to diets at Stymphalos and Zaraka.

Dioscorides in *De Materia Medica* places the value of emmer over that of barley, indicating that emmer is more wholesome and nourishing than barley, but less nourishing than wheat when made into bread (Powell 2003: 54, 1.13).

Mnesitheos (Powell 2003: 52–53) states that eating bread of einkorn and emmer, even in large quantities, provides very little nourishment and that it is utilized mainly because of its ability to survive cold weather and grow in inhospitable regions, thus making it abundant but not particularly nutritious.

Regarding rice it is clear that this grain was not used extensively and should not be considered a dietary staple. Galen in *On the Properties of Foodstuffs* suggests that rice is useful for restraining the stomach but as a dietary grain compared to wheat is hard to digest, less nourishing, and overall less pleasant to consume (Powell 2003: 57, 1.17).

3.2.2.3–Vitamin C Content of Grains

Grains, including wheat, barley, millet and rice, offer no vitamin C (USDA 2006). If these foodstuffs were to provide the primary source of nutrition for an individual, without significant further supplementation of vitamin C, it is highly likely that the individual would eventually suffer from scurvy.

3.2.3–Legumes

The role of legumes in late Roman–Byzantine diets remains uncertain. Historical and paleobotanical evidence suggest that a large variety of legumes, namely varieties of vetch, peas, beans and lupins, were widely cultivated in Greece during this time period (Powell 2003: 57–67; Garvie-Lok 2001; Dembinska 1985; Celsus 1935: 2.18.5; Cato 1934: 1.34-37; Columella 1941: 2.7; Pliny 1938: 18.30-32; Varro 1934: 1.32). The ambiguity of legumes in diets of this era lies in the fact that legumes were often used for animal fodder, crop fertilization and their superior soil enrichment properties; as well, some have suggested that legumes were grown as an export crop (Megaloudi 2006: 52; Powell 2003: 68, 1.36; Sarpaki 1992; Sallares 1991; Laiou-Thomadakis 1980; Teall 1959; Columella 1941: 2.10.7, 24; Pliny 1938:18.36).

Several authors have suggested that the legumes were a less important source of nutrition than grains, with some suggesting that legumes may have been consumed primarily by the lower classes or only during times of famine or crop failure, seeing them as the "poor man's meat" (Powell 2003: 68, 1.36; Garnsey 1999; Sarpaki 1992; Columella 1941: 2.10.24; Pliny 1938: 13.36). The statement that legumes were the "poor man's meat" refers to the belief of various scholars that legumes were consumed frequently and in significant quantities by lower classes of society, as legumes were an affordable and excellent source of protein and as such are believed to have contributed significantly to the diet of lower classes of society during the late Roman–Byzantine era (Powell 2003: 57–70, I.18–37; Garnsey 1999; Dalby 1996; Sarpaki 1992; Sallares 1991; Table 3.2). Faas (2003) suggests that all levels of society likely consumed legumes to some degree, as there are a series of Roman recipes that call for legumes along side wild game and exotic spices, foods that were typically only available to the upper echelons of society.

Based on the prevalent discussion of legumes in the works of authors such as Columella (1941), Varro (1934), Pliny (1938), and Galen (Powell 2003) it appears most likely that legumes did in fact serve as a typical dietary element for a large component of late Roman-Byzantine society, particularly the lower and rural classes.

3.2.3.1–Vitamin C Content of Legumes

There is a relatively minor amount of vitamin C in legumes (Table 3.1). The vitamin C content provided by legumes could contribute to the recommended daily intake (RNI) of vitamin C but is unlikely to provide enough vitamin C to fulfill the required daily intake, as this would require consumption of approximately 560–2270g of legumes per day based on the RNI of 25 mg/day for a 0–6 month old individual, and an even larger amount for older individuals (USDA 2006; WHO/FAO 2004: table 7.1). Thus if legumes along with grains were to comprise the main dietary staples without further vitamin C supplementation it is likely that scurvy would develop.

Table 3.1–Vitamin C Content of Legumes

Legume	Vitamin C Content
Beans	~1.1 mg/100g
Chick Peas, raw	4.0 mg/100g
Chick Peas, boiled	1.3 mg/100g
Lentils, raw	4.4 mg/100g
Lentils, boiled	1.5 mg/100g
Lupins, raw	4.8 mg/100g
Lupins, boiled	1.1 mg/100g

Vitamin C content of legumes. Values provided in this table are derived from USDA (2006).

3.2.4–Olives, Olive Oil and Wine

Throughout the works of antiquity there are extensive references to the use of olives, olive oil and wine establishing that these items were used in significant quantities in the diets of the late Roman–Byzantine period (Matelas 2006; Elliot 2003; Faas 2003; Columella 1941: 5.8–9; Pliny 1938: 15.3–6; Cato 1934: 64–69, 144–146; Varro 1934: 1.55). Jeanselme and Oeconomos (1923) support the concept of widespread use of olives and olive oil by all classes of society by stating that olive oil was an essential dietary staple of lower-class Byzantine diets.

It is also clear that all classes of society consumed wine, though the quality would have varied significantly (Dalby 1996; Choniates 1984: 635).

3.2.4.1–Vitamin C Content of Olives, Olive Oil and Wine

Olives, olive oil and wine offer no vitamin C (USDA 2006). Thus the addition of these three foodstuffs to a diet of grains and legumes would not have reduced the likelihood of developing scurvy.

3.2.5–Fruits and Vegetables

Fruits and vegetables played a significant role in the diets of the later Roman-Byzantine period. Such foods would have served as one of the main sources of vitamin C and were likely the crucial food sources for preventing scurvy.

Regarding vegetables it is clear that these foods played an important role in the diets of the late Roman–Byzantine period. Dalby (1996: 196) states that a majority of the diets of the lower classes would have been vegetarian, being composed predominantly of local produce. This belief is supported by Faas (2003: 209) who details how vegetables were not necessarily viewed as a side dish to a meal but rather were often taken as the main course of a meal. Such primary value of vegetables is clear among the ancient authors seeing Theophrastus (1916, 1976), Galen (Powell 2003: 2. 40–69), Pliny (1938: 19) and Columella (1941: 10), among others, provide thorough details about the growing, uses and consumption of vegetables. Vegetables represented a significant portion of the ancient Greek diet at all levels of society and most certainly would have been a primary source of nutrition among the lower classes of society at this time, particularly in rural regions where growing one's own food would have been more common.

A wide variety of fruits were consumed on a frequent basis during the late Roman–Byzantine period and were abundant within the Byzantine Empire to the point that fruits became an important commodity of trade (Dalby 1996; Laiou-Thomadakis 1980). Fruit was often eaten dried, candied, or in honey (Dalby 1996). The predominant consumption of fruit in this manner was due to the fact that fruits spoil quickly and thus drying or candying the fruit would let it last significantly longer and be of greater dietary use. Celsus (1935: 2.18.6) suggests that fruits such as grapes, figs and dates are more potent than those of the orchard, while Galen (Powell 2003: 76, 2.7) suggests that moist fruits are of little nutritional value, while solid fruits (i.e. dried figs, raisins etc…) are of a much better nutritional value. These statements support the belief that fruits were preferred in a dried format for consumption, though fresh fruits undoubtedly were also consumed. The overall dietary value that fruits contributed to the average diet of the late Roman–Byzantine period remains unclear as fruits were not typically viewed as a main course but rather would have served in many cases as a garnish with other foods or as a desert to the main meal.

It is clear that both fruits and vegetables were frequently consumed by all classes of society during the late Roman–Byzantine period. However it can be said that where vegetables could serve as a main staple of a meal, fruits would have been consumed more as an accessory to the meal, not as a main meal in and of itself. Nutritionally it was almost certainly vegetables which had the greater dietary impact during this time period, while fruits would likely have comprised a less significant, or less depended upon source of food.

3.2.5.1–Vitamin C content of Fruits and Vegetables

Fruits and vegetables would have provided an excellent source of vitamin C among late Roman–Byzantine diets. The content of vitamin C however would have differed significantly depending upon whether the fruits and vegetables were consumed fresh, cooked, dried, or (in the case of fruit) candied, as all of these different methods of preparation can alter the overall vitamin C content significantly (Table 3.2).

Table 3.2–Vitamin C Content of Fruits and Vegetables

Fruit	**Vitamin C**	**Fruit**	**Vitamin C**
Apple, raw	4.6 mg/100g	Lemons	77.0 mg/100g
Apple, dried	3.9 mg/100g	Oranges	53.2 mg/100g
Apple, cooked	0.2 mg/100g	Pears, raw	4.2 mg/100g
Candied fruit	0.0 mg/100g	Pears, dried	4.0 mg/100g
Cherries, raw	7.0 mg/100g	Plums, raw	9.5 mg/100g
Figs, raw	2.2 mg/100g	Quinces	15.0 mg/100g
Figs, dried	4.4 mg/100g	Raisins	2.3–5.4 mg/100g
Grapes	10.8 mg/100g	Zante Currants	4.7 mg/100g
Vegetable	**Vitamin C**	**Vegetable**	**Vitamin C**
Artichokes, cooked	11.7 mg/100g	Lettuce	18.0–24.0 mg/100g
Asparagus, cooked	7.7 mg/100g	Onion, cooked	5.2 mg/100g
Aubergine, cooked	1.3 mg/100g	Turnip, greens	27.4 mg/100g
Cabbage, cooked	37.5 mg/100g	Turnips, raw	21.0 mg/100g
Carrot, cooked	3.6 mg/100g	Turnips, cooked	11.6 mg/100g
Cucumber	2.8–3.2 mg/100g	Spinach	9.8 mg/100g
Grape Leaves	11.1 mg/100g		

Vitamin C content of a selected sample of fruits and vegetables available in Byzantine Greece. Values provided in this table are derived from USDA (2006).

3.2.6–Honey

Honey was one of the first foods prescribed for feeding newborn children. The use of this product to feed children in the late Roman–Byzantine period was thus significant. However despite the frequent use of honey for infant feeding it also poses a serious risk to the health of the child as honey is know to be a source of botulism, particularly in children. Aside from the risk of botulism honey is a poor source of vitamin C, containing approximately 0.5 mg/100g, and as such cannot be viewed as a significant anti-scorbutic foodstuff (USDA 2006).

Honey played a significant role in the dietary culture of the late Roman–Byzantine periods. From the lengthy discussion of apiculture and the uses of honey provided in the works of the ancient authors it is clear that honey was highly valued in antiquity being used for food, sweetening, preserving, garnish, candy, medicine and wine among other applications (Kelhoffer 2005; Columella 1941: 9.2–16; Pliny 1938: 11.5–15; Varro 1934: 3.16; Virgil 1910: 4.1–314).

Archaeological examples of beehives have been found among the excavated remains of Isthmia and Corinth suggesting that active apiculture was being practiced in the north-eastern region of the Peloponesse during the late Roman–Byzantine period (Anderson-Stojanovic and Jones 2002; Crane 1983).

Though honey was consumed frequently and in various ways there was also knowledge in ancient times of the dangers of consuming bad honey. Xenophon, Aristotle, Pliny and Strabo all attest to the dangers of eating "maddening honey" (Kelhoff 2005: 65). Honey from the Pontus and regions in Asia Minor was said to be particularly dangerous to consume (Strabo 1917: 12.3.18; Xenophon 1918b: 4.8.20–21). Columella (1941: 9.4.7) states that honey from the woodlands is the worst, while Pliny (1938: 21.74–75) details how one year's crop of honey can be deadly while honey from the same source the year before was perfectly fine. This knowledge that honey can be deadly due to the different types of plants used by the bees for pollination and the presence of bacteria in the honey itself posses a difficulty for the use of honey in antiquity (Kelhoff 2005). Though there was knowledge about the harmful effects of bad honey, it was not always possible to detect which honeys would be harmful. This proves a particular challenge when dealing with infant feeding, as honey was often one of the first foods prescribed for feeding the newborn (Lascaratos and Poulakou-Rebelakou 2003; Soranus 1991). Galen (1951: 209) indicates that all honey can be used for consumption except malodorous honey, while Hippocrates (Chadwick and Mann 1950: 143) states that the combination of honey and water typically enfeebles people and hastens death.

The implications of consuming dangerous honey will be discussed further in the following section on infant feeding practices.

3.2.7–Animal and Marine Resources

The role of animal and marine resources in diets of the late Roman-Byzantine period is debated. Meat would have been less frequently consumed among the lower classes of society, though this is not to say that no animal products were consumed by the lower classes as it is apparent that products such as milk, eggs, and cheese would have been used frequently by lower and rural classes of society (Pennycook 2008b: 30–32).

In the case of Greece such products would have typically been derived from sheep and goats because these animals can thrive on a relatively marginal and diverse diet in a sparse landscape, while cows require large pasturage and significant amounts of food making it impractical to keep them in a mountainous region such as the Peloponesse where there is limited fodder and grazing (Garnsey 1999; Semple 1922).

Regarding marine resources, with particular focus on the region of Stymphalos, it is unlikely that such resources were frequently consumed. Despite the relative proximity of Stymphalos to the coast the territory in between is largely mountainous and difficult to traverse making it unlikely that fresh marine resources would have been consumed by individuals living in this region (Pennycook 2008b: 37–41). When consumed, marine resources typically would have been preserved. It is possible that freshwater resources from Lake Stymphalos were also consumed, though significant consumption is unlikely based on stable isotope values (Pennycook 2008b: 39).

Though occasional consumption of marine resources is possible, isotopic research on the diets of individuals from Stymphalos and Zaraka by Pennycook (2008b: 181) shows that the use of marine resources in the valley of Stymphalos was quite insignificant, particularly compared to the use of grains. Furthermore, in terms of the diet of newborn children there are no apparent recommendations by ancient authors that marine resources should be consumed in the early years of life.

Based on the isotopic research presented by Pennycook (2008b), the landscape and location of Stymphalos, and the proposed lower or rural class status of the inhabitants of the valley in the periods under examination, the role which animal and marine resources played in the diets of individuals in the Stymphalos area was in all likelihood less significant than that of foodstuffs such as grains and vegetables. The main animal products that would have been used would undoubtedly have been milk, eggs and cheese. However when considering the diet of a child, as will be discussed further in the following sections, unless the mother was deficient in breast-milk it would have typically been seen as unnecessary to provide the child with animal milk until after the cessation of breastfeeding (Dupras et al. 2001; Garnsey 1999; Soranus 1991).

3.2.7.1–Vitamin C Content of Animal Products

Animal products, aside from organ meats and fish roe which provide significant amounts of vitamin C, are not a significant source of vitamin C. Thus diets depending heavily on grain, legumes, and animal products would have carried a significant risk of scurvy if further foods rich in vitamin C were not consumed (Table 3.3).

Table 3.3–Vitamin C Content of Animal Products

Animal Product	**Vitamin C Content**
Fowl, meat	0.4 mg/100g
Lamb/Goat, meat	0.0 mg/100g
Organ meats	3.7–28.0 mg/100g
Fish	0.0–2.9 mg/100g
Fish roe	16.4 mg/100g
Eggs	0.0 mg/100g
Goats milk	1.3 mg/100g
Sheeps milk	4.2 mg/100g

Vitamin C content of animal products. Values provided in this table are derived from USDA (2006).

3.2.8–Vitamin C Content and Scurvy in Late Roman–Byzantine Diets

Based on the material presented it is clear that a large majority of the foodstuffs consumed as part of the late Roman-Byzantine diet were deficient in, if not entirely devoid of, vitamin C. The heavy reliance on grains and grain-based products, such as porridge and bread, could have contributed significantly to the development of scurvy. As has been shown it is only truly vegetables and fruits that appear to be frequent sources of vitamin C within late Roman-Byzantine diets. However even in the case of fruits and vegetables it is evident that preparation, either cooking or preservation through drying and candying can alter the vitamin C content of these foods significantly, particularly candied fruit which losses almost all vitamin C content.

Considering the foods that comprised the average late Roman-Byzantine diet several inferences regarding the potential development of scurvy can be made. If the medical recommendations of the period were followed and the use of grains and legumes comprised the bulk of individual diets, without further vitamin C supplementation, there is significant potential that scurvy would have developed. Looking at fruits and vegetables it is clear that these were both important vitamin C rich foodstuffs; however, such foods are prescribed for infant feeding on a limited basis compared to grain based foods, as will be discussed in the following section. Furthermore the use of fruits and vegetables would have fluctuated on a basis of seasonal availability. Thus in the winter months, and in years of poor crop growth when fresh fruits and vegetables were not readily available, are two times at which scurvy would be likely to develop. This aspect of seasonality and poor crop growth is important as it may provide a means of understanding cases of scurvy in which an individual developed scurvy but survived due to the reintroduction of vitamin C sufficient foods in the non-winter/sufficient crop growth periods. Such instances of scurvy may have occurred in a cyclical pattern where an individual may have repeatedly suffered from scurvy due to seasonally insufficient access to vitamin C resources, before recovering due to returned access to vitamin C rich foodstuffs.

3.3–Infant Nutrition

Infantile scurvy is strongly linked to recommended practices of infant feeding. Despite availability of vitamin C rich foods prescribed practices for feeding and caring for newborn children often resulted in the development of scurvy in past populations, particularly at the weaning transition. The following sections will seek to outline the nutritional importance of breastfeeding and the associated infant feeding practices of the late Roman-Byzantine period in an attempt to show the connection between prescribed feeding practices and the development of infantile scurvy.

3.3.1–*In Utero* Nutrition

As a result of the child's total reliance on the mother while *in utero* there remains the potential that if the mother develops a nutritional deficiency or other illness during the pregnancy the child may suffer a variety of ill effects on health and development and may develop a nutritional deficiency such as scurvy due to the inability of the mother to provide essential nourishment at this critical time (Lewis 2007; Hirsch et al. 1976; Jaffe 1972; Burns 1963; Jackson and Park 1935).

3.3.2–Nutritional Value of Colostrum and Human Breast-Milk

Human breast-milk develops in three stages, being colostrum, transitional milk and mature milk, and is composed of an ever-changing mixture of over 100 different constituents providing for the health and growth of the newborn child (Lewis 2007; Lawrence and Lawrence 2005; Table 3.4). It is important to understand that none of these stages are defined by rigid time periods but rather are a continuum of transition over time and as such the duration of each production period is highly variable between individuals (Lawrence and Lawrence 2005; Almroth 1978).

3.3.2.1–Nutritional Value of Colostrum

Colostrum refers to a mammary secretion produced for between 4–5 days postpartum (Neville et al. 1983). Colostrum is significantly different from mature human milk, serving predominantly to pass on immunoglobins and antibodies acting as an anti-infective substance to help build the postpartum immunity of the perinate as well as to provide nutrition for the infant (Lawrence and Lawrence 2005; Garnsey 1999; Garnsey 1991; Stini 1985; Casey and Hambidge 1983).

Regarding composition, human colostrum appears as a thick yellowish mucus like substance (Lewis 2007; Casey and Hambidge 1983).[4] Human colostrum contains approximately 3.52±0.56 mg/100 ml of vitamin C (Ahmed et al. 2004: 3). Human colostrum is significantly higher in protein content than mature human breast-milk, containing approximately 7g/100 ml, and approximately half of the fluid produced may be comprised of immunoglobins (Casey and Hambidge 1983; Jelliffe and Jelliffe 1978). Human colostrum also contains significantly higher concentrations of fat-soluble vitamins and minerals as well as sodium and chloride compared to mature human breast-milk (Casey and Hambidge 1983; Neville et al. 1983). Conversely the average caloric value of human colostrum is in the range of 58 kcal/100 ml, a value lower than mature

[4] One proposed reason as to why human colostrum appears so yellow is due to the significant concentration of ß-carotene (Casey and Hambidge 1983: 202).

human breast-milk (Casey and Hambidge 1983: 232). Human colostrum also contains less lactose and fat compared to mature human breast-milk (Casey and Hambidge 1983).

The generally accepted view on the function of colsotrum is to provide immunoglobins and antibodies to help protect the infant against pathogens present in the birth canal and outside of the womb (Lawrence and Lawrence 2005; Garnsey 1999; Garnsey 1991; Stini 1985). Research has shown that colostrum helps to develop *Lactobacillus bifidus* flora in the digestive tract of the perinate, helping to protect against the development of enteric diseases such as *E. coli*, salmonella, dysentery and cholera, as well as illnesses such as polio, rotavirus, staphylococci, streptococci and pneumococci, among other pathogens (Lewis 2007: 99; Lawrence and Lawrence 2005: 114; Hoshower 1994; Katzenberg et al. 1996: 178; Popkin et al. 1990: 875; Jelliffe and Jelliffe 1978: 85–86).

The role of colostrum is thus to help provide immunological protection as well as nutrition for the newborn during the transitional period directly postpartum up to the first week of life (Lawrence and Lawrence 2005).

3.3.2.2–Nutritional Value of Human Breast-Milk

After the cessation of colostrum production approximately 7 days postpartum human breast-milk passes through a phase of transitional milk production in which the nutritional content of the milk shifts from the original composition of the colostrum toward the final nutritional composition of mature milk (Lawrence and Lawrence 2005; Almroth 1978). Transitional milk production begins approximately 7–10 days postpartum and lasts until approximately two weeks postpartum (Lawrence and Lawrence 2005; Almroth 1978). Transitional milk is defined by a decrease in protein, immunoglobin and fat soluble vitamin content, with an increase in lactose, fat, and total caloric content (Lawrence and Lawrence 2005; Almroth 1978).

Following the cessation of transitional breast-milk production is the production of mature breast-milk, which is the final and longest stage of breast-milk production. One of the main differences between human breast-milk and animal milk is the difference in composition. Breast-milk, unlike animal milk, contains all of the necessary nutrients, except vitamin D, which a newborn child requires to thrive successfully (Dettwyler 1995; Hervada and Newman 1992; Dettwyler and Fishman 1992). Mature milk is composed predominantly of water, to the extent that the breastfeeding child obtains enough water from breast-milk so as to require no additional supplementation (Lawrence and Lawrence 2005: 117; Almroth 1978).

There remains difficulties in quantifying the amount of nutrients that a child receives at each breastfeeding as the composition of milk can vary significantly based on time of day, temperature, climate, health of the mother and a variety of other such factors (Lawrence and Lawrence 2005). Thus there is no one uniform composition of breast-milk but rather varying compositions at different times and on an individual by individual basis, allowing for only estimates of the average nutritional composition of breast-milk (Lawrence and Lawrence 2005: 106; Munks et al. 1945; Table 3.4). The amount of milk taken in and utilized by the child at each breastfeeding also remains difficult to measure and quantify. As such only relative approximations based on test studies can be provided at this time (Lawrence and Lawrence 2005; Munks et al. 1945).

Regarding vitamin C intake, studies have shown that vitamin C levels in breast-milk increase within 30 minutes of the administration of a vitamin C tablet, indicating that the uptake and integration of vitamin C into breast-milk is quite rapid (Lawrence and Lawrence 2005). Further studies have shown that the amount of vitamin C that a child receives from breastfeeding remains relatively static regardless of the mother's intake (Jelliffe and Jelliffe 1978). In a case where the mother consumed ten times the daily recommended intake of vitamin C the breastfeed child still only received between 49–86 mg/day, suggesting that there is a regulatory mechanism that restricts the amount of vitamin C that can be passed to the child through breast-milk (Lawrence and Lawrence 2005; Jelliffe and Jelliffe 1978).

Alternatively studies have also shown that in cases where the mother is deficient in vitamin C the necessary amount of vitamin C will be allotted to the child over the mother in order to maintain a proper store of vitamin C in the child; given this, cases of infantile scurvy are almost never observed in breastfed infants (Jelliffe and Jelliffe 1978). This is not to say that there are never cases of so-called congenital scurvy, or scurvy among breastfed children, for if the mother is devoid of vitamin C the child may develop scurvy very shortly after birth because it is impossible for the child to obtain this vitamin from the breast-milk provided (Hirsch et al. 1976; Jaffe 1972; Burns 1963; Jackson and Park 1935; Still 1935).

Approximately 85% of vitamin C obtained through breastfeeding is absorbed by the child, indicating a relatively high level of bodily integration of this vitamin in the newborn (Lawrence and Lawrence 2005: table 2–49).

Table 3.4–Estimates of the Nutrients in Mature Human Milk

Nutrient	Amount in Human Milk
Lactose	72.0 ± 2.5 g/litre
Protein	10.5 ± 2.0 g/litre
Fat	39.0 ± 4.0 g/litre
Iron	0.3 ± 0.1 mg/litre
Vitamin C	40.0 ± 10.0 mg/litre
Niacin	1.500 ± 0.200 mg/litre
Vitamin D	0.55 ± 0.10 μg/litre

Chart depicting the estimated nutritional composition of mature human breast-milk. Adopted from Lawrence and Lawrence (2005: table 4-8).

3.3.3–Cultural Background to Breastfeeding

Many of the medical treatises of antiquity discussing infant feeding and associated practices were written by authors who would have served the upper classes of society, such as Galen who was physician to Marcus Aurelius and Commodus, Oribasisus who was physician to Julian, and Aëtius of Amida who was physician to Justinian (Clark 1993: 64). As such a great deal of information recorded by these authors was taken from dealing with patients from the upper classes. However the material presented, though garnered from the examination of largely upper class patients, is pertinent to all levels of society, as the treatises written would have been utilized by various physicians dealing with various different classes of society. As such the practices suggested in the various ancient works would undoubtedly have affected how all levels of society approached infant feeding (Clark 1993). For despite the different classes of late Roman–Byzantine society it is generally held that recommendations for breastfeeding would have eventually penetrated all levels of society and thus recommendations made by the various ancient authors among the elite would have reached less elite physicians as well as midwives who would have dealt with lower classes of society on a frequent basis. Thus though not all levels of society had access to elite physicians, the practices recommended by such physicians over time would have likely filtered into the common medical knowledge of society and thus would have contributed to ideas among the various social classes as to how breastfeeding should be conducted.

Until relatively recently in history there has been no true alternative to breastfeeding. As such, the role which breastfeeding plays in the newborn child's life is a vital one. The first month after birth is arguably the most dangerous in an individual's life for it is during this time period when the new child is exposed to all the assaults of the world and must struggle to overcome the obstacles of disease and malnutrition (Stuart-Macadam 1995). How breastfeeding is practiced and the choice of weaning foods that are to be introduced into the child's diet play a significant role in the survival or death of a child (Stuart-Macadam 1995; Dettwyler 1995). It is for this reason that breastfeeding plays an integral role in understanding children and childhood diseases in antiquity. The following sections will examine diet and infant feeding practices during the late Roman–Byzantine period.

3.3.3.1–Ancient Views on Colostrum

Many of the ancient medical authors viewed colostrum as a hazard to the newborn due to the thick, viscous and abnormally yellowish nature of the fluid (Lewis 2007; Lascaratos and Poulakou-Rebelakou 2003). Soranus (1991: 89, 2.18), as well as Oribasius, recommended that before feeding an infant, this “abnormal” fluid should be suctioned or squeezed out of the breasts for approximately the 4 days during which colostrum is produced (Lascaratos and Poulakou-Rebelakou 2003: 186). Such a practice would effectively remove this dangerous fluid from the body, which if consumed by newborns was thought likely to “clog” their digestion due to its density (Garnsey 1999; Soranus 1991: 89, 2.18). Soranus (1991: 88) also makes the recommendation that the newborn child should not be fed anything until two days after birth, but rather should be allowed to rest and digest the last of the food that was received *in utero*.[5]

Alternatively Aristotle believed that children should be given the breast for feeding beginning the first day after birth and had nothing detrimental to say regarding the consumption of colostrum by newborn children (Garnsey 1991: 59; Aristotle 1943: 4.8). In fact the true function of colostrum and the vital need for the child to consume it was not truly understood until the 19th century CE (Garnsey 1999: 106).

3.3.3.2–Ancient Attitudes on Breastfeeding

In examining medical texts regarding breastfeeding in the late Roman–Byzantine era it is apparent that views on breastfeeding were largely derived from ancient Greece and Rome which were preserved in the writings of later authors in the Byzantine period, with essentially no new contributions on the topic during the Byzantine era (Davidson 1953). Though certain details of the prescribed practices

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[5] The necessity of providing nourishment for the newborn child directly after birth is paramount and as such the practice of withholding food from a newborn child for up to two days would have posed a significant, and undoubtedly often fatal, risk to the child. The combination of withholding food for up to two days in conjunction with the use of highly nutritionally deficient weaning foods (see below) would have increased the risk of early mortality.

undoubtedly changed to an extent over time it remains clear that the prescribed practices and views on breastfeeding remained basically the same throughout the periods of history under examination. As a result it is fair to state that the practices proposed by the texts examined were maintained by a majority of the eastern Mediterranean populations during the time periods examined in this thesis.

3.3.3.2.1–Views on Breastfeeding in Antiquity

Though it is generally agreed among the ancient authors that breastfeeding is overall the best method for feeding a child there is division among the ancient authors as to the approach that should be taken. Several authors recommend wet nurses while others argue that the mother herself should nurse the newborn child. The following section will look at the argument for the birth mother to breastfeed her own child, while the use of wet-nurses will be addressed in more detail in a following section.

Galen (1951: 30) provides a description of what appropriate breast-milk should look like, suggesting that it should be sweet, white and midway between thick and thin. Galen further details how poor milk is thick and cheesy or alternatively watery thin and livid, of variable consistency and colour, and sour to the taste (Galen 1951: 30).

From *The Attic Nights* of Aulus Gellius (1927: 12.1.1–17) the philosopher Favornius voices a strong protest to the mother and senatorial husband of a girl who has just had a baby, entreating the mother to allow her daughter to breastfeed her own child rather than employ a wet nurse. Favorinus states that using a wet nurse is akin to abortion, for the mother is the best suited to feed the child as nature has provided her the ability to do so and as such her natural ability should be employed for this task.[6] This anecdote presented by Gellius provides valuable insight into the period in which wet nursing was often the preference among those who could afford it, though conversely the Church of Late Antiquity encouraged mothers to breastfeed their own children (Clark 1993: 45; Gellius 1927: 12.1.1–17). The proposed superiority of using a wet nurse is not necessarily true as Soranus (1991: 90) explains that all things being equal it is better for the mother of the child to breastfeed it than any sort of wet nurse. This practice, Soranus argues, is only natural as the mother has fed the child *in utero* for so long it is only practical that the mother should continue to feed her own child after birth. Galen also supports this practice stating "thus nature herself planned for children, providing them mother's milk as a moist sustenance" (1951: 23). Augustine believed that a mother should feed her own child, and that breast-milk was simply meat and bread transformed in the mother's body into a food more appropriate for the newborn child (Nielsen 1998: 62). This view is further supported in the later work of Avicenna who also recommends that whenever possible the mother's milk should be given to the newborn child as it is the most similar in nature to the food that the child would have received in the womb (Gruner 1930: 365).

The belief that the child should be breastfed by the birthing mother was further supported in antiquity due to views on how character traits were passed on from parent to child. It was believed that the semen was responsible for the

[6] Though Gellius seems to present Favorinus as a real philosopher he is almost certainly a fictional character of Gellius' creation.

shaping of similar physical features between parent and child, while breast-milk was responsible for the formation of similar natural dispositions of body and mind between parent and child (Clark 1993; Macrobius 1969: 5.11.16–17; Gruner 1930: 365). Thus for the mother to breastfeed her own child would ensure that appropriate similar traits and dispositions would be passed on to the child.

3.3.3.3–Ancient Views on Wet Nursing

It is important to understand that though wet nurses were frequently used in antiquity they would have been used almost exclusively by the upper classes of society, as the cost of employing a wet nurse would have been significant and thus prohibitive to the lower classes of society (FitzGerald et al. 2006; Garnsey 1991; Jelliffe and Jelliffe 1978).

The prevalent use of wet nurses during the late Roman–Byzantine era is clear from many of the works of ancient authors. From Aulus Gellius (1927: 12.1.1–17) it is observed how a lengthy protest was needed to try and get the mother to feed her own child rather than employ a wet nurse. Further support for the common use of wet nurses in Roman-Byzantine society can be observed in the *Dialogues* of Tacitus (1932: 293, *Germania* 20) where Tacitus expresses amazement that German women breastfeed their own children and do not employ wet nurses.

The frequency of wet nursing was such that many of the ancient medical authors provide criteria for selecting an appropriate wet nurse (Fildes 1986; Jelliffe and Jelliffe 1978). Soranus (1991: 90) suggests that a wet nurse should not be younger than 20 and should not be older than 40, an age range which is also reflected in the work of Aëtius (Adams 1844: 5). Oribasius, largely following the prescriptions of Soranus, provides a narrower age range suggesting that wet nurses should preferably be between the ages of 25 and 35 years of age, with the optimal age of the wet nurse being the same as that of the birthing mother (Lascaratos and Poulakou-Rebelakou 2003: 186). This narrower age range is also reflected in the later works of Paul of Aegina and Avicenna who both recommend an age range between 25–35 years as the most suitable for a wet nurse (Wickes 1953: 155; Gruner 1930: 367; Adams 1844:5).

Along with these age limits for selecting a wet nurse were physical descriptions that should be satisfied when selecting a wet nurse. According to Soranus (1991: 90–91), and reflected in the later works of Oribasius, Paul of Aegina and Avicenna, the appropriate wet nurse should have nipples which are medium in size, lax, soft, unwrinkled and able to provide a flow of milk that is neither too strong nor too weak (Lascaratos and Poulakou-Rebelakou 2003: 187; Wickes 1953: 155; Adams 1844:5).

Regarding demeanor it was viewed as preferable to have a nurse who is not too young, so as to ensure that she will be knowledgeable of how to rear a child (Soranus 1991: 91). The wet nurse should also have already given birth two to three times, with one of her own children, preferably male, having been born recently, before being appointed as a wet nurse so that she will have enough milk (Wickes 1953: 155; Adams 1844:5). The wet nurse should be well structured having strong broad shoulders (Lascaratos and Poulakou-Rebelakou 2003: 187; Wickes 1953: 155; Gruner 1930: 366; Adams 1844:5). The wet nurse should not be ill, particularly with epilepsy or gastrointestinal disease, so as not to infect the child and she should avoid bad habits and should bathe regularly (Lascaratos and Poulakou-Rebelakou 2003: 187; Fildes 1986; Gruner 1930: 366; Adams 1844:5).

The diet of the wet nurse at first should consist of bread, boiled barley and wheat broth, rock-dwelling fish, and tender chicken (Lascaratos and Poulakou-Rebelakou 2003: 187). Once the wet nurse begins to produce more milk her diet can expand to include other fish, pork, lamb, goat, moderate amounts of wine and oxymel[7] (Lascaratos and Poulakou-Rebelakou 2003: 187). Alternatively the wet nurse is to avoid salty and acidic foods as they are believed to sour the milk, as well as those thought to cause epilepsy, such as celery (Lascaratos and Poulakou-Rebelakou 2003: 187).

Based on the thorough discussion presented in the medical texts of the era it is clear that wet nurses were frequently employed during the late Roman–Byzantine period by the classes of society that could afford a wet nurse (Garnsey 1991). However it is also apparent that many of the medical authors of the period were largely in support of the birth mother breastfeeding her own children unless she was physically unable, a practice that was likely the more common due to the prohibitive cost of employing a wet nurse (Lascaratos and Poulakou-Rebelakou 2003; Soranus 1991; Gruner 1930).

[7] Oxymel is a syrup-like mixture of honey and vinegar.

3.3.3.4–Attitudes on Weaning in Late Roman-Byzantine Society

3.3.3.4.1–Background to Weaning

The term weaning, derived from the Anglo-Saxon term *wenian* “to become accustomed to something different,” has various interpreted meanings but is herein taken to mean the introduction of food other than breast-milk into the diet of a child in a progression towards the point at which the diet of the child consists entirely of foods other than breast-milk (Lawrence and Lawrence 2005; Davies and O’Hare 2004; Hervada and Newman 1992; Whitehead 1985). It is important to recognize that weaning does not refer to one specific event but rather is in reference to a progressive change over time that varies in duration from case to case. Thus weaning does not refer to an immediate cessation of breastfeeding in favor of introducing solid foods, but rather refers to the introduction of supplementary foods, typically several months after birth, in conjunction with continued breastfeeding over an extended period of time, typically 2–3 years in the late Roman-Byzantine period, until the child no longer requires breast-milk for nourishment (Prowse et al. 2008; Lawrence and Lawrence 2005; Dupras et al. 2001; Hervada and Newman 1992; Whitehead 1985).

The daily nutritional needs of a child from birth to 3 months are approximately 120 kcal/kg, from 6–8 months 110 kcal/kg, decreasing to 106 kcal/kg at one year (Whitehead 1985: 449). It can easily be understood how as the child continues to grow it becomes increasingly harder for the mother to produce enough breast-milk to provide appropriate nourishment for the new child and as such it becomes necessary to introduce supplemental foods into the diet of the child (Whitehead 1985). Modern pediatric recommendations regarding weaning suggest that semi-solid foods should begin to be introduced into the child's diet between 4 and 6 months postpartum (Hervada and Newman 1992).

A formula that has been proposed regarding the cessation of weaning suggests that weaning, based on a healthy child, is typically completed on a ratio of 4:1, that is to say when the child has reached four times its birth weight. This weight is typically reached between 2 and 3 years of age at which point weaning is typically complete or very near completion, though this is by no means a universality (Lawrence and Lawrence 2005; Detwyller 1995). This formula is surprisingly consistent with the typical age at which weaning occurred in the late Roman–Byzantine period (Pennycook 2008a, 2008b; Bourbou and Garvie-Lok 2009). The trend of weaning up to 2–3 years of age has declined over history with increasingly shorter weaning periods in modern times.

3.3.3.4.2–Duration of Breastfeeding in Antiquity

Recommendations suggest that a child should be breastfed exclusively for six months after which time solid foods are added in conjunction with continued breastfeeding (Davidson 1953; Gruner 1930). It is apparent from the relative consensus of the ancient authors that the believed appropriate time period for the cessation of breastfeeding should be between 2 and 3 years postpartum. Though there were undoubtedly exceptions to the pattern, 2 to 3 years of breastfeeding appears to be the standard recommendation.

Among the ancient authors there is general consensus about the duration for which breastfeeding should be carried out. Galen recommends that a child should be breastfeed into the third year of life, while Paul of Aegina recommends breastfeeding for only two years (Galen 1951: 29; Adams 1844: 8). Aëtius of Amida recommends that breastfeeding should last for twenty-months, while Moschion suggests a time period of eighteen months up to two years (Adams 1844: 9).

3.3.3.4.3–Ancient Authors on the Weaning Process

Looking at the medical works of ancient authors it is the work of Soranus (1991) that provides one of the first and most thoroughly utilized approaches to weaning. Soranus (1991) recommends that a gradual weaning transition period, in which soft cereals are introduced to the child only beginning after six months, should take place until the child is comfortable taking in only soft cereals, which typically occurs around 1.5 to 2 years of age (Prowse et al. 2008). Soranus (1991: 118–119) also clarifies that weaning should not begin before the child has teeth. With regard to the genders he stated that there is no reason for female children to be breastfed for longer periods of time than males as both genders are strong and thus should be weaned by the end of the second year of life (Garnsey 1991: 63). Soranus (1991: 119) further suggests that if a child falls ill during the weaning process the child should be returned to exclusive breastfeeding and should only be weaned again after the illness has passed. Soranus (1991: 118) even goes so far as to recommend preferable seasons for weaning, with spring being the best and autumn the worst. Galen (Prowse et al. 2008: 298) builds upon the work of Soranus suggesting a slightly later period for weaning at approximately the end of the third year postpartum. This 2 to 3 year window for weaning is preserved through the Byzantine period being reflected once again in the work of Avicenna who suggests that breastfeeding usually occurs for two years, while also further supporting the belief that weaning must be a progressive transition and not an abrupt halt (Gruner 1930: 370). Avicenna also recommends that weaning should not take place before the child has developed teeth (Gruner 1930: 370).

Soranus and Avicenna largely provide the same recommendations for weaning, however they disagree on one minor note. Soranus (1991: 118) states that the mother should never apply ointment to her nipples in an attempt to diminish the desire of the child for taking breast-milk, while Avicenna (Gruner 1930: 371) suggests that if the child continues to cry for the breast the mother should apply an ointment of myrrh and pennyroyal to discourage the child.

3.3.3.4.4–Isotopic Examination of Weaning Among Archaeological Populations

Isotopic examination of human remains from archaeological contexts in the eastern Mediterranean have provided results for the weaning ages of children in antiquity that are consistent with the recommendations of Soranus and other medical writers of the era. From the Monastery of St. Stephen in Jerusalem (ca. 5^{th}–7^{th} century CE) the established average weaning age was 2–3 years (Gregoricka et al. 2007: 119). The work of Prowse et al (2008: 297) from a series of sites in Roman Italy established that the average weaning age for this region during the Roman period was approximately 2–3 years. Research conducted by Bourbou and Garvie-Lok (2009) on a series of Byzantine sites from Greece showed that the average weaning age among the sub-adult individuals of these sites was approximately 3 years of age.

In her isotopic research at Stymphalos and Zaraka, Pennycook (2008b) showed that the stable isotope values of the sub-adult individuals examined from these sites are consistent with a weaning age of 2–3 years (Pennycook 2008b: 177).

The process of weaning within the late Roman–Byzantine era, both in theory, as described by the medical authors of antiquity, and in practice, as determined from isotopic research on archaeological populations, indicates that the average age at which weaning took place was between two and three years. Exceptions to this time frame exist; however the typical pattern was one of a gradual transition at 2–3 years.

3.3.3.5–Weaning Foods of the Late Roman-Byzantine Period

3.3.3.5.1–Recommendations of the Ancient Medical Texts

As is the case with breastfeeding and weaning there exists a significant literature regarding appropriate foods and practices for feeding children during the late Roman–Byzantine period.

As early as the time of Hippocrates the association between diet and disease was becoming clear as Hippocrates warns that the components of a diet have a direct link to the development of disease (Chadwick and Mann 1950). It must be recognized that the quality of food which a child consumes is just as important as the availability of breast-milk, for the quality of weaning foods plays a significant role in the interaction of the child with the environment and thus the incidence of disease (Katzenberg et al 1996; Chadwick and Mann 1950; Gruner 1930).

The ancient medical authors recommended foods that were deemed preferable and those that were to be avoided for feeding children. For example, both Oribasisus and Soranus recommend that butter should not be fed to children as this food is too dense and hard on the stomach (Lascaratos and Poulakou-Rebelakou 2003: 188; Soranus 1991: 88). One of the first foods that is recommended by many of the ancient authors, including Soranus, Galen, Oribasius, Paul of Aegina and Avicenna, is honey, particularly crumbled bread dipped in hydromel (a combination of honey and water) or sweetened wine (Bourbou and Richards 2007; FitzGerald et al. 2006; Lascaratos and Poulakou-Rebelakou 2003: 188; Dupras et al 2001; Garnsey 1999; Soranus 1991; Dalby 1996; Jackson 1988; Gruner 1930; Adams 1844: 8).

The introduction of honey soon after birth is a common dietary recommendation throughout antiquity, with Avicenna (Gruner 1930: 365) stating in *The Canon of Medicine* that a child may be given honey first before it is given the breast, showing how highly valued honey was as a food for infants. Rufus of Ephesus (Lascaratos and Poulakou-Rebelakou 2003: 188) goes even further and suggests that only honey be given to the child at first after birth followed by a few drops of breast-milk. However the danger of this recommendation to introduce honey before any other food was not entirely recognized.

Research has shown that honey can contain *Clostridium botulinum* and thus can expose the child to botulism, posing a serious and potentially fatal risk to the child's health (Lewis 2007; Dupras et al. 2001; Fairgrieve and Molto 2000; Holland and O'Brien 1997). This danger is only significantly apparent among infants during breastfeeding for once the child begins to eat solid foods the acidity of the digestive tract will be strong enough to destroy or prevent the development of the botulin toxin, thus explaining why older children and adults do not typically suffer from botulism due to honey consumption.[8]

Following the period directly after birth when honey and milk are the essential foods further recommendations regarding the introduction of weaning foods into the child's diet are dictated. The majority of foods recommended for weaning would have been largely, if not entirely, devoid of vitamin C and as such would have posed a serious risk of scurvy to the child.

Soranus (1991: 117) recommended that children should be fed on spelt soup, very moist porridge, and an egg that can be sipped, all foods that are poor sources of vitamin C (Garnsey 1999: 107). It is recommended that children should not consume bread covered with poppy or sesame seeds nor consume spicy foods as these were viewed as bad for digestion (Soranus 1991: 117).

Galen (1951) recommends that grains, namely bread, should be the first solid food given to the child followed by vegetables and then meat and other such things (Garnsey 1999: 107). Oribasius prescribes largely the same diet, with bread being an integral part, however he also recommends that children should not consume meat as it causes them to become phlegmatic (Wickes 1953: 155).

[8] It is important to realize that honey was viewed as a highly useful and beneficial foodstuff. In antiquity, as was previously mentioned, it was known that honey could in certain cases be dangerous to one's health. Thus certain types of honey may have been avoided, but this does not imply that honey as a food was stigmatized as dangerous or unhealthy. Rather the contrary seems true, as honey was frequently consumed, being highly valued for sweetening, preserving, and overall flavor. It must also be understood that the association of honey with botulism in infants and associated enteric disorders would not have been abundantly clear in antiquity as this association is largely derived from modern medical-nutritional research.

Avicenna goes so far as to suggest that the first solid food a child consumes should be pre-chewed bread (Gruner 1930: 370–371).

It is at this time during the initial stages of weaning and directly after the cessation of weaning that the child is most vulnerable to disease and malnutrition, as the child's developing immune system may react harshly and the foods provided may not be nutritionally sufficient (Brothwell and Brothwell 1998). Furthermore though grain and legume based foods such as bread and porridge were undoubtedly hearty they lack essential vitamins, including vitamin C. As well the consumption of phytates, especially with every meal, can significantly inhibit iron absorption, particularly if the diet is sparse in meat and other haem rich foods, which over time may lead to the onset of anemia (Lewis 2007; Working Group 1994; Baynes and Brothwell 1990).

It is clear that grain based foods, particularly among the non-elite classes of society, comprised the main dietary staple for infant feeding and would remain a staple food throughout life as was elaborated upon in Section 3.2 (Garnsey 1991). The use of grain based foods as the primary source of infant nutrition during and following the weaning phase would have served as a poor nutritional choice as grains are devoid of vitamin C content. A heavy reliance on such foodstuffs would have posed a serious risk of developing scurvy if significant vitamin C supplementation was not obtained through the consumption of other foods.

3.3.3.5.2–Hazards Associated with Infant Feeding

Assessing the hazards of infant feeding Garnsey (1991: 62) identified two phases during which children are particularly at risk. The first is when supplementary foods are beginning to be introduced at the onset of the weaning phase, at which time unsanitary foods may cause illness in the child, and the second is towards the end of the weaning phase when breast-milk begins to diminish and children become increasingly reliant on supplementary foods. These periods are difficult as they are periods of significant growth and nutritional need; however in antiquity they would also have commonly been periods of developing malnutrition and disease.

Supplementary weaning foods in antiquity had significant potential to introduce food borne illnesses into the child, often resulting in weanling diarrhoea and other enteric illnesses. Foods chosen to supplement fully nutritionally complete breast-milk were often lacking in essential nutrients and thus there was significant potential for the child to become malnourished (FitzGerald et al. 2006; Motarjemi et al. 1993; Garnsey 1991; Walker 1986; Carlson et al. 1974).

Though this scenario of malnutrition and food borne illness is by no means the only possible outcome of the weaning transition in antiquity it would have been a large problem for all levels of society as the majority of infant feeding practices suggested by the ancient medical authors are such that malnutrition and disease would have been common. This being the case, it is important that attention continue to be given to the role that juvenile diet, particularly the availability and choice of supplementary foods, played in antiquity and how the role of such foods can be linked to the development of malnutrition and diseases such as scurvy among sub-adults.

3.4–Summary of Late Roman-Byzantine Approaches to Juvenile Nutrition

Juvenile scurvy during the late Roman-Byzantine period would have been a significant problem if a diet of predominantly grains, which was recommended by the ancient medical authors, was followed. The main source of vitamin C in the adult diet during this time period would have been vegetables and fruits. However there are only limited recommendations for vegetable consumption among the diets proposed for children during this time period and the use of fruit was typically as a dessert or garnish, making it unlikely to have served as a staple in the diets of children. Furthermore the fact that the valley of Stymphalos receives snow in the winter months and is sometimes affected by drought in the summer months would have periodically limited the amount of food that could be produced in this region, which would have had a significant effect on overall population nutrition for individuals residing in the valley. Taking into account the availability of foods in conjunction with the dietary recommendations of the ancient medical authors, if the sub-adult children from Stymphalos and Zaraka were fed predominantly on a diet of grains and legumes, with only minimal use of vegetables and fruits and no further vitamin C supplementation there is a significant chance that scurvy would have been a common occurrence among the juvenile individuals of this population.

Chapter 4–Study Sites, Samples and Methods

4.1–The Geography and Environment of Greece

Greece is comprised of the mainland, including the large southern peninsula known as the Peleponesse, and over 3000 islands (Higgins and Higgins 1996; Pepelasis and Thompson 1960). There is significant regional variation between the northern regions of Greece, which have a more continental environment, the mountainous regions of Greece, which have an alpine climate, and those of southern Greece, which are typified by a Mediterranean climate (Furlan 1977). Overall the predominant climate of Greece is Mediterranean, with winter rains, followed by warming temperatures that precede very hot and dry summers, which often result in regional droughts (Higgins and Higgins 1996; Pepelasis and Thompson 1960).[1] Despite the large percentage of Greece that is located in close proximity to the Mediterranean, Aegean, and Ionian seas, the country is largely comprised of steep mountainous terrain, which typically experiences increasingly rainier conditions and cooler temperatures that often result in freezing and snow during the winter months (Pepelasis and Thompson 1960; Polybius 1922: 4.70.1). Due to the highly variable and mountainous geography of Greece, only 19% of available land is identified as arable (Higgins and Higgins 1996; Furlan 1977: 185; Pepelasis and Thompson 1960). The effects of drought in Greece can be severe commonly leading to crop failure and subsequent food shortages. Such droughts are often most intense in the south-eastern regions of Greece, the region

[1] Data from Furlan (1977: table 35) indicates that for Athens (Lat. 37º58'N, Long. 23º43'E, elevation 107 m) average temperatures range from a mean daily of 9.3ºC in January to 27.6ºC in July, with an average annual mean daily temperature of 17.8ºC. Precipitation varied from an average mean monthly rainfall of 71 mm in December to 6 mm in July, with an average mean annual rainfall of 402mm.

in which the sites under examination in this present study are located (Higgins and Higgins 1996; Forbes and Foxhall 1995; Garnsey 1999; Garnsey 1988; Pepelasis and Thompson 1960).

It is the factor of drought that must be considered when examining the effects of climate on the region of Stymphalos. On first examination the valley of Stymphalos appears rich and fertile, able to grow grapevines, barely and wheat, among other crops (Higgins and Higgins 1996: 70). Yet it is clear that drought has affected this region more than once. Thus, despite the relative fertility of the valley the effects of drought are not unknown in this region.[2]

4.2–Study Sites

4.2.1–Stymphalos

4.2.1.1–Location and Geographic Description of Stymphalos

Stymphalos (Lat. 37º51'26" N, Long. 22º27'21" E) is located in the northeastern region of the Peloponesse on the frontier of ancient Arcadia, in the modern province of Corinthia (Williams 2007; Williams et al. 2002: 135; Pikoulas 2001; Ptolemy 1991: 91). The valley of Stymphalos is approximately 10 km. in length and is bounded along the northern aspect by Achaia, along the east by Sicyonia and Phliasia, by Mantineia and Orchomenus in the south and by Pheneus along the western aspect (Bell 1989: 258; Frazer and Van Buren 1930; Bursian 1862: 194).

The site of Stymphalos is located south of Kionia in the valley of Stymphalos, which is enclosed by surrounding mountains, approximately 1 km

[2] The association of drought with near epidemic outbreaks of scurvy is well documented both historically and in modern cases. One of the most recent outbreaks of scurvy occurred in 2002 in Afghanistan during a severe drought (Wang and Still 2007: 447; Cheung et al. 2003).

south of the modern village of Stymphalia (formerly Driza) (Williams et al. 1997; Lolos 1997; Higgins and Higgins 1996; Simpson and Dickinson 1979; Smith 1872; Boblaye 1836: 147).[3] The ancient site of Stymphalos is located some 600 m above sea level and is situated along the northern shore of the lake in this valley (Williams et al. 1998; Simpson and Dickinson 1979; Smith 1872).[4] Lake Stymphalos is the only permanent, though seasonally fluctuating, lake in the region, being formed by waters from Mt. Ziria, Mt. Kyllini, Mt. Apelaurum, and three streams, while the spring of Stymphalos is drained by a subterranean outlet or *katavothra* that re-emerges and empties into the Gulf of Argos (Higgins and Higgins 1996; Bourne 1982; Tozer 1882; Leake 1830: 3.108; Pouqueville 1822; Gell 1817).[5]

The site of ancient Stymphalos extends for over a kilometer from the northern shore of the lake almost all the way to the base of the mountains, with the acropolis of the site being located at the eastern end of a spur of Mt. Kyllini known as Mt. Stymphalos (Williams 1984; Ptolemy 1991: 91; Smith 1872; Boblaye 1836; Leake 1830: 3.111). Evidence of seasonal flooding and associated burial of parts of the site under silt is clear at Stymphalos, with flooding being one of the primary causes of artefact and architectural element displacement at this site (Williams and Price 1995; Williams 1983; Bourne 1982).

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[3] The village of Stymphalia is also occasionally identified as the village of Zaraka, particularly in the writings of the 19th century travel authors such as Fiedler (1840: map) and Leake (1846: map of the Morea).

[4] The lake in question is referred to in the publications of Williams et al. as Lake Stymphalos. Lock (1995) in discussing a letter sent by Geoffrey de Villehardouin identifies the lake as Lake Stymphalia, as does Panagopoulos (1979), while Simpson and Dickinson (1979) refer to this lake as Lake Zarakas.

[5] Mt. Kyllini is also commonly spelt Mt. Cyllene or Mt. Kyllene.

4.2.1.2–References to Stymphalos in Ancient History

Historically relatively little is known of ancient Stymphalos, despite its proximity to the more prominent sites of Nemea and Corinth and its location along the frequently traveled route between Corinthia and Argolis (Grossman 2004; Williams et al. 1998; Bell 1989; Wilamowitz-Moellendorff 1930; Fig. 4.1).

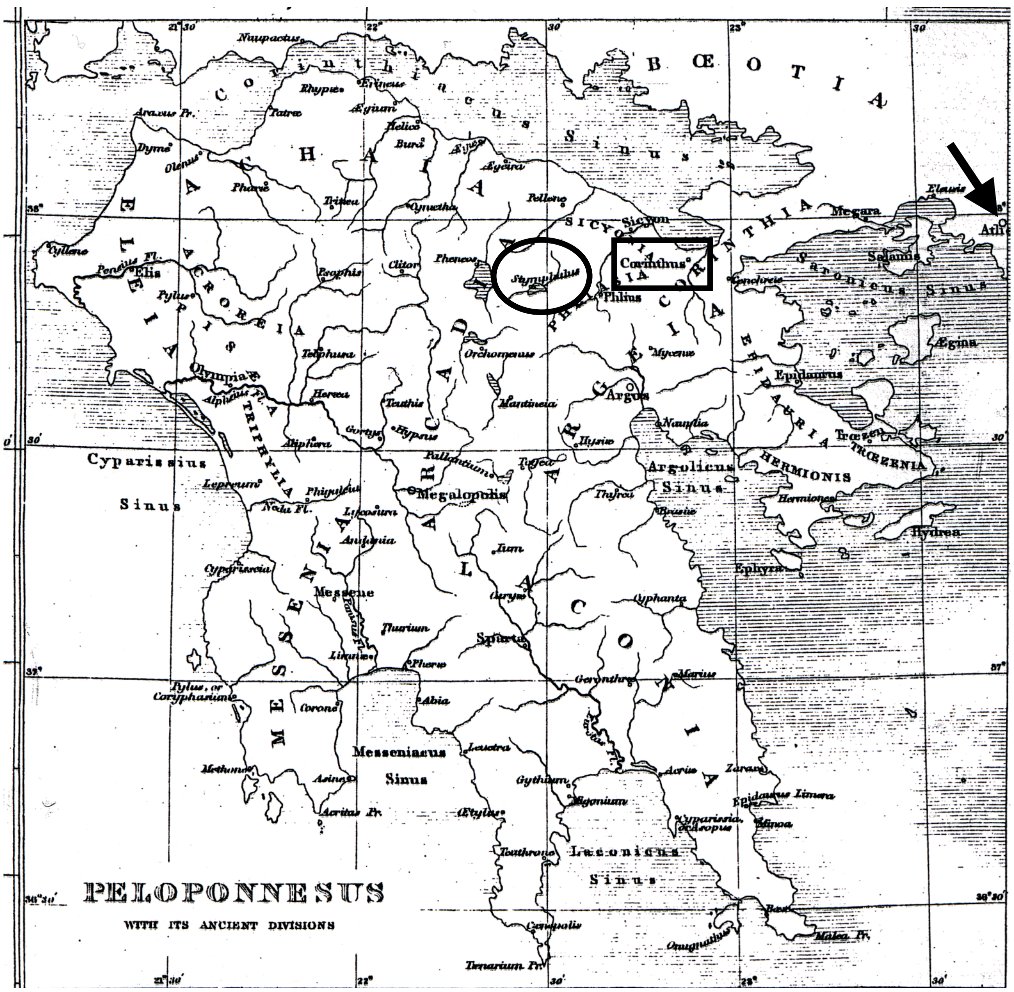

Fig. 4.1–Map showing the location of Stymphalos (black circle) in relation to Corinth (black box) and Athens (black arrow). Adapted from Leake (1846: map of the Morea).

Stymphalos is best known as the location of the mythical sixth labour of Herakles, where Herakles using a brass rattle and arrows drove out the troublesome birds known as Stymphalides, which where said to resided in lake

Stymphalos (Williams et al. 1998; Apollonios Rhodios 1997: 2.1052–1057; Diodorus Siculus 1933: 4.12.13.2; Dio Chrysostom 1932: 47.4; Lucretius 1931: 5.29; Apollodorus 1921: 2.5.6; Strabo 1917: 8.6.8; Smith 1872).

One of the earliest references to the region where the site of Stymphalos is located can be found in the *Iliad* of Homer (1965: 2.603–608) where it discusses "they that held Arcadia beneath the steep mountain of Cyllene…and that held Stymphalus," denoting a possible early occupation of the valley and indicating specifically the region where the site of Stymphalos would continue to develop in later years.

Detailed evidence of the existence of the site of Stymphalos in antiquity is scarce. An early reference to the city can be found in the 5th century BCE work of Pindar who notes that Hagesias, an Olympic victor of the mule chariot race, most probably in 472 BCE, was from Stymphalos (Williams et al. 1998; Pindar 1961: *Olympian Odes* 6).

From the work of Pausanias (ca. 2nd century CE), it is learned that Stymphalos was an Arcadian city in the northeastern Peloponesse, though allegedly not included among the Arcadians by the time of Pausanias, which belonged to the Argive League in the Nome of Corinthia (Williams et al. 2002; Williams and Schaus 2001; Pausanias 1918: 8.22). According to Pausanias the name of Stymphalos is derived from Stymphalus the founder of the city, who was the son of Elatus, grandson of Arcas who was the son of Callisto (Grote 1937: 1.150–159; Pausanias 1918: 8.22.1; Smith 1872). Pausanias ascribes the name Stymphalus not only to the ancient city, but also to a nearby river and aqueduct

(Lolos 1997; Leake 1846: 384). Regarding the river Stymphalus, Aelian (1997: 2.33) notes that the Stymphalians worshipped the Erasinus and the Metope, which are alternative names for the river Stymphalus (Herodotus 1963: 6.76).[6] Further information is provided by Pausanias about the chronology of the settlement in the account of his travels through the region of Stymphalos, during which he describes coming upon a still functioning temple to Artemis, remarking, however that the site of Stymphalos was largely abandoned by this time (Pausanias 1918: 8.22; Martha 1883). Pausanias also notes that the site he observed is believed to have been founded upon the remains of an earlier site, indicating an earlier occupation of the valley, though the location of such an earlier occupation is as yet unknown (Pausanias 1918: 8.22.1; Curtius 1851: 161).

Evidence of the existence of Stymphalos in antiquity can also be drawn from passing references to the site in a number of other ancient works. Xenophon identifies Aeneas, general of the Arcadians, as being from Stymphalos and further discusses attacks in the region of Stymphalos by the Athenian general Iphicrates in 391 BCE or 370 BCE (Xenophon 1918a: 4.4.9–15, 6.5.49–52, 7.3.1; Williams et al. 2002). Diodorus details the sudden nighttime capture of the city by Apollonides in 315 BCE (Williams et al. 2002: 136). Polybius, in discussing the Peloponnesian military presence of Philip of Macedonia in ca. 219 BCE, details troops moving through the territory of Stymphalos and "past Stymphalus itself in the direction of Caphyae" (Polybius 1922: 4.68.2–7). Though Polybius makes no

[6] Metope is taken to refer to the river Stymphalus before it leaves the valley, while Erasinus is taken to refer to the river after it re-emerges from its subterranean course near Argolis (Herodotus 1963: 6.76; Pausanias 1918: 8.22.3; Tozer 1882: 112; Smith 1872: 1039; Curtius 1851: 202; Leake 1830: 2.343, 3.113; Gell 1817: 154). Pouqueville (1822: 106) on observing the river in the valley of Stymphalos notes that in his opinion it is approximately as wide as the Seine in Paris.

mention of actual structures or inhabitants at Stymphalos the phrasing of the reference seems clear in indicating that the region of Stymphalos was overseen by inhabitants of the valley, undoubtedly those residing at "Stymphalus itself." Livy (ca. 59 BCE–17 CE) in *Ab Urbe Condita* details the ca. 197 BCE plans of Nicostratus to amass forces at Apelaurum in the land of Stymphalia, though no specific details are provided about Stymphalos or its inhabitants (Livy 1961: 33.14.10).[7] By the time of Strabo (ca. 63 BCE–24 CE) Stymphalos is listed as one of the abandoned cities of Arcadia, an abandonment that most likely occurred around the time of the campaign of Mummius against the Achaean League resulting in the defeat of Corinth in 146 BCE (Williams 2008; Williams 1996: 80; Williams and Price 1995: 8; Catling 1982–83: 22; Strabo 1917: 8.8.2).

4.2.1.3–Archaeological Investigations of Stymphalos in the Modern Era

Between the time of antiquity and the modern era there is little mention of Stymphalos, except for several observations about the design and structural remains of the ancient settlement and surrounding valley provided by travelers (Williams et al. 1998; Wilamowitz-Moellendorff 1930; Fougeres 1898; Beulé 1875; Bursian 1862; Vischer 1857; Curtius 1851; Leake 1846; Boblaye 1836; Leake 1830: 3.110; Pouqueville 1822: 105–108; Gell 1817: 148–154; Coronelli 1687).

[7] The order to amass near Apelaurum is taken to be in reference to the area near Mt. Apelaurum in the southern part of the valley of Stymphalos. Smith (1872: 1039) notes that there is also a small town known as Apelaurus which he proposes as being the location of the victory of the Achaeans over the Macedonians in 197 BCE, as described by Livy (1961: 33.14.10) in *De Urbae Condita*. The name Apelaurus also appears in Polybius (1922: 4.69.1). It is likely that Apelaurum and Apelaurus refer to the same or very similar locations as Leake (1830: 3.112, Peloponnesus map) uses the spelling Apelaurus in reference to the mountain in the southern part of the valley of Stymphalos suggesting the synonymity of the two locations.

It was not until 1910 under the auspices of the German Archaeological Institute that Stymphalos was investigated archaeologically (Williams and Schaus 2001). The explorations of the German Archaeological Institute were cursory and revealed little about the remains at Stymphalos.

The first significant excavations of Stymphalos were conducted in 1924–1930 under the direction of Anastasios Orlandos, on behalf of the Archaeological Society of Athens (Williams and Schaus 2001; Orlandos 1930, 1929, 1928, 1927, 1926, 1925, 1924). The excavations of Orlandos focused primarily on the area adjacent to the lake and along the southern side of the city, with limited excavations also being conducted in what is now known to be the sanctuary of Athena (Williams and Schaus 2001: 76). The excavations conducted under Orlandos were also responsible for identifying the Phlious Gate, one of three main gates identified at Stymphalos (Orlandos 1925, 1926; Williams et al. 2002: 167; Williams 1984: 174). Unfortunately a significant portion of the excavation records compiled by Orlandos were lost (Williams and Schaus 2001).

With the completion of the work conducted by Orlandos excavations at Stymphalos ceased until 1982, when Dr. Hector Williams of the University of British Columbia (UBC), in association with the Canadian Archaeological Institute at Athens (CAIA) and the Archaeological Institute at Athens, once again began excavations at this site. The excavations conducted under the direction of Dr. Williams are the most extensive to date, lasting until 2001 and including geophysical, conductivity, magnetometry, ground penetrating radar and resistivity surveys of the surrounding landscape (Williams et al. 2002; Williams et al. 1997;

Catling 1982–83). Excavations at the Frankish site of Zaraka, located in close proximity to the ancient site of Stymphalos, were also conducted under the aegis of Williams' project under the direction of Dr. Sheila Campbell of the University of Toronto (Campbell 1997).

4.2.1.4–History of Stymphalos Based on Excavation Data

From the excavations conducted by Williams and colleagues it was ascertained that the site of Stymphalos was most likely first occupied around 375–350 BCE (Williams et al. 2002: 136). There has been some evidence to suggest an earlier and more sporadic period of occupation in the area of Stymphalos around 400 BCE, based on the identification of artefacts dating to the Late Archaic and Early Classical periods, as well as silver coins of the Arcadian League dating to 465–455 BCE, though there has been no accompanying settlement identified from this period thus far (Williams et al. 2002). Thus a settlement date closer to 350 BCE remains the most likely date of establishment (Williams et al. 1997).

Excavation data suggests that during the 4th century BCE occupation there was a limited destruction and re-settlement of the site (Williams et al. 2002: 136). Weir (2004) proposed that re-construction of the site's fortifications in the early 3rd century BCE may have been undertaken by Macedonian soldiers in the region.

During the 2nd century BCE it appears that Stymphalos was partially destroyed and subsequently saw a significant decline in use, though it is unlikely that total abandonment occurred at this time (Williams et al. 2002: 136). It has been suggested that this 2nd century BCE decline was likely due to Roman military activity in the region during the Achaean war, as the destruction of

Corinth in 146 BCE is well documented and it would not be improbable for similar destruction to have befallen Stymphalos considering the military activity in the region and the relative proximity of Stymphalos to Corinth (Williams et al. 2002: 136; Williams 1996: 80).

Following this period of decline it is known that re-settlement of Stymphalos took place during the Roman period (Williams et al. 1998, 1997). During the Roman period of occupation the history of Stymphalos becomes relatively scant. Excavations indicate that Stymphalos and the surrounding area continued to be occupied into at least the 6th century CE (Williams et al. 2002). Evidence for this occupation is based predominantly on the identification of a series of Late Roman–Early Byzantine burials among the abandoned structures of the site as well as coins and pottery from this period, though such artefacts were few (Garvie-Lok n.d.: 11; Williams et al. 1998: 297). The presence of the burials suggests that there were inhabitants living in the valley during the 5th–6th century CE who were using the non-arable land occupied by the buildings of the ancient site of Stymphalos for their cemeteries. The occupants of the valley during this time period likely lived elsewhere nearby, though the exact location and function of the settlement remains unclear at this time (Williams et al. 2002).

4.2.1.5–The Remains of Stymphalos, with Particular Focus on the Burials

This section is intended to provide a brief description of the physical remains of the ancient site of Stymphalos, as identified through excavation. As the present work is not overly concerned with the methods of construction or city planning the descriptions provided of such elements in this section will be cursory, while descriptions of the burials identified will be necessarily more detailed.

The Late Classical site of ancient Stymphalos follows a typical orthogonal plan and is enclosed by a ca. 3m wide rubble core triangular pattern wall of stone and mudbrick construction, with three gates and intervals of semi-circular towers along the outer wall, which encloses approximately 800 m x 800 m of land (Williams et al. 2002: plan 1; Williams et al. 1997; Williams 1984: 174; Catling 1982–83: 23).[8] The layout of the city is patterned into north–south blocks approximately 30 m wide and over 100 m long with 6 m wide streets on each side and a main access street that was 8 m in width leading to the Phlious gate (Williams et al. 2002: 139; Williams 1984: 178; Catling 1982–83: 22).

Excavations of the ancient city revealed a number of buildings including various houses, a fountain house, a theatre, an artillery bastion, several temples of various function, a sanctuary to Athena on the acropolis, a gymnasium or palaestra, and two large towers that may have been intended for artillery, with one on the south side and one on the west side of the site; also present are the remains of an aqueduct constructed under the Roman emperor Hadrian to facilitate the transfer of water from Lake Stymphalos to Corinth (Williams 2008; Williams et al. 1997; Williams 2000; Lolos 1997; Catling 1982–83; Pausanias 1918: 8.22.3; Bursian 1862: 38; Curtius 1851: 529; Pouqueville 1822: 99; Gell 1817: 148–149).

Analysis of the pottery, both fine and coarse wares, recovered from excavations at Stymphalos provided insightful information about the origin and

[8] The three gates are referred to respectively as the Westgate, Pheneos Gate, and Phlious Gate (Williams et al. 2002: plan 1).

use of various vessel types at the site. Pottery analysis revealed that a majority of the fine wares were imported while coarse wares were typically produced from local sources (Williams et al. 1997; Williams 1996). Based on the fact that coarse wares, including storage vessels, were locally produced Williams et al. (1997) have proposed that the inhabitants of Stymphalos were predominantly independent agriculturalists.

Looking at the burials of Stymphalos it is apparent that they do not belong to the original period of the site's occupation but rather date to a later period of occupation in the valley, belonging to the 5^{th}–6^{th} century CE. Williams et al. (2002: 139) explain that the site utilized by the 5^{th}–6^{th} century CE inhabitants of the valley has yet to be located, and it is unclear at this time if the valley was continually inhabited after this time period (Efthymiou 1999: 19).

Several clusters of burials, typically poorly preserved, were identified among the abandoned buildings of ancient Stymphalos as well as in close proximity to the modern village of Stymphalia (Williams et al. 2002). To date, Garvie-Lok (pers. comm. 2008) has identified a minimum number of individuals (MNI) of 40 from the site of Stymphalos. The burials identified typically employed the remains of ancient buildings of Stymphalos, both as graves and grave coverings (Garvie-Lok n.d.: 11–12). Of the burials identified it was typical for bodies to be located between walls or foundations with stone tiles forming a lining as well as a makeshift vault or covering over the burials (Garvie-Lok n.d.: 11–12; Pennycook 2008b). It appears clear from the lack of inhabitation at the site of Stymphalos during the era of these burials that the site itself acted as the locus of a number of cemeteries for individuals living in the valley and not as a re-occupied settlement site (Williams et al. 2002). Such an assertion is easily understood in context. The site of Stymphalos had been abandoned yet its physical remains were still present. As later occupants in the valley arguably sought to practice agriculture, it is only practical that the site of Stymphalos would have been chosen for burial. This proposal is based on the facts that there are already materials and space for burials; the land occupied by the abandoned city could not have been used with any success for crop cultivation and the prominence of the site would have allowed for easy identification of the cemeteries on the landscape (Williams et al. 2002).

The individuals identified from these burials were predominantly interred on an east-west axis, with the heads of the individuals pointing west (Williams et al. 2002). Furthermore, very few burial goods were found with the bodies (Williams et al. 2002). This particular axis of burial in conjunction with the scarcity of burial goods correlates strongly with the Christian burial practices of the period, and as such provides further evidence that the burials in question belonged to a later and potentially Christian group (Williams et al. 2002). Looking at the specific interments in different regions of the site it can be seen that while there is some variation, there are many commonalities in burial style.

A multiple burial was uncovered in the northeastern corner of the pronaos of the temple of the sanctuary of Athena (Williams et al. 1998: 288). This burial contained five individuals, including an articulated sub-adult, as well as various commingled remains of an infant, an older juvenile (10–15 years old) and three adults, identified as a middle aged male and two females, one older and one younger than the male individual (Garvie-Lok n.d.: 9–10; Williams et al. 1998: 287). Garvie-Lok (n.d.: 12; Williams 2005) has suggested, based on the age and sex distribution of the individuals represented in this grave, that burials from this time period at Stymphalos may have been used as family plots, where family members would be added to the grave as they died. The sub-adult recovered from the burial described was interesting in that this individual was buried with what are believed to have been copper earrings, based on copper staining on the temporal bones, and small beads, potentially from a bracelet or necklace (Williams et al. 1998: 288). Such items were rare among the burials excavated and are also unusual based on the fact that children were typically interred with relatively few burial items, making this individual particularly interesting. Based on the observation of earrings it has been proposed that this sub-adult individual was likely female (Williams et al. 1998: 288). The burial containing these individuals was constructed of re-used roof tiles, as well as rough stones and square cut blocks taken from the ruins of the buildings of Stymphalos (Williams et al. 1998: 287).

Trench excavations at Site III, the “Monastiraki” area, revealed a series of burials. Three bronze coins of mid-6th century CE date were found in close proximity to these burials, further supporting the date of such burials to the 5th–6th century CE (Garvie-Lok n.d.: 11; Williams et al. 1998: 297). In a separate trench in the same area, located a few metres north of the temenos wall foundation, various further scattered human remains were identified (Williams et al. 1998: 300).

In the bastion area of the site some 10 burials were identified, of which four were excavated overlying the bastion and the surrounding wall (Williams 2000; Williams et al. 1998). As a result of the concentration of burials in this section of the bastion this area has subsequently been referred to as a necropolis (Williams et al. 1998: 311). The burials represented in this necropolis area were comprised of two forms. There were shallow pit graves covered with re-used Laconian roof tiles, which were leaned one against the other to form a vault and subsequently covered with soil (Williams et al. 1998: 311). There was also one large burial, consisting of a pit lined with pieces of stacked tiles, which were then coated with plaster to seal the burial (Williams et al. 1998: 311). Grave goods among these burials were few with one individual having a bowl behind his knees, while another individual was identified with a 4th century CE imitation Athenian "Leaf workshop" bowl of Corinthian production (Williams et al. 312). The bastion necropolis according to Williams et al (1998: 313) was likely established between 350–400 CE. The bastion, more so than other areas, is believed to have been chosen for use as a necropolis due to the easily re-usable materials at this location as well as the prominence of the area on the landscape allowing for easy identification from surrounding locations (Williams et al. 1998: 312).

Looking at the construction and utilization of the burials identified at this site it is clear that there was a preference for employing previously used materials, particularly tiles, to form vaults for the burials (Garvie-Lok n.d.: 12). It is also apparent, based on burials the size of the juveniles who were interred within them, that graves were dug to fit the size of the initial individual buried and as such grave sizes do not conform to a standard dimension (Garvie-Lok n.d.: 12). Furthermore there is evidence that many of the graves were re-utilized over time, being employed in a secondary fashion where the remains of the previous body would be moved aside and the new individual would be interred, typically on their back in an extended position with the arms along the sides or crossed over the chest (Garvie-Lok n.d.: 12). Such a practice can be identified based on the presence of one well-articulated individual among a series of commingled secondary remains. Though various elements were recovered in excellent condition from a number of the burials, the large majority of osteological elements recovered from the burials at Stymphalos were in a state of poor preservation.

4.2.2–Zaraka

4.2.2.1–Location and Geographic Description of Zaraka

The site of Zaraka (Lat. 37º52'01" N, Long. 22º27'29" E) is located west of the modern village of Stymphalia along the south side of the main road running through the village and approximately 2 km north of the ancient site of Stymphalos (Salzer 1999; Campbell 1997; Williams 1996; Panagopoulos 1979; Bon 1969; Kirsten and Kraiker 1967; Boblaye 1836; Leake 1830). The site of Zaraka is situated in the same valley as the site of ancient Stymphalos and as such the geographical description of the region is identical to that of Stymphalos (Fig. 4.1).

4.2.2.2–History of the Franks in Greece with a Focus on the Area of Zaraka

Historical references to the site of Zaraka[9] are intrinsically linked to the 4th crusade and the subsequent rise of Frankish power in the region of the Aegean in the 13th century CE (Campbell 1997; Panagopoulos 1979; Brown 1958). With the rise of Frankish power in the region of the Peloponesse came the introduction of the Cistercian monastic order (Brown 1958). The rise of the Cistercian order in Greece was a seemingly natural occurrence as it is well documented that the Cistercian order was a preferred monastic order of many Crusaders, as the Cistercian order was of considerable aid to the papacy during the Crusades (Grossman 2004; Bolton 1976; Brown 1958). The Cistercians themselves were known to have been active supporters of the second (1147–1149 CE), third (1189–1192 CE) and fourth (1202–1204 CE) crusades, and in some cases participants in the crusades, particularly in the fourth (Efthymiou 1999; Lock 1995; Froehlich 1987; Bolton 1976; Brown 1958).

With Frankish victory in the Peloponesse came the establishment of Cistercian monasteries in the region. Between 1204–1276 CE it is known that the Cistercian order developed at least twelve houses, one of which was the monastery at Zaraka, which is believed to have been named for the valley in which it was built, a practice that was common in the naming of Cistercian

[9] Zaraka is also referred to in various sources as Sarakez, Saracez or Saracaz, as this was the Latinized spelling of the name in antiquity (Panagopoulos 1979; Brown 1958). Gell (1817) provides a spelling of Zaracca, while Pouqueville (1822) in referring to the general region of the valley gives the spelling as Zaraca.

monasteries (Panagopoulos 1979: 160). However nine of the twelve monasteries established are known to have been subsequently lost within a relatively short period of time (Brown 1958).

The first indication that a monastery might be constructed in the region near Zaraka can be traced to 1210 CE when on November 5, acting in response to the suggestion of Geoffrey I Villehardouin as prompted by the archbishop of Patras, Pope Innocent III requested that monks be sent from Hautecombe to archbishop Anselmo of Patras to establish a monastery on lands that Geoffrey I was willing to grant for such a construction (Salzer 1999; Panagopoulos 1979; Clair 1961; Haluscynskyj 1944: 525, no. 38).

