To the Graduate Council:

I am submitting herewith a thesis written by Susan Mary Thurston Myster entitled "A Trace Element Analysis of the Gordon Town Site (40DV6): An Investigation of Intra-Individual Variation and Dietary Inference." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

Fred H. Smith, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Vice Provost and Dean of
The Graduate School

A TRACE ELEMENT ANALYSIS OF THE GORDON TOWN SITE (40DV6): AN EXAMINATION OF INTRA-INDIVIDUAL VARIATION AND DIETARY INFERENCE

A Thesis

Presented for the

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Susan Mary Thurston Myster

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For James, Mom and Dad

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ABSTRACT

The results of trace element analyses of archaeological human bone have been used to investigate questions pertaining to the dietary practices and subsistence behavior of various prehistoric populations. As a technique still in the experimental stage, however, a number of methodological difficulties have been identified. This thesis examined two aspects of trace element analyses of human bone. First examined was a methodological problem that has received increased attention since the initiation of this study: the documentation, measurement and control of intraindividual variability of trace element concentrations. Secondly, the validity of dietary inference from trace element concentrations were addressed using the results from the analysis of the Gordon Town (40DV6) skeletal sample, a Late Mississippian group from Nashville, Tennessee.

Five elements were measured in from two to four bones in 12 adult individuals. The elements chosen for measurement were manganese, magnesium, strontium, zinc and copper. High levels of the first three elements are indicative of a diet containing a large amount of plant foods. High levels of the last two elements indicate a diet composed of a high proportion of meat resources. The bones selected for analysis were the femur, humerus,

rib and vertebra. The 12 individuals that comprised the sample met a number of stringent criteria designed to control for extrinsic (environmental) and intrinsic (physiological, biological) factors that may alter the trace element concentrations of an individual from those determined by diet.

Descriptive statistics, Student's T-tests and Analysis of Variance (ANOVA) techniques assessed mean bone element concentration differences between males and females, individuals of different age groups, individuals buried in different areas of the site and different bones of the skeleton. Results indicate that no differences in element concentrations existed between males and females, age groups and different areas of the site. Significant element concentration differences were found to exist in the four different bones analyzed. The differences seem to be related to the type of bone (compact, trabecular), bone turnover rates and stability of the trace element. It was also determined that intraindividual variation of element concentrations is in some instances greater than interindividual variation. These results indicate that the element concentrations of one bone cannot legitimately be compared to the element levels of a different bone.

Dietary inferences from the trace element

concentrations of the bone analyzed were limited. Absolute or even relative proportions of plant versus animal foodstuffs in the diet were impossible due to the unusual elemental composition of the carnivore sample and the inaccurate strontium concentrations. It was concluded from the relative element levels, however, that the Gordon Town inhabitants consumed a diet composed of a variety of both plant and animal foodstuffs. The consumption of a varied diet by the Gordon Town people is in contrast to the predominant subsistence strategy of Late Mississippian peoples.

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CHAPTER I

INTRODUCTION

The chemical analyses of artifactual materials have contributed greatly to the amount and quality of information that can be derived from archaeological sites, features and artifacts. Chemical analytical techniques have been used successfully on such diverse materials as ceramics, coins, glass, textiles, lithics, metal tools and weapons, soils, ethnobotanical remains, animal bone and, more recently, human bone. Such analyses have been instrumental in the development of both relative and chronometric dating techniques (e.g. fluorine and Carbon 14 dating, respectively) and also in the reconstruction of artifact manufacture technology, trade routes, growth patterns of major economic centers, local and regional environmental conditions, and local floral and faunal resource exploitation (Levey 1967; Michels 1973; Wessen et al. 1978; Zurer 1983). It is clear that chemical analyses of artifactual materials have tremendously increased our understanding of past human behavior.

The chemical analysis of human skeletal remains is a more recent application of such techniques. Two techniques most often applied to bone are the analyses of stable isotopes and trace elements. Isotope analyses

are based on characteristic changes in isotopic ratios (fractionation) in plants and animals. Isotopic differences are initially produced during photosynthesis, and different biochemical and metabolic processes in plants and animals change the isotopic ratios in distinct ways (Brothwell and Burleigh 1978; Klepinger 1984; Schwarcz et al. 1985; van der Merwe 1982). Isotopic values within bone collagen have been correlated with diet and consequently, isotopic analyses have been used in dietary reconstruction and to identify the adoption and intensification of maize agriculture in the New World (Bender et al. 1981; DeNiro and Epstein 1978a, 1978b, 1981; van der Merwe et al. 1978, 1981).

The second technique is based on the measurement of trace element concentrations in both human and animal bone. Trace element analyses and the information that may be derived from them are the focus of this thesis.

Trace element analyses of human bone have been applied primarily to questions of dietary practices and subsistence behavior. The first anthropological application of this technique took place in the mid-1960s when Toots and Voorhies (1965) measured strontium (Sr) concentrations in five different Pliocene terrestrial vertebrates: one carnivore, two browsing herbivores, and two grazing herbivores. They observed significant differences in the Sr concentrations of

carnivores and herbivores. Concentration differences between herbivorous browsers and grazers were also significant. They concluded that different feeding patterns could be inferred from Sr concentrations of fossilized bone.

A.B. Brown (1973) was the first scientist to apply the analysis of trace elements to prehistoric human skeletal remains. As did Toots and Voorhies (1965), she measured strontium concentrations. Her study addressed numerous questions of subsistence behavior within and between numerous sites. Bone strontium concentrations were compared within the Bussinger site - a Middle Woodland site located in the Michigan Lower Peninsula, the Farukhabad site in southwestern Iran (5000 B.C. - A.D. 200), and the Huitzo site in the Valley of Oaxaca, Mexico (1000 B.C - Postclassic period), and between three Middle Woodland sites from the lower Illinois River Valley - Peisker, Ledders, and Gibson. Results from the analysis of individuals from these different sites were used to answer various subsistence-related questions and highlighted Sr concentration differences between adults and subadults, males and females, high and low status individuals, and dietary stability and change over time.

Since the first applications of trace element analyses to anthropological questions, researchers have

investigated numerous topics pertaining to the dietary practices and subsistence behavior of various prehistoric populations. The results of trace element analyses have, for example, been used to directly assess a population's proportional reliance on animal versus plant food resources, identify the presence and character of dietary stress, document changes in the diet and subsistence practices of a population over time, and pin-point the introduction, cultivation, and subsequent intensified reliance on specific classes of cultigens (Brown 1973; Connor and Slaughter 1984; Gilbert 1977; Huss-Ashmore et al. 1982; Price and Kavanagh 1982; Wing and Brown 1979). Social practices of differential access to food resources by subgroups within a population based on social status and/or gender have also been identified from trace element concentrations (Blakely and Beck 1981; Brown 1974; Hatch and Geidel 1985; Schoeninger 1979). More indirect applications of trace element analyses have attempted to ascertain weaning practices and patterns (Sillen and Smith 1984) and differentiate between the skeletal remains of wild and domesticated animals (Dinan 1988).

Despite the increase in the type and number of questions addressed by the application of trace element analyses on human bone, it is in many ways a technique still in the experimental stage. Throughout the past 25

years of experimentation a number of methodological difficulties have been identified. Questions concerning the effects of such complicating factors on trace element concentrations, as well as how to control for them persist. A majority of anthropologically-oriented trace element research since 1980 has focused on the methodological and theoretical constraints of the technique. The most serious complicating factors identified include the effects of diagenesis - the postdepositional exchange of elements between soil and bone (Kyle 1986; Lambert et al. 1985a, 1985b; Nelson and Sauer 1984; Pate and Brown 1985; Pate and Hutton 1988; Von Endt and Ortner 1984; White and Hannus 1983), the histomorphological integrity of the archaeological bone (Hanson and Buikstra 1987; Hare 1980), and the biochemical, physiological, and metabolic processes and interactions at work within the organism during life (Grupe 1988; Klepinger et al. 1986; Parker and Toots 1980). The progress made in recognizing and controlling the effects of some of these complicating factors has been great; however, numerous questions persist and continue to frustrate researchers. It is the intent of this thesis to further investigate the validity and applicability of trace element analyses to the reconstruction of paleodiets and subsistence behavior in humans.

Research Goals

The research goals of this thesis are two-fold. The first goal will address a methodological problem that has received increased attention since the initiation of this study: the documentation, measurement and control of intraindividual variability of trace element concentrations. To realize this goal trace element concentrations will be measured in two to four different bones in each of 12 individuals. The degree of intraindividual variation will be determined and compared to the variability in element concentrations between the individuals in the sample.

Klepinger et al. (1986) measured trace element concentrations in the femur, tibia and humerus within 12 single individuals. Their results reveal a greater within individual range of variation in element concentrations than that between individuals. They tentatively conclude that trace element levels in one long bone are not interchangeable with those of another. Therefore, trace element studies that compare element concentrations between individuals as measured in different bones may result in inaccurate conclusions regarding dietary practices.

Grupe (1988) compared trace element concentrations in trabecular versus compact bone. She concluded that the element levels in compact bone are less susceptible

to the effects of diagenesis and are more representative of total body element content. Consequently, samples of compact bone are more reliable in trace element analyses. The results of this thesis will contribute to the growing base of knowledge regarding the variability of trace element concentrations within an individual. The conclusions reached in this study will be compared to previous studies that have addressed the issue of intraindividual element variability. The results of this analysis, in conjunction with the results of related studies, will aid in the selection of the most reliable bone from which to sample trace elements for intergroup comparisons. The choice of which bone to analyze may have a significant impact on the results of any trace element analysis of human bone.

The second research objective of this thesis is to complete a trace element analysis on a skeletal sample from a late Mississippian settlement near Nashville, Tennessee. The Gordon Town site (40DV6) is located in the outer portion of the Nashville Basin, away from the floodplain of the Cumberland River, the major river nearest to the site. Mississippian site location has been highly correlated with the fertile soils of the floodplains and a disproportionate reliance on maize agriculture. The upland location of Gordon Town allows one to speculate about the nature of their subsistence

practices and economic well-being. Were the Gordon Town inhabitants as reliant on maize agriculture as contemporary villages located on the floodplains? If not, was their diet sufficient to maintain a reasonable level of health and prevent any nutritionally-related diseases?

It is hypothesized that Mississippian site locations away from floodplains resulted from population pressure (Klippel and Bass 1984) and related resource depletion. Such environmental and dietary stresses should be manifested skeletally by evidence of, for instance, nutritionally-related diseases, growth retardation, harris lines, enamel hypoplasias and high mortality rates. The trace element concentrations measured in the Gordon Town skeletal sample will suggest the consumption of a varied or more restricted diet. Furthermore, the results of this analysis will contribute to our understanding of late Mississippian adaptations in an upland environment--an environment that has previously been thought of as less than ideal and has been less extensively studied than Mississippian floodplain sites.

CHAPTER II

THEORETICAL CONSIDERATIONS IN TRACE ELEMENT ANALYSES OF HUMAN BONE

The validity of trace element analyses in human paleodietary research is based on the fundamental assumption that varying concentrations of trace elements in bone reflect the relative amount of those elements present in the diet (Bumsted 1985; Nelson and Sauer 1984). Previous research has identified a relationship between the presence or absence of certain nutrients in the diet and the incidence of certain nutritional diseases. For example, a high correlation between the incidence of goiter and insufficient amounts of iodine in the diet has been demonstrated. This condition is greatly reduced when the diet is supplemented with iodine (Hetzel and Maberly 1986).

Research has determined that trace element concentrations are not fixed in exact quantities throughout an organism's life. Bone is a living tissue and its chemical composition during and after life is the result of many factors. Diet is only one of these. Therefore, an accurate interpretation of the trace element concentrations in archaeologically-derived human bone requires an awareness of the factors that may modify an organism's trace element concentrations both

during and after life. A basic knowledge of what trace elements are, their functions, their environmental sources, and the various environmental, biochemical and physiological factors that act on them is necessary. An exhaustive discussion of each of these factors is impossible within the scope of this thesis; however, a brief discussion can sufficiently outline the possible effects of each source of variation on the trace element concentrations within human bone.

The Definition and Functions of Trace Elements

Early scientists identified certain elements that were present in plants and animals in minute amounts. The exact concentrations of these elements in particular organisms were unknown, because analytical techniques at that time were not able to quantify such small amounts. As a result, more imprecise terms, including "trace elements", "minor elements" and "trace minerals" (used only when the elements in question are naturally-occurring inorganic substances) were used to describe their concentrations in living organisms. With the development of more sophisticated techniques, accurate measurement of trace element concentrations became possible. Trace elements are now quantitatively and arbitrarily defined as those elements that occur in the body in amounts less than 0.01 percent of the total

human body mass (Schroeder 1973). This definition is not completely accurate, however, since the concentrations of the minor elements vary between different organisms, sometimes at amounts greater than 0.01 percent. Iron is an example of such an element; it is usually present in humans in an amount greater than 0.01 percent (Schutte 1964).

Trace elements are divided into three categories: those essential for normal metabolic functioning, those possibly essential, and those that are nonessential. Table 1 presents the trace elements considered both essential and possibly essential.

Table 1. Essential and Possibly Essential Trace Elements

Essential	Possibly Essential
*Iron	Bromine
Manganese	Cadmium
Chromium	Barium
Zinc	Strontium
Copper	
Cobalt	
Molybdenum	
Iodine	
Selenium	
Tin	
Nickel	
Arsenic	
Fluorine	

* not considered to be a trace element by many researchers.
Source: Underwood 1971:2, 1977:1

While most trace elements have a variety of functions, they generally act as catalysts in enzyme systems (Schutte 1964; Underwood 1977). Schroeder (1973:viii) describes the importance of trace elements metaphorically, "... they are the basic spark-plugs in the chemistry of life, on which the exchanges of energy in the combustion of foods and the building of living tissues depend." The primary function of each element is, however, dependent upon both its chemical form and combination and its location in body tissues and fluids. Deficiencies and surpluses of trace elements have numerous and varied effects. Dwarfism, mental retardation, hypertension, atherosclerosis, goiter, and impairment of growth and development are a few such effects (Schroeder 1973:50-51).

Sources and Modifying Factors of Trace Element Concentrations in Humans

Sources. The major source of all elements in human bone is soil. The trace element composition of different soils is ultimately affected by the make-up of the underlying parent material and the processes of weathering and pedogenesis (soil formation) (Jenny 1941; Kabata-Pendias and Pendias 1984). Additional factors that contribute to the development of different soils are climate (temperature and precipitation), vegetation and other soil biota, topography, time, and human

activity (i.e. degradation, contamination, recultivation) (Kabata-Pendias and Pendias 1984:19-22). The individual effects of each of these processes on the overall soil composition are unequal and vary from place to place.

An important interactive relationship exists between soils, plants, and animals. Plants derive their nutrients and thus chemical composition from the soil. Humans and other animals receive a majority of their nutrients, trace and otherwise, from plants. The mineral composition of plants reflects to a great extent the composition of the soil. This is not to say, however, that plants absorb elements indiscriminately from the soil. The nutrient uptake by plants is selective and governed primarily by the genus and species of the plant (Underwood 1977). Within each species of plant physiological factors determine the eventual distribution and concentrations of trace elements. These physiological factors include the absorption and transportation of trace elements within the plant, the nutrient needs of enzymatic processes, the chemical forms and concentrations of each available element, deficiency and toxicity states of the plant, and competition and interaction between the trace elements. The overall result of these different processes is not only great variation in the trace

element concentrations of different plant species grown on the same soil (Table 2), but also different trace element concentrations in different organs of a single plant (Table 3).

Modifying Factors. The trace element concentrations in humans are determined primarily by their dietary intake of nutrients. As discussed above, the nutrient composition of the diet is strongly influenced by the properties of soils and the plants that receive their nutrients from the soils. In addition to diet, trace element concentrations may be affected by processes acting within an individual. Individual variability is primarily due to age, sex, and metabolic differences.

Within an individual, the trace element concentrations in bone are a function of the biochemical actions of the ions present in the elements and their interaction with the mineral component of bone (Wing and Brown 1979). Human bone is a dynamic system made up of a mixture of organic and mineral components. In dry bone the organic matrix comprises approximately 20-25% of the bone, inorganic minerals make up the balance. Ninety percent of the organic matrix is made up of the protein collagen. Collagen's main function is to provide centers for initiating bone calcification. The mineral phase of bone is principally composed of calcium

Table 2. Variation in Trace Element Concentrations (ppm)* of Different Plants From the Same Site.

Plant	Copper	Iron	Manganese	Zinc
Grass				
Agrostis alba	4.2	80.0	740.0	59.0
Clover				
Trifolium pratense	6.0	115.0	136.0	99.0
Mosses				
Polytrichum juniperinu	9.2	800.0	176.0	69.0
Entodon schreberi	10.3	425.0	180.0	77.0
Lichens				
Parmelia physodes	5.0	1100.0	62.0	78.0
Lobaria pulmonaria	7.5	1450.0	66.0	74.0
Edible fungi				
Cantharellus cibarius	24.5	49.0	19.0	150.0
Leccinum scabra	18.0	44.0	6.0	125.0

* parts per million or micrograms per gram of bone
Source: Taken in part from Kabata-Pendias and Pendias 1984:56.

Table 3. Trace Element Concentrations (ppm) in Different Parts of Pine Trees

Plant Organ	Boron	Copper	Iron	Manganese	Vanadium
Needles					
1 year old	18.0	4.2	150.0	430.0	0.6
Branches	6.0	3.0	650.0	430.0	1.8
Knots	4.5	1.2	78.0	185.0	0.8
Bark	4.5	2.0	100.0	123.0	2.8
Wood	0.1	0.6	5.0	61.0	0.2
Roots					
5 mm diam.	3.2	1.2	46.0	50.0	0.5

Source: Taken in part from Kabata-Pendias and Pendias 1984:55.

phosphate ($CaPO_4$) which is present in the body in both a crystalline and amorphous form. The amorphous form is converted to the crystalline form during bone calcification. In adults this crystalline form is predominantly hydroxyapatite [$Ca_{10}(PO_4)_6(OH)_2$]. Hydroxyapatite crystals are composed of calcium, phosphate, hydroxyl ions, as well as macro and trace elements (Chaplin 1971; Ham and Cormack 1979; McLean and Urist 1968; Weiss 1983). Macro elements are those elements present in bone in amounts greater than 0.01 percent (e.g. magnesium, sodium, sulfur, potassium). The hydroxyapatite crystals form a lattice with three zones: 1) the crystal interior; 2) the crystal surface; and 3) the hydration shell. These zones all present areas for ionic transfer between hydroxyapatite and the trace and macro elements present in body fluid (Weiss 1983).

The age of an individual may have an effect on the concentrations of trace and macro elements absorbed into bone. Several researchers have observed differences in skeletal element concentrations between individuals who died at different ages (Hodges et al. 1950; Lambert et al. 1979; Sowden and Stitch 1957). Lambert et al. (1979) compared the concentrations of ten elements between six age categories (range: 0-50+ years) of prehistoric human remains. Age-related differences were

observed in all instances; however, the patterns of those differences varied according to the specific chemical element. They determined age related effects were the result of at least three sources: normal biological development of bone, variations in diet, and diagenesis. Hodges et al. (1950) analyzed the strontium (Sr) levels of a modern sample of individuals varying in age at death from fetal (over 10 cm in length) to 75 years. The results indicated lower Sr concentrations in fetal bones compared to all other age groups. Sowden and Stitch (1957) also found significantly lower levels of strontium in the bones of younger individuals (0-13 years) than those of an older age (19-74 years). A biological explanation is appropriate in the latter two examples. Strontium levels are generally lower in subadults for several reasons. First, there is a natural biological discrimination against strontium, in favor of calcium, by the placenta and mammary glands in humans and other animals (Shipman et al. 1985, Sillen and Kavanagh 1982). This negative discrimination results in lower bone strontium levels in infants and unweaned children. Secondly, subadults are more sensitive to short-term dietary fluctuations because of their increased nutritional needs during growth. And finally, individuals who die before reaching skeletal maturity exhibit incomplete bone mineralization. This

incomplete mineralization, plus increased sensitivity, results in variable levels of most elements (Hodges et al. 1950).

Significant differences in the trace element concentrations in bone between males and females in the same population have been reported (Blakely and Beck 1981; Brown 1973; Brown and Blakely 1985; Gilbert 1975; Lambert et al. 1979). This variation may be the result of biological differences between the sexes or as a result of dissimilar dietary intake. Biological differences seem to be most notably expressed by significant divergence in the concentrations of the alkaline earth metals (e.g. strontium, barium, calcium). As stated above, the placental tissues and the mammary glands discriminate against strontium and other alkaline earth metals in favor of calcium (Price et al. 1985; Sillen and Kavanagh 1982). In a population where males and females consume relatively the same foodstuffs this discrimination will manifest as higher levels of the alkaline earth metals in females relative to males. Reproductive stress may also alter element levels in females (Martin and Armelagos 1985). Variable element levels between males and females, however, may also be the result of differential access to certain food classes in the subsistence regime. High concentrations of those elements associated with protein-rich foods

(e.g. red meat) in males coupled with high concentrations of those elements associated with plant resources by females has been documented (Blakely and Beck 1981; Brown 1973). An accurate interpretation of differing concentrations between males and females requires an awareness of all possible explanations for such variability.

Metabolic processes also affect the concentrations of trace elements. All elements (trace and macro) interact and influence each other. States of specific elemental deficiencies and toxicities often result from the presence or absence of certain other elements. High levels of zinc, for example, will inhibit copper absorption (Underwood 1958). The accurate interpretation of element levels in bone must take possible interaction between elements into consideration. Disease states may also alter trace mineral concentrations in bone (Beck 1985; Martin and Armelagos 1985). Researchers suggest that nonpathological specimens be analyzed and that bone specimens be microscopically analyzed to highlight individuals that may exhibit histological anomalies or instability (Hanson and Buikstra 1987; Martin and Armelagos 1985).

Diagenesis. The modifying factors discussed above act on the element composition of bone during life. The

element concentrations of archaeological bone are subject to an additional alteration through diagenesis. Diagenesis effectively modifies the antemortem trace element concentrations through substance exchange between bone and the burial environment (Nelson and Sauer 1984; Parker and Toots 1980). The identification and control of the sources of diagenesis are essential to the successful application of trace element analyses to paleodietary questions.

The majority of research involving trace element analyses on bone during the last decade has addressed the effects, causes, and processes of diagenesis (Hanson and Buikstra 1987; Hare 1980; Kyle 1986; Lambert et al. 1979, 1982, 1983, 1984, 1985a, 1985b; Nelson and Sauer 1984; Parker and Toots 1980; Pate and Hutton 1988; Von Endt and Ortner 1984; White and Hannus 1983). These studies have been instrumental in identifying a number of intrinsic and extrinsic variables that have varying effects on the susceptibility to and rate of diagenesis. Post-mortem alteration may occur through enrichment and/or depletion of an element (Price et al. 1985). Following death there are three mechanisms of elemental enrichment of bone: (1) substitution into the apatite crystal structure (heteroionic exchange); (2) deposition into the minute voids and fractures in the bone; and (3) the assimilation of foreign elements onto the crystal

surfaces (adsorption) (Lambert et al. 1985b; Parker and Toots 1980; Wing and Brown 1979).

Size, permeability, and histological strength are three intrinsic factors that influence the susceptibility of bone to diagenesis. Researchers have determined that smaller, more porous bone is more likely to suffer the effects of diagenesis than larger more compact bone (Grupe 1988; Kyle 1986; Lambert et al. 1982). Lambert et al. (1982) studied the diagenetic effects on femora and ribs from two Woodland sites in Illinois. Their results demonstrate extensive diagenesis in the more porous ribs as compared to the denser femora. Similarly, bones that possess a poor histological framework (i.e. a weakened protein-mineral bond) from poor mineralization, deficient nutrient intake, or a destructive burial environment are also more susceptible to diagenesis (Hanson and Buikstra 1987; Hare 1980; Von Endt and Ortner 1984).

Extrinsic factors affecting diagenesis involve characteristics of the burial environment. Certain environmental conditions foster the macro- and microstructural breakdown of bone and thus facilitate diagenesis. Soil pH, temperature, groundwater, and the presence of soil microorganisms have all been implicated in bone deterioration and subsequent diagenesis (Hanson

and Buikstra 1987; Lambert et al. 1979, 1982, 1983, 1984, 1985a, 1985b).

A number of researchers have explored the specific relationship between bone preservation and soil pH (Gordon and Buikstra 1981; Hare 1980; Pate and Hutton 1988; White and Hannus 1983). Results of these studies generally agree that postdepositional bone deterioration is accelerated as soils becomes more acidic (i.e. pH < 7.0). Bone deterioration may be gauged microscopically by the integrity and strength of the protein-mineral (organic-inorganic) bond. A weakening of the crystal structure results in a greater number of voids and vacated lattice positions for foreign ions.

A more recent study by Hanson and Buikstra (1987) suggests that more alkaline soils (pH > 7.0) may also accelerate the microscopic breakdown of bone. According to their research, the activity of soil microorganisms are responsible for significant destruction of the histological structure of bone and result in extensive diagenesis. Soil microorganisms are more abundant in neutral to slightly alkaline soils. They stress, however, that the "success" of a microorganismic invasion of bone is dependent on the physical and chemical characteristics of the bone as well as the burial environment.

Temperature and contact with percolating groundwater also effect the rate and extent of diagenesis. Higher temperatures increase the rate of chemical change (Von Endt and Ortner 1984). Increased exposure to groundwater facilitates bone disintegration and the introduction of foreign elements into the bone matrix (Hare 1980; Pate and Hutton 1988).

The postdepositional alteration of element concentrations is additionally dependent on the stability and chemical behavior of the elements themselves (Lambert et al. 1979, 1982, 1983, 1984, 1985a). Certain elements have been proven more susceptible to depletion and transfer than others. From the small number of elements studied by most researchers, both strontium and zinc are the most stable elements postdepositionally and thus the most resistent to diagenesis (Gilbert 1975; Lambert et al. 1985a, 1985b; Nelson and Sauer 1984). Magnesium, lead, and copper have given mixed results (Gilbert 1975; Lambert et al. 1985a, 1985b; Parker and Toots 1980). Elements that appear to be most susceptible to diagenesis are chlorine, potassium, and manganese (Lambert et al. 1985a, 1985b; Parker and Toots 1980). Nelson and Sauer (1984), however, observed manganese to be relatively stable in alkaline soils.

Summary

The discussion above highlights the primary ways element concentrations in human bone are determined. The main point is that the element concentrations of an individual during life are a function of many factors but are primarily determined by the local physical environment, diet and physiological/metabolic mechanisms. Element levels in archaeological bone are a function of the same factors plus the effects of diagenesis.

CHAPTER III

ARCHAEOLOGICAL AND ENVIRONMENTAL SETTING OF THE GORDON TOWN SITE (40DV6)

Site Location and Excavation History

The Gordon Town site (40DV6) is located in Davidson County one mile northeast of the town of Brentwood within the present-day city limits of Nashville, Tennessee. Prior to the 1920s the site was known as "Brentwood" and was cursorily described on by Joseph Jones (1876:37-38) and Frederic W. Putnam (1883a:526-529, 1883b:292). Jones (1876:37) explored a small mound and noted "the remains of an aboriginal earthwork ... surrounding the site of an extensive encampment and several mounds." Putnam (1883a:527) excavated 80 stone box graves and removed "forty skulls and many skeletons." In the late 1800s, General G. P. Thruston partially excavated a mound at the site (results unpublished). In 1920 the presence of the actual village was "rediscovered" and subsequently christened the Gordon Town site by William E. Myer during explorations in the Cumberland River Valley around Nashville for the Bureau of American Ethnology (Myer 1928:493). The site has been referred to as "Gordon Town" or "Gordontown" in recent literature (Dowd 1986a, 1986b, 1987; Eisenberg 1987; Thurston 1987).

Myer's extensive excavation took place in 1920 under the sponsorship of the Smithsonian Institution. He excavated and mapped 87 structures, two mounds, a major cemetery area and a more loosely defined area of scattered graves (Myer 1928). From his investigations, Myer determined the presence of a palisade wall "equipped with semi-circular towers about every 55 feet", a level open town square in the center of the site, and surrounding structures and mounds (Myer 1928:495). The total area encompassed by the site was approximately 11.2 acres. Limited funding restricted the excavation to seven house circles, two mounds and one temple building. Twenty burials were also excavated by Myer at this time and are now housed at the Smithsonian Institution. These remains are currently undergoing analysis (Eisenberg, personal communication 1988) and were not included in this study.

According to Myer's map the main cemetery is located on a knoll at the northeast corner of the site and the area designated as "scattered graves" in the southeast portion of the site. Two natural springs are located near the village, one on the northern perimeter and the other to the southwest of the site (Figure 1) (Jones 1876:37; Myer 1928:496; Putnam 1883a:526). The Brentwood Branch, a spring-fed stream, borders the western and northern boundaries. Myer hypothesized that

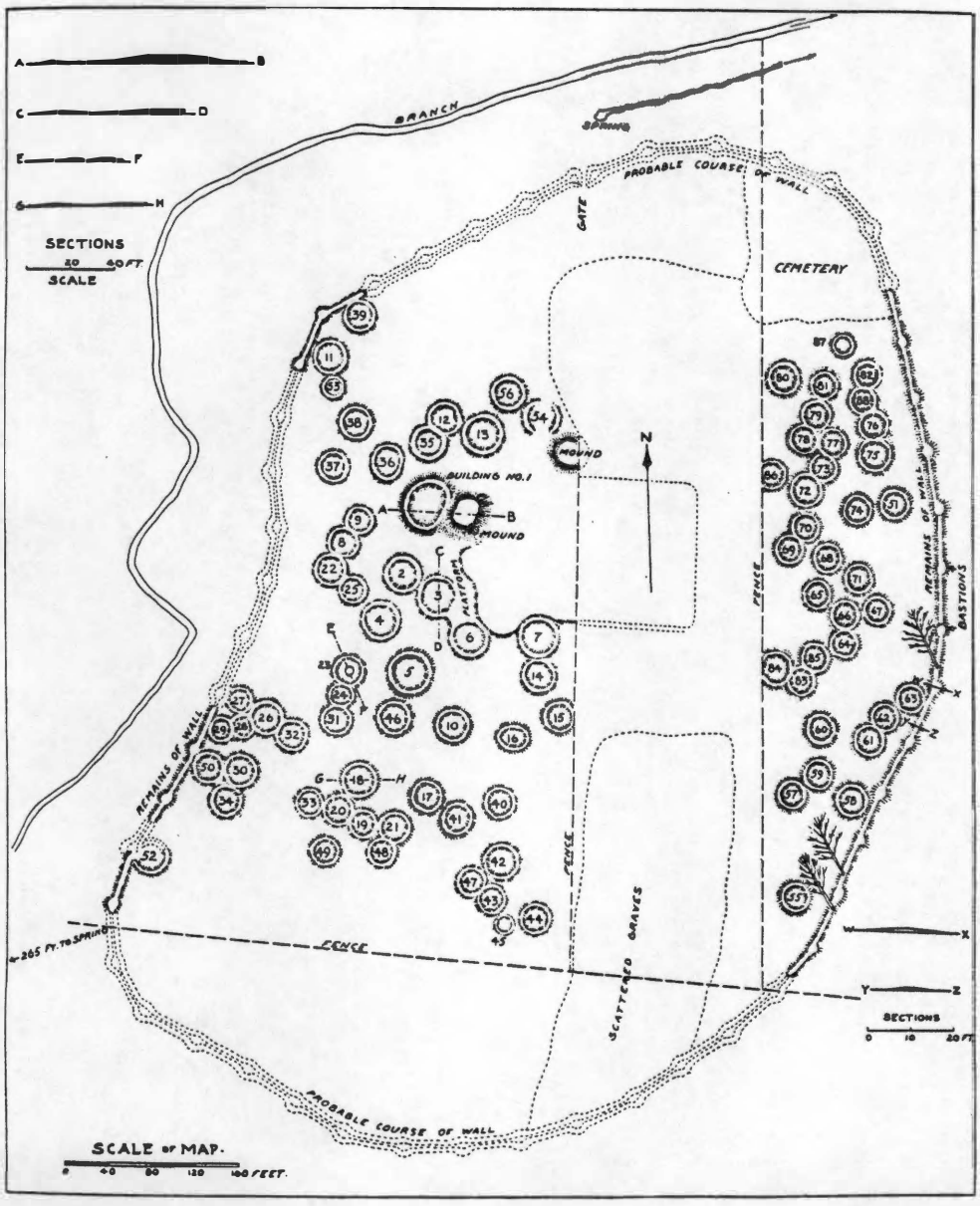


Figure 1. Myer's 1928 Map of the Gordon Town Site (40DV6).

Source: W.E. Myer, Two Prehistoric Indian Villages in Middle Tennessee. U.S. Bureau of American Ethnology, 41st Annual Report, 1919-1924, p. 494a.

the location of Gordon Town was most likely due to its proximity to the two springs, the fertility of the soil, and the adaptability of the site to fortification (Myer 1928:496).

In the summer of 1966, a group from Vanderbilt University under the direction of Ron Spores, excavated three of Myer's "house circles". Two of these yielded no archaeological remains. The third house circle yielded material characteristic of a trash pit (Tennessee State Site File, recorded by J. Dowd, 1972). The results of the 1966 excavation question the accuracy of Myers' identification and designation of observable land depressions as "house circles".

In 1985 Gordon Town once again caught the attention of archaeologists. During housing construction activities on what is now known as Lake Hemingwood Estates, a large concentration of graves was discovered. With the cooperation of the developer, Edsel Charles, the newly discovered "cemetery" (ironically located on Mr. Charles' own lot) was left in situ and set aside as a "park" or grassy area. The areas Myer had designated "cemetery" and "scattered graves" were also set aside and left undisturbed. Not surprisingly, additional graves were located outside of these designated areas in and along the road cuts and within the boundaries of the first four house lots (Figure 2). With Mr. Charles'

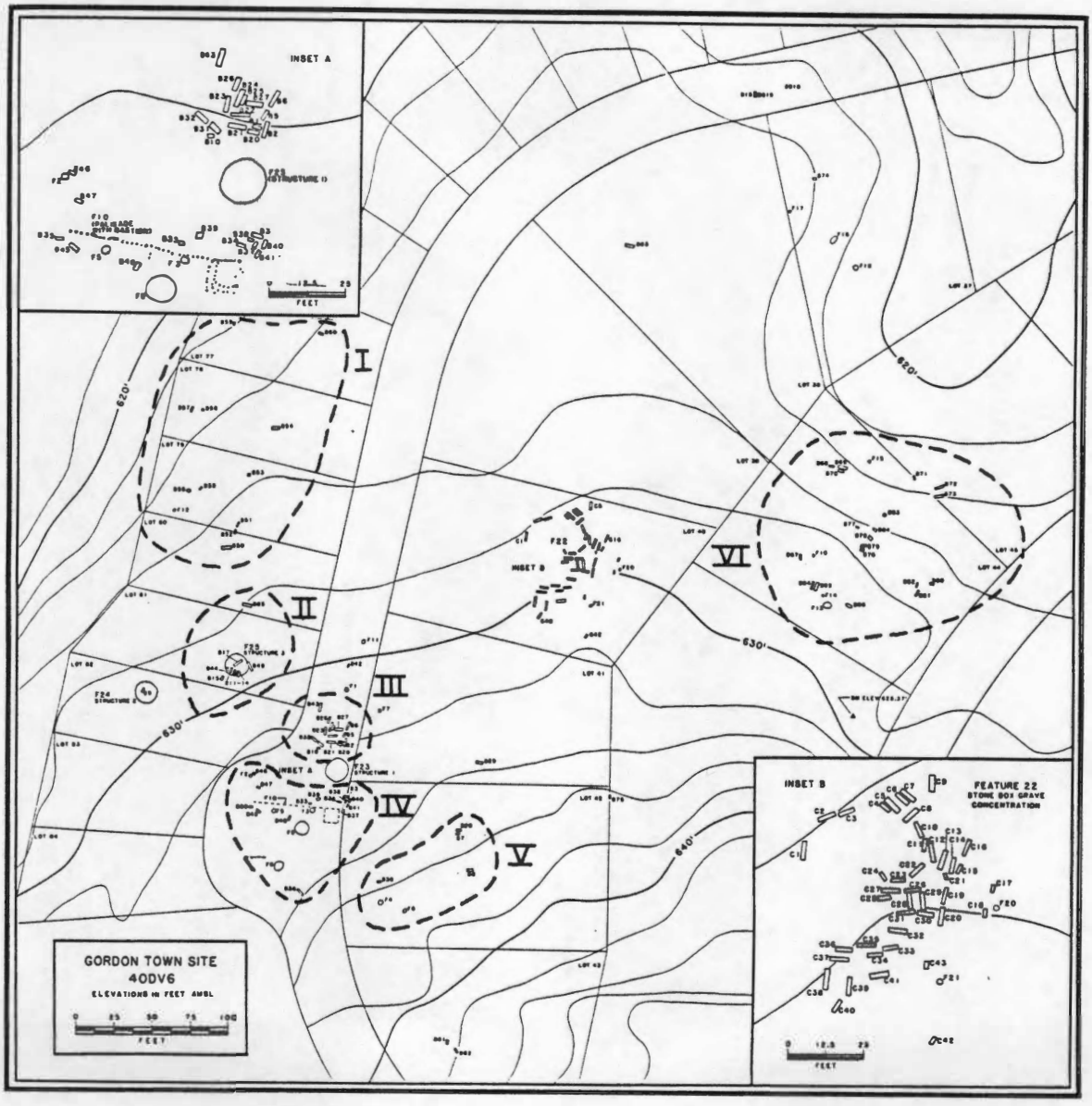


Figure 2. Map of the Gordon Town Site (40DV6) Showing Location of the Stone Box Graves and Burial Clusters.

continued cooperation these burials were excavated by several archaeologists under the auspices of the Tennessee Division of Archaeology. The skeletal remains are currently undergoing analysis at the University of Tennessee - Knoxville (Eisenberg 1987, 1988; Liston 1987; Myster in preparation; Thurston 1987).

The salvage excavation of the Gordon Town site took place during the fall of 1985 and spring-summer 1986. In addition to 93 human burials, the excavations identified additional house structures and nonburial features (including additional sections of the palisade), as well as collected artifactual material (Dowd 1986a, 1987).

Radiocarbon dates were obtained from two samples taken from Feature 23 (Structure I) and Feature 25 (Structure III). The two dates from these samples, 1310 AD and 1430 AD, correspond to the locally-defined Middle Cumberland Culture (Dowd 1987), of the Late Mississippian period (1200 - 1500 AD).

The Mississippian Period

The Mississippian period developed around 700-900 AD along the central portion of the Mississippi River. From this area Mississippian cultures spread south along the major river systems to virtually all areas of the Southeastern United States (Hudson 1976). These

cultures were fully developed by 1000 AD and lasted through the 16th century (Smith 1978b, 1986; Snow 1976; Spencer and Jennings 1965). The Mississippian represents the final and most complex prehistoric period in the Southeast.

The Mississippian period has been extensively and vigorously investigated by archaeologists. Smith (1986:57) in his review of Southeastern archaeology states that the period of A.D. 950 to A.D. 1450 is "in terms of excavated sites and published reports, the best documented and most detailed portion of the archaeological record of the Southeast [United States]." A majority of these excavated Mississippian sites have been located on or adjacent to the floodplains of major river systems. The reconstruction of Mississippian lifeways based on these floodplain locations emphasizes certain characteristics commonly associated with late prehistoric settlements in the Southeast. Culture traits that have traditionally "defined" Mississippian groups include pyramidal platform mounds, rectangular house structures, shell-tempered ceramics, pallisaded villages, densely populated settlements, a hierarchically ranked social organization and most importantly for this study, primary village site location along lowland floodplains and river valleys with an associated dependence on maize horticulture

(Green and Munson 1978; Griffin 1967; Hudson 1976; Peebles and Kus 1977; Smith 1978b, 1986; Snow 1976; Spencer and Jennings 1965; Willey and Phillips 1958).

Ward (1965) and others have documented an apparent association between sandy loam and silt loam soils with the location of maize-dependent Mississippian sites. These soils are found mostly in riverine environments and are well-suited to maize cultivation. Prehistoric farming techniques were easily able to work the soil. Furthermore, periodic and annual flooding provided constant replenishment of depleted soil nutrients. (Maize is a nutrient-demanding crop and can deplete the nutrient base of soil within a few years). The conditions and locations of these soils thus offered the potential for high crop yield (Larson 1972).

The apparent relationship between alluvial soils and Mississippian site location, as well as a belief in the primary and ubiquitous dependence on maize horticulture by late prehistoric populations, resulted in the continued focus of Mississippian research on floodplain locations through the 1970s.

During the last decade, however, a number of nonfloodplain upland sites have been excavated and interpreted (Butler 1981; Kline and Crites 1979; Klippel and Reed 1984; Smith 1978a). The location and occupation of these "aberrant" sites challenged the

traditional assumptions of Mississippian site-soil (alluvial) association and the concomitant dependence on maize horticulture (Butler 1981; Eisenberg 1986; Harn 1978; Klein and Crites 1979; Klippel and Bass 1984). A number of Mississippian sites in Tennessee, for example, have been located on nonalluvial soils (Butler 1981; Klippel and Reed 1984). Furthermore, botanical remains recovered from the Ducks Nest site (40WR4) in Warren County, Tennessee show greater quantities of some species of nuts and nondomesticated plants (e.g. hickory nut, knotweed, goosefoot and maygrass) than maize (Kline and Crites 1979). It is recognized that both natural and cultural processes affect the recovery of ethnobotanical remains; however, the recovered plant taxa do suggest qualitative insights into the role of plants in overall subsistence systems (Kline and Crites 1979; Miksicek 1987; Munson et al. 1971; Schiffer 1976, 1987).

Averbuch (40DV60), an upland Late Mississippian site in central Tennessee, also contradicts the widespread belief that late prehistoric populations were primarily dependent on maize agriculture (Klippel and Bass 1984). Excavations at Averbuch recovered a great variety of faunal and floral remains. Both wild and domesticated plant foods (including maize) were identified (Crites 1984), as were a great variety of

vertebrate and invertebrate fauna (Romanoski 1984a, 1984b). While it is clear the Averbuch inhabitants were maize horticulturalists, domesticates were only one component of the food resources utilized. Other sites, such as Gypsy Joint (Smith 1978a) and the Duck's Nest Site (Kline and Crites 1979) are also indicative of this. Furthermore Sellars (40W1-1), another Late Mississippian settlement in Tennessee, was located in a cedar glade biotic community, an environment quite unsuited to maize horticulture (Butler 1981).

Accompanying the assumption of maize-dominated Mississippian subsistence regimes is the hypothesis that the increased dependence on maize agriculture led to a decrease in the exploitation of a variety of locally available faunal resources (Cleland 1976). Robison (1982:62), however, rejects this idea and contends that "the adoption of maize agriculture by eastern North American groups caused no major selection changes in the overall types of animal species exploited." The exploitation of animals with high meat yield (e.g. deer) does not appear to have significantly decreased since the Middle Archaic period. Robison shows that the hunting of small game animals as supplemental meat sources does not appear to have diminished. White-tailed deer, wild turkey, migratory and permanent water fowl, fish and bivalves formed an important component of

the subsistence system of Mississippian peoples (Fogarty 1984; Hudson 1976; Robison 1982; Romanoski 1984a, 1984b; Smith 1974, 1975, 1978a, 1978b).

The Middle Cumberland Culture

The Gordon Town site, by virtue of its location and date of occupation (Carbon 14 dates of 1310 AD and 1430 AD), belongs to the Middle Cumberland Culture, a local variant of the regionally defined Mississippian period (Ferguson 1972). The area most intensively occupied by the Middle Cumberland peoples lies in Middle Tennessee, "between the confluence of the Caney Fork River and the Cumberland on the east, and the junction of the Cumberland and Ohio Rivers on the west" (Ferguson 1972:3).

The Middle Cumberland Culture was fully developed by A.D. 1200 and lasted into the 1600s. Sometime prior to the eighteenth century as pioneers were first beginning to settle in Tennessee, the Middle Cumberland people had virtually vanished from the area. Pioneers of the Nashville area in the mid-1700s did, however, observe the remains of their presence (Haywood 1823:108-109, cited in Ferguson 1972:4):

> This country as far as to the Elk River and beyond it, had not a single permanent inhabitant except the wild beasts of the forest, but it had been

> inhabited many centuries before by a numerous population. At every lasting spring is a large collection of graves, ... At many springs is the appearance of walls inclosing ancient habitations, the foundations of which were visible whenever the earth was cleared and cultivated, ... These walls sometimes inclose six, eight, or ten acres of land; and sometimes they are more extensive. Judging from the number and frequency of these appearances, it cannot be estimated but that the former inhabitants were ten times, if not twenty times, more numerous than those who at present occupy the country.

As a result of their disappearance prior to historic occupation of the area, the record of the Middle Cumberland Culture is strictly archaeological. Most of what is known about the Middle Cumberland Culture has been derived from mortuary analyses. The systematic and extensive excavation of the Averbuch site (40DV60) in 1984, however, has contributed a wealth of information on previously unreported aspects of Middle Cumberland adaptations (Klippel and Bass 1984). The unequivocal hallmark of the Middle Cumberland peoples is the limestone lined graves that are distributed throughout the Middle Cumberland region, centered around Nashville. These "stone box" graves, however, have been found outside of this region as well. They have been reported elsewhere in the Southeast and in the Midwest (e.g. Ohio, Indiana, Illinois) (Brown 1981; Jones 1876; Putnam 1883a, 1883b; Thruston 1890).

Stone box graves were primarily constructed of limestone slabs which were set on end in the shape of a rectangle and covered with a capstone(s). The floors of these "boxes" were either left bare or lined with crushed ceramic vessels or mussel shell. A majority of these stone box graves held only one extended individual. In many instances, however, two or more individuals were interred in the same box, with the bones of the earlier burial pushed to one end and the most recent occupant laid out in an extended position (Brown 1981; Dowd 1986b; Putnam 1883a, 1883b). Of the 85 stone box graves excavated at Gordon Town in 1985-86, 75 were single extended burials and ten were multiple burials.

Stone box graves are generally found in clusters and/or cemeteries; however, sparsely scattered graves, as well as individual graves found under the floors in house structures, have been reported. It has not been determined if burial location at Gordon Town reflects status, age or any other social or physical characteristic. In a comprehensive study on Moundville Phase settlement size and location, Peebles (1978) identified decreasing evidence for ascribed and/or achieved status differentiation as the distance away from the major ceremonial center increased. According to Peebles (1978) categories, Gordon Town could be

classified as a minor ceremonial center. Evidence for a ranked social organization was not observed at Averbuch (Klippel and Bass 1984). Artifacts are sometimes placed within the graves. At Gordon Town 30 (35%) of the 85 stone box graves contained burial accoutrements. Distinctive grave goods associated with Middle Cumberland burials include hunch-backed or blank faced effigy water bottles, filleted rim bowls and strap-handled pottery (Boyd 1984).

Environmental Setting

Gordon Town is an upland village site adjacent to the Cumberland River Valley. It is situated in the outer portion of the Nashville Basin at 36^0 2' 42" North latitude and 86^0 46' 3" West longitude. The Nashville Basin is an elliptical physiographic feature in the Interior Low Plateau province of Eastern North America (Fenneman 1938). It is located almost entirely within the state of Tennessee and encircled completely by the Highland Rim. The Nashville Basin encompasses an area of about 5900 square miles and has been divided into an inner and outer portion; the geology, topography, soils, flora, and fauna differ between the two portions. The Outer Basin, in contrast to the Inner Basin, is "deeply dissected and consists of steep slopes between narrow rolling ridgetops and narrow valley floors" (Edwards et

al. 1974:2). The average elevation of the outer portion is 750 feet above sea level. The topography of the Inner Basin is less hilly and dissected with an average elevation of 600 feet (Edwards et al. 1974; Miller 1974).

The Outer Nashville Basin is almost completely underlain by phosphatic limestones. Due to the underlying substrate a majority of the soils of the outer portion are moderate to high in phosphorus. The phosphorus content affects the natural fertility of the soils and those in the Outer Basin are quite productive agriculturally (Edwards et al. 1974:2; Klippel and Bass 1984:I.2.2). Rice (1965:50), in fact, describes the Nashville Basin soils "as the most fertile soils of Tennessee."

A majority of the soils that comprise the Gordon Town site are from the Maury series. A soil type from the Stiversville series is present in two small areas along the northern and eastern perimeter of the site (North 1981). Maury silt loam, two to seven percent slope, is a well-drained soil that "formed in residuum of phosphatic limestone" (North 1981:54). This soil and the others of the Maury series are located on the uplands of the Outer Basin and is medium acidic in reaction. The phosphorus content of the soil is medium to high and the farming potential of this soil series is

also high (North 1981:19; Edwards et al. 1974:44). North (1981:19) states that "this Maury soil is one of the most productive soils on the uplands in Davidson County" (my emphasis). Stiversville soils are also well-drained, loamy and underlain by phosphatic limestone (Edwards et al. 1974:5; North 1981:25). The Stiversville soil associated with Gordon Town (Stiversville loam, three to 12 percent slope) is medium to very high in phosphates and medium acidic in reaction. The potential for farming is "medium for row crops and high for small grains" (North 1981:25).

The soils that underlie the Gordon Town site and surrounding areas were, and are, rich and fertile. The capability of this area to support maize agriculture as well as various other kinds and amounts of vegetation is excellent. North (1981) rates the potential of the different soil types for providing habitat and supporting various kinds of wildlife. The relevant Maury soil is rated "good" as a potential habitat for grain and seed crops (domestic grains and seed-producing herbaceous plants; e.g. corn), grasses and legumes (domestic perennial grasses and herbaceous legumes; e.g. clover, beggerweed, ryegrass), wild herbaceous plants (native or naturally established grasses and forms, including weeds; e.g. wild bean, pokeberry, cheatgrass), hardwood trees (produce nuts or other fruit, buds,

catkins, twigs, bark, and foliage; e.g. oaks, hickory, maple), coniferous plants (furnish browse, seeds, and cones; e.g. pines, cedar), openland wildlife (e.g. cottontail, red fox, bobwhite quail), and woodland wildlife (e.g. squirrels, raccoon, deer). The relevant Stiversville soil is also highly rated for the same classes of wildlife as the Maury soil; a 'fair' rating for grain and seed crops is the only difference (North 1981:88-89). A rating of 'good' "indicates that the element or kind of habitat is easily established, improved or maintained .... A rating of 'fair' indicates that the element or kind of habitat can be established, improved or maintained in most places" (North 1981:33).

Until the late 1970s a number of researchers believed that Mississippian sites located away from floodplains were primarily small hamlets and farmsteads (Smith 1978a). Large settlements located on floodplains and river terraces were believed to represent the optimum choice for meeting subsistence needs (Green and Munson 1978). Evidence for this assumption was seen in the ubiquitous location of the large ceremonial centers and "minor" civic centers along major rivers and streams. As stated earlier, however, a number of larger Mississippian village sites have now been located in areas outside of the fertile alluvial floodplains, in a

variety of physiographic zones. These areas appear to be quite diverse and rich in floral and faunal resources (Butler 1981; Jolley 1983; Klippel and Bass 1984). One explanation that has been proposed for the upland locations of these sites is increased population pressure during the Late Mississippian period (Klippel and Bass 1984). In the Nashville Basin, these sites were nonrandomly situated on soils high in phosphates (Klippel and Reed 1984). Soils high in phosphates are naturally fertile and are capable of sustaining a vast and varied resource base and thus capable of sustaining a large population.

Due to financial and time restrictions, a systematic excavation of Gordon Town during 1985-86 was not possible. The primary objective was to remove the stone box burials that had been disturbed, or were in danger of being disturbed, during housing construction activities. Although a number of nonburial features and sections of the palisade were also excavated, little evidence of subsistence was systematically collected. Several medium-sized boxes of faunal material were collected and will be analyzed in the near future. A cursory investigation of the faunal remains collected noted a high percentage of white-tailed deer. Other animals represented include, but are not limited to, bear, turkey, rabbit, skunk, turtle, and cougar (not in

order of frequency). Little in the way of floral material was collected. Burial 30, however, contained evidence of burnt maize (Stripling, personal communication 1988).

The faunal material recovered at Gordon Town in 1920 by Myer was analyzed by Mr. G. S. Miller, Curator, Division of Mammals, United States Museum (Myer 1928). He determined that 85% of the faunal material recovered was from the "Virginia" deer, 10% from the wild turkey, the remaining 5% consisted of other animals such as box turtle, snapping turtle, black bear, raccoon, skunk, gray fox, squirrel, cottontail rabbit, small birds, and fish. One fresh-water drum, two fresh-water suckers, one unidentified fish and a few mussel and periwinkle shells were also recovered (Myer 1928:607). In House Circle No. 79 and in Grave P possible evidence of maize was noted (Myer 1928:540-541). It is interesting to note, however, that Myer was unable to determine "whether any trace of a cleared spot, indicating cultivated fields belonging to this town, was in evidence" (Myer 1928:497).

Attainment of the goals of this thesis require further insight into the subsistence practices of the Gordon Town inhabitants. Since there is little empirical evidence of dietary practices at this point, inferences regarding subsistence will be made based on

indirect evidence from predicted prehistoric resource availability. This availability is reconstructed from both the geographic location of the site itself and a preliminary paleopathological analysis of the skeletal sample (Eisenberg 1987, 1988).

As previously stated, Gordon Town is located in the outer portion of the Nashville Basin, between the Highland Rim and the Inner Basin. The location of Gordon Town in this area suggests the inhabitants had access to a wide variety of exploitable resources (Larson 1972). The Nashville Basin supported, and continues to support in the undeveloped and uncultivated areas, diversified deciduous forests (Braun 1950). The presence of these forests qualify the Basin for inclusion in the Carolinian Biotic province (Dice 1943:16-17) and Braun (1974) characterizes the vegetation as Western Mesophytic. A diverse and plentiful supply of faunal species are present and maintained in this area.

The vegetation of the Outer Basin is difficult to characterize because much of the land has been cleared for agricultural use. Early historic accounts, however, attest to the availability of a wide range of faunal and floral resources that must have been procurable in prehistoric times (Fogarty 1984). Potential subsistence resources available to prehistoric inhabitants of the

Nashville Basin have been summarized by Fogarty (1984) and Romanoski (1984b). See Table 4 for a detailed enumeration of these resources. Clearly the natural fertility of the outer portion of the Nashville Basin does not exclude the possibility that the Gordon Town inhabitants practiced maize horticulture. In fact, the medium to high phosphate levels of the soils suggest that "prehistoric horticulture could have been productive in those areas" (Klippel and Reed 1984:I.14.3). The question is what proportion of their diet consisted of maize.

It is unlikely that the Gordon Town inhabitants were primarily relying on maize horticulture. As previously mentioned, little evidence of maize was recovered from any of the excavations of Gordon Town. Myer (1928) recovered some remains of maize but could not find any evidence of cultivated fields. Furthermore, a preliminary analysis of the paleopathologies present in the Gordon Town sample did not report any gross nutritional deficiencies that would suggest an overreliance on maize (Eisenberg 1987, 1988).

Table 4. Potential Subsistence Resources of the Outer Portion of the Nashville Basin

Type	Description	Common name
Flora	Arboreal	White Oak
		Southern Red Oak
		Northern Red Oak
		Black Oak
		Scarlet Oak
		Shagbarck Hickory
		Red Maple
		Sugar Maple
		Yellow Poplar
		White Basswood
		American Chestnut
		American Beech
		Hackberry
		Black Walnut
		American Elm
		Dogwood
		White Elm
		Winged Elm
		Red Oak
		Ash
		Red Bud
		Bur Oak
		Black Locust
		Choke-cherry
		Spicebush
		Mulberry
		Dwarf Sumac
		Southern Black-haw
		Black Willow
		Sycamore
		Silver Maple
		Green Ash
		Basswood
		Pignut
	Herbaceous (as greens)	Weak Nettle
		Goose Grass
		Small Cane
		Spanish Needle
		Chickweed
		Pale Dock
		Common Plantain
		White Heath Aster
		Lambs Quarters

Table 4 (Continued)

Type	Description	Common name
	(as flour)	Pale Dock
		Water Smartweed
		Wire Grass
		White Vervain
		Swamp Sunflower
	Herbaceous (roots and tubers)	Frank's Sedge
		Lancaster Sedge
		Common Evening Primrose
		Jerusalem Artichoke
		Wild Carrot
	(misc.)	Bess
		Red Clover
		Sunflower
		Ragweed
Fauna	Mammals	Elk
		Mountain Lion
		Black Bear
		Grey Wolf
		Fisher
		Eastern Cottontail
		Oppossum
		Red Fox
		Raccoon
		Beaver
		Woodchuck
		White-tailed Deer
		Eastern Fox Squirrel
		Southern Flying Squirrel
		Eastern Chipmunk
		Spotted Skunk
		River Otter
		Long-tailed Weasel
		Striped Skunk
	Birds	Turkey
		Passenger Pigeon
		Canadian Goose
		Snow Goose
		Great Horned Owl
		Barred Owl
		Screech Owl
		Pied-billed Grebe
		Little Blue Heron

Table 4 (Continued)

Type	Description	Common Name
		Eastern Green Heron
		Bob-white
		Eastern Ruffled Grouse
		Marsh Hawk
		Sparrow Hawk
		Red Shouldered Hawk
		Red-tailed Hawk
		Mallard
	Fish	Sturgeon
		Gar
		Mooneye
		Shad
		Sucker
		Minnows
		Catfish
		Pike
		Eels
		Blind Cave Fish
		Bass
		Perch
		Drum
	Reptiles	Hellbender
		Eastern Newt
		Marbled Salamander
		Spotted Salamander
		Small-mouthed Salamander
		Dusky Salamander
		Two-lined Salamander
		Long-tailed Salamander
		Cave Salamander
		Mud Salamander
		Red Salamander
		Mudpuppy
	Frogs	Bull Frog
		Green Frog
		Pickerel Frog
		Toad
		Spring Peeper Toad

Table 4 (Continued)

Type	Description	Common Name
	Turtles	Snapper
		Mud
		Stinkpot
		Painted
		Map
		Eastern Box
		Smooth Softshell
		Spring Softshell
	Lizards	Eastern Fence
		Slender Glass
		Fire-lined Skink
		Southeastern five-lined Skink
		Broadheaded Skink
		Ground Skink
	Snakes	Worm
		Scarlet
		Racer
		Brown
		Garter
		Copperhead
		Timber Rattler
	Mussels (taxa)	Actinonaias carinata
		Andonta gradis
		Pleurobema clava
		Quadrula quadrule
		Dysnomia arcaeformis
		Lampsilis ovata
		Medionidus conradicus
		Carunculina parva
		Villosa trabilis
		Pegias fabula
		Strophitus undulatus
		Leptodea fragilis
		Quadrula nodulata
		Pleurobema cordatum coccineum

Sources: Behler 1979; Bull and Ferrand, Jr. 1977; Burt and Grossenheider 1976; Frick 1937; Gilmore 1931; Jones 1936; Kuhn 1939; Lincoln 1939; Shaver and Dennison 1928; Wilson and Clark 1914 - all above in Fogarty 1984; Romanoski 1984b.

CHAPTER IV

MATERIALS AND METHODS

The skeletal sample excavated from the Gordon Town site in 1985 and 1986 is composed of 98 individuals from a total of 85 stone box graves. Table 5 presents the demographic profile of the Gordon Town collection. From the table it is clear that over half (54.1%-- 53 of 98) of the sample is represented by subadult individuals 16 years of age or younger, with the greatest percentage represented by children in the birth - 3 year category (n=34). This high frequency of subadults is somewhat greater than that seen in the Averbuch skeletal sample, another Middle Cumberland Culture population. The highest frequency of adults fall into the 30-40 year category (n=16). Adult Males (n=23) and females (n=19) are nearly equally represented.

All of the stone box graves excavated by the Division of Archaeology in 1985-86 were buried outside of both the main cemetery and scattered graves area identified by Myer (1928) and the more recently discovered mound cemetery set aside by the developer, Edsel Charles (Stripling, personal communication 1988) It is currently undetermined whether burial in or exclusion from the main cemeteries were

Table 5. Demographic Profile of the Gordon Town Skeletal Sample.

Age[a] (yrs)	Sex[a]			Row Total		
	Indet.	Males	Females	N	(%)	(Cum. %)
Fetal	2			2	(2.0)	2.0
Birth-3	34			34	(34.7)	36.7
3-10	7			7	(7.1)	43.8
10-16	3			3	(3.1)	46.9
16-21		3	2	5	(5.1)	52.0
25-35			1	1	(1.0)	53.0
30-40		10	6	16	(16.3)	69.3
35-45		5	1	6	(6.1)	75.4
40-50		1	4	5	(5.1)	80.5
45-55		2		2	(2.0)	82.5
40+		1	4	5	(5.1)	87.6
"Subadult"*	7			7	(7.1)	94.7
"Adult"*	3	1	1	5	(5.1)	99.8
Col. Total	56	23	19	98	(99.8)	

* Remains are too fragmentary to age more specifically

[a] Age and sex of individuals determined using standard techniques summarized in Bass (1987); Krogman and Iscan (1986); Ubelaker (1978).

dependant upon age, sex and/or social status. Mississippian settlements have traditionally been characterized by a hierarchically ranked social structure (Griffin 1967; Smith 1986); however, ranked status is not always evident at Mississippian sites located away from the major ceremonial centers (Peebles 1977). Regardless, it cannot be assumed that the Gordon Town skeletal sample is a representative cross-section of the overall population from the site.

Sample Selection for Trace Element Analysis

As discussed in Chapter II trace element concentrations in bone result from a number of extrinsic and intrinsic factors. In order to infer dietary behavior from the trace element levels in bone, the effects of the other modifying factors (age, sex, metabolism, diagenesis) must be held constant or minimized. If not controllable, however, their possible effects on the trace element concentrations must be considered in the final interpretation of the results. It was with an awareness of the modifying factors discussed earlier that the human and animal bone samples to be analyzed and the elements to be measured were selected.

The Human sample. Twelve adult individuals, seven males and five females, were selected from the larger

skeletal sample for trace element analysis. Great care was exercised in the choice of these individuals. Selection for chemical analysis was dependent on meeting certain criteria set up to minimize the effects of intrinsic and extrinsic modifying factors. Each criteria will be briefly discussed below and a summary of the sample will follow.

Adult individuals greater than 16 years of age at death were selected in order to minimize the effects of age on element levels. In addition to age effects discussed earlier, the bones of children exhibit a high degree of variation in element levels. This variability is reflected statistically by large coefficients of variation. The coefficient of variation is significantly lower after the age of 14 (Sillen and Kavanagh 1982).

Both males and females were selected for analysis in order to highlight any element concentration differences between the sexes. Although no status differences between males and females were evident during the excavation (i.e. by the presence of grave goods or burial location), differential access to certain classes of food may have taken place. The existence of such a situation may be evident from the trace element analysis. If no significant differences exist between the sexes, males and females will be

pooled for other comparisons in order to increase the overall sample size.

A majority of the 12 individuals included in the analysis were well-preserved and free of any severe bone pathologies, active infectious lesions, or nutritional disorders. The chance of altered element concentrations due to disease interaction decreases with the absence of obvious nutritional deprivation (Beck 1985). Overall, the Gordon Town skeletal collection exhibits few instances of active infection and little evidence of nutritional stress (Eisenberg 1987, 1988). Three of the 12 individuals selected for analysis, however, exhibit slight to moderate degrees of osteoporosis (Burials 22A, 34A, and 65). These three individuals were included for two reasons. First, the criteria set up to control the modifying factors were so restrictive that only a small number of all the burials could even be considered for analysis. Burials 22A, 34A, and 65 meet all other criteria and were the least diseased of the other possible choices. Secondly, it is well-known that one of the effects of osteoporosis is loss of bone mass and thus bone mineral. An analysis of the element concentrations in these individuals will possibly enable the researcher to assess the effects of osteoporosis on various element levels in bone.

The remains of 11 of the 12 individuals were well-preserved. According to a bone preservation scale devised by Gordon and Buikstra (1981:568) the skeletal material of the 11 well-preserved burials may be classified as "Category 1, Strong Complete Bone". Category 1 includes "skeletal elements [that] are whole and undamaged. There is no evidence of postmortem destruction of osseous material which is not directly referable to local roots, microorganisms, or burrowing mammal activity" (1981:568). One individual, Burial 34A, can be classified as Category 2: "Bony elements may be fragmented, but they are completely reconstructible. External surfaces may show some etching. Articular surfaces of long bones ... show superficial destruction ... microstructure studies could be severely limited" (p.568). The element concentrations of individual 34A will be interpreted with respect to her osteoporotic condition and moderate state of preservation.

Unfortunately, gross bone preservation does not always correlate positively with histological integrity (Hanson and Buikstra 1987). In some cases histological deterioration may be well-advanced in specimens that are macroscopically well-preserved. The texture of bone in the last stages of histological decomposition is friable with cross-sections that are chalk-like. None of the specimens included in this analysis exhibited friable or

chalk-like texture. Furthermore, a majority of the individuals sectioned exhibited well preserved bone with thick compact cortices. Skeletal material that exhibits dense cortices is less likely to have undergone nutritional stress than bone that is less dense, "osteoporotic" or exhibits pathological lesions.

Intrasite Variables. In addition to the control of modifying factors, an attempt was made to control within site variables that may have affected individual susceptibility to diagenesis, thus distorting antemortem element concentrations.

Site Location of Burials. Six loosely organized burial clusters were defined by the author (Figure 2, p.29). Inclusion of individual burials in a cluster was determined solely by their proximity to other graves. The 12 individuals included in this analysis were selected from three of the six clusters. Five were from Cluster III, three were from Cluster IV and four were from Cluster VI. Individuals in each cluster were compared to individuals in the other clusters to see if any statistically significant trace element concentrations are present between the three clusters. This selection criