HEALTH AND MORTALITY AT FIDLER MOUNDS (EaLf-3): A BIOARCHAEOLOGICAL ASSESSMENT

BY

BARBARA R. HEWITT

A Thesis Submitted to
The Faculty of Graduate Studies
In Partial Fulfillment of the Requirements for the Degree of

MASTER OF ARTS

Department of Anthropology
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THE UNIVERSITY OF MANITOBA

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Abstract

The Fidler Mounds skeletal sample was recovered in a salvage excavation during 1963 and has been curated in the Department of Anthropology at the University of Manitoba since then. In an age when impending repatriation of archaeological material is simply a matter of time, it is critical that we study the human remains currently housed in universities and museums so that the information they hold is not lost. Since the last time the Fidler Mounds human remains were examined, in the early 1970's, technology has substantially advanced our ability to examine and interpret the health and well-being of past populations, particularly through biochemical studies.

As a means to better understanding the challenges faced by those interred at the Fidler Mounds, multiple approaches were employed in this study. Accelerator Mass Spectrometry dating of several of the discrete burials in the sample was carried out in order to generate a range of dates during which the mound was used. Gross osteological analysis was coupled with archaeological and ethnographic information for the region to paint a picture of who the builders (or users) of the mounds may have been, and how they fit into the currently understood culture history of the northeastern Great Plains. Recent developments in the geological sciences allowed for a test of the applicability of Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry to the study of changes in trace element concentrations during childhood. While the interpretation of these data is still a challenge, the results are very encouraging.

Acknowledgements

This project could not have been completed without the moral, scholarly and financial support of many individuals and institutions. Acknowledgments must go out to numerous individuals whose skill and patience I drew upon while undertaking this research. I am certain that at times it must have been drudgery for each of them and I sincerely hope that after reading this they will find that their time was well spent. My thesis supervisor, Robert D. Hoppa, provided helpful discussions, guidance and support through all phases of this project. Rob's dedication to his students inspires within them a desire to learn and a sense of loyalty towards him that is truly amazing – and I am certainly no exception. Scott Hamilton gave generously of his time and knowledge in helping with the structure and focus of my research, and was always available for a beer and a chat when we were in the same city. Norman Halden provided a considerable amount of his time and expertise teaching me about geochemical analyses and Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry technology, and has a sense of humour that made me laugh even in the last days of writing.

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Several individuals outside of my committee were involved in helping me to complete this research. Leigh Syms shared freely with me many of his valuable

references and thoughts on Plains prehistory in general, and burial mounds in particular. Kevin Brownlee was instrumental in pointing me in the right direction when I first began researching the Woodland period in and around Manitoba.

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Chapter 1

Introduction

1.1 Introduction

Understanding the factors that interact to affect the health and well being of past peoples is currently one of the greatest challenges to modern researchers. Genetics, environment, disease processes and dietary practices all contribute directly to the overall health of individuals and populations. By examining in detail the remains of past populations, it may be possible to shed new light on the interaction of these variables, and how they influence modern human groups.

It is somewhat rare that large collections of human remains from the northern Great Plains are available for study. One such skeletal collection is currently housed in the Department of Anthropology at the University of Manitoba. The remains of over 66 individuals were recovered in a salvage operation during the summer of 1963 from the Fidler Mounds, 19km north of Winnipeg, Manitoba (see Figure 1.1). This sample represents an opportunity to study the overall health of a precontact population from a

Figure 1.1 The Province of Manitoba, with the Fidler Mounds noted by black triangle

geographic region that is still generally poorly understood in terms of physical anthropological analyses. The Fidler Mounds skeletal sample also allowed this researcher to investigate the applicability of a relatively new geological method to testing for dietary indicators in human dentition.

1.2 Goals and Objectives of the Research

This thesis has two general aims. First, it seeks to generate a body of information that will add to the understanding of the lives of occupants of the Northeastern Plains prior to sustained European contact. Second, it tests the applicability of a recently developed geological method for assessing health via skeletal remains. In attempting to meet these aims, this thesis combines both traditional and innovative approaches to the assessment of skeletal samples for indications of health and well-being in past populations.

The patterns of general health remain understudied in Plains Woodland Period peoples of the Northern Plains. Sample sizes from this period are generally small and overall, not very well preserved (Owsley, 1992; Owsley and Jantz, 1994). While a single radiocarbon date, from a piece of charcoal, has been accepted by previous researchers as sufficient for dating the Fidler burial mounds, the construction of a such mounds generally takes place over an extended period of time (Garvie, 1993; Snortland, 1989; Syms, 1979; Syms, 1982). By sampling bone collagen from several of the burials themselves, a set of new accelerator mass spectrometry (AMS) dates suggest a range of time during which the Fidler Mounds were actively in use. This manner of dating burial

mounds is still relatively uncommon, yet it better reflects the accretionary nature of burial mound construction.

The second general objective stems from recent innovations in technology and methodology used in the geological sciences. A feasibility study of the applicability of Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) analyses as a means of assessing nutritional status were undertaken in an effort to expand our understanding of the suitability of these methods for archaeologically-derived human remains. This technique, commonly used in the material sciences, allows researchers to examine the major and trace elemental composition of a sample. Such applications have been applied to the analysis of archaeologically derived mineralized human tissue in a limited way, yet results from these early studies suggested that the information obtained through biochemical analyses have tremendous potential for dietary and health reconstructions of past populations.

1.3 Overview of the Thesis

Gone are the days when simple inventories of human remains and descriptive reports suffice in physical anthropology; as modern researchers aim to more fully understand the lives of past peoples, a holistic and multi-disciplinary approach is required. This body of work is built upon well-established biological imperatives and incorporates a number of archaeological and cultural perspectives into the analyses. It also attempts to integrate current geological techniques into the suite of methods currently available for the study of human remains. To this end, an overview of the biological basis for the examination of human remains as a means to understanding

growth, development and health in past groups is provided in Chapter 2. A review of the relevant aspects of biochemistry and geochemistry is provided in Chapter 3. Chapter 4 provides a geographical, social, and material culture context for the analysis and interpretation of the human remains recovered from the Fidler Mounds site. This information is gleaned primarily from the surviving artifacts of the material culture of area occupants as well as historic information regarding groups at the point of sustained European contact. Materials and methods used in this study are summarized in Chapter 5. The results of these analyses and a discussion of their significance are presented in Chapters 6 and 7 respectively.

1.4 Conclusion

This study documents the osteological information for a sizeable collection from a period and geographic region that is, relatively speaking, still poorly understood. The human remains from the Fidler Mounds are examined using standard osteological methods as well as some new techniques. Interpretation of the data generated provides a better understanding of the health and mortality of this population, and relates those characteristics to their life and overall well-being. By looking at the conditions under which the populations that made use of the Fidler Mounds lived, and the health of those groups, researchers can gain insight into the long-term interactions of health and environment for modern humans. By examining the overall health and pathology patterns prior to the influence of European diseases, investigators can better understand the daily environmental, metabolic and nutritional challenges faced by early native groups. This is of particular importance for providing information to the public,

including modern Aboriginal communities, as these remains represent a unique cultural resource and a snapshot of their heritage.

Chapter 2

Life Histories from Skeletons: Osteobiography

2.1 Introduction

When presented with a human skeleton, the physical anthropologist must make assessments regarding a number of different factors in order to gather the most information possible from the remains. In an archaeological context, age, sex, stature, and general health indicators are examined so that inferences about the individual's history can be made and so comparisons to other individuals or groups are possible. These variables are assessed in a number of ways, depending on the availability of certain skeletal elements and the level of preservation of the bones themselves.

Since, in most cases, the skeleton of an individual is all that remains in the archaeological record, this chapter introduces the methods that physical anthropologists use to assess life history from human skeletal remains. The biological basis for such analyses will be reviewed, the methods of assessing and evaluating life history will be

presented, and the difficulties inherent in this kind of research will be discussed. The primary objectives of this research centred upon macroscopic assessment of bone, and dental development, and as such, microscopic methods of examination of bone will not be addressed in detail. For a complete review of microscopic bone development see excellent reviews by Schultz (1997), Hancox (1972), Lacroix (1951), and Jaworski (1992). Given the focus of this study, dental development will be reviewed in more depth than skeletal formation.

2.2 Biology of the Human Skeleton

The calcified tissues of the human body are often all that is left of a body, and physical anthropologists base their work on the knowledge that bones and teeth grow in predictable and understood ways. Without an understanding of the way calcified tissues form, it would be impossible to say, for example, if particular characteristics of bones are pathological or normal, or if certain features are indicative of physiological stress or normal activity.

2.2.1 Bones

Osteogenesis is the formation of bone. All bone growth is the result of bone being deposited as replacement for, and often on top of, pre-existing connective tissue (White, 2000). New bone is laid down at the beginning of skeletogenesis, the formation of the skeleton, or when a bone is broken and in need of repair (Bonjour and Tsang, 1999; Dixon *et al.*, 1991; Hall, 1992; Hancox, 1972; Itani and Tsang, 1996). Bone is a highly specialized type of connective tissue, which is distinguished from other connective

tissues in the body by both its hardness and its continuous remodelling. The primary functions of bones, within the musculoskeletal system, are to protect and support soft tissues, act as anchors for muscles, tendons and ligaments, and to work with muscles to induce movement. Bone is also instrumental in the formation of blood cells, and the storage of fat and calcium (White, 2000). Each of these functions is a direct result of the specialized composition of bone.

There are several different types of bone that are categorized primarily by their density. Cortical bone is the thin external surface of bones. When it is solid and thick it is called compact bone, and makes up the external shaft of long bones. Trabecular, or cancellous, bone is found in flat bones such as the vertebral bodies, ends of long bones, and short bones (White, 2000). Joints have a specialized type of compact smooth bone called subchondral bone, which is designed to allow the smooth movement of joints (Steele and Bramblett, 1988).

Mature bone is constructed in a series of differentiated layers. There are two layers of external connective tissue, called periosteum. Rich in collagen strands called Sharpey's fibres, the stratum fibrosum is the outermost layer and it forms a dense network which binds the fibres to the surface of the bone to form a strong skin (Lacroix, 1951). Next to the stratum fibrosum is the stratum osteogenicum, which contains blood vessels, nerves and cells. It is this layer that is one of the most important structures for the regeneration of bone tissue. Underneath this second fibrous covering, the articular surfaces of bone are protected by a layer of cartilage. On the internal surface of bone is a thin structure of flattened cells of connective tissue called the endosteum. This surface covers the trabeculae of cancellous bone and the walls of the blood vessel canals.

Protected by the endosteum are areas of red and yellow bone marrow, which aid in the formation of the blood system and storage of fat cells respectively (Schultz, 1997).

The initial site in the bone where mineralization begins is known as an ossification centre, and there may be several in a single bone. Each diaphysis and each epiphysis of long bones arise from a single centre (Ciba Foundation, 1973; Hall, 1992), and fuse only when the growth process is complete. Epiphyses become well mineralized, but as long as growth is continuing in the shaft of a bone, mineralization only goes as far as the cartilaginous disc between epiphysis and diaphysis. The surface of the diaphysis remains cartilaginous, and grows longer through the continual addition of cartilage to the ends of the bone. When growth ceases, the addition of new cartilage stops and ossification of the area begins. The cellular membrane surrounding the cartilage can stop producing cartilage cells and begin to produce bone cells instead, thus transforming itself into the periosteum of the bone surface. Alternatively, bone cells can be imported from other areas of the body through the vascular system to slowly replace the cartilage. Through either mechanism, the plate between the epiphysis and diaphysis of the bone hardens and in time an epiphyseal line is all that remains to delineate the two areas (Ciba Foundation, 1973; Hall, 1992; Pyle, 1961; Roche, 1978).

2.2.2 Teeth

Aside from bone, teeth are the only other mineralized tissues in the human body. Teeth are formed as by-products of neural crest-derived ectomesenchyme, while bone is mesodermal in origin (Hillson, 1986). Humans have a heterodont dentition, which means their teeth have several different shapes. There are three tooth forms in the modern

human dentition, and their primary function is to tear and grind food; they are anchored in a "U" shaped dental arcade of bone called the alveolar process (Dean, 1989; Demirjian, 1984; Hillson, 1986; Ten-Cate, 1998). All human teeth are made up of several different tissue types, which when combined result in an extremely durable and resilient product not found in any other part of the human body.

2.2.2.1 Types of Teeth

Teeth can be divided into three general categories, based on morphology and function. Incisors are designed for cutting through food, and are found in the anterior portion of the mouth. Canines are the longest teeth in the mouth, have pointed cusps, and are designed for tearing. Molars can be divided into premolars and molars, however both have broad occlusal surfaces with multiple cusps for grinding food (Carlsen, 1987; Van Beek, 1983).

Human incisors are single rooted teeth with a simple morphology; they are spade-shaped and typically the lateral incisor is smaller than the central one. Central incisors tend to be less morphologically variable than lateral ones. Incisors in the lower jaw are generally narrower, have thinner and shorter roots and are narrower at the base than their maxillary counterparts (El-Najjar and McWilliams, 1978; Schwartz, 1995). Both upper and lower canines are similar in form and function. They are the longest teeth in the dental arcade, with crowns as long as those of the central incisors, although roots are generally longer. Canines have a single, well-developed cusp, with crowns and roots markedly convex (El-Najjar and McWilliams, 1978). Premolars have a more complex morphology than either incisors or canines. They have one or two cusps, and can be

single- or double-rooted. The crown and roots of premolars are notably more gracile than molars, with the first premolar smallest of all (Schwartz, 1995). Molars are the most morphologically complex of all human teeth. Crowns are square or rectangular in shape, have more than two cusps and more than two roots. All molar roots show a slight curve near their tip, pointing distally. The third molar is the most variable in form and position in modern humans. Often M3 does not erupt into the mouth, is seldom fully developed, and is often completely or partially impacted (El-Najjar and McWilliams, 1978; Schwartz, 1995).

The number and type of teeth is usually expressed as a dental formula. In modern adult humans, the dental formula for permanent dentition is 2.1.2.3/2.1.2.3. These numbers represent the number of each type of tooth found in one half of the top and one half of the bottom of the adult human mouth. The first number represents the number of permanent incisors, the second is for the canine, the third for premolars, and the final number represents molars (Demirjian, 1984; Hillson, 1986; Scott and Symons, 1982; Sullivan, 1978; Ten-Cate, 1998).

2.2.2.2 Tooth Anatomy

Each tooth has an enamel crown, which projects above the gum line and is the hardest portion of the tooth, as well as a root or roots that are imbedded in alveolar bone. Where the crown and root meet is a slightly constricted area known as the neck. Inside each tooth is a pulp chamber, which houses arteries, nerves and tooth producing cells called odontoblasts. The periodontal ligament holds the tooth in place against the alveolus, along with a layer of cementum (FitzGerald and Rose, 2000; Steele and

Bramblett, 1988). Figure 2.1 is a schematic representation of the anatomical regions of a tooth and its surrounding and supporting structures. Each of these regions has a different degree of hardness, and a unique biochemical structure.

The innermost area of each tooth, the pulp chamber, is filled with a relatively soft tissue that is sensitive to trauma or changes in temperature and bodily chemical balance.

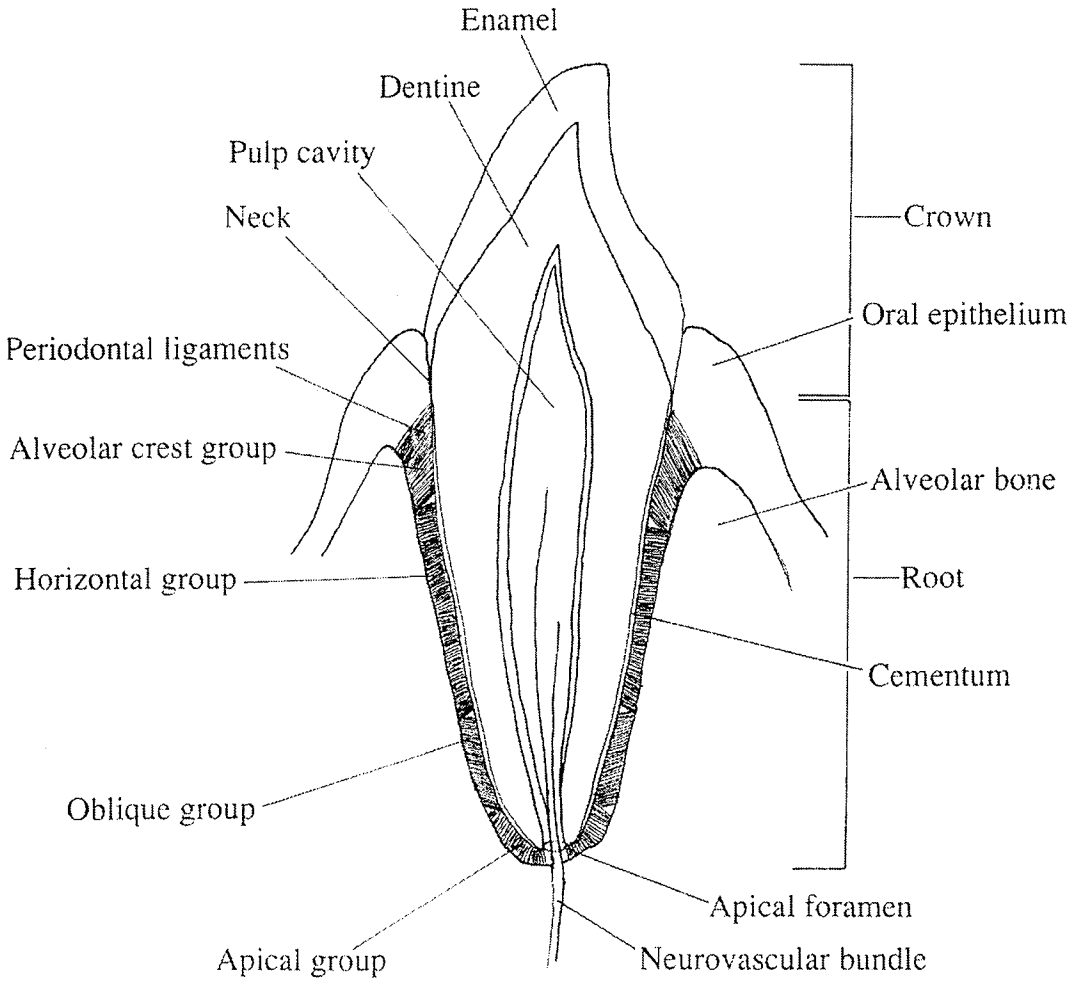


Figure 2.1 Anatomical Regions of a Tooth
From Schwartz, 1995:153

The pulp is a highly vascularized connective tissue which supplies dentin and enamel with nutrients during formation, and continues to provide nutrients to the dentin during the life of the tooth (Lazzari, 1976; Ten-Cate, 1998). This nourishment flows into the pulp via foramen in the apex of the root of the tooth, as do its blood vessels, nerve fibres and lymphatics (Scott and Symons, 1982). Aside from furnishing the tooth with vital nutrients, the pulp is also responsible for the formation of the dentin as required, and carries the nerves that give dentin its sensitivity (Ten-Cate, 1998). In recently erupted and erupting teeth, the roots and root canals are incomplete, so the pulp cavity is relatively wide; as growth progresses and the roots taper toward one another and finally close, the pulp chamber narrows (Carlsen, 1987; Scott and Symons, 1982; Ten-Cate, 1998).

Surrounding the pulp cavity is a layer of dentin, which is approximately thirty percent organic material, protein, collagen and minerals. Dentin has a higher mineral content than bone or cementum, but is always less mineralized than enamel (Lazzari, 1976; Ten-Cate, 1998). Dentin makes up the bulk of the tooth, and is composed of dentine tubules and odontoblasts. Dentine tubules run parallel to one another and in one direction, from the outer surface of the dentine to the pulp cavity (Scott and Symons, 1982). Dentin is laid down by odontoblasts in approximately daily microscopic increments, and also within a larger rhythmic cycle of between seven and twelve days. The patterning of this larger series is known von Ebner lines (Ten-Cate, 1998). In those teeth that have begun to calcify before birth an accented band known as the Neo-natal line is found between the dentin formed before and after birth, and it is produced by the change in nutrition and external environment (Scott and Symons, 1982). Hillson (1986)

argues that because dentin formation continues through life with new layers being deposited along the pulp chamber, it may be difficult to distinguish between primary and secondary dentin. Steele and Bramblett (1988) however, point out that secondary layers can be distinguished from primary dentin by its irregular microscopic structure, altered colour and texture. Dentin is surrounded by an enamel coating at the crown, and by cementum in the root of the tooth.

Enamel is the hardest substance in the human body, and covers the crown of the tooth that protrudes from the gum. Tooth enamel is unique in that it has no definitive organic precursor, and its embryonic form is ectodermal rather than mesodermal (Hillson, 1986; Williams and Elliot, 1989). The enamel matrix is a combination of inorganic material (approximately 96%) and organic material, and is particularly vulnerable to demineralization and therefore caries (Scott and Symons, 1982; Ten-Cate, 1998). The cells responsible for amelogenesis, the ameloblasts, cover the entire surface of the enamel as it forms, but are lost as the tooth erupts into the oral cavity. This leaves the enamel insensitive and unable to regenerate when destroyed (Ten-Cate, 1998). The hydroxyapatite crystal rods in enamel are larger, longer and more highly oriented than those in dentin, creating a structure which is permeable (Williams and Elliot, 1989). In a manner similar to that of dentin formation, enamel is laid in incremental layers called Striae of Retzius, which appear primarily in permanent teeth. Where these Striae meet the surface of the enamel they form microscopic furrows called perikymata, which manifest as tiny channels across the crown surface (Lazzari, 1976; Ten-Cate, 1998).

The tooth root is surrounded by a thin covering of cementum, which, of the hard dental tissues, most approximates bone in composition, structure and behaviour. While

dentin is approximately 30% organic, and enamel only about 4%, cementum is approximately 25% organic material, consisting primarily of collagen fibrils embedded in a cementing substance of acid mucopolysaccharide (Scott and Symons, 1982). Cementum can be acellular or cellular, depending on when it is laid. Acellular cementum is deposited around the root from the cement-enamel junction to near the root apex as the tooth grows. The cellular cementum is found in the apical part of the root, and gradually increases in thickness as the apex of the root is approached (Scott and Symons, 1982; Ten-Cate, 1998). Like dentin, cementum is laid down in incremental layers throughout the life of the tooth, and the overall thickness of the layer surrounding the root grows with time (Lazzari, 1976; Carlsen, 1987).

2.2.2.3 Development of Teeth

Tooth development depends on the interaction of two cell types: neural crest-derived ectomesenchyme and epithelium. All tissues required to make up a tooth are derived from the cell mass that initiates tooth formation. Neural crest cells migrate into the developing jaw tissues. This is the dental lamina and it follows the line that will eventually be taken by the dental arcade (Hillson, 1986; Schwartz, 1995). On the edge of the lamina grow small swellings, proliferation's of epithelial cells that differentiate into external and internal enamel epithelium. These are the beginnings of tooth germ, within which the enamel and dentine will be laid down. The dental follicle, with nerves and arteries passing through the base and into the follicle, itself surrounds the entire tooth germ. Initially there are only enough germs for the deciduous teeth. Permanent germs

form later, arising lingually from the external dental epithelium of the tooth it will eventually replace (Scott and Symons, 1982; Carlsen, 1987).

Calcification of the deciduous dentition starts in the early period of foetal life. In each tooth, dentine formation always starts before enamel. Odontoblasts just under the cusps lay down predentin first, and dentin is built up as series of conical layers, stacking one inside another, with space in the centre that becomes the pulp chamber (Hillson, 1986; Steele and Bramblett, 1988). Humans, like most mammals, shed their first set of teeth as the permanent set develop and grow in.

Primary teeth develop in connection with the oral epithelium via the dental lamina, and form a different dental arcade than do successional teeth. While permanent molars are developing in infancy and childhood, only deciduous permanent molars erupt into the mouth, therefore the non-adult dental pattern is presented as 2.1.2/2.1.2 (Schwartz, 1995). A total of 20 teeth erupt during infancy and are evulsed during childhood. Deciduous teeth have smaller crowns, more clearly defined features, and enamel that is milkier than permanent teeth. The neck of a deciduous tooth is more visibly constricted than an adult one. The roots of deciduous teeth are shorter relative to crown height, have a larger root canal opening and taper more drastically to apices than permanent teeth. The continual development of the immature jaw results in single rooted-teeth with narrow roots and crowns that flare outward from the neck. The crowded jaw has less room in which the deciduous teeth can anchor themselves, so the direction of root growth can be variable (Schwartz, 1995).

A total of 32 permanent teeth make up the adult dentition, erupting during childhood, through adolescence and sometimes into adulthood. Adult permanent teeth

grow in the same general manner as deciduous teeth, slowly pushing their way into the jaw and maxilla as the deciduous teeth are lost. Because of their greater size and slower rate of formation than deciduous teeth, from three to six years are required for the completion of the crowns of permanent teeth (Humphrey, 2000). Crowns develop first, through the continual accumulation and mineralization of enamel. Root formation begins when the crown is completed, and the time required for its completion depends on the rate of dentin formation and the length of the root. The development of the cuspids requires the most time, because of their long roots.

2.3 Construction of the Osteobiography

The primary source of biological evidence from past humans comes from the archaeological recovery of human skeletal remains. While not without analytical limitations, human remains are one of the single best resources researchers have for looking into the lives of past peoples. Information regarding patterns of activity, subsistence strategies, population demographic structure, pathological processes and other factors of everyday life are often recorded in the bones of our ancestors. By studying the remains of once living individuals and groups, physical anthropologists can begin to reconstruct the framework of life in the past, as recorded in the remains of the people who lived during those periods. While useful in their own right, analyses of the material culture of any given group can only go so far in informing modern researchers about the challenges faced by individuals and groups in the past. Coupling both cultural and biological evidence from the archaeological record however, enables anthropologists

to consider more comprehensively the lives of the individuals and populations under study.

Assessing life history and creating an osteobiographical profile for individuals or populations is no simple task. Multiple factors must be taken into account before the researcher can decide which variables are most informative, and what kinds of patterns best fit with the data generated. Age and sex are, of necessity, assessed very differently in adults and non-adults when constructing the osteobiographical profile. Dietary regimes, health indicators and growth patterns and overall indicators of health are also variables that are assessed and considered when constructing such profiles, and the methods by which this is done are similar regardless of the age of the individual. These parameters are then assessed at a broader level if it is determined that multiple individuals representative of a population are present in a given sample.

One of the most difficult variables to gauge from adult human skeletons, age at death is one of the first factors to be assessed when creating an osteobiographical profile. Skeletally, changes to bone resulting from degeneration is an indicator of age in adults. Once growth has ceased and the individual reaches adulthood, the bones begin to wear and degenerate. Changes on the face of the pubic symphysis, auricular surface of the ilium, obliteration of the cranial sutures, thinning of cortical bone and loss of trabeculae, changes to rib end morphology and lipping of joint surfaces are all indicators used to assess advancing age from skeletonized adult remains (e.g. Bass, 1995; Buckberry and Chamberlain, 2002; Buikstra and Ubelaker, 1994; Iscan and Loth, 1989; Key *et al.*, 1994). Due to the nature of changes in the adult skeleton, age ranges used by researchers are generally broad, and therefore somewhat less informative than the narrower ranges

possible for non-adults. Since permanent molars erupt into the oral cavity only until the approximate age of 21 years (Hillson, 1986; Ubelaker, 1989), dental development and eruption patterns are not useful for age determination with adult skeletal remains. Wear of permanent teeth has been suggested as a means of gauging age in adults, however the amount of wear is heavily dependant on the dietary regime followed by the individual (e.g. Bass, 1995; Gustafson, 1950; Hillson, 1986; Miles, 1963).

If a skeleton is relatively complete, the sex of an adult is often readily visible in the morphology of the bones themselves. In adults, characteristic indicators of sex are the morphology of the pelvic girdle, the cranium and mandible, and the robusticity of long bones (Bass, 1995; Buikstra and Ubelaker, 1994; Krogman and Iscan, 1986; Mall *et al.*, 2001; Mall *et al.*, 2000; Rathbun and Buikstra, 1984; Sutherland and Suchey, 1991; White, 2000). Physical anthropologists have found that the most reliable sex identifiers are found in the adult pelvis; the width of the sciatic notch, sub pubic angle, length of the pubic bone, morphology of the pubic symphysis, and presence of a defined preauricular sulcus are the most common indicators of sex in the adult pelvis. The morphology of the skull and mandible are also quite reliable when assessing sex of an individual, and brow ridges, frontal bossing, orbital margins, mastoid process, gonial angle eversion and chin shape are all areas that demonstrate differences between the sexes (Bass, 1995; Buikstra and Ubelaker, 1994; Rathbun and Buikstra, 1984; White, 2000).

Unlike adults, age is one of the most straightforward parameters to assess in non-adults. Since skeletal and dental changes are taking place rapidly and in well documented patterns as children grow, they act as markers of biological age. In non-adults, long bone diaphyseal lengths and the timing of epiphyseal fusion are all employed

in estimating age in non-adult skeletal remains (Scheuer and Black, 2000a). Tooth eruption patterns are well documented, and are the primary criteria for determining the stage of development in non-adults. Tooth formation begins in the embryonic stage between 14 and 16 weeks, and is often examined through radiography. The level of development of unerupted teeth indicates the stage of growth attained (Schwartz, 1995; White, 2000). The timing and pattern of development and eruption of teeth is depicted in Figure 2.2. Deciduous teeth are grey in colour, permanent teeth are shown in white. Most deciduous teeth emerge in the first two years of life, but developing permanent teeth can already be seen developing in the mandible and maxilla on x-rays by this point.

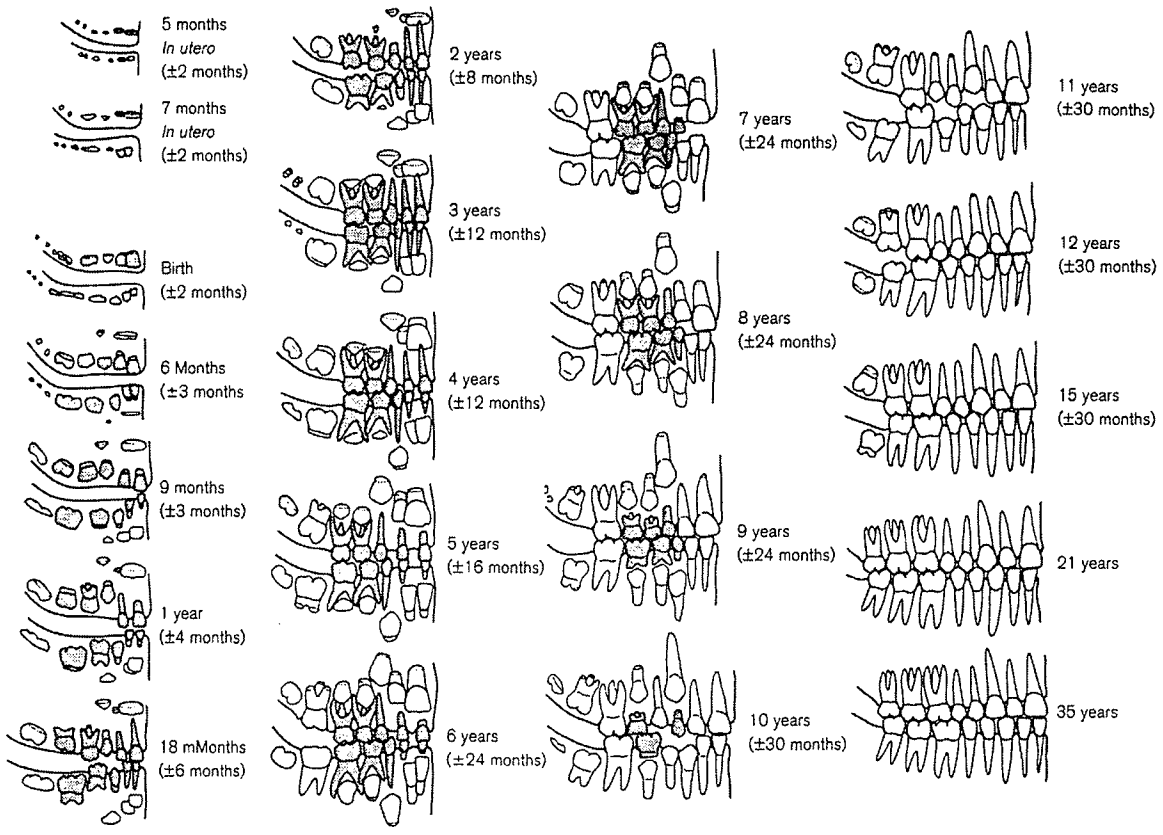


Figure 2.2 Tooth development and eruption.
From Ubelaker (1989: Figure 71)

Tooth size and overall morphology are also used as indicators of stage of development, however, the fact that these two elements are highly interdependent must be recognized (Mayhall, 2000).

Determining sex is arguably the most difficult, and often impossible, biological parameter to assess in non-adults. Numerous authors have reported successful determination of sex in non-adults from various skeletal elements (Choi and Trotter, 1970; Holcomb and Konigsberg, 1995; Mittler and Sheridan, 1992; Sundick, 1977; Weaver, 1980), and while some research has been done regarding sexual differences in deciduous dentition (Black, 1978; De Vito and Saunders, 1990; Saunders, 1992), there appears to be too much variation and overlap in skeletal and dental morphology in non-adults to confidently assess sex of an individual. Although there may be sexual differences in the skeleton between males and females early in life, they do not appear to be of sufficient magnitude for reliable determination of sex prior to the onset of puberty (Scheuer and Black, 2000a).

Diet and health are so intricately interwoven in modern populations that it is often problematic to try to separate the two in archaeological samples, except in the case of congenital abnormalities. Some dietary deficiencies and chronic illnesses manifest themselves in the form of characteristic lesions in the skeleton and dentition, enabling researchers to examine the effects of those conditions at the intra- and inter-personal levels in past populations. The dietary regime followed by an individual is often analysed through trace element and stable isotope studies that can determine the level of reliance on marine or terrestrial food resources and the types of plants and animals exploited (Ambrose and Krigbaum, 2003; Bocherens *et al.*, 2001; Buikstra, 1992;

Chisholm *et al.*, 1982; Cordain *et al.*, 2000; Freedman, 1975; Harper and Le Beau, 2003; Katzenberg *et al.*, 1993; Katzenberg and Lovell, 1999; Katzenberg, 2000; Tuross and Fogel, 1994; Wing and Brown, 1979).

The primary difficulty in biochemical assessment of diet via these techniques is the destructive nature of the analysis, which is sometimes prohibited when precious archaeological samples are being tested. There are also limitations to the information that may be generated using trace element and stable isotope analysis – different combinations of resource use can result in similar patterns and ratios, but often this effect can be offset to some degree by investigating multiple elements and being familiar with local availability of foods through other avenues of research, such as local ecological niches (Katzenberg, 2000). Trace element analysis of human remains will be discussed in more detail in the next chapter.

General health is assessed through the overall morphology of the remains and from the absence of pathological features. According to Lovell (2000), pathology is assessed through four criteria: 1) the presence of pathological lesions, 2) the distribution of lesions across the skeleton, 3) the location of lesions on skeletal elements, and 4) the distribution of lesions within the sample as a whole. Despite the relatively few disease process that leave unique patterns of lesions on the skeleton, differential diagnoses is usually not possible with skeletal samples since bone can only respond to infection, malnutrition or trauma in two ways: by producing more bone or through the loss of bone (Hancox, 1972; Schwartz, 1995). The assessment of health status is limited by the fact that only long-term conditions and some traumatic injuries are visible in the skeleton. Acute illness which are often causes of death in modern populations do not generally

affect the skeleton and are therefore often underrepresented in archaeological samples by virtue of their invisibility (Aufderheide and Rodriguez-Martin, 1998; Buikstra, 1992; Bush and Zvelebil, 1991; Hart, 1983; Lovell, 2000; Ortner, 1992).

Human growth is nothing if not variable, yet it is one of the biological parameters often examined in the creation of an osteobiograhy. Growth, however, is influenced by more than just the health of the individual, and is represented by factors other than height and weight. The environment, climate, genetics, health, birth weight and socio-economic situations are all factors that have an influence on the rate and trajectory of development (Farkas, 1996; Fogel, 1986; Hoppa, 1992).

Numerous types of events can disrupt normal growth of bones and teeth. Nutritional deficiencies or excesses can cause changes in the growth rate, or halt growth entirely if the stress is sufficiently severe or prolonged (Itani and Tsang, 1996; Klepinger, 1984). Traumatic events can also alter the growth trajectory and rate, as can disease, illness or metabolic disorders (Bailey *et al.*, 1978; Brighton, 1982; Dixon *et al.*, 1991; Sullivan, 1978). The amount of disruption is directly related to the duration and severity of the condition, as well as the timing of the situation. In archaeological samples, levels of growth attained are measured by stature in adults (e.g. Cole, 1994; Duyar and Pelin, 2003; Özaslan *et al.*, 2003; Pelin and Duyar, 2003), and by a combination of long bone diaphyseal measurements against dental aging techniques in non-adults to assess percentage of adult stature achieved at the time of death (e.g. Humphrey, 1998; Jantz and Owsley, 1984a; Lovejoy *et al.*, 1990; Saunders *et al.*, 1993). Given the complexities of human growth, a simple measure of stature achieved from skeletal samples is inadequate

to capture the timing and rate of growth spurts that can be measured in modern populations with longitudinal studies.

2.4 *Methodological and Theoretical Considerations*

When drawing upon methods designed to study living populations, physical anthropologists encounter a number of difficulties, both theoretical and methodological. The appropriateness of reference standards, sample biases, and the interplay of factors affecting health and growth each contribute to the challenges facing researchers who work with a static sample. Theoretical problems arise primarily as a result of base assumptions and inferences drawn when studying human remains.

Issues of reference standards can affect any research protocol, and must be considered before an osteobiographical assessment begins. For example, certain ethnic groups have higher or lower bone density than others (Bleibtreu, 1967), and other groups have unique dental eruption timings (Garn, 1965), so physical anthropologists must be aware of these differences and compare samples only to appropriate standards. Even the applicable standards may change, however, and gradual changes in populations over time may lead to false results if reference standards become outdated (Farkas, 1996).

Changes in environment, climate, genetics, or socio-economic situations can also cause confusion in assessments of life history. For example, Fogel (1986) reports that an increase in meat in the diet of 19th century American populations should have resulted in increased nutritional values and an increase in heights and weights. Instead, these measures of growth dropped during that period, and this was attributed to low birth weights and poor *in utero* nutrition. This raises the question of the validity of proxy data

(such as diet) to measure general health, and the use of height as an indicator of health status.

Pathological processes are also challenging to interpret. Disease and illness can impact the normal development of bones and teeth in numerous ways, and each individual reacts with differing severity to these factors. Metabolic, hereditary and infectious processes can influence the most vulnerable (young and old) differentially, and these changes often correlate with changes in subsistence, sedentism, population growth, living conditions and social change (Ribot and Roberts, 1996). There are also limitations to the use of skeletal remains to reconstruct the presence and impact of pathological conditions in the past. Acute diseases are very rarely expressed in either the gross or microscopic morphology of the skeleton, and diseases with dissimilar aetiology can affect the skeleton in similar ways. Only one stage of illness is presented, in what would have been an on-going process, and a number of factors influence pathogenesis (Wall, 1991).

Some macroscopic techniques used to assess health from the skeleton have fewer problems than do others. For example, the interpretations of growth disruption lines that are visible in radiographs of long bone diaphyses (Harris lines) are problematic. Mays (1995) reports that these lines are frequently altered by resorption and remodelling of bone, and that no relationship exists between Harris lines in adult bones and other indicators of stress. Lewis and Roberts (1997) agree with Mays, pointing out that in only one quarter of cases of disease and stress are indicators left on adult bones, and that ten percent of lines formed when no appreciable stress was apparent. Generally, however, there are few difficulties with radiographic techniques. X-rays can occasionally be difficult to read, and the interpretation can be variable between researchers. This variation

between studies is a difficulty that is encountered in numerous techniques. Metrics are used by many physical anthropologists and most researchers follow one of a variety of published standards (e.g. Bass, 1995; Brothwell, 1981; Buikstra and Ubelaker, 1994). Deviations from published norms are common however, and often make cross-study comparisons meaningless. Even within the same study, when using the same technique and tools, researchers achieve different measurements (Farkas, 1996). El-Najjar and McWilliams (1978) argue that the utility of metric studies is severely limited by a number of factors. The genetics of metrically inherited traits is poorly understood, the low phenotypic specificity, age progressive and age regressive tendencies combine with other environmental factors that influence the development and growth of an individual to such a degree that metric studies are, according to these authors, at best only descriptive of overall morphology.

When Wood *et al.* published "The Osteological Paradox" in 1992, debate began regarding the validity of methods used and conclusions drawn from the study of human remains, and physical anthropologists were challenged to examine the assumptions underlying their research (Wood *et al.*, 1992). While certain biological imperatives that apply to living populations can be used in the study of past populations, researchers encounter problems demonstrating that a direct relationship exists between information gained from archaeological material and the health status of the past populations that gave rise to the collection (Wood *et al.*, 1992). Populations are always in a state of change – they are not constant entities, and each skeleton represents but a brief picture of events for a single individual. Physical anthropologists are limited to cross-sectional studies, since longitudinal studies are not possible, and this approach assumes that growth

patterns have remained constant over time and between cohorts within a given population.

Biases in the samples with which a researcher is working can also affect the assessment of life history. Mortality bias and hidden heterogeneity are factors that can influence the composition of a skeletal sample (Wall, 1991; Wood *et al.*, 1992). Obviously, all of the individuals examined are deceased. Are they so for a particular reason? Were they more susceptible to disease processes than perhaps the overall population from which they originate? A study by Saunders, Hoppa and Southern (1993) suggests that this may not necessarily be as problematic as once thought. They point out that the sample with which they are working "... is comparable to (a modern population) [and the] study supports the supposition that archaeologically derived skeletal growth profiles are not biased simply because they consist of individuals who died prematurely" (Saunders *et al.*, 1993). This study focused on an examination of under-12 year olds, therefore the differences between this sample and modern samples, when normalized for adult stature, suggest that the mortality bias may only become problematic when teenage and adult skeletons are recovered. In a further comparison of the data from the St. Thomas' sample to modern standards, Saunders and Hoppa found that the "biological mortality bias is minimal or absent in some non-adult skeletal collections and that the differences in growth between samples ... represent real differences in the overall health" of the populations (Saunders and Hoppa, 1993: 146).

Other authors argue that non-adults who died of acute illness may be a better indicator of overall health of the population represented (Milner *et al.*, 2000; Ortner,

1992; Wood *et al.*, 1992). For purposes of analysis, the use of skeletons of non-adults who died of acute infections may be best for assessing levels of overall health in a population, since their remains are less likely to have been impacted by the disease process and thus present a clearer picture of the overall 'norm' in the past (Humphrey, 2000; Larsen, 2000; Saunders, 2000).

The differential preservation of skeletal material also causes an inherent bias in a given sample. Since the bones of infants and children are thinner and more susceptible to taphonomic and diagenetic change, they are less likely to preserve as readily as the skeletons of adults (Lyman, 1996; Saunders, 2000; Scheuer and Black, 2000b). Human remains from an archaeological site therefore, are generally not thought to be an accurate representation of the population from which they originate. Practical difficulties with archaeological samples include poor or biased preservation and recovery of remains, small sample size and variable temporal resolution. For example, the sample may span several generations, or be temporally discontinuous. The study of groups that are temporally, geographically and ecologically varied has however, expanded our understanding of the challenges faced by past populations.

2.5 Conclusion

By modifying and applying research methods designed to address modern populations, physical anthropologists are able to increase the accuracy with which they once assessed general population parameters in the past. Modern osteobiographical studies now include an array of methods and techniques that can be applied singly or in

conjunction with one another for a more comprehensive picture of past populations than was once possible, within the limitations noted above.

Creating an osteobiography for an individual from their skeletal remains is possible through an assessment of age, sex, general health, diet and growth. When multiple individuals from a discrete population are presented for study, these kinds of data can be combined in order to study the demographic profile of the larger populations from which the sample is drawn. Even in modern cases, researchers find it challenging to create an osteobiographical profile that is completely accurate, but physical anthropologists must recognize the limitations of the methods employed and work consciously to overcome them. Despite the difficulties inherent in the study of the archaeological human remains, the information to be gained from these studies is critical to the deeper understanding of the life histories of past peoples.

Chapter 3

Biochemistry:
Using Chemical Signatures to Study the Past

3.1 Introduction

In order to understand how researchers can use human remains to examine the health and diet of past populations, a general understanding of the biochemistry of human bone and dentition is necessary. For years researchers have examined the osteological remains of past peoples in the hopes of better understanding the challenges they faced. Researchers have used a number of methods to reconstruct past environments and diets, in the hope of unravelling the complex interactions between diet, environment, overall health and growth. Methods once used to test the chemical composition of archaeological artifacts are now being applied to bones and teeth in the hope of enhancing the level at which health analyses are carried out. The old saying "you are what you eat' is only partially true, and when it comes to analysing archaeological human remains for indicators of past health and diet, numerous factors affect the biochemical

structure. While the body absorbs nutrients from the food and water consumed, it can also take in elements from the physical surroundings both *intra vitam* and post mortem, confusing the interpretation of data observed.

3.2 Human Biochemistry

A solid understanding the chemical structure of human remains is useful in order for researchers to examine indicators of dietary patterns, pathological conditions, and overall health status from human remains. The unique chemical signature left in the bones and teeth of an individual as they age can reflect the foods consumed and general health status of the person through time. The interactions between physiological processes and nutrients available to the body are highly complex and not fully understood. Many biochemical interactions have been investigated, however, and some of those interactions have been mapped. In discussing the elemental composition of body tissues, when an element is first noted the full clinical name and its scientific abbreviation is used; thereafter only the abbreviation will appear.

3.2.1 Bone

Bone consists of two components: an organic and an inorganic, or mineral, fraction. Only about 25 % of the organic component is dry, and 90% of that is type 1 collagen (a fibrous protein found in dentin, cementum and bone). It is collagen, arranged in fibrous bundles, that give bone its tensile and torsional strength (Sandford, 1995). Collagen, like any living organic matter, contains minute amounts of the weakly

radioactive isotope ^{14}C as well as the non-radioactive isotope ^{12}C. These isotopes are key factors in the absolute dating of human remains (discussed in chapter 5).

The remaining 75% of bone is its inorganic component. This mineral fraction is made up of calcium phosphate in the form of hydroxyapatite, which has a cell formula that approximates $Ca_{10}(PO_4)_6(OH)_2$ (Neuman and Neuman, 1958; Sillen, 1989). Both the crystalline and amorphous forms, as well the chemistry, are highly variable due to the constant uptake and loss of elements in both living and buried bone (Sillen, 1989). Table 3.1 lists the normal elemental concentration of modern human bone.

Sodium (Na)	1.50 ±0.57%
Strontium (Sr)	120 ± 49 ppm
Zinc (Zn)	210 ± 46 ppm
Magnesium (Mg)	4600 ± 1000 ppm
Iron (Fe)	400 ± 300 ppm
Manganese Mn)	2-10 ppm
Aluminum (Al)	5-110 ppm
Bromine (Br)	0.2 - 5 ppm

Table 3.1 Elemental Composition of Human Bone

Adapted from Tipton and Shafer 1964, cited in Lambert *et al.* (1985a) and Schauss (1999)

3.2.2 Teeth

Every layer of a human tooth has a unique chemical structure, but there are certain similarities between them as well. Each layer is composed of an organic and inorganic component. The inorganic component in every section is hydroxyapatite, however the amount of hydroxyapatite varies greatly between anatomical layers (Hillson, 1986; Schauss, 1999). The concentrations of particular elements within the layers of teeth differs by virtue of the amount of organic component within the structure and the

elements available within foodstuffs consumed (Buikstra *et al.*, 1989; Williams and Elliot, 1989).

Enamel is the hardest calcified tissue in the human body, and it is almost entirely inorganic hydroxyapatite in crystalline form. The crystals of enamel are considerably larger than those of bone or other dental tissues, and are packed together to make a very fine and dense crystalline mass that holds the organic component in between (Hillson, 1986). The small portion of organic material within enamel consists mainly of proteins and peptides concentrated in planes radiating out from the enamel-dentin junction. The normal elemental structure of human enamel is listed in Table 3.2.

Calcium (Ca)	33.6 – 39.4%
Phosphorus (P)	16.1 – 18.0%
Sodium (Na)	0.25 – 0.90%
Magnesium (Mg)	0.25 – 0.56%
Chlorine (Cl)	0.19 – 0.30%
Potassium (K)	0.05 – 0.30%
Fluorine (F)	50 – 5000 ppm
Iron (Fe)	8 – 218 ppm
Zinc (Zn)	152 – 227 ppm
Strontium (Sr)	50 – 400 ppm
Copper (Cu)	10 – 100 ppm
Manganese (Mn)	0 – 18 ppm
Silver (Ag)	0 – 100 ppm
Beryllium (Be)	0 - 16 ppm
Bromine (Br)	1 - 34 ppm

Table 3.2 Elemental Composition of Human Enamel

Adapted from Schauss (1999) and Williams and Elliot (1989)

Dentin is a composite of organic and inorganic mineral components, consisting of approximately 75% hydroxyapatite, 18% collagen, 5% water and 2% trace materials (Hillson, 1986). In dentin, calcium phosphates, in the form of apatites, have shorter prisms than in enamel. They are closer in form to those in bone or cementum (Hillson,

1986). Elements may not be evenly distributed throughout dentin due to its higher organic component; for example, F, Pb and Zn concentrate around the pulp chamber. Concentrations of particular elements also vary significantly from the amounts found in other biological material: levels of Mg can be double that found in enamel or bone and Sr can vary by up to 10% from these tissues (Buikstra *et al.*, 1989). The normal elemental composition of human dentin is found in Table 3.3.

Calcium (Ca)	26 – 28%
Phosphorus (P)	12.2 – 13.2%
Sodium (Na)	0.70%
Magnesium (Mg)	0.8 – 1.0%
Chlorine (Cl)	0.40%
Potassium (K)	0.02 – 0.04%
Fluorine (F)	50 – 10000 ppm
Iron (Fe)	60 – 150 ppm
Zinc (Zn)	200 – 700 ppm
Strontium (Sr)	100 – 600 ppm
Bromine (Br)	10 - 100 ppm

Table 3.3 Elemental Composition of Human Dentin

Adapted from Schauss (1999) and Williams and Elliot (1989)

Cementum is remarkably similar to bone in elemental composition and structure, with an inorganic component of approximately 65 – 70% and an organic component between 24 – 26%. The vast majority of the mineral fraction is in the form of apatite minerals, while over 20% of the inorganic component consists of collagen (Hillson, 1986).

3.3 Trace Elements and Human Health

Trace elements play a critical role in regulating the biochemistry of the human body, and fluctuations in the levels of some elements can be either beneficial or detrimental to health (Munoz-Olivas and Camara, 2001). The vast majority of elements

enter the body via the digestion of food, which allows soluble ions to enter the bloodstream directly. Trace elements will also be absorbed from the local environment through the consumption of water, and the inhalation of dust, aerosols, and spores (Nnerdal, 2000). In many ways, the trace elements in the body are believed to reflect the elements present in the local environment (Ahlberg and Akselsson, 1976; Buoso *et al.*, 1992; Lane and Peach, 1997).

3.3.1 Elements of Interest

Nutrients are taken into the body in the form of elements, which are defined as "a substance that cannot be broken down into other substances by ordinary chemical methods" (Plummer *et al.*, 1999:28). Isotopes of an element are atoms containing different numbers of neutrons, but the same number of electrons and protons, and an ion is a particle that carries an electrical charge – either positive (cations) or negative (anions). Each of these basic chemical entities has a role in the homeostatic balance of the human body, and contributes to the visibility of past dietary patterns in human remains.

Elements found in the human body are typically categorized as either major or trace, based primarily on the optimal quantity of a given element. Major elements are required in relatively large quantities by humans, and include carbon (C), hydrogen (H), nitrogen (N), Ca, P, oxygen (O), potassium, sulfur (S), Cl, Na and Mg. In contrast, trace elements are required in very small doses, and excessive uptake in larger doses over time can be toxic (Aufderheide, 1989; Freedman, 1975; Schauss, 1999). Johansson (1988) considers any element with a concentration under 10^{-5} in biological tissue as a trace

element. Elements are further broken down into essential and toxic, although virtually any element is toxic in doses beyond what the body can metabolize (Ebdon, 2001). Essential trace elements are Cobalt (Co), Cu, Chromium (Cr), Fe, Iodine (I), Mn, Mo, Nickel (Ni), Se, Si, V and Zn, while Al, As, Cd, Sb, Sn, Pt, Hg, Pb and Bi are considered potentially toxic (Ebdon, 2001; Munoz-Olivas and Camara, 2001). Elements are also classified as either antagonistic or synergistic, meaning they either inhibit or enhance the absorption of other elements (O'Dell, 1985).

Relatively few trace elements are of research interest when investigating the health and diet of past populations. A fairly comprehensive listing of dietary minerals, their sources and metabolic interactions are listed in Table 3.4. Plants and animals living on land have a particular elemental signature because of the minerals and trace elements available to them via photosynthetic and metabolic processes; marine resources have a different signature. How researchers 'read' the amount of terrestrial or marine resources in the diet of a sample group through ratios of Ca and N isotopes will be discussed in more detail below. Trace elements that are considered indicators of dietary intake are Sr, Mg, Mn, Vanadium (V) and N, with low Cu for plant-based diets, while those based on a primarily meat diet should show high Zn, Cu, Se and Mo and low Mg (Buikstra *et al.*, 1989; Price, 1989; Van Der Merwe, 1989). By looking at the ratios of particular elements to one another, and the overall elemental structure of the bone or tooth, different dietary patterns become visible in human remains.

Table 3.4 Dietary Minerals From (Campbell *et al.*, 2000)

Mineral	Dietary Source	Functions in the Body	Symptoms of Deficiency
Calcium (Ca)	dairy products, dark green veggies, legumes	bone and tooth formation, blood clotting, nerve and muscle function	stunted growth, possibly loss of bone mass
Phosphorus (P)	dairy products, meats, grain	bone and tooth formation, acid base balance, nucleotide synthesis	weakness, loss of minerals from bone, calcium loss
Sulfur (S)	proteins from many sources	component of certain amino acids	symptoms of protein deficiency
Potassium (K)	meats, dairy products, many fruits and vegetables, grains	acid-base balance, water balance, nerve function	muscular weakness, paralysis
Chlorine (Cl)	table salt	acid base balance, gastric juice	muscle cramps, reduced appetite
Sodium (Na)	table salt	acid base balance, water balance, nerve function	muscle cramps, reduced appetite
Magnesium (Mg)	whole grains, green leafy veggies	component of certain enzymes	nervous system disturbance
Iron (Fe)	meats, eggs, legumes, whole grains, green leafy veggies	component of haemoglobin and of electron carriers in energy metabolism	iron deficiency anaemia, weakness, impaired immunity
Fluorine (F)	drinking water, tea, seafood	maintenance of tooth and bone structure	higher frequency of tooth decay
Zinc (Zn)	meats, seafood, grains	component of certain digestive enzymes and other proteins	growth failure, scaly skin inflammation, reproductive failure, impaired immunity
Copper (Cu)	seafood, nuts, legumes, organ meats	component of enzymes in iron metabolism	anaemia, bone and cardiovascular changes
Manganese (Mn)	nuts, grains, veggies, fruits, tea	component of certain enzymes	abnormal bone and cartilage
Iodine (I)	seafood, dairy products, iodized salt	component of thyroid hormones	goitre
Cobalt (Co)	meats and dairy products	component of vitamin B-12	none, except as B-12 deficiency
Selenium (Se)	seafood, meats, whole grains	component of enzyme, functions in close assoc with vitamin E	muscle pain, maybe heart muscle deterioration
Chromium (Cr)	brewer's yeast, liver, seafood, meats, some veggies	involved in glucose and energy metabolism	impaired glucose metabolism
Molybdenum (Mo)	legumes, grains, some veggies	component of certain enzymes	disorder in excretion of nitrogen containing compounds

3.3.2 Elemental Uptake and Storage

Keeping the level of minerals in balance in human tissues is key to maintaining good general health. The availability of minerals and trace elements in the environment however, does not mean those resources are necessarily accessible biologically to those who consume them. Different resources in the human food repertoire contain disparate levels and kinds of elements, depending on their unique biogenic processes. When these items are ingested, the digestion of food releases those elements into the individual's bloodstream, where they may become available to the body tissues (Buikstra *et al.*, 1989; Ebdon, 2001; Munoz-Olivas and Camara, 2001; O'Dell, 1985).

The bioavailability of minerals is highly dependant on a number of complex and inter-related factors, and is generally poorly understood. The relationship between the amount of an element absorbed and the quantity utilized strongly depends on the chemical form. Age, sex, pathological conditions, reproductive status, percent intake, physico-chemical form of the element, multi-element and antagonist interactions all affect bioavailability (Buikstra *et al.*, 1989; Munoz-Olivas and Camara, 2001).

Some trace elements are dependant on exposure to stomach acid in order to liberate them into ionic (charged) form, in which the body more readily absorbs them. The pH state of sections of the gastrointestinal tract can affect the absorption of trace elements. In the colon, the pH is in the range of 7.5 and 8.0, while in the ileum it stays around 7.6, and the duodenum ranges between 4.5 and 8.2 (Schauss, 1999). Intestinal absorption of many trace elements probably occurs by saturable and carrier-mediated processes, but these transport systems often show competition between "similar chemical species, resulting in inhibition of uptake of essential elements and uptake of competing

potentially toxic elements" (Duffus, 2001: 369). Bremner and Mills (1981) argue that there is conflicting evidence for the roles of plasma albumin, transferrin and caeruloplasmin in the transport of many trace elements. Some, such as Fe, are carried and regulated by transferrin receptors on particular cells. The mechanisms by which Zn, on the other hand, is acquired by cells remains a mystery (Nnerdal, 2000).

Once acquired by the body, trace elements are stored in bones and teeth through ion exchange with the hydroxyapatite of the material. The surface area of bone is more accessible to ions in body fluids by virtue of the microcrystalline nature of individual bone crystals. This endows crystals with large charged surface areas, which present numerous opportunities for ionic substitution (Neuman, 1980). The elemental construction of interior unit cells are more stable (Buikstra *et al.*, 1989). Enamel close to the crown surface is more heavily mineralized than the inner enamel, which also has a higher carbonate concentration (Hillson, 1996).

There are three zones within hydroxyapatite where ion transfer can occur, and the chemical behaviour of the mineral portion of bone involves the transfer of ions across these surfaces. The crystal interior is known to concentrate Sr, radium (Ra) and F, while the crystal surface draws all three of these elements in addition to Na, Mg and uranium (U). The hydration shell of the hydroxyapatite crystals diffuses K, Cl, Na and F, but these elements do not concentrate there; Mg, Sr, Ra, U and carbonate (CO_3^{2-}) tend to collect in the hydration shell (Neuman and Neuman, 1958; Wing and Brown, 1979).

Ions most commonly exchanged include replacing Ca with various cations such as Sr, lead (Pb), Mg and Na, and the replacement of phosphate (PO_4^{3-}) and hydroxide (OH^-) by anions including CO_3^{2-} and fluoride (F^-) and chloride (Cl^-) respectively (Klepinger,

1984; McLean and Urist, 1955). Al, Pb, Si, V, Mn and Sr are strongly bound to the mineral component of materials, while Cu and Fe associated with the organic portion (Spadero *et al.*, 1970). Generally, isotopes are found in organic bone (collagen), while elements are concentrated in the mineral portion of bone (apatite) (Hillson, 1996; Price, 1989).

3.4 Biochemistry in Ancient Materials

Most biochemical research in physical anthropology has focused on its application for general dietary reconstructions and nutritional standing of past populations. Single element approaches assess one element of interest that is typically associated with a particular pathological condition. Iron (Fe) (Williams and Elliot, 1989; Zaino, 1968), and lead (Pb) (Aufderheide, 1989) are the two elements primarily studied using this approach. Multi-elemental studies focus on a wide range of elements, usually for the purposes of reconstructing dietary patterns and illustrating changes in those patterns over time (Buikstra *et al.*, 1989; Gilbert, 1977; Klepinger, 1984; Lambert *et al.*, 1979). In dietary reconstruction, the most common multi-elemental studies are those that examine the ratios of stable and unstable isotopes of C and N.

3.4.1 Dietary Reconstruction

The interpretation of data from studies of stable isotope rations in bones and teeth allows for the creation of dietary reconstructions. Stable isotope studies focus on particular elements, usually various isotopes of C and N, to determine the relative importance of marine versus terrestrial food resources (Chisholm *et al.*, 1982;

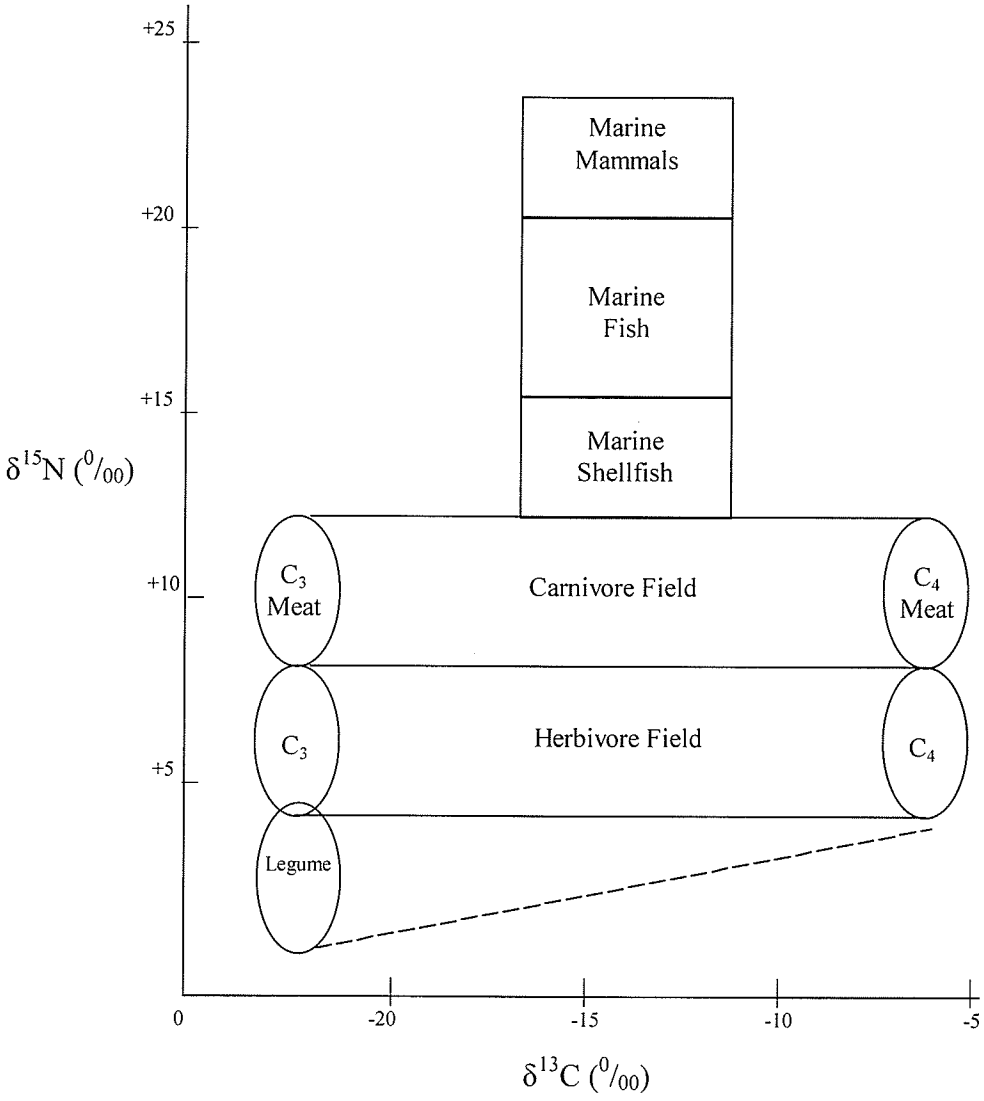
Katzenberg, 2000; Mays, 2000; Schoeninger, 1989; Tauber, 1981), environmental reconstructions (Ebdon, 2001; Valero-Garces and Laird, 1997), and patterns of migration (Cox *et al.*, 2001). Stable isotopic studies that examine bone apatite and collagen assess the protein portion of diet, while stable isotopes in carbonate from bone mineral are more reflective of the entire dietary repertoire (Harrison and Katzenberg, 2003).

Diets based on terrestrial resources are normally depleted in ^{15}N versus$\delta^{14}N$, and are higher in Sr and Barium (Ba), when compared to marine resources (Price, 1989). Carbon isotope values are useful for evaluating the relative dietary contribution of two groups of plants: those with C_3 photosynthetic pathways (temperate zone vegetation) are more depleted in ^{13}C than are those using the C_4 pathway (tropical and subtropical vegetation, including maize). The introduction of marine organisms into the diet is thought to confuse the $\delta^{13}C$ signature (Wing and Brown, 1979), however some authors indicate that the ratio of marine foods is simply intermediate between those of C_3 andC_4 terrestrial foods (Mays, 2000). Figure 3.1 demonstrates how researchers interpret stable isotope data for food resource use in past populations. Where the combined $\delta^{15}N$ and $\delta^{13}C$ readings fall on the chart indicates the general dietary pattern followed by the individual.

Sr/Ca ratios have also been investigated to determine the dietary proportions of animal and plant resources, as well as dietary differences based on gender or socio-economic standing (Price *et al.*, 1985; Radosevich, 1989; Schoeninger, 1989; Sillen and Kavanagh, 1982; Sillen, 1989; Wing and Brown, 1979). Plants do not discriminate between strontium and calcium in the uptake and utilization of these elements, but in mammals, calcium is preferentially absorbed. Plant materials have a relatively high

Sr/Ca ratio, and by ingesting herbivore meat, carnivores are consuming tissue that has already discriminated against Sr. By examining the Sr/Ca ratios in human skeletons, researchers can examine the extent to which vegetable or meat resources dominated a particular individual's diet (Sillen and Kavanagh, 1982). One such study focused on the nutritional and pathological status of a Greek population during the transition to an

Figure 3.1 Composite geochemical model of diet based on gelatin $\delta^{15}N$ and $\delta^{13}C$ analysis. After (Ericson *et al.*, 1989: 91)



agricultural economy. The readings strongly indicated that the diet was focused on C_3 terrestrial resources, including mainly agricultural plants and almost certainly some animal products (Papathanasiou, 2003).

As previously noted, the exchange or substitution of ions within the forming matrix locks in the chemical signature at the time of tooth or bone formation. Nutritional information at time of incremental formation is what is reflected in the teeth, but nutritional information in most recent years is what is reflected in bone (Goodman and Rose, 1991). By comparing data from both sources, researchers can examine changes in the dietary patterns at multiple points in an individual's life.

3.4.2 Biochemical Dating of Human Remains

During life, every organism takes in both ^{12}C and ^{14}C from the air, water and food it consumes; upon death this process ceases. From that point onward, the concentration of the weakly radioactive ^{14}C decreases in relation to the stable ^{12}C isotope. A known and stable half life of 5730 years (Fagan, 1997; Sherratt, 1980), allows researchers to use the ratio of ^{12}C to ^{14}C as the basis for dating the sample. It is necessary, in dating human bones and teeth, to use the extracted protein fraction (collagen). The amount of collagen that remains in the skeleton is entirely dependant upon taphonomic processes; where collagen still exists however, the ratio of ^{14}C to ^{12}C can be used to generate a timeframe within which the individual most likely died.

When Accelerator Mass Spectrometry (AMS) is used, the number of ^{14}C and ^{12}C atoms in the sample are physically measured. The technique is complex, and the specific protocol followed for this study is discussed in more detail in Chapter 5, but essentially

bone samples are cleaned, crushed, and the collagen is chemically extracted. The collagen fraction is then purified using filters, and converted into graphite before being radiocarbon dated. The C is ionized and accelerated toward a magnet that separates atoms by weight; the ^{14}C atoms, with two extra neutrons, are heavier than ^{12}C and can therefore be measured, giving a precise ratio of the two (Ambrose and Krigbaum, 2003)

Small variations in the ratio of ^{14}C to ^{12}C in the past make it necessary to calibrate the results from radiocarbon years to calendar years through dendochronology. By examining the ratio in tree rings, researchers have been able to measure the changes in ^{14}C and ^{12}C levels in the past, and use calibration curves derived from that data so that dates more accurately reflect the calendar period in question (Peregrine, 2001). Most modern North-American dates are calibrated using curves published by Stuiver *et al.* (1998). A second correction is necessary if the N levels (measured along with C in AMS dating) indicate a significant marine component to the diet. Since C circulates more slowly in a marine reservoir than it does in the terrestrial food web, a correction is applied to offset the effect of less C entering the organisms system through the ingestion of marine food sources (Bayliss *et al.*, 2004).

3.4.3 Weaning, Pathology and Toxicity

Weaning of infants from breast milk to solid foods has also been investigated biochemically in past populations. Much in the same way that elements are concentrated or discriminated against in plants and animals, human breast milk concentrates $\delta^{15}N$ relative to $\delta^{14}N$ (Fogel *et al.*, 1989). As children nurse $\delta^{15}N$ values increase, and begin to decrease with weaning (Herring *et al.*, 1998; Katzenberg *et al.*, 1993; 1995; Tuross and

Fogel, 1994). Carbon and O isotopes are also useful in the identification of breast feeding and weaning in skeletal samples. Researchers use $\delta^{13}C$ to document the introduction of solid foods to infant diet and $\delta^{18}O$ to monitor the decline of breastfeeding. Wright and Schwarcz (1998) examined the dentition of children from the Guatemalan site of Kaminaljuyu and found that teeth developing at older ages are more enriched in ^{13}C and more depleted in ^{18}O than teeth developing at younger ages. From this the authors concluded that "many children continued to drink ^{18}O enriched milk between the ages of 2 years and 6 years, when the premolars were mineralizing" (Wright and Schwarcz, 1998: 15). Richards and colleagues (2002) compared rib collagen to dentin in an attempt to examine the age of weaning and magnitude of the delay between weaning and the changes in rib collagen $\delta^{15}N$ levels. By looking at the skeletal remains of children from a Medieval British site, they determined that weaning was relatively abrupt – less than one year, which was reflected in the material as a sudden decrease in $\delta^{15}N$ levels.

Other studies look at specific pathological conditions and attempt to link them with elemental imbalances (Dreosti and Smith, 1983; Freedman, 1975; Klepinger, 1984; Schoeninger, 1989; Zaino, 1968). Instead of being caused by a trace element imbalance, however, many pathological conditions lead to changes in trace element concentrations in the body (Ebdon, 2001; Freedman, 1975; Johansson and Campbell, 1988). For example, it is thought that variations in ^{15}N and ^{13}C results in pathological bone are "likely the result of collagen being formed from the catabolism of existing proteins in the body" (Katzenberg and Lovell, 1999: 316). This has implications for the interpretation of N isotopes ratios in individuals who may have died from nutritionally-related illnesses, such

as children or infants who should be expected to have elevated ^{15}N levels as a result of breastfeeding (Katzenberg and Lovell, 1999).

Specific trace element studies most often examine the interaction between health and deficiency or excess of a given element and its impact on overall health, specifically Zn (Hambidge, 1981; Lambert *et al.*, 1982; Sandstead and Klevay, 1975), Pb (Budd *et al.*, 1998; Jankuhn *et al.*, 1998; Moller *et al.*, 1982; Szostek and Glab, 2001), and Sr (Elias, 1980; Klepinger, 1984; Lambert *et al.*, 1979; Schoeninger, 1989; Sillen and Kavanagh, 1982). Most of these studies are exploratory in nature, since very few trace elements can affect health without interaction with some other chemical in the body.

Lead (Pb) is commonly the focus of single element studies, for both modern medical purposes as well as archaeological and physical anthropological ones. Research into how human exposure to toxic elements, such as Pb, can be seen in bones and teeth has led to the creation of modern baselines used to assess skeletal remains (Bremner and Mills, 1981; Freedman, 1975; Strain *et al.*, 1975). Excessive Pb exposure negatively influences numerous biological functions, and levels of exposure were once thought to have been minimal in the pre-metallurgical past. At least one recent study, however, suggests that natural exposure to Pb in food and water may have been higher than once thought, and that the link between atmospheric Pb and human exposure in natural environments requires more detailed examination (Budd *et al.*, 2000).

3.5 Limitations and Difficulties

Despite recent progress in investigating diet and health in past societies, there are still numerous processes at work that are not fully understood. The two primary

confounding factors in these studies are the bioavailability of minerals from the diet and the estimation of the level of chemical interaction between the human remains and post-mortem burial environment. The availability of minerals in the resource base of a group does not equate to bioavailability of minerals to any given individual within that group. The chemical changes that take place in bones and teeth post mortem are dependant on a large number of factors that are often individual- and site-specific.

There are two primary assumptions that researchers make when examining diet in past peoples via human remains. The first is that the element or elements in question vary predictably across the ancient diet and that food preparation and storage do not distort the dietary pattern. The second assumption is that accurate sampling of tissues will reflect dietary levels in life (Buikstra *et al.*, 1989). As was previously noted, however, the availability of minerals and trace elements within one's dietary regime is not necessarily reflected in the levels of minerals and trace elements found within the calcified tissues of the human body. The quantities of elements taken up by the body change with the age of an individual, slowing as age increases (Munoz-Olivas and Camara, 2001). Females take up minerals and trace elements at different rates than males, and their reproductive status can alter the rate at which elements are absorbed and used within the body. The health of the individual at the time of elemental uptake can also influence the rate at which minerals are acquired, used and stored, as can the chemical form of the element and the inter-elemental relationships (Buikstra *et al.*, 1989; Duffus, 2001; Munoz-Olivas and Camara, 2001; Schauss, 1999). Determining, with confidence, the rate at which a given individual absorbs and stores nutrients is virtually impossible given the interactions of these variables.

Dietary reconstructions and profiles of overall health investigated via stable isotope analysis are also often problematic. The numbers of factors that influence these aspects of life are numerous, making the assessment of nutritional evidence from archaeologically derived material difficult. Studies of stable isotope signatures from bone can be informative for differentiating terrestrial- and marine-based diets (Chisholm *et al.*, 1982; 1983), and for establishing the presence of maize in diets (Bender *et al.*, 1981; Katzenberg, 2000). The results of these assays, however, reflect only dietary patterns over the final five to ten years of the individual's life (Ciba Foundation, 1973; Roche, 1978). Thus, once an individual has reached adulthood, an examination of diet and health during the critical period of growth and development via this method is severely limited.

The *intra vitam* chemical structure of bones and teeth is not necessarily enduring. Human remains interact with the soils within which they are buried to ultimately alter the mineralogical content of the materials. The concept of diagenesis was developed in geology to refer to the many processes that modify sediments that make up sedimentary rocks following deposition in water (Berner, 1980). In physical anthropology, the term is used specifically when referring to post mortem alteration in the chemical structure of human remains (Sandford and Weaver, 2000). Spaces in the material can be filled when soil minerals percolate into the small crack and pores of bones and teeth. Soluble ions in soil may be exchanged for those that normally occupy lattice positions in skeletal hydroxyapatite. Recrystalization and growth of apatite crystals can occur as minerals are absorbed by the surface of the material (Pate and Hutton, 1988; Sillen, 1989). Typically cations of such elements such strontium, barium and lead take the place of calcium, while

anion substitutions involve hydroxyl (OH^-), phosphate (PO_4^{3-}), and crystalline surface positions (Sillen, 1989). If this process continues for a prolonged period of time, fossilization of the remains occurs as the transformation from biogenic apatite to mineral is completed (Pate and Hutton, 1988).

Taphonomy is defined as the transfer of organic remains back to the lithosphere, and consists of the study of the "processes that operate on organic remains after death to generate archaeological skeletal deposits" (Micozzi, 1991: 3). Factors that influence the taphonomic changes include cultural processes such as intentional disarticulation of the body, scavenging, site soil pH and chemistry, geological processes, hydrology, temperature fluctuations, and the organic content of the material itself (Gilbert, 1977; Micozzi, 1991; Nielsen-Marsh *et al.*, 2000; Pate and Hutton, 1988; Sillen, 1989; White, 2000). Greater porosity, less bone density, larger amounts of amorphous material may predispose a bone to diagenetic change (Buikstra *et al.*, 1989; Lambert *et al.*, 1982). Non-adult bones, for example, often have less mineralised content than do adult bones, and therefore are often completely broken down in situations where adult bone material survives (Buikstra *et al.*, 1989; Sandford and Weaver, 2000). Skeletal chemistry and microstructure effectively ensure that elemental exchange between skeletal material and the burial environment will take place; it is this propensity for ion exchange that makes human remains especially vulnerable to post mortem alteration in elemental composition through contact with most soil types (Lyman, 1996; Pate and Hutton, 1988; Radosevich, 1989).

"Whether minerals are ultimately of dietary, physiological or diagenetic origin, their presence in bone is a product of the interaction between the chemical properties of

the tissue and its environmental milieu" (Sandford, 1995:80). As Katzenberg (1992) points out however, while it is true that bones undergo both taphonomic and diagenetic change post mortem, indicators of such changes can be isolated in Ca/N ratios and amino acid analysis. Sr, Zn and Mg are known to be associated with indicators of dietary patterns, while Fe, Al, K, Cu, Ba and Mn are more mobile and likely to enrich bone during burial (Lambert *et al.*, 1982; 1985a; Van Der Merwe, 1989). One study by Lambert and colleagues (1985a) indicates that a drop in Ca and Na counts is indicative of trace element leaching out of skeletal tissues into the surrounding neutral to alkaline soil in a Woodland sample. Another such study found that hydroxyapatite is insoluble at soil pH of 7.5, but that solubility increases below a pH of 6 (Buikstra *et al.*, 1989). The fact that levels of ion exchange differ in soils of varying pH presents researchers with yet another set of challenges, since in many cases the pH of burial environment is not tested or known.

Difficulties can also arise unless the sensitivity of particular skeletal elements to chemical alteration is considered in a given study. Few trace elements such as Fe and Cu are deposited chiefly in the organic matrix, but most studies look at the inorganic matrix or mineral fraction of a given material (Spadero *et al.*, 1970). Various skeletal elements show differences in chemical signature, and have varying susceptibility to diagenetic and taphonomic processes (Elliot and Grime, 1993; Lambert *et al.*, 1985b; Radosevich, 1989; Richards *et al.*, 2002). Bones such as ribs are generally very porous and are therefore more sensitive to diagenetic and taphonomic processes than a long bone such as the femur that are more compact (Lambert *et al.*, 1982). The particular area of the material sampled can be a factor in assessing how much chemical change has taken place. Any

surface or exposed areas are, of course, in direct contact with the surrounding soil and are more likely to have taken up minerals and trace elements from the environment than those areas located deeper within the material (Buikstra *et al.*, 1989). Also of note is the fact that skeletal elements remodel at varying rates in adults, with the skull and long bones remodelling more slowly than other elements (Buikstra *et al.*, 1989).

The vast majority of studies of diagenetic and taphonomic processes focus on changes in osteological material, while only a handful examine the effects of those processes on dental materials. One such study found that if a tooth is undamaged is virtually sealed to chemical interaction with the burial environment. If the enamel or cementum is deteriorated, however, the exchange of elements will become a factor in the chemical composition of the tooth (Coote and Vickridge, 1988). These researchers also found that F levels in dentin can indicate if taphonomic processes need to be considered when assessing the chemical structure of the tooth.

3.6 Conclusion

Proper diet is a known factor in maintaining an optimal health and nutritional status, and the body stores essential minerals and trace elements in its hard tissues. When an individual dies, those elements remain stored within bones and teeth and if the taphonomic and diagenetic changes associated with burial can be accounted for, those minerals should be reflective of the individual's overall health status and dietary experiences. Since taphonomy and diagenesis affect bones at a much higher proportion than teeth, studies that focus on the elemental structure of teeth should be a relatively reliable indicator of the dietary patterns during the period of tooth formation. Given what

researchers know about the formation of teeth and the chemical structure of the different aspects of dental anatomy, the spatial distribution of minerals throughout the tooth should exhibit changes that mirror changes in subsistence strategies that occurred while the tooth was forming. Based on this assumption, the Fidler Mounds osteological material was examined for gross indications of dietary regime and health status, and a new method of testing the spatial distribution of minerals across the tooth surface was explored.

Chapter 4

Setting the Stage:
The Northeast Plains Periphery

4.1 Introduction

This chapter provides a brief synthesis of the ecological, social and archaeological history of the northeastern Great Plains in order to contextualize the data recovered from the Fidler Mounds material. An examination of the geographic, cultural and temporal distribution of people across the region, within the framework of mound building complexes, is crucial to a more complete understanding of where the Fidler Mounds fit into the culture history of the area.

4.2 Culture History of The Northeast Plains Periphery

Extending from the foothills of Alberta south to the Gulf of Mexico, and from Montana eastward to Iowa and Missouri, the Great Plains cover an area of approximately 1,166, 000 km^2 (Gilbert, 1980; Schlesier, 1994). This study focuses only on a relatively

small area on the northeast periphery of the Great Plains, which straddles the current political border between Canada and the United States of America.

The Great Plains region of North America covers a vast and varied landscape. While not all scholars agree on the exact boundaries of the plains region, it is generally accepted that grasslands of central North America, ranging from southern Alberta to the northeastern shores of Mexico, make up the bulk of the Great Plains. Figure 4.1 shows a general outline of the Great Plains in orange across the continent. The area of concern for this study includes the regions of North and South Dakota, Minnesota, Southern Manitoba and Ontario outlined in black.

4.2.1 The Natural Environment

The northeastern periphery of the Great Plains is an area of grasslands bordered on the north by Aspen Parkland, leading into the Boreal Forests of the Canadian Shield. Along its eastern borders lie the hardwood forests of northern Minnesota and Wisconsin, while to the west the short grass prairies merges with the foothills of the Rocky Mountains. The grasslands extend southward into Texas, and beyond the Rio Grande (Bamforth, 1988; Schlesier, 1994). Weather conditions in the northeast Great Plains are extreme: droughts and floods are relatively commonplace, summer and winter temperatures range from 40°C to -40°C respectively, and winds are persistent and often intense (Gilbert, 1980; Wedel, 1986). Soils in the region tend to be Mollisols, which are very rich in organic matter and have a high natural level of fertility (Scott, 1995). The mixture of grassland and deciduous forests in the northeast periphery of the Plains are

Figure 4.1 The Great Plains of North America

Modified from Gilbert (1980) and Schlesier (1994)

home to thousands of species of vegetation (Bird, 1961; Budd, 1987; Johnson *et al.*, 1995), which in turn supports a considerable variety of terrestrial, aquatic and avian wildlife (Clarke, 1981; Conant and Colling, 1991; Fedoruk, 1971; Peterson, 1980; Wrigley *et al.*, 1974). In short, despite the harsh climatic conditions, the abundance of resources within this region would have made it a very attractive to precontact populations.

4.2.2 Culture History

The constrained spatial and temporal distribution of material culture units has often been assumed to be the product of distinct social groups, and a discrete dispersal in style of artifacts is generally how archaeologists define such boundaries (Conkey and Hastorf, 1990; Hodder, 1982; Jones, 1997; Sackett, 1977). By focusing on the recognition of patterns in lithic and ceramic artifacts from the archaeological record, delimited groups are identified. The issues inherent in classifying social groups based on the remains of the material culture are enormously complex, and beyond the scope of this research. In order to provide a context for the current study, however, some background regarding which groups occupied the northeast Plains periphery over time is necessary. The reader needs to be aware that the groups discussed below have been identified in the archaeological record based on distinct artifact assemblages, and during the Woodland Period they are most often named on the basis of distinctive lithic or ceramic types recovered from archaeological sites. While it may be inappropriate to refer to past peoples by modern names assigned to aspects of their material culture, for ease of identification it has become the norm.

A synthesis of the cultural chronology of the Northeastern Great Plains region is not a straightforward task. The inconsistent use of terminology in the literature makes it difficult for researchers to compare information, since the terms phase, period, tradition, complex, and focus are all used in reference to cultural constructs and timeframes (Badertscher, 1982; Dickson, 1980; Gibbon, 1994; Gryba, 1980; Hlady, 1970a; MacNeish, 1958; Nash, 1969; Wright, 1995). Some of the terminology stems from the cultural taxonomy of the Great Plains, while other phrasing is taken from Eastern Woodlands models. In the northeast Plains, a combination of traits from both of these areas is visible archaeologically, and deciding which terminology is most appropriate becomes difficult. This lack of consistency often results in confusion regarding the intended meaning of the terms used. In some cases, even the names of periods and sub-phases differ between authors. For example, what Nicholson (1987) calls the Sisters Hill Complex is named Caribou Lake by Pettipas (1983). The authors both refer to a single group of people using similar artifact assemblages within one region, yet they use two different names.

Adding to the previously noted difficulties with terminology is the fact that the northeast periphery appears to have been a zone of convergence for the resident cultural groups over time, making it a very dynamic area, both ecologically and culturally. Influences from regions far outside the northeast periphery are noted in the remains of the material culture and burial pattern of groups as they changed over time (Bamforth, 1988; Charles, 1992; Gregg, 1994; Reeves, 1983; Schlesier, 1994; Shay, 1990; Snortland, 1994). This level of diversity within the region has resulted in some difficulty in securely identifying distinct populations who inhabited the region during the Woodland Period.

What follows is a general overview of the main occupation periods and groups that are known to have lived in the area during the Middle to Late Woodland Periods. Cultural groups have been identified that co-existed across the study area during the span of the Woodland Periods, and distinctions are frequently made between groups in the eastern and western areas of the northeast Great Plains Periphery based on artifact assemblages. For ease of understanding, this east-west split will be maintained here. In order to eliminate confusion regarding terminology, this discussion follows the classification systems employed by numerous authors in discussing the culture history of the northeast plains area (Bass and Phenice, 1975; Gibbon, 1994; Gibbon, 1990; Gregg, 1994; Griffin, 1978; Hannus, 1994; Johnson, 1973; Meyer and Hamilton, 1994; Snortland, 1994; Syms, 1979). The term 'period' refers to a chronological division, and the term 'phase', as used here, refers to a defined grouping of distinctive material remains that have been recovered from multiple archaeological sites in a given region. When discussing specific burial patterns within a phase, the term 'complex' is employed. This cultural chronology is by no means exhaustive; it is intended only to provide a general framework within which to examine the material recovered.

4.2.2.1 The Woodland Period

The Woodland Period in the northern Great Plains periphery spans 2,250 years, between 500 BC and AD 1750 (Capes, 1963; Hlady, 1952; Nicholson, 1987; Pettipas, 1983; 1970; Wright, 1995), and is divided into Early, Middle and Late Woodland. The appearance of pottery in the archaeological record marks the end of the Archaic period and the beginning of the Early Woodland period. Early Woodland (500 BC – 100 BC)

on the northern Plains is poorly understood, and known from only a few sites (Johnson and Johnson, 1998). This period is generally characterized by a hunting and gathering subsistence pattern very similar to the preceding Archaic period.

The Middle Woodland Period ranges from 100 BC to AD 600 on the northern Plains (Charles, 1992; Syms, 1978), and the northeastern periphery is influenced by the Hopewellian cultures to the southwest during this time (Griffin, 1978). The construction of burial mounds - large scale mortuary earthen works - and an increase in quality and quantity of pottery are mark the beginning of the Middle Woodland in this region, although the building of mounds is known to have begun much earlier to the south (Birmingham and Eisenberg, 2000; Braun *et al.*, 1982; Hurley, 1974; Orser, 1980). During the Middle Woodland Period the adoption of hunting techniques that developed much earlier to the south and west of the region, such as the use of bison pounds and the atlatl, allows for an increase in population density. This increase is visible in the archaeological record as a rise in the number and density of habitation sites, an increase in trade, and the diffusion of burial mound usage across the region (Charles, 1992; Johnson and Johnson, 1998; Snortland, 1994).

The division between Middle and Late Woodland (AD 600 – 1750) is marked by a period of change in adaptive strategies of people living within the region. Both the number and size of sites visible in the archaeological record increase considerably during this period, which has been interpreted as a corresponding growth in population size (Shay, 1990; Syms, 1977). This period is noted for an increasing efficiency in food procurement, and people followed a wide variety of subsistence strategies (Fawcett, 1988; Gregg, 1985; Shay, 1990). Group trade becomes more highly visible in the

archaeological record, and continues until the time of sustained European contact (Nicholson, 1991; Syms, 1977; 1979).

4.2.2.1.1 The East

The Laurel Phase began at approximately the beginning of the Middle Woodland and continues into the beginning of the Late Woodland Period. Laurel pottery appeared approximately 2,200 years ago, and did not fade out until about 800 years ago (Dickson, 1980). Throughout this period, several varieties of Laurel ware are recognised, based upon the differences in decorative ceramic motifs. This pottery type is characteristically thin-walled, conical shaped, with stamped or impressed decorations around the upper third of the vessel. Laurel groups relied on stone tools, with projectile points that stylistically ranged from side-notched and stemmed to triangular forms (Hlady, 1970a). Other implements in the Laurel tool kit include awls, chisels, scrapers, beads and other objects composed of native copper. It is thought that Laurel cultures had a hunting and gathering subsistence pattern and lived a nomadic lifestyle (Schneider, 1986; Syms, 1977) predominately in the Boreal Forest, but also extending along the northeastern edge of the Great Plains. Laurel burial mounds are located around the Rainy River in northwestern Ontario, (Syms, 1978; Wilford, 1970), in southern Manitoba (Wright, 1967), the eastern Dakotas, and Minnesota (Lass, 1978).

The Blackduck Phase is dated from approximately AD 800-1500, and its diagnostic traits include distinctive pottery that differs from the earlier Laurel vessels in form, technique of production and decoration. During this period there is an increase in the numbers of camps and burial mounds, and a tighter clustering of populations, which

result in some territorial localizing of cultural groups in and around Minnesota (Gibbon, 1994). The ceramic vessels produced during this period were relatively large, had thin walls and the temper was smaller, and less abundant, than in earlier wares (see Figure 4.2). Pots from this period are decorated with cord wrapped object impressions, punctates and linear impressions and are made using the paddle and anvil technique, and localized expressions of Blackduck designs are not uncommon (Mayer-Oakes, 1970; Pettipas, 1983).

Projectile points from this period are shaped with side-notches of several designs, as well as triangular without notches (Badertscher, 1982). Bifaces, end scrapers, scrapers, drills and worked flakes have all been found in the Blackduck tool assemblage.

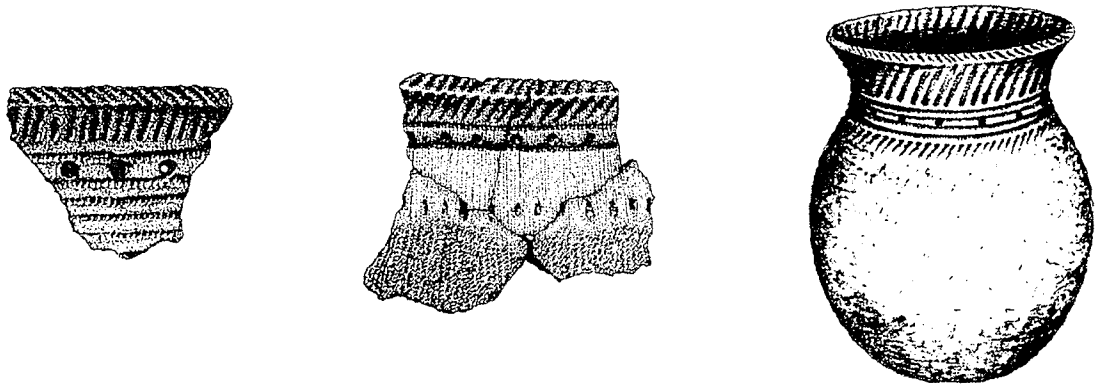


Figure 4.2 Artists Reconstruction of Blackduck Ceramics

Modified From McKinley, 2001:312

Blackduck pottery is sometimes associated with a burial mound complex (Gregg, 1985; 1994; MacNeish, 1958). Such mounds often contain individuals buried in a seated position, with grave goods placed in deep cylindrical pits within mounds and no evidence for secondary burials (MacNeish, 1958).

The Arvilla Burial Complex begins during the Blackduck Phase and its temporal range is from AD 550 to 1250 (Syms, 1982), but the vast majority of mounds within this category are dated between 600 – 900 AD (Johnson, 1973). Found in Minnesota, North and South Dakota, and southern Manitoba, these mounds are normally located along beach strands left by the receding waters of glacial Lake Agassiz, but a few have been found on surrounding points of land as well (Johnson, 1973). This complex is characterized by linear and circular burial mounds underlain by deep pits containing complete and disarticulated primary, secondary, and intrusive burials with a variety of associated grave goods (Johnson, 1973; Syms, 1982). Burial orientation is not well defined in this complex and there appears to be no pattern to the distribution of bodies within the mounds, however red and yellow ochre are frequently found scattered over the remains (Johnson, 1973). The grave goods within Arvilla mounds consist of distinctive miniature mortuary vessels with textile impressed surfaces, pottery elbow pipes, and high quantities of shell, bone and antler ornaments (Johnson, 1973; Syms, 1982).

The Selkirk Phase is the terminal precontact phase in this region. It dates from 1000 to 1800 AD, and ends with the beginning of the fur trade (Hlady, 1970b). It is defined by its small round or oblong end scrapers and a proliferation of Prairie Side Notched, Selkirk Notched, and Eastern Triangular projectile points. All of these point types are small enough to have been used with a bow and arrow. Bone tools are more common from this period than any other, however this may be a reflection of taphonomic factors. Pottery dating to this period is globular in shape, has flattened lips, out-flaring rims, angled shoulders, and is manufactured using the paddle and anvil technique (Mayer-Oakes, 1967; Nicholson, 1987). Decoration consists of fabric impressions and

simple punctates along the rim. Burial mounds are thought to have fallen into disuse during this period, as historic groups at the time of European contact had no recollection of their ancestors interring their dead within mounds (Birmingham and Eisenberg, 2000; Gregg, 1985; Orser, 1980; Silverberg, 1974).

4.2.2.1.2 The West

The Pelican Lake Phase (1000 BC – 1 AD) began during the Archaic Period, but continued throughout the Early Woodland and into the Middle Woodland on the western edge of the Northeast Plains periphery. Pottery belonging to the groups who lived during this time has been identified by MacNeish (1958), but geographic distribution, high bison content in faunal assemblages, and its distinctively barbed and corner notched Pelican Lake projectile points (see Figure 4.3) are the signature traits of this phase (Pettipas, 1983). The nature of Pelican Lake campsites found in the northern plains suggests a pattern of primarily nomadic bands coming together seasonally for bison hunting. Burials dating to this time frame are poorly documented (Griffin, 1952), but one study suggests that groups occupying the region during this period interred their dead in naturally occurring mounds of sand and gravel, with modest grave goods and a sprinkling of red ochre (Morgan, 1952).

The Besant Phase follows the Pelican Lake in the western areas of the Northeastern Great Plains. Known from sites in Manitoba, Saskatchewan, Alberta, Montana, the Dakotas and Minnesota, this phase dates to between AD 1 and AD 1000 (Gregg, 1994; Johnson and Johnson, 1998). According to Nicholson (1987), the Besant Phase is defined by the introduction of the atlatl, Besant Side-notched points, and the bow

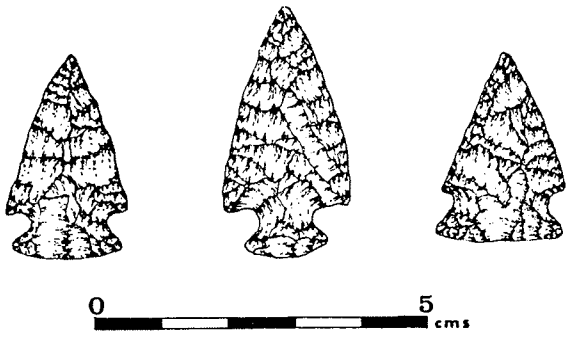


Figure 4.3
Pelican Lake Projectile Points
From Pettipas, 1983: 75

and arrow with Samantha Side-notched points. Groups that lived during this period also made use of unnotched points with convex or straight body edges and obtuse shoulders; small, well made triangular or rectangular scrapers were also a part of the Besant toolkit (Reeves, 1970). Ceramic pots from these sites are shoulder-less conoidal vessels with straight walls and rounded bases (Gregg, 1994; Hannus, 1994). Evidence from sites across this area indicate that people affiliated with this phase were nomadic peoples who came together seasonally to hunt bison in pounds and traps (Gregg, 1985; Pettipas, 1983).

Within the Besant Phase is the Sonota Burial Complex, which is thought to have developed in response to the influences of the Hopewell to the East (Gregg, 1985; Johnson and Johnson, 1998; Syms, 1978). While some present Besant and Sonota as distinct cultural groups (Gregg, 1985; 1994; Neuman, 1975; Pettipas, 1983), the lack of evidence for demonstrated cultural differences noted by others (Johnson and Johnson, 1998; Reeves, 1983; Vickers, 1994) suggests that the Sonota Burial Complex represents the burial practices of Besant groups within the region. This mortuary complex is characterized by the construction of elaborate circular burial mounds built on the natural ground surface, with grave goods including objects obtained through trade, and the inclusion of large numbers of bison crania or skeletons within the mound (Neuman,

1975). Normally found on the edges of a high terrace or valley edge overlooking a river, many of these mounds are located near camp areas (Neuman, 1975; Syms, 1978). Sonota burial mounds contain large oval sub-floor burial chambers which are centrally located, contain multiple bundle burials as well as partially articulated remains, with evidence for intentional post-mortem disarticulation (Hannus, 1994; Neuman, 1975). Both sexes and all ages are represented within these mounds, and most of the burial pits were covered by burned or unburned logs (Hewes, 1949; Neuman, 1975).

The Avonlea Phase begins slightly later than Besant in this region, and is dated between AD 100-1200 (Hannus, 1994; Joyes, 1988). Small, finely made, corner-notched projectile points are occasionally recovered as isolated finds from Avonlea sites (Nicholson, 1987). Reeves (1970) identifies these points as belonging to the Head Smashed-In category, with barbed shoulders, a convex or straight body, and edges that may be serrated. They are thin, sharp, and very finely worked. The pottery of the phase is conoidal in shape, and decorated with fabric impressions, bosses or punctates (Pettipas 1983; Reeves 1970). Surfaces are net impressed, decoration is simple and minimal (see Figure 4.4). Settlement and subsistence patterns during this period are intricately linked with the hunting of bison and other woodland game, and settlement types include bison

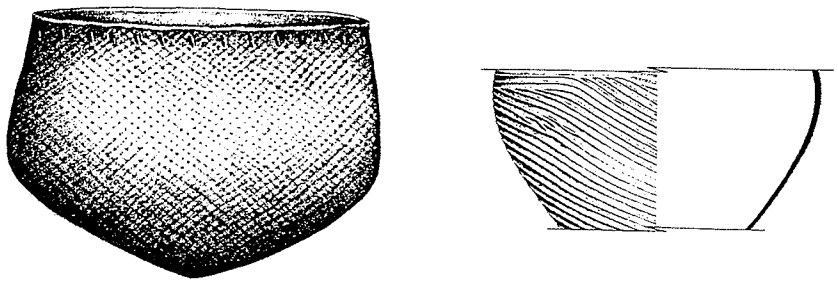


Figure 4.4 Artists Reconstruction of Avonlea Ceramic Vessels

pounds, jumps and traps, camps on stream terraces (Gregg, 1994).

The Plains Village Phase began at approximately 900 AD and was maintained until the time of sustained European contact (Gregg, 1994; Wedel, 1978). This period is characterized by a change in lifeway from subsistence patterns based on horticulture and hunting and gathering, to fixed, semi-permanent villages near floodplains (Gregg, 1994). Evidence for the intensification of horticulture and a reduction in the level of mobility stems from the discovery of large storage or refuse pits, bison scapulae hoes, and villages fortified with simple ditches and palisades (Blakeslee, 1994). This phase demonstrates several Middle Missouri variants and influences, including the use of earth lodges, a well developed bone tool industry, as well as the beginnings of ground stone technology (Gregg, 1985; 1994; Wedel, 1978). Ceramics from this period are predominantly round bottom jars, with smooth interiors and cord marked, stamped and brushed exteriors. Arrow points from the Plains Village Phase are finely manufactured, with the widest point above the side notches (Blakeslee, 1994). Gregg (1994) argues that direct, in-ground interment with marked burial grounds begin during this period, and that scaffold burials were the most common burial type, with some secondary burials in large pits and re-use of old mounds.

The Devil's Lake-Sourisford Burial Complex is dated between AD 950 and 1400, and while Gregg (1985) asserts that this complex falls within the Plains Village Phase, Syms (1979) argues that this pattern of burial was used by bison hunters who interred their dead in mounds seasonally. This complex is confined to central and northern portions of North Dakota, southwestern Manitoba, and southeastern Saskatchewan, and is generally confined to areas west of the Red River (Syms, 1979). The identifying

characteristics of the Devil's Lake-Sourisford Burial Complex are exotic burial goods, such as miniature ceramic vessels, whelk shell gorgets, beads, pendants, tubular catlinite pipes and beaver-tooth gouges. Also commonly found are copper bands and beads, flat incised tablets with animal motifs carved into them, and curved bone bracelets and wrist guards (Syms, 1978; 1979; 1982). Burial pits are frequently log covered or capped by clay tablets (Syms, 1982), however the primary mode, or modes, of burial for this complex have not been identified.

4.3 Mounds in the Periphery of the Northeastern Great Plains

The initiation of the construction of burial mounds in the northeast periphery most likely developed as a result of influences from further south and east, and specifically from the Ohio Valley area of the United States. The Early Woodland Adena peoples are one of the most well-documented and prolific mound builders of their period in the Ohio Valley region (Griffin, 1978; Morgan, 1952). They developed circular earthen enclosures that contained log-covered pits or chambers that often contained the cremated remains of individuals (Birmingham and Eisenberg, 2000; Griffin, 1978). Grave goods were common, and while males received preferential treatment in terms of grave location, children were buried with a greater number of objects (Griffin, 1978). The Hopewell culture is thought to follow the Adena very closely chronologically, and mound building in the Ohio Valley reached its peak at this time. Massive geometric earthworks covered vast tracts of land, and large clusters of burial mounds were often enclosed within these constructions (Birmingham and Eisenberg, 2000; Shaffer, 1992). Mounds were large, and often covered "single or multiple mortuary structures or charnel houses" (Griffin,

1978: 246), and secondary interments in the form of bundle burials have been uncovered in numerous Hopewell mounds (Shaffer, 1992). Hopewellian grave good were numerous, ornamental and appear to have had 'prestige' value (Birmingham and Eisenberg, 2000). It is most likely that as people moved north and west over time, and as contact between groups increased as a consequence of the widespread ceremonial exchange network of the Hopewell, the concept of mound building spread into the northeastern Great Plains periphery. Similarities in pottery styles between regions have been noted, and certainly there are resemblances between the form of mounds in the northeast Great Plains and the Ohio Valley area (Birmingham and Eisenberg, 2000; Braun *et al.*, 1982; Griffin, 1978; Struever and Houart, 1972).

Native burial mounds have been excavated and looted since the early days of European colonization, and were sought out by explorers, antiquarians, and curiosity-seekers of all manner for their treasures (Bell, 1885b; 1887b; 1895; Birmingham and Eisenberg, 2000; Bryce, 1890; Gregg, 1985; Harf and Tamplin, 1886; Lewis, 1895; Montgomery, 1906). In the context of burial mounds in the Northeast Plains, this type of excavation dominates the early history of archaeological research. While notions of a society of Mound Builders (Bryce, 1890; 1904; Charles, 1992; Harf and Tamplin, 1886; Krause, 1995; McCharles, 1887) have fallen away in scholarly circles, questions do remain regarding who actually built and used many of the burial mounds in this region.

As with the relationships between groups in this region, relatively little is known about the specifics of mound burials in the northeastern periphery of the Great Plains of North America. Thousands of these mounds are documented in the literature (Birmingham and Eisenberg, 2000; Braun *et al.*, 1982; Capes, 1963; Charles, 1992;

Gregg, 1985; Hewes, 1949; Johnson, 1973; Kenyon, 1986; Krause, 1995; Lass, 1978; Lothson, 1967; Syms, 1979; Syms, 1982; Wilford, 1970; Wilford *et al.*, 1969); many of which have been studied extensively. Questions remains however, regarding specifics such as who made use of the mounds, at which times during the past this type of burial practice was employed, and what the significance of the mounds may have been. The generally poor level of preservation of human remains from within such mounds has also led to a paucity of information regarding the health and biological characteristics of people interred there.

A burial mound, like a historic cemetery, should generally contain the remains of the people who lived in the surrounding areas over the period of its use. These may include any of the permanent inhabitants of the immediate vicinity or people who visited the area seasonally. Alternatively, specific selective criteria may have been employed to determine who was interred within the mound and who was not. Determining with confidence who the builders of any given mound were however, is enormously challenging, and in many instances, simply not possible. Though the cultural classification of burial mounds is fraught with difficulties, the primary function of such mounds is something upon which many scholars appear to agree.

4.3.1 Mounds as Cultural Constructions

Disposal of the dead is a culturally regulated process in all societies, but it is by no means uniform. Since the groups inhabiting the northeastern plains prior to European colonization are thought to have been primarily nomadic or semi-nomadic, it is suggested that the purpose for creating such burial mounds may have served to encourage socio-

cultural cohesion within or between groups (Charles, 1992; Kenyon, 1986; Syms, 1978). If the ultimate function of the mound construction was to serve as a focal point for social gathering and cooperative behaviour through communal interment of the deceased, the existence of such features across the landscape becomes more comprehensible. "Mutually intelligible mortuary ritual would have served to legitimate community membership and territorial claims within the region" (Charles, 1992:191).

The physical construction itself may not have been the most important aspect of the mounds; it is likely that the rituals and ceremonies associated with them were more meaningful and valuable (Lass, 1978; Orser, 1980). Both familial and community sentiment can be strengthened by participation in common social activities, and some authors argue that mound ceremonialism was the centre of an integrative mechanism that united groups through the sharing and reinforcement of common values and expectations (Mallam, 1976). This would have been of particular importance for small, dispersed bands who would have met only periodically during the year.

Support for this argument stems from an analysis of the orientation of burial mounds in southwestern Manitoba. This study demonstrated that the consistency in site choice for burial mounds in the area reflects "the cosmology of the builders and their understanding of sacred landscape" (Nicholson, 1994:161). Nicholson argues that the alignment of several burial mounds in the southwest corner of the province is similar to the sunrise of both the winter and summer solstices, and that this patterning of mound location was intentional and culturally determined. Yet another line of corroboration for the argument that burial mounds served multiple ideological purposes comes from analogies with historic groups at the time of European contact. Forager groups in the

area around Sault Saint Marie in Ontario are known to have carried out joint ceremonies centred around the Feast of the Dead (Hickerson, 1970; Lass, 1978). Held every eight to twelve years, distinct groups united for this ceremony, which served as a platform to relieve tensions between them, to reaffirm alliances and to trade: meetings of Woodland groups to bury their dead within mounds could have served a similar purpose (Mallam, 1976).

As groups interacted they undoubtedly influenced one another's cultural practices and ideology (Caldwell, 1964; Struever, 1964; Struever and Houart, 1972; Syms, 1977). This kind of interaction allowed for the spread of material cultural traits, which remain visible in the archaeological record and allow researchers to examine the patterns of inter-group relationships. The similarities in mounds across the northeastern Great Plains as a whole may indicate that the general practice was one of the basic tenants of spiritual and social life during the Plains Woodland period, and regional differences may reflect localized variation in style and implementation (Charles, 1992; Kenyon, 1986; Syms, 1978). It is primarily upon the basis of these differences and similarities in aspects of construction and content that mounds are examined and categorized archaeologically. Much in the way historical archaeologists examine changes in tombstone designs over time, the shape, geographical distribution, and types of artifacts found within mounds, and the pattern of burials themselves, can allow modern researchers to examine the outcome of this culturally-driven behaviour of past groups.

4.3.2 Distribution

Burial mounds have been investigated since the first Europeans made their way into northeastern Great Plains, yet the number of burial mounds that exist within the region is still not certain. This researcher could find no comprehensive study of the burial mounds in the area, and most authors appear to concern themselves only with mounds that exist within modern political boundaries or those assigned to a particular burial complex. Vickers (1948) lists the number of mounds in Manitoba at approximately 90, while Syms (1978) estimates the number at just over 200. In Minnesota, 25,000 are thought to have existed during the precontact period, but due to agricultural practices, only about 7,700 remain (Lothson, 1967). Johnson (1969) is more conservative in his estimate, stating that approximately 10,000 mounds once covered Minnesota. There were 21 known mound *groups* in the Rainy River area of northwestern Ontario when the Great Mound was excavated in 1884 (Bryce, 1904). Maps of burial mound groupings exist for the Dakotas (Johnson, 1973; Lewis, 1886; Neuman, 1975; Ossenberg, 1974; Syms, 1979), but estimates of the number of burial mounds within those states could not be located. Adding to the confusion regarding the quantity of mounds in the area is the problem of 'false mounds' as noted by Syms (1979). Suffice it to say that thousands of burial mounds dating to the Woodland Period once dotted the northeast Great Plains landscape, and the major groupings are noted in Figure 4.5.

Patterns within the geographic distribution of burial mounds are apparent. Regardless of the type of mound (see discussion below), burial mounds follow the major waterways of the region very closely. In Manitoba, the vast majority of burial mounds are close to the edge of a river valley, but also can be found on high hills (Syms, 1978).

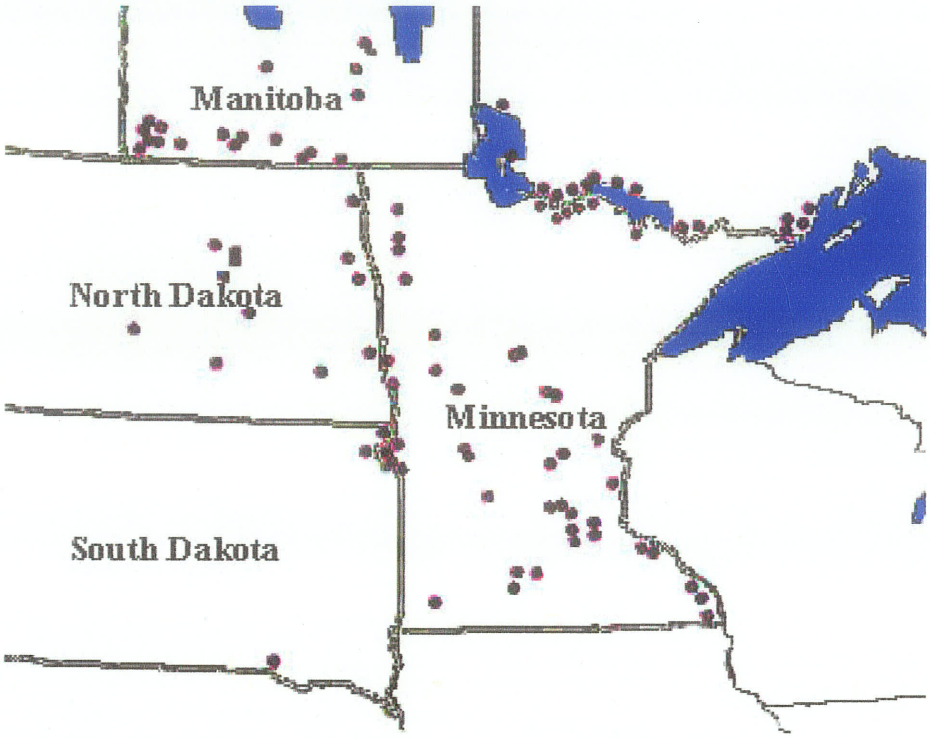


Figure 4.5 Distribution of major mound groups in the northeast Great Plains

Modified From Birmingham and Eisenberg (2000); Capes (1963); Charles (1992); Hurley (1974); Johnson (1973); Kenyon (1986); Lewis (1886); Lothson (1967); Neuman (1975); Nicholson (1994); Salzer (1974); Struever and Houart (1972); Syms (1978; 1979; 1982).

Kenyon (1986) reports that this choice of location holds true for Ontario mounds as well. More specifically, in Ontario, burial mounds are often located on points of land rather than in sheltered bays, and are virtually always placed so that they overlook broad stretches of water, on the highest elevation possible within the selected area (Kenyon, 1986). In Minnesota, 98% of mounds fall within 2.4 km of a large stream, lake or river (Lothson, 1967), and when travelling by water throughout the state it is impossible to cross any major river without being surrounded by burial mounds (Lothson, 1967; Silverberg, 1974).

4.3.3 Variety of Form and Burial Mode

A variety of mound forms exist within the Great Plains northeastern periphery, and often the different types are found together as a group. Linear mounds are long raised tumuli, and there are two types: linear grade and linear composite (Syms, 1978). Linear grade mounds are relatively simple mounds that follow a straight line, while linear composite mounds are long straight mounds of earth with rounded mounds at each end (see Figure 4.6). Circular, or rounded, mounds are the most common type across the northeast plains (Birmingham and Eisenberg, 2000; Capes, 1963; Gregg, 1985; Johnson and Johnson, 1998; Johnson, 1973; Kenyon, 1986; Lass, 1978; Lothson, 1967; Syms, 1978; Vickers, 1948; Wilford, 1970; Wilford *et al.*, 1969). They are usually constructed through the repeated heaping of dirt over one or more sub-surface burial pits, vary greatly in height, and can contain the remains of large numbers of individuals (Blakeslee, 1994; Johnson, 1973; Kenyon, 1986; Lass, 1978; Lothson, 1967; Orser, 1980; Syms, 1978; 1979; 1982; Wilford *et al.*, 1969).

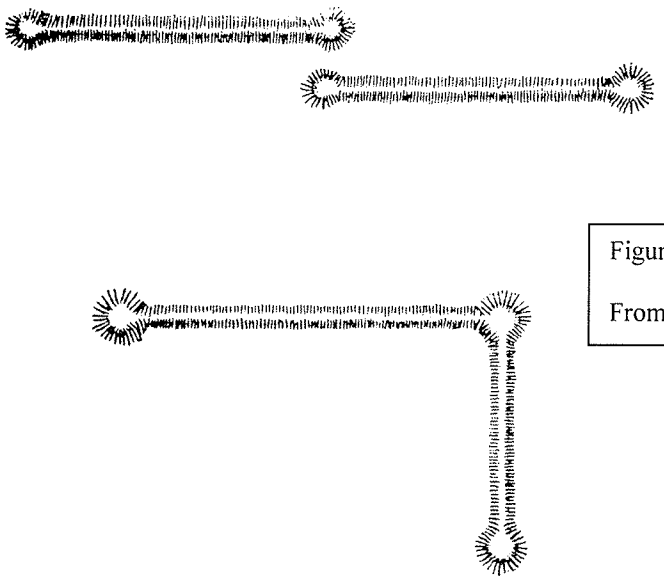


Figure 4.6 Composite Linear Mounds

From Pettipas (1983:117)

Effigy mounds are most common in Wisconsin and Minnesota (Johnson, 1969), however two possible effigy mounds have been noted in south-western Manitoba (Syms, 1978). Located in clusters along lakes, beside rives and on hilltops, and found in very large groups, nowhere else in the world are such mounds found in such high concentrations. These mounds are usually very low, only a meter or less in height, but have enormous aerial linear proportions (Mason, 1981). Shapes vary, but flying birds, fish, deer, turtles, or bears are common; the animal shape is thought to represent the totem of individuals interred within the mound, and their connection to one of the natural realms (see Figure 4.7) (Hurley, 1974; Mason, 1981). Burials are normally located in the head or heart region of the animal, and flexed, bundled or cremated burials are the most common (Birmingham and Eisenberg, 2000). Burial pits are sometimes covered with bark, mats, wooden logs or skins, and clay hearths or altars have also been noted (Lass, 1978; Mason, 1981). Grave goods are sparse, and usually consist of utilitarian items.

Burial mode is as variable as mound form, but all modes of burial are represented in mounds across the northeastern Plains periphery, and more than one form is normally found within a given mound. Burials can contain the remains of a single individual or multiple individuals. They can be primary burials, which means that the body was interred in 'fleshed' condition, or secondary, which means that the body was allowed to decompose somewhat in a different location before being interred in its final resting place. The positioning of the body itself is highly variable. People can be laid with the body stretched out prone, partially or fully flexed in a lying or seated position, or their remains can be bundled after being disarticulated. In some cases, there is no orientation at all, and bones are found scattered within a burial pit, or in cases of disturbed mounds,

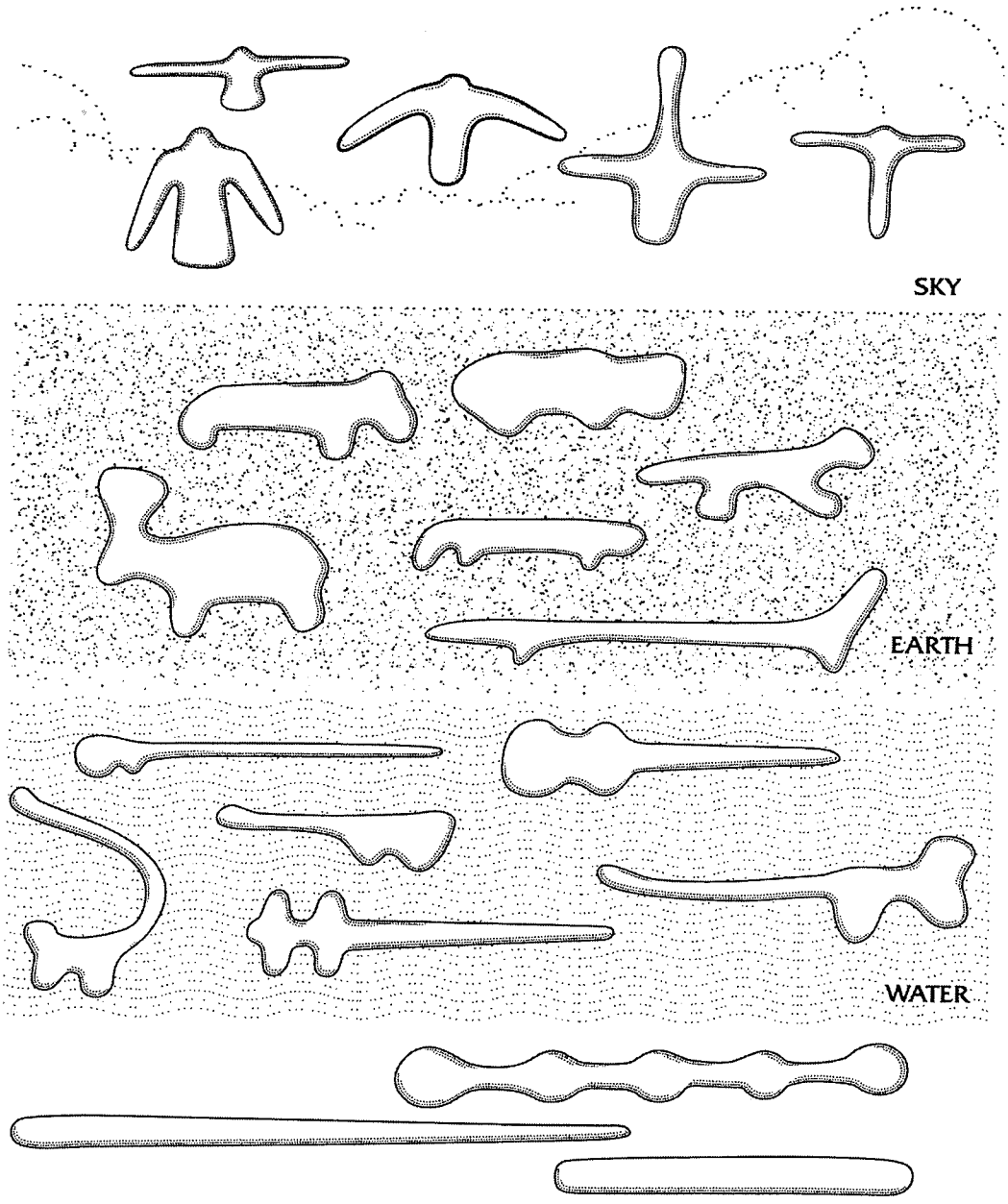


Figure 4.7 Mound forms thought to represent the natural realms.

From Birminghan and Eisenberg (2000:114).

throughout the mound fill. Bodies are found both wrapped in some material or left exposed, and can be purposefully prepared for burial or simply set into the grave without

preparation. Burials can be inclusive in a mound, being set there at the time of construction, or they can be intrusive (dug into the mound after its initial period of use). Burial pits themselves can be lined with materials or covered, or left exposed before dirt is placed atop of them, and they can contain gave goods or nothing except the body itself.

Over time the preferred mode of burial can change dramatically within groups, and mounds can be reused both by descendants of the people who created the mound initially, or by other groups in the area. In this way, burial mounds are accretionary features, built up over time and repeated use (Birmingham and Eisenberg, 2000; Blakeslee, 1994; Charles, 1992; Gregg, 1985; Kenyon, 1986; Mallam, 1976; Nicholson, 1994; Silverberg, 1974; Wilford, 1970; Birmingham and Eisenberg, 2000). For example, during the Middle Woodland period primary burials appear to have been rare occurrences, but by the period of Late Woodland burial mound usage, primary burials were the preferred burial mode (Johnson, 1969). Mounds can also be re-used by groups unrelated to the original builders. During historic times, for example, the Sioux, Dakota, Potawatomi and Ho-Chunk all interred their dead in existing mounds during epidemics, when the numbers of dead demanded timely disposal of remains (Birmingham and Eisenberg, 2000; Johnson, 1969; Wilford *et al.*, 1969)

4.4 Conclusion

Opinions differ significantly regarding the cultural and temporal meaning of the Fidler Mounds and their role in the culture history of the northeastern Plains as outlined above. Until recently only a single uncalibrated radiocarbon date was available from the site that derives from charcoal from the central burial chamber (380 ±80 bp Lab S-225)

(Rutherford *et al.*, 1984). This led to the general perspective that the Fidler Mounds predated the arrival of the first Europeans by only a small margin, and few authors have questioned the validity of a single date. This date firmly placed the Fidler Mounds within the Late Woodland period, when Blackduck and Selkirk peoples (among others) are known to have inhabited the region.

Syms (1978; 1982) assigns the Fidler Mounds to the Devil's Lake Sourisford Burial Complex, based primarily upon the recovery of artifacts from the mound fill, in conjunction with the single available radiocarbon date. Johnson (1973), however, argues that the artifacts recovered are more indicative of an affiliation with the Arvilla Burial Complex. Due to the similarity in artifact assemblages used to define these complexes it is has proven difficult to assign these mounds to a single burial complex, and there is new evidence, which will be discussed below, to indicate that both authors may be correct.

Chapter 5

Materials and Methods: Examining the Recoveries from Fidler Mounds

5.1 Introduction

The intentional excavation of known burial mounds, outside of cultural resource management mandates, is uncommon in modern archaeological investigations but this reluctance is a relatively recent phenomenon. Mound excavation has evolved over the years in several stages. Early on, unorganized excavations were aimed primarily at the acquisition of collector's items, usually in the form of grave goods or human crania. These practices slowly gave way to semi-professional and then professional excavations, where data was methodologically collected and traits analyzed for indicators of cultural practices between and within groups. More recently, debate surrounding the ethics of recovering and analyzing human remains in North America has effectively halted such activities. However, by examining materials recovered in earlier excavations, and undertaking more detailed analyses than were possible when these remains were first

uncovered, researchers are continuing to develop new ways of looking at the lives of past populations.

5.2 The Fidler Mounds

Burial mounds have been documented in Manitoba history since the late nineteenth century (Bell, 1885b; Harf and Tamplin, 1886; Lewis, 1886; McCharles, 1887), and the Fidler Mounds are first noted in the literature by Donald Gunn (Gunn, 1868). The Fidler Mounds Site, EaLf-3 in the Borden designation system of Canadian archaeological sites, is located on the east bank of the Red River, approximately 19 km north of Winnipeg, Manitoba. There were two burial mounds at the location, set several meters apart and aligned in a north east-south west orientation to one another.

5.2.1 History of Excavation

There have been five documented excavations of the Fidler Mounds site over the last two centuries. The first took place in 1866 when a resident of the area dug into the edge of Mound Two in order to construct a root cellar (Gunn, 1868). In 1879, Bryce excavated portions of the Fidler Mounds, but details regarding the recoveries are scarce (Capes, 1963; Syms, 1978). The next documented opening of the mounds took place in 1885, when Bell excavated parts of both Mound One and Two, and McCharles excavated the central portion of Mound Two (Bell, 1887a; 1895; McCharles, 1887). Most recently, a team of archaeologists from the University of Manitoba excavated the majority of Mound One and half of Mound Two in an operation designed to salvage any human

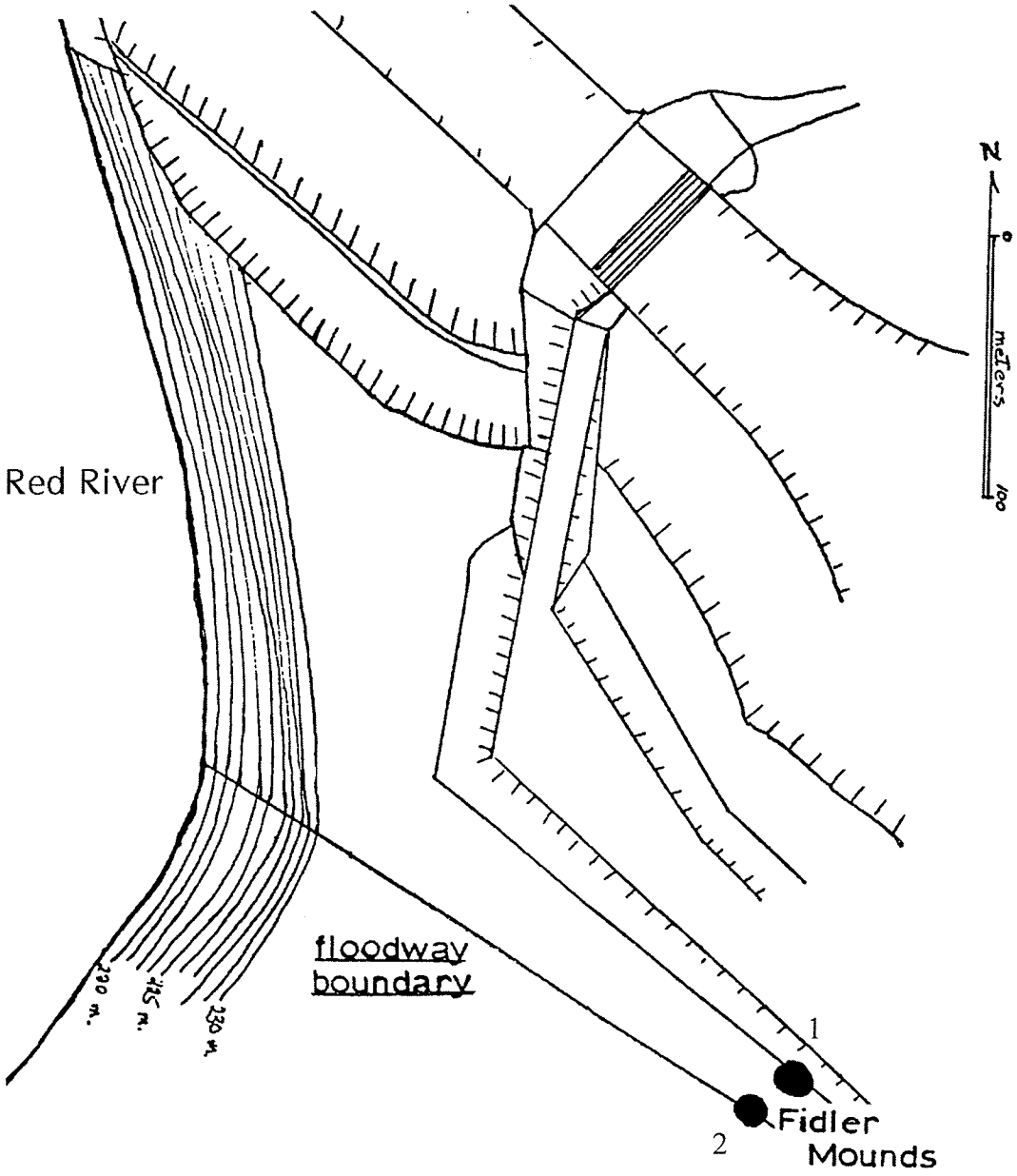
remains and artifacts prior to the destruction of the mounds during a major construction project.

5.2.2 The 1963 Salvage Operation

During the summer of 1963, the City of Winnipeg began construction on the Greater Winnipeg Floodway. Fidler Mound 1 was fully situated on the property designated for development, while Mound 2 straddled the border of the floodway and land that was privately owned (see Figure 5.1). In an attempt to salvage the human remains and artifacts that the mounds contained, a team of archaeologists and students from the University of Manitoba excavated 70% of Fidler Mound 1 and approximately 50% of Mound 2 (Fiske, 1963; 1964; 1965b; 1965a; Mayer-Oakes, 1964). The south west half of Mound 2 was situated on private property at the time and permission to excavate that section was not obtained (Fiske, 1963). At the time that the 1963 excavations began, Fidler Mound 1 was 19 metres in diameter and Mound 2 measured approximately 17 metres across (Fiske, 1963). Both mounds were trenched at the beginning of the field season using natural levels where possible and arbitrary levels where it was not; areas of further interest were then gridded and excavated by hand using shovels and trowels (Fiske, 1963). It was known from the history of the area that the upper central portions of both mounds had been highly disturbed by prior looting and excavation, however the lower levels and peripheral areas were thought to have been less disturbed. All material recovered from the mounds was taken to the University of Manitoba Anthropology Laboratory, where items were cleaned and curated.

Figure 5.1 Area of Development for Winnipeg Floodway

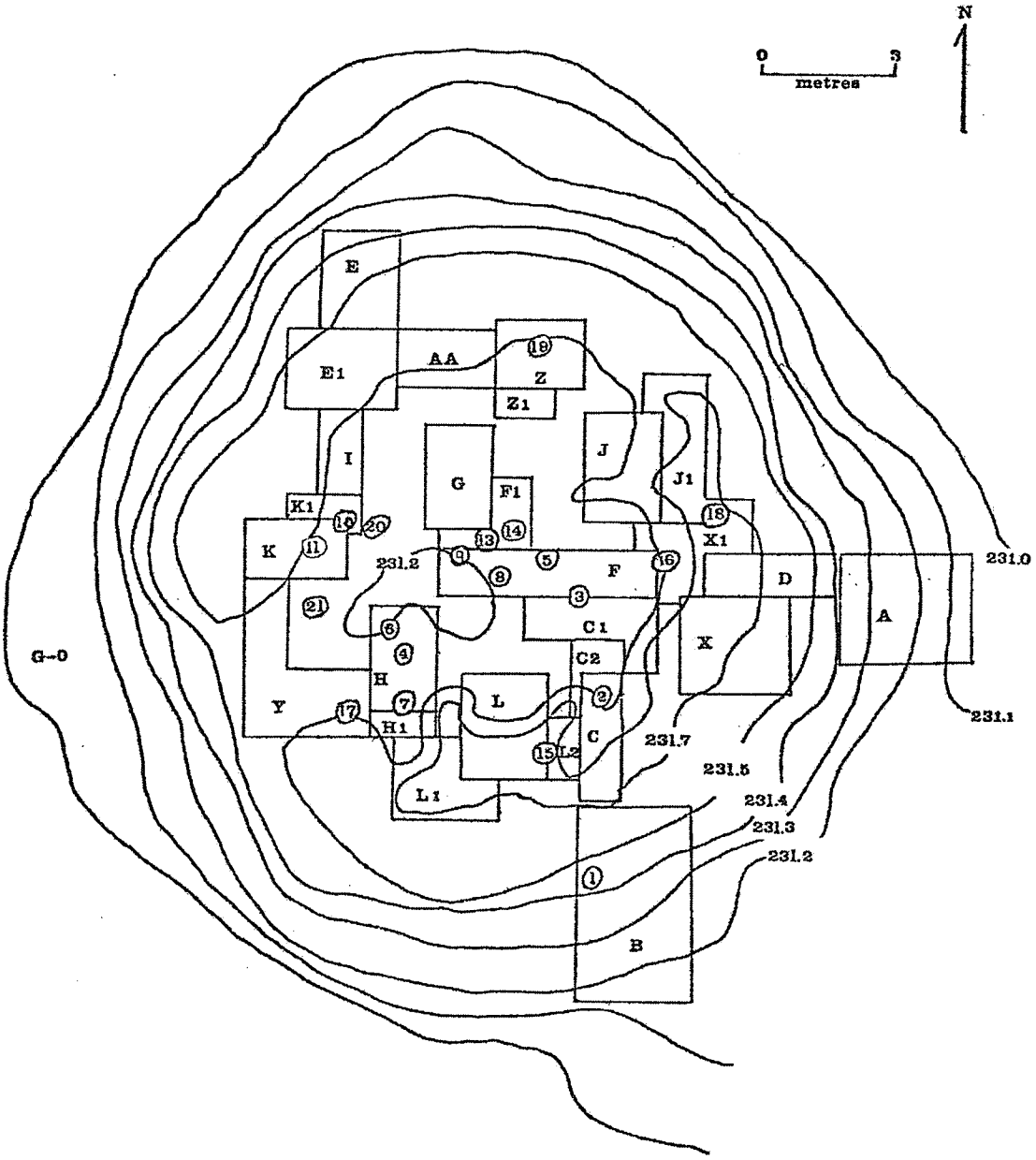
Adapted From Unpublished Map on File University of Manitoba Anthropology Laboratory



5.2.3 The Burials

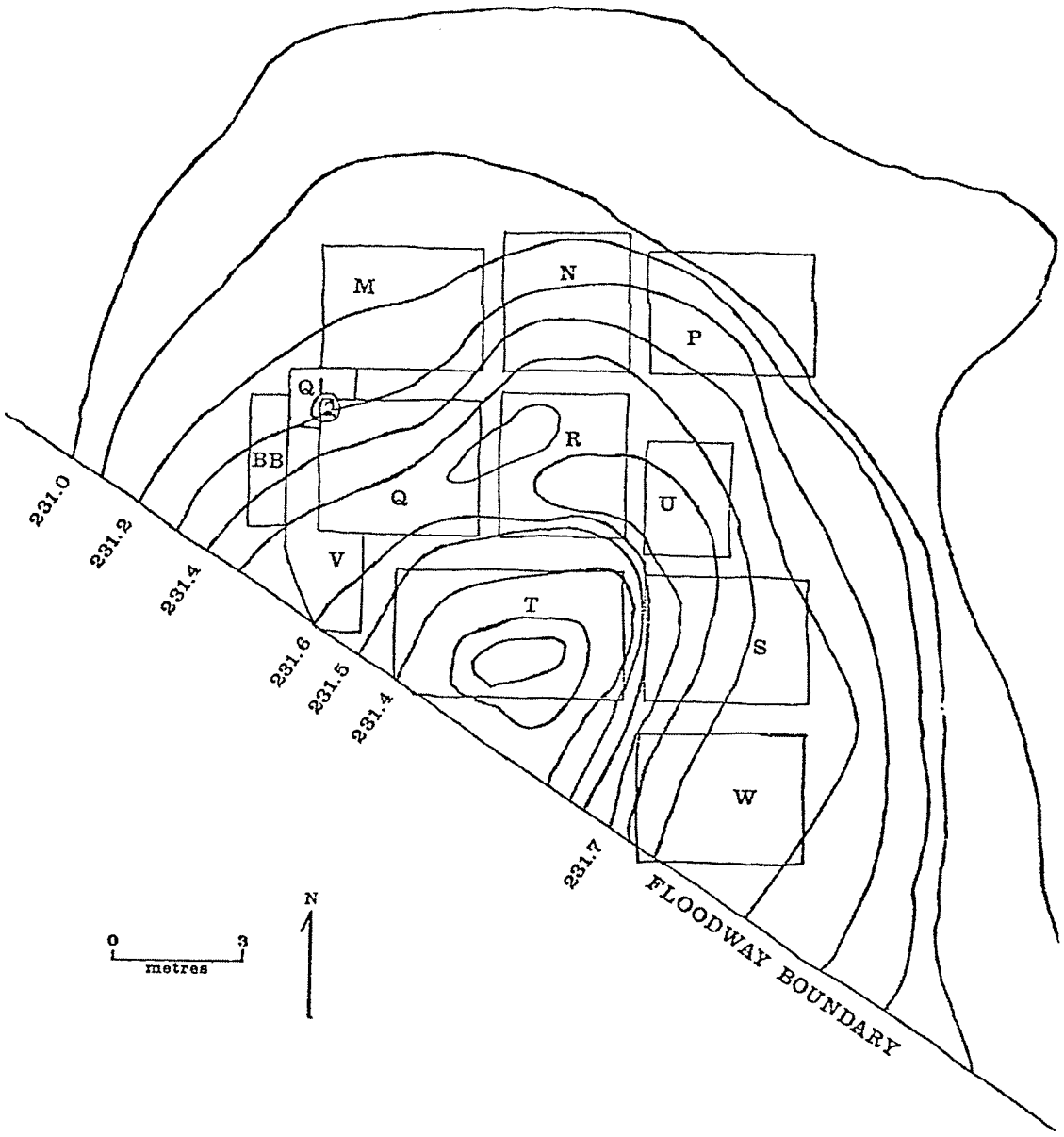
The remains recovered from Mound 1 were recovered from twenty discrete burials, containing bones from forty-six individuals (see Figure 5.2). Another seventeen

Figure 5.2 Fidler Mound 1 From Saylor 1976:18



individuals are represented in skeletal material recovered from the mound fill, along with an additional 1685 unidentified human bone fragments. Mound 2 recoveries were much more sparse; only one discrete burial was uncovered in the section excavated (see Figure 5.3). Bones from three other individuals were recovered from the fill of Mound 2, as

Figure 5.3	Fidler Mound 2	From Saylor 1976:27



were forty unidentifiable human bone fragments. Discrete burials were numbered in the order they were uncovered, and are noted in Figures 5.2 and 5.3.

Burial types documented during the 1963 excavation include primary and secondary; single and multiple; flexed and extended; sitting and prone; in mound fill and in subsoil pits; and burials with grave goods and/or red ochre, and some without either (Mayer-Oakes, 1964). The most common burial pattern in the apparently undisturbed areas of Mound 1 was interment in an intrusive subsoil pit with both primary and secondary burials (Fiske, 1963). Previous burial types noted at the Fidler Mounds include oak logs covering seated burials (Bell, 1885a; 1895; 1898; Gunn, 1868), bundle burials (Bell, 1885a; Bell, 1895), and extended supine burials (McCharles, 1887).

In fourteen of the twenty-one discrete burials, the outline of a grave remained visible; they were "oval or rounded, tapered inward as they deepened and most went for some depth into the subsoil" (Saylor, 1976:35). Eleven of the fourteen burials found in graves were primary, one comprised both primary and secondary, two were secondary bundle burials, and one was indeterminate.

Saylor (1976) reports that the relationship of the burials to the natural ground surface ranged from 43 cm above it to 130 below, with a mean of 44cm DBS. Most of the burials lay on or within the 231.7 elevation level, which may have represented the rim of the original mound. The orientation of the burials was quite varied. Of the secondary bundles, two lined up in a north-south direction and one was oriented east-west. Three of the primary burials lay in an east-west orientation facing south, and one faced north; six lay along a north-south axis, two facing west and one facing east – notes regarding the other three are inconclusive. Two of the three seated burials faced north and the other north east (Saylor, 1976).

5.2.4 Artifacts Recovered

As the primary focus of this research centred on the human remains from the Fidler Mounds, only a brief overview of the cultural material recovered will be addressed in this study. Saylor (1976) presents a more detailed discussion and analysis of the artifacts collected.

Over one thousand potsherds, sixteen projectile points, one hundred and seven scrapers, fifty-two other lithic tools, eight historic artifacts, two bone bracelets, a bird bone whistle, as well as trade and modern material were recovered during the 1963 salvage operation (Fiske, 1963; 1965a; Mayer-Oakes, 1964). Very few artifacts were recovered in direct association with burials. Despite published reports linking a small ceramic mortuary vessel with one of the discrete burials (Garvie, 1993; Johnson, 1973), the original excavation notes indicate that this item was recovered from the fill of Mound 1.

Of the artifacts recovered in direct association with burials, it appears that the two bone bracelets were recovered with, or from the area around, burial number four, and that a single Trumpeter Swan ulna whistle was recovered in direct association with burial number seven. A worked antler was recovered from the lumbar region of burial eleven, and three pieces of a pottery pipe were found in direct association with burials seventeen A and B. Bone tools were associated with burials two, six, ten, eleven, fourteen, eighteen and twenty-one, and were either cutting or digging tools, or ceremonial items. Associated with burial fourteen was a half shell from a river clam, with a hole drilled through it. Indications of the presence of copper artifacts were present in green stains on the bones of burials seven and nineteen; the only such artifact was a ring found with the

adult in burial nineteen (Fiske, 1965a; Mayer-Oakes, 1964; Saylor, 1976). Lithics associated with burials were also few; two brown chalcedony knives and an unmodified chert flake were associated with burial seven; a lump of schist was associated with the skull of burial seventeen B; and a notched stone baton was found near the skull of burial eighteen (Saylor, 1976).

Of the pottery recovered from the mound fill, the following types were identified: North Bay Dentate (Ontario variety) (Mason, 1981), several varieties of Laurel (Epp and Dyck, 1983; Gregg, 1985; Meyer and Hamilton, 1994), Madison Corded (Birmingham and Eisenberg, 2000; Hurley, 1974), Blackduck (Epp and Dyck, 1983; Gregg, 1985; MacNeish, 1958), Azatlan Collared (Birmingham and Eisenberg, 2000; Hurley, 1974), Sandy Lake (Gregg, 1994), and several varieties of Selkirk (Hlady, 1970b; Meyer and Hamilton, 1994). Pottery fragments were directly associated with only two burials (thirteen and seventeen), however they were not diagnostic items.

Identified projectile point types from the fill included one Archaic point, most likely Oxbow (Epp and Dyck, 1983), one Pelican Lake point (Epp and Dyck, 1983; Hannus, 1994), Laurel (Epp and Dyck, 1983; Gregg, 1985), Besant (Epp and Dyck, 1983; Pettipas, 1983), Avonlea (Epp and Dyck, 1983; Kehoe, 1973; Meyer and Hamilton, 1994), Plains Side Notched (Epp and Dyck, 1983; Kehoe, 1973; MacNeish, 1958), Plains Triangular (Gregg, 1985), and several varieties of Blackduck points (Epp and Dyck, 1983; Evans, 1961; Gregg, 1985; MacNeish, 1958).

Other diagnostic artifacts include tubular cut shell beads normally associated with the Arvilla Complex (Johnson, 1973), and a notched clam shell pendants similar to

those found in both Laurel and Arvilla sites (Johnson, 1973; Lugenbeal, 1976; Wright, 1967).

5.3 Methods

5.3.1 Sorting Remains

The University of Manitoba has curated the human remains recovered from the Fidler Mounds since they were excavated from the mounds in 1963. Remains were sorted by discrete burial; no attempt was made to separate individuals where a burial contained bones from more than one body. The first of many tasks was to determine, as accurately as possible, which bones belonged to a given individual. The remains from each burial were laid out, and an inventory of each burial was recorded. This inventory was compared to one previously published (Saylor, 1976), and where multiple individuals were represented, bones were sorted into probable individuals. Some changes to Saylor's original assignment of skeletal elements to individuals were made based on relative size, age of the individual, and morphological characteristics of the element. These probable assignments were later substantiated or refuted using metric measurements. Material retrieved from the mound fill was treated as a discrete unit. Bones from the fill were taken to indicate separate individuals when they could not possibly belong to one of the individuals already established in the designated burials. Identifiable bones from the fill of each mound were also laid out on trays, by element, in order to more accurately determine the MNI therein and to assess the age range of those individuals.

5.3.2 Osteological Assessment

Due to the fragmentary nature of some of the skeletons, no one suite of methods could be used consistently in constructing a biological profile for each individual. Aging of adult skeletons was limited to classification as either young, middle or old adult, and also followed guidelines published by Bass (1995), Buikstra and Ubelaker (1994) and White (2000). Categorization was based on pubic symphysis, iliac auricular surface and sternal rib end morphology, as well as cranial and palatal suture closure; the presence or absence of degenerative skeletal changes such as osteoarthritis and joint lipping were also considered. Assessment of sex for adults was based on morphological criteria as described in Bass (1995), Buikstra and Ubelaker (1994) and White (2000). These methods included visual observation of both the pelvis and cranium and, where possible, were verified with metric measurements of all available elements using the software package ForDisc.

Age of non-adults was assessed primarily following the methods outlined in Bass (1995), Buikstra and Ubelaker (1994) and White (2000) using a combination of dental eruption patterns, epiphyseal fusion of long bones, size of the element, and development of the pubic symphysis. Mandibular radiographs were used to assess age ranges for several non-adults in the sample, using dental development charts as published in Buikstra and Ubelaker (1994) and dental development patterns outlined in Trodden (1982). The dentition of the Fidler Mounds collection was analysed morphologically. All skeletal elements were examined visually and/or radiographically for non-metric

traits, as well as pathology, taphonomic alteration, and peri- or post-mortem cultural modification, as outlined in Bass (1995) and Buikstra and Ubelaker (1994).

X-rays were taken using a Faxitron Cabinet X-Ray system, housed in the Bioanthropology Digital Image Analysis Laboratory at the University of Manitoba. Radiographs were taken at 40Kv for 6.5 minutes, with films set on the bottom shelf. Metric measurements of all post-cranial bones were taken following the standards set by Buikstra and Ubelaker (1994). Long bone lengths were acquired using large Mitutoyo sliding digital callipers, model number CFC-P24", while smaller measurements were taken using small Mitutoyo sliding digital callipers, model number NTD12P-6". All measurements were transmitted directly from the instruments to a Microsoft Excel spreadsheet to eliminate transcription errors.

5.3.3 Dating of Burials

Given the rather questionable single radiocarbon date generated for the Fidler Mounds decades earlier (Saylor, 1976), the decision was made to take bone samples directly from the skeletons of eight individuals and have them radiocarbon dated using bone collagen measured by an Accelerator Mass Spectrometry (AMS) system. Burials were chosen for dating on the basis of level of preservation, previous testing for stable isotope analysis (Garvie, 1993), location of the burial within the mound itself, and skeletal completeness. Remains in a poor state of preservation or those that were poorly represented were deemed inappropriate for destructive testing. In all, eight distinct individuals were sampled for AMS bone collagen dating. Individuals sampled, the elements chosen and their respective weights are listed in table 5.1.

Table 5.1 Samples Sent to Beta Analytic for AMS Bone Collagen Dating

Burial & Individual	Skeletal Element	Weight of Sample
Burial 4a	Rib shaft fragment	8.3 grams
Burial 7	L metatarsal #1	8.4 grams
Burial 9	L calcaneus	4.0 grams
Burial 11	Rib shaft fragment	4.5 grams
Burial 13a	L first proximal foot phalange	3.7 grams
Burial 15	L metatarsal #1	7.6 grams
Burial 19a	L rib fragment	6.6 grams
Burial 21a	L rib fragment	4.5 grams

The method outlined by Beta Analytic Inc. for processing and analysis of bone collagen is a variation of the Longin (1971) method of collagen extraction, and is summarised below. The bone sample is tested prior to the collagen extraction process to determine that the collagen fraction is still present. The bone is then washed and powdered. Repeated washing in 0.1N hydrochloric acid (HCl) at 33° C removes the mineral fraction, and additional treatment with sodium hydroxide (NaOH) ensures the removal of secondary organic acids. The collagen fraction is then converted into carbon dioxide by burning in a sealed quartz-glass ampoule in a combustion furnace, and finally converted into graphite before being sent for analysis in an accelerator mass spectrometer. The results are calibrated using Stuiver *et al.* (1998) and the cubic spline fit mathematics as published by Talma and Vogel (1993).

5.3.4 Trace Element Analysis of Teeth

Hair, nails, calcified tissues, teeth and bone can be examined biochemically, yet few studies of the application of LA-ICP-MS to these materials have been undertaken.

Through other biochemical methods, bone has been analysed for overall health status (Jankuhn *et al.*, 2000) and indicators of diagenetic change (Elliot and Grime, 1993; Jankuhn *et al.*, 1998); teeth for specific pathology indicators (Cua, 1990; Lane and Peach, 1997), taphonomic susceptibility (Szostek and Glab, 2001; Williams *et al.*, 2002) and metal uptake rates (Budd *et al.*, 2000; Moller *et al.*, 1982); and hair for longitudinal studies of diet and mineral uptake rates (Orlic *et al.*, 1984).

It is believed that trace element distribution patterns in human dentin can be used to interpret the dietary patterns of past populations. Given the fact that dentin may be relatively protected from diagenetic and taphonomic factors by the impervious nature of its enamel coating, the elemental composition of the material ought to reflect the elements present in the local environment during the period of life when the tooth was forming. The primary challenge to this theory is the uncertain nature of the burial environment, and the changes in elemental composition that may have taken place post mortem.

The choice of which tooth type to sample was based on the duration of time that passes between enamel mineralization and final root closure. The permanent canine teeth begin to form at approximately 4 months of age and roots are usually complete by the age of 15 years (Hillson, 1986), making it one of the best choices for this study. Twelve canine teeth were ultimately selected for testing, based on their overall condition and presence of the enamel dentin junction, which allows for the calculation of approximate age stages within the tooth (Liversidge, 2000; Reid and Dean, 2000). Where canines chosen for testing remained in the alveolar bone they were extracted manually. With the exception of one sample (No. 11), all were extracted without breakage to either the tooth

or the bone. Several of the samples had been glued together by previous researchers, and these were loosened in the socket with the application of small amounts of water.

Laser Ablation Inductively Coupled Plasma Mass Spectroscopy (LA-ICP-MS) was employed to investigate the pattern of trace elements in the dentin of permanent teeth. LA-ICP-MS technology makes use of a laser beam to remove a portion of the material from a solid sample, which generates a micro-particulate matter that is directed into an argon stream and injected into the plasma. Plasma temperature is high enough to atomize solid particles, and emission are measured using the mass spectrometer. Virtually all elements in the periodic table may be detected via LA-ICP-MS, with a spatial resolution of about 20μm (Jackson *et al.*, 2001; Perkins and Pearce, 1995). Low detection limits, on the order of a few parts per billion (ppb) and wide elemental range allow for longitudinal and highly sensitive studies in nutrition that cannot be performed with other methods (Warren *et al.*, 2002; Watt and Grime, 1995).

When the laser is scanned across a surface it generates a map of elements, so that the spatial distribution of elements in a target material become visible. The material ablated from a target contains elemental abundances in the atomic proportion in which they occur in the material. The number of ions which reach the detector depends on the atomic proportions of the element in the source, the amount of material removed during ablation, the ionization potential of the element in the plasma and its isotopic abundance. The results are normalized to an internal standard if quantitative results are desired (Perkins and Pearce, 1995). In this study, spatial resolution or distribution is the factor under investigation and as such, normalization to an internal standard was not necessary.

In order to practice the technique and determine the most appropriate laser settings, one modern tooth was prepared and scanned prior to the process being carried out on the Fidler Mounds material. This 'dry run' established that it was better to work with thick targets (i.e. thick enough that the laser would not penetrate all the way through the tooth), and enabled the assessment of the most appropriate settings for the LA-ICP-MS system. The final embedding, sectioning and polishing procedures for the teeth, and settings for the analytical equipment, that are discussed below were determined as a result of using this practice tooth.

Thin sections, while suitable for aging the teeth, proved to be too thin for Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry analysis. Samples were ultimately prepared as "thick targets" i.e. at a thickness capable of stopping the laser beam. The teeth were embedded in resin, and then sectioned longitudinally. These thick sections were scanned into a photo editing program (Photoshop 6.0.1) mapped for age on the basis of published literature (Liversidge, 2000; Reid and Dean, 2000), and the ring mapped in to guide the technician (see Figure 5.4). The desired sections of teeth were cut and embedded in circular molds. Now embedded in plastic rings, the teeth were again scanned into Photoshop and a guideline drawn onto the image to guide the laser (see Figure 5.5). The sections of the teeth chosen for testing were based on the assertion that diet changes most significantly during early childhood. If changes in trace element distributions in the dentin could be measured, the most dramatic changes would likely be found during this period. With these images as a guide, samples were sent for trace

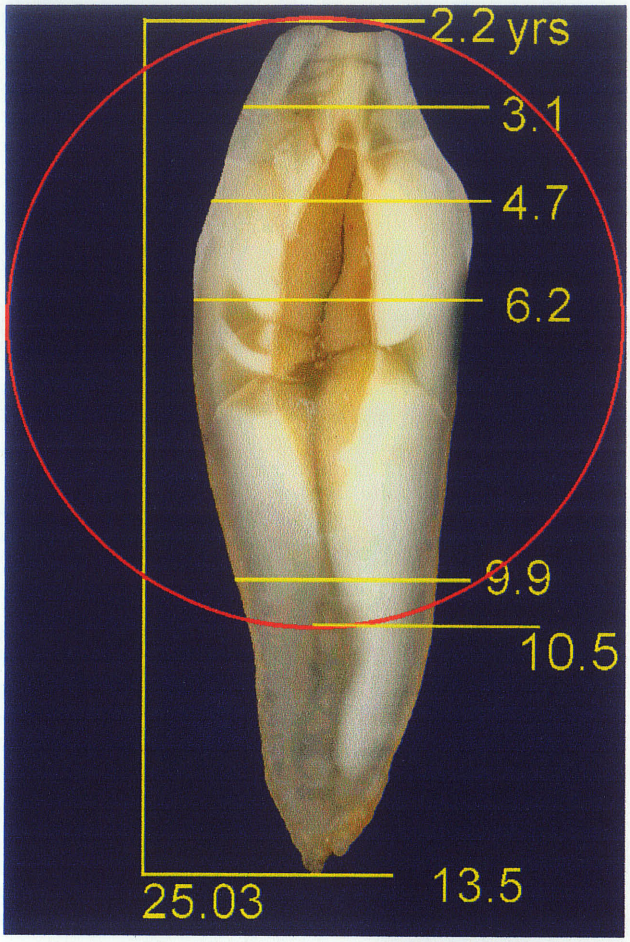


Figure 5.4

Burial 19a lower left canine. The number on the left indicates total length of the tooth in mm. Numbers on the right indicate the approximate age of the individual when that section of tooth completed development. The red circle is a guide for the technician as to which portion of the tooth to embed.

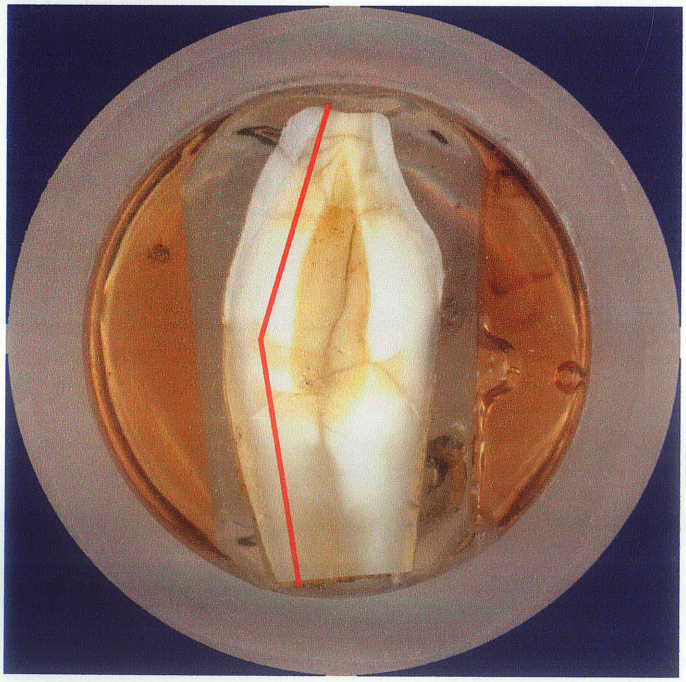


Figure 5.5

Burial 19a lower left canine after embedding in the plastic mold and polishing. The red line is a guide for the pathway of the laser.

element analysis. Samples were analyzed using an Element 2 ICP-MS with a Merchantek LUV 213 laser. Equipment settings used and data acquisition parameters are outlined in Appendix A. For line scans, the laser was run on a continuous burn at 20Hz, with the beam of 40 μm across at 80% power. The magnet was scanning the entire range of material to be analyzed in approximately one second and the laser beam was advancing across the tooth surface at 5 μms^{-1} .

5.4 Conclusion

The salvage excavation of the Fidler Mounds that occurred in 1963 resulted in the recovery of an enormous amount of cultural material and numerous human remains. Although the majority of the material cultural material was found in the mound fill, it has been used in the past to assign the Fidler Mounds to specific cultural groups and distinct burial complexes. The human remains recovered from the mounds have not been examined in several decades, and given that methods of analysis have changed substantially during that period it was felt that a reassessment of the material would result in new information. Since the focus of this study was the human skeletal remains, with only contextual consideration of the material cultural items, the discussion that follows will centre on the human remains and discussion of the artifacts will be limited to those items recovered in direct association with discrete burials.

Given the enormous cultural value and research potential that exists within human remains recovered from archaeological contexts, it is critical that all possible avenues of investigation are pursued. Once the remains from the mounds were inventoried, sorted and measured the information was recorded and analysed. In this research, AMS bone

collagen dating was employed in order to generate a range of dates during which the Fidler Mounds were actively used for human burials. An attempt was made to modify an existing geological analytical method (LA-ICP-MS) for application to human dental material as a means by which to examine human health and dietary patterns in past peoples. The results of each facet of this study will be presented in the following chapter.

Chapter 6

Results:

6.1 Introduction

Numerous approaches were employed in this study to achieve the most comprehensive interpretation of the sample. Some of these methods were more informative than others, and newer ones will need to be refined and expanded upon in order to understand their full significance for the study of human remains. This chapter presents to the reader the information and data generated as a result of this study.

6.2 Dating the Human Remains

A total of eight samples were chosen for dating via Accelerated Mass Spectrometry, and the results are presented below in Table 6.1) (Hewitt and Hoppa, 2003). Along with radiocarbon dates, the results provided by Beta Analytic Inc. included the ratio of ^{13}C to ^{12}C and N^{15} to N^{14}, which can be used to address the prominent dietary regime of the individual *intra vitam*. The eight burials dated, representing just over 17%

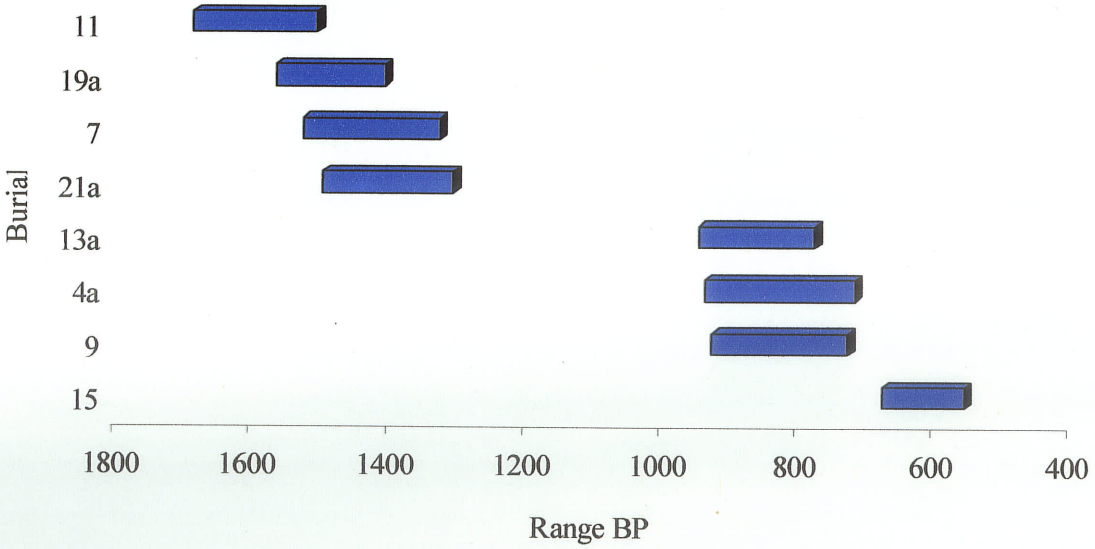
of the discrete burials, fell into two distinct groups separated by a span of approximately 360 years (see Figure 6.1).

Table 6.1 Results of AMS bone collagen dating

Burial & Individual	2 Sigma Calibration	$^{13}C/^{12}C$ Ratio	N^{15}/N^{14} Ratio	Measured Radiocarbon Age	Sample Number
Burial 4a	BP 940 - 720	-20.3 o/oo	+14.5 o/oo	840 +/- 50 BP	Beta-180690
Burial 7	BP 1530 - 1330	-20.3 o/oo	+13.2 o/oo	1460 +/- 40 BP	Beta-177841
Burial 9	BP 930 - 730	-21.0 o/oo	+13.8 o/oo	840 +/- 40 BP	Beta-180691
Burial 11	BP 1690 - 1510	-19.0 o/oo	+10.4 o/oo	1570 +/- 40 BP	Beta-180692
Burial 13a	BP 950 - 780	-19.9 o/oo	+14.7 o/oo	880 +/- 40 BP	Beta-180693
Burial 15*	BP 680 - 630 BP 600 - 560	-16.1 o/oo	+12.0 o/oo	540 +/- 40 BP	Beta-177842
Burial 19a	BP 1570-1410	-18.3 o/oo	+11.0 o/oo	1500 +/- 40 BP	Beta-177843
Burial 21a	BP 1500 - 1310	-18.3 o/oo	+17.7 o/oo	1390 +/- 40 BP	Beta-180694

* Burial 15 had two intercepts

Figure 6.1 Dated burials from the Fidler Mounds



Once the two groupings were noted, it was hoped that by testing osteological variables within these groups and comparing the data to that gathered from the sample as a whole, patterns in undated burials might allow them to be categorized as similar to 'older' or 'more recent' burials. As a result, the sections that follow regarding taphonomy, pathology, non-metrics and metric measurements will include discussion of these groups in comparison to one another and the entire skeletal sample.

6.3 Osteological Assessment

6.3.1 The Sample

When first recorded, it was thought that the remains of only forty-nine individuals were recovered from the Fidler Mounds (Manitoba Historic Resources Branch, 2001; Saylor, 1976). The true MNI for the Fidler Mounds is 25, based on the number of right scapulae in the sample. A simple MNI of this nature however, is not an accurate reflection of the number of individuals represented since many elements belong to individuals of different age categories. In examining the size, condition, and number of elements present, it appears that a minimum of sixty-six individuals are represented by the skeletal material recovered from the Fidler Mounds (see Appendix B). The discrepancy between the current and previous inventories is most likely a result of earlier researchers not including remains from the mound fill or ignoring isolated elements recovered with a discrete burial. For example, Saylor's unpublished notes indicate that Burial 21 contained remains from four individuals *plus one extra* femoral head. In disregarding isolated elements, or portions thereof, an incorrect MNI was initially

published. The current inventory indicates that the number of individuals recovered from Mound 1 is sixty-two, while the total for Mound 2 is only four.

Following Buikstra and Ubelaker (1994), three levels of completeness for burials were identified. The completeness of burials represented by less than 25% of the total bones in the body were classed as 'poor', those between 26-75% complete were considered 'partial', and those with more than 76% of the total skeleton were considered complete. Discrete burials ranged in skeletal completeness from 0.49% (one element) to 75.24% complete. The majority of burials (forty out of forty-seven) are less than 25% complete, only four are between 26-50% complete and three are between 51-75% complete; none are over 76% intact. It is fairly common with archaeological human remains that small elements such as carpals, tarsals and phalanges are not recovered. Given that nearly half of the bones in the human body are located in the hand and feet, simple counts of elements present are often a misleading representation of the relative completeness of a skeleton. When such elements are omitted from calculations of completeness for the Fidler Mounds sample however, theses levels do not changed dramatically. Only three of the total forty-seven identifiable bodies are between 76-100% complete when the bones of the hands and feet are omitted from the inventory. The number of bodies poorly represented drops to 37, while those between 26-75% complete remains at seven. As expected, the remains of adults were better represented than those of non-adults. Assessing completeness excluding bones from the extremities, non-adults remains were 12.49% complete on average, while adults were 21.16% complete. There was no appreciable difference in completeness between adult males and females.

Only 13 of 47 identified individuals (27.7%) yeilded either maxillary or mandibular teeth. Adults account for 77% of those individuals, and are split quite evenly between the sexes (see Table 6.2). Permanent dentition predominates within the sample, as only three individuals have deciduous teeth. All tooth forms are present in the permanent dentition of the sample. Anterior teeth are present in alveolar bone in 70% of the adults with dentition, and premolars or molars are present in all adults with dentition. In non-adults, anterior and posterior teeth are equally represented in the sample. In most cases, with both adults and non-adults, the anterior teeth appear to have been lost post-mortem, which is not uncommon with single-rooted teeth.

Table 6.2 Dentition in the Fidler Mounds skeletal sample

	Non-Adult	Female	Male	Adult (Sex Unknown)
Absent	13	6	5	10
Present	3	3	4	3

6.3.2 Age and Sex

All ages and both sexes are represented in the Fidler Mounds sample. The remains of adults make up 61.7% of the sample, while non-adults of varying ages account for 38.3% of the total. Of the non-adults, 21% of those are under the age of ten years. Just under half of the remains in the sample (46.81%) are unidentifiable to sex, however the majority of those are non-adults. Of the adults in the sample, 21.28% are male, 31.91% are females, and 10.64% are of indeterminate sex. A more detailed breakdown of age and sex for the sample is outlined in Table 6.3.

Table 6.3 Age distribution of discrete burials within the Fidler Mounds skeletal sample

Interval	Male	Female	Indeterminate	%
0-5 years	-	-	5	10.64
6-10 years	-	-	5	10.64
11-15 years	-	-	1	2.13
16-20 years	-	1	4	10.64
Young Adult (21-35)	4	6	1	23.4
Middle Adult (36-50)	3	3	1	14.89
Old Adult (over 50)	1	3	1	10.64
Non-adult (Age Unknown)	-	-	2	4.25
Adult (Age Unknown)	2	2	2	12.77
Total	10	15	22	100

6.3.3 Taphonomic Changes

Virtually every skeleton in the Fidler Mounds sample shows some level of taphonomic alteration as a result of time spent underground. Only 28 of the identifiable 47 individuals (59.6%) however, exhibit marked taphonomic changes, and 20 of those individuals are adults. When the adults are divided by sex, 14 are unidentifiable to sex, 9 are female and the remaining 5 are male. Of the dated burials, all four of the earlier burials showed appreciable taphonomic changes, while only two of the four more recent burials were notably affected.

Scavenging marks and severe weathering are generally indicators that the skeletal remains were exposed for some period either before or after the primary interment. When the remains were examined, it was noted that the majority of the sample demonstrated little or no evidence of either phenomenon (see Table 6.4). Of the eight individuals who display signs of scavenging, five are adults (three of whom are female, two are of indeterminate sex) and three are non-adults. Only one of the eight dated

Table 6.4
Scavenging and weathering of the Fidler Mounds skeletal sample

	Frequency	Percentage
Scavenging	8	17
Weathering	1	2.1
Unaffected	38	80.9
Total	47	100

burials demonstrated signs of having been scavenged by animals, and it is part of the 'early' group. Scavenging marks were limited to canine puncture wounds inflicted by a small to medium sized mammal (see Figure 6.2) and gnawing by small to medium sized rodents, and were evenly distributed across the post-cranial regions of the body. Severe weathering was evident on only one set of remains (Burial 12), and it is worth nothing that this skeleton was the only discrete burial recovered from Fidler Mound 2.

Only 17 of the 47 identifiable individuals, or 36.2%, show evidence of staining, either by copper or red ochre. Of those individuals, eight are non-adults and the

Figure 6.2

Canine puncture marks in the left ilium of Burial 2a. In total 26 marks were found, left by a small to medium sized mammal.

remaining eleven are adults, with an approximately even distribution between sexes (see Table 6.5). Each of the four 'early' dated burials are affected, two with ochre only and the other two with both types of stain. Only two of the more recent dated burials showed evidence for staining with red ochre. The lower body is the region most heavily affected (53%), followed by the thoracic (30%) and cranial areas (17%). The majority of the staining was light to medium in quantity; only 10.5% of bones were heavily stained and both of those were from the lower body.

	Ochre	Copper	Both
Unknown	8	1	1
Female	5	0	0
Male	4	0	1
Total	17	1	2

Table 6.5 Sex distribution of staining in the Fidler Mounds sample

Cut marks were in evidence on 16 skeletons (34%) in the sample, but the majority of those (11 out of 16) are attributable to damage inflicted during the excavation process. One skeleton from each group of dated burials showed evidence of trowel trauma - Burial 7 from the 'early' group and Burial 19a from the more recent group. Only four skeletons exhibit evidence that may be indicative of intentional post mortem disarticulation; one male (Burial 4c), one female (Burial 14a), and two non-adults of indeterminate sex (Burials 2a and 9).

Since teeth are the most durable calcified tissue in the human body, they generally survive the burial process intact. In the case of the Fidler Mounds sample, the remaining teeth show cracking and chipping of the enamel that can be attributed to the recovery, storage and handling over time. As noted earlier, in the vast majority of those samples where anterior teeth are missing the losses appear to be attributable to post-mortem

processes. The original excavation notes indicate that in most cases the anterior teeth were not recovered with the burials at the time of excavation.

6.3.4 Gross Pathology

Of the 47 individuals represented in discrete burials in the Fidler Mounds 23, or 48.9%, exhibit evidence that some kind of skeletal pathological process was active *intra vitam*. All individuals in this category are adults; eight are female, seven are male, and 8 are of undetermined sex. Nineteen out of those 23 cases demonstrate some form of arthritis or other degenerative change associated with aging. Other forms of disease appear to account for 8.7% of the pathological sample and the remaining 17.4% are attributable to trauma. The distribution of pathology across sexes for the sample is listed in Table 6.6. The location of pathological indicators on the skeletons is primarily post-cranial, with an even distribution between the thoracic and lower body regions, and only three individuals exhibit pathological changes to the cranium. All four of the early dated

Table 6.6 Sex distribution of pathology among adults in the Fidler Mounds sample

	Arthritis	Trauma	Disease	Undetermined Origin
Unknown Sex	4	0	0	4
Female	9	2	1	0
Male	6	2	1	0

burials exhibit some type of pathology, while only two of the more recent burials are pathological (see Table 6.7).

Table 6.7 Pathology types in dated and undated burials from the Fidler Mounds

	Arthritis	Trauma	Disease
Early Burials	3	1	1
Recent Burials	2	0	0
Undated Burials	14	3	1

Arthritic individuals within the sample show varying degrees of affliction, ranging from mild degenerative joint disease to complete collapse of vertebral bodies and extreme osteophytic growth (see Figures 6.3 and 6.4). Of those individuals who show signs of arthritis, nine have indicators of early stage degeneration, three are somewhat more advanced, and seven are severely afflicted. Females are affected a third more than males in this sample, however the severity appears relatively evenly distributed between

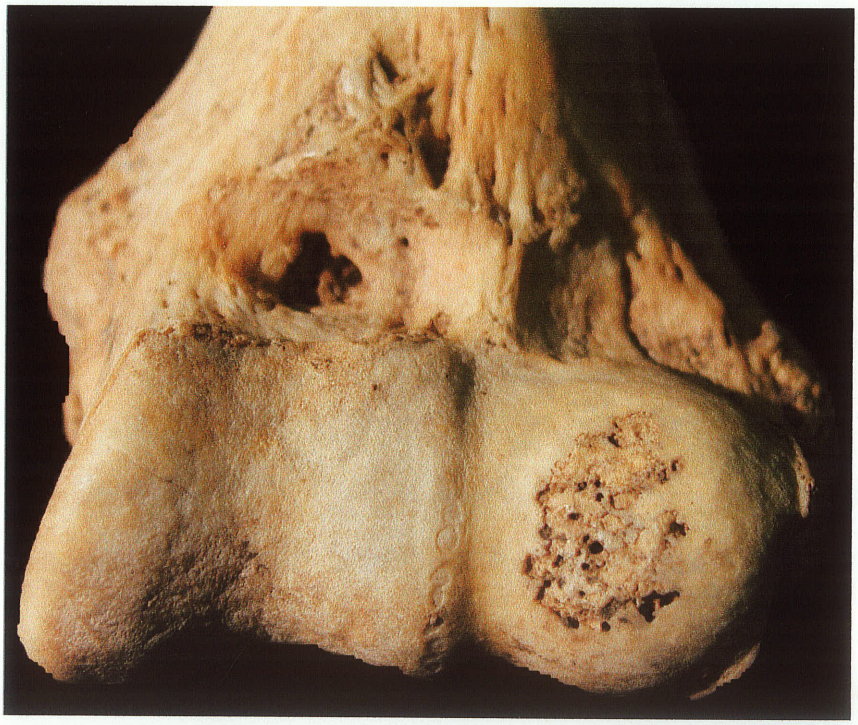
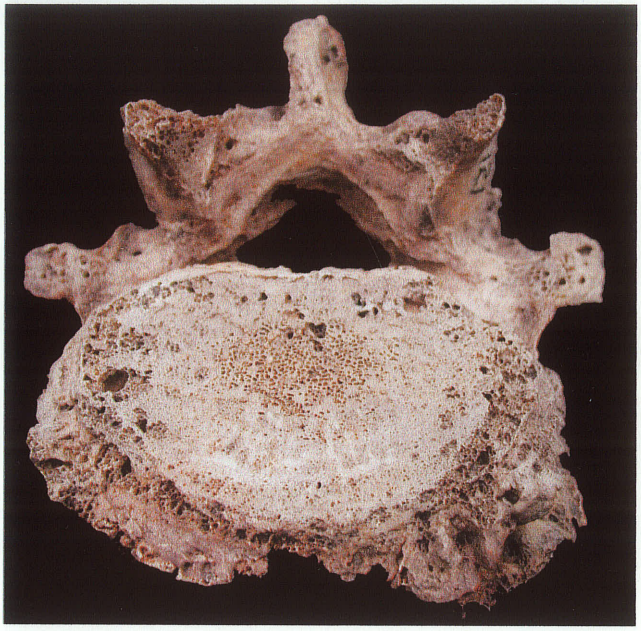


Figure 6.3

Early stages of arthritis on the surface of the capitulum from the left humerus of Burial 10b

the sexes. Not surprisingly, the severity of the condition appears to be positively correlated with increasing age, with each individual exhibiting severe arthritic degeneration falling into the 'middle' or 'old' adult category.

Figure 6.4 Severe osteophytic lipping related to advanced arthritis of lumbar vertebra from Burial 11.

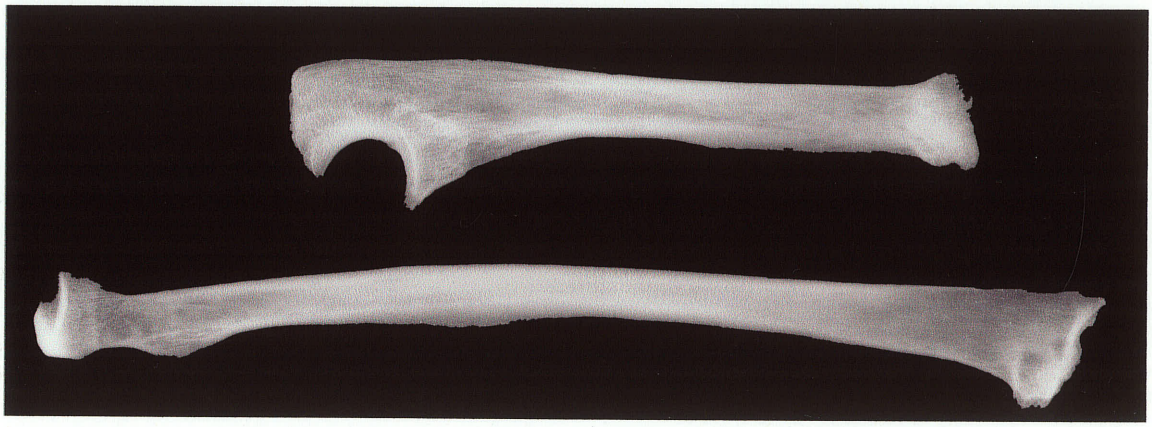


Traumatic injuries are visible in four of the 47 sets of skeletal remains from the sample. The right femur of Burial 4c shows evidence of a hip dislocation or break, with a flattened and degenerating femoral head and severe neck compression, with an acute change of angle. The right ulna of Burial 10b, an adult male, displays a medial twist in the distal 1/3 of the shaft as well as a compressed and eburnated distal radial articular surface, indicative of an offset break that has healed over time (see Figure 6.5). X-rays confirm a thickening of the shaft at the site of the break. Burial 17a is a highly pathological individual, and has three sites where trauma is indicated. There is a well-healed lesion over the left orbit of the frontal bone, and one unsided proximal phalange

Figure 6.5 Right ulna of Burial 10b. Note the change of angle in the distal shaft and the truncated distal epiphysis.

was broken *intra vitam*, just under the head of the bone, and has healed slightly misaligned. The most striking break occurred in the right ulna, which is significantly shortened and the distal end is grossly malformed. It is most likely that the ulna was broken cleanly into two pieces, which then failed to unite as the break healed. Subsequent infection may have played a role in the failure of the two halves to unite, as evidenced by the healing lesions on the distal right radius (see Figure 6.6). Since the distal portion of the bone is missing however, it is difficult to say with certainty. Burial 21a also has a well-healed lesion on the frontal bone, although it is centered between the

Figure 6.6 **Radiograph of the left ulna and radius from Burial 17a.**

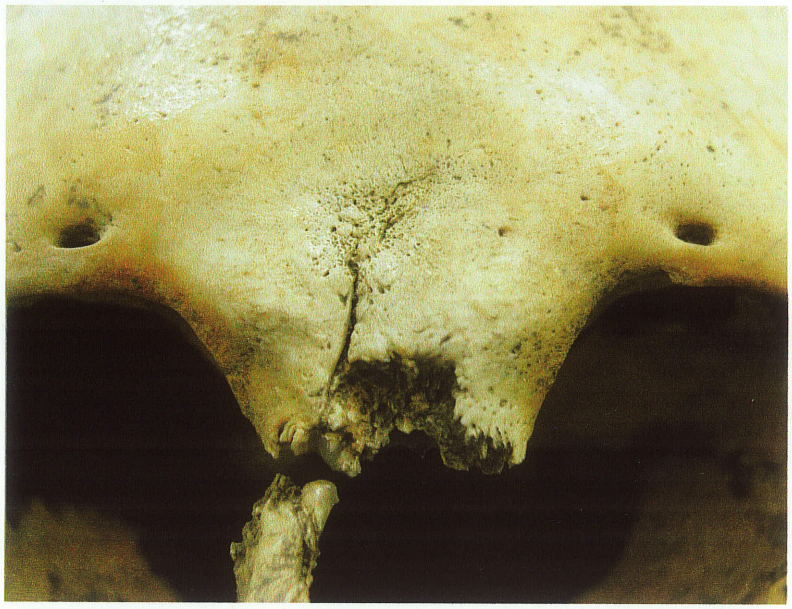


orbits (see Figure 6.7). Close inspection under high power magnification reveals that the lesion was still healing when the individual died.

Numerous individuals within the Fidler Mounds sample exhibit signs of infections that were active at the time of death. Non-specific periosteal reactions are visible on the left tibia and fibula of Burial 4c, on the left ulna and radius of Burial 11, on the right

Figure 6.7

Healing lesion on the frontal bone of Burial 21a



humerus of Burial 12, and on the majority of elements from Burial 19a. The extent of the infection in the left lower limb of individual 4c would indicate that it had been active for some time.

Two individuals in the sample show characteristic signs of chronic disease processes. Burial 7 is highly pathological and appears to have suffered from a severe and chronic systemic infection, with thickening and deformation of the right radius, ulna, tibia and fibula, and severe osteophytic reaction along the surface of the shaft of the tibia and fibula (see Figure 6.8). The vertebrae, sacrum, and innominates are also affected, in the form of osteophytic growth and surface pitting. This cranium of this individual was

Figure 6.8

Pathological right fibula from Burial 7

trephined shortly prior to death, and there is a subsequent roughly rounded hole in the occipital (see Figure 6.9). The second individual in the sample to show significant pathology is 17a, and this skeleton displays indicators of pathology in nearly every element present. This is the same individual whose broken right ulna is shortened by a failure of the two pieces of bone to unite. As previously noted there is a healing lesion on the frontal bone above the left orbit, and the frontal boss is pronounced and unusually thickened for a female. Severe arthritis is present in the shoulder girdle, vertebral column

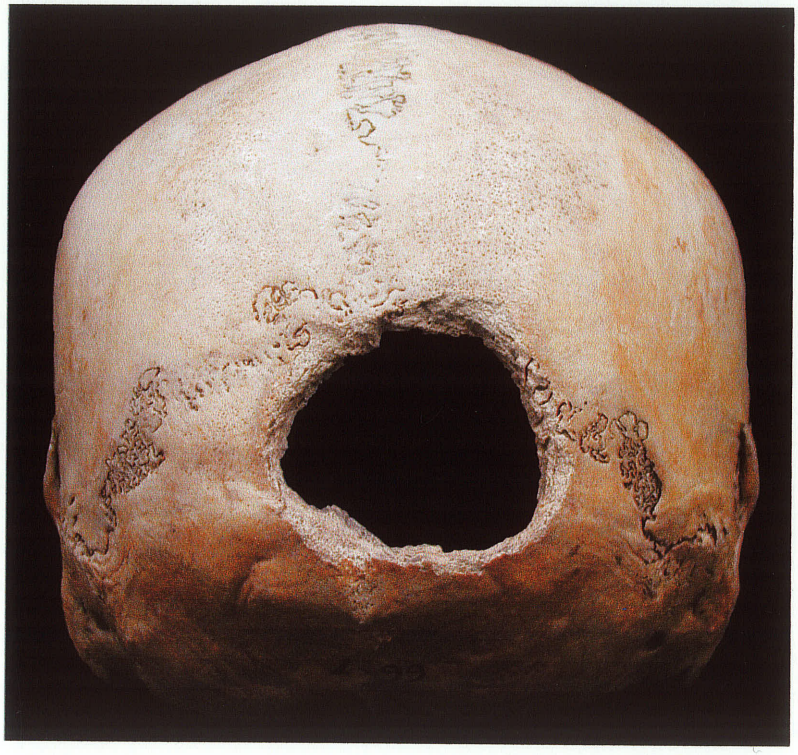


Figure 6.9

Trephined cranium of Burial 7

and in the joints. In the lower limbs, there is a lesion on the fovea capitis of the right femur, a significant malformation of the distal right tibia and subsequent deformation of the right distal fibula (see Figure 6.10), as well as extensive pitting of the calcaneus, navicular and first metatarsals. The articular surfaces of the tibia, fibula, calcaneus and

navicular have been destroyed and in the case of the tarsals, are almost unrecognizable. The illness was active at the time of death, as evidenced by the cavities left by drainage of pus (see Figure 6.11).

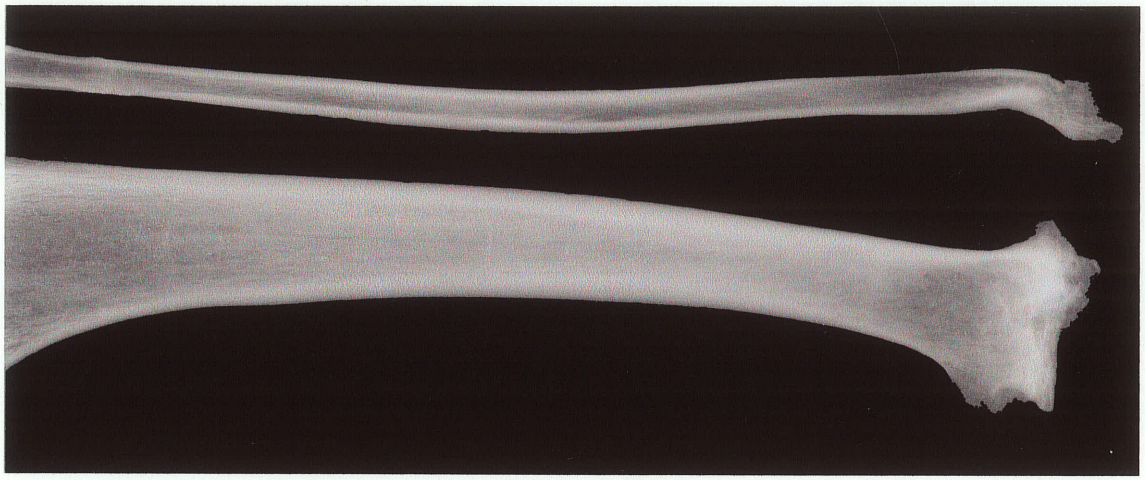


Figure 6.10

Radiograph of the distal tibia and fibula from Burial 17a

Figure 6.11

Drainage cavity on the distal end of the right tibia from Burial 17a

Since dentition is poorly represented in the sample overall, the actual counts of pathological conditions of the teeth may poorly reflect the levels of periodontal disease and attrition within the populations from which the Fidler Mounds sample is drawn. For a complete dental inventory, please see Appendix B. In all cases, the heaviest wear is concentrated on the maxillary molars and premolars, with dentin showing to fully exposed. Of the thirteen individuals who have teeth, three are non-adults and ten are adults.

The only caries detected in the sample belong to adults. Four of the ten adults display dental caries, and all are found in the mandibular molars. Burials 2b, 10b and 21a each have at least one to two small occlusal caries. Burial 17a has five small caries in total on permanent molars one and two. The only abscess in the sample is evident on the right mandible of Burial 11, near M3. There is a preponderance of females exhibiting caries when compared with males (4:1), however this is most likely an artifact of the small sample size. Of the dated burials, two individuals from the 'early' group show dental caries or abscesses, while none of the four of the more recent burials was affected. Periodontal disease, as assessed by the condition of the alveolus (Hildebolt and Molnar, 1991), has occurred in six mandibles. Burials 2a, 11, 17a and 17b are severely affected (see Figure 6.12), while Burials 7 and 10 show moderate alveolar resorption.

6.3.5 Non-Metric Observations

Non-metric traits were assessed in accordance with the guidelines in Buikstra and Ubelaker (1994), and only those traits visible in the Fidler Mounds sample are noted. Of the 47 identifiable sets of remains, only 12 are positive for non-metric traits; two are non-

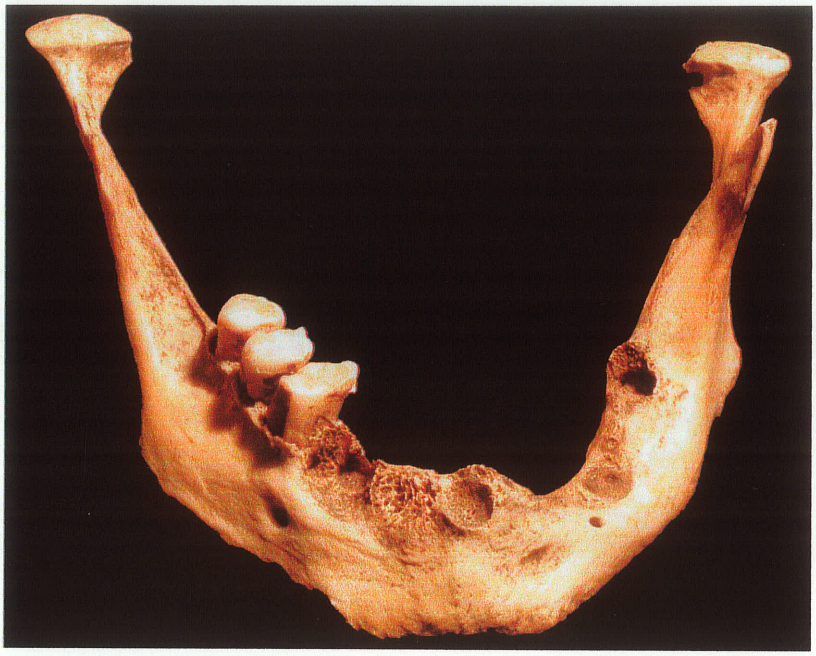


Figure 6.12

Severe alveolar resorption of the left mandible from Burial 2a

adults, four are of undetermined sex, four are female and two are male. Three of the burials dated to the older group are affected in some way, while non-metric traits are present in only one of the more recent burials. The traits visible in the sample are listed in Table 6.8.

Coronal and sagital ossicles are present in the crania of four adult individuals (two of each sex), while lambdoid ossicles are found in three females and four males. Two female adults have double infraorbital foramina, and four females and four males have parietal foramen. Two individuals, one male and one female, have a complete single inca bone. In the mandibles, a mental foramen is present in eight individuals, with even distribution between the sexes, and mylohyoid bridging is visible bilaterally in one male.

Four examples of an accessory transverse foramen exist within the sample. Three are adults, all female, and one non-adult who exhibit the trait. One burial from each of

Table 6.8 Non-metric traits present in the Fidler Mounds skeletal sample

Burial	Element	Trait	Location	Additional Information
1	occipital	os inca	crania	single bone
2d	R humerus	septal aperture	olecranon fossa	true perforation
3a	R humerus	septal aperture	olecranon fossa	true perforation
3b	C vertebra	accessory transv foramen	L transverse process	partial
7	L humerus	septal aperture	olecranon fossa	true perforation
7	atlas	bridging	L posterior bridge	bridge from L superior articular facet to L side of arch
8a	R humerus	septal aperture	olecranon fossa	true perforation
15	occipital	os inca	crania	single bone
15	C vert 4	accessory transv foramen	L & R side	complete on L and partial on R
15	C vert 5	accessory transv foramen	L & R side	complete on R and partial on L
15	C vert 6	accessory transv foramen	L side	complete
15	C vert 7	accessory transv foramen	L & R side	both sides partial, R side more advanced
16a	L humerus	septal aperture	olecranon fossa	true perforation
17b	R humerus	septal aperture	olecranon fossa	true perforation
17b	L humerus	septal aperture	olecranon fossa	true perforation
17b	C vertebra	accessory transv foramen	L transverse foramen	complete
19a	L humerus	septal aperture	olecranon fossa	true perforation
20a	R humerus	septal aperture	olecranon fossa	true perforation
21a	R humerus	septal aperture	olecranon fossa	true perforation
21a	L humerus	septal aperture	olecranon fossa	true perforation
21a	C vertebra	accessory transv foramen	R & L transverse foramen	R complete, L partial

the dated groups displays an accessory transverse foramen. The expression of septal aperture is seen in nine individuals, all of whom are adults, three of whom are female and two are male. Three of the nine individuals are dated to the 'early' group of burials, and none are from the more recent group.

6.3.6 Metric Measurements

Due to the highly fragmentary nature of the remains recovered from the Fidler Mounds, sets of complete metric measurements are few. Given the relatively small sample size, comparisons of means within the sample and between identified groups are possible, but in most cases not meaningful. Only those measurements that are informative and relevant to the questions asked are discussed below.

Comparisons of cranial metrics between the sexes are difficult, since the skull of only one male (Burial 7) is sufficiently intact to allow for a range of valid metric measurements. Cranial metrics are possible for only four females, and numerous specific measurements are not possible given the level of preservation of elements and features. In all but two of the possible cranial metrics, the male means are larger than the mean for females. The exceptions are the maximum frontal breadths and the mastoid lengths, however the differences are not statistically significant.

A higher number of mandibles in the sample allows for comparison of those measures between sexes and identifiable groups. In all respects except condylar height, male mandibles were larger than female ones (see Table 6.9). Between the sexes, only six measurements were significantly different (see Table 6.10), and there are no meaningful differences in mandibular metrics between and within dated burials. For the most part, the high levels of occlusal wear in the sample invalidate dental metrics. Only six individuals have teeth that are not heavily worn; three of those are non-adults and the other three are young adults that show some wear on M1, but less on M2 and M3. There are practical difficulties with measuring mesio-distal diameters on teeth still embedded in

Table 6.9 Metric measurements of mandibles by sex

		N	Mean	Std. Deviation	Std. Error Mean
Height of Mandibular Body	Female	6	28.872	1.248	0.509
	Male	4	31.35	3.041	1.521
Breadth of Mandibular Body	Female	6	11.757	1.517	0.619
	Male	4	13.318	0.935	0.467
Mandibular Length	Female	6	95.32	7.275	2.97
	Male	3	99.623	1.415	0.817
Bigonial Breadth	Female	5	97.084	1.98	0.885
	Male	2	108.725	0.007	0.005
Bicondylar Width	Female	4	115.053	8.522	4.261
	Male	3	127.237	10.189	5.882
Ramus Height	Female	5	57.876	2.339	1.046
	Male	4	66.298	5.025	2.513
Min Ramus Breadth	Female	6	35.868	4.802	1.961
	Male	4	38.29	2.798	1.399
Gonial Angle (Vertical)	Female	5	73.7	11.851	5.3
	Male	3	75.667	7.638	4.41
Coronoid Height	Female	5	59.172	3.801	1.7
	Male	3	65.743	3.076	1.776
Distance btwn Mental Foramen	Female	5	47.176	1.411	0.631
	Male	3	49.79	2.391	1.381
Mandibular Notch Breadth	Female	4	25.845	2.338	1.169
	Male	3	29.443	3.969	2.291
Bi-coronoid Distance	Female	3	93.167	4.017	2.319
	Male	3	101.853	3.547	2.048
Condylar Process Height	Female	4	57.39	3.552	1.776
	Male	4	53.695	24.496	12.248
Mandibular Condyle Breadth	Female	5	20.568	1.722	0.77
	Male	3	23.507	1.223	0.706

alveolar bone since it is virtually impossible to fit standard callipers between teeth, and as a result those measures should be considered estimates. Of the three non-adults in the sample with dentition, Burial 1b is a child of approximately 10 years of age, with only the right I2, P1 and M1 remaining. Burial 9 is approximately 6 years of age, and is missing only the left deciduous canine, and Burial 18 is a child between three and four years of age, with only the left canine and deciduous molars one and two remaining. The three

adults who have metrically measurable dentition remaining are Burials 12, 19a and 21a (for inventory see Appendix B). Although the sample is small, and in most cases comparisons of metrics between adults and non-adults are not possible, where dentition could be evaluated there are no significant differences in size. There are also no statistically meaningful differences in tooth sizes within and between dated burial groups.

Table 6.10 Significant differences in mandibular metrics between males and females

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Ramus Height	-3.595	7	0.01	-9.185	2.555	-15.225	-3.144
Coronoid Height	-2.752	7	0.03	-7.239	2.63	-13.459	-1.019
Distance btwn Mental Foramen	-2.6	7	0.04	-3.304	1.271	-6.309	-0.299
Bi-coronoid Distance	-3.455	5	0.02	-9.366	2.711	-16.334	-2.398
Condylar Process Height	-3.672	6	0.01	-9.12	2.484	-15.198	-3.043
Mandibular Condyle Breadth	-2.766	6	0.03	-3.103	1.122	-5.847	-0.358

Postcranial elements are more numerous in this sample, and are therefore more useful for comparative purposes in this study than cranial measurements. Comparisons of means from paired elements between sexes and groups combine the right and left sides in order to increase the sample size, but obviously pathological specimens were omitted from these combined calculations. Metrics for paired elements were also analyzed for bilateral asymmetry within individuals, however the only significant differences were found in individuals who are grossly pathological.

As expected, males and females vary in numerous morphological respects. When analysed metrically however, there are fewer differences. Mean long bone lengths and diameters for identified males and females in the sample are reported in Table 6.11. Nine of those measurements are significantly different between the sexes. All dimensions of

Table 6.11 Paired long bone means for males and females in the sample

		N	Mean	Std. Deviation	Std. Error Mean
Clavicle Max Length	Female	3	143.78	6.19	3.57
	Male	2	163.47	1.32	0.93
Clavicle Diam Midshaft A-P	Female	4	9.76	0.77	0.39
	Male	3	12.72	1.83	1.06
Humerus Max Length	Female	5	306.11	11.3	5.05
	Male	4	328.4	23.07	11.53
Humerus Max Midshaft Diam	Female	6	6.02	0.44	0.18
	Male	4	6.89	0.46	0.23
Radius Max Length	Female	6	247.18	13.23	5.4
	Male	3	262.06	3.21	1.85
Radius Max Midshaft Diam	Female	7	4.3	0.32	0.12
	Male	3	4.82	0.26	0.15
Ulna Max Length	Female	5	258.93	11.05	4.94
	Male	3	287.23	8	4.62
Ulna Max Midshaft Diam	Female	6	6.34	4.13	1.69
	Male	3	5.03	0.42	0.24
Femur Max Length	Female	7	436.76	15.31	5.79
	Male	3	470.08	26.75	15.45
Femur Midshaft Diam A-P	Female	9	25.97	1.39	0.46
	Male	4	29.64	1.32	0.66
Femur Midshaft Diam M-L	Female	9	24.75	1.72	0.57
	Male	4	27.7	1.8	0.9
Tibia Length w/o Spine	Female	5	365.54	20.31	9.09
	Male	6	386.47	13.09	5.35
Tibia Length w Spine	Female	5	374.01	20.19	9.03
	Male	6	390.97	13.41	5.47
Tibia Diam at Nutrient Foramen A-P	Female	6	31.99	1.62	0.66
	Male	6	33.74	14.58	5.95
Tibia Diam at Nutrient Foramen M-L	Female	6	22.18	1.65	0.67
	Male	6	28.38	1.85	0.75
Fibula Max Length	Female	5	343.17	31.19	13.95
	Male	3	362.53	17.72	10.23
Fibula Max Midshaft Diam	Female	6	15.12	1.63	0.67
	Male	4	17.54	2.97	1.48

the clavicle are larger in males than females, the overall length of the ulna and femur are smaller in females than in males, and the robusticity, as measured by midshaft diameter, is greater in males in the humerus, radius, femur and tibia. Significance levels and means for these features are listed in Table 6.12.

Table 6.12 Significant differences in post cranial metrics between males and females

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Clavicle Max Length	-4.22	3	0.02	-19.693	4.667	-34.546	-4.841
Clavicle Midshaft Diam A-P	-2.971	5	0.03	-2.957	0.995	-5.515	-0.399
Humerus Midshaft Diam	-3.007	8	0.02	-0.871	0.29	-1.539	-0.203
Radius Max Midshaft Diam	-2.435	8	0.04	-0.517	0.212	-1.006	-0.027
Ulna Max Length	-3.823	6	0.01	-28.298	7.402	-46.409	-10.187
Femur Max Length	-2.564	8	0.03	-33.318	12.996	-63.287	-3.349
Femur Midshaft Diam A-P	-4.456	11	0	-3.663	0.822	-5.472	-1.854
Femur Midshaft Diam M-L	-2.81	11	0.02	-2.948	1.049	-5.257	-0.639
Tibia Diam at Nutrient Foramen M-L	-6.129	10	0	-6.2	1.012	-8.454	-3.946

Between groups of dated burials, there were no differences in metric measurements that were statistically significant. Between all of the dated burials and the undated ones, the only significantly different dimensions were the maximum cranial breadth, the fibula maximum midshaft diameter, and the transverse measurement of the neural canal of the fifth lumbar vertebra. In all cases the mean of the dated burials was larger than the rest of the sample. While these three metrics measurements are statistically significant, sample sizes are small (n=4:3, 5:7,and 3:1 respectively).

Tibiae and femora are the most commonly occurring bones in the sample, therefore stature was calculated using these elements where possible, and using the FORDISC software package where only other long bones were present. The tibia stature calculation (stature = 678.68 + 2.738 x tibia length) comes from Duyar and Pelin (2003), while the calculation of stature from the femur (stature = femur length x 100 / 26.74) is from Feldesman *et al.* (1990). All results were then converted and rounded to the nearest millimetre. The results of stature calculations for 23 adults with long bones are listed in

Table 6.13. This produces a sample where the mean height of nine males is 1752 mm, while the female average for fourteen individuals is 1636 mm; a difference that is

Table 6.13 Stature estimations for skeletally mature individuals with long bones

Burial	Sex	Stature (mm)	Element Used	Calculated Using:
2b	F	1690	Femur	Feldesman et al. 1990
2c	F	1488	Fibula	FORDISC Max Length
2d	F	1578	Femur	Feldesman et al. 1990
3a	M	1740	Humerus	FORDISC Max Length
3c	M	1750	Humerus	FORDISC Max Length
4c	M	1668	Femur	Feldesman et al. 1990
7	M	1761	Femur	Feldesman et al. 1990
8a	F	1588	Ulna	FORDISC Physiological Length
8b	M	1708	Tibia	Duyar & Pelin 2003
10b	F	1847	Femur	Feldesman et al. 1990
11	M	1760	Tibia	Duyar & Pelin 2003
12	F	1593	Femur	Feldesman et al. 1990
13a	M	1755	Tibia	Duyar & Pelin 2003
14a	F	1786	Radius	FORDISC Max Length
15	F	1589	Femur	Feldesman et al. 1990
16a	F	1533	Femur	Feldesman et al. 1990
16b	F	1599	Tibia	Duyar & Pelin 2003
16c	M	1775	Humerus	FORDISC Max Length
17a	F	1604	Femur	Feldesman et al. 1990
17b	F	1720	Femur	Feldesman et al. 1990
19a	M	1847	Fibula & Radius	FORDISC Max Length
20a	F	1636	Humerus	Feldesman et al. 1990
21a	F	1657	Femur	Feldesman et al. 1990

statistically different at 0.003. When groups of dated burials are compared to one another and to the rest of the sample, there are no meaningful differences in stature estimations.

6.3.7 Growth and Development

The skeletal development of non-adults in the Fidler Mounds sample is difficult to assess since the remains are generally not well represented. Metric measurements for

paired elements were combined in order to increase the sample size, and long bone measures are listed in Table 6.14. Only five non-adults had long bone epiphyses that

Table 6.14 Metric measurements, in mm, for long bone diaphyses of non-adults from the Fidler Mounds. Where both left and right elements are present, the mean is given.

	Fidler 2a	Fidler 2c	Fidler 4b	Fidler 6	Fidler 8a	Fidler 9	Fidler 10a	Fidler 18	Fidler 21d
Clavicle Max Length						91.15			
Clavicle Max Midshaft Diam	6.95			6.37		6.23			
Humerus Max Length	166.13				253.57	168.71		111.88	
Humerus Max Midshaft Diam	12.11				19.55	13.5	20.87	10.7	
Radius Max Length					203.61	131.03			
Radius Max Midshaft Diam					14.89	8.49		6.91	
Ulna Max Length					224.1				
Ulna Max Midshaft Diam					14.64	9.91			
Femur Max Length								156.02	
Femur Max Midshaft Diam		25.59						11.57	
Tibia Length w/o Spine	148.63					189.94		129.34	
Tibia Diam at Nutrient Foramen A-P	15.41		26.26			18.35	20.89	11.79	12.93
Tibia Diam at Nutrient Foramen M-L	13.7		22.56			15.38	26.52	11.76	12.45
Fibula Max Length		305.11				191.19			
Fibula Max Midshaft Diam		14.75				9.21		6.51	

were sufficiently preserved from which to take measurements for comparison against adult mean long bone lengths. The long bone lengths from adults (included fused epiphyses) of both sexes were averaged and percentage of adult growth achieved was calculated for all five non-adults (see Table 6.15).

Dental development was examined via radiographs of all three partially complete mandibles from non-adults. In each case, the dental and osteological ages were in very close agreement (see Table 6.16). No visible pathological conditions of the dentition or alveolar bone were apparent. The only possible pathology found on the non-adult remains consisted of a single shallow lesion on the medial surface of the proximal shaft of the left humerus of Burial 9.

Table 6.15 Percent of adult growth attained by non-adults, measured in mm

	Adult Mean Max Length	Burial 2a	Burial 2c	Burial 8a	Burial 9	Burial 18
Humerus	317.26	166.13 (52.36%)		253.57 (79.92%)	168.71 (53.18%)	111.88 (35.26%)
Radius	254.62			203.61 (79.97%)	131.03 (51.46%)	
Ulna	273.08			224.10 (82.06%)		
Femur	453.42					156.02 (34.41%)
Tibia	382.49	148.63 (38.86%)			189.94 (49.66%)	129.34 (33.82%)
Fibula	352.85		305.11 (86.47%)		191.19 (54.18%)	

Table 6.16 Dental and skeletal age of non-adults with mandibular radiographs

Burial	Skeletal Age (White 2000, Buikstra and Ubelaker 1994)	Dental Age (Buikstra and Ubelaker 1994)	Dental Age (Trodden 1982)
1b	n/a	9-10 yrs	10.81-10.90 yrs
9	6-7 yrs	6-7 yrs	6.08-6.79 yrs
18	2-4 yrs	3-5 yrs	3.15-3.52 yrs

6.4 Biochemistry

Twelve permanent canine teeth from the Fidler Mounds sample were subjected to qualitative trace element analysis along line scans by LA-ICP-MS in an effort to see if the distribution of trace elements can be interpreted as an indicator of the dietary regime or overall health of individuals. In nearly all of the samples the ablation line begins just prior to the surface of the tooth to ensure that all points along the tooth are examined. A

dramatic increase in intensity (counts per second) for the elements of interest is seen as the laser moves from the mounting medium to the tooth (see Figure 6.13).

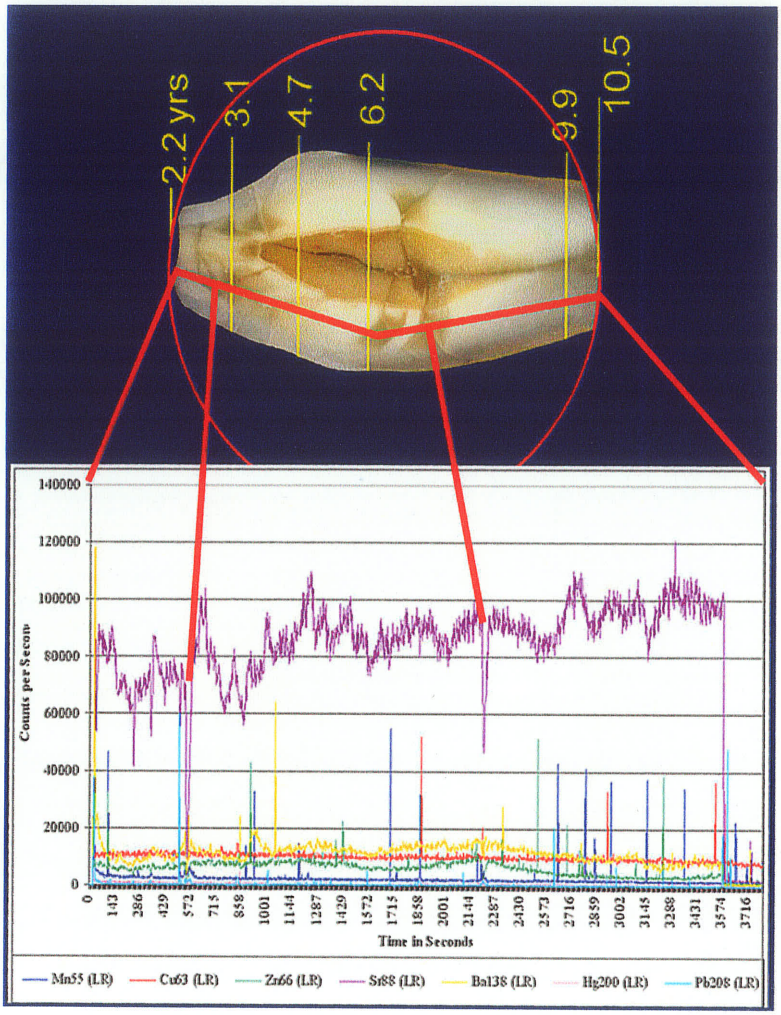


Figure 6.13

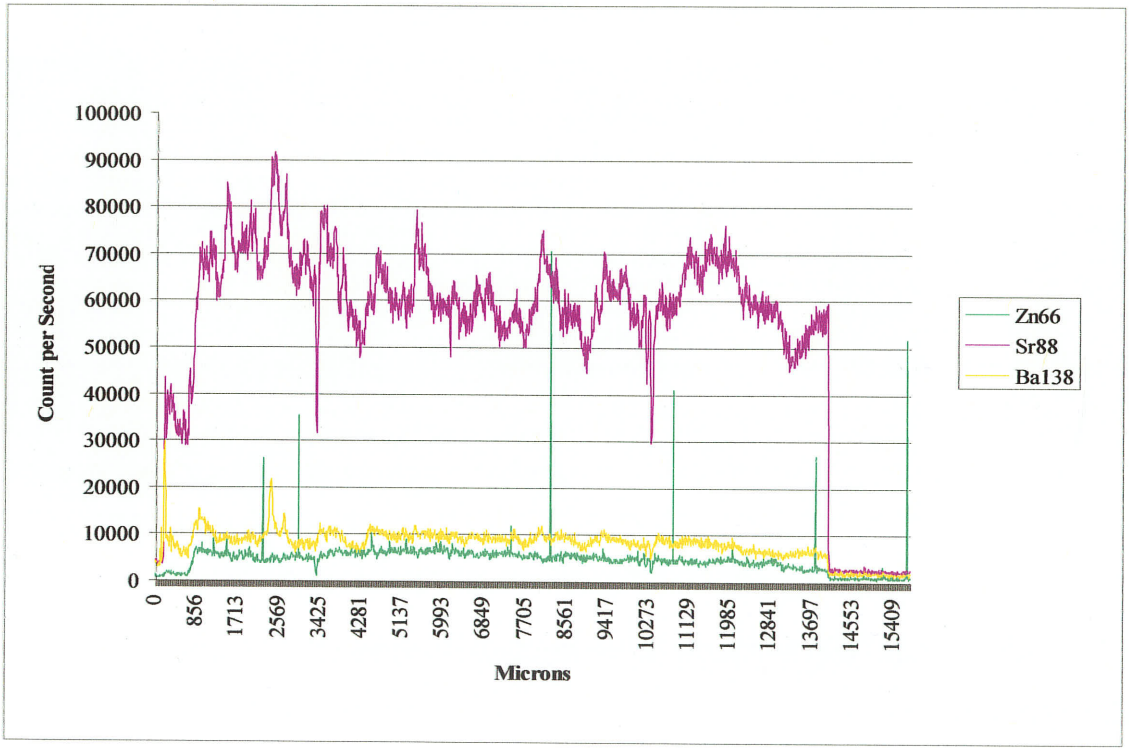
Burial 19a lower left canine. The red lines indicate the point at which the scan begins, the location of two major cracks with the corresponding changes in elemental volume, and the point at which the scan ends.

Trace elements are measured in counts per second and while intra-tooth comparisons are possible, inter-tooth comparisons are not valid at this level. And while the samples are not directly comparable to one another, certain patterns are apparent across all twelve line scans. Trace elements measured in this study include ^{55}Mn, ^{88}Sr, ^{138}Ba, ^{63}Cu, ^{208}Pb, ^{200}Hg, and ^{66}Zn. In the following section, observations are made regarding each scan, the output is displayed, and general trends are noted (see Figures

6.14 – 6.25). Where elements are relatively unchanging and uninformative throughout the line scan, they are omitted from the output for the sake of clarity.

In the scan of Burial 7 (Figure 6.14), the burn starts well off the tooth surface and in the resin that surrounds the tooth. The amounts of Ba and Sr increase rapidly in quantity when the laser encounters the enamel surface, and jump up again when the beam moves into the dentin of the tooth. Barium and Sr appear to be correlated, if one looks at

Figure 6.14 Output for Burial 7 lower right canine.

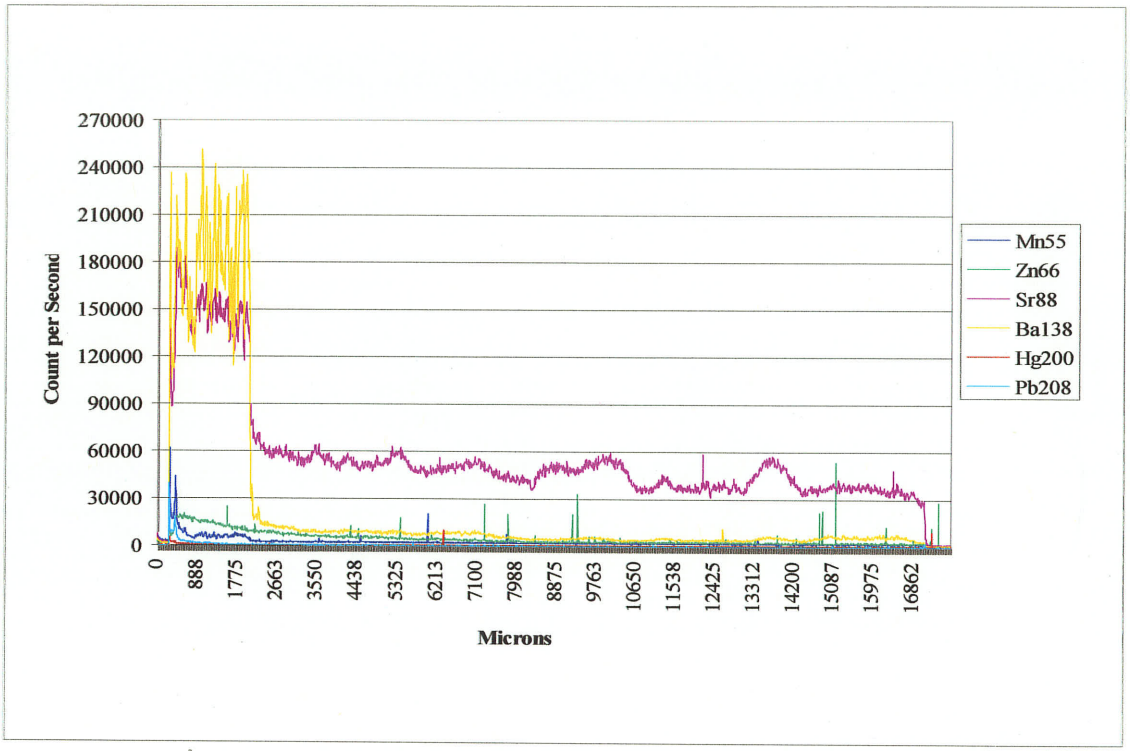


the trends in increases and decreases of elements without considering too heavily the fluctuations in between. Zinc appears to be independent of Ba and Sr to some degree, although overall it appears to conform to the changes visible in Ba and Sr. At approximately 14,185 microns the laser appears to burn directly through the dentin

surface and into the resin – and this is borne out when one examines the thick section; the lower sections of the tooth appear thinner than the upper areas.

Burial 10b (Figure 6.15) shows early fluctuations in Ba, Sr, Zn, and Mn, which do not correspond to any visible feature on the tooth. In this case there is no enamel being

Figure 6.15 Output for Burial 10b lower right canine

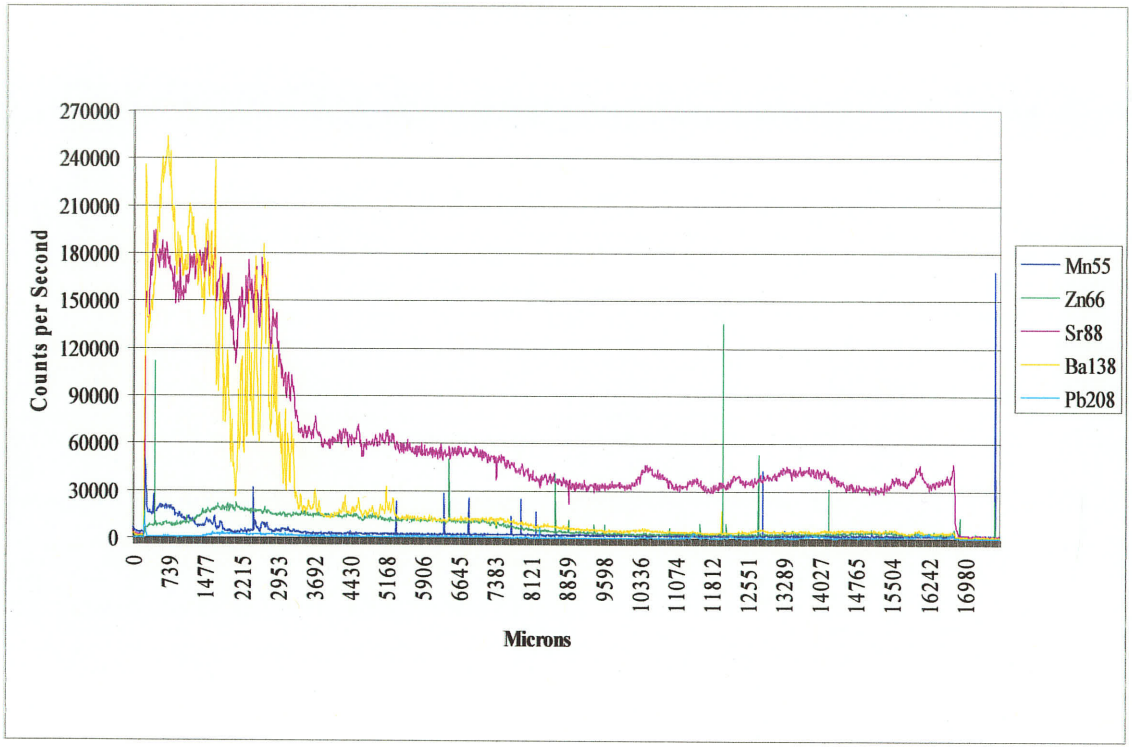


ablated. The intensities levels off to a more even pattern between 2,100 and 2,200 microns. Again, Ba and Sr seem to follow the same pattern or periodicity, although on a different order of magnitude. When Ba and Sr are removed, it becomes clear that Pb and Hg also follow each other very closely in the early period of the scan and then flatten out. Manganese appears to follow Hg and Pb, but then fluctuates when they die out, before becoming and staying steady throughout. Zn decreases steadily over the period of the

burn. At approximately 16,980 microns the laser reaches the end of the tooth surface and burns into the resin.

In Figure 6.16, Burial 11, there is again no visible morphological change in the tooth that would explain these early fluctuations in trace element abundances. Again, Ba

Figure 6.16 Output for Burial 11 lower left canine

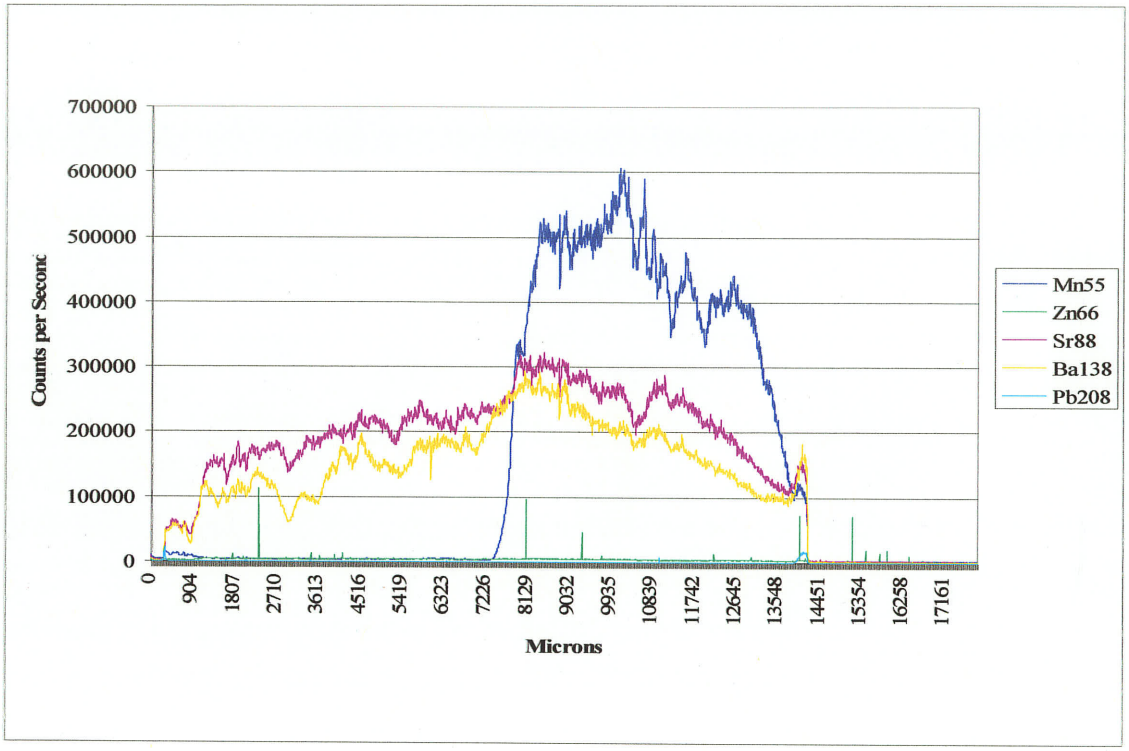


and Sr appear to be linked to one another throughout the burn. Between 650 and 3,265 microns Mn falls but then stays steady while Zn shows a reverse pattern before becoming flat for most of the scan. Zinc has a single small peak at approximately 15,000 microns that cannot be attributed to background noise or a morphological feature of the tooth. At approximately 1,575 microns Pb has small rise and comes back down, before a series of

fluctuations between 11,510 microns and the end of the scan. At approximately 16,775 microns the laser runs off the surface of the tooth and into resin.

In the output for Burial 12 (Figure 6.17) the enamel portion of the tooth is visible in the early part of the scan, and the rise in abundance of trace elements is seen at

Figure 6.17 Output for Burial 12 lower right canine

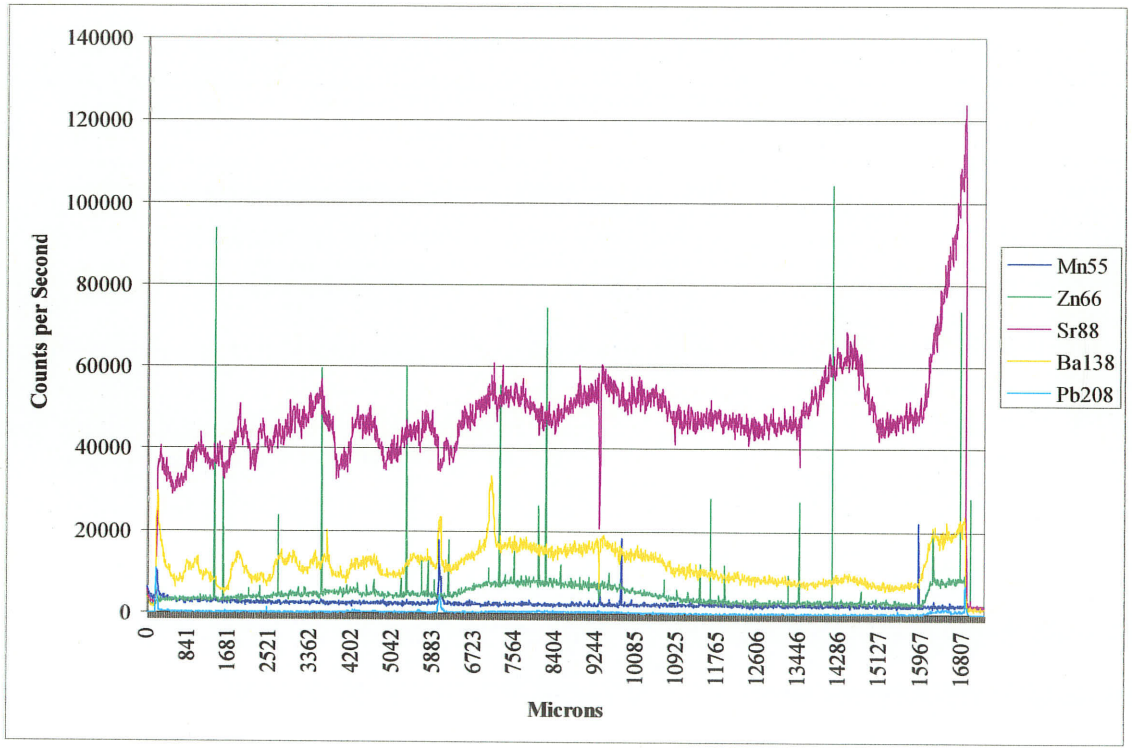


approximately 1,250 microns. The defining feature of this scan is the sharp rise in Mn at about 7,700 microns that cannot be explained by morphology of tooth. This element is present in a higher quantity than all other elements, and stays unusually high until approximately 13,000 microns when it begins to decline sharply and drops off until end of run. Lead is steady except for a sharp spike at approximately 14,100 microns, where Ba, Zn, Sr and Mn spike too. At this point in the scan the integrity of the sample is

visibly degraded and the results become suspect. Zinc, along with all other elements, remains low in the enamel phase of the scan, rises marginally approximately 1,250 when the laser moves onto the dentin and stays somewhat steady until tooth structure becomes degraded approximately 14,100 microns.

The upper right canine of Burial 15 (Figure 6.18) shows that Sr and Ba once again follow a similar periodicity throughout the length of the tooth, although not to the same

Figure 6.18 Output for Burial 15 upper right canine

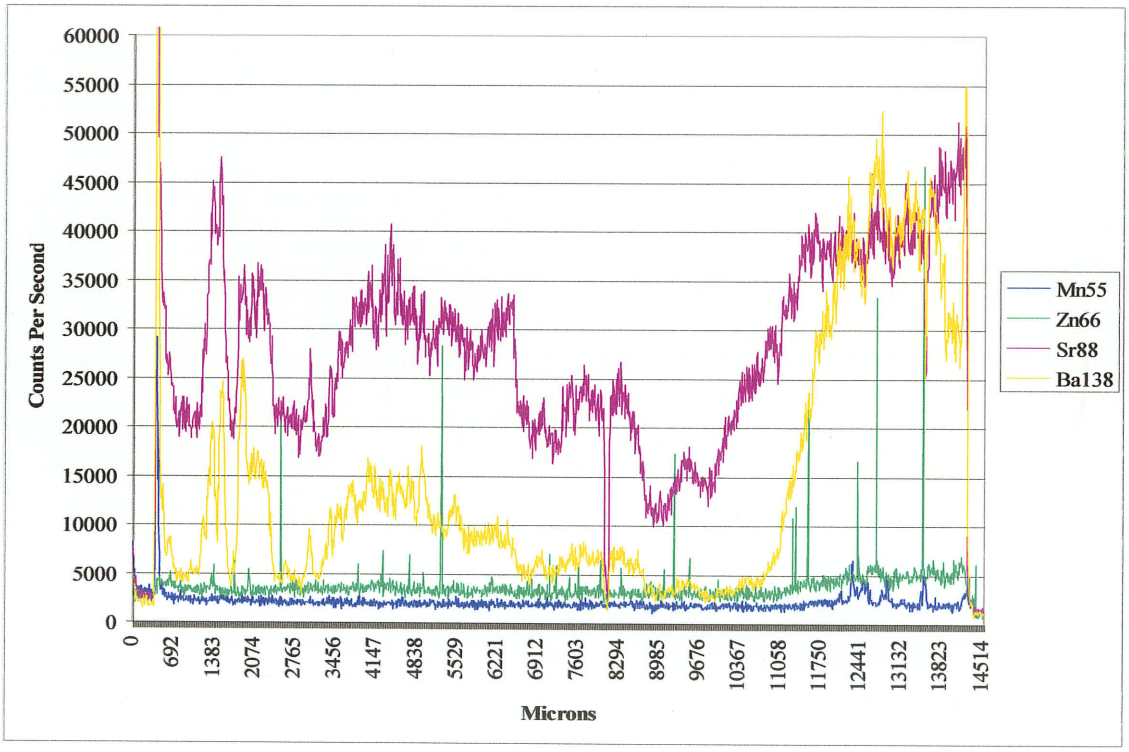


scale. There are numerous spikes in the Zn pattern that cannot be attributed to tooth morphology, but are considered to be background noise. The slow increase of Zn until approximately 4,350 microns appears to be a genuine pattern of change, as does the gently fall again by approximately 11,150 microns. Lead appears to follow the overall Zn

pattern, but on a much smaller scale. Manganese is relatively constant throughout, except for spike at crack in tooth approximately 6,000 microns. At approximately 16,070 microns the nature of the output changes, and at this point the laser may have caused microcracks in the already weakened cut end of the tooth, resulting in a dramatic change in volume of trace elements being counted by the system.

Again in Burial 17a (Figure 6.19), Ba and Sr follow same general patterns. Zinc

Figure 6.19 Output for Burial 17a upper left canine

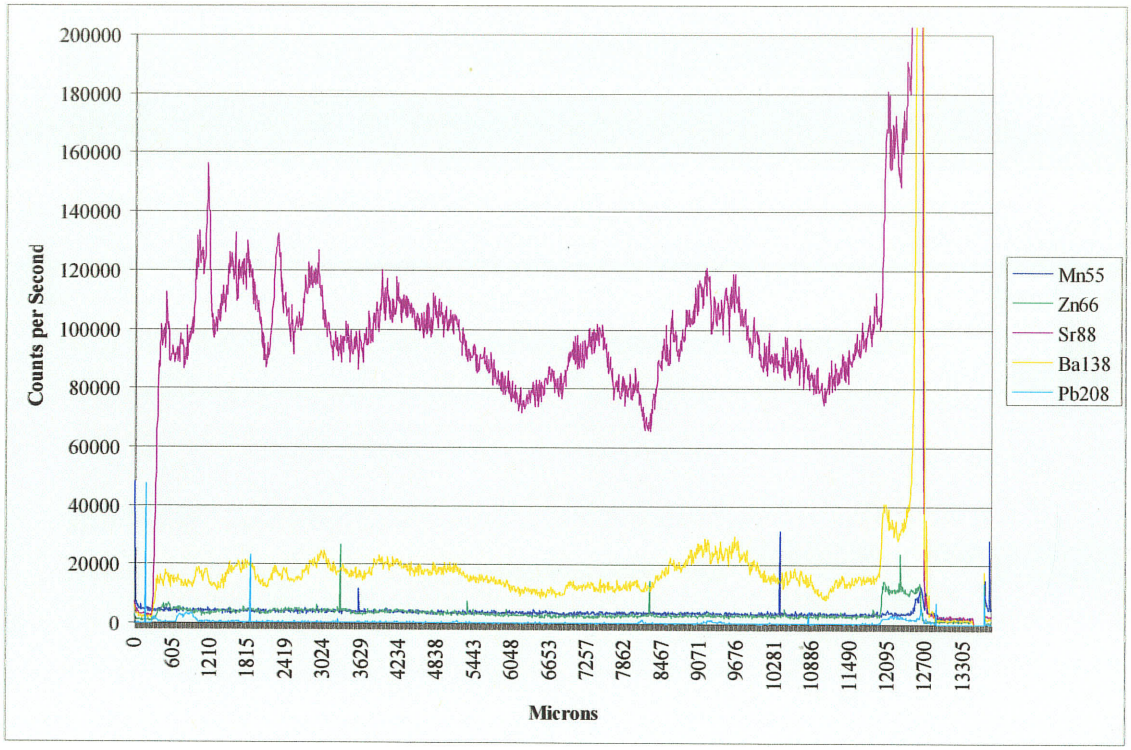


and Mn follow one another overall, with good consistency until approximately 12,125 microns, where all trace elements are altered. Given the morphology of the tooth, it is likely that the laser has crossed into an area of cementum. Lead and Hg follow virtually

identical patterns, staying consistent throughout, except for spikes attributable to tooth morphology, and have been removed from the output.

Figure 6.20 shows the output for Burial 17b. Once again, Ba and Sr follow the same general pattern, with a sharp rise in both where tooth structure is suspect at

Figure 6.20 Output for Burial 17b lower right canine

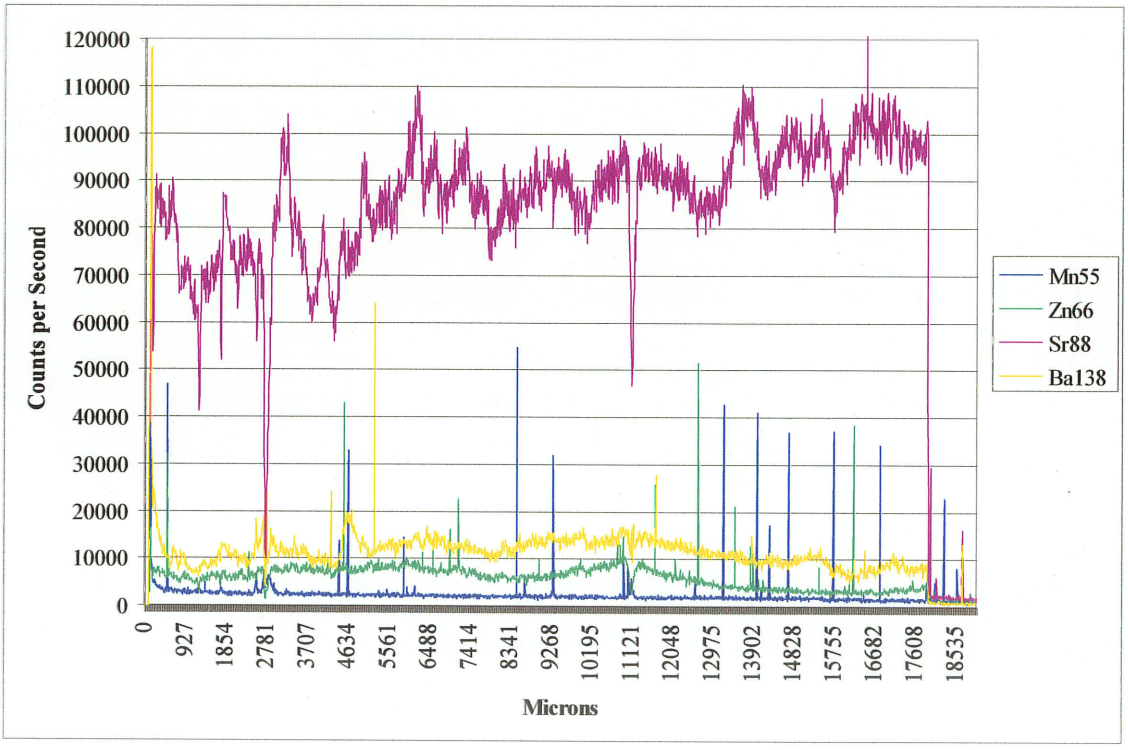


approximately 12,000 microns. At this point, all elements rise suddenly and fluctuate in similar patterns; the uniform nature of the fluctuations seems to indicate that this is structural in nature - burning into resin behind tooth perhaps. Prior to this section of the scan, Mn and Zn follow very similar pattern to one another, and are relatively steady until approximately 5,500 microns, where Zn drops slightly and the two elements then maintain this new equilibrium until the fluctuation at approximately 12,000 microns.

Lead rises sharply at approximately 750 microns, but drops back down to same level by approximately 1,000 microns. It then stays constant, with a few small peaks at approximately 5,175, 8,150, and 9,250 microns, where no visible markers exist on the tooth.

The output for the lower left canine of Burial 19a is illustrated in Figure 6.21. Once again, Ba and Sr follow a very similar overall pattern, with Sr fluctuating primarily between 90,000 and 60,000 counts per second, and 80,000 to 100,000, and then it climbs

Figure 6.21 Output for Burial 19a lower left canine

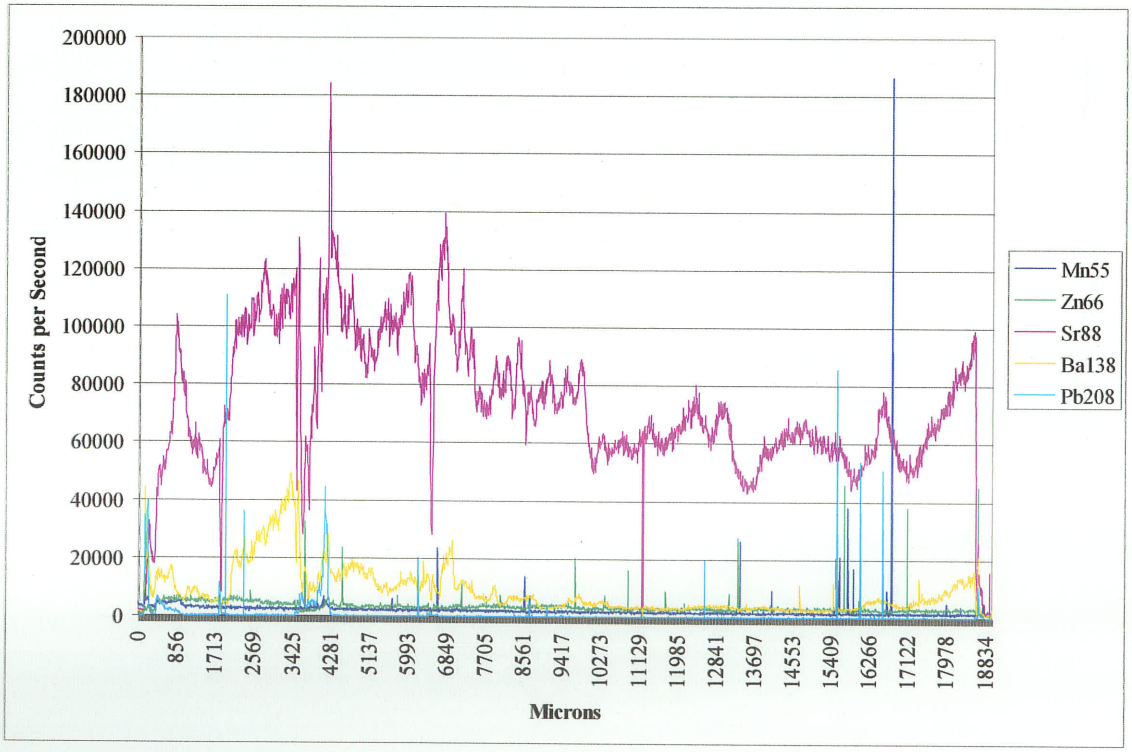


at approximately 13,500 microns and stays high until the end of the run. During this period Ba fluctuates in same pattern until Sr climbs for the last time - at that point Ba falls of slightly and stays low until end of run. Manganese drops slightly throughout the

run, but very steadily and only slightly – the peaks visible on the output correspond to peaks and valleys in other elements that follow cracks in the surface of the tooth. Zinc follows the Ba patterns throughout most of the scan, except for a peak in Ba at approximately 4,700 microns, which is not seen in the Zn.

The output for Burial 21a is depicted in Figure 6.22. Again, Ba and Sr follow the same general pattern throughout, but on a different order of magnitude. After a peak early on, Mn drops very slowly and steadily, with a single real peak at approximately 4,100 microns, which corresponds to a dramatic rise in Pb at the same point. Between approximately 3,500 and 4,250 microns there is a major crack in the tooth, which has left the resin exposed and a dramatic changes in trace element abundance is visible. Features

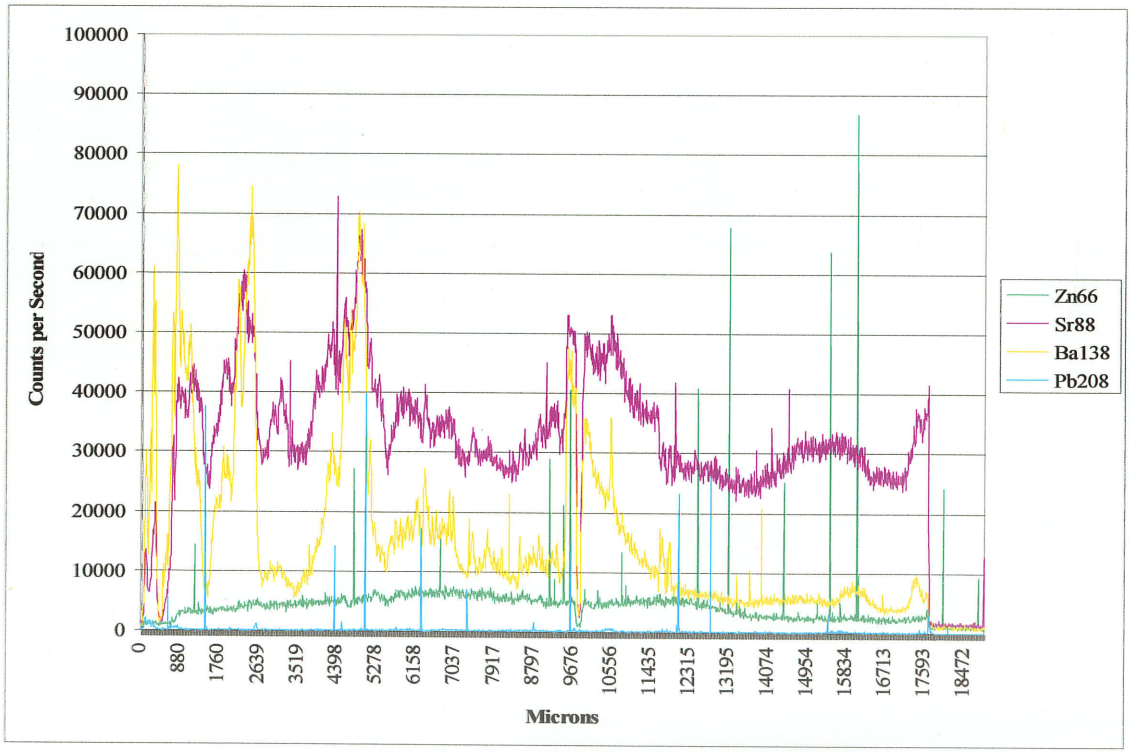
Figure 6.22 Output for Burial 21a lower left canine



of this type are good orientation points, so we can be sure that what we are reading is the dentin and not some other material. At the crack, Zn and Ba drop out while Sr, Pb, and Mn peak. Aside from some early noise, and peaks related to tooth morphology, Pb is relatively steady throughout the burn. Zinc follows Ba early on, but drops off and stays low and relatively steady from approximately 4,500 microns to the end of the scan.

One lower right canine was extracted from a mandible (1-228) recovered from the mound fill (see Figure 6.23). In this sample, Ba and Sr follow similar patterns very

Figure 6.23 Output for Fill 1-228 lower right canine

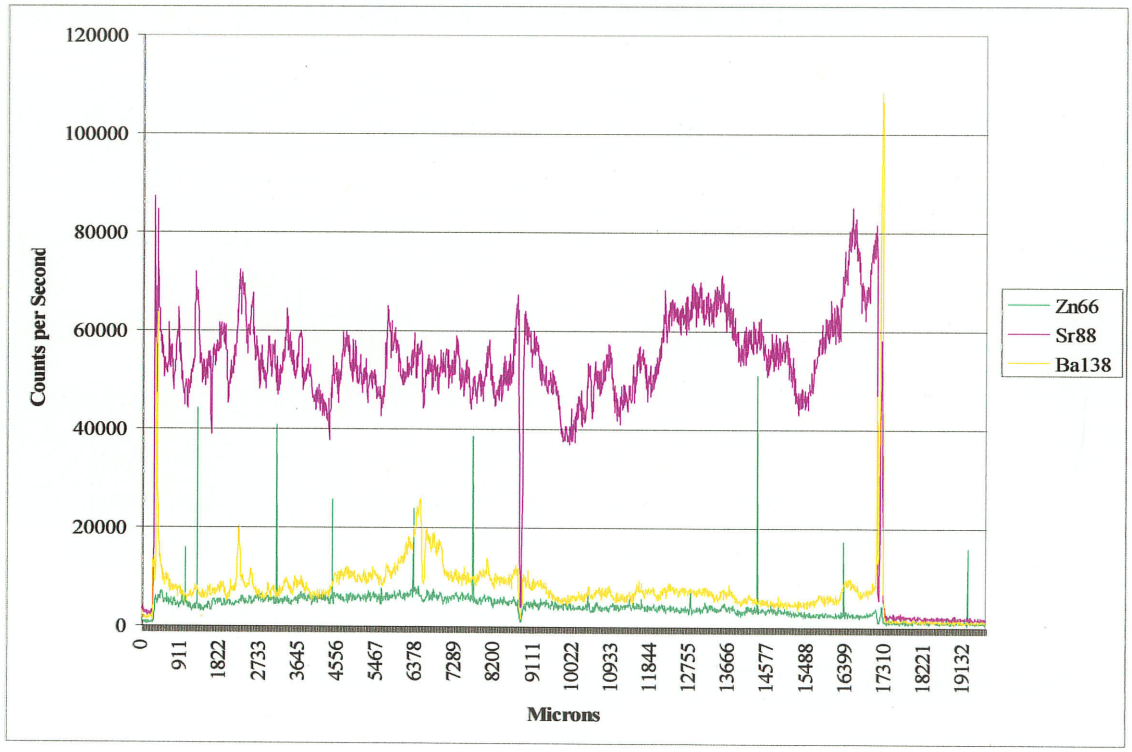


closely throughout, with crossovers early on. After this point, Ba settles in under Sr by approximately 20,000 counts per second through the rest of the burn. Lead is relatively

steady throughout, but has three small peaks that do not correspond to tooth morphology. After some initial noise, Zn rises slowly, levels off through most of the scan, and then drops at approximately 13,000 microns and levels off again until end of the run.

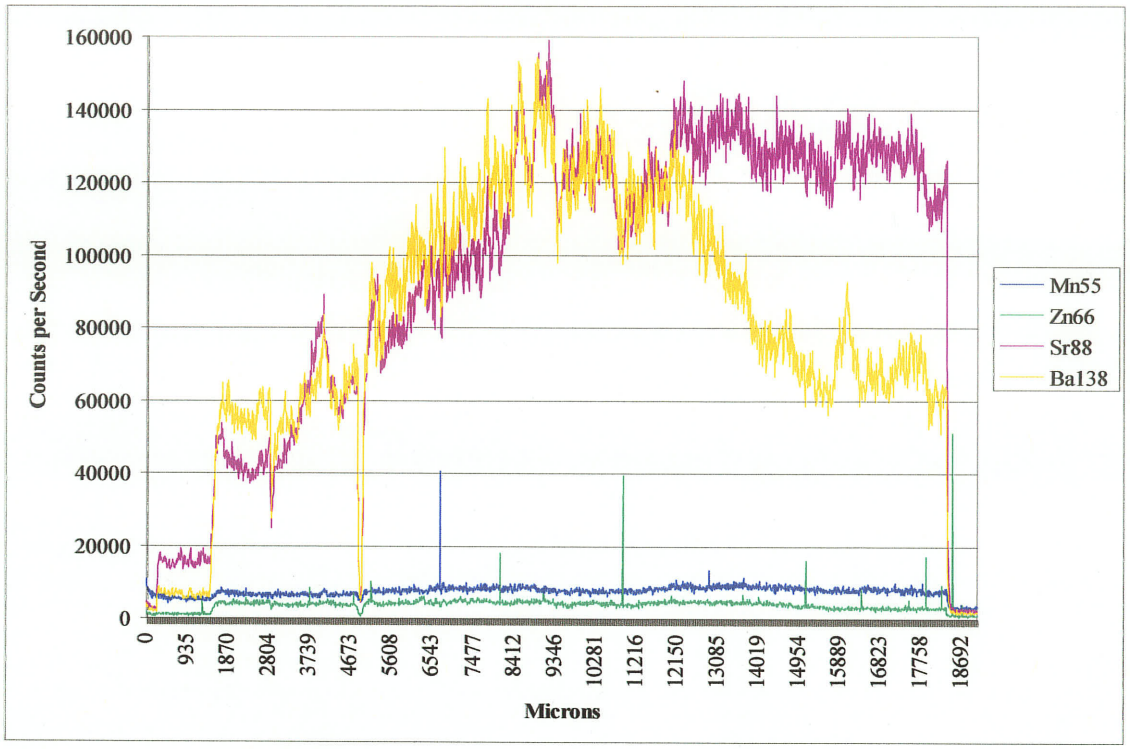
Two loose canine teeth from the fill of Mound One were also tested (see Figures 6.24 and 6.25). Fill tooth A has the same Ba and Sr patterning that is visible in each

Figure 6.24 Output for Fill A



output. While the order of magnitude is different, the two elements appear to follow the same arrangement, except for a peak in Ba Sr and Ba follow same overall pattern, but different order of magnitudes, except for a gradual rise in Ba at approximately 6,500 microns that is not reflected in the Sr. In this tooth, Zn follows Ba in some of the overall

Figure 6.25 Output for Fill B



pattern, but on a much smaller magnitude, and drops very gradually over the run. In the laser scan of the Fill B tooth (figure 6.25), the scan begins in the enamel portion of the tooth, which is reflected in the low concentration of trace elements early on. Once the scan moves into the dentin, Ba and Sr follow each other closely but cross over one another several times until approximately 12,00 microns, where Sr stays up between 120,000 and 140,000 counts per second and Ba drops down and levels off between 80,000 and 60,000 counts per second. Manganese and Zn also follow each other quite closely in this sample, and they stay relatively consistent, with a small decrease around approximately 10,000 microns, rising again gently around approximately 12,500 microns, and then falling off around approximately 15,500 microns and staying consistent until the end of the run.

6.5 Conclusion

A great deal of information was generated by this study, including both positive and negative data. The decision to undertake AMS bone collagen dating of eight discrete individuals resulted in a slightly unexpected but exciting result. Some of the osteobiographical information presented is at variance with previously published reports regarding the Fidler Mounds sample, while in some respects it is similar. A very large amount of data was generated in the course of the LA-ICP-MS study of twelve teeth from the sample, and the interpretation of that data, along with the rest of the information available about the sample, will be discussed below.

Chapter 7

Discussion and Conclusions: Tying it all Together

7.1 Introduction

When this research began, it had two general aims. The first was to examine the Fidler Mounds skeletal sample in order to generate a body of information that would add to the understanding of the lives of precontact groups across the northeast Plains. This was addressed by constructing as complete an osteobiographical profile for each discernable individual in the sample as the level of preservation allowed, and by sending eight samples for AMS bone collagen dating. The second general objective was to test the applicability of LA-ICP-MS technology to the study of diet and health in past populations. By sectioning twelve permanent canine teeth from the collection, and generating a map the spatial distribution of trace elements in the dentin, this aim was met.

From these two primary goals arose a number of specific questions regarding this sample. How can the osteobiographical information from the Fidler Mounds sample

contribute to our understanding of who built the mounds and where they fit into the spatial and temporal distribution of the groups across the northeast Plains? What was the status of their health overall? Previous research (Garvie, 1993) has suggested that a number of individuals in the sample were most likely maize eaters – a suggestion that is somewhat contentious. Was this borne out by the results of the current study? Can long laser ablation scans map the spatial distribution of select trace elements in human teeth, and are those maps a true representation of the general health and well-being of individuals sampled? During the course of this research, these were the types of questions that arose, as did some considerations for future research.

7.2 Who Were These People?

7.2.1 Where they fit in time

Early studies of skeletal collections recovered from burial mounds were often limited by the technology of the day, and there are still some obstacles that cannot be overcome. In discussing some of those limitations, Syms noted that "all burials in particular mounds must be lumped together and treated as a single cultural unit because the crude techniques, haste and lack of concern for context failed to account for possibilities of different groups building accumulative mounds..." (Syms, 1978: 60). Fortunately, this is no longer true. By dating discrete burials or individuals through the radiocarbon dating of bone collagen, we can examine them independently, and can begin to look for patterns that might identify individuals not subjected to dating. Radiocarbon dates derived directly from skeletal material are preferable over relative dating techniques because they provide absolute ages for the specimen.

With the eight burials from the Fidler Mounds that were sampled, the dates generated fell quite distinctly into two groupings. The early burials ranged in time from 1690 to1310 BP, while the recent burials dated between 950 and 560 BP, with a gap of 360 years between the groups. These new dates make the Fidler Mounds one of the earliest dated burial mounds in the province for which data could be uncovered. Burial mounds to the south are slightly older than those found in Manitoba, but in most cases not excessively so. In North Dakota burial mounds are dated between 1920 and 265 BP (Bender *et al.*, 1980; Reeves, 1983; Syms, 1979; Trautman, 1963; Williams, 1985b; 1985a), in South Dakota from 1850 to 830 BP (Haberman, 1993; Reeves, 1983; Trautman, 1963; Wood and Johnson, 1973) and dated mounds in Minnesota range from 3475 to 1025 BP (Johnson, 1964; Lass, 1980; Syms, 1979). The only Minnesota mounds with very old dates are the Haarstad Mound at 3475 BP and Morrison Mound at 2640 BP (Johnson, 1964; Syms, 1979), all other dated mounds in the state range between 1980 and 1025 BP. The new dates from the Fidler Mounds fit very well within the currently understood timeframe of peak burial mound usage in the northeast Great Plains.

The fact that the burials do not span the range of dates is curious; does this imply that mound usage during this period stopped? The gap in the dates does not correspond to the known social disruption south of Manitoba that was associated with the Medieval Warm Period (700 – 550 BP), and at nearby archaeological sites it is thought that this period actually saw an influx of migrants from the south (Flynn, 2002). An examination of nearby archaeological sites demonstrates that the region was not depopulated during the time in which no burials are represented, and in fact that occupation was fairly consistent over several thousand years (Buchner, 1983; Deck, 1989; Enns, 1998; Finch

and Waddell, 1996; Flynn, 2002; Greenfield, 1999; McKinley, 2001; Pettipas, 1996). Given the level of site disturbance at the Fidler Mounds prior to the 1963 salvage excavation, it is impossible to say that the gap between dated burials is not an artifact of the recovery process. One would expect however, that if looting of the mounds biased the radiocarbon dates there would be no discernable pattern. Although the number of burials dated in this study is far more than the norm for a burial mound, it is still quite small. The only way to be sure that no interments took place during this period would be to date each individual recovered from the mounds.

One other factor to consider when examining the dates generated by AMS dating is the possibility that the individuals sampled did in fact incorporate aquatic resources into their diet. All dates are calibrated for a terrestrial diet, but given the location of the mounds and the resources available nearby, it is highly unlikely that groups living in the area did not make use of the river's abundance as a food source. Current marine calibrations of radiocarbon dates are based on saline marine resources however, so those calibrations are not appropriate for a northeast Plains sample. Recent research in Europe regarding a freshwater reservoir effect may indicate that these dates are younger than the current study reports. One study examining diet and the dating of human remains from the Netherlands has found that consumers of fish will exhibit a freshwater reservoir effect, and that dates generated without this calibration are generally appear on the order of several hundred years *older* than those calibrated for a freshwater aquatic diet (Lanting and van der Plicht, 1996). To the best of this researcher's knowledge, this phenomenon has only recently been addressed in North America (Syms, 2003), and no information is available locally to calibrate the Fidler Mounds AMS dates to account for this effect.

Even if this information was available and the dates are more recent than indicated here, the fact remains that there are two distinct burial episodes, the duration of mound use is much longer than was originally assumed, and the Fidler Mounds remain one of the oldest dated burial mounds in the region.

Saunders and Herring (1995) argue that most mortality samples represent a broader population than is recovered archaeologically because communities rarely exist in isolation through time; they interact and intertwine over time and space. This is very true in the case of the individuals interred in the Fidler Mounds. Given the range of time over which the mounds were in use for disposal of the dead, it is highly unlikely that the remains recovered represent a single discrete population.

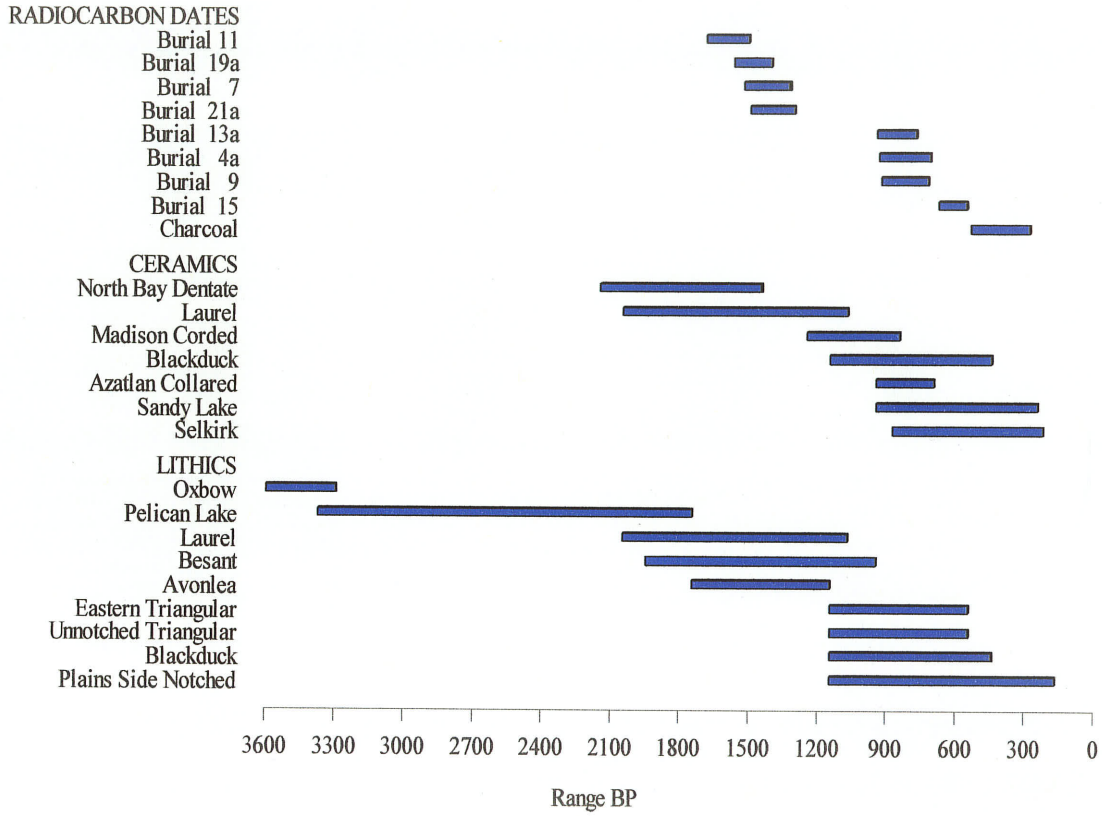
7.2.2 Where they fit in the northeast Plains cultural framework

The close proximity of the Lockport archaeological site to the Fidler Mounds has led previous researchers to speculate that the individuals interred within the mounds were most likely inhabitants of the Lockport site (Fiske, 1965b). The dates of the eight burials fit very closely with the dated stratigraphy of the occupation area of the Lockport site, specifically beds B-F (Buchner, 1988; Deck, 1989; Deck and Shay, 1992; McKinley, 2001). Unfortunately the previous looting of the mounds obscures most of the archaeological evidence for cultural affiliation.

The artifacts recovered from the mounds have been examined by previous researchers (Johnson, 1973; Saylor, 1976; Syms, 1979), and were not re-analysed in any depth as part of this research. Diagnostic pottery and lithic items were inspected only in order to classify them in terms of the culture history of the region. A listing of all

identifiable ceramic sherds and lithic tools is found in Chapter 5, and for the most part they coincide very closely with the new dates assigned to the burials (see Figure 7.1). Many of the artifacts are not specifically diagnostic to a particular culture or group, but are suggestive of connections between cultures. For example, the bone items recovered

Figure 7.1 Dates for the Fidler Mounds material



at the Fidler Mounds have a great temporal and geographic span, and are therefore not terribly informative. The decorative motif on the bone bracelets, however, closely resembles specimens from the Arvilla complex (Johnson, 1973) and some Laurel mounds to the east (Stoltman, 1973; Torbenson *et al.*, 1994). The trumpeter swan ulna recovered

with Burial 7, while unique to this sample, is relatively common to many precontact groups and cannot be used to identify the individual culturally.

A few items however, are worthy of particular attention due to their somewhat unique nature. Pottery pipe pieces found with burials 17 a and 17b are very similar in size, shape and decoration to ones recovered from the Snake Mounds in Minnesota, which are assigned to the Arvilla Complex (Johnson, 1973). Tubular cut shell beads are non-diagnostic to a cultural group, but shell gorgets are characteristic of Arvilla burial mounds, and notched clamshell pendants are found in both Arvilla and Laurel sites (Capes, 1963; Johnson, 1973; Stoltman, 1973). Of the pottery recovered, two varieties indicate an association with groups to the south of the Dakotas and east beyond Minnesota. Madison Corded (700-1100AD) and Azatlan Collared (900-1200 AD) ceramics are known to be linked to groups in southern Wisconsin during the Middle Mississippian period, and in the Great Plains to the southwest of the study area (Birmingham and Eisenberg, 2000; Hurley, 1974). The Plains Side Notched and Plains Triangular points recovered are also indicative of ties to the southeast (Epp and Dyck, 1983; Gregg, 1985; Kehoe, 1973; MacNeish, 1958). The marine shells recovered are also indicative of relations with groups along the Mississippi Valley (Willey, 1966), although since all of these items were recovered from the fill there is no immediate connection between these groups and the individuals interred in the Fidler Mounds.

Burials 7 and 19 were the only two individuals dated who were recovered with artifacts in direct association. The known timeframes associated with these artifacts do fall within the range of radiocarbon dates for the skeletal remains; unfortunately those items are not distinct enough to be identifiable to culture. Artifacts recovered with Burial

7 include the trumpeter swan ulna, two brown chalcedony knives, and an unmodified chert flake – all of which are indistinct culturally. Burial 19 was found with native copper ring, thought to have been affixed to a garment (Fiske, 1964; Saylor, 1976). Native copper is a familiar decorative item far back into the Archaic Period and cannot be assigned to any specific culture, although it was more common among groups to the east around the Great Lakes than it was in the Red River Valley of the Dakotas (Hewes, 1949; Hurley, 1974; Johnson, 1973; Lenius and Olinyk, 1990; Mason, 1981; Neuman, 1975; Shay, 1990; Steinbring, 1974; Wilford, 1970).

In many cases, the burial modes and orientation are difficult to identify for the Fidler Mounds burials, and are not unique enough to allow for assignment to a particular defined cultural group. Linear and circular mounds with complete and disarticulated secondary burials are considered hallmarks of the Arvilla burial complex (Johnson, 1973; Snortland, 1994; Syms, 1982), however they are not distinctly Arvilla traits. Burials classed as Sonota are often multiple bundle burials that also show signs of intentional disarticulation and defleshing, with some articulated primary burials, in a central oval burial pit covered by logs (Bass and Phenice, 1975; Neuman, 1975; Snortland, 1994). Although log covered burials were not found during the 1963 excavations, they are noted in the literature that documents the history of excavation at Fidler, and these modes of burial were noted during the salvage operation in 1963. Plains Village period burials, in particular Devil's Lake-Sourisford mounds, do not have a well-defined burial strategy, however it is noted that often the burials recovered from these mounds are also covered by logs (Snortland, 1994; Syms, 1979). Laurel mounds normally have small numbers of interments with accretional episodes of burial and mound enlargement (Kenyon, 1986;

Lenius and Olinyk, 1990; Snortland, 1994; Torbenson *et al.*, 1994; 1996) , which appears to be the case with the Fidler Mounds. Seated burials, of which the Fidler Mounds have two, are found in Laurel and Arvilla mounds (Johnson, 1973; Kenyon, 1986; Snortland, 1994; Syms, 1979; Torbenson *et al.*, 1994; 1996).

As becomes evident from this brief discussion, the variety of burial modes implies a fairly early date for the original construction of the mounds, with use by successive groups over time. Certainly knowing that Laurel groups built mounds in Minnesota and northwestern Ontario early on, that there is a distinct Laurel component at the nearby Lockport habitation site, and that the earliest radiocarbon dates recovered thus far from the human remains fall into that period, implies that the original construction of the Fidler Mounds took place during that time and that the mounds were re-used either by descendants of the original builders or other groups who moved into the region over time. The re-use of old mounds is well documented in Wisconsin and Minnesota, where native groups decimated by disease dug into existing burial mounds, whose original builders were unknown to them, in order to dispose of their dead (Birmingham and Eisenberg, 2000; Gibbon, 1994; Gregg, 1994). The majority of the artifactual and burial pattern evidence appears to point toward an initial westward expansion of the burial pattern associated with the Laurel culture from Minnesota and northwestern Ontario, concurrent with, or followed very closely by, a period of use by people employing Arvilla or Sonota burial practices from the southeast and southwest respectively, with a final period of use by groups associated with the Devil's Lake-Sourisford Burial Complex from the Red River Valley to the south.

7.2.3 The Skeletal Material

Studies examining the health and well-being of past peoples are, of necessity, cross-sectional in nature. There is no way to track changes in the populations over time, so physical anthropologists examine the skeletal remains of individuals in order to assess broader patterns of health within the group from which the sample is drawn. Physical anthropologists use population comparisons, differential growth rates and assessments of environmental factors to gauge overall health in ancient populations. By looking at such things as the relationship between physical size attained at specific developmental ages, indicators of prolonged skeletal growth, and delayed skeletal maturation relative to dental development, researchers are able to better understand the physiological developmental challenges faced by extant populations (Humphrey, 2000).

7.2.3.1 Health and Well Being

Generally, the Fidler Mounds individuals were relatively healthy. Numerous individuals within the sample lived long enough to develop symptoms of degenerative joint disease, an indication that their health was adequate for long-term survival. In fact, the majority of pathological changes noted within the sample are related to the aging process. Most of those individuals who display signs of illness demonstrate symptoms of non-specific periostitic reactions to infections; only a small number of individuals show indications of more severe or chronic infections.

Burial 4c is that of a young adult male, between the ages of 25-35 years, who is represented only by postcranial elements. There is osteophytic growth along the radial articulation of the right ulna, head and neck of trace element ribs, and in the lower lumbar

vertebrae. There is some lipping of the distal articular surface of the right femur, and the proximal shaft is rotated forward as if it was dislocated during life. The most striking pathological feature of Burial 4c however, is the severe osteomyelitis and periostitis along the diaphyses of the left tibia and fibula. With involucrum and sequestrum along both shafts, the illness appears to have been active at the time of death. The active site of infection appears limited to the lower left leg, and it is likely that this is the primary site of infection secondary to traumatic injury. All indications are that the infection was active for a long period of time, and the involvement of the vertebra, and minor periostitic reactions in the ribs and ulna may suggest that the individual was becoming septic, but there is insufficient evidence to support a conclusive diagnosis.

Burial 7, a young (30-35 years) male, is the second most severely pathological individual in the Fidler Mounds sample. There is a gross thickening of the shaft of the right ulna, radius, tibia and fibula, with some lesser involvement of the left tibia. There is increasingly severe osteophytic growth on the superior and inferior articular facets of all thoracic vertebrae from mid-spine toward the lumbar vertebra, with abnormal growth on the body of the sacrum and pitting along the dorsal walls.

The lesions present on the long bones of Burial 7 are clustered in pits, with striations, cavitations, and a roughened and markedly hyper-vascularised shaft of the right tibia and fibula. There is a thick periosteal build-up on all affected long bones, and lesions have rough and thin margins. Saylor (1976) offers the suggestion that the condition of the right lower limb of individual 7 is a result of Paget's Disease, however the fibula and tarsals of this individual are affected by the pathological process. In most cases of Paget's Disease, these elements are not normally affected (Itani and Tsang,

1996; Ortner and Putschar, 1981). As previously noted, the vertebrae of this individual show signs of advanced degeneration and there is some lipping of the distal articular surfaces of both femora. A complete cranium is present for this individual, and there are no visible signs of pathology on the cranial vault, although this is the only individual in the sample who was trephined. The nature of the lesions on the long bones is suggestive of a treponemal infection, however a differential diagnosis of Paget's disease cannot be ruled out without histological examination. The involvement of the spinal column and femoral articular surfaces are known to occur with treponema (Ortner and Putschar, 1981; Roberts and Manchester, 1995). In several types of treponemal infections the cranium is a central site of lesion formation, however, in endemic syphilis and yaws there is no cranial pitting (Aufderheide and Rodriguez-Martin, 1998; Baker and Armelagos, 1988; Rogers and Waldron, 1989). Individuals in the end stages of syphilis often display highly erratic behaviour (Arnott *et al.*, 2003; Aufderheide and Rodriguez-Martin, 1998; Bush and Zvelebil, 1991; LiVolsi *et al.*, 1994) and it is entirely possible that medical intervention was attempted in this case.

The evidence for treponemal disease during the Middle Woodland Period in the Plains is scarce, and some authors have concluded that pre-Columbian treponematosis was virtually non-existent (Gregg and Gregg, 1987; Walker, 1983). Evidence for the presence of treponemal disease during the precontact period does exist, however the majority of samples demonstrating traits of the disease comes from rather late sedentary, horticultural groups (Baker and Armelagos, 1988). Some earlier evidence of treponema exists in the north east Plains, specifically in several sites in Iowa, as early as 610 BC, in populations who are thought to have practiced a hunter gatherer subsistence economy

(Schermer *et al.*, 1994), so it is not inconceivable that the individuals interred at the Fidler Mounds could have suffered from the same malady.

The practice of trephination is known to have been practiced extensively in prehistory, however the evidence for trephination in precontact North American native societies is minimal (Arnott *et al.*, 2003; Aufderheide and Rodriguez-Martin, 1998; Brothwell, 1981; Roberts and Manchester, 1995). Reports of trephination or trephination-like openings in the cranium do exist however, from burial mounds in Minnesota and the Rainy River area that are assigned to the Laurel culture (Stoltman, 1973; Wilford *et al.*, 1969; Wilford, 1950). Other indicators of affiliation with Laurel groups are found within the Fidler Mounds, and this particular burial dates to the appropriate period, so it is very likely that the practice was familiar to the groups who made use of the Fidler Mounds to dispose of their dead.

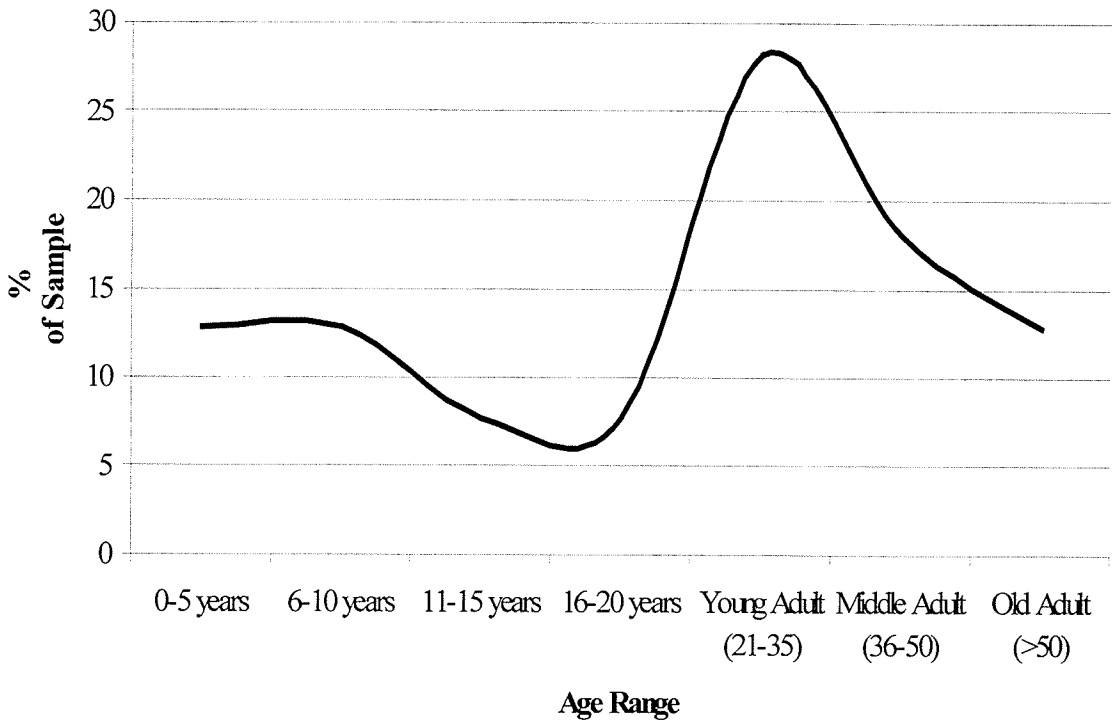
The final exceptionally pathological individual in the Fidler Mounds sample is Burial 17a. This female lived past the age of fifty years, and demonstrates symptoms of pathology that are in keeping with her advancing years, and well as signs of past infections and traumatic injury. The majority of skeletal elements for this individual demonstrate advanced levels of arthritis: extensive articular surface lipping on the intact long bones, osteophytic growth along the margins of the vertebrae, sacrum and auricular surface of the ilium, and lipping of the costal notches of the corpus sterni, rib tubercles, and glenoid fossa of both scapulae. Alveolar resorption in the mandible is severe, and is only slightly less so in the maxilla. Trauma is indicated in the right radius, ulna, and one proximal hand phalange. A disunited fracture of the right ulna has resulted in the loss of the distal portion of the bone, and in an apparent increase in muscle attachments along the

radial tuberosity of the radius, which is likely the reaction of the body to differential loading on the arm as a result of the break to the ulna (Kvien, 2004; Rothenberg and Chapman, 1989; Turesson and Jacobsson, 2004). Illness or infection appears to be a factor in the gross morphology of the left radius and tibia, both of which demonstrate evidence of a non-specific inflammatory response. The right tibia and fibula are highly pathological, with severe malformation of the distal ⅓ of the tibia; instead of a normal articular surface and medial malleolus there is a bony growth protruding medially out from the shaft, and a lateral bowing of the shaft. The distal end of the fibula is distorted, has none of the features of a healthy fibula, and fits underneath the distal end of the tibia. The calcaneus and navicular of the right side are grossly malformed and are marked by draining sinuses, indicating a long term and painful condition.

Generally, the individuals that make up the Fidler Mounds skeletal series were in good health, which is in direct contrast to later Plains Village populations who depended more heavily on horticulture for subsistence (Gregg and Gregg, 1987; Gregg *et al.*, 1981). Although DJD is common in the sample, few examples are severe enough to have limited the daily activities of the individual. Trauma and infections are rather low in frequency, although a few of the observed conditions are significant. The level of dental attrition and number of dental caries is in keeping with that of a precontact group who existed on a hunter-gatherer subsistence pattern. Given the majority of the individuals in the sample show no signs of having suffered from long-term illness, it is most likely that pathological contributors to mortality were acute and deadly.

Looking at the age at death distribution for the Fidler Mounds sample, it is apparent that the distribution is not normal (see Figure 7.2). The distribution could be

Figure 7.2 Age-at-death distribution of Fidler Mounds sample



attributed to a number of factors, not the least of which is the fact that the Fidler Mounds sample does not constitute a discrete population and as such the assemblage should not be expected to conform to a mortality curve generated for a defined population who are subjected to the same ecological, pathological and societal factors. The Fidler Mounds sample is a cumulative aggregate, from multiple generations, of individuals who died at different times during the precontact period and under a variety of circumstances. The previous looting of the mounds almost certainly guarantees that the remains recovered during the 1963 salvage excavation are not accurate reflections of the age and sex distribution within the populations from which they were derived. There is no way to know what the demographic composition of the mound sample was originally. The

differential preservation of adult versus non-adult remains is typically a factor in skeletal samples, and non-adults are normally under-represented in these situations (Cipriano-Bechtle *et al.*, 1996; Guy *et al.*, 1997; Herring *et al.*, 1991; Jackes, 1992). In this sample, it appears that the period at which an individual was most at risk of death was during early adulthood. While there is no immediately apparent reason for this, it is most likely related to sample bias, in that young adults are over-represented in the sample.

7.2.3.2 Growth and Development

Since researchers cannot study the progressive growth of past individuals and populations, they examine indicators of growth and development in skeletal samples. In this way they are able to gauge the rate, trajectory, and progress of growth in the past. Rates of growth, and indicators of growth disruption, are explored as indicators of overall health status and may be linked to differential resource availability that is culturally, genetically or practically dictated (Bhan, 2001; Brass, 1975; Iyun, 1993; Saunders and Hoppa, 1993; Wood and Magno de Carvalho, 1988).

Information regarding the growth patterns and trajectories within the Fidler Mounds sample however, is disappointingly sparse. At the outset of the study it had been hoped that the material would provide an opportunity to study the growth and development of a precontact Plains population. The poor representation of the non-adults in the sample, and the dates that indicate that this is almost certainly not a discrete population, forced the reduction of this aspect of the project to a much smaller portion than was originally intended. There is however, still some information that can be gleaned from these individuals regarding their growth, overall health and particular

aspects of their culture, and how those variables compare to other precontact groups across the north east Plains.

One of the best documented precontact Plains populations is the Arikara of South Dakota (Jantz and Owsley, 1984a; 1984b; Merchant, 1973; Merchant and Ubelaker, 1977; Olsen and Shipman, 1994; Orser, 1980; Ubelaker and Willey, 1978), and while the date assigned to this group is slightly more recent than the Fidler Mounds sample, it remains one of the most appropriate samples for comparative purposes. When measuring the Fidler Mounds data against that of the Arikara, it becomes apparent that the growth pattern of Fidler non-adults, as assessed by osteological and dental ages, matches the growth pattern of Arikara non-adults quite closely. Humeral and tibial diaphyseal lengths for the Fidler Mounds non-adults were compared to the same measurements for the Arikara sample, for which dental ages were also available, in order to estimate the ages of the Fidler non-adults (see Table 7.1 and 7.2). All other long bones were also assessed, and within individuals the age categories for all long bone diaphyseal lengths are very close to one another.

When all possible aging methods for non-adults were employed for the Fidler Mounds sample, the age categories are generally in good agreement (see Table 7.3). This uniformity between osteological and dental ages appears to indicate that the Fidler Mounds non-adults were individuals whose growth trajectory was on par with that of other precontact native groups within the northeast Plains. There is no bilateral asymmetry that might indicate a period of prolonged developmental stress (Albert and Greene, 1999; Buschang, 1982), and when intra-individual diaphyseal lengths are

Table 7.1 **Humerus**: Relation of maximum diaphyseal length with increasing age at death for Arikara non-adults and diaphyseal length of Fidler Mound non-adults. Arikara data from Merchant and Ubelaker (1977)

Estimated Age in Years	Arikara Range in mm	Fidler Burial 2a	Fidler Burial 2c	Fidler Burial 8a	Fidler Burial 9	Fidler Burial 18
NB-0.5	63.50-89.00					
0.5-1.5	84.00-119.00					111.88
1.5-2.5	121.00-138.00					
2.5-3.5	118.00-157.00					
3.5-4.5	154.00-159.00					
4.5-5.5	161.00-179.50	166.13			168.71	
5.5-6.5	172.50-192.00					
6.5-7.6	187.50-204.00					
7.5-8.5	206.50-217.00					
8.5-9.5	--					
9.5-10.5	225.00-235.00					
10.5-11.5	--					
11.5-12.5	251.00-258.00			253.57		
12.5-13.5	--					

Table 7.2 **Tibia**: Relation of maximum diaphyseal length with increasing age at death for Arikara non-adults and diaphyseal length of Fidler Mound non-adults. Arikara data from Merchant and Ubelaker (1977)

Estimated Age in Years	Arikara Range in mm	Fidler Burial 2a	Fidler Burial 2c	Fidler Burial 8a	Fidler Burial 9	Fidler Burial 18
NB-0.5	59.50-94.00					
0.5-1.5	81.00-131.50					129.34
1.5-2.5	125.00-151.00	148.63				129.34
2.5-3.5	127.00-184.00	148.63				129.34
3.5-4.5	165.00-176.00					
4.5-5.5	181.00-201.50				189.94	
5.5-6.5	191.00-222.00					

compared for percentage of adult growth achieved, there is a good fit between elements, with the exception of Burial 2a (see Table 6.15, pg. 124). With this child, the humeral

Table 7.3 Assessment of age for non adults in the Fidler Mounds sample

Burial	Osteological Age by Epyphseal Union (White 2000)	Osteological Age by Long Bone Metrics (Merchant and Ubelaker 1977)	Dental Age (Buikstra and Ubelaker 1994)	Dental Age (Trodden 1982)	Osteological Age, Other Criteria as Noted
1b	n/a	n/a	9-10 yrs	10.81-10.90 yrs	n/a
2a	n/a	1.5-5.5 yrs	n/a	n/a	n/a
2c	14-19 yrs	>12.5 yrs	n/a	n/a	n/a
3b	n/a	n/a	n/a	n/a	5-10 yrs (size of illium similar to Burial 9)
4a	n/a	n/a	n/a	n/a	0-5 yrs (size of clavicle similar to Burial 18)
4b	10-14 yrs	n/a	n/a	n/a	n/a
6	2-3 yrs	n/a	n/a	n/a	n/a
8a	n/a	11.5-12.5 yrs	n/a	n/a	n/a
9	6-7 yrs	4.5-6.5 yrs	6-7 yrs	6.08-6.79 yrs	n/a
13c	n/a	n/a	n/a	n/a	5-10 yrs (size of ribs similar to Burial 9)
14b	0-2 yrs	n/a	n/a	n/a	n/a
18	2-5 yrs	0.5-3.5 yrs	3-5 yrs	3.15-3.52 yrs	n/a
19b	15-20 yrs	n/a	n/a	n/a	n/a
20c	n/a	n/a	n/a	n/a	n/a
21a	15-20 yrs	n/a	n/a	n/a	n/a
21d	n/a	n/a	n/a	n/a	5-10 yrs (size of tibial shaft similar to Burial 9)
21e	n/a	n/a	n/a	n/a	n/a

diaphyseal length suggests that over 52% of adult bone length has been achieve while the tibial length is just below 39% of the mean adult length for this sample. There are no apparent pathological indicators present on the bones to suggest that illness played a role in this phenomenon. It is possible that the discrepancy in ages indicates that the remains of more than one non-adult are present in Burial 2, however the most probable interpretation of these data is that this individual had undergone a growth spurt in arm length but had not yet experienced the same kind of growth in the lower limbs.

Adult long bone length, and therefore stature, is the end product of childhood growth and development patterns. A study by Cole (1994) presents data on long bone length for several populations in the northeast Plains, which is compared to the Fidler Mounds sample in Table 7.4. The Woodland sample consists of remains recovered from sites dated to the Middle and Late Woodland Period and assigned to the Sonota Burial

Table 7.4 Comparison of selected long bone maximum lengths (in mm) between Fidler Mounds sample and three Great Plains populations
Data from Cole (1994) and Mensforth (1985)

	Femur	Tibia	Humerus	Ulna
Fidler Mounds sample AD 260-1390				
Male	470	391	328	287
Female	437	374	306	259
Woodland sample AD 610-1033				
Male	462	385	n/a	n/a
Female	423	347	n/a	n/a
Libben Population AD 800-1100				
Male	464	388	333	286
Female	430	358	311	264
Coalescent sample AD 1625-1817				
Male	451	382	n/a	n/a
Female	416	348	n/a	n/a

Complex in North Dakota. Individuals from this period and area are thought to have depended heavily upon a hunting and gathering subsistence pattern, with some seasonal dependence on horticulture (Johnson and Wood, 1980). The Coalescent sample is slightly more recent than the Fidler Mounds sample, and is considered part of the Plains Village period of northeast Plains prehistory along the Missouri River and into the northern Plains (Cole, 1994). This sample is thought to have subsisted on a combination

of intense maize horticulture and bison exploitation (Johnson and Wood, 1980). While the results of this comparison show that the Fidler Mounds individuals were larger on average than the two comparative populations, the ranges of long bone lengths do overlap considerably. A slight trend toward shorter long bone length may be reflective of an increasing dependence on a horticulture, and in particular maize horticulture, as reported by numerous researchers (Garn and Clark, 1975; Key, 1980; Meiklejohn *et al.*, 1984; Newman, 1975).

When the Fidler Mounds individuals are compared to yet another Plains populations, however, this trend towards decreasing long bone length disappears (see Table 7.4). The Libben site is a Late Woodland occupation and burial site in Ohio, whose inhabitants were dependant on hunting and gathering for subsistence, and which is contemporaneous with the Fidler Mounds (Mensforth, 1985). When mean long bone measurements are compared between these groups, the averages are very similar. From these comparisons, it appears that the Fidler Mounds individuals are more similar in stature, as indicated by long bone lengths, to the Woodland Period populations who practiced hunting and gathering for subsistence than they are to the later, horticultural, group examined.

7.2.3.3 Patterns of Behaviour

One of the secondary questions that arose during this research centered on a previous study that investigated the possibility of maize consumption by the Fidler Mounds population through an examination of the C stable isotope ratios (Garvie, 1993). Information generated as part of the AMS bone collagen dating process is suggestive of

results. As is evident from Figure 7.3, none of the results from the burials tested in this study are clearly indicative of maize eaters. While the δd13C levels are not indicative of maize consumption as such the δ15N readings do suggest that the individuals sampled had a mixed terrestrial-marine dietary pattern, which centered on C-3 based animal products.

In the previous research, Burials 15 and 21a were reported to have $\delta^{13}C$ levels that

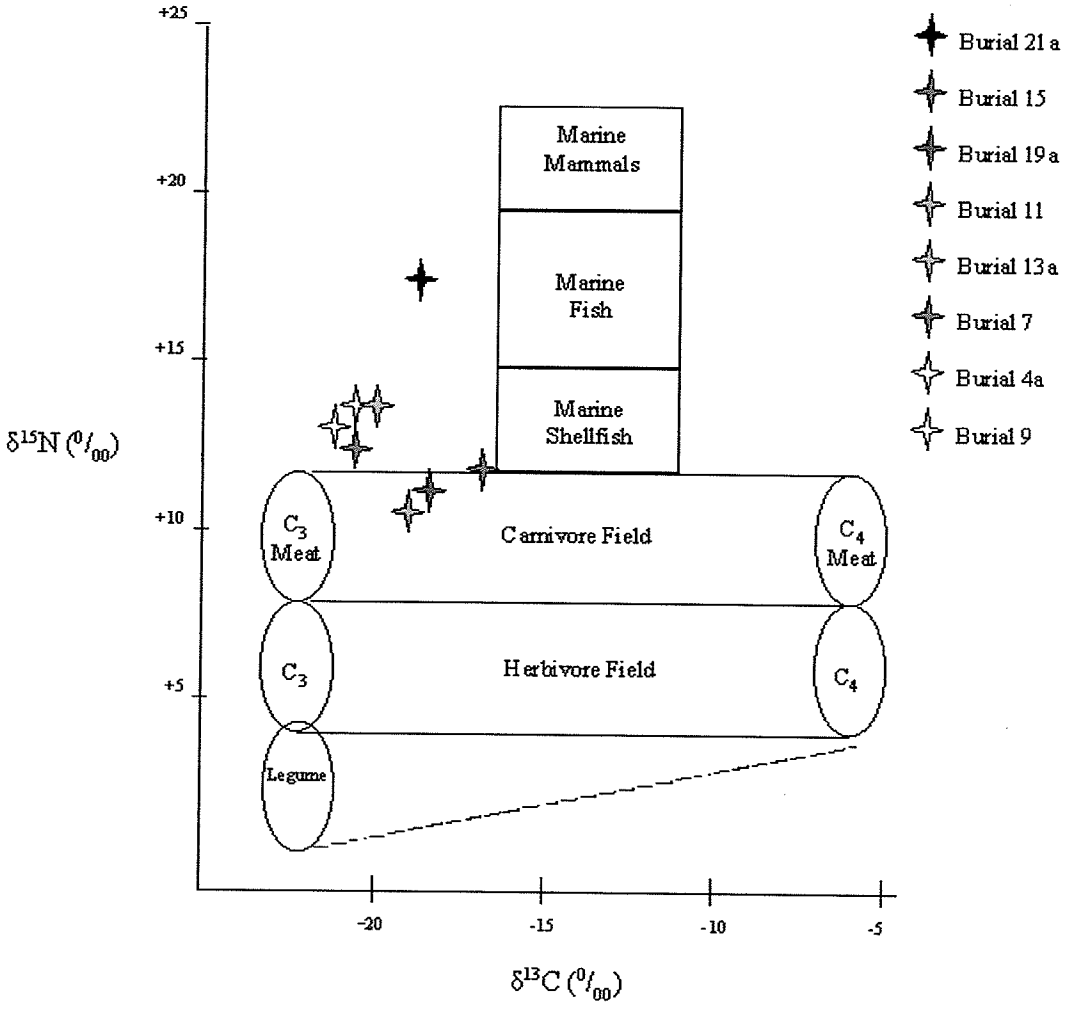


Figure 7.3

$\delta^{13}C$ and $\delta^{15}N$ levels of the dated burials from Fidler Mounds

were at odds with the rest of the Fidler mortuary population at ⁻14‰ and ⁻17.7‰ respectively (Garvie, 1993). In the current study, Burial 15's $^{13}C/^{12}C$ ratio is ⁻16.1‰, and Burial 21a has a $^{13}C/^{12}C$ ratio of ⁻18.3‰. Garvie (1993) also reported that the females in the Fidler Mounds sample had a more positive $^{13}C/^{12}C$ ratio than males. Burials 15 and 21a are the only adult females dated by AMS bone collagen, and while the $\delta^{13}C$ levels for these two individuals are among the most positive in the sample, there is no statistical difference in $^{13}C/^{12}C$ ratios between males, females and unsexed non-adults. Burial 21a does however, have a significantly more positive $\delta^{15}N$ level than the rest of the sample, indicating a heavier reliance on marine resources than the rest of the individuals tested. This individual is a young adult female, who may have joined the Fidler Mound group through marriage or migration, whose native diet may have been more centred on fishing than on hunting and gathering.

Evidence that the Fidler Mounds groups cared for their sick and injured comes from the levels of healing seen in Burials 4c, 7, 10b, 17a, and 21. The severity of infection, as indicated by skeletal morphology in Burials 4c, 7 and 17a, would have incapacitated or severely compromised the individual's ability to provision themselves and maintain their activities of daily living, at least for some period of time. Despite the fact that these individuals all died while their infections were active, there is evidence that these illness were chronic conditions, and as such, others in the group would have had to care for these people during their periods of incapacity. The same can be said for those who show evidence for severe traumatic injuries (Burials 10b, 17a and 21). The most striking medical intervention in the sample is clearly the trephination of the occipital of Burial 7. As already noted, this individual shows signs of having suffered

from treponemal disease, which ultimately affects cognitive ability and rationality. There is some slight healing around the opening, as evidenced by the closure of the bone over the diploe and slight osteoporosis around the hole, which indicates that the individual was trephined during life – most likely in an attempt to relieve the symptoms associated with the advancing disease process.

And treatment of the ill apparently did not cease when the individual died. The location and nature of the cut marks on five individuals are suggestive of intentional disarticulation and defleshing of the remains. Cut marks associated with disarticulation and defleshing are normally located in areas of well-developed muscle and tendon attachment, and are generally short cuts appearing in clusters that are oriented in a single direction (Bass and Phenice, 1975). Short fine cuts across the shaft of long bones are indicative of defleshing by slicing or sawing, and cuts along the descending ramus and gonial angle of the mandible are common (Olsen and Shipman, 1994).

In the case of the Fidler Mounds sample, such marking are found on the mandible of Burial 11 along the anterior border of the ascending ramus and coronoid process where the strong fibres and fascia of the temporalis attach. Burial 9 displays characteristic cut marks along the lateral surface of the gonial angle where the masseter and medial pterygoideus attach, and along the shaft of the clavicle, radius and fibula. Cranial cut marks are found across the frontal, around the orbits, along the temporals and where the temporalis attaches to the parietal and the masseter to the zygomatic arches in Burial 2a. Burial 4c is an adult male with short cut marks occurring in a single cluster along the anterior surface of the proximal ⅔ of the right tibial shaft, and with Burial 14a (an adult

female) there are distinct cut marks across the superior surface of the calcaneus anterior to the calcaneal tuber.

Evidently, at least in a few cases, the disposal of the dead for these groups involved disarticulating or defleshing the remains. Olsen and Shipman (1994) report that scaffold burials are known to have been common in the north east Plains during the Woodland period, and that bodies were intentionally defleshed after some decomposition had occurred in order to bury the body before the ground froze or after the thaw. The idea of scaffolding the bodies prior to final inhumation would account for both the amount of weathering and the level of scavenging found on the bones. Mammalian scavengers prefer to strike while the bones are still somewhat fresh, and prefer bone elements that are highly cancellous or that are likely to have soft tissue still attached, such as where major muscles or tendons attach to the bone. Rodents leave characteristic gnawing marks along the edges of bone, and prefer dry bone over fresh or at the very least when bones retain little of the natural grease (Lyman, 1996; Micozzi, 1991; O'Connor, 2000). Both types of scavenging are found on the remains from the Fidler Mounds, although never within the same individual. Only three individuals (Burials 2a, 2b and 17a) show signs of canid or canid-like scavenging, with distinct cratering and clustering of puncture wounds, which would imply that the remains had lain exposed for some time prior to complete decomposition of the soft tissue. Three other burials (2c, 10a and 19a) show distinct rodent gnawing. This could have occurred at any point after interment, perhaps during one of the earlier excavations at the mounds, but clearly indicates that the remains were exposed at some time after their initial burial.

7.3 *What Can LA-ICP-MS Offer?*

In order to address the second primary goal of the research, laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) was used in this study to generate elemental fingerprints of individual teeth that were sectioned to provide a sample that represents the time axis of tooth development. As in bone, teeth reflect the growth pattern of the individual and can indicate when interruptions to growth occurred. For this reason, teeth are often used as indicators of stage and rate of growth, as well as to gauge health. Their importance in assessing development lies in the fact that throughout their formation, teeth act as a permanent record of the biology of the body during growth. The dentition begins to form very early in gestation and is not completed until adulthood. While bone can be remodelled during the life of the individual, obscuring patterns of growth and development, the structure of the tooth is set once formation is complete. Thus teeth reflect the changing concentrations of trace elements during the period of their formation and are an ideal site within the human body at which to study such exposure.

Seven elements, selected on the basis of their probable reflection of food resources and markers of environmental exposure, were measured for each tooth. Dietary trace elements tested include Mn, Cu, Zn, Ba and Sr, and indicators of environmental toxins were Pb and Hg. It was quickly discovered that in most cases, only three or four trace elements appear to reflect real changes in abundances over time, while some of the elements chosen for assessment were virtually consistent throughout the scans and appear to be uninformative regarding diet and subsistence patterns in past populations. Methodological 'noise' at the beginning and end of each scan was caused by the formation of microfractures in the tooth as the laser moved onto or off of the tooth

surface, and renders the very earliest and final points of the scan unreliable. Visible, pre-existing cracks in the tooth were useful however, in that they acted as markers during the scan to which spikes or dramatic drops in elemental abundances could be attributed. The output of trace elements is measured in counts per second, and since the mapping of spatial distribution of trace elements was the focus, these counts were not converted to the parts per million readings. If comparisons between individuals or between teeth from the same individual was desired, this could be, and has been, done (Dolphin *et al.*, 2003; Haverkort, 2001).

The overall patterns apparent in the results produced from the LA-ICP-MS scans (see Figures 6. 13 – 6.24) is that Ba and Sr, in all cases, appear to be correlated following a similar pattern or periodicity throughout, although the concentrations are of varying magnitudes. This corresponds to the results of one previous study, in which the researcher found that the biochemical behaviour of Ba and Sr were very similar (Haverkort, 2001). It seems that these two elements may be reflective of large order trends, while other elements may be indicators of shorter duration exposure to trace elements within their food sources or environment. In all twelve LA-ICP-MS scans, Cu remains virtually unchanged throughout the test. Whether the lack of change in the Cu concentration is reflective of a steady bioavailability of this element during tooth formation is a matter of conjecture, but when Haverkort (2001) tested for this element, she also found that the levels of Cu were consistently low within and between individuals.

In most cases, Zn appears to have an independent pattern, although it occasionally follows the general trend visible in Ba and Sr. As is to be expected from a precontact

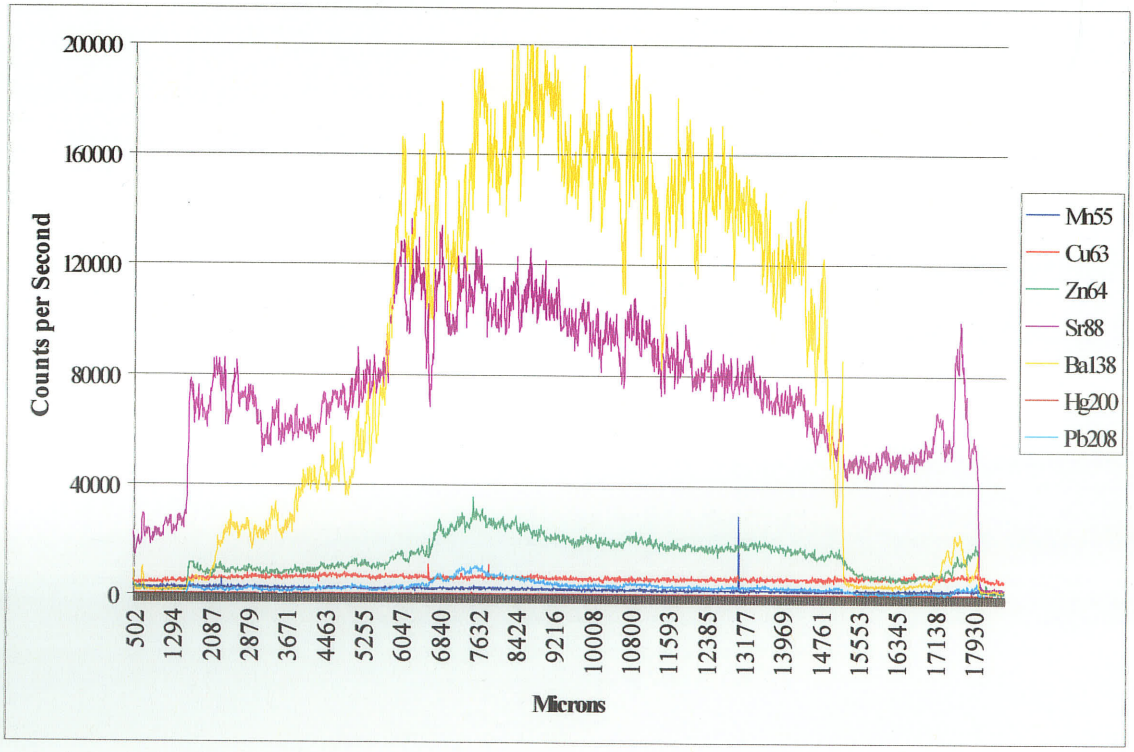
sample, levels of Pb and Hg were minimal, followed one another quite closely, and were generally uninformative except as markers of cracks in the tooth. In two cases, Burials 10b and 15, Pb appears to follow the pattern of Zn with some elevation in levels, but the meaning of those changes is unclear. The only burial in which Mn shows significant changes throughout the scan is in Burial 12, which has a substantial and sustained jump in concentration at approximately 5.3 years of age, and stays high until it drops off about 8.2 years of age, and settles back into its previous pattern. This may be suggestive of a dietary pattern that included the exploitation of wild rice stands across the region, since brown and wild rice are the richest source of Mn currently known to researchers (Ensminger *et al.*, 1994; Groff *et al.*, 1995). At this level of resolution however, it is impossible to say if changes in trace element quantities are related to dietary patterns, environmental exposure, or other, unknown factors.

It had been hoped that one of the secondary questions in this study, regarding maize consumption by Fidler Mounds individuals, could be addressed via LA-ICP-MS. Previous research had indicated that Burials 12 and 21a were most likely maize eaters (Garvie, 1993), however the data generated from AMS bone collagen dating does not support this assertion for Burial 21a; Burial 12 was not subjected to AMS. Since the previous study was focused on stable isotope analysis of adult bone and the current research examines data regarding childhood during the period of tooth formation, no direct comparison of data is possible. Since maize does not have a distinct trace element signature, and is not high in any documented trace elements, it is not possible to evaluate this particular aspect of diet via this method. While there are some limitations to the

method, it can be applied to the study of spatial distribution of trace elements across human teeth with good results overall.

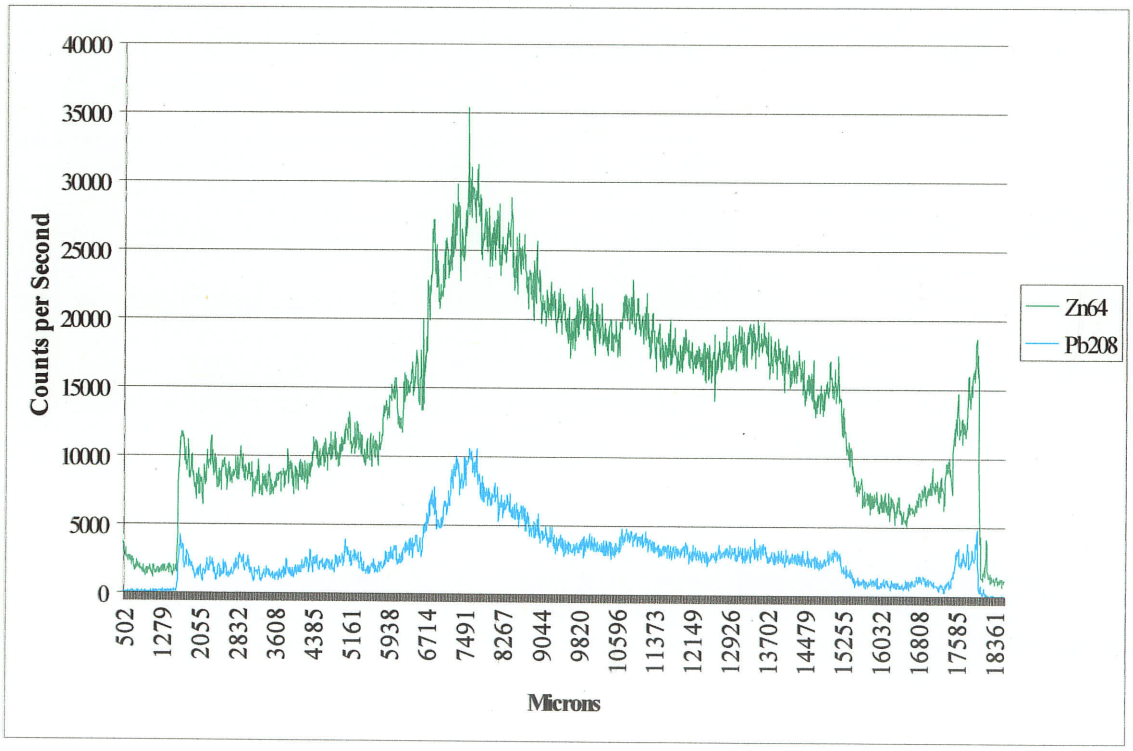
Although it was not intended to become a baseline for this study, the single modern tooth used to test equipment settings and target sample thickness turned out to be highly informative. Since the life history of the individual is known, changes in relative abundances of trace elements could be linked with changes in dietary patterns and area of residence. Overall, the pattern generated for the modern tooth is similar to the archaeological samples, as is visible in Figure 7.4. Strontium and Ba follow the same general periodicity, Cu, Hg and Mn are virtually flat throughout the scan, and Zn appears to loosely follow the pattern of Ba and Sr, but on a much smaller scale. The most striking difference between the archaeological samples and the modern tooth is the Pb content.

Figure 7.4 Trace element output for modern tooth



While very few of the archaeological teeth show meaningful elevations in Pb levels, in the modern sample there is a dramatic increase in the level of Pb that follows the periodicity of Zn very closely (see Figure 7.5). This episode can be linked to a change in residence during childhood from a rural to urban environment, and a corresponding increase in exposure to Pb in the environment. Whether these kinds of changes are what are visible in the output of the archaeological samples is unclear at this stage of the research.

Figure 7.5 Zn and Pb output for modern tooth, with other elements removed



7.4 Conclusions

The aims of this study were met through an osteobiographical analysis of the remains recovered from the Fidler Mounds during the 1963 salvage excavation, and

through the application of LA-ICP-MS to twelve teeth from the sample in order to assess if longitudinal changes in trace element abundances during tooth formation could be investigated. Some of the questions asked at the outset of the study were answered, and others remain a mystery.

The AMS dates established early on that the Fidler Mounds skeletal sample is not derived from a single population; rather is drawn from an unknown number of groups who may or may not have been culturally or genetically related, over a span of at least 1400 years (if the earlier radiocarbon date is considered accurate). Affiliation with any particular cultural group is simply not possible at this stage, and given the extent of the disturbance of the Fidler Mounds, will likely never be possible. Given the evidence at hand, the most conclusive inference that can be drawn is that at least some of the individuals interred here were affiliated the Laurel cultural groups along the Rainy River system, and that some connection existed over time with groups to the south along the Red River Valley and the Mississippi drainage basin in Minnesota. The groups who buried their dead at the Fidler Mounds were generally healthy, they cared for their sick and injured over extended periods of time, and considerable labour was expended on burials. No comment on grave goods can be accurately made due to past looting. The mounds were almost certainly used during the warmer months of the year, as the local climate would make digging during the winters impossible.

Spatial distribution of trace elements in human dentin can be investigated via LA-ICP-MS. At this point, the interpretation of such results is difficult given the limitations of the current study. Can this method be applied to human remains for the study of diet and health in the past? Almost certainly, given the results from the modern tooth, the

answer is yes. Does this mean that the output generated for the Fidler Mounds samples can be interpreted as reflecting the dietary or health patterns of these groups? Since taphonomic changes to human dentin has not been thoroughly investigated, and the uptake and storage of trace elements has not yet been sufficiently mapped out by biologists and biochemists, the answer must be no.

7.5 Future Directions

Trying to assign the remains from the Fidler Mounds to a particular archaeological complex is likely a waste of time, given how poorly defined some of the possible complexes are, and how disturbed the mounds were. Researchers should focus now on what the collection has to offer in terms of research possibilities. The data generated from the Fidler sample should be combined with that from other regional collections in order to examine health and mortality patterns more broadly across the northeast Plains during the precontact period. This kind of data is lacking in the literature, since many of the studies of these skeletal samples were conducted prior to the establishment of modern methods of assessing health and mortality. As part of this undertaking, multiple burials from mounds across the region should be dated in order to more accurately establish the timeframe during which each mound was in active use.

North American researchers have largely ignored the possibility that freshwater aquatic resources have an impact on radiocarbon dates generated by AMS from bone collagen, and only a handful of European researchers (Lanting and van der Plicht, 1996) appear to be aware of this effect. Further investigation into this possibly confounding

factor should be undertaken, and if found to be true, calibration curves must be established in much the same way these curves exist for marine resources.

Possibly the most critical suggestion for future consideration to come out of this research is the need to establish a modern baseline from which researchers can evaluate the trace element composition of human teeth. Teeth from individuals with documented life histories must be subjected to LA-ICP-MS testing, elements of dietary and environmental interest must be investigated. In order to address the issue of taphonomic alteration to the elemental structure of teeth, soil samples and archaeological teeth from a single site could be ablated so that the trace element structure of both could be examined. This study should help to begin the process of constructing a readily applicable and informative method of applying LA-ICP-MS to the palaeodietary studies, but is not limited to this avenue alone. Changes in diet are certainly thought to be the primary factors in changes in trace element distribution over the period of tooth formation, but patterns of mobility, changes in environmental conditions or pathological interference with health are all issues that could be investigated via this technique. With refinement and further study, the application of LA-ICP-MS to human remains will vastly improve the ability of researchers to investigate the lifeways of past populations.

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APPENDICES

ICP-MS

Model	Element 2
Forward Power	1336 W
Plasma gas flow	16 L/min
Shield Electrode	Used for analysis

LAM

Model	Merchantek LUV 213
Wavelength	213 nm
Repetition rate	20 Hz
Pre-ablation warm-up	none
Pulse duration	5 ns
Spot size	40 μm
Incident pulse energy	~0.131 mJ
Energy density on sample	~10.45 Jcm^{-2}

Data Acquisition Parameters

Data acquisition protocol	Time resolved analysis
Scanning mode	BScan and EScan
Detector mode	analog and counting
Dwell time (segment duration)	150 ms
Magnet settling time	0.001 – 0.3 s
Time/scan	1.563s

C = CompletePresent		L=left	R=right	(x5)=five items	*=abnormal	
		-1 = >75%	-2 = 75 - 25%	-3 = <25%		
burial #	1	2	3	4	5	6
MNI	2	4	3	3	1	1
C cranium					C-2	
occipital	C-2					
parietal						
temporal	R (x2)-1 L-1	R-1	L-1			
frontal		C-1				
mandible	R-1	C-1				
hyoid	C-2					
teeth	I(x1) P(x2) M(x1)	P(x3)				
scapula				L-3		L-2
clavicle		R-1				R-1
humerus		R-1 L(x2)-1	R(x2)-1	L-1	R-2 L-1	
ulna	L(x2)-3	L-1	L-1	R-1		
radius	R-2	L-1	L-1			
carpals						
metacarpals		R-1				
phalanges		R(x1)-1		Int(x1)-1		
sternal body						
manubrium						
rib #1				R-1		
rib #2						
ribs 3-10		L(x1)-2 F(x3)	R(x1)-1	R(x3)-1 L(x2)-1		R(x6)-3 L(x1)-1 F(x5)

rib 11						
rib 12						
atlas						
axis						
C vert 3-6		C-1	C-1			C-1
C vert 7						
T vert 1-9		C-2 & 1 spine-1	C-1			C-1 3 Arches-1
T vert 10						
T vert 11						
T vert 12						
L vert 1						C-1 1 Centrum-1
L vert 2-5			C-1			
sacrum				S4&5-1		
C pelvis						
ilium		L(x2)-1	R-1			
ischium		L-1				
pubis		R-1 L-1				
femur		R-1 L(x3)-1		R(x2)-1 L-1		
patella		R-1				
tibia		R(x2)-1 L-1		R(x2)-2 L(x2)-1		
fibula	L-2	R-1		L(x2)-3		
calcaneus			L-1			
talus		L-1	R-2			
tarsals		L(x2)-1	L(x1)-1			
metatarsals	L2-1	R2&5-1 L1-1	L3-2 R4-1	R4-1		
phalanges		L(x1)-1	R(x1)-1		L Int 1-1	
unid'd frags	flat(x38)		flat(x6) long(x1)	flat(x4)	flat(x7)	

C = CompletePresent		L=left	R=right	(x5)=five items	*=abnormal	
		-1 = >75%	-2 = 75 - 25%	-3 = <25%		
burial #	7	8	9	10	11	12
MNI	1	2	1	2	1	1
C cranium	C-1				zygomatic R-1	C-1
occipital						
parietal		L-2	Unsided F(x1)	L-2 F(x4)		
temporal					R-3 L-3 (mastoids only)	
frontal						
mandible	C-1		C-1	C-1	C-1	C-1
hyoid						
teeth	I(x7) C(x3) P(x8) M(x12)		I(x4) C(x1) m(x4) M(x2)	I(x1) C(x1) M(x5)	C(x2) P(x1)	C(x3) P(x2) M(x8)
scapula	R-1 L-1			L-2	R-2	R-3 L-3
clavicle	R-1 L-1	R-3	R-1	R-1	R-1	R-2
humerus	R-1 L-1	R-1	R-2 L-2	R-1 L(x2)-1		R-1 L-1
ulna	R-1 L-1	R-1 L-2	R-2	R(x2)-1 L-2		R-2
radius	R-1 L-1	R-1 L-2	R-2	L-1		R-1
carpals	R(x4)-1 L(x2)-1				L(x4)-1	
metacarpals	R(x2)-1 L(x3)-1				R (2,3,4)-1	R(x1)-1
phalanges	R(x2)-1 L(x1)-1	Dist 1-1		Dist 2-4-1	R(x9)-1 L(x1)-1	Medial unsided(x1)-1
sternal body						
manubrium						
rib #1	L-1	L-1		L-1	L-1	
rib #2	R-1 L-1			L-2		
ribs 3-10	R(x7)-1 L(x8)-1	R(x4)-2 L(x1)-2 F(x1)		R(x6)-1 L(x8)-2 F(x3)	R(x4)-3 L(x4)-2 F(x21)	F(x8)

rib 11	R-2 L-1					
rib 12						
atlas	C-1			C-1		C-2
axis	C-1					
C vert 3-6	C (x4)-1		C-1			C(x2)-1
C vert 7	C-1					
T vert 1-9	C(x9)-1	C(x2)-1		C(x8)-1		C(x3)-2
T vert 10	C-1			C-1		R-2 L-2
T vert 11	C-1			C-1		
T vert 12				C-1	C-1	
L vert 1	C-1			C-1	C-1	
L vert 2-5	C-1	C-1			C(x4)-1	
sacrum	C-1	F(x1)		C-1	F(x6)	C-3
C pelvis	R-1 L-1			R-1 L-1		
ilium					R-1 L-1	
ischium			R-1		R-1 L-1	
pubis						
femur	R-1 L-1			R-1 L-1	R-1 L-1 F(x14)	R-1 L-1
patella	R-1 L-1					
tibia	R-1 L-1	L-1	R-1 L-1	R-1 L-1	R-1 L-1	R-1 L-3
fibula	R-1	R-1 L-2	R-1 L-1		L-1	R-1 L-1
calcaneus	R-1 L-1		R-1 L-1	R-1	L-1	R-2
talus	R-1 L-1		R-1 L-1	R-1	L-1	R-2
tarsals	R(x1)-1 L(x2)-1		R(x2)-1		R(x2)-2 L(x2)-1	R(x2)-1
metatarsals	R(x4)-1 L(x2)-1		R(x1)-1 L(x1)-1 unsided(x4)	L2-1	R(x4)-1 L(x3)-1	
phalanges	R(x4)-1		unsided epip(x11)		R(x2)-1 L(x2)-1	
unid'd frags	(x2)		body of sphenoid?			(x61)

C = Complete/Present		L=left	R=right	(x5)=five items	*=abnormal	
		-1 = >75%	-2 = 75 - 25%	-3 = <25%		
burial #	13	14	15	16	17a	17b
MNI	3	3	1	4	1	1
C cranium			C-1	F(x11)	C-1	R L maxilla F(x23)
occipital				Squam-2		
parietal				R(x2)-1 L(x2)-1 and 2		
temporal		L-3				
frontal				C(x2)-1		
mandible			C-1		C-1	
hyoid						
teeth			I(x2) C(x2) P(x5) M(x11)		I(x2) C(x1) P(x2) M(x6)	C(x2) P(x2) M(x3)
scapula			R-1 L-1		L-2	R-1 L-1
clavicle			R-1 L-1			R-1 L-1
humerus			R-1 L-1	R(x3)-1 and 2 L(x3)-1	R-1 L-1	R-1 L-1
ulna			R-1 L-1	L(x2)-1 and 2	R-1 L-1	R-1 L-1
radius		L-1	R-1 L-1		R-1 L-1	R-1 L-1
carpals	Unsided(x1)-1	L(x2)-1	R(x2)-1 L(x2)-1		R(x1)-1	
metacarpals	L-1	R(x2)-1 L(x4)-1	R(x3)-1 L(x1)-1		R(x2)-1 L(x2)-1	R(x1)-1
phalanges	L-1	L(x3)-1	R(x8)-1 L(x2)-1		L(x3)-1	
sternal body			C-1		C-1	C-3
manubrium			C-1		C-1	C-1
rib #1		R-1	R-1 L-1		L-1	
rib #2			R-1 L-1			R-1 L-1

ribs 3-10	F(x3)	R(x2)-2	R(x7)-1 L(x8)-1		R(x2)-1 L(x7)-1 F(x2)	R(x8)-1 F(x15)
rib 11			R-1 L-1			L-2
rib 12			L-1			L-1
atlas			C-1			
axis			C-1			
C vert 3-6			C(x4)-1			C(x1)-1
C vert 7			C-1			
T vert 1-9		Neural Arch only (x1)	C(x9)-1		C(x8)-1	C(x2)-1
T vert 10			C-1		C-1	C-1
T vert 11			C-1			C-1
T vert 12						C-1
L vert 1			C-1			C-1
L vert 2-5			C(x4)-1		C(x1)-1	C(x4)-1
sacrum			R-1 L-1			
C pelvis			R-1 L-1		R-1 L-1	
ilium						
ischium						
pubis						
femur			R-1 L-1	R-1 L-2	R-1 L-1	R-1 L-1
patella			R-1 L-1		R-1 L-1	R-1 L-1
tibia	R-1 L-1		R-1 L-1	R(x2)-1 L-1	R-1 L-1	R-1 L-1
fibula	R-1 L(x2)-1 and 2	L-1	R-1 L-1	R-1	R-1 L-1	R-1 L-1
calcaneus	R-1 L-1	L-1	R-1 L-1			R-1 L-1
talus	R-1 L-1	L-1	R-1 L-1		R-2	L-1
tarsals	R(x5)-1 L(x3)-1	R(x1)-1 L(x1)-1	R(x5)-1 L(x5)-1		R(x1)-1	R(x2)-1
metatarsals	R(x4)-1 L(x5)-1	R(x3)-1 L(x1)-1 Unsided(x1)	R(x5)-1 L(x5)-1		R(x1)-1	R(x1)-1
phalanges	R(x2)-1 L(x7)-1	R(x3)-1 L(x7)-1	R(x4)-1 L(x10)-1		R(x1)-1 L(x1)-1	
unid'd frags						Flat(x10) Long (x7)

Complete/Present		L=left	R=right	(x5)=five items	*=abnormal	
		-1 = >75%	-2 = 75 - 25%	-3 = <25%		
burial #	18	19	20	21	Fill Mound 1	Fill Mound 2
MNI	1	2	3	5	17	3
C cranium		F(x41)	F(x3)	C-1	Maxillae R(x3) L(x1) F(x378)	F(x4)
occipital	C-1	C(x2)-1 and 2				
parietal	R-1 L-1	R(x2)-1 L(x2)-1				
temporal	R-1 L-1	R-1 L-1				
frontal	C-1	C(x2)-1 and 2			C-1	
mandible	L-1	R-1 L-1		C-1	R(x7) L(x5)	
hyoid					(x2)	
teeth	c(x2) m(x2)	C(x1) P(x2) M(x5)		I(x4) C(x3) P(x8) M(x12)	C I(x6) P(x4) M(x7) m(x5)	
scapula		R-1 L-1		R-2 L-1	R(x16) L(x12) F(x6)	F(x1)
clavicle		R-1		R-1	R(x3) L(x6)	L(x1)
humerus	L-1 (shaft)	R-1 L-1	R-1	R-1 L-1	R(x11pcs) L(x7pcs) ?(x3pcs)	L(x2)
ulna		R-1 L-1	R(x2)-1 and 3 L-1	R-1 L-1	R(x10pcs) L(x7pcs)	R(x1)
radius	R-1 (shaft) - cutmarks?	R-1 L-1	R-1 L-1	R-1 L-1	R(x10pcs) L(x5pcs)	R(x1)
carpals		R(x2)	R Scaphoid-1		R Scaphoid(x8) L Scaphoid(x7) R Lunate(x5) L Lunate(x2) R Hamate(x4) L Hamate(X3) R Trapezoid(x5) L Trapezoid(x4) R Capitate(x1) L Capitate(x3) Unsided Pisiform(x4)	R(x2)

metacarpals					Unsided(x20) #1(x18) R#2(x4) L#2(x5) R#3(x7) L#3(x4) R#4(x7) L#4(x4) R#5(x8) L#5(x4)	R#2(x1) R#4(x1)
phalanges			Unsided(x4)	Unsided(x1)-2	(x76)	(x2)
sternal body		C-1			(x4)	
manubrium		C-2		C-1	(x3)	(x1)
rib #1		R-1 L-1		R-1 L-1	R(x3) L(x5)	
rib #2		R-1 L-2		R-1 L-1	R(x4) L(x2)	
ribs 3-10	F(x1)	R(x8)-2 L(x10)-2 F(x81)	R(x1)-1	R(x8)-1 L(x9)-1 and 2 F(x21)	R(x39) L(x34) F(x291)	R(x1) L(x3) F(x9)
rib 11		R-2 L-2			L(x1)	R(x2)
rib 12		R-1		L-1	R(x3) L(x2)	
atlas					(x15)	
axis				C-1	(x6)	
C vert 3-6				C(x2)-1	(x1)	
C vert 7					Vert body F(x31) Vert NA F(x28) Vert transverse proc(x10) Vert articular srfc(x24)	
T vert 1-9		Body(x9) Neural Arch(x8)		C(x9)-1	C(x8) NA(x18) Spine(x7)	C(x1) NA(x1) Spine(x1) Artic Srfc(x4) BodyF(x2)
T vert 10		C-1		C-1		
T vert 11		C-1		C-1		
T vert 12		C-1			(x1)	
L vert 1		C-2 Lumbar F(x11)		C-1		
L vert 2-5		C(x4)-2		C(x4)-1	(x7)	C(x1)
sacrum		C-1	F(x1)	C-1	(x10) Coccyx(x1)	

C pelvis		L-1		R-1 L-1	Acetabulum ?(x1)	
ilium	L-1	R-1	R-2 L-2		R(x12) L(x3)	
ischium		R-1	R-2 L-2		R(x7) L(x2)	
pubis					R(x4) L(x3)	R(x2)
femur	R-1 L-1 (shafts)	R-1 L-1 Unsided Dist Epip(x1)	R(x2)-1 and 3 L-1	R-1 L-1 Unsided Dist Epip(x1)	R(x12) L(x6) Unsided Head (x6)	R(x1)
patella			R-1		R(x3) L(x4)	R(x1) L(x1)
tibia	R-1 L-1 (shafts)	R-1 L-1	R(x2)-1 and 3 L-2	R(x2)-1 L-1	R(x5pcs) L(x7pcs)	L(x1)
fibula	Unsided-1 (shaft) cutmarks?	R-1 L-1	R-1 L-1	R-1 L-1	R(x8pcs) L(x5pcs) ?(x12pcs)	
calcaneus		R-1 L-1	R-1 L-1	R-1 L(x2)-1	R(x5) L(x10)	
talus			L-1	L-1	R(x7) L(x11) ?(x1)	R(x1)
tarsals		R Cuboid-1	R(x1)-1 L(x3)-1	L(x1)-1	R Cuboid(x4) L Cuboid(x7) R Navicular(x8) L Navicular(x2) Unsided Cuneiform(x30)	
metatarsals	Unsided(x2)	R4-1	R(x5)-1 L(x3)-1	R3-1	R#1(x9) L#1(x5) R#2(x7) L#2(4) R#3(x6) L#3(x3) R#4(x8) L#4(x6) R#5(x8) L#5(x10)	R#2(x1) R#3(x1) R#5(x1) L#4(x1)
phalanges	Unsided(x4)		R(x6)-1 L(x2)-1	L1-1	(x116)	(x2)
unid'd frags		Long(x21) Flat(x4)	Long(x17) Flat(x12)		Long(x132) Irregular(x59) Flat(x25) Unid'd(x148)	Unid'd(x3) Unid'd Meta's(x7)-juvenille Long(x3)