One of the earliest references to the construction of the monastery at Zaraka was on the part of Geoffrey I Villehardouin who in 1225 CE had requested from the Chapter General[10] that a group of monks be sent from Hautecombe to construct a monastery in Achaia[11] (Campbell 1997; Lock 1995; Clair 1961; Brown 1958).[12] The monastery in question is believed to have been Zaraka in the

[10] Chapter General or the General Chapter refers to the general assembly of representatives from all of the Cistercian monasteries.

[11] Achaia refers to the ancient Greek province located along the northern coast of the Peloponesse. The term Achaia during the Frankish period was used to refer to the Frankish kingdom of the Peloponesse. The term Morea was the more colloquial or vulgar Latin term used by the Frankish Crusaders to refer to the parts of the Peloponesse under Frankish control (Salzer 1999: 298; Campbell 1997: 178; Sheppard 1985).

[12] There is a certain level of confusion in discussing the historical material regarding the request to establish a monastery in Achaia. Brown (1958: 93) states that Geoffrey of Villehardouin had offered to build a house in Patras in 1210 and then in 1225 asked the Chapter General to build a monastery in Achaia, a task which is stated as having been entrusted to the abbot of Morimond. Panagopoulos (1979: 28–29) indicates that before 1210 the prince of Morea, William of Champlitte, requested from Pope Innocent III that Cistercian monks be sent from Hautecombe in Savoy to establish a monastery in Morea on land that he would donate. Panagopoulos goes on to detail that on a separate, unspecified, occasion Geoffrey I of Villehardouin asked the Chapter general to send monks to establish a monastery in Achaia, a task that was entrusted to the abbot of Morimond. Lock (1995: 224) seems to simplify this by stating that in 1210 Geoffrey de Villehardouin offered the monks of Hautecombe a house in Patras. Lock (1995: 224) further

archdiocese of Corinth, though this remains uncertain as the reference could also have been either the monastery at Andravida or that at Isova (Lock 1995; Panagopoulos 1979; Brown 1958; Canivez 1934: 236).[13] As the exact details of the establishment of a monastery at this site remain obscure it is proposed by Brown (1958) that it was not necessarily construction of a new monastery that took place at Zaraka but may simply have been a transfer and expansion of an already constructed settlement to Cistercian control, seeing a foundation date of ca. 1223–1224 CE, though this foundation date still remains questionable (Lock 1995; Millet 1899).[14] Following this period there is strong evidence that the monastery at Zaraka was thriving by 1236 CE (Brown 1958; Janauschek 1877: 227).

A reference to the monastery at Zaraka appears in 1236 CE when the Latin Empire was under pressure from invading forces (Brown 1958).[15] It was at this

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details that in 1225 Geoffrey summoned monks from Hautecombe to Achaia to found the monastery at Zaraka. Salzer (1999: 302–303) states that in 1225 Geoffrey I requested from the Chapter General that a Cistercian abbey be constructed, which order was relayed by the Chapter General to the abbot of Morimond, bringing into question which monastery, Hautecombe or Morimond, was the mother house of Zaraka (Canivez 1934: 47).

[13] There is a level of minor inconsistency in the statements made by Brown (1958) and Lock (1995). Brown states that the monastery at Zaraka was founded in the diocese of Corinth, while Lock states that the monastery was in the archdiocese of Corinth. The difference between these two statements is that a diocese is a district under the pastoral care of a bishop, while an archdiocese is a district for which an archbishop is responsible. It is likely that both statements in this case are true with the reference to diocese being at a more specific level than archdiocese.

[14] Salzer (1999: 304) disagrees with Brown on this point. Salzer notes the use of the Latin terms for construction, *construendo/construenda*, with that for transfer, *transferre*, noting that all of the entries in the records of the Chapter General regarding the establishment of Zaraka use the terms for construction and never those for transfer, thus in Salzer's view negating the possibility of a transfer and necessitating the interpretation of construction.

[15] The term "Latin Empire" refers to territory captured from the Byzantine Empire during the Fourth Crusade and thereafter controlled by a Crusader state. One of the purposes of the Latin Empire was to replace the power of the Orthodox Byzantine Greeks with a western Catholic Emperor, an objective which is clearly implicated in the establishment of Cistercian monasteries such as Zaraka where Roman Catholic monks would have lived (Lock 1995; Panagopoulos 1979; Bolton 1976; Ostrogorsky 1969; Brown 1958; Hussey 1957; Haluscynskyj 1944: 303–304, no. 81).

time that Pope Gregory IX ordered the Archbishop of Patras and all those under his control to give one-tenth of the annual revenue of their churches to put towards the campaign to save Romania (Campbell 1997; Brown 1958; Tautu 1943: 292–293, no. 217). One of the individuals sent to collect this money was the Cistercian abbot of Zaraka, suggesting that the monastery at Zaraka was functional at this time (Brown 1958; Tautu 1943: 292–293, no. 217; Miller 1908).

In 1237 CE the Abbot and Prior of Zaraka are mentioned in several letters from Pope Gregory IX. The letters detail how the Abbot and Prior of Zaraka were to investigate and permit requested permissions for the exemption and transfer to the Order of the Hospice of St. Mary of the Teutons of Romania, as well as permission for such transfer to the Praeceptor and Brother of St. James, a task which was completed before April of 1241 CE (Strehlke 1975: 134–137, nos. 134, 135, 139; Potthast 1874: 887 no. 10452).

In 1241 CE an order from the Chapter General was given to the abbots of Zaraka and Daphni to put an end to the issue of fugitive monks who had apparently been absent from their respective monasteries without appropriate leave; if the monks did not return upon warning it was advised that they be excommunicated (Campbell 1997; Brown 1958; Canivez 1934: 236–237).

Reference to the continued activity of the monastery at Zaraka can be observed in the order of the Chapter general in 1257 CE that the abbot of Zaraka should undergo punishment for failing to attend the meetings of the Chapter General on several occasions (Brown 1958; Canivez 1934: 432). Further evidence is provided by the order given to the abbot of Zaraka in 1260 CE regarding arriving at a judgment of a case concerning a complaint received by a knight named Lord Aymo de Molay against the abbot of Daphni (Campbell 1997; Brown 1958; Canivez 1934: 470).

In the same year the abbot of Daphni and the abbot of Rufinianai were sent to inspect the location to which the monastery of Zaraka was scheduled to be relocated (Salzer 1999; Brown 1958). The relocation of the monastery of Zaraka is believed to be due to the increasing presence of Greek forces in the region, exposing the monastery to potential attack. Due to this increased danger the abbot of Zaraka decided it was appropriate to relocate the monastery to a safer location (Clair 1961: 275). It is at this time that the decline of the monastery of Zaraka begins to become apparent.

It is clear that in 1260 CE Zaraka was still a functioning monastery, though 1260 CE is the last recorded mention of Zaraka in the Chapter General, when a request for a transfer of location is recorded (Salzer 1999; Bon 1969; Canivez 1934: 473). It is at this time that the monastery at Zaraka is believed to have entered into an irreversible decline. Brown (1958) claims that the monastery at Zaraka was likely abandoned in 1260 CE or shortly thereafter, while Campbell (1997: 195) proposes that the ultimate abandonment of the site was likely closer to 1275–1280 CE, admittedly with a significant period of decline before this date of abandonment. Within the next decade the monastery at Zaraka would go out of use; however the exact date of abandonment of this monastery is not presently known (Brown 1958).

The abandonment of Zaraka at this time correlates with the abandonment of many Cistercian monasteries (Brown 1958). By 1276 CE all of the Cistercian monasteries in Greece, except for the monastery at Daphni and one on Crete, were abandoned (Campbell 1997: 180). This abandonment can be linked to security concerns and to the fact that the western Christian monasteries were not necessary for the local population, as the Greek population largely continued to maintain the traditions of the Orthodox Church, and in several cases may have shown animosity towards the Latin Church (Salzer 1999: 301; Campbell 1997: 186; Bolton 1976; Jacoby 1973; Schmitt 1967: lxx).[16]

4.2.2.3–Archaeological Investigations of Zaraka in the Modern Era

As was the case with Stymphalos, the site of Zaraka was essentially uninvestigated until the modern era, being mentioned most frequently by travelers in the region as the name of the nearby village/lake/valley in close proximity to ancient Stymphalos, with only infrequent mention of the remains of the monastic compound (Curtius 1851; Leake 1846; Boblaye 1836; Leake 1830; Gell 1817).[17]

Archaeological excavations at Zaraka were not undertaken until the time of Orlandos who conducted research in the area in connection with the

[16] Salzer (1999: 302) disagrees with the generally presented view that the indigenous Greek populations of the Peloponesse were in constant struggle with the foreign Frankish powers present in the region. Rather Salzer suggests that the Greeks of the Morea, despite their proposed dislike of the Franks, in actuality had a working tolerance of the Franks. Such a belief is largely based on the fact that there are only two recorded Greek rebellions in the region during the era of Frankish control, both of which occurred in Skorta.

[17] The lack of mention given to the remains of the monastic compound at Zaraka in the accounts of travelers in the region is surprising, particularly considering the preservation and prominence of these remains on the landscape compared to those of ancient Stymphalos. Mention of the remains at Zaraka is provided by Boblaye (1836: 147) when he records observing the Catholicon or church at Zaraka.

excavations he was undertaking at Stymphalos during the period from 1924 to 1930 (Orlandos 1957, 1926; Panagopoulos 1979; Williams and Schaus 2001).

Excavations at Zaraka were continued under E. Stikas beginning in 1962. It is unclear as to how long Stikas continued to excavate at Zaraka as none of his work has been formally published; given this it is reasonable to propose that his excavations were limited (Panagopoulos 1979: 29; Bon 1969: 554). From the excavations of Orlandos and Stikas a fairly clear plan of the church and associated buildings of the monastery site were generated (Panagopoulos 1979: 29).

After the work of Orlandos and Stikas excavations at Zaraka ceased until research conducted by Williams et al. as part of the UBC/CAIA project in the 1980's. The UBC/CAIA project aerial photography and geographical survey investigations resulted in the compilation of a detailed plan of Zaraka and the surrounding area (Williams 1996; Williams and Price 1995; Williams 1985; Williams 1984). However Zaraka was not the primary focus of the UBC/CAIA project and as such significant research on the site was not conducted until the work of Dr. Sheila Campbell.

From 1993–1997 excavations at the site of Zaraka were conducted as part of the UBC/CAIA Stymphalos Valley project under the direction of Dr. Sheila Campbell (Campbell 1997; Williams 1996). The excavations carried out by Dr. Campbell were conducted under the auspices of the Pontifical Institute of Medieval Studies (Campbell 1997).

4.2.2.4–The Remains of Zaraka, with Particular Focus on the Burials

The remains of the settlement at Zaraka are identified as the best preserved and one of the most important examples of a Frankish monastic site in Greece (Bouras 2001: 248–249; Campbell 1997: 177; Panagopoulos 1979).

The excavations conducted by Campbell identified the remains of a gate, a two-storey gatehouse and tower associated with the partial remains of an enclosure wall, and a rectangular church constructed using a rubble core technique and oriented southwest to northwest, measuring 34 m by 16 m (Campbell 1997: 181). It is clear from the remains at Zaraka that various materials used to construct the buildings had been taken from the nearby ancient site of Stymphalos (Salzer 1999; Campbell 1997; Catling 1982–83).

Architecturally the church at Zaraka followed a design pattern common to many Cistercian churches, exhibiting a rectangular protruding apse, single side aisles, possible rib vaulting, a narthex or semi-open porch along the southwest aspect of the western façade, a square choir flanked by square chapels, and the complete absence of a transept (Grossman 2004; Efthymiou 1999; Salzer 1999; Campbell 1997; Panagopoulos 1979; Bon 1969; Orlandos 1957; Aubert 1947).

On the eastern side of the church excavations revealed a tomb, which was possibly the tomb of the founding abbot of the monastery (Campbell 1997: 181).It is proposed that the church was lighted by large windows at floor level, and may also have employed clerestory windowing, however there is a lack of agreement on this aspect between the reconstructions of Panagopoulos (1979) and Campbell (1997). The design chosen for the construction of the buildings at Zaraka has strong links to the patterns of construction seen at many of the Cistercian monasteries throughout Western Europe (Campbell 1997; Aubert 1947).

An interesting architectural element that was identified at Zaraka, but is far less common among other Cistercian monasteries, was the presence of a stone bell tower on the northeastern side of the church (Campbell 1997: 190). The employment of stone bell towers was forbidden according to the general chapter as of 1157 CE (Panagopoulos 1979: 30; Canivez 1933: 61). However despite being forbidden it is also known that this particular rule was only truly observed in France and Germany, while it is clear that this rule was not strictly observed in Spain, England, Italy, and Greece (Panagopoulos 1979; Aubert 1947). Panagopoulos proposes that the bell tower at Zaraka may have been constructed because the surrounding valley was likely widely used for agricultural purposes and monks could have potentially traveled a significant distance from the monastery so as to be out of range of hearing a human voice. The bell tower may have been employed to signal the monks in the field to return to the monastery (Panagopoulos 1979). The theory of extensive agriculture taking the monks to distant areas of the valley is further supported by the identification of an extensive irrigation system in the valley (Campbell 1997).

With regard to ornamentation very little decoration, both statuary and architectural, was identified at Zaraka, being limited to decorated column bases and capitals (Campbell 1997; Panagopoulos 1979). Such frugality in ornamentation is a typical feature of Cistercian monasteries (Panagopoulos 1979).

Several Venetian coins dating to the 14th century CE, two antlers, bronze fittings, a pair of scissors, a knife handle, as well as bone and pottery fragments were recovered from Zaraka, indicating that the site was re-used to some extent after its initial abandonment in the late 13th century CE (Campbell 1997: 192).

Based on the small finds recovered at Zaraka Campbell (1997) proposes three phases of utilization. The initial phase was that of the Cistercian monastery, the second use occurred in the 14th century CE, and a third phase dating to the 15th century CE was identified based on the deposition of ash and debris at the site, which was likely a result of excavations to facilitate burials in the area (Campbell 1997: 196).

The relative scarcity of evidence indicating a permanent occupation of Zaraka after its initial abandonment suggests the site may have been used as a temporary shelter for groups traveling through the region (Campbell 1997: 196). This proposition is not unlikely considering the significant level of preservation of the architectural remains at this site in the modern era, thus making them an ideal location for seeking shelter in the valley.

The presence of burials dispersed, seemingly at random, around the site suggests that Zaraka may also have served as a makeshift cemetery to bury individuals who potentially may have died en-route to another location and thus could not be carried any further (Campbell 1997). The use of Zaraka as a makeshift cemetery from a later occupation period seems viable for several reasons. The preservation of the architectural remains would allow for easy location of the burials on the landscape, making re-locating and visiting the site a potential, particularly if the group or groups in question frequently traveled through the region. Furthermore the sex and age composition of the burials identified makes the possibility of their association with the monastic use of this site unlikely.

Garvie-Lok (pers. comm. 2008) established an MNI of 7 individuals from the burials at Zaraka. The remains of an infant were found approximately 1 m north of an adult burial in close proximity to the church wall (Campbell 1997: 192). Four further burials were identified, with two being located north of the lay brothers' door under a floor of thick coarse mortar in the narthex, with one individual being identified as an adolescent female based on the presence of earrings, a necklace, and a bracelet (Campbell 1997: 192). The other two burials were identified in the cloister (Campbell 1997: 192).

Of these seven individuals five were identified as sub-adults, while the remainder were identified as an adult male and female (Campbell 1997: 192). The mixed sex, age, and relatively few burials at this site suggest that these individuals were not part of the monastic community. If these were monastic burials one would typically expect to find more, if not almost exclusively, adult males. One would also expect a more uniform area of the site to have been designated as a cemetery. Furthermore one would not expect to find burials in the cloister and the narthex of the site if these burials had belonged to the monastic phase of occupation at Zaraka (Campbell 1997: 192).

Considering the evidence presented, the opportunistic nature of the areas of the site used for the burials, and the evidence of grave excavations after the original abandonment of the site, it can be confidently asserted that the burials represented at Zaraka date to a later period of occupation, after the initial abandonment of the monastery.

4.2.3–The Chronology of the Burials at Stymphalos and Zaraka

Considering the burials identified at Stymphalos and Zaraka it is apparent that none of the burials examined are associated with the original occupation of the sites at which they were interred. It is clearly observed at Stymphalos that materials such as roof tiles and other debris were utilized to bury individuals in the structural remains of the site. The same pattern of material re-use can be seen at Zaraka where individuals were buried in the abandoned remains of the former monastic compound. Considering the opportunistic nature of all of the burials identified at both Stymphalos and Zaraka it is not unlikely, and in fact is most probable, that later occupying groups in the valley were responsible for the graves identified at both Stymphalos and Zaraka.

4.3–Research Samples and Methods

4.3.1–Samples

The research samples utilized for the present study were excavated during the 1996, 1997 and 2000 field seasons as part of the UBC/CAIA Stymphalos Valley Project. At the time of examination for the present study in the summer of 2008 the remains of the individuals herein examined were being curated in the village of Stymphalia. Of the 40 individuals identified at Stymphalos, nine sub-adults were used for the purpose of the present study (Table 4.1). Of the seven individuals identified at Zaraka, five sub-adults were used for the purpose of the present study (Table 4.1).

Table 4.1–Inventory of Stymphalos and Zaraka Individuals Examined

Individual	Age (in years unless specified)	Aging Method
STYM II-97-1	1.5–2.5	Dental development
STYM III-97-1	9–10	Dental development
STYM III-97-2	4–6	Dental development
STYM III-97-3	6–8	Dental development
STYM IV-97-1	10–12	Dental development
STYM IV-97-2	5–9	Dental development
STYM IV-97-5	10–12	Dental development
STYM IX-00-2-1	10	Epiphyseal union
STYM IX-00-2-2	16–18	Epiphyseal union
ZAR 96-2	12–15	Skeletal and dental development
ZAR 96-4	0–6 months	Dental development
ZAR 97-1	3–4	Epiphyseal union and dental development
ZAR 97-2	6–12 months	Dental development
ZAR 97-3	12–24 months	Dental and skeletal development

Sample examined for the presence of juvenile scurvy. No sexing data is provided as all of the individuals examined are sub-adults, an age range for which there is currently no reliable sexing technique. Aging was done by S. Garvie-Lok based on methods presented in Scheuer and Black (2000).

4.3.2–Methods

Two methods of observation were employed for the present study, macroscopic examination and radiography. Initial macroscopic examination of the 14 sub-adult individuals included in this study was undertaken in the village of Stymphalia where the remains in question are being curated. Photographs of the remains were taken to create a database of the remains under observation as well as to allow for future reference to the macroscopic observations made at this time. Radiography was conducted at the Wiener Laboratory at the American School of Classical Studies at Athens.

4.3.2.1–Macroscopic Examination

Macroscopic examination was carried out on all individuals. This examination sought to identify, examine and quantify the presence of porosity believed to be caused by juvenile scurvy as described by Ortner et al. (2001, 1999; Ortner and Ericksen 1997; Ortner 1984).[18] Although most porosity was documented on a present/absent basis, the extent of orbital porosity was graded, and the extent of distal and proximal metaphyseal porosity on the long bones was measured in millimeters (Table A3.2). The severity and extent of orbital porosity observed was graded based on the classification system presented in Stuart-Macadam (1991). This classification system is as follows: 0= normal bone surface, 1= capillary-like impressions on the bone, 2= scattered fine foramina, 3= large and small isolated foramina, 4= foramina have linked into a trabecular structure, 5= outgrowth in trabecular form from the outer table surface.

Regarding abnormal porosity, the research presented here has used the definition provided in Ortner and Ericksen (1997: 212) where abnormal porosity is defined as a localized, abnormal condition in which fine holes, visible without magnification but typically less than 1 mm in diameter, penetrate a lamellar bone surface. The lamellar bone may be normal or abnormal (hypertrophic). Porosity as used in the present research to discuss evidence of juvenile scurvy thus refers to the result of chronic inflammation and not hyperplasia of haematopoietic marrow as is seen in anemia.

[18] For a clarification of the porosity being examined please refer back to sections 2.4.2–Assessment of Skull Lesions and 2.4.3–Assessment of Long Bone and Scapular Lesions in Chapter 2.

4.3.2.2–Radiographic Examination

Based on the identification of the proposed suite of porous lesions believed to be associated with juvenile scurvy, both on the skull and on the long bones, skeletal elements were selected for radiography. Only the long bones, associated epiphyses and in several cases the calcanei of the affected individuals were radiographed. There are no clinical correlates for radiographs of the skull as cranial radiographs of living children are typically avoided unless absolutely necessary. Radiography was conducted under the guidance of Dr. Sherry Fox at the Wiener Laboratory of the American School of Classical Studies at Athens using a MinXray 750 unit and an Agfa Automatic film processor. Results gathered from the Stymphalos and Zaraka radiographs were compared to known clinical radiographic indicators of juvenile scurvy in an attempt to determine if the proposed suite of macroscopic lesions observed, as presented by Ortner et al. (2001, 1999; Ortner and Ericksen 1997; Ortner 1984), can be correlated with known radiographic indicators of juvenile scurvy (Shore 2008; Burton and Brody 1999; Schumacher 1999; Silverman et al. 1993; Marcove and Arlen 1992; Oestreich 1984; Edeiken 1981; Gordon and Ross 1977; Hirsch et al. 1976; Sprague 1976; Jaffe 1972; Edeiken and Hodes 1967; McCann 1962) as a means of identifying juvenile scurvy among osteoarchaeological remains.

4.3.2.2.1–Definitions of Radiographic Terms

The following terms have been used throughout this work and are defined below to clarify their use. Table 4.2 provides a brief description of the main radiographic indicators of juvenile scurvy. For a full description of the radiographic indicators of juvenile scurvy refer to Section 2.1.3.

Radiolucent/Radiolucency – refers to the transparent appearance of osteological features on radiographs. For instance the area of decreased density behind the white line of scurvy known as the Trümmerfeld zone is identified as radiolucent due to the diminished and general transparent appearance of this region due to a decrease in the number of trabeculae in cases of scurvy.

Radiopaque/Radiopacity – refers to the opaque white appearance of osteological indicators on radiographs. For instance the white line of scurvy is identified as radiopaque due to the vivid dense white appearance that results from the inhibited proliferation of the provisional zone of calcification in cases of scurvy.

Radiopaque Transverse Lines – this term is used in the present context to discuss transverse radiopaque bands, being bands that span laterally across the surface of the diaphysis of the long bones. Radiopaque transverse lines are differentiated from the white line of scurvy based on the fact that radiopaque transverse lines occur along the diaphysis and have numerous aetiologies, while the white line of scurvy occurs along the metaphysis and is linked to a more specific aetiology.

Table 4.2–Summary of Radiographic Indicators of Juvenile Scurvy

Radiographic Indicator	**Description**
White line of scurvy	Dense radiopaque band along the metaphyses caused by interruption of proliferation of the provisional zones of calcification.
Trümmerfeld zone	Radiolucent zone of diminished density along the shaftward side of the provisional zones of calcification.
Ground glass appearance	Blurring of the trabecular markings at the ends of the long bone shafts.

Wimberger ring	Dense radiopaque bands around the epiphyses with rarefied radiolucent central zones.
Cortical thinning	Thinning of the cortices
Corner sign	Defects in the spongiosa and cortex below the provisional zone of calcification causing clefting.
Pelkan spurs	Formation of marginal bone spurs that typically occur at right angles to the axis of the shaft.
Metaphyseal fractures	Commonly comminuted and most often located at the ends of the longs bones. Such fractures typically only extend part way through the shaft.

Material presented in this chart has been adapted from Brickley and Ives (2008) and Waldron (2009).

4.3.2.3–Correlation of Macroscopic and Radiographic Examinations

The data compiled from the macroscopic examination of the individuals involved in the present study will be correlated with the radiographic data gathered in an attempt to ascertain the likelihood of the individuals examined having had scurvy at some point in their lifetime, based on clinical standards of radiographic assessment.

4.4–Hypotheses

Based on the material discussed in the preceding chapters it is possible at this time to present some hypotheses about the proposed outcome of the examination of both the macroscopic and radiographic lesions of the individuals in question.

Examination of the Stymphalos and Zaraka populations has identified a number of individuals who exhibit the suite of lesions proposed as being indicative of juvenile scurvy by Ortner et al. (2001, 1999; Ortner and Ericksen 1997; Ortner 1984). This is not inconsistent with evidence for diet in the periods in question. Considering the prominence of grains, it is likely that children once weaned would be subjected to a significant amount of deficiency stress and as such it is not unlikely that scurvy would be present among the remains examined.

Based on the presence of the proposed indicative lesions of juvenile scurvy it is hypothesized that corresponding radiographic indicators will also be identified in these individuals. The presence of radiological indicators may be in the form of early signs of scurvy, signs of active scurvy at the time of death, or evidence of healing scurvy suggesting that the individuals in question had suffered from scurvy at some point in their lifetimes and were in a period of healing scurvy at the respective ages of death.

If in fact radiographic indicators consistent with a diagnosis of juvenile scurvy can be observed in these 14 individuals, this would provide support for the argument that the suite of macroscopically observed lesions proposed by Ortner et al. (2001, 1999; Ortner and Ericksen 1997; Ortner 1984) indicate the presence of juvenile scurvy among archaeological populations.

Alternatively if there are no or limited radiographic indicators suggesting the presence of juvenile scurvy among the sample examined for the present study, this would bring the macroscopic lesions identified by Ortner et al. (2001, 1999; Ortner and Ericksen 1997; Ortner 1984) into question and would necessitate further radiological and macroscopic research before these macroscopic lesions can be necessarily identified as indicative of juvenile scurvy, simply coincidental, or caused by other problems.

In summation the hypotheses that the present work seeks to investigate are as follows:

1.) The macroscopic suite of lesions proposed by Ortner et al. (2001, 1999; Ortner and Ericksen 1997; Ortner 1984) are indicative of the presence of juvenile scurvy among archaeological populations. Clinically established radiographic indicators of juvenile scurvy will be correlated with the proposed porous macroscopic lesions in question.
2.) The use of heavily grain based infant diet regimens in late Roman–Byzantine Greece posed a serious risk to the child and was a stress factor significant enough to potentially induce scurvy in a sub-adult if pursued for extended periods of time. Thus, evidence of scurvy will be seen in the Stymphalos and Zaraka remains.

Chapter 5–Results

5.1–Remains Examined

The following sections will present the complete record of lesions identified, both macroscopic and radiographic, in the remains of the individuals examined from the Stymphalos and Zaraka populations. Only elements that exhibited lesion formation will be discussed below. For complete details of all elements examined see Tables A3.1 and A3.2. All elements that were examined but are not discussed below either exhibited normal bone formation and remodeling or were unobservable. Table A3.3 provides the complete record of radiographic indicators diagnostic of juvenile scurvy identified from the sample examined. A full description of all radiographic terms used can be found in Sections 2.1.3 and 4.3.2.2.1. The accompanying photographic and radiographic images of the material discussed below can be located in the appendices at the back of this volume. Section 5.4 presents a discussion on difficulties and possible limitations of assessing radiographic indicators of juvenile scurvy among osteoarchaeological remains.

All radiographs presented were taken at .50 Kv, 15 ma at a distance of 40 cm using a MinXray 750 X-ray unit. The only variable that was altered was time of exposure. Radiographs were developed using an Agfa automatic X-ray film processor.

Consultation was made with Dr. Ravi Bhargava, MD, FRCPC, associate professor of radiology and diagnostic imaging of the University of Alberta, to assist in interpreting and verifying the findings identified among the radiographs discussed.

This chapter will present observations on the osteological remains of the individuals under examination in the current study and interpretation at the individual level. Interpretation at the group level and discussion of the diagnostic value of the indicators will be presented in Chapter 6.

5.2–Individuals Examined from Stymphalos

5.2.1–STYM II-97 Grave 1 (STYM II-97-1)

Estimated Age at Death: 1.5–2.5 years old, based on dental age.

Macroscopic Observations

Several of the skeletal elements examined suffered from weathering hindering full observation.

Greater Wing of the Sphenoid (GWS)-scattered fine pores were observed along the extent of the left GWS, while the right GWS was not available for observation.

Temporal Squama (TS)–a series of small pores were observed along the anterior margin of the left TS. However, this porosity is believed to be normal. The right TS appeared normal. Green copper staining left by an earring was observed along the right TS.

Posterior Zygomatic (PZ)–the temporal aspect of both the right and left zygoma exhibited marked porosity, with porosity being more marked on the left zygoma. Evidence of healing was observed in the form of smoothed rounded edges of several pores indicating remodeling and renewed bone proliferation. Though remodeling was observed many of the pores exhibited sharp edges and a lack of remodeling indicating that healing was in an early stage at the time of death.

Infraorbital Foramen (IF)–porosity of varying sizes in the region of the right infraorbital foramen was observed. The left maxilla was unavailable for observation.

Orbital Roof (OR)–type 3–4 porosity was present in the right orbit, while type 3 porosity was present in the left orbit. Significant damage was present in the right orbit hindering full observation. Orbital porosity was greatest along the medial aspect.

Radii–the right radius was well-preserved exhibiting 9 mm of metaphyseal porosity along the distal anterior aspect, and 8 mm along the distal posterior aspect. The left radius had damage to the distal end and exhibited 9 mm of porosity along the distal anterior aspect.

Femora–both femora exhibit erosional damage. 11 mm of porosity was observed along the distal posterior aspect of the left femur.

Tibiae–the right tibia was damaged to the extent that it was not usable for the present study. The left tibia exhibited porosity extending to the popliteal line (16 mm) along the proximal posterior aspect. A region of damage was observed along the proximal anterior aspect of the left tibia. Though this damage is not indicative of a pathological process it is of interest because it reveals the underlying trabeculae, which exhibit inhibited bone formation in the form of a horizontal band of abnormal bone followed by resumed vertical trabecular bone deposition superior to this region.

Radiographic Observations

Elements selected for radiography were the distal left and right femora, proximal left and right tibiae, left and right radii, and the left ulna. In total three radiographs were taken, all three of which were of both the upper and lower limbs. The three films were taken at exposures times of 0.10 secs., 0.08 secs., and 0.06 secs.

Radiopacity was observed along the distal metaphyses of both radii. Both tibiae exhibit radiopacity along the proximal metaphyses. The right femur exhibits a wide radiopaque band along the distal metaphysis, while the left femur exhibits only minor radiopacity along the distal metaphyseal surface. The radiopacity identified along the radii, tibiae and femora begins faint along the margins of the metaphyseal surface and becomes increasingly strong toward the centre. Demineralization of the metaphyses forming a radiolucent band was observed in both femora and both radii. Transverse radiopaque bands (Harris lines) were also observed in this individual, being particularly noticeable along the distal right femur, while faint radiopaque transverse lines can also be observed along the distal radii (Figs. A1.1).

Summary of STYM II-97-1

The appearance of porosity consistent with the suite of lesions presented by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) on the cranial bones, particularly the sphenoid and orbits, in conjunction with the observation of several diagnostic radiographic indicators is consistent with juvenile scurvy (Fig. A2.1–5). The observation of a layer of horizontal inhibited bone formation followed by resumed vertical trabeculae suggests that this individual suffered from a disorder that would have caused inhibited bone formation, such as can be observed in cases of juvenile scurvy. The identification of transverse radiopaque lines suggests that this particular individual had suffered from developmental stress at some point, a further indicator of the probable presence of a deficiency disorder such as juvenile scurvy.

5.2.2–STYM III-97 Grave A, Individual 1 (STYM III-97-1)

Estimated Age at Death: 9–10 years old, based on dental age.

Macroscopic Observations

A small area of porosity was observed on the cranial base adjacent to the occipital condyle. Porosity was also observed on the cranial vault. A patch of well remodeled subperiosteal bone was observed medially along the anterior aspect of the right femur. This patch of subperiosteal bone adhered firmly to the cortex, being punctuated by several large ovoid foramina that penetrate the cortex. Due to metaphyseal damage an exact measurement of the new bone formation could not be obtained. However an approximation of the overall size of the subperiosteal new bone observed was determined, with the formation starting at the damaged edge extending 48 mm superiorly along the shaft and having a width of 27 mm. Though the left tibia is significantly damaged it was possible to observe a similar patch of subperiosteal new bone formation at about midshaft along the anterior aspect of the bone (Figs. A2.6).

Radiographic Observations

Elements selected for radiography were the left and right femora and epiphyses, the left tibia, left and right humeri and the left ulna. One radiograph at an exposure of 0.16 secs. was produced.

In the radiographs, metaphyseal radiolucency of the distal right tibia was identified, as well as a possible example of Wimberger's ring (Bhargava 2008: pers. comm.) based on central rarefaction accompanied by radiopacity around the right distal femoral epiphysis (Fig. A1.2–3).

Summary of STYM III-97-1

The porosity observed in the region of the occipital condyle does not appear to be related to the lesions under examination for the current study, while the porosity observed on the cranial vault was identified as being the result of normal bone remodeling. No porous cranial lesions consistent with the suite presented by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) were observed in STYM-III-97-1. The only lesion observed that may have an aetiological association with juvenile scurvy was the subperiosteal new bone. However, considering the various conditions that can cause subperiosteal bone deposition, in conjunction with the lack of other proposed macroscopic indicators of scurvy, such new bone formation is not strong evidence for the presence of scurvy in this individual. The radiographic observation of a lucent metaphyseal band, despite the absence of a radiopaque metaphyseal band, in conjunction with a possible Wimberger's ring is consistent with juvenile scurvy yet contrasts significantly with the lack of macroscopically observable lesions in the cranium.

5.2.3–STYM III-97 Grave B, Individual 1 (STYM III-97-2)

Estimated Age at Death: 4–6 years old, based on dental age.

Macroscopic Observations

Observations of the cranial bones failed to identify any lesions believed to be associated with juvenile scurvy. Due to poor preservation a large amount of the cranial material was unavailable for observation. A focused region of small pores believed to be consistent with normal bone growth was identified at the base of the acromion on both scapulae.

In the long bones, poor preservation due to erosion, chipping and spalling prevented many of the elements from being observed to any significant degree. The left humerus exhibited 12 mm of porosity extending along the metaphysis of the proximal anterior aspect and 14 mm of porosity extending along the metaphysis of the proximal posterior aspect. The right femur exhibited 14 mm of porosity extending along the metaphysis of the distal anterior aspect as well as a number of large vessel tracks along the distal posterior aspect. The left femur exhibited 15 mm of porosity extending along the metaphysis of the distal posterior aspect. The right tibia exhibited 10 mm of porosity along the distal medial aspect of the metaphysis and 16 mm of porosity along the distal lateral aspect of the metaphysis (Figs. A2.7–8).

Radiographic Observations

Elements selected for radiography were the left humerus, the left and right femora including the distal epiphyses, the right tibia, and the right fibula. Two radiographs were taken of this individual, one of the lower limbs at an exposure of 0.14 secs. and the second of the left humerus at an exposure of 0.14 secs.

Evidence of radiopacity consistent with the white line of scurvy was observed along the distal metaphyseal surfaces of the right femur and both tibiae, while a broader more diffuse radiopaque band is seen on the distal left femur. Several transverse radiopaque bands are seen near the distal ends of the diaphyses of both tibiae and both femora. Radiopaque banding was most prominent along the distal femora. Both the left and right tibiae exhibit a faint but marked radiopaque band at approximately 5 mm superior to the distal end. The other characteristic radiographic indicator of juvenile scurvy identified with this individual was the appearance of a faint band of metaphyseal radiolucency in the distal tibiae (Figs. A1.4–5).

Summary of STYM III-97-2

The porosity observed in the region of the acromion along the scapulae was identified as being a result of normal bone remodeling. The metaphyseal porosity observed in the right femur is suggestive of formation due to a pathological process. The absence of a large number of the cranial bones hindered observation, making it impossible to fully examine for the suite of porous lesions proposed by Ortner et al. (2001, 1999; Ortner and Ericksen 1997). The observation of multiple radiopaque transverse bands suggests several episodes of developmental stress in this individual. The observation of radiopaque transverse bands co-occurring with radiolucency of the left tibial metaphysis and the presence of radiopaque metaphyseal bands, in conjunction with the observation of metaphyseal porosity, is consistent with a diagnosis of juvenile scurvy for this individual.

5.2.4–STYM III-97 Grave B Individual 2 (STYM III-97-3)

Estimated Age at Death: 6–8 years old, based on dental age.

Macroscopic Observations

***Radii*–**12 mm of porosity was observed along the distal anterior aspect of the right radius.

Radiographic Observations

No radiographic observations were possible for STYM III-97-3 due to the lack of preservation of appropriate long bone elements.

Summary of STYM III-97-3

Due to poor preservation and the absence of a large number of skeletal elements macroscopic observation of STYM III-97-3 was limited. Due to the lack of available elements radiography was not conducted on this individual prohibiting any identification of possible radiographic indicators of juvenile scurvy. Of the elements observed there was no significant evidence to suggest the presence of juvenile scurvy as no abnormal porosity was observed aside from the potential abnormal bone formation identified along the right radius. Based on the limited amount of material available for observation it remains impossible at this time to assess the probability of this individual having suffered from juvenile scurvy.

5.2.5–STYM IV-97 Skeleton 1 (STYM IV-97-1)

Estimated Age at Death: 10–12 years old, based on dental age.

Macroscopic Observations

No macroscopic examination of the cranial bones of this individual was undertaken in 2008 due to the absence of observable cranial elements. Significant damage to the long bones was observed. Weathering damage was noted on the distal aspect of the right femur, while the distal end of both the right tibia and left femur were absent. The proximal right radius as well as the proximal left ulna and humerus were also absent. ***Radii***–porosity extending 8 mm along the distal anterior aspect of the right radius was observed.

Radiographic Observations

Elements selected for radiography were the left and right femora, right tibia, left and right ulnae, and the left humerus. Two radiographs were taken of this individual, one being of the upper limbs at an exposure of 0.10 secs, and the second being of the lower limbs at an exposure of 0.14 secs.

Radiographic observation identified faint radiopaque lines along the metaphyseal borders of the distal right femur and proximal right tibia, with faint associated radiolucency along the distal right femur (Figs. A1.6–7).

Summary of STYM IV-97-1

The lack of preserved cranial elements prevented any assessment of the suite of lesions proposed by Ortner et al. (2001, 1999; Ortner and Ericksen 1997). However radiographic investigation identified some lesions consistent with clinical examples of juvenile scurvy.

5.2.6–STYM IV-97 Skeleton 2 (STYM IV 97-2)

Estimated Age at Death: 5–9 years old, based on dental age.

Macroscopic Observations

No macroscopic examination of the cranial bones was possible due to poor preservation and the absence of many elements. The long bones of this individual were significantly better preserved than the cranial bones allowing for detailed observation. Minor porosity was observed along the metaphyseal edges. However none of this porosity appeared to be pathological.

Radiographic Observations

Elements selected for radiography were the left and right femora, right tibia, right humerus, left and right ulnae. One radiograph was taken of the upper limbs at 0.10 secs., while a second radiograph of the lower limbs was taken at 0.14 secs.

A dense radiopaque line was identified along the proximal metaphyseal surface of the right tibia. The radiopaque metaphyseal line varied in intensity along the metaphyseal surface, exhibiting greatest radiopacity along the centre of the bone. Radiolucency was also identified along the proximal metaphysis of the right tibia. A series of radiopaque transverse lines were identified along the diaphyses of the femora. The epiphyses of this individual were unavailable for radiography, so it was not possible to examine for evidence of Wimberger's ring (Figs. A1.8–9).

Summary of STYM IV-97-2

Due to the absence of cranial remains it was impossible to identify any potential pathological changes that may be consistent with the proposed suite of lesions presented by Ortner et al. (2001, 1999; Ortner and Ericksen 1997). The transverse radiopaque bands, suggesting previous episodes of developmental stress, in conjunction with the observation of metaphyseal radiolucency in the proximal right tibia and radiopaque metaphyseal line in the proximal right tibia, are consistent with a diagnosis of juvenile scurvy for this particular individual.

5.2.7–STYM IX-00 Grave 2 Individual 1 (STYM IX-00-2-1)

Estimated Age at Death: 10 years old, based on epiphyseal union.

Macroscopic Observations

Greater Wings of the Sphenoid (GWS)–diffuse small–medium pores penetrating the cortices of both greater wings of the sphenoid were observed for this individual. The porosity observed spread across the greater wing of the sphenoid and onto both the temporal and frontal bones, though porosity along the temporal and frontal was marginal and quickly diminished.

Temporal Squama (TS)–small pores similar to those identified along the greater wings of the sphenoid were observable along the squama of both temporals. The porosity observed along the squamae was less severe than that on the greater wings of the sphenoid. Porosity along the squamae was most abundant at the union with the greater wing of sphenoid and quickly diminished as it moved farther from this sutural border.

Posterior Zygomatic (PZ)–large pores penetrating the cortices were observed. On the right posterior zygomatic abnormal porosity was focused near the inferior aspect, with some evidence of remodeling apparent in this area. On the left zygomatic a patch of abnormal porosity was observed along the temporal aspect.

Posterior Maxilla (PM)–large pores penetrating the cortex were observed on the right maxilla near the junction with the posterior zygomatic. Evidence of remodeling was apparent. In the left posterior maxilla medium-large pores penetrating the cortex were observed along the border of the zygomatic as well as in the region of the developing molars.

Infraorbital Foramen (IF)–medium-large pores penetrating the cortex were observed in the region of the right infraorbital foramen. The porosity identified covers the region inferior to the infraorbital foramen. Conversely the left infraorbital foramen exhibited only minor porosity that appeared to be borderline between normal and abnormal.

Orbital Roof (OR)–large pores penetrating the cortices were observed in both orbits. Porosity was type 2 towards the midline and increased in severity to type 3 along the lateral extent of the orbit. The lateral zygomatic aspect of both orbits was normal.

Cranial Vault (CV)–a small well-defined patch of pores penetrating the outer table of the vault near bregma was identified. A small patch of well-healed porosity was also identified along the parietals near lambda.

Long Bones–A patch of localized periostitis was observed along the anterior midshaft of the right tibia suggesting the presence of inflammation in the region.

Radiographic Observations

Elements selected for radiography were the left and right femora including distal epiphyses, left and right tibiae including proximal epiphyses, left and right fibulae, left and right humeri, left and right ulnae and the left and right radii. Three radiographs were taken of the bones selected at exposures of 0.14 secs. and 0.16 secs. for the upper limbs, and 0.16 secs. for the lower limbs.

Observation of STYM IX-00-2-1 reveals faint metaphyseal radiolucency in conjunction with a radiopaque metaphyseal band in the distal left and right radii and the distal right ulna. A radiopaque metaphyseal band without associated radiolucency was also observed in the distal right tibia (Figs. A1.10–13).

Summary of STYM IX-00-2-1

The observation of abnormal porosity in several locations is consistent with the suite of lesions presented by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) (Figs. A2.9–15). The association of such porosity with the presence of juvenile scurvy is tentatively substantiated in the case of STYM IX-00-2-1 by the co-occurrence of the cranial porosity with metaphyseal radiolucency and associated radiopaque metaphyseal band, two significant clinical radiographic indicators of juvenile scurvy. Thus, the observation of abnormal cranial porosity in conjunction with significant radiographic lesions are consistent with a diagnosis of juvenile scurvy for STYM IX-00-2-1.

5.2.8–STYM IX-00 Grave 2 Individual 2 (STYM IX-00-2-2)

Estimated Age at Death: 16–18 years old, based on epiphyseal union.

Macroscopic Observations

Greater Wing of the Sphenoid (GWS)–both the left and right greater wings of the sphenoid exhibited fine penetrating pores. Porosity was observable along the extent of the bone, with increasingly focused porosity along the inferior aspect.

Temporal Squama (TS)–porosity along the temporal squamae was focused predominantly along the border of the greater wings of the sphenoid.

Orbital Roof (OR)–both the right and left orbits exhibited type 2 porosity towards the midline, with increasingly focused porosity of the type 3 variety towards the lateral margin.

Supraspinous (SS)–small diffuse pores were observed along the supraspinous area. However, such porosity is believed to be consistent with normal bone development.

Cranial Vault (CV)– three focused patches of healed porotic hyperostosis were observed in the region of lambda. One patch was located on the left parietal, one patch was on the right parietal and the third patch was on the occipital. All three of the patches identified were of a similar dimensions and nature, being composed of pores of varying sizes.

Radiographic Observations

Elements selected for radiography were the left and right femora, left and right tibiae, left and right humeri including the proximal epiphyses, left and right ulnae and the left and right radii. Three radiographs were taken of these remains. A radiograph of the upper limbs was taken at an exposure of 0.18 secs. A radiograph of the lower limbs was taken at an exposure of 0.18 secs. A radiograph of the epiphyses of the distal femur and proximal tibia were taken at an exposure 0.14 secs.

Metaphyseal radiolucency with a faint associated radiopaque metaphyseal band was observed along the distal left and right ulnae. Radiopaque metaphyseal bands were also observed along the distal right radius and the distal left and right femora (Fig. A1.14–17). STYM-IX-00-2-2 was also initially identified as showing evidence of metaphyseal fractures (Bhargava 2008: pers. comm.). However, it was ultimately decided that this appearance may have been caused at least in part by depositional damage.

Summary of STYM IX-00-2-2

The observation of cranial porosity was consistent with the criteria presented by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) (Fig. A2.16–18). The observation of significant porous cranial lesions in conjunction with the occurrence of possible radiographic indicators is consistent with a diagnosis of juvenile scurvy for the lesions observed in this individual.

5.3–Individuals Examined from Zaraka

5.3.1–ZAR 96-2

Estimated Age at Death: 12–15 years old, based on skeletal and dental development.

Macroscopic Observations

Greater Wing of the Sphenoid (GWS)–the right greater wing of the sphenoid exhibited marked porosity with large pores penetrating the cortex along the extent of the bone. Evidence of remodeling along the right greater wing of the sphenoid was observed. Only the root of the left greater wing of the sphenoid was available for observation, on which dispersed large pores penetrating the cortex were observed.

Orbital Roof (OR)–only the right orbital roof was available for observation. Type 1 porosity with evidence of healing was observed.

Long Bones–periostitis was observed along the anterior midshaft and spreading onto the posterior midshaft of the right tibia. The identification of periostitis suggests the presence of an inflammatory process.

Radiographic Observations

Elements selected for radiography were the left and right femora, including the distal epiphyses, left and right tibiae including the proximal epiphyses, left and right fibulae, left and right humeri, including the proximal epiphyses, left and right ulnae, left and right radii and the left and right calcanei. Three radiographs were taken of ZAR 96-2. Two radiographs of the upper limbs, with one radiograph including the calcanei, were taken at exposures of 0.18 secs., and 0.14 secs. One radiograph of the lower limbs was taken at an exposure of 0.18 secs.

Radiographic examination of ZAR 96-2 did not identify any anomalies consistent with juvenile scurvy (Figs. A1.18–21). The distal tibiae exhibit a sequence of radiopaque lines in close proximity to one another. However such radiopaque lines are not unique to scurvy but may have resulted from another condition or even simply growth in this area.

Summary of ZAR 96-2

The macroscopic porous lesions observed from ZAR 96-2 correlate significantly with the suite of lesions presented by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) (Figs. A2.19–22). Conversely the lack of clinically diagnostic radiographic indicators brings into question the diagnosis of juvenile scurvy in this individual.

<u>5.3.2–ZAR 96-4</u>

Estimated Age at Death: 0–6 months old, based on dental age.

Macroscopic Observations

Macroscopic observation of ZAR 96-4 identified normal porosity associated with bone growth on the bones of the skull. No well-preserved long bone elements were available for observation. As a result of the absence of any suitable long bones no radiography was conducted on this individual.

Summary of ZAR 96-4

Based on the material examined there is no evidence to suggest the probable presence of juvenile scurvy in this individual.

5.3.3–ZAR 97-1

Estimated Age at Death: 3–4 years old, based on epiphyseal union and dental development.

Macroscopic Observations

Greater Wing of the Sphenoid (GWS)–on both the left and right greater wings a large number of pores were observed penetrating the smooth cortical surface.

Temporal Squama (TS)–both the left and right temporal squamae exhibited pores penetrating the cortices similar to those observed along the greater wings of the sphenoid. The pores along the temporal squamae, however, are difficult to assess. They appear normal in formation but may be lesions based on the proximity and association with the abnormal porosity observed along the greater wings of the sphenoid.

Posterior Zygomatic (PZ)–smooth edged porosity indicative of abnormal bone formation was observed on both the left and right posterior zygomatics.

Posterior Maxilla (PM)–an area of small sized pores penetrating the cortices was identified in the area above the developing molars on both the left and right posterior maxilla. Porosity was less extensive on the left posterior maxilla compared to the right.

Orbital Roof (OR)–mild type 1 cribra orbitalia was observed on both orbital roofs. The cribra orbitalia observed was well-healed and remodeling.

Cranial Vault (CV)–a small patch of well-healed porotic hyperostosis was identified midway along the lambdoidal suture on the right parietal. A similar small patch of well-healed porotic hyperostosis was also observed along the lambdoidal suture of the left parietal. No such porosity was observed on the occipital.

Radiographic Observations

Elements selected for radiography were the left and right femora, including the proximal epiphyses and the distal epiphysis of the right femur, left and right tibiae including the proximal epiphysis of the right tibia, right fibula, left and right humeri, left and right ulnae and the left and right radii. Four radiographs were taken of ZAR 97-1. Two radiographs were taken of the upper and lower limbs at exposures of 0.16 secs. and 0.12 secs. Two radiographs were taken of the upper limbs at exposures of 0.10 secs. and 0.08 secs.

The femora both exhibit radiopaque bands near the distal metaphyses and at approximately 34–38 mm from the distal end. Radiopaque bands of diminished intensity were also observed at approximately 4 mm from the distal end of the tibiae. Metaphyseal radiolucency was observed in both of the proximal tibiae and the distal femora, while metaphyseal radiopacity was observed along the distal left and right femora, the distal left tibia and the proximal left and right tibiae (Fig. A1.22–23, 28).

Summary of ZAR 97-1

The macroscopic observation of porous cranial lesions consistent with the suite of lesions presented by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) suggests a probable diagnosis of juvenile scurvy for this individual (Figs. A2.23–29). The radiographic alterations observed suggest the presence of developmental stress and inhibited bone growth. The co-occurrence of radiopaque transverse bands, metaphyseal radiolucency and radiopaque metaphyseal bands are consistent with the presence of juvenile scurvy.

5.3.4–ZAR 97-2

Estimated Age at Death: 6–12 months old, based on dental development.

Macroscopic Observations

Cranial Vault (CV)–a patch of superficial woven bone was observed in the region of the cruciform eminence along the endocranial surface of the occipital. Evidence of remodeling suggesting active healing was apparent. Similar depositional lesions were also observed along the endocranial surface of the parietals, though complete observation was impeded by post-mortem damage.

Supraspinous (SS)–a well defined region of woven bone and abnormal porosity with evidence of remodeling was observed along the supraspinous fossa of the left scapula.

Radiographic Observations

Elements selected for radiography were the left and right femora, left and right tibiae, right humerus, left and right ulnae, left and right radii, and the epiphyses. Four radiographs were taken of ZAR 97-2. Two radiographs were taken of the upper and lower limbs at an exposure of 0.12 secs. and 0.06 secs. One radiograph was taken of the lower limbs at an exposure of 0.10 secs. One radiograph was also taken of the epiphyses at an exposure of 0.06 secs.

Both radii exhibit faint transverse radiopaque bands at approximately 12–15 mm superior to the distal metaphyses. The left and right femora also exhibit radiopaque bands between 3–5 mm from the distal end. The proximal and distal metaphyses of the left and right tibiae and the distal metaphyses of the left and right femora exhibit radiopacity consistent with the white line of scurvy. Metaphyseal radiolucency was observed in the left and right distal femora as well as along the distal metaphyses of the left and right tibiae, though the tibial radiolucency is much less pronounced than that observed in the femora. A possible Wimberger's ring was also identified in both of the proximal epiphyses of the tibia and in an unidentifiable epiphysis of this individual (Figs. A1.24–25, 28).

Summary of ZAR 97-2

The lesions identified along the endocranial surface of this individual are consistent with the endocranial lesions discussed in Lewis (2004), being diffuse layers of disorganized immature new bone formation on the original cortical surface of the occipital and parietals (Figs. A2.30–32). Though such lesions may sometimes be related to juvenile scurvy, they can also been associated with infections such as meningitis and tuberculosis (Lewis 2004). Their presence in the absence of other porous cranial lesions does not provide a strong basis upon which to suggest a diagnosis of juvenile scurvy. Despite the lack of porous cranial lesions consistent with the suite presented by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) there are radiographic signs consistent with juvenile scurvy in this individual. The co-occurrence of a possible Wimberger's ring, a radiopaque line at the metaphyseal border, metaphyseal radiolucency, and radiopaque transverse bands would support the identification of juvenile scurvy in this individual.

5.3.5–ZAR 97-3

Estimated Age at Death: 12–24 months old, based on dental and skeletal development.

Macroscopic Observations

Cranial Vault (CV)–abnormal porosity comprised of large penetrating pores was observed around lambda along the parietals. Similar porosity was also observed along the occipital near lambda.

Radiographic Observations

Elements selected for radiography were the left and right femora, left and right tibiae, left and right fibulae, left and right humeri, left and right ulnae, left and right radii, and the epiphyses. Six radiographs were taken of ZAR 97-3. Three radiographs were taken of the upper limbs at exposures of 0.14 secs., 0.10 secs. and 0.06 secs. Two radiographs were taken of the lower limbs at exposures of 0.14 secs. and 0.10 secs. One radiograph was taken of the epiphyses at an exposure of 0.06 secs.

Radiopaque bands were observed at approximately 8 mm from the distal ends of the femora. Radiopaque bands were observed at approximately 5 mm from the distal ends of the tibiae. Similar, though much fainter, radiopaque bands were also observed in the fibulae at approximately 5 mm from the distal end. The radii both exhibit two faint radiopaque bands at approximately 4 mm and 6–7 mm from the distal end. This individual also shows distal metaphyseal radiolucency of the left and right femora and the left tibia co-occurring with radiopaque bands at the metaphyseal border of the distal left and right femora, the distal left and right tibiae and the proximal right tibia. A faint possible Wimberger's ring in the form of an epiphysis inside of an epiphysis, suggesting healing[1] (Bhargava 2008: pers. comm.), was observed in one of the distal femoral epiphyses and in one of the proximal tibial epiphyses of this individual (Figs. A1.26–28).

Summary of ZAR 97-3

The porous cranial lesions observed do not provide a significant basis upon which to suggest a diagnosis of juvenile scurvy for this individual. However several of the cranial bones were absent, preventing full examination for cranial porosity (Figs. A2.33–34).

[1] See Shore 2008: fig. 167–24 for a description of a healing epiphysis inset inside the growing epiphysis.

Despite the lack of observable porous cranial lesions consistent with those presented by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) there are several radiographic signs consistent with a diagnosis of juvenile scurvy. The observation of metaphyseal radiolucency co-occurring with white line of scurvy, radiopaque transverse bands, and what was identified as the remnants of Wimberger's ring, would support a diagnosis of juvenile scurvy for this individual.

5.4–Difficulty of Observation

Two of the clinical radiographic indicators of juvenile scurvy, diffuse demineralization and washed out trabeculae "ground glass" appearance, are very difficult to identify among osteoarchaeological remains.

When examining the radiological indicators present among the individuals from Stymphalos and Zaraka diffuse demineralization was tentatively observed as being present in individuals STYM II-97-1, STYM-III-97-1, STYM-III-97-2 and STYM-IV-97-1 (Bhargava 2008: pers. comm.). Washed out trabeculae with a "ground glass" appearance was tentatively observed as being present in individuals STYM III-97-2, STYM IV-97-1, STYM IV-97-2, STYM-IX-00-2-2 and ZAR 97-2 (Bhargava 2008: pers. comm.).

The minute alterations of bone structure caused by these two indicators of juvenile scurvy are relatively clear when dealing with living individuals. However in archaeological populations the exposure of bone to harsh depositional environments often causes significant alteration to the bone structure, particularly the internal trabecular structure. Though this is not always the case, as there are many examples of well-preserved osteological specimens, it is the case with the remains under examination here, as many of them are poorly preserved.

The trabecular structure of many individuals examined was significantly altered by depositional damage. Such damage can resemble diffuse demineralization and ground glass appearance on radiographs, but examination of the radiographs at greater magnification in conjunction with examination of photographs of the elements makes it clear that significant depositional damage occurred. This has significantly affected the possibility of accurately identifying either diffuse demineralization or ground glass appearance among the individuals examined (See Appendix 1 photos). Because of this problem, diffuse demineralization and washed out trabeculae as indicators of juvenile scurvy have been removed from consideration, so as not to bias the number of radiographic scurvy indicators observed as present among the remains under investigation. Of the individuals identified as having diffuse demineralization and washed out trabeculae it is only truly ZAR 97–2 that is preserved well enough to potentially verify these findings; however, even this remains difficult.

The difficulty of assessing the radiographic indicators of diffuse demineralization and washed out trabeculae brings forward an impediment that remains difficult to fully quantify: the effects of depositional damage. In some of the radiographic plates apparent lesions initially believed to be indicative of juvenile scurvy were later seen to be due to soil deposition and structural damage of the bone, when the radiographs were compared with the photographs.

Regarding radiographic indicators of juvenile scurvy further research into the effects of depositional damage and the impact of such damage on radiographic images remains necessary at this time.

5.5–Summary of Findings

Observation of the skeletal remains of the juvenile individuals from Stymphalos and Zaraka has presented macroscopic and radiographic evidence to suggest the possibility that several of the individuals examined may have suffered from juvenile scurvy during their lifetime. Further analyses and discussion of the results presented will be addressed in Chapter 6.

Chapter 6–Discussion

Based upon the results presented in Chapter 5, several observations can be made regarding the potential for identifying cases of juvenile scurvy among archaeological populations. The following sections will discuss the results presented as well as a number of practical concerns regarding the ability to accurately identify juvenile scurvy in osteoarchaeological remains. Discussion will also be presented on potential avenues of research that could increase the accuracy of diagnosis of juvenile scurvy among archaeological populations. Cultural implications of the material presented will be addressed in Chapter 7.

6.1–Using Radiology to Assess Potential Archaeological Cases of Scurvy

After having examined the sub-adult remains from Stymphalos and Zaraka, it is apparent that none of the radiographically diagnostic clinical features of juvenile scurvy are useful by themselves when assessing proposed osteoarchaeological examples of juvenile scurvy. Rather, several indicators appear to be of greater value for identifying potential cases of juvenile scurvy among archaeological populations, while some other indicators are only truly useful in association with one of the first group. Yet a third group of radiological indicators is very difficult to identify archaeologically due to preservation problems and the nature of the minute structural changes associated with these indicators. It is important to note that no one indicator can identify scurvy independently in clinical practice; rather a combination of indicators is necessary (Shore 2008; Grewar 1965). It is also known that not all indicators carry the same diagnostic strength in clinical assessment.

The following section addresses the feasibility of using the various clinical radiological features of juvenile scurvy to assess proposed osteoarchaeological examples of this disorder. The classification described below was developed using the clinical literature, in light of experience and insights gained during the radiography of the Stymphalos and Zaraka remains.

6.1.1–Clearly Indicative Radiological Signs of Juvenile Scurvy

The term "clearly indicative" is used here to indicate radiographic features of juvenile scurvy that are so strongly associated with the disorder that their occurrence in osteoarchaeological remains can be taken as a strong indication of the presence of juvenile scurvy. Radiographic signs that are proposed as being clearly indicative of juvenile scurvy when examining osteoarchaeological remains are the white line of scurvy, Wimberger's ring, transverse metaphyseal fractures and Pelkan spurs.

6.1.1.1–White Line of Scurvy (Metaphyseal Radiopacity)

Concentrated radiopacity along the metaphyseal surface is a feature that is specific to very few disorders and is highly indicative of juvenile scurvy (Shore 2008). It is due to the primary association of this radiographic feature with juvenile scurvy that the white line of scurvy is taken to be a clearly indicative marker of juvenile scurvy when examining osteoarchaeological remains. As described in Chapter 5, metaphyseal radiopacity consistent with the white line of scurvy was observed in a number of individuals from Stymphalos and Zaraka.

6.1.1.2–Wimberger's Ring

The identification of radiopacity around the epiphyses accompanied by central radiolucency is a feature that is clinically diagnostic of juvenile scurvy. Other disorders that cause "ring-epiphyses" include osteogenesis imperfecta types I, II, III, and IV, where severe deficiency of osseous tissue results in thin sparse trabeculae arranged in a wide mesh causing extreme porosity of the epiphyses (Shore 2008; Schumacher 1999; Jaffe 1972). However these disorders are associated with bowing alterations of the long bone and other deformities not seen in juvenile scurvy.

The identification of Wimberger's ring is particularly helpful for differentiating juvenile scurvy from rickets as epiphyseal changes in cases of rickets are actually the opposite of those seen in scurvy. In rickets the outer ring of the epiphysis appears radiolucent while the integrity of the central region of the epiphysis is maintained (Shore 2008: 2742). Shore (2008: 2743) further notes that when scurvy and rickets co-occur the scorbutic indicators typically predominate over the rachitic indicators, due to inhibited osteoblastic activity. Though the predominance of scorbutic indicators may cause difficulty for the identification of cases of combined scurvy and rickets it allows for a strong positive identification of scurvy. Thus, the identification of Wimberger's ring is identified as a clear indicator of the presence of juvenile scurvy.

Despite the diagnostic strength of Wimberger's ring, caution is necessary when attempting to identify it in archaeological remains. The epiphyses of sub-adults are often not recovered during excavation. When they are recovered they often show depositional damage. The epiphyses are likely to suffer from depositional damage due to the small, fragile trabecular nature of these skeletal elements. Given this, it is necessary to ensure that the apparent presence of Wimberger's ring is not simply a manifestation of structural damage to the bone. When depositional damage can be excluded, Wimberger's ring is clearly indicative of juvenile scurvy. As described in Chapter 5, apparent Wimberger's rings were observed in two individuals from Zaraka and one from Stymphalos.

6.1.1.3–Transverse Metaphyseal Fractures

In clinical cases, transverse metaphyseal fractures are clearly indicative of juvenile scurvy when syphilis can be excluded (Shore 2008: 2740). However caution must be taken when assessing archaeological remains to ensure that the signs of fracture observed are not false-positives associated with depositional damage. If syphilis and depositional damage can be excluded, the identification of transverse metaphyseal fractures is clearly indicative of juvenile scurvy. As described in Chapter 5, one apparent case of transverse metaphyseal fracture was initially identified at Stymphalos, but was ultimately not accepted due to the confounding presence of depositional damage.

6.1.1.4–Spur Formation (Pelkan Spurs)

Spur formation is a radiographic feature that is strongly indicative of juvenile scurvy in clinical cases. Such spurs form as a result of healing metaphyseal fractures (Tamura et al. 2000). Though spur formation is clearly indicative of juvenile scurvy, the identification of Pelkan spurs is unlikely among osteoarchaeological remains due to the highly fragile nature of the spurs and the unlikeliness that such bone formations would survive in the depositional environment. As was the case with Wimberger's ring and transverse metaphyseal fractures, when examining osteoarchaeological remains it is important to establish that the apparent presence of spur formation is not due to depositional damage. No possible examples of spur formation were seen in the remains examined for this study.

6.1.2–Dependent Radiological Signs of Juvenile Scurvy

The term "dependent" is used in the present context to denote radiological features of juvenile scurvy that help to identify juvenile scurvy when seen in conjunction with clearly indicative radiological signs. They are classed as dependent to reflect their less specific association with scurvy. The dependent signs are considered here to be metaphyseal demineralization, Harris' lines, corner sign, cortical thinning and signs of subperiosteal hemorrhage of the limbs.

6.1.2.1–Metaphyseal Demineralization (Metaphyseal Radiolucency)

Demineralization or radiolucency of the metaphyseal region is a radiographic marker that occurs both naturally, such as in cases of premature births, and in a number of pathological disorders, including rickets, congenital syphilis, leukemia, and rubella (Shore 2008; Schumacher 1999; Keats 1984). Thus, this particular feature, if observed in isolation, cannot be taken as a strong indicator of juvenile scurvy (Shore 2008; Park et al. 1935). Furthermore metaphyseal radiolucency in cases of juvenile scurvy has been shown to vary significantly in manifestation. It does not always occur in the early stages of scurvy, and may occur to a limited extent spanning only part way across the metaphysis, depending on the stage to which scurvy has developed. This makes metaphyseal radiolucency alone a poor indicator of juvenile scurvy (Park et al. 1935). However, in cases of juvenile scurvy it is unlikely that demineralization of the metaphyseal region would actually occur alone as this particular marker is typically found in conjunction with the white line of scurvy due to impaired collagen and osteoid synthesis. Thus, in co-occurrence with the white line of scurvy, demineralization of the metaphyseal region can be seen as a significant indication of the presence of juvenile scurvy. As described in Chapter 5, a number of individuals from Stymphalos and Zaraka show this sign.

6.1.2.2–Radiopaque Transverse Lines (Harris' Lines)

Transverse radiopaque lines are a common feature of developing bones, both normal and pathological, indicating previous episodes of stress. This being the case, the association of radiopaque transverse lines with the presence of juvenile scurvy is highly dependent upon the identification of other radiological scorbutic indicators. The observation of transverse radiopaque lines in conjunction with other indicators of scurvy can be taken as evidence of prior episodes of scurvy, as it is known that in healing scurvy the white line of scurvy progressively moves up the diaphysis as the individual continues to grow resulting in a transverse radiopaque line (see section 2.1.3.13). However, it may also indicate previous stress of a different aetiology. Due to the highly variable aetiologies related to the formation of transverse radiopaque lines this indicator should be used with caution as a supporting indicator of previous stress rather than a primary indicator of scurvy, as a direct association with scurvy is particularly difficult to establish

(Alfonso et al. 2005; Martin et al. 1985; Keats 1984; Birkner 1978; Garn et al. 1968; Marshall 1968).

6.1.2.3–Corner Sign

The corner sign associated with juvenile scurvy is a valuable clinical indicator. However, similar fractures are also known to occur in cases of trauma, particularly child abuse, and rickets (Schumacher 1999). Due to the high potential for the co-occurrence of rickets and scurvy as well as the common occurrence of traumatic injuries it is proposed that corner sign be carefully examined and only attributed to an aetiology of scurvy when further radiological scorbutic indicators are present. Caution must be taken when attempting to identify corner sign among archaeological populations to ensure that the signs of fracture observed are not false-positives associated with depositional damage. No potential cases of corner sign were observed in the Stymphalos and Zaraka remains.

6.1.2.4–Cortical Thinning

Cortical thinning (osteopenia) caused by scurvy is a common radiographic indicator of this disorder (Shore 2008; Jaffe 1972; Joffe 1961). Despite the development of cortical thinning in cases of scurvy, cortical thinning is also observed in a large number of other pathologies making the association of cortical thinning with an aetiology of scurvy highly contingent upon the presence of other radiographic indicators of this disorder (Shore 2008). No potential cases of cortical thinning were seen in the Stymphalos and Zaraka remains.

6.1.2.5–Subperiosteal Hemorrhage/Hematoma of the Limbs

In clinical cases of juvenile scurvy it is possible to observe ossified hematomas in the limbs, with the shell of the periosteum elevated from the underlying bone by subperiosteal hemorrhage. When looking at archaeological populations it is difficult to identify this particular sign, as it is unlikely that the highly fragile elevated shell of bone would survive for any significant period of time. However, archaeological evidence of subperiosteal hemorrhaging may be observable radiographically or by gross examination in the form of appositional periosteal new bone along the diaphysis. The formation of periosteal new bone is a very generalized response to stress and is seen in many archaeological populations. It should be associated with an aetiology of juvenile scurvy only when observed in co-occurrence with other radiographic indicators of juvenile scurvy. As described in Chapter 5, some instances of subperiosteal new bone formation were seen in the Stymphalos and Zaraka remains.

6.1.3–Difficult Radiological Signs of Juvenile Scurvy

The term "difficult" is distinguished here from the use of "dependent" in that while dependent indicators are relatively nonspecific, and thus only indicative of scurvy when co-occurring with other scorbutic indicators, difficult indicators would be strongly diagnostic of juvenile scurvy if they could be confirmed, but are difficult to identify in osteoarchaeological remains due to the potential effects of depositional alteration. Identification of the following radiographic indicators requires that clear observation of the bone structure for evidence of deposition and mechanical damage be conducted before an appropriate association with scurvy can be made.

6.1.3.1–Diffuse Demineralization

As presented in Chapter 5, an observation of diffuse demineralization is particularly difficult to confirm due to depositional damage. If the trabecular structures of the bone are damaged a radiographic appearance similar to that of diffuse demineralization can arise. Thus it is necessary to establish the quality of skeletal preservation before attempting to use diffuse demineralization as a radiographic indicator of juvenile scurvy among archaeological populations.

6.1.3.2–Washed Out Trabeculae (Ground Glass Appearance)

Much as is the case with diffuse demineralization the effects of depositional and mechanical damage to the trabeculae of the bone make ground glass appearance very difficult to identify archaeologically. It is of great importance to establish the state of preservation before attempting to identify washed out trabeculae in osteoarchaeological remains.

6.1.4–Summary of Radiographic Indicators

Considering the material presented above it is apparent that not all radiographic indicators of juvenile scurvy used to diagnose this disorder in clinical settings can be equally applied to archaeological populations. Rather it is clear that there are several indicators that lend great strength to the identification of juvenile scurvy among archaeological populations, while others can only be dependably ascribed to juvenile scurvy when seen in conjunction with the stronger indicators.

6.2–Addressing the Identification of Juvenile Scurvy at Stymphalos and Zaraka

The sub-adult remains from Stymphalos and Zaraka have yielded significant evidence to suggest the presence of juvenile scurvy in a number of the individuals examined. The following sections will discuss this evidence. Interpretations have been presented based on the diagnostic strength of lesions observed for each individual.

6.2.1–Analysis of Macroscopic Lesions

Macroscopic lesions were assessed based on the criteria presented by Ortner et al. (2001, 1999; Ortner and Ericksen 1997). Individuals were assigned to a category based on the degree of lesion formation observed (Table 6.1). For the purpose of this section, individual cases of scurvy will be classed as strong, possible, unclear or unlikely based on the Ortner et al. criteria. The implications of the radiographic findings for the validity of the criteria will be discussed further in this chapter.

6.2.1.1–Cases Identified as Strong Based on Macroscopic Examination

Individuals for which a strong case of scurvy can be made exhibited significant cranial porosity consistent with the suite of lesions proposed by Ortner et al. (2001, 1999; Ortner and Ericksen 1997). In all of the cases categorized as strong, the individual exhibited significant sphenoid porosity, which is proposed by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) as being the most pathognomonic macroscopic indicator of juvenile scurvy. Orbital porosity of types 1 to 4 was also noted in all cases categorized as strong. Porosity of varying degrees consistent with juvenile scurvy was also observed at several of the other locations described by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) in cases identified as strong (See Chapter 5 and Appendix 3 for full details of the porosity observed). Based on the consistency of the porous lesions observed with those proposed as being indicative of juvenile scurvy by Ortner et al. (2001, 1999; Ortner and Ericksen 1997), there is strong macroscopic evidence to suggest the presence of juvenile scurvy in individuals STYM-II-97-1, STYM-IX-00-2-1, STYM-IX-00-2-2, and ZAR 97-1 if the Ortner et al. diagnostic criteria are used.

Table 6.1– Potential Scurvy Cases Based on Macroscopic Lesions

Strong	**Possible**	**Unclear**	**Unlikely**
STYM-II-97-1 STYM-IX-00-2-1 STYM-IX-00-2-2 ZAR 97-1	ZAR 96-2	STYM-III-97-1 STYM-III-97-2 ZAR 97-2 ZAR 97-3	STYM-III-97-3 ZAR 96-4
(4/11=36%)	**(1/11=9%)**	**(4/11=36%)**	**(2/11=18%)**

The term strong is used here to indicate individuals who exhibit significant porous cranial lesion formation consistent with the proposed lesions of juvenile scurvy (Ortner et al. 2001, 1999; Ortner and Ericksen 1997). Possible refers to an individual who exhibits a lesser degree of lesion formation. Unclear is used to indicate individuals who exhibit lesion formation, but whose lesions are either unclear or of only limited potential relevance to scurvy. Unlikely is used here to indicate individuals who do not exhibit significant evidence of the presence of scurvy based on the macroscopic criteria employed. STYM-IV-97-1, STYM-IV-97-2 and STYM-IV-97-5 had no associated cranial remains, and were impossible to assess for the Ortner et al. (2001, 1999; Ortner and Ericksen 1997) suite of cranial lesions.

6.2.1.2–Cases Identified as Possible Based on Macroscopic Examination

ZAR 96-2 was the only individual identified as having possible macroscopic evidence of the presence of juvenile scurvy. This assessment was based on the presence of sphenoid porosity and type 1 orbital porosity. In contrast to 'significant' cases, no further lesions are seen on the maxilla, temporal, scapulae, or other observable bones. However, Ortner et al. (2001, 1999; Ortner and Ericksen 1997) argue that the presence of these two lesions alone is significant evidence for the presence of juvenile scurvy. Although the periostitis observed is a non-specific pathological indicator, its presence in conjunction with sphenoid and orbital porosity provides additional evidence to suggest a diagnosis consistent with juvenile scurvy considering the significant extent of subperiosteal hemorrhaging in modern cases (van der Merwe et al. 2009; Paine et al. 2007).

Based on the model advanced by Ortner et al. (2001, 1999; Ortner and Ericksen 1997), it may be that the porous lesions and periostitis observed in the case of ZAR 96-2 represent an early or mild stage of manifestation of juvenile scurvy. Theoretically if an individual were to manifest porous cranial lesions as a response to hemorrhaging it is likely that the rate of lesion formation would be highly variable depending on the stage of disease development and the location on the cranium. Porous cranial lesions due to hemorrhage would likely manifest first on the sphenoid, due to trauma caused by chewing, talking and suckling, and along the orbital roof due to trauma caused by typical eye movement (Ortner and Ericksen 1997; Brickley and Ives 2006). Other areas (such as the maxilla, zygomatic and cranial vault) may represent later locations for the formation of porous lesions.

Alternatively, it is also possible that the porous sphenoid and orbital lesions observed in ZAR 96-2 represent a healed case of juvenile scurvy in which porous lesions were most severe along the sphenoid and orbital roofs, and thus are preserved, while other cranial lesions either were milder (and thus have fully remodeled) or never manifested.

6.2.1.3–Cases Identified as Unclear Based on Macroscopic Examination

Of the four individuals identified as showing unclear cases, none exhibited porous lesions consistent with the suite of lesions proposed by Ortner et al. (2001, 1999;

Ortner and Ericksen 1997). Cranial material for these individuals is largely absent, and in the cases of STYM-III-97-1, STYM-III-97-2 and ZAR 97-2 the sphenoid could not be observed. Minor porosity was observed among the four individuals categorized as unclear. However none of the porosity observed suggested an aetiology of scurvy according to the model used by Ortner et al. In fact, no diagnosis is put forth based on the porosity observed, due in part to the poor preservation of the cranial material. It is due to the poor preservation of cranial material that these four individuals were identified as unclear rather than unlikely, for the preservation of cranial material does not allow for a dismissal of the possibility that these individuals suffered from scurvy. However the poor preservation of cranial elements hinders the ability to fully assess the possible presence of juvenile scurvy.

6.2.1.4–Cases Identified as Unlikely Based on Macroscopic Examination

The two individuals identified as being unlikely to have suffered from scurvy were categorized as such based on the overall normal appearance of the cranial bones observed. The cranial remains of STYM-III-97-3 were largely absent; those that were observable exhibited normal bone formation. The macroscopic examination of ZAR 96-4 identified only normal bone formation. It is due to the general normal appearance of the recovered bones of these individuals that they are judged unlikely to have suffered from juvenile scurvy. The differentiation made here between unclear and unlikely cases is that those individuals classed as unclear exhibited some lesions suggesting that a pathological process had affected these individuals at some point, even if the absence of a large number of elements prevents diagnosis. In contrast, the individuals identified as unlikely yielded no evidence of abnormal bone formation suggesting illness.

6.2.2–Analysis of Radiographic Indicators

Radiographic lesions were assessed against known clinically diagnostic radiographic indicators of juvenile scurvy (Shore 2008; Burton and Brody 1999; Schumacher 1999; Silverman et al. 1993; Marcove and Arlen 1992; Oestreich 1984; Edeiken 1981; Gordon and Ross 1977; Hirsch et al. 1976; Sprague 1976; Jaffe 1972; Edeiken and Hodes 1967; McCann 1962), taking into account their diagnostic value in archaeological remains as described in section 6.2.2. Based on the level of correlation observed between the lesions seen and the known clinically diagnostic indicators of juvenile scurvy each individual was placed into a category (Table 6.2).

6.2.2.1–Cases Identified as Strong Based on Radiography

The two cases identified as strong were designated as such based on the presence of extensive radiographic indicators of juvenile scurvy (Table A3.3). Both ZAR 97-2 and ZAR 97-3 presented with evidence of Wimberger's ring. Both cases identified as strong also showed demineralization of the metaphyseal scurvy zone in conjunction with the presence of the white line of scurvy. As discussed above, Wimberger's ring and the combination of the metaphyseal scurvy zone and the white line of scurvy are clearly indicative of the presence of juvenile scurvy. Transverse radiopaque lines are a non-specific indicator in isolation. However when observed as a co-occurring radiographic indicator, as was observed in ZAR 97-2, they provide further supporting evidence of the presence of past developmental stress in a given individual. In the cases presented, this may be understood as a likely consequence of nutritional deficiency stress such as juvenile scurvy.

Table 6.2–Potential Scurvy Cases Based on Radiographic Lesions

Strong	**Possible**	**Unclear**	**Unlikely**
ZAR 97-2 ZAR 97-3	STYM-II-97-1 STYM-III-97-2 STYM-IV-97-1 STYM-IV-97-2 STYM-IX-00-2-1 STYM-IX-00-2-2	STYM-III-97-1 ZAR 97-1	ZAR 96-2
(2/11=18%)	**(6/11=54%)**	**(2/11=18%)**	**(1/11=9%)**

The term strong is used here to indicate individuals who exhibited significant radiographic indicators of juvenile scurvy based on correlation with known diagnostic indicators of this disorder. Possible refers to individuals who exhibited less definitive evidence of the presence of juvenile scurvy. Unclear is used here to indicate individuals who exhibited minimal, unconvincing or difficult to observe radiographic lesions of juvenile scurvy. Unlikely is used here to indicate individuals who show no radiographic lesions consistent with the presence of juvenile scurvy. The criteria presented in Section 6.1 were used in accordance with the literature cited in Section 6.2.2 when assigning individuals to a category. STYM-III-97-3, STYM-IV-97-5 and ZAR 96-4 were not radiographed.

6.2.2.2–Cases Identified as Possible Based on Radiography

The six individuals identified as exhibiting possible evidence of juvenile scurvy were differentiated from those exhibiting strong evidence based on the decreased number of indicators observed. The six individuals designated as possible all exhibited the combination of metaphyseal demineralization of the scurvy zone in conjunction with the presence of the white line of scurvy (Table A3.3). This combination provides significant evidence from a clinical standpoint and can be understood as diagnostically consistent with the presence of juvenile scurvy. STYM-III-97-2, STYM II-97-1 and STYM-IV-97-2 also exhibited transverse radiopaque lines further suggesting that these individuals had been under stress earlier in their lives, possibly due to a nutritional disorder such as juvenile scurvy.

As it was impossible to observe the epiphyses of these individuals, evidence for Wimberger's ring could not be examined. The presence of the epiphyses is not a requisite for assessing scurvy. However the ability to observe the epiphyses helps significantly from a radiographic viewpoint in determining the potential presence of juvenile scurvy. The evidence of juvenile scurvy observed among the six individuals designated as possible is thus good, though less compelling than the cases identified as strong.

6.2.2.3–Cases Identified as Unclear Based on Radiography

The two individuals identified as displaying unclear indications of the presence of juvenile scurvy were designated as such due to the lack of specificity and limited observation of radiographic lesions consistent with juvenile scurvy.

STYM-III-97-1 was identified as exhibiting evidence of Wimberger's ring, and demineralization of the metaphyseal scurvy zone, suggesting a possible episode of juvenile scurvy. However depositional damage to the metaphyses limited the ability to observe for other characteristic radiographic indicators of juvenile scurvy in this individual. It remains possible that STYM-III-97-1 may have suffered from scurvy at some point, however, preservation problems limit confidence in this diagnosis.

ZAR 97-1 was identified as exhibiting unclear evidence of the presence of juvenile scurvy. The identification of metaphyseal radiolucency accompanied by the presence of transverse radiopaque lines suggests that this individual was subject to developmental stress at some point. However the identification of these two particular radiographic indicators are not significant enough to allow for a firm radiographic diagnosis of juvenile scurvy.

6.2.2.4–Cases Identified as Unlikely Based on Radiography

The radiographs of ZAR 96-2 yielded no clinically diagnostic indicators of juvenile scurvy, despite the overall excellent preservation, indicating that it is highly unlikely that ZAR 96-2 suffered from juvenile scurvy at or shortly before the time of death.

6.2.3–Analysis of Combined Macroscopic and Radiographic Results

A combined assessment of macroscopic and radiographic indicators was undertaken to examine the level of correlation between results obtained from the individual macroscopic and radiographic analyses presented in Sections 6.2.1 and 6.2.2 (Table 6.3). Examination was undertaken based on the logic generally expressed in the literature (and forming the original rationale for this thesis research) that the macroscopic and radiographic lesions of scurvy should co-occur. Where conflicts arose between the two classes of lesions when attempting to categorize individuals as being likely or unlikely to have suffered from scurvy, the radiographic indicators were given a stronger weight due to the fact that such indicators can be correlated with clinical examples of juvenile scurvy.

6.2.3.1–Cases Identified as Strong Based on Correlated Results

The four cases identified as strong under the combined radiographic and macroscopic criteria are proposed as being the most likely individuals to have suffered from juvenile scurvy. All four of these individuals exhibited substantial diagnostic radiographic indicators (See Fig. A3.3). All of them, except ZAR 97-2, also exhibited extensive porous cranial lesion formation consistent with the suite of lesions proposed by Ortner et al. (2001, 1999; Ortner and Ericksen 1997). Although only minor porosity was observed in the case of ZAR 97-2, many of the suite of lesions proposed by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) could not be properly assessed because this individual lacked a majority of its cranial remains.

The cases identified as strong provide good support for the argument that the suite of porous cranial lesions proposed by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) can be linked to juvenile scurvy, as they verify the co-occurrence of these porous cranial lesions with clinically diagnostic radiographic indicators of scurvy.

6.2.3.2–Cases Identified as Possible Based on Correlated Results

Cases identified as possible presented with both radiographic and macroscopic indicators suggesting the presence of juvenile scurvy. These cases, however, are differentiated from those designated as strong because the indicators observed were less compelling than those of the strong cases.

Individuals STYM-III-97-2, STYM-IV-97-1 and STYM-IV-97-2 were identified as exhibiting possible evidence of the presence of juvenile scurvy based on radiographic indicators. Only limited cranial elements were observable for STYM-III-97-2, while no cranial elements were available for observation for STYM-IV-97-1 and STYM-IV-97-2. Thus it was impossible to identify whether porous cranial lesions were also present. Individual ZAR 97-1 was included in the 'possible' category based on macroscopic lesions. The radiographic lesions identified in ZAR 97-1 (demineralization of the metaphyseal scurvy zone and transverse radiopaque lines) are not diagnostic in isolation, but their co-occurrence with significant cranial porosity in this individual can be taken as possible evidence for the presence of juvenile scurvy. ZAR 97-3 was included as 'possible' due to radiographic indicators, while only manifesting limited porosity in the region of lambda despite the presence of a majority of the cranial bones.

The combined indicators observed can be interpreted in several ways. It is possible that the lesions observed represent juvenile scurvy in its early or significantly healed stages. It is also possible that the lesions observed are simply a variation of the full suite of proposed macroscopic and known radiographic clinical indicators of juvenile scurvy. Finally, it is possible that the indicators observed are due to a problem other than scurvy. The issue of variability of lesion formation and degree of manifestation remains poorly understood in both archaeological and clinical populations. There is evidence, discussed below, to suggest that lesion formation in juvenile scurvy is not bound to follow a uniform development.

Table 6.3–Potential Scurvy Cases Based on Combined Results

Strong	Possible	Unclear	Unlikely
STYM-II-97-1 STYM-IX-00-2-1 STYM-IX-00-2-2 ZAR 97-2	STYM-III-97-2 STYM-IV-97-1 STYM-IV-97-2 ZAR 97-1 ZAR 97-3	STYM-III-97-1 ZAR 96-2	STYM-III-97-3 STYM-IV-97-5 ZAR 96-4
(4/14=29%)	(5/14=36%)	(2/14=14%)	(3/14=21%)

The term strong is used here to indicate individuals who exhibited significant macroscopic and radiographic indications of the presence of juvenile scurvy. Possible refers to an individual who exhibited lesion formation of a less definitive nature. Unclear is used to indicate individuals who exhibited lesion formation of a mild or clinically non-diagnostic nature. Unlikely is used here to indicate individuals who failed to exhibit significant evidence for the presence of juvenile scurvy.

6.2.3.3–Cases Identified as Unclear Based on Correlated Results

Individual ZAR 96-2 was identified as exhibiting unclear evidence of juvenile scurvy based on the observation of no radiographic indicators of juvenile scurvy and only limited porosity of the sphenoid and healed type 1 orbital porosity. Though this is weak evidence it still may suggest the presence of juvenile scurvy at one time. ZAR 96-2 was identified as being 12 to 15 years old. At this age it is possible that ZAR 96-2 suffered from juvenile scurvy of an unknown degree at a younger age and survived. Over time as this individual continued to grow remodeling would have taken place allowing for the resolution of radiographic indicators of juvenile scurvy, while the presence of porosity along the sphenoid and orbital roof may have persisted for years due to the lack of growth pressure placed on these locations, resulting in relatively slow remodeling and allowing for the extended preservation of the observed porous lesions.

Individual STYM-III-97-1 was identified as presenting unclear indications of the presence of juvenile scurvy based on the limited radiographic and macroscopic findings. A large number of the cranial bones were not observable, while those that were observed presented only limited and typically normal porosity. The long bones exhibited metaphyseal porosity of abnormal extent along the distal femur, distal tibia, and proximal humerus, with large and multiple vessel tracks observed along the distal end of the right femur, suggesting the potential presence of a pathological process, though no specific aetiology can be assigned. Radiographically Wimberger's ring was observed along with metaphyseal radiolucency, suggesting a diagnosis consistent with juvenile scurvy. At this time it is not possible to completely dismiss the likelihood of individual STYM-III-97-1 having suffered from scurvy at some point, however based on the material observed there is only unclear evidence to suggest the presence of juvenile scurvy.

6.2.3.4–Individuals Identified as Unlikely Based on Correlated Results

Individuals STYM-III-97-3, STYM-IV-97-5 and ZAR 96-4 were identified as unlikely to have suffered from juvenile scurvy. Although both individuals were missing significant skeletal elements, those that could be observed exhibited normal bone growth. Radiography could not be conducted on either individual. Although the remains are very incomplete, the absence of pathological bone formation does not suggest any potential presence of juvenile scurvy in these two individuals.

6.2.4–Discussion of Results Regarding the Diagnostic Value of Porous Cranial Lesions

The material from Stymphalos and Zaraka has provided a good basis upon which to examine the validity of the criteria for assessing potential archaeological cases of juvenile scurvy proposed by Ortner et al. (2001, 1999; Ortner and Ericksen 1997).

The results of the current study have shown that in 21% of cases examined there is significant evidence for the co-occurrence of clinically diagnostic radiographic indicators of juvenile scurvy and the proposed suite of porous cranial lesions (Ortner et al. 2001, 1999; Ortner and Ericksen 1997). The identification of both macroscopic and radiographic indicators among several individuals suggests a pattern of co-occurrence, supporting the accuracy of the proposed association of porous cranial lesions with probable cases of juvenile scurvy. The observations made on the sub-adult individuals from Stymphalos and Zaraka also suggest that juvenile scurvy can show a variety of manifestations, both radiographic and macroscopic.

6.2.5–Addressing Macroscopic Long Bone Lesions

Looking at the long bones of the individuals from Stymphalos and Zaraka, there is clear evidence of metaphyseal porosity in a number of the individuals observed (Table A3.2). Metaphyseal porosity is typical of rapid remodeling in the sub-adult skeleton. Such porosity is known to vary due to rate of growth and age, but it typically does not extend beyond 5–10 mm from the metaphyseal edge (Ortner et al. 2001: 348). Ortner et al (2001) consider metaphyseal porosity past this point, like that observed in several of the individuals from Stymphalos and Zaraka, to be potential evidence of a disruption in bone remodeling secondary to scurvy. If this model is correct, the porosity, in the context of the other substantiating evidence, may be further evidence of the presence of juvenile scurvy.

An interesting possible pathological alteration of the long bones that was observed among several individuals from Stymphalos and Zaraka was the presence of multiple and highly pronounced vessel track foramina along the distal posterior aspect of the femora (Fig. A2.8). Such vessel tracks were observed in individuals STYM-III-97-2, STYM-IX-00-2-2, ZAR 96-2, ZAR 97-1 and ZAR 97-2 along the distal diaphysis extending towards the metaphysis. The vessel tracks observed presented with a shallow depressed track leading to a relatively large foramen. The multiplicity and type of vessel tracks observed in these individuals appears to be abnormal (Lovell 2009: pers. comm.). Considering the other lesions observed it is possible that such vessel tracks are associated with juvenile scurvy, being a possible sequela to inflammation and hemorrhaging. However, caution is necessary when attempting to identify and interpret such vessel tracks, as Mann and Hunt (2005: 170) suggest that such vessel tracks or vertical striations are a normal aspect of sub-adult bone growth and should not be conflated with disease.

Periostitis was identified among individuals STYM-III-97-1, STYM-IX-00-2-1 and ZAR 96-2. The periostitis identified was remodeled in all three cases, suggesting that healing had begun to occur prior to death. Periostitis is a non-specific reaction to inflammation and as such cannot be linked to a particular aetiology in isolation. However the identification of periostitis in conjunction with both macroscopic and radiographic lesions consistent with juvenile scurvy suggests that these particular examples of periostitis can be attributed to a likely aetiology of juvenile scurvy.

The long bones of the individuals examined from Stymphalos and Zaraka have provided limited macroscopic pathological evidence. However the evidence that has been identified has provided support for a probable diagnosis of juvenile scurvy and has not provided significant evidence to suggest an aetiology linked to another disorder.

6.3–Addressing Variability in Scorbutic Lesion Formation

It is well known that scurvy has a significant latency and prodromal period and thus significant variation in the manifestation of this disorder can be expected. The following sections will seek to examine the issue of variability in the manifestation of the lesions of juvenile scurvy.

6.3.1–Differences in the Timing of Manifestation and Remodeling of Juvenile Scurvy Indicators

An issue that future research may seek to address is the rate at which various scorbutic lesions manifest and remodel. The research presented here has shown that in certain cases there is evidence of scurvy based on macroscopic diagnosis while radiographic evidence is absent, such as was observed in the case of ZAR 96–2. Conversely, ZAR 97–3 exhibited radiographic lesions of scurvy but no macroscopic lesions. These observations could be taken as evidence that the macroscopic signs discussed are not reliable indicators of scurvy. However, they could also be explained by differences in the timing of appearance of the lesions.

Such manifestations bring into question the variation between different lesions of scurvy in terms of the timing of their appearance over the course of illness (Gillman and Gillman 1951). Clinical research has shown that radiographic lesions of scurvy are typically identifiable before soft tissue and musculo-skeletal manifestations (Akikusa et al. 2003). Taking this into consideration it is proposed that the same pattern may occur in archaeologically visible lesions, with alteration to the microstructures of the bones being radiographically visible before gross macroscopic alterations, such as porous cranial lesions, which are caused by reaction to a soft tissue symptom. On the premise that impairment of osteoid formation will be radiographically visible before gross bone lesions it is possible – and highly likely – that individuals may show radiographic lesions while having few or no macroscopic lesions indicative of juvenile scurvy.

Conversely clinical studies have shown that with the introduction of vitamin C, the resolution of radiographically identifiable microstructural changes occurs at a relatively rapid rate, beginning in as little as 2–6 weeks after the re-introduction of vitamin C (Brickley and Ives 2008; Ratanachu-Ek et al. 2003). On this basis it can be argued that the radiographic changes of scurvy associated with impaired bone formation of the epiphyses and metaphyses may remodel and thus resolve to a normal appearance at a significantly faster rate than gross porous macroscopic lesions of the skull. The long bones of sub-adults grow at a rapid rate, and with the resolution of scurvy bone remodeling and growth of the limbs would lead to relatively quick resolution of the radiographic changes caused by scurvy. There are, however, two radiographic indicators of scurvy that persist for an extended period of time. The white line of scurvy is buried in the diaphysis by subsequent growth, forming a Harris line, and the mark of Wimberger's ring is maintained inside the growing epiphysis, causing the appearance of a buried 'epiphysis within an epiphysis' (See section 2.1.3.13). In contrast, the bones of the sub-adult skull have less growth stress placed on them, causing the gross macroscopic lesions of the cranial bones due to hemorrhage to remodel at a significantly slower rate. Furthermore, the porous cranial lesions noted do not affect the developing microstructure of the bone, as is the case with the various radiographic indicators of juvenile scurvy in the long bones. Rather, they manifest as a reaction to hemorrhagic bleeding and their resolution is not integral to the continued growth of the individual as is the case in the long bones. On this premise it is proposed that porous cranial lesions may persist for significantly longer than radiographically identifiable lesions of juvenile scurvy in the long bones, with the exception of the appearance of an 'epiphysis within an epiphysis' and the preservation of the white line of scurvy as a Harris line . When examining archaeological populations it is thus possible that the observation of porous cranial lesions in the absence of radiographic lesions of scurvy may represent a different stage of disease resolution rather than a lack of juvenile scurvy.

The ability to identify the lesions of juvenile scurvy also has to be considered from the perspective of disease development. Following from the argument above it can be surmised that depending on the stage at which scurvy is observed, various indictors of this disorder may be absent, underdeveloped, or resolved. If an individual in the early stages of scurvy were to have died it remains possible that only radiographic indicators may be observable as there may not have been enough time to allow for the development of gross macroscopic lesions. This argument is particularly cogent if the implications of infection and associated rapid death, as presented in Sections 6.3.4 and 3.3.2.1, are considered (Follis 1942; Taylor 1937; Jaffe 1927). Waldron (2009: 132–133) states that more children died of scurvy in the first half of the twentieth century than of measles, suggesting a relatively high rate of fatality associated with this metabolic disorder.

It is proposed that if an individual were to have died at the peak of florid scurvy it is likely that both macroscopic and radiographic indicators of scurvy may be present and observable. However even in cases of florid scurvy there is the chance that due to variable manifestation not all proposed lesions of this disorder may be observable.

It is proposed that if an individual had suffered from scurvy and had survived for an extended period of time after the resolution of this disorder it is probable that the individual would preserve macroscopic lesions of the cranium for longer than radiographically identifiable indicators of scurvy, with the exceptions of white line of scurvy preserved as a Harris line and 'epiphysis within epiphysis', as discussed above. After the relatively rapid resolution of most radiographic lesions, the macroscopic lesions could continue to persist for a significant period until full remodeling occurred. Such full resolution may take a significant period of time, possibly years, and may potentially not occur at all.

Following the resolution of scurvy, scorbutic lesions begin to resolve becoming progressively less identifiable with the passage of time. On this basis it is asserted that the order for the development and manifestation of scorbutic indicators proceeds with radiographic indicators as the earliest markers, followed by the development and co-occurrence of macroscopic and radiographic indicators, the duration of which will be highly variable between cases, followed by the resolution of microstructural radiographic indicators and the preservation of macroscopic indicators until such time that both radiographic and macroscopic indicators of scurvy have been resolved as a result of continued bone remodeling over time.

6.3.2–Lesion Variability and the Debate over the Diagnostic Value of Porous Cranial Lesions in Cases of Juvenile Scurvy

6.3.2.1–Variability in the Manifestation of Porous Cranial Lesions

Melikian and Waldron (2003), Maxwell et al. (2006) and Waldron (2009) question the validity of the lesions proposed by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) as indicators of juvenile scurvy among archaeological populations. Melikian and Waldron (2003) observed a variety of porous lesions among the sample they examined from Romano-British Poundbury, Medieval Abingdon, and from the Natural History Museum, London. From this they conclude that though such porous lesions may have an association with scurvy, the lesions were too common and followed too random a pattern for any one suite of lesions to be accepted as indicative of juvenile scurvy without substantiation using clinical radiographic indicators (Waldron 2009:133). Based on that research it is clear that there may be significant variability in the manifestations of macroscopic porous cranial lesions in archaeological populations. However, variability in lesion manifestation is expected under the Ortner et al. model. Ortner and Ericksen (1997: 215) and Brickley and Ives (2006: 165) attribute the development of the proposed porous cranial lesions to mechanical and traumatic stress due to weakened cell structures causing hemorrhaging along the cranial bones. If juvenile scurvy were to be in the latent or early clinical stages it is likely that limited cranial porosity would be observed. Furthermore the level of hemorrhaging caused by mechanical stresses, such as chewing, sucking, or talking, may vary significantly on a case-by-case basis. As a result, the extent and distribution of porous cranial lesions caused by hemorrhaging may be highly variable. Variability due to progression of the condition, as discussed above, must also be considered. However, this does not mean that the lesions are any less valuable as indicators of juvenile scurvy. The issue seems to be one of inter-personal variability in the extent of lesion development rather than a lack of connection between the lesions and juvenile scurvy.

Melikian and Waldron (2003) have called for the use of curated remains representing clinically confirmed cases of juvenile scurvy to establish the types and extent of lesions than can be expected in cases of juvenile scurvy. Though this concept is intended to provide a way of linking archaeologically identified cranial lesions with clinically known lesions it falls short in its ability to account for variability. Museums and clinical collections typically only maintain study specimens that show extreme or peculiar manifestations of a particular disorder and in this regard cannot be taken as a representative sample of the widely variable manifestations that may be encountered in any given disorder (Mays 2008b: 225). Furthermore Ortner et al. (2001: 350) stress caution when using museum and clinical collections because misdiagnoses, particularly in historical cases, can and do occur and often data on possible co-morbidity and previous illnesses, which may have effected the development and extent of skeletal lesions, are not provided.

The research presented on the individuals from Stymphalos and Zaraka has provided additional evidence that the porous cranial lesions in question are associated with the presence of juvenile scurvy. Individuals STYM-II-97-1, STYM-IX-00-2-1 and STYM-IX-00-2-2 represent a group of sub-adults of various age ranges who manifested with strong macroscopic evidence, porous cranial and long bone lesions, and clinically consistent diagnostic radiographic indicators of juvenile scurvy. The co-occurrence of both clinically consistent diagnostic radiographic indicators of juvenile scurvy and proposed porous cranial lesions provides a good basis upon which to assert the association of such porous cranial lesions with a probable aetiology of juvenile scurvy.

6.3.3–Variable Manifestations of Radiological Indicators of Juvenile Scurvy

It is well documented that in cases of juvenile scurvy radiographic changes to the microstructure of the long bones are some of the first indicators of the presence of juvenile scurvy to manifest in a given individual (Shore 2008). However research into the radiographic manifestations of juvenile scurvy has also shown that the radiographic indicators of this disorder occasionally do not manifest at all or manifest only to a limited degree (Brailsford 1953). Akikusa et al. (2003) observed no identifiable radiographic changes of scurvy except for the non-diagnostic presence of generalized osteopenia in a 9 year-old female with fully developed clinical scurvy. Similar results are presented by Shetty et al. (1998) from the observation of a 6 year-old male who also presented with diffuse osteopenia as the only possible radiographic alteration caused by scurvy. Gomez-Carrasco et al. (1994) presented findings on a 12 year-old female with several ecchymotic regions, hemorrhagic gingivitis, follicular hyperkeratosis, and petechial hemorrhages but no discernable radiographic changes. These reported cases suggest that the manifestation of radiographic changes in cases of juvenile scurvy may be more variable than is commonly understood. This is not intended to suggest that the accepted clinical radiographic indicators of juvenile scurvy should be called into question when attempting to use these indicators to examine archaeological populations. Rather it is intended to show that variability of the clinical radiographic indicators of juvenile scurvy can and do occur and that it is possible that even in cases of severe juvenile scurvy there may be a lack of diagnostic radiographic indicators of this disorder.

6.3.4–The Role of Infection in Cases of Scurvy

Clinical studies on the development and effects of scurvy on the body have shown that individuals suffering from scurvy are increasingly susceptible to infection and as a result infection is commonly observed in cases of scurvy (Gestsdottir 1998; Warkany 1962). Follis et al. (1950) reported observing acute illness, predominantly infection, in 64.5% of children with scurvy. The decrease in the strength of the immune system due to the absence of vitamin C poses a serious risk of infection to the individual, the result of which is often rapid fatality (Grewar 1965; Warkany 1962; Jaffe 1927).

Based on the studies conducted on guinea pigs by Jaffe (1927) and Schultz (1936), if infection[1] and scurvy develop at the same time the infection may actually prevent the development of classic scurvy symptoms for a significant

[1] In the study conducted by Jaffe (1927) the infection was caused by staphylococcus, while Schultz (1936) employed hemolytic streptococcus.

period of time.[2] Conversely, Jaffe (1927) and Schultz (1936) showed that if an individual was already suffering from scurvy and subsequently developed an infection the infection caused a significant increase in the rate of development of scurvy, typically leading to rapid fatality (McCann 1962; Schultz 1936; Jaffe 1927).

The research presented on infection by Jaffe (1927) and Schultz (1936) has significant implications and is important to the archaeological investigation of juvenile scurvy in two ways.

The work presented on infection by Jaffe (1927) and Schultz (1936) suggests that infection may compound the difficulty of interpersonal variability in rates of scorbutic development by hindering the development of symptoms, leading to increasingly disparate time periods between the development of latent scurvy and the appearance of clinical symptoms. This latency and lengthy prodromal period presents a challenge to the investigation of this disorder among osteoarchaeological remains as the number of individuals who may have suffered from scurvy may not be represented accurately as osteological lesions may fail to form for extended periods of time, if at all (Paine et al. 2007; Gestsdottir 1998). It can further be argued that the full extent of scurvy can never be accurately quantified among archaeological populations as it remains possible that an extended period of latency may be overcome by the re-introduction of vitamin C and thus individuals who in a clinical sense were scorbutic may never manifest osteological symptoms of this disorder.

[2] In Jaffe's study animals that were injected with staphylococcus and put on a scorbutic diet at the same time failed to develop scorbutic indicators for 19 to 40 days, whereas animals on a scorbutic diet without infection developed scorbutic indicators by 2 weeks (Jaffe 1927: 505).

The second important aspect of the work of Jaffe (1927) and Schultz (1936) is the role which super-imposed infection plays on the increased pace of the development of scurvy (McCann 1962). In antiquity when antibiotic treatments were largely unavailable it would have been difficult to fight infections. Furthermore the risk of developing an infection would have been significant among past populations, particularly in cases of weakened immunity such as is seen in scurvy. The super-imposition of infection on scurvy resulting in rapid death may prove problematic to the archaeological identification of scurvy due the to fact that with rapid death symptoms of scurvy and thus lesion formation, both macroscopic and radiological, may have only developed to a limited degree and thus may not be fully visible.

The role that infection plays in the development and manifestation of scurvy poses a difficult problem when attempting to identify this disorder among archaeological populations. Such difficulties should not dissuade further research into this disorder, but rather should be considered as a potential obscuring factor in the ability to fully identify juvenile scurry among ancient populations.

6.3.5–Summary of Lesion Variability in Cases of Juvenile Scurvy

The research presented on the individuals from Stymphalos and Zaraka has shown that based on the co-occurrence of the proposed porous cranial lesions and clinically diagnostic radiographic lesions of juvenile scurvy there is strong evidence for the model of porous cranial lesions and juvenile scurvy presented by Ortner et al. (2001, 1999; Ortner and Ericksen 1997). Radiographic indicators of juvenile scurvy provide a method for confirming a diagnosis of this disorder.

These indicators have significant diagnostic strength, as they are linked to clinically validated diagnoses and thus can be used in isolation for assessing archaeological cases of juvenile scurvy.

It is important to appreciate that variability in the manifestation of both proposed macroscopic and clinically diagnostic radiographic indicators of juvenile scurvy does occur. This variability should not be taken as an argument for discrediting the methods of identifying scurvy among archaeological populations, but rather should be understood as a potential difficulty that needs to be accounted for in the identification of this disorder. It is recommended that in an attempt to provide increasingly verifiable and valid diagnoses of juvenile scurvy future investigations of this disorder should seek to use a variety of approaches including macroscopic, radiographic, and histological in an attempt to provide a robust and multi-faceted approach to the identification of juvenile scurvy in antiquity. The inclusion of as many diagnostic methods as allowable in any one investigation provides a strength of diagnosis that cannot be provided by the isolated use of any one technique. Furthermore the use of multiple approaches may help in identifying variation in the manifestation of juvenile scurvy as each method provides a mechanism for the observation of different scorbutic changes that may not be possible with any one given method. Thus the various stages of development and different manifestations of juvenile scurvy may be all the more identifiable through the inclusion of multiple means of investigation.

6.4–Scurvy and Starvation

Juvenile scurvy being a dietary disorder is unlikely to have occurred in isolation among ancient populations. As was discussed in Chapter 2 it is probable that other dietary disorders such as rickets and anemia would co-occur with scurvy, potentially altering the manifestation of radiographic and skeletal lesions. An issue that has not been previously addressed in this work, but is nonetheless pertinent, is the issue of starvation. It is possible that in cases where an individual is starving scurvy may manifest. However it is also likely that if an individual were starving other significant nutritional deficiency disorders would also be observed in the skeletal remains. Due to the limited skeletal manifestation of some dietary disorders, such as pellagra, it is not possible to entirely dismiss the presence of other dietary disorders among the Stymphalos and Zaraka individuals examined. However, the failure to find observable signs of any other dietary disorders in the remains suggests that starvation is a less likely cause of the lesions observed than is juvenile scurvy.

6.5–Further Approaches to the Archaeological Investigation of Juvenile Scurvy

Substantial research has been done in recent years to help identify potential cases of juvenile scurvy among archaeological populations (e,g, Ortner et al. 2001, 1999; Ortner and Ericksen 1997; Brickley and Ives 2008, 2006). The suite of porous cranial lesions proposed by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) has created significant debate as to the validity of a method that seeks to use macroscopic skeletal lesions to identify juvenile scurvy. Research supporting (e.g. Brickley and Ives 2008, 2006), and contesting (e.g. Waldron 2009; Maxwell et al. 2006; Melikian and Waldron 2003) the proposed method has become increasingly frequent. In an attempt to confirm the identification of juvenile scurvy among archaeological populations, research into other potential means of diagnosis has continued. The following sections examine two approaches that may be helpful in aiding in the identification of juvenile scurvy among archaeological populations.

6.5.1–Rib Lesions

A suite of lesions that has not been significantly investigated among archaeological remains yet has potential for aiding in the identification of juvenile scurvy is that seen in the ribs.

Clinical cases of scurvy often show alteration of the costo-chondral junction, resulting in what is known as a scorbutic rosary. This scorbutic rosary appears as a series of nodule-like enlargements of the costo-chondral junction due to subperiosteal hemorrhage at the sternal end of the ribs and disruption of the costo-chondral junction due to infractions and fractures (Jaffe 1972; Gillman and Gillman 1951; Park et al. 1935). An increase in the size of the cartilage at the costo-chondral junction causes the sternal aspect of the rib to enlarge so as to be able to accommodate the enlarged cartilage, resulting in cupping around the enlarged cartilage which causes increased concavity as well as flaring of the sternal end of the rib (Jaffe 1972; Park et al. 1935: fig. 37).

The formation of such nodules may alter the angle of the sternal end of the rib and represents a distinct change in the appearance of the ribs in cases of scurvy. Park et al. (1935: 277) notes that the impairment of osteoid formation leads to a weakening of the skeletal structure of the ribs, similar to the scorbutic weakening of the metaphyseal regions of the long bones. This weakening can cause partial or complete transverse fractures at the sternal end of the ribs (Jaffe 1972).

Based on research conducted on 535 living children Park et al. (1935: 269) noted that the ribs are affected in scurvy earlier than the bones of the extremities, suggesting that alteration of the skeletal structure of the ribs, when it appears, may be present for a significant period of the duration of juvenile scurvy.

Due to the impairment of osteoid formation the sternal end of the ribs manifest similar radiographic signs to those seen in the long bones of scorbutic individuals. Transverse zones of radiopacity, due to the presence of calcified cartilage caused by inhibited endochondral bone formation, can commonly be observed at the costo-chondral junction (See Jaffe 1972: 450, fig. 113a). Adjacent to the region of radiopacity moving away from the sternal end of the rib is a thin "slit-like" region of radiolucency caused by infractions of the local cortex of the rib shafts (Jaffe 1972). Such radiographic indicators provide strong evidence of impaired bone formation at the costo-chondral junction and could prove of significant use when examining archaeological populations for evidence of juvenile scurvy.

Jaffe (1972: 454) notes that subperiosteal hemorrhaging along the pleural and pectoral surfaces may also occur for some distance along the shaft of the ribs. Such hemorrhaging, as is also the case with hemorrhaging seen along the long bones in cases of juvenile scurvy, may result in isolated formations of subperiosteal new bone along part of the ribs adjacent to the sternal end.

Park et al. (1935: 280) notes that the scorbutic rib deformities described above are most pronounced in the 5th, 6th and 7th ribs, while the 8th and 9th ribs may show significant alterations as well, but are typically less involved.

Considering the significant changes that take place at the costo-chondral junction in cases of scurvy it is proposed that observable macroscopic enlargement, alteration of the sternal angle of the rib, the presence of periosteal new bone formation associated with hemorrhaging and increased concavity of the sternal aspect of affected ribs, along with the observation of fracturing and demineralization accompanied by radiopacity and adjacent radiolucency of the sternal end, in the 5th to 7th, and possibly 8th and 9th ribs should be investigated as a potential additional indicator of juvenile scurvy among archaeological populations.

6.5.2–Histology

Histology does not represent a new approach to the examination of deficiency diseases, as there has been much paleopathological research conducted using this method. Rather, histology should be included in the investigation of deficiency disorders as a further supporting technique to aid in strengthening and confirming diagnoses made based on macroscopic and radiographic observations. Histology provides a level of accuracy in diagnosis that is often superior to macroscopic and radiographic observations of archaeological remains (Schultz 1993, 1988b). Histology allows for the observation of minute skeletal structure changes and is of great value in differentiating the various dietary deficiencies, each of which has specific microstructural bone changes and formation processes (Schultz 2001). With the use of histology the mechanisms of pathological change can be clearly observed at the microscopic level and more securely attributed to a given aetiology.

The ability to attribute osteological changes to specific aetiologies is particularly helpful when attempting to identify the process responsible for the formation of porous orbital lesions (Schultz 2001). It is this ability to differentiate between different pathologies based on observation of minute structural changes, particularly between juvenile scurvy, rickets and anemia, that makes histology a valuable method to consider along with macroscopic and radiological observation when examining dietary deficiency disorders among archaeological populations.

Though histology can provide specific details about the presence and state of disease among archaeological populations this technique is destructive. Due to this, the method is recommended as a supplementary approach to help support previous findings when macroscopic and radiological findings are unclear.

6.6–Summary and Discussion of Findings

Based on the results presented in this chapter there is clear evidence, both macroscopic and radiographic, suggesting the presence of juvenile scurvy among a number of the individuals examined from Stymphalos and Zaraka. Furthermore based on the observations made on the Stymphalos and Zaraka populations it is apparent that the diagnostic clinical radiographic indicators of juvenile scurvy used in this study correlate significantly with the proposed macroscopic porous cranial lesions of juvenile scurvy as presented by Ortner et al. (2001, 1999; Ortner and Ericksen 1997).

The present study has also shown that correlation between proposed macroscopic and known radiographic indicators of juvenile scurvy is not necessarily always the case. The example of ZAR 96–2 showed that the presence of macroscopic lesions believed to be consistent with juvenile scurvy did not coincide significantly with the presence of known radiographic indicators of juvenile scurvy. Conversely the case of ZAR 97–3 appeared to be normal based on macroscopic observations of the skeletal structures, while the identification of several diagnostic radiographic indicators suggest the presence of juvenile scurvy in this individual. These examples of non-correlation, despite the overall agreement between the macroscopic and radiographic indicators used in this study, provide evidence to support the variability in manifestation of lesion formation in cases of juvenile scurvy.

Considering the lack of correlation in these two cases it is proposed that future research should investigate the rate at which macroscopically identifiable lesions appear and are resolved in cases of juvenile scurvy compared to radiographically identifiable indicators of juvenile scurvy. Such an investigation would be of significant value for future archaeological investigations, as it is possible that one type of lesion, either macroscopic or radiographic, may manifest and subsequently remodel at a different rate from the other type. If this is the case it could be argued that depending on the stage at which the disorder is observed - before full onset, during active scurvy, or after resolution - there may be variability in the extent to which macroscopic and radiographic lesions are manifested. Thus, the level of correlation between the sets of lesions may vary. If this does create a differential time period for the development and resolution of lesions, the presence of one type in the absence of the other may be attributed to the timing of death relative to the episode of scurvy rather than a flaw in the method of investigation. Such a conclusion cannot be made at this time, as further work into other populations is required to test this proposal, research which is beyond the scope of the present study.

Based on the evidence presented, the results from Stymphalos and Zaraka have shown that the macroscopic lesions proposed by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) are largely in agreement with the diagnostic clinical radiographic indicators used to diagnose juvenile scurvy in living children (Shore 2008; Burton and Brody 1999; Schumacher 1999; Silverman et al. 1993; Marcove and Arlen 1992; Oestreich 1984; Edeiken 1981; Gordon and Ross 1977; Hirsch et al. 1976; Sprague 1976; Jaffe 1972; Edeiken and Hodes 1967; McCann 1962). The co-occurrence of porous cranial lesions and diagnostic clinical radiographic indicators of juvenile scurvy should continue to be investigated among further archaeological populations in an attempt to provide increasingly well defined evidence of the association of the suite of porous cranial lesions proposed by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) with an aetiology of juvenile scurvy.

Chapter 7–Conclusions

The research presented in this thesis has examined possible cases of juvenile scurvy among the sub-adult individuals from late Roman–Byzantine Stymphalos and Frankish Zaraka. This has led to a number of conclusions about the prospects and problems of identifying juvenile scurvy among archaeological populations as well as a number of recommendations for further avenues of research into the topic of archaeological cases of juvenile scurvy. This chapter presents conclusions regarding the hypotheses addressed in the present work.

7.1–Addressing the Proposed Hypotheses

Returning to the hypotheses originally presented in Chapter 4, it is possible at this time to evaluate their validity.

7.1.1–Hypothesis 1–Correlation of Radiographic and Macroscopic Lesions

The first hypothesis presented asserted that the macroscopic suite of lesions proposed by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) as indicative of juvenile scurvy among archaeological populations would be correlated with clinically established radiographic indicators of juvenile scurvy. Based on the radiographic investigation of the sub-adult remains from Stymphalos and Zaraka this hypothesis has been accepted.

The material presented has shown that 36% of the individuals examined from Stymphalos and Zaraka exhibited strong evidence of macroscopic osteological lesions consistent with the criteria presented by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) as indicative of juvenile scurvy. Radiographic examination of the same osteological remains identified 18% of the cases examined as exhibiting strong evidence of lesions consistent with clinically diagnostic indicators of juvenile scurvy. Taking into account the co-occurrence of macroscopic and radiographic lesions as a whole, 21% of the individuals examined were identified as exhibiting a strong combination of macroscopic lesions consistent with those described by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) and strong radiographic evidence of lesion formations consistent with juvenile scurvy.

These results provide significant evidence to substantiate the argument that the osteological lesions proposed by Ortner et al. (2001, 1999; Ortner and Ericksen 1997) are indicative of juvenile scurvy among archaeological populations. The present study shows that clinical radiographic indicators of juvenile scurvy correlate significantly with the proposed macroscopic suite of lesions indicative of juvenile scurvy, as presented by Ortner et al. (2001, 1999; Ortner and Ericksen 1997). These radiographic indicators should continue to be developed and employed in future paleopathological examinations of juvenile scurvy as a viable means for identifying this disorder among ancient populations.

The frequency of macroscopic and radiographic indicators of scurvy identified among the sub-adult remains from Stymphalos and Zaraka suggests that juvenile scurvy would have been a common occurrence in the valley of Stymphalos. The percentage of cases identified at the two sites cannot be taken as representative of a problem specific to only one time period, but rather must be understood as indicative of the general presence of juvenile scurvy. The material presented strongly suggests that scurvy would have been a frequent problem in the valley of Stymphalos and would have had continual and significant detrimental effects on the sub-adult population throughout the late Roman–Byzantine and Frankish occupation of the valley.

7.1.2–Hypothesis 2–Diet

The second hypothesis proposed was that the use of heavily grain based infant diet regimens poses a serious risk to the child and is a stress factor of significant enough detriment to potentially induce scurvy in a sub-adult individual if pursued for extended periods of time. This hypothesis has also been accepted.

As reviewed in Chapter 2, the historical and isotopic data presented in other research from the general Eastern Mediterranean region supports a heavily grain based diet, which would be poor in vitamins. The research presented on the individuals from Stymphalos and Zaraka suggests that a typical diet was followed (Pennycook 2008b).

The data presented in this thesis supporting the presence of juvenile scurvy strongly suggests that the sub-adult individuals of Stymphalos and Zaraka were nutritionally deprived to the point that scurvy was able to develop in a significant number of the individuals examined. Scurvy arises in an individual only as a result of dietary insufficiency and thus the observation of this disorder among the populations at Stymphalos and Zaraka is indicative of dietary problems. There is clear macroscopic and radiographic evidence among the individuals examined not only of juvenile scurvy at the time of death, but also evidence of previous episodes of scurvy or other deficiency stress. This conclusion is made based on multiple observations of both indicators of juvenile scurvy, including 'epiphysis within an epiphysis' suggesting healing scurvy, and Harris lines, with several individuals exhibiting multiple Harris lines suggesting not only one previous episode of insufficiency stress but multiple episodes. These observations provide a basis upon which to assert that significant dietary stress, to the point of causing scurvy, was occurring within the valley of Stymphalos during both periods under examination in this thesis.

7.2–Implications for Sub-Adult Life in Late Roman–Byzantine Stymphalos

The results of the research presented have a number of implications for aspects of sub-adult life in late Roman–Byzantine and Frankish Stymphalos.

Of the cases examined 29% of the individuals exhibited strong combined radiographic and macroscopic evidence suggesting the presence of juvenile scurvy (STYM-II-97-1, STYM-IX-00-2-1 and STYM-IX-00-2-2, which combine radiographic indicators with the Ortner et al. suite of porous lesions, and ZAR 97-2, which combines strong radiographic indicators with endocranial lesions consistent with scurvy). As well, 36% of individuals examined exhibited possible evidence of juvenile scurvy based on combined macroscopic and radiographic evidence. Such relatively large percentages suggest that sub-adult life in the valley of Stymphalos during the late Roman–Byzantine and Frankish periods was frequently subjected to dietary insufficiency stress.

The historically and isotopically documented extensive use of grains and nutrient poor weaning foods in conjunction with the osteological and radiological evidence of scurvy observed strongly suggests that the sub-adult individuals observed from the valley of Stymphalos frequently suffered from dietary stress and nutritional disorders, such as juvenile scurvy. Even with easy access to vitamin C rich foods the largely humoral based dietary prescriptions of the day did not call for frequent consumption of vitamin C rich foods, and thus children were not necessarily receiving such foods on a regular basis.

The ability to observe not only cases of juvenile scurvy at the time of death but also healing and previous cases among the individuals examined from Stymphalos and Zaraka provides a strong basis upon which to state that the episodes of juvenile scurvy observed among the Stymphalos and Zaraka populations were not simply a one time occurrence, such as might be seen in cases of natural catastrophe. Rather the observation of multiple episodes of scurvy in various stages of development and healing among the individuals from Stymphalos and Zaraka suggests that sub-adult dietary insufficiency was a frequent and continually occurring problem in the valley of Stymphalos resulting in the repeated occurrence of juvenile scurvy during the later Roman–Byzantine and Frankish periods of occupation of the valley.

The review of infant feeding practices during the periods in question identified factors that could have caused the scurvy seen in juveniles from the late Roman–Byzantine and Frankish periods in the valley of Stymphalos. These problems, however, should also be understood in light of the location of the valley of Stymphalos. The valley of Stymphalos is remote, being bounded by mountainous terrain and thus difficult to traverse. This region often receives snow in the winter and has suffered from drought and crop failure on a number of occasions. These geographical and meteorological factors may have further stressed the population.

The osteological and radiographic lesions consistent with juvenile scurvy observed in Stymphalos juveniles in the later Roman–Byzantine and Frankish periods provide strong evidence to support the hypothesis that infant feeding practices in this region created significant nutritional deficiency to the point of causing scurvy. These problems may be explained as the result of dietary practices of the times in conjunction with the remote location of the valley of Stymphalos.

7.3–Research Directions for the Future

The research presented in this thesis has examined the combined use of macroscopic and radiographic lesions to identify archaeological cases of juvenile scurvy. Significant evidence has been presented to support the identification of juvenile scurvy among the sub-adult individuals from Stymphalos and Zaraka.

Future research on juvenile scurvy should seek to employ the method herein presented among other populations to verify the validity of the use of radiography in conjunction with macroscopic lesions to investigate juvenile scurvy among archaeological populations. Continued use of this method would also help to establish a database of correlated macroscopic and radiographic cases of juvenile scurvy, which would be of great benefit to future archaeological examinations of juvenile scurvy.

A potential avenue of research that would benefit from further investigation is the rate of development and resolution of radiographic and osteological lesions of juvenile scurvy. This thesis has presented data suggesting that the co-occurrence of radiographic and osteological lesions of juvenile scurvy may be variable due to the rate of lesion formation and remodeling. Future research would benefit from the investigation of the timelines of lesion formation and remodeling periods and the applications of such timelines to the identification of archaeological cases of juvenile scurvy.

Future investigations of juvenile scurvy among archaeological remains should also attempt to employ the use of histology as this method, when employed in conjunction with macroscopic and radiographic observation, can provide significant microscopic confirmatory data about the presence of juvenile scurvy and other co-occurring pathologies among past populations.

Attempts should also be made in future research to refine and continue to investigate potential lesions that may be consistent with juvenile scurvy. This thesis has discussed at length the possible use of rib lesions to aid in the identification of juvenile scurvy. In the future such lesions should be taken into consideration when attempting to examine juvenile scurvy among past populations.

The research presented in this thesis has provided significant evidence upon which to conclude that juvenile scurvy can be effectively documented among past populations. Research into this dietary disorder should continue to be pursued in an attempt to help refine the paleopathological identification of this disease and the implications of juvenile scurvy within past populations.

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Appendix 1–Radiographs of Individuals Examined from Stymphalos and Zaraka

Fig. A1.1–STYM-II-97-1, Left to Right= R. femur, R. tibia, L. tibia, L. femur, R. radius, L. ulna, L. radius. Grey arrows= radiopaque metaphyseal band, Red arrows= metaphyseal radiolucency, Yellow arrows= transverse radiopaque line.

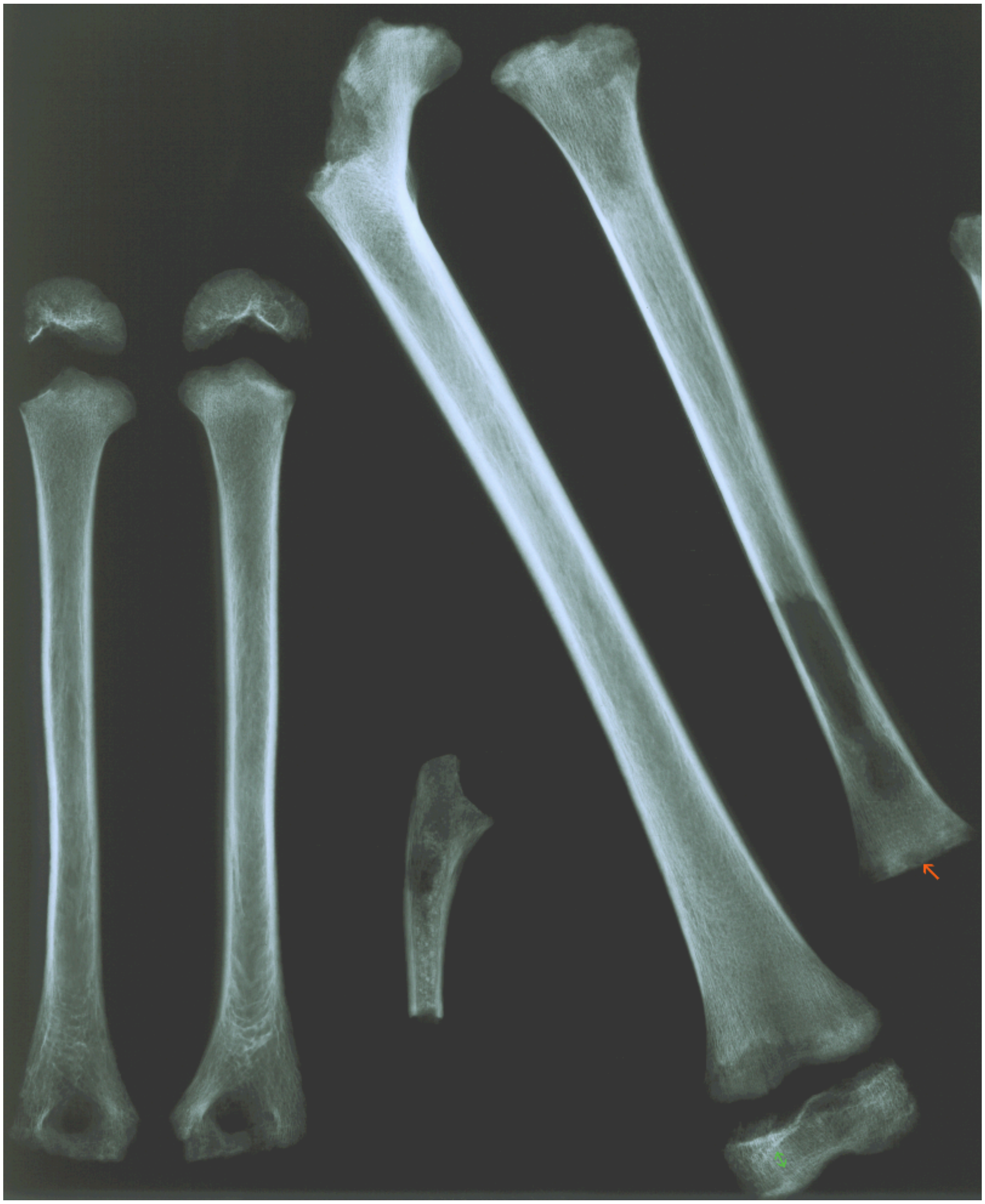

Fig. A1.2–STYM-III-97-1, Left to Right= L. humerus, R. humerus, L. ulna, R. femur, R. tibia. Red arrow= metaphyseal radiolucency, Green arrow= Wimberger's ring.

Fig. A1.3–STYM-III-97-1, Left to Right= L. femur, L. tibia.

Fig. A1.4–STYM-III-97-2, Left to Right= R. femur with distal epiphysis, R. tibia, R. fibula, L. tibia, L. femur. Grey arrows= radiopaque metaphyseal band, Red arrows= metaphyseal radiolucency, Yellow arrows= transverse radiopaque line.

Fig. A1.5–STYM-III-97-2, L. humerus.

Fig. A1.6–STYM-IV-97-1, Left to Right= R. femur, R. tibia, L. femur. Grey arrows=radiopaque metaphyseal band, Red arrow= metaphyseal radiolucency.

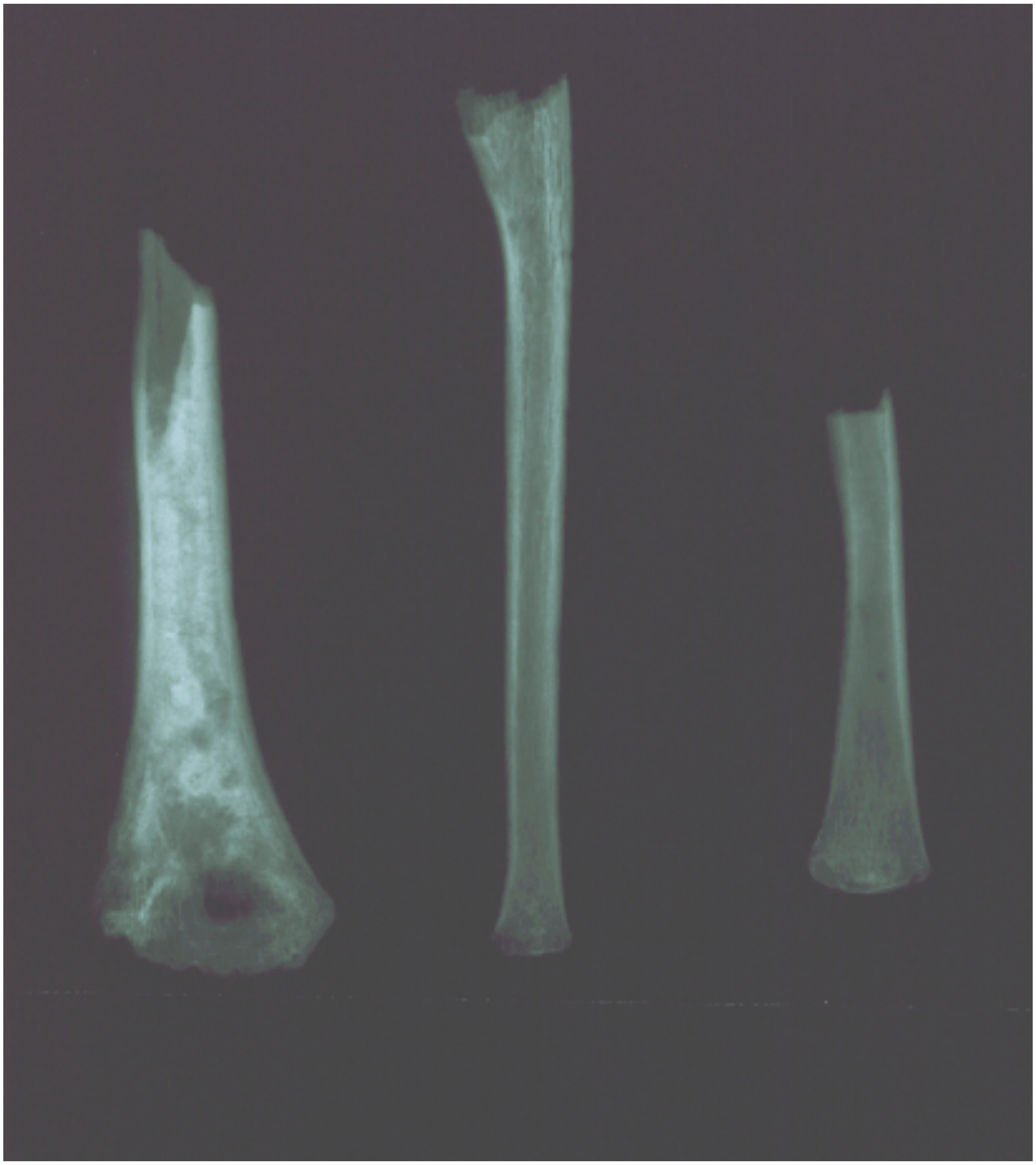

Fig. A1.7–STYM-IV-97-1, Left to Right= L. humerus, L. ulna, R. radius.

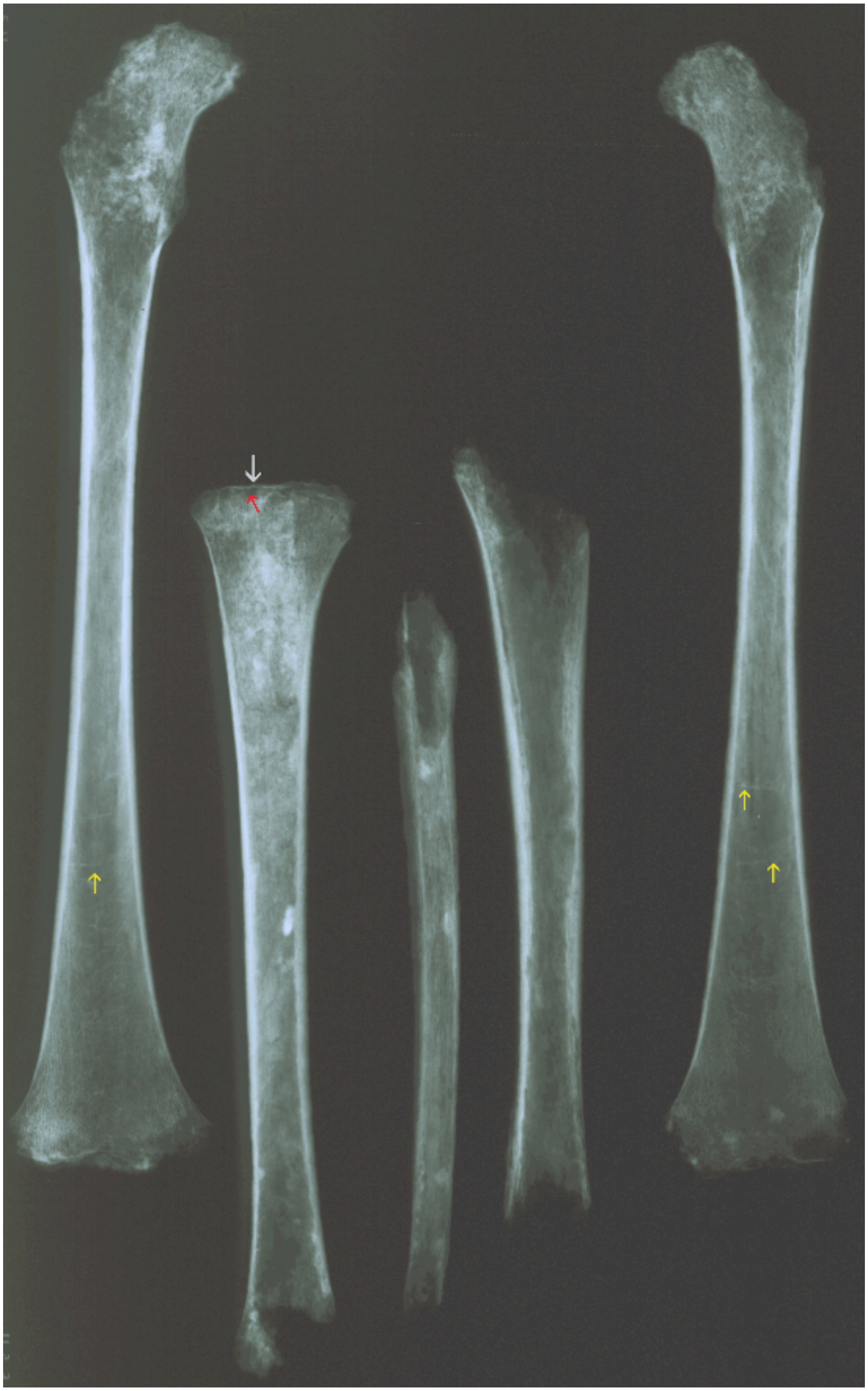

Fig. A1.8–STYM-IV-97-2, Left to Right= R. femur, R. tibia, R. fibula, L. tibia, L. femur. Grey arrow=radiopaque metaphyseal band, Red arrow= metaphyseal radiolucency, Yellow arrows= transverse radiopaque line.

Fig. A1.9–STYM-IV-97-2, Left to Right= R. humerus, L. radius, L. ulna, R. ulna, R. radius.

Fig. A1.10–STYM-IX-00-2-1, Left to Right= L. radius, L. ulna and L. humerus. Grey arrow=radiopaque metaphyseal band, Red arrow= metaphyseal radiolucency.

Fig. A1.11– STYM-IX-00-2-1, Left to Right= R. humerus, R. radius, R. ulna. Grey arrows=radiopaque metaphyseal band, Red arrow= metaphyseal radiolucency.

Fig. A1.12–STYM-IX-00-2-1, Left to Right= R. femur and distal epiphysis, R. tibia and proximal epiphysis, R. fibula. Grey arrow=radiopaque metaphyseal band.

Fig. A1.13–STYM-IX-00-2-1, Left to Right= L. femur and distal epiphysis, L. tibia and proximal epiphysis, L. fibula.

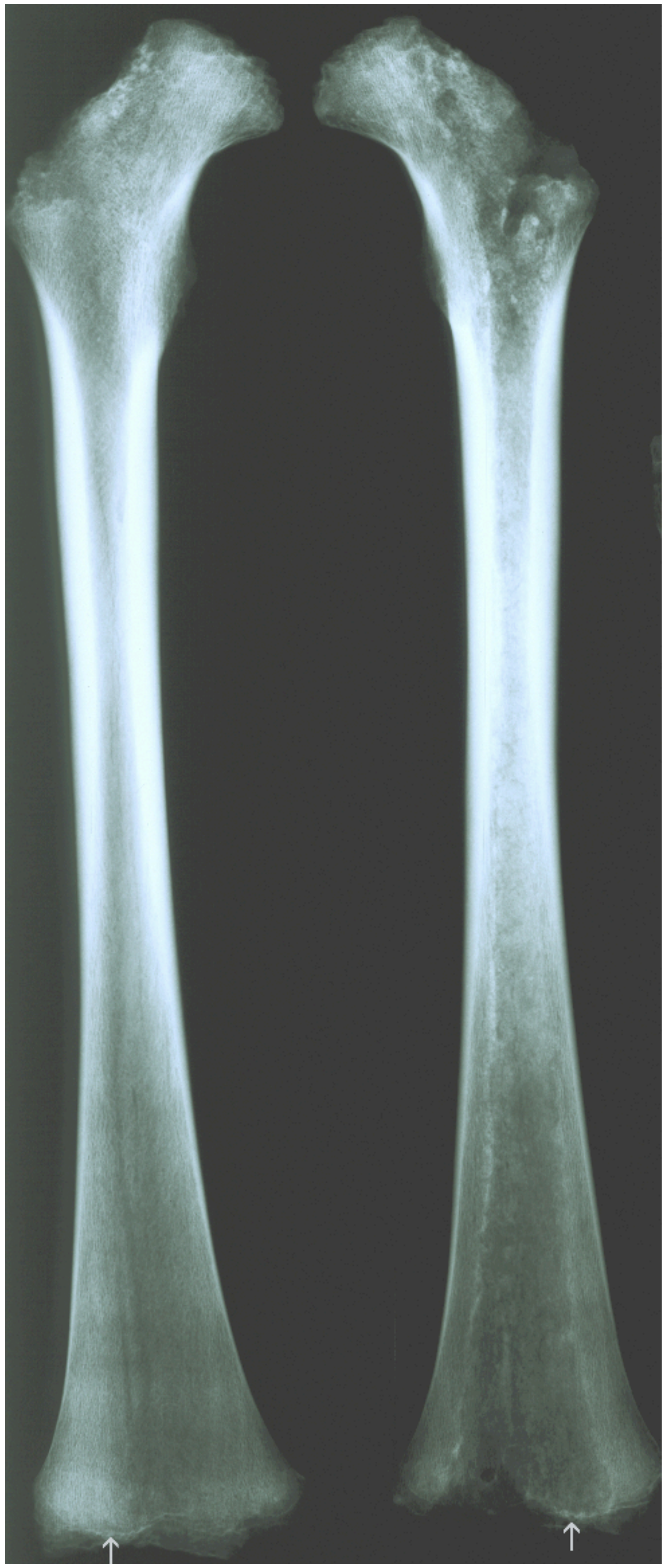

Fig. A1.14–STYM-IX-00-2-2, Left to Right= R. femur and L. femur. Grey arrows= radiopaque metaphyseal band.

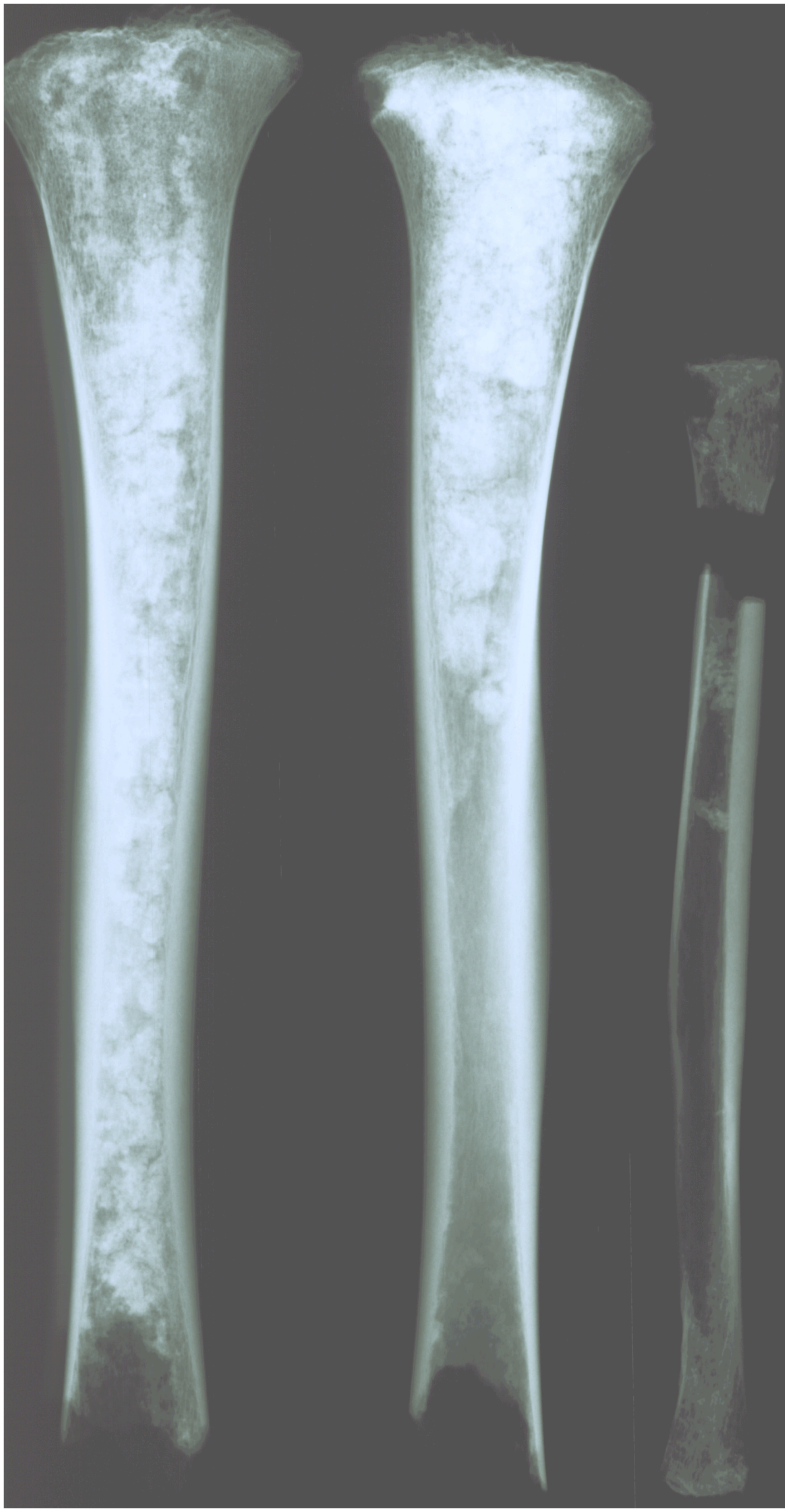

Fig. A1.15–STYM-IX-00-2-2, Left to Right= L. tibia, R. tibia, fibula.

Fig. A1.16–STYM-IX-00-2-2, Left to Right= L. humerus and proximal epiphysis, L. radius, L. ulna, Grey arrow= radiopaque metaphyseal band, Red arrow= metaphyseal radiolucency.

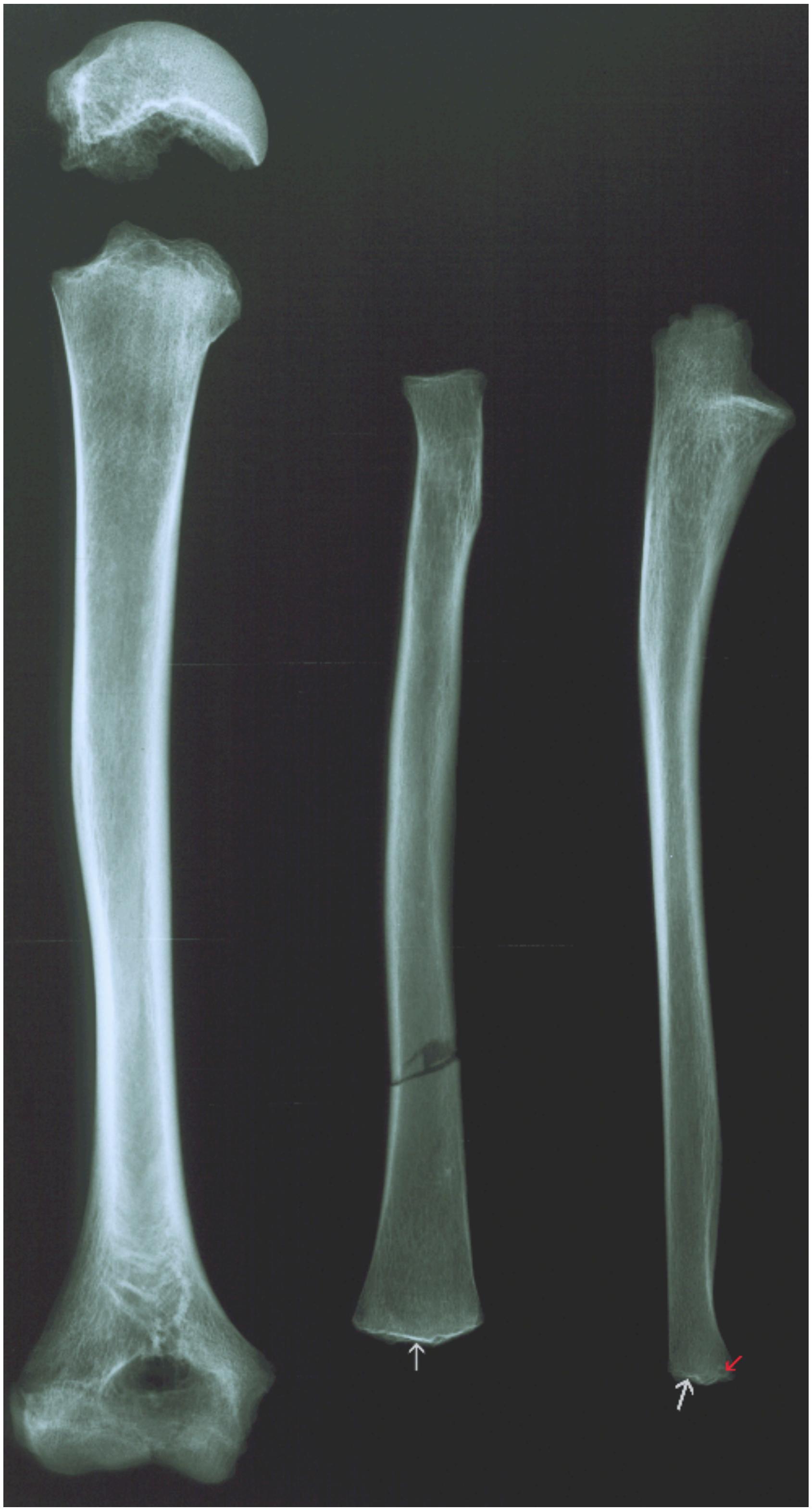

Fig. A1.17–STYM-IX-00-2-2, Left to Right= R. humerus and proximal epiphysis, R. radius, R. ulna. Grey arrows= radiopaque metaphyseal band, Red arrow= metaphyseal radiolucency.

Fig. A1.18–ZAR-96-2, Left to Right= R. femur and distal epiphysis, R. tibia and proximal epiphysis, R. fibula.

Fig. A1.19–ZAR-96-2, Left to Right= L. femur, L. tibia, L. fibula.

Fig. A1.20–ZAR-96-2, Left to Right= R. humerus, R. ulna, R. radius.

Fig. A1.21–ZAR-96-2, Left to Right= L. humerus, L. ulna, L. radius.

Fig. A1.22–ZAR-97-1, Bottom to Top= L. humerus, L. ulna, L. radius, R. radius, R. ulna, R. humerus.

Fig. A1.23–ZAR-97-1, Left to Right= R. femur, R. tibia, L. tibia, L. fibula, L. femur. Grey arrows= radiopaque metaphyseal bands, Red arrows= metaphyseal radiolucency, Yellow arrows= transverse radiopaque line.

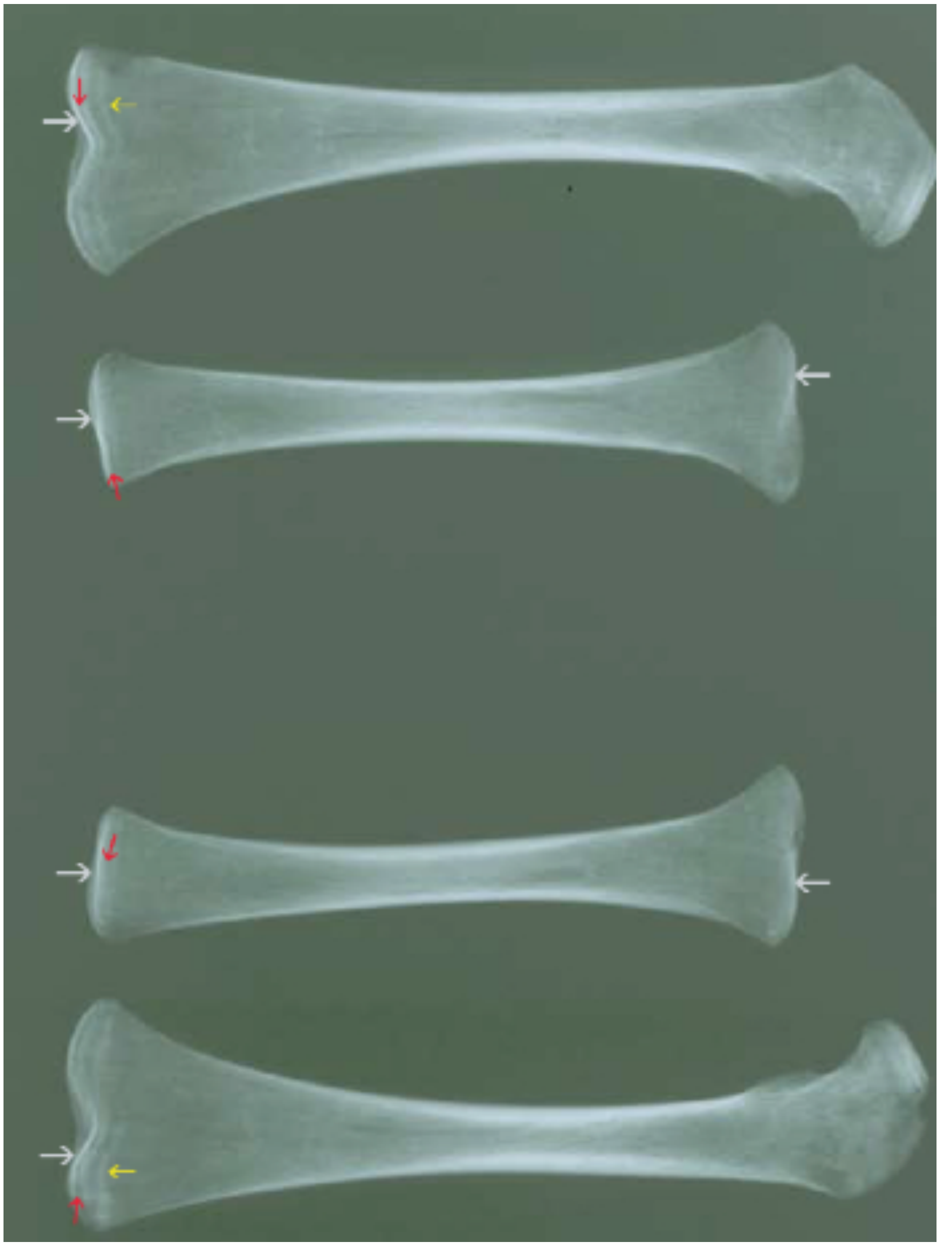

Fig. A1.24–ZAR-97-2, Bottom to Top= L. femur, L. tibia, R. tibia, R. femur. Grey arrows=radiopaque metaphyseal band, Red arrows= metaphyseal radiolucency, Yellow arrows= transverse radiopaque line.

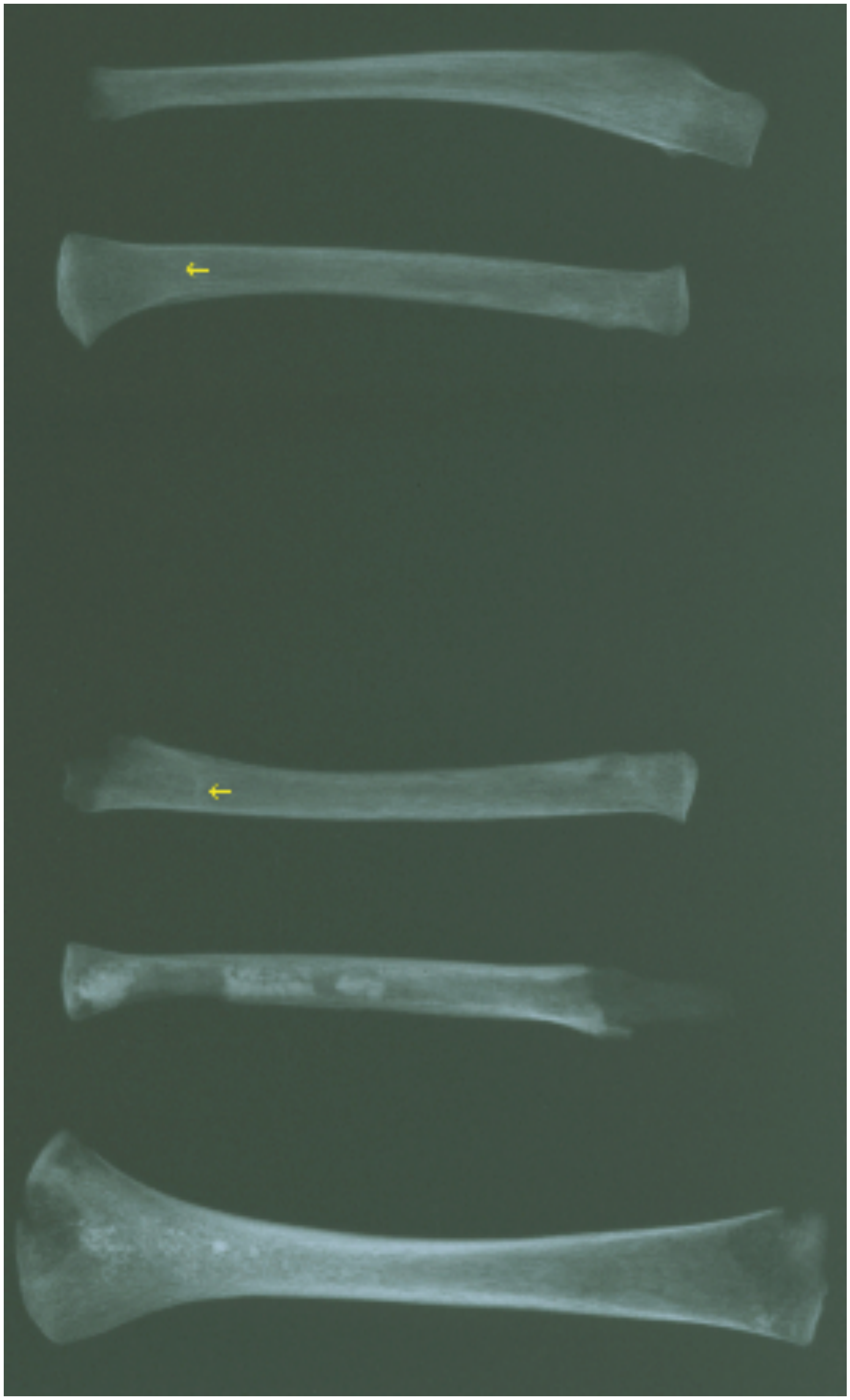

Fig. A1.25–ZAR-97-2, Bottom to Top= L. humerus, L. ulna, L. radius, R. radius, R. ulna.

Fig. A1.26–ZAR-97-3, Bottom to Top= R. femur, R. fibula, R. tibia, L. tibia, L. fibula, L. femur. Grey arrows= radiopaque metaphyseal band, Red arrows= metaphyseal radiolucency, Yellow arrows= transverse radiopaque line.

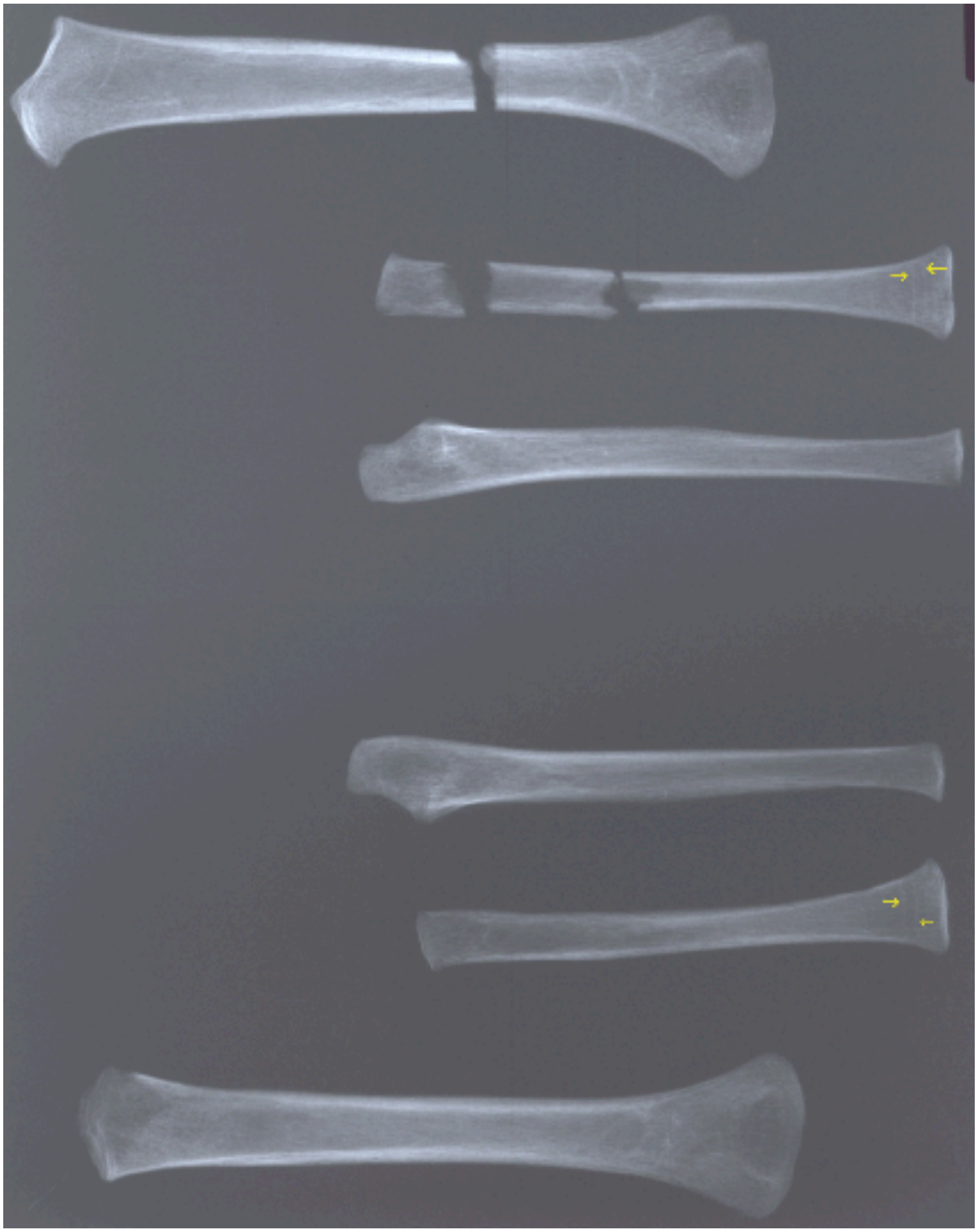

Fig. A1.27–ZAR-97-3, Bottom to Top= R. humerus, R. radius, R. ulna, L. ulna, L. radius, L. humerus.

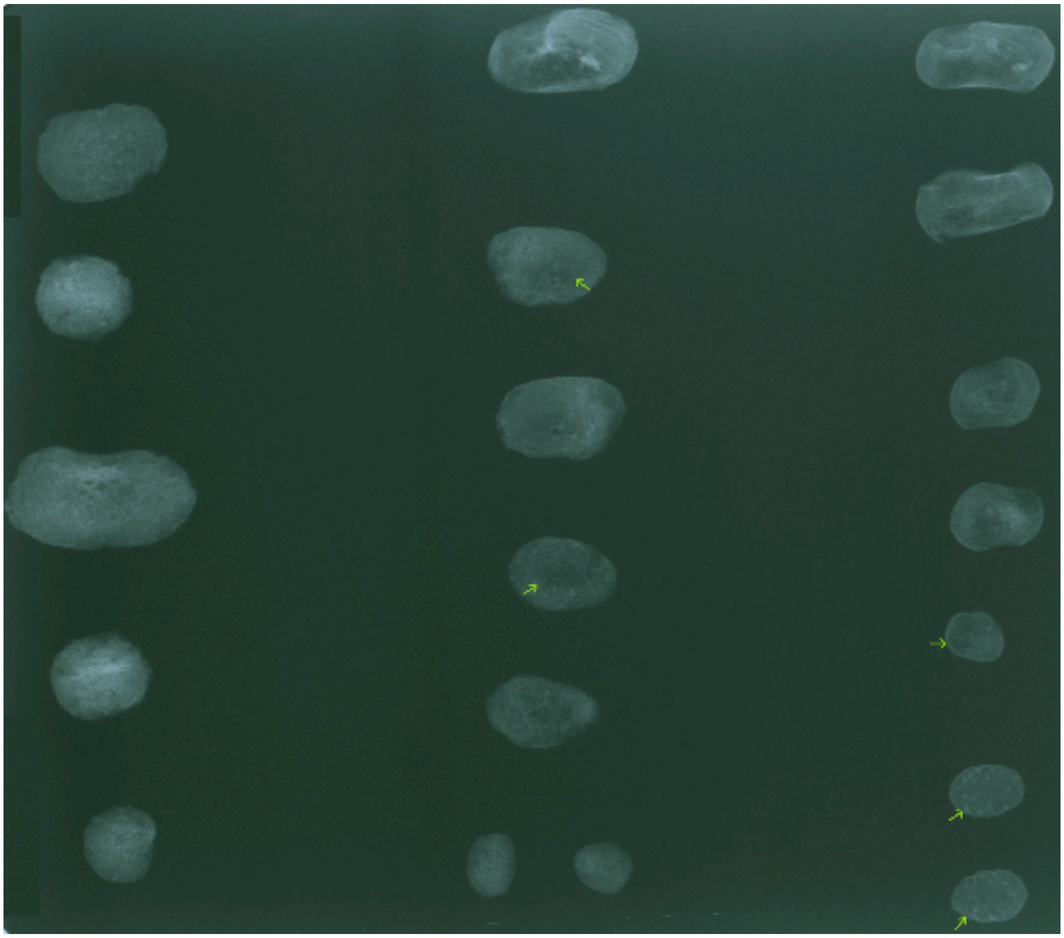

Fig. A1.28–Epiphyses, Left to Right and Top to Bottom= ***ZAR-97-1***, proximal tibia, proximal femur, distal Femur, proximal femur, proximal humerus, ***ZAR-97-3***, L. calcaneus, distal femur, distal femur, proximal tibia, proximal tibia, proximal femoral, ***ZAR97-2***, L. calcaneus, R. calcaneus, L. talus, R. talus, unkown, proximal tibia, proximal tibia. Green Arrows= Wimberger's ring.

Appendix 2–Photographs of Individuals Examined from Stymphalos and Zaraka

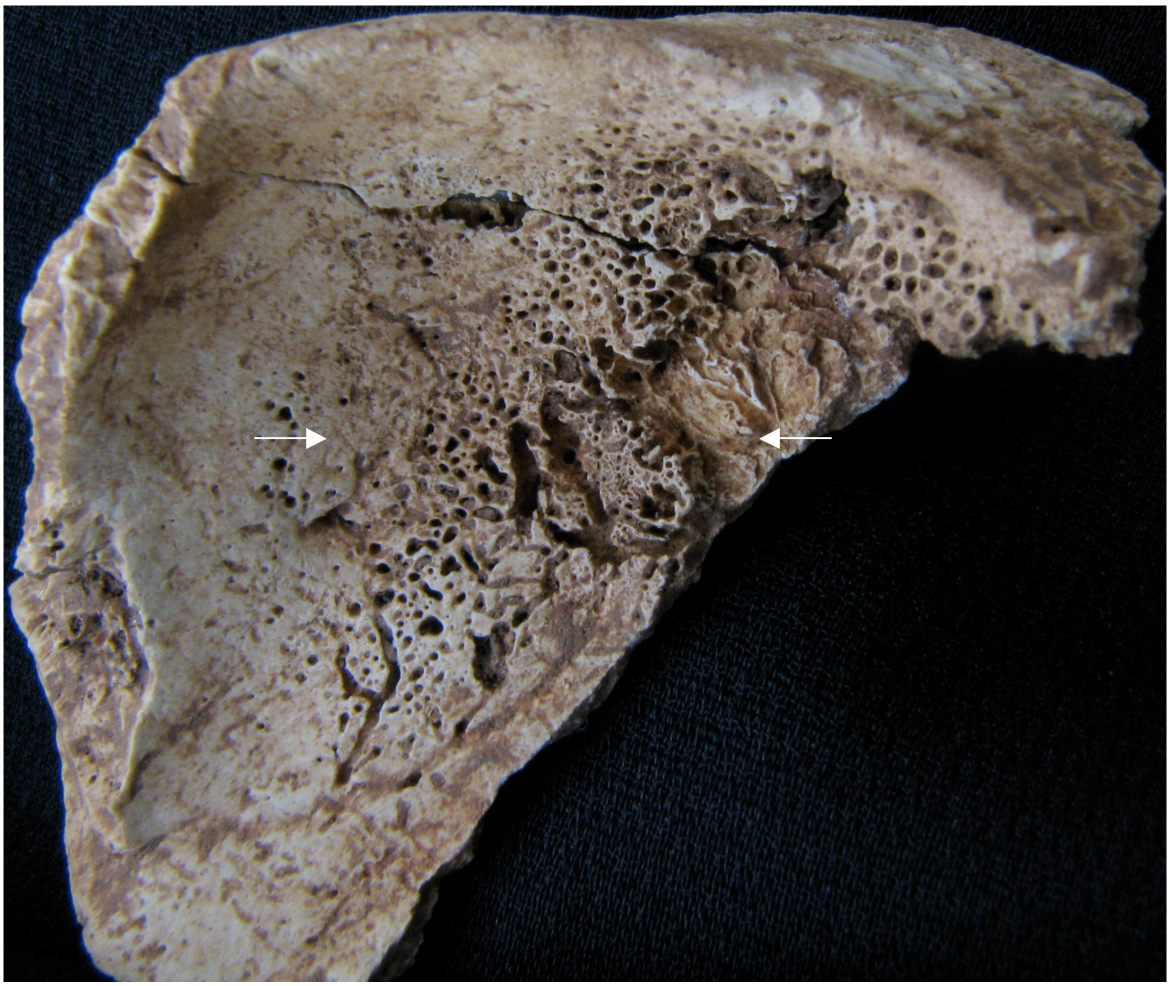

Fig. A2.1–STYM-II-97-1, R. orbital roof exhibiting Type 3–4 porosity (white arrows).

Fig. A2.2–STYM-II-97-1, L. greater wing of the sphenoid exhibiting scattered fine pores.

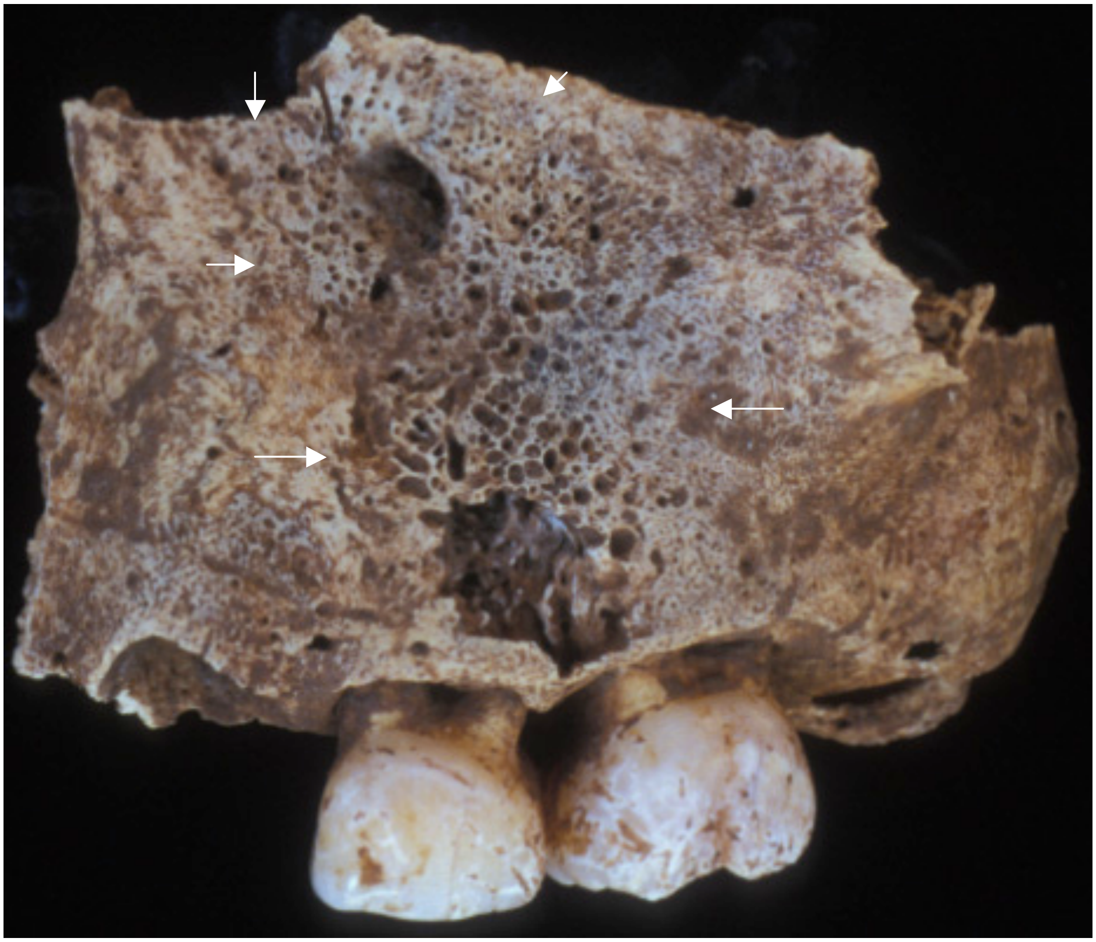

Fig. A2.3–STYM-II-97-1, R. maxilla exhibiting abnormal porosity in the region of the infraorbital foramen (white arrows).

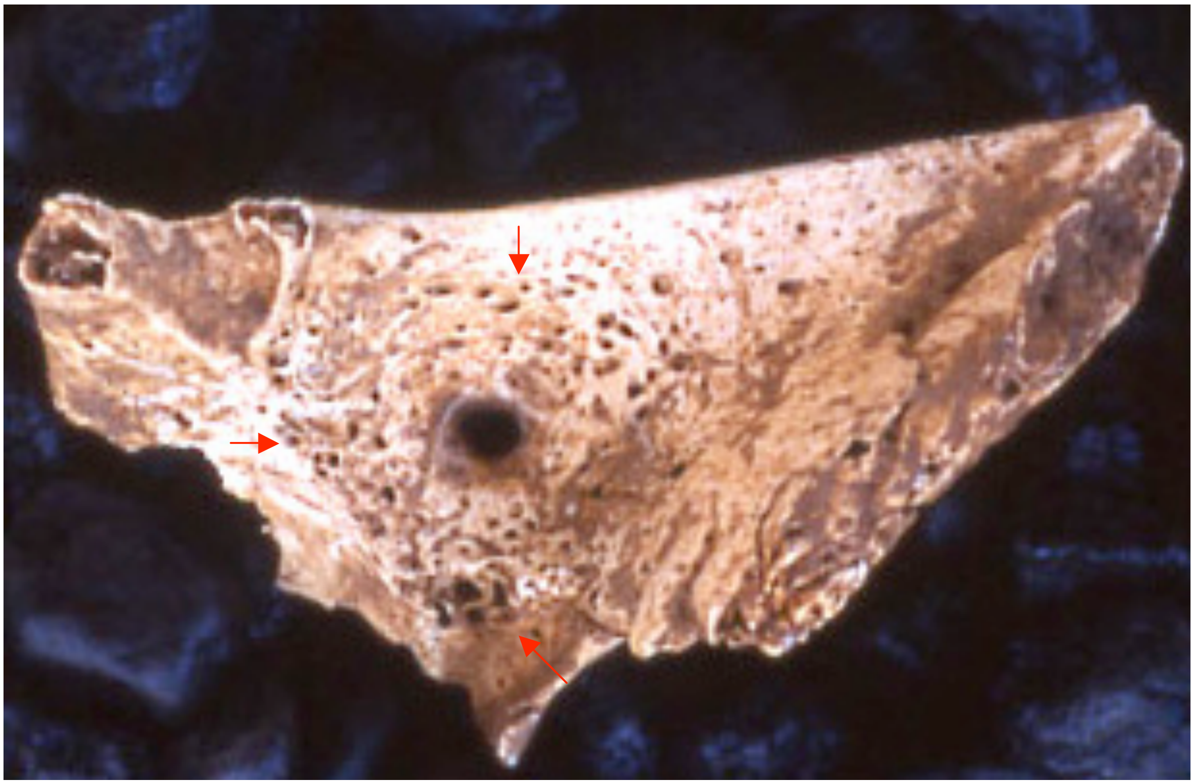

Fig. A2.4–STYM-II-97-1, L. zygoma exhibiting abnormal porosity and evidence of remodeling along the temporal aspect (red arrows).

Fig. A2.5–STYM-II-97-1, L. proximal anterior tibia exhibiting interrupted bone formation as evidenced by the presence of a horizontal layer of abnormal bone (red arrow) followed by resumed normal trabeculae (white arrow).

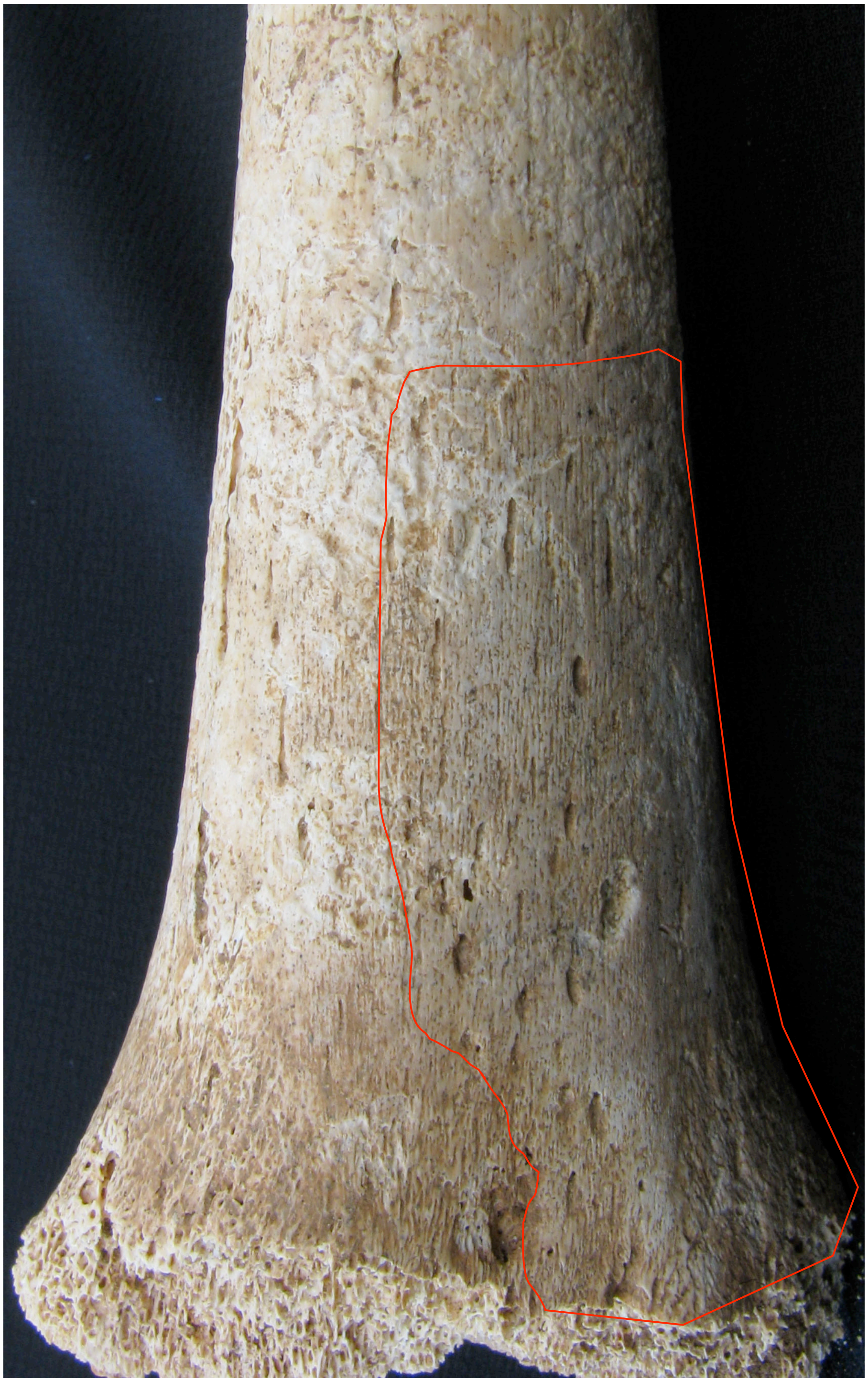

Fig. A2.6–STYM-III-97-1, R. distal anterior femur exhibiting periostitis (red border).

Fig. A2.7–STYM-III-97-2, L. scapula exhibiting normal porosity along the supraspinous fossa.

Fig. A2.8–STYM-III-97-2, R. distal posterior femur exhibiting multiple large vessel tracks.

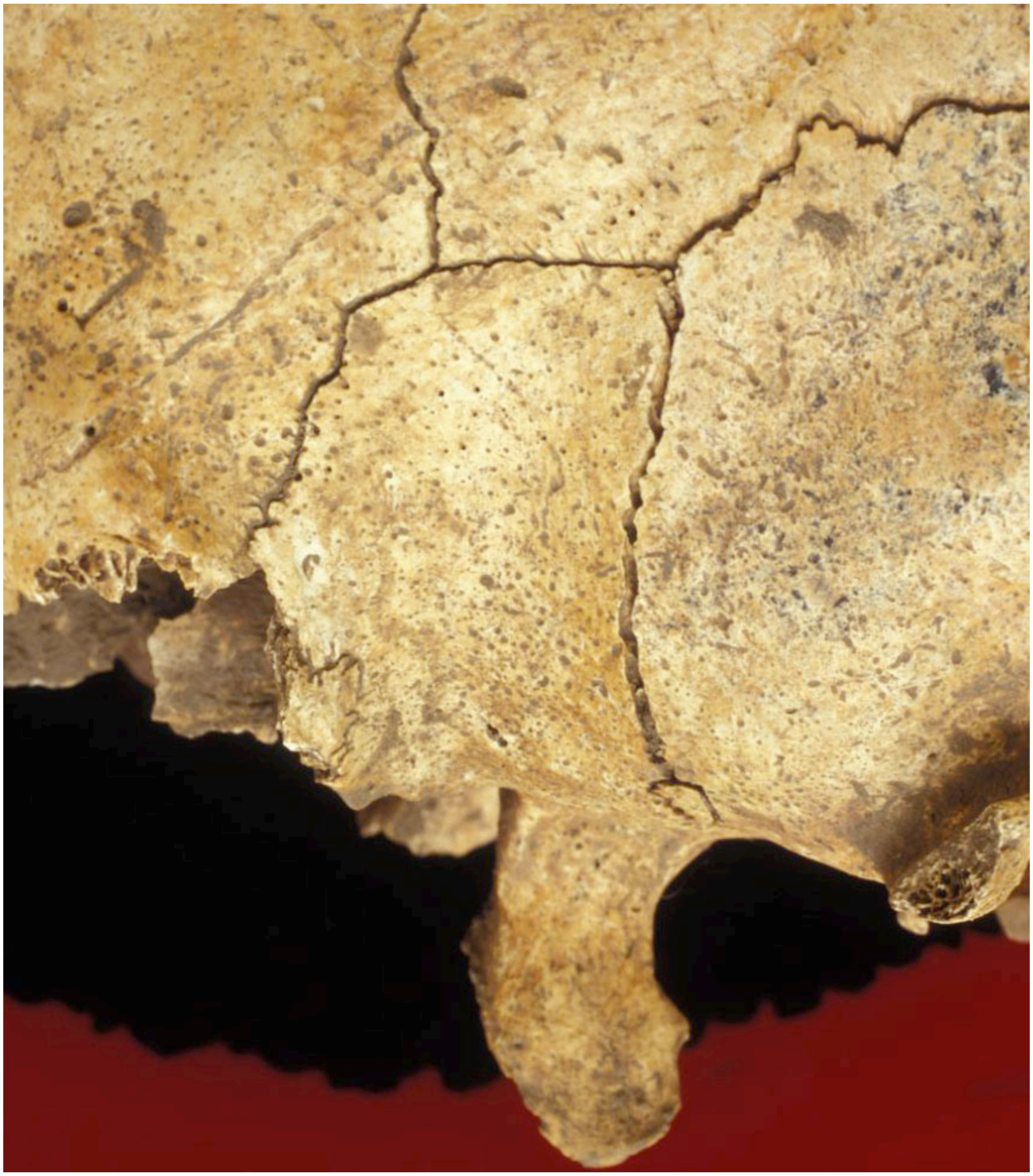

Fig. A2.9–STYM-IX-00-2-1, L. greater wing of the sphenoid and temporal exhibiting diffuse small-medium pores penetrating the cortex.

Fig. A2.10–STYM-IX-00-2-1, L. and R. orbital roof exhibiting type 2 porosity towards the midline and type 3 porosity towards to lateral aspect.

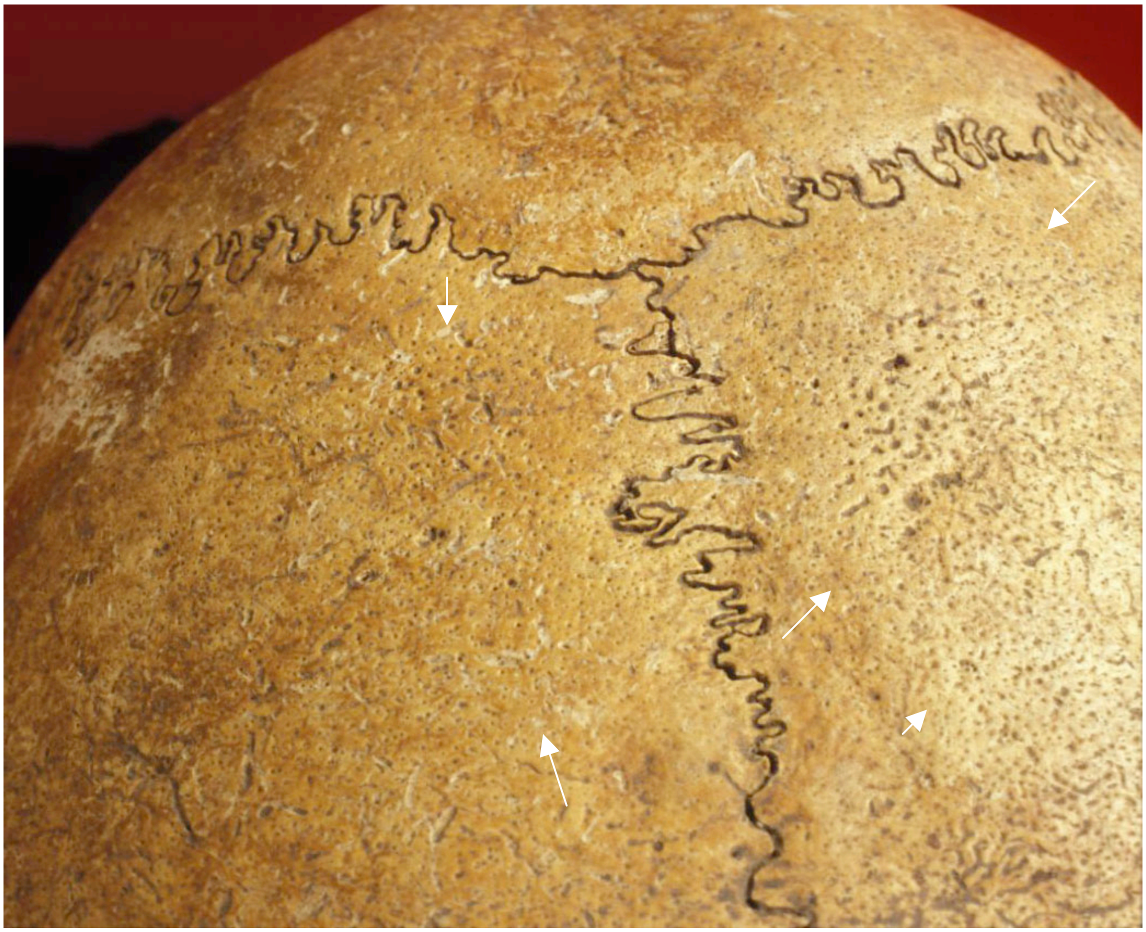

Fig. A2.11–STYM-IX-00-2-1, L. and R. parietals, exhibiting a well defined region of porosity penetrating the cortex near bregma (white arrows).

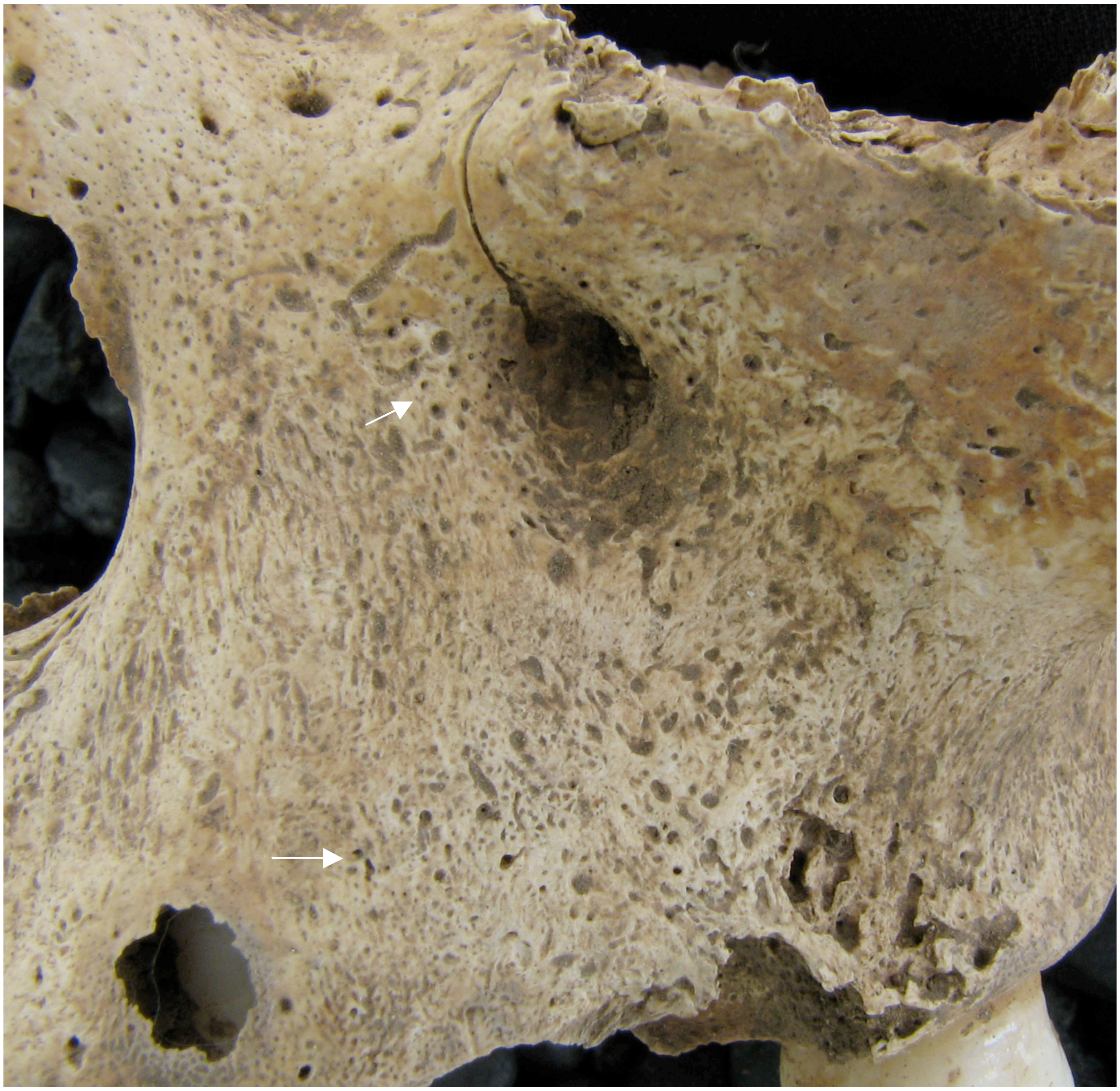

Fig. A2.12–STYM-IX-00-2-1, L. maxilla exhibiting borderline normal-abnormal porosity along the infraorbital region (white arrows).

Fig. A2.13–STYM-IX-00-2-1, R. maxilla exhibiting abnormal porosity along the infraorbital region (white arrows).

Fig. A2.14–STYM-IX-00-2-1, L. maxilla exhibiting abnormal porosity along the posterior surface (white arrows).

Fig. A2.15–STYM-IX-00-2-1, L. zygoma exhibiting abnormal porosity along the temporal aspect (white arrow).

Fig. A2.16–STYM-IX-00-2-2, R. sphenoid and temporal exhibiting fine penetrating pores.

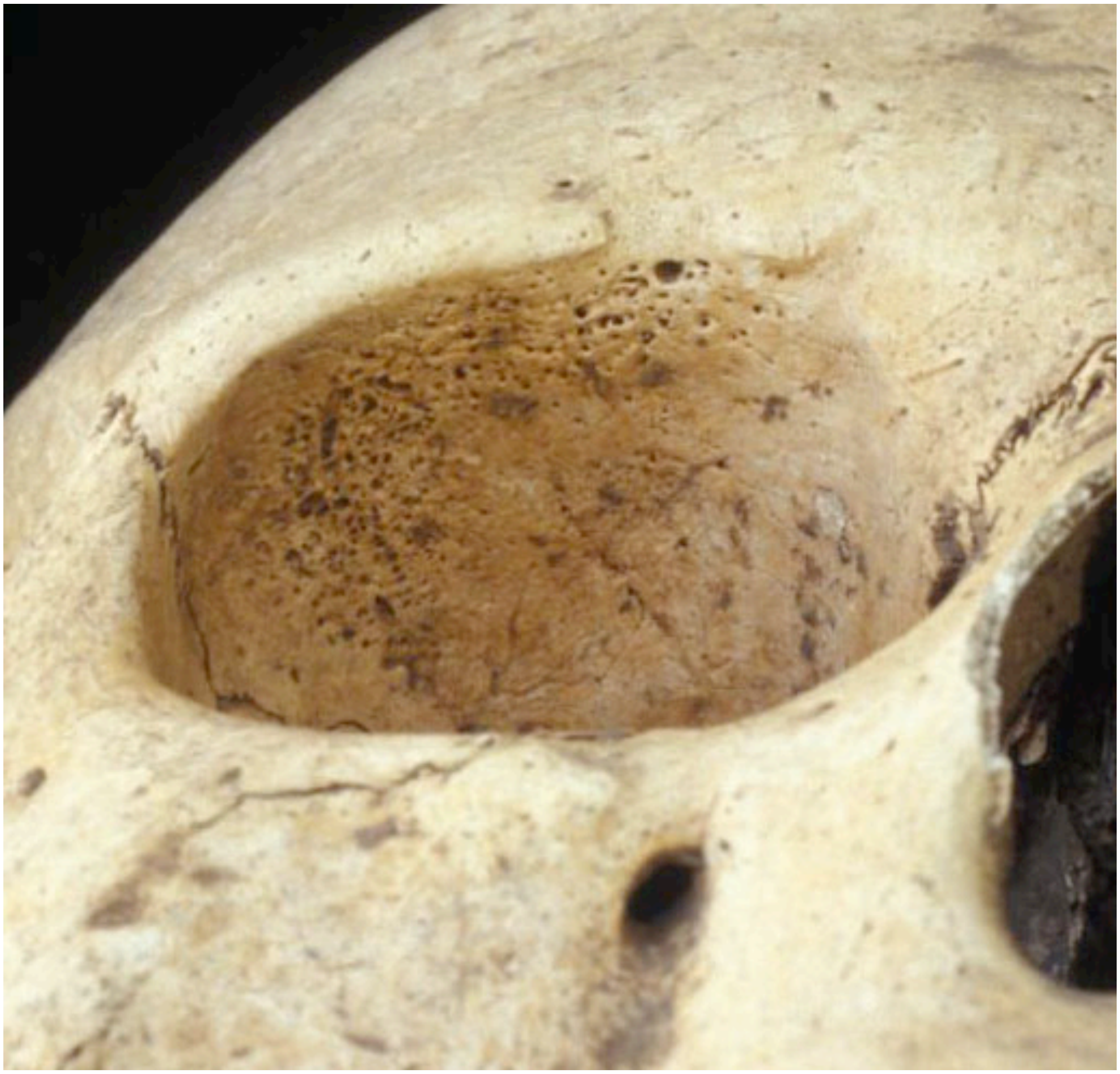

Fig. A2.17–STYM-IX-00-2-2, R. orbital roof exhibiting type 2 porosity towards the midline and type 3 porosity towards the lateral aspect.

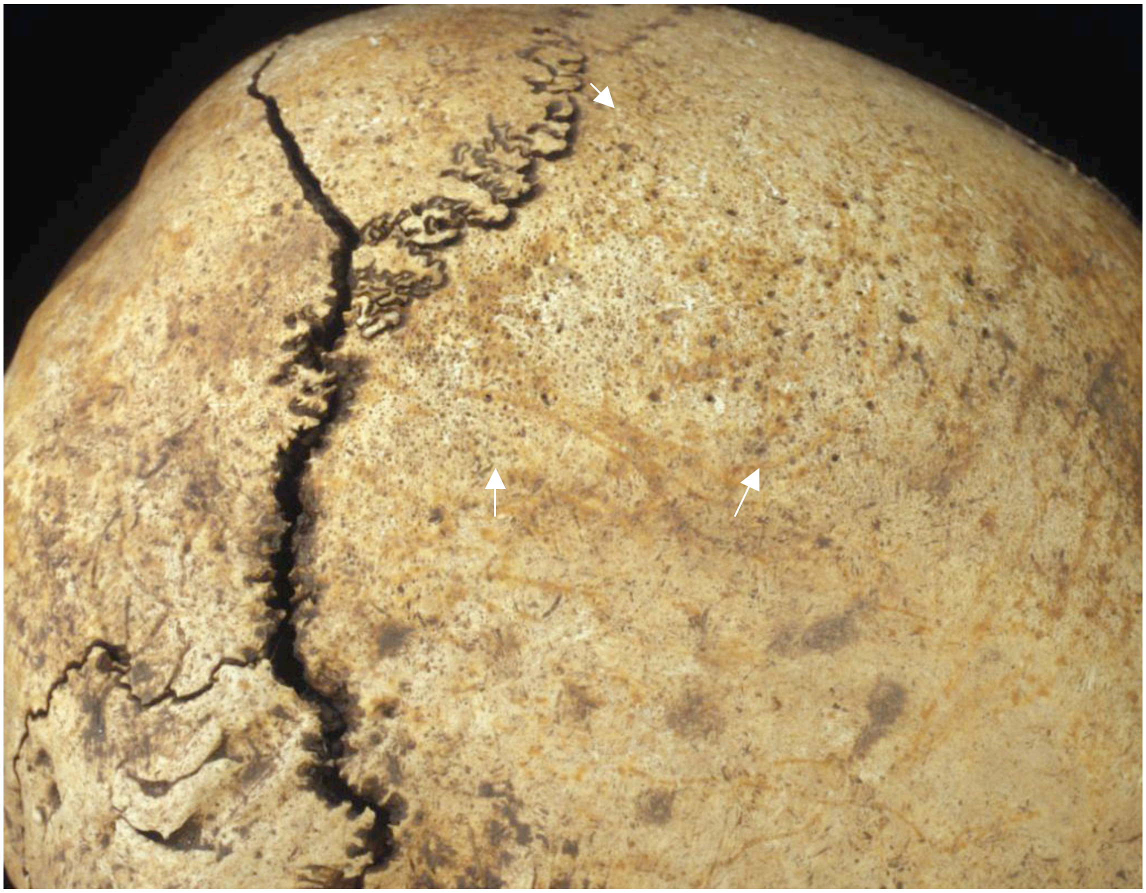

Fig. A2.18–STYM-IX-00-2-2, R. parietal exhibiting healed porotic hyperostosis near lambda (white arrows).

Fig. A2.19–ZAR 96-2, L. greater wing of the sphenoid exhibiting dispersed large pores penetrating the cortex.

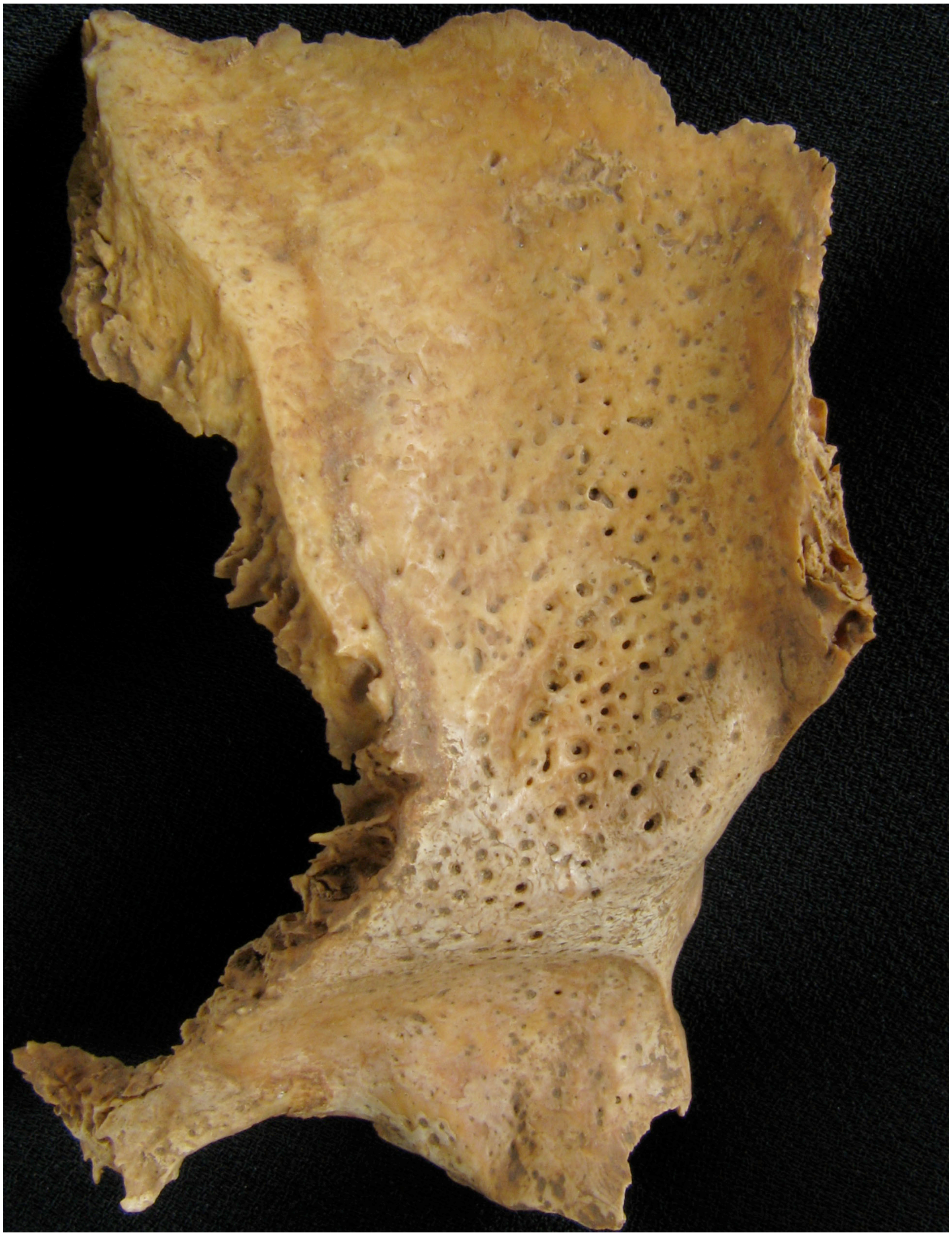

Fig. A2.20–ZAR 96-2, R. greater wing of the sphenoid exhibiting marked porosity penetrating the cortex. Evidence of remodeling can also be observed.

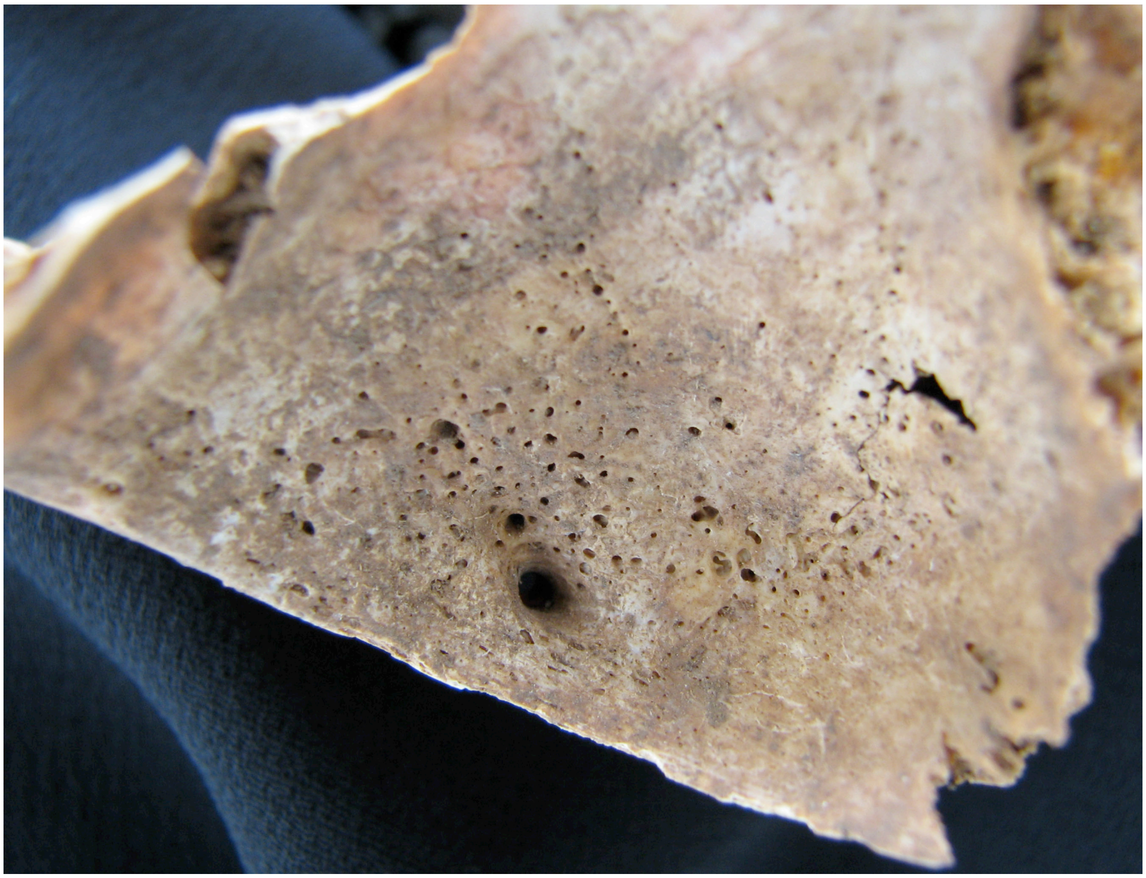

Fig. A2.21–ZAR 96-2, R. orbital roof exhibiting Type 1 porosity and evidence of remodeling.

Fig. A2.22–ZAR 96-2, R. tibia exhibiting periostitis along the anterior midshaft.

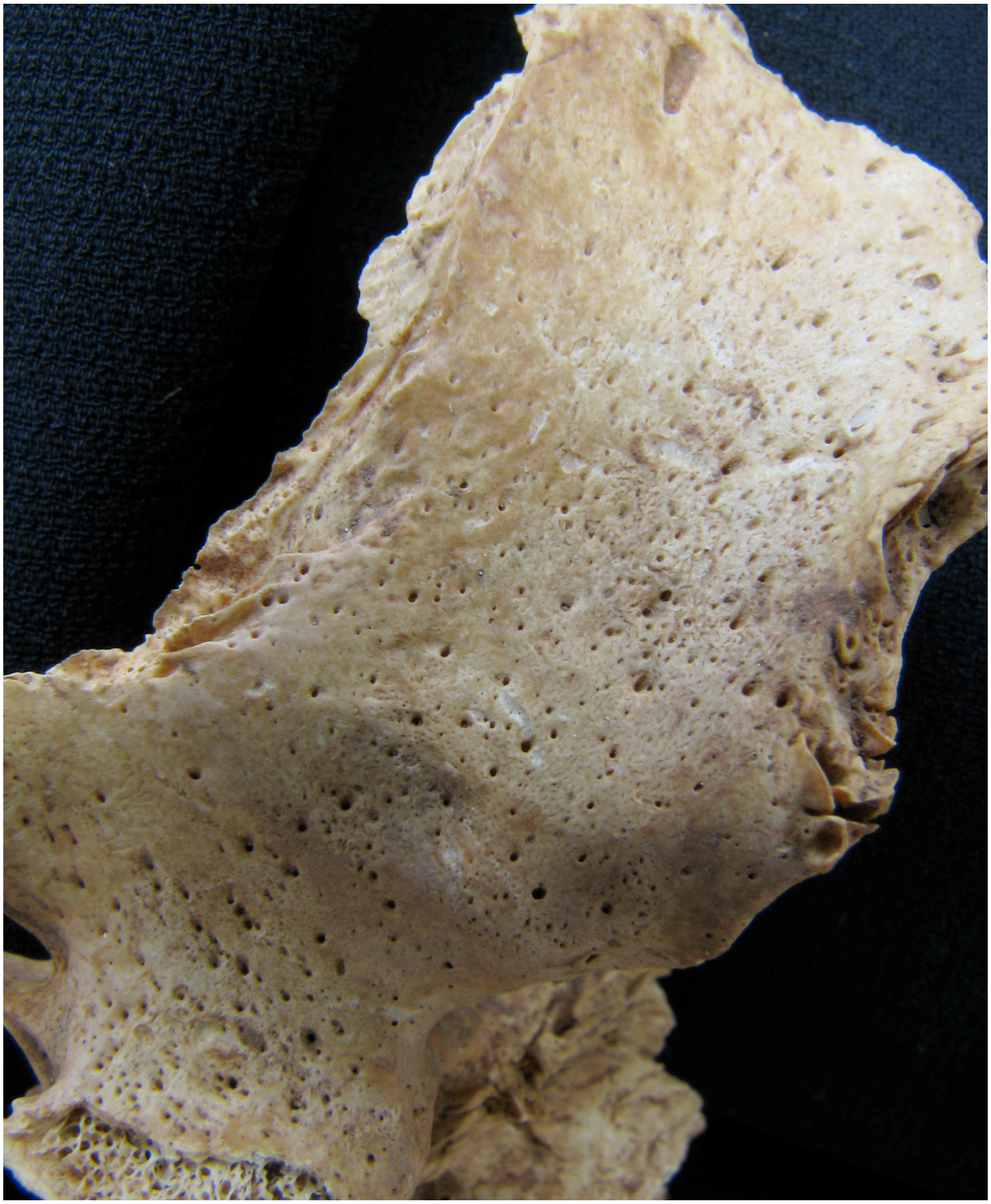

Fig. A2.23–ZAR 97-1, R. greater wing of the sphenoid exhibiting a large number of abnormal pores penetrating through the cortex.

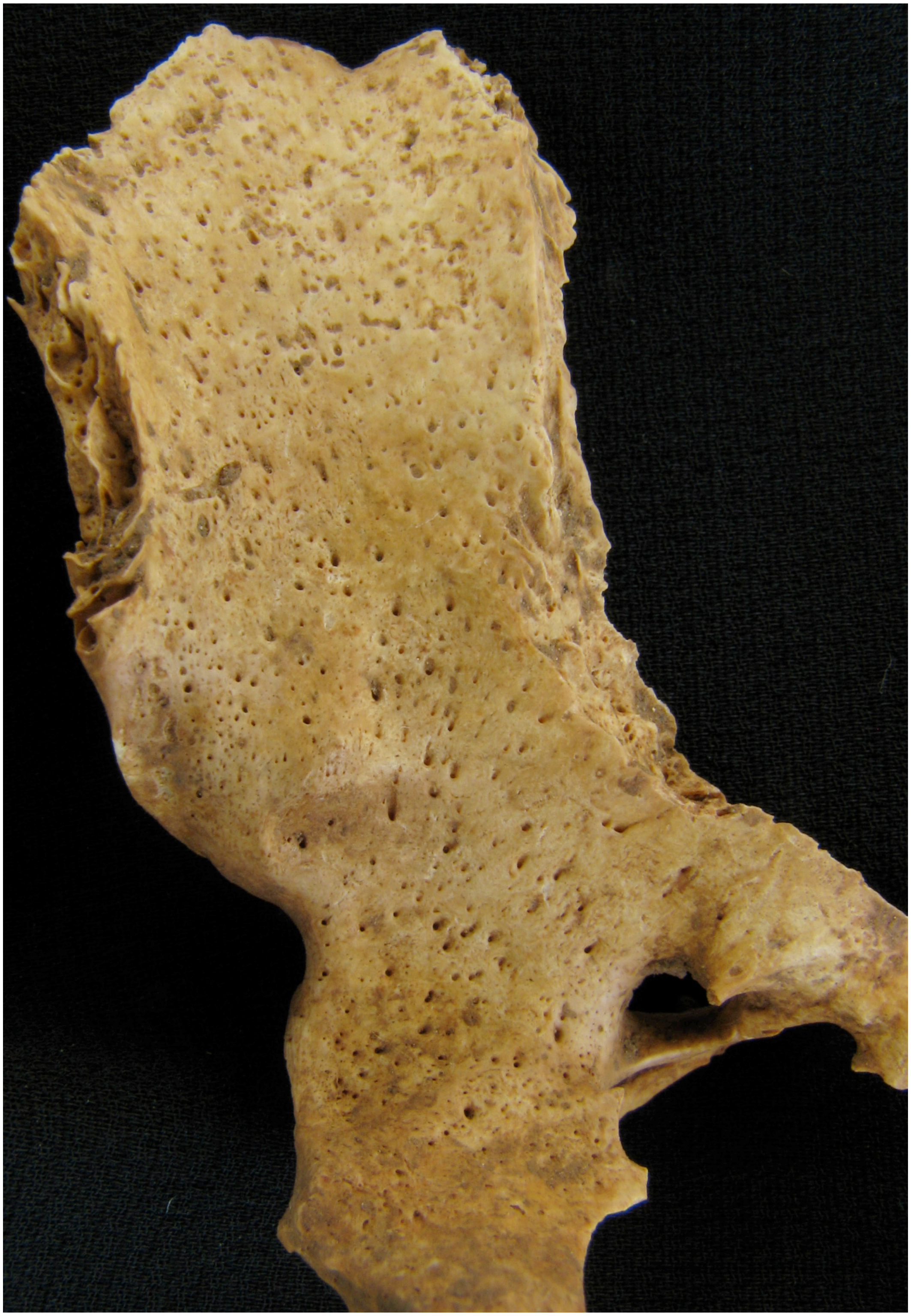

Fig. A2.24–ZAR 97-1, L. greater wing of the sphenoid exhibiting a large number of abnormal pores penetrating through the cortex.

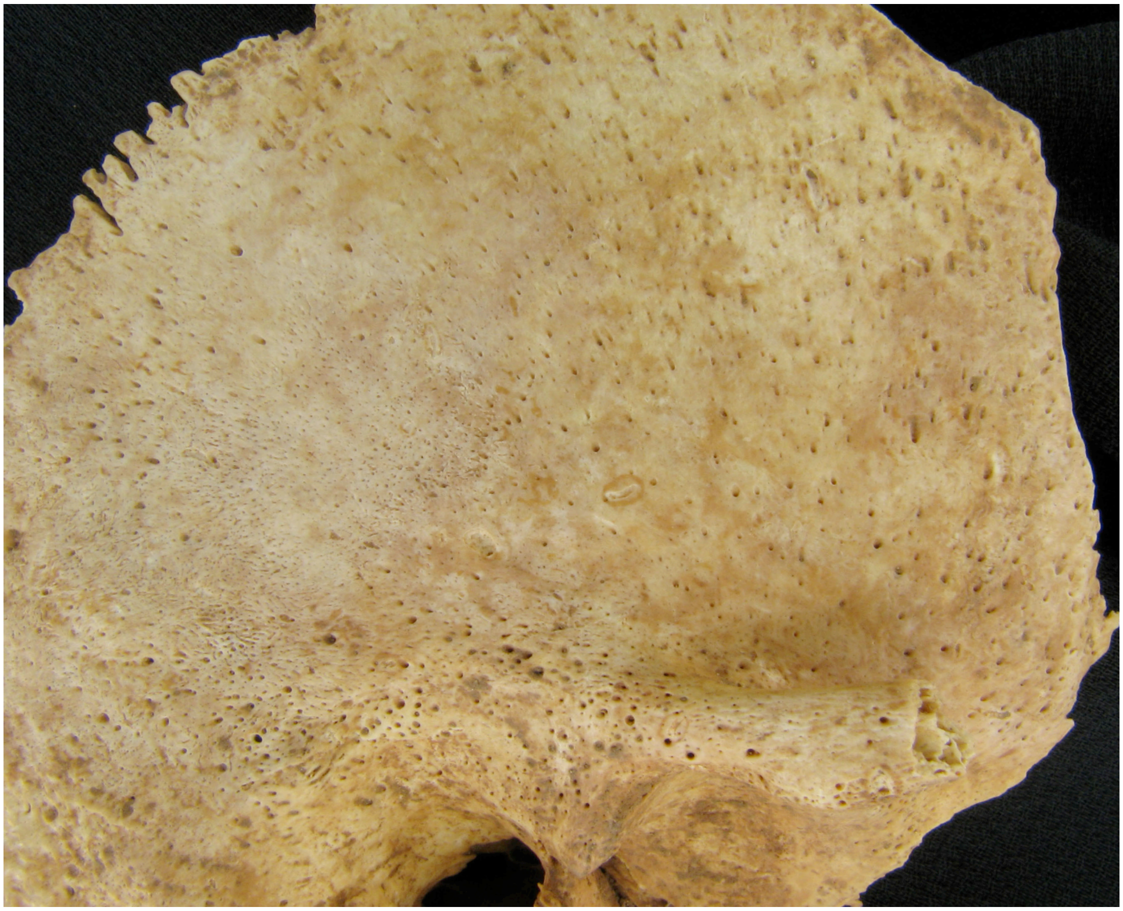

Fig. A2.25–ZAR 97-1, R. temporal exhibiting diffuse pores that penetrate the cortex. However a number of the pores observed may be normal.

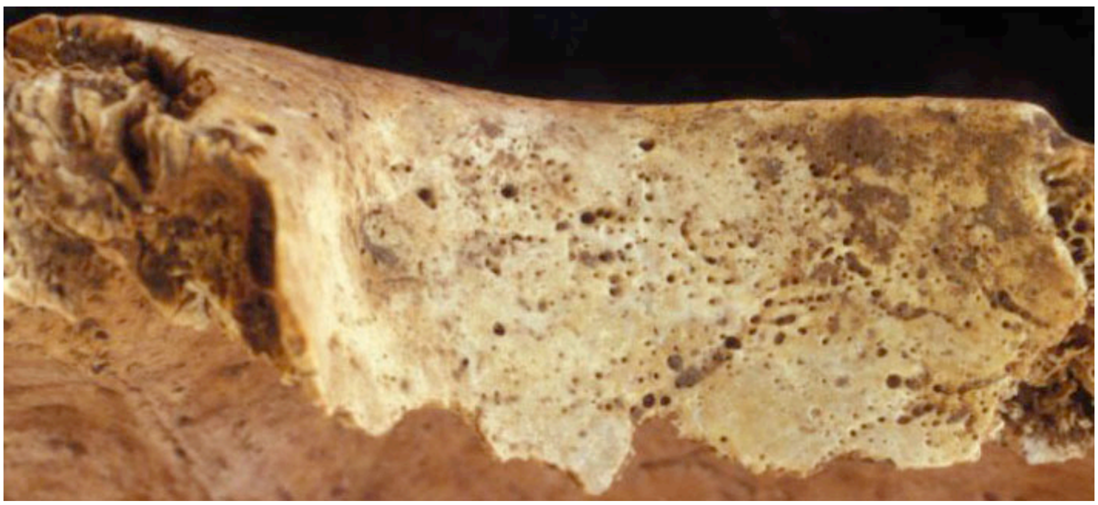
Fig. A2.26–ZAR 97-1, L. orbital roof exhibiting type 1 porosity.

Fig. A2.27–ZAR 97-1, L. maxilla exhibiting abnormal porosity penetrating the cortex along the posterior surface.

Fig. A2.28–ZAR 97-1, R. zygoma exhibiting smooth edged porosity along the temporal aspect that is indicative of an abnormal condition (white arrows).

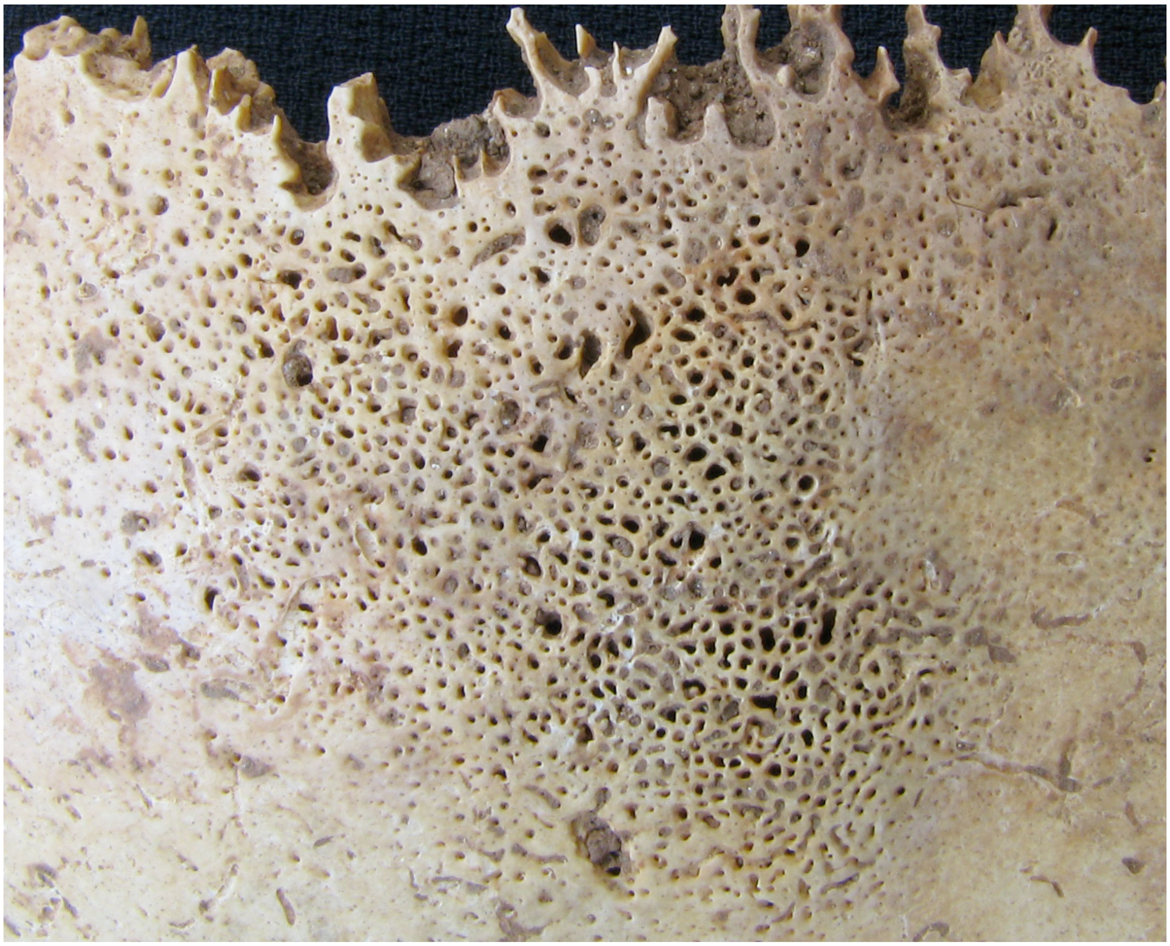

Fig. A2.29–ZAR 97-1, R. parietal exhibiting evidence of remodeling porotic hyperostosis located midway along the lambdoidal suture.

Fig. A2.30–ZAR 97-2, L. scapula exhibiting a well defined region of abnormal porosity and woven bone with evidence of remodeling along the supraspinous fossa (white arrows).

Fig. A2.31–ZAR 97-2, R. parietal exhibiting superficial woven bone along the endocranial surface (white arrows).

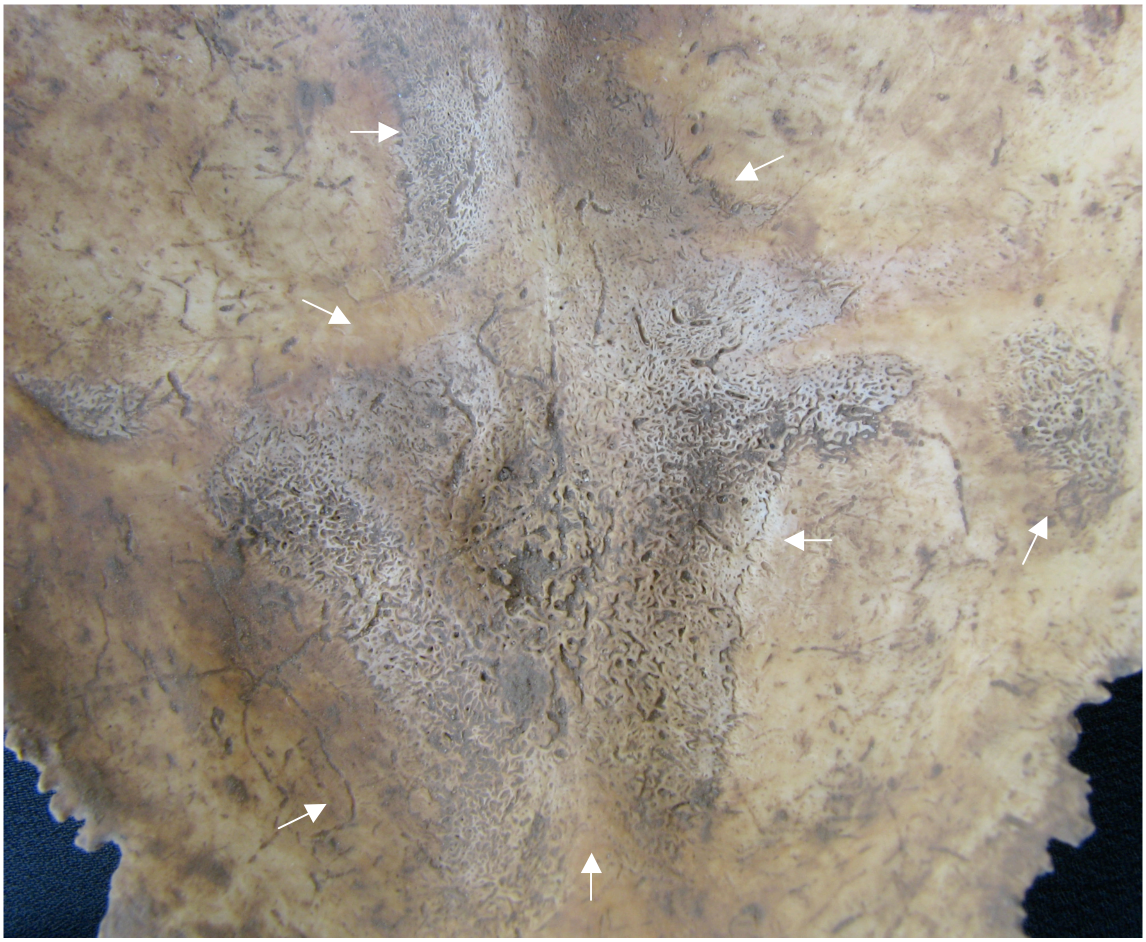

Fig. A2.32–ZAR 97-2, Occipital exhibiting superficial woven bone around the cruciform eminence along the endocranial surface (white arrows).

Fig. A2.33–ZAR 97-3, R. parietal exhibiting large abnormal pores penetrating the cortex around lambda (white arrows).

Fig. A2.34–ZAR 97-3, Occipital exhibiting large abnormal pores penetrating the cortex around lambda (white arrows).

Appendix 3–Tables of Skeletal Elements Examined and Radiographic Indicators Observed

Element	***STYM II-97-1***	***STYM III-97-1***	***STYM III-97-2***	***STYM III-97-3***	***STYM IV-97-1****	***STYM IV-97-2***	***STYM IV-97-5***	***STYM IX-00-2-1***	***STYM IX-00-2-2***	***ZAR 96-2***	***ZAR 96-4***	***ZAR 97-1***	***ZAR 97-2***	***ZAR 97-3***
GWS(R)	N	N	N	N	N	N	N	Y	Y	Y	N	Y	N	Y
GWS(L)	Y	N	N	N	N	N	N	Y	Y	Y	Y	Y	N	N
TS(R)	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y
TS(L)	Y	N	N	N	N	N	N	Y	Y	Part.	Y	Y	Y	N
PZ(R)	Y	N	N	Y	N	N	N	Y	Y	N	N	Y	N	Y
PZ(L)	Y	N	N	N	N	N	N	Y	Y	Y	Y	Y	N	N
PM(R)	N	N	N	N	N	N	N	Y	Y	N	Y	Y	N	Y
PM(L)	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	N	N
IF(R)	Y	N	N	N	N	N	N	Y	Y	N	Y	Y	N	Y
IF(L)	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	N	N
OR(R)	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	N	N
OR(L)	Y	N	N	N	N	N	N	Y	Y	N	Y	Y	N	N
LO(R)	Y	N	N	N	N	N	N	Y	Y	N	N	Y	N	Y
LO(L)	Y	N	N	N	N	N	N	Y	Y	Y	Y	Y	N	N
C(R)	Y	N	N	N	N	N	N	Y	Y	Y	N	Y	Y	Y
C(L)	Y	N	Y	N	N	N	N	Y	Y	Y	Y	Y	Y	Y
SS(R)	N	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y
SS(L)	N	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	Y	Y
IS(R)	N	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	N	Y
IS(L)	N	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	N	Y
CV	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y

Table A3.1–Summary of cranial elements observed from the sub-adult remains at Stymphalos and Zaraka. Y= indicates the element was observable/observed, N= indicates the element was damaged to the point of not being observable or was completely absent, *= not re-observed in 2008, Part.= partial, GWS(R)= Greater wing of the sphenoid (right), GWS(L)=Greater wing of the sphenoid (left), TS(R)=Temporal squama (right), TS(L)=Temporal squama (left), PZ(R)= Posterior zygomatic (right), PZ(L)=posterior zygomatic (left), PM(R)= posterior maxilla (right), PM(L)= posterior maxilla (left), IF(R)= infraorbital foramen (right), IF(L)= infraorbital foramen (left), OR(R)= orbital roof (right), OR(L)= orbital roof (left), LO(R)= lateral orbit (right), LO(L)= lateral orbit left, C(R)= coronoid (right), C(L)= coronoid (left), SS(R)= supraspinous (right), SS(L)= supraspinous (left), IS(R)= infraspinous (right), IS(L)= infraspinous (left), CV= cranial vault.

Element	***STYM II-97-1***	***STYM III-97-1***	***STYM III-97-2***	***STYM III-97-3***	***STYM IV-97-1***	***STYM IV-97-2***	***STYM IV-97-5***	***STYM IX-00-2-1***	***STYM-IX-00-2-2***	***ZAR 96-2***	***ZAR 96-4***	***ZAR 97-1***	***ZAR 97-2***	***ZAR 97-3***
HUM.R/L(PA)	ND/ND	NO/NO	ND/12	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
HUM.R/L(PP)	ND/ND	NO/NO	ND/14	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
HUM.R/L(DA)	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
HUM.R/L(DP)	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
ULN.R/L(PA)	ND/NO	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
ULN.R/L(PP)	ND/NO	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
ULN.R/L(DA)	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	NO/NO	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
ULN.R/L(DP)	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	NO/NO	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
RAD.R/L(PA)	NO/ND	ND/ND	ND/ND	ND/ND	ND/ND	NO/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
RAD.R/L(PP)	NO/ND	ND/ND	ND/ND	ND/ND	ND/ND	NO/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
RAD.R/L(DA)	9/9	ND/ND	ND/ND	12/ND	8/ND	ND/ER	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
RAD.R/L(DP)	8/ER	ND/ND	ND/ND	ND/ND	NO/ND	ND/ER	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
FEM.R/L(PA)	ND/ND	NO/ND	NO/NO	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
FEM.R/L(PP)	ND/ND	NO/ND	NO/NO	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
FEM.R/L(DA)	ER/ER	NO/ND	14/ER	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
FEM.R/L(DP)	ER/11	NO/ND	ER/15	ND/ND	ND/ND	≤ 8/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
TIB.R/L(PA)	ND/ER	ND/ND	ER/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
TIB.R/L(PP)	ND/16	ND/ND	ER/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
TIB.R/L(DA)	ND/ND	ND/ND	10/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
TIB.R/L(DP)	ND/ND	ND/ND	16/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
FIB.R/L(PA)	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
FIB.R/L(PP)	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
FIB.R/L(DA)	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
FIB.R/L(DP)	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND

Table A3.2–Summary of the extent of porosity identified along the proximal and distal metaphyseal regions of the major long bones from the sub-adult individuals represented in the Stymphalos and Zaraka populations. All measurements presented in this table are in millimeters (i.e. 9/9= 9mm/9mm). HUM.= humerus, ULN.= ulna, RAD.= radius, FEM.= femur, TIB.= tibia, FIB.= fibula, R/L= right/left, PA= proximal anterior, PP= proximal posterior, DA= distal anterior, DP= distal posterior, ND= not determined, NO= no porosity/ normal bone/ remodeling observed. ER= eroded or damaged to the extent that observation was hindered.

Individuals	Diffuse Demineralization	Ground Glass Appearance	Wimberger's Ring	Metaphyseal Radiolucency	Metaphyseal Fractures	Spur Formation	Subperiosteal Hematoma	Corner Sign	Transverse Lines	Meta-physeal radi-opacity
STYM II-97-1	Unverifiable	Unverifiable	N/A	Present	Absent	Absent	Absent	Absent	Present	Present
STYM III-97-1	Unverifiable	Unverifiable	Present	Present	Absent	Absent	Present*	Absent	Absent	Absent
STYM III-97-2	Unverifiable	Unverifiable	Absent	Present	Unverifiable	Absent	Absent	Absent	Present	Present
STYM IV-97-1	Unverifiable	Unverifiable	N/A	Present	Absent	Absent	Absent	Absent	Absent	Present
STYM IV-97-2	Unverifiable	Unverifiable	N/A	Present	Absent	Absent	Absent	Absent	Present	Present
STYM IX-00-2-1	Unverifiable	Unverifiable	Absent	Present	Absent	Absent	Absent	Absent	Absent	Present
STYM IX-00-2-2	Unverifiable	Unverifiable	Absent	Present	Absent	Absent	Absent	Absent	Absent	Present
ZAR 96-2	Unverifiable	Unverifiable	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent
ZAR 97-1	Unverifiable	Unverifiable	Absent	Present	Absent	Absent	Absent	Absent	Present	Present
ZAR 97-2	Unverifiable	Unverifiable	Present	Present	Absent	Absent	Absent	Absent	Present	Present
ZAR 97-3	Unverifiable	Unverifiable	Present	Present	Absent	Absent	Absent	Absent	Present	Present

Table A3.3–Chart outlining the radiographic indicators of juvenile scurvy identified among the individuals examined from Stymphalos and Zaraka. N/A indicates that the necessary skeletal element(s) or area(s) in question were not available for observation. The term Unverifiable is used to indicate that the element in question may have had the radiographic indicator noted however structural damage hindered effective observation of the proposed radiographic indicator. *based on macroscopic identification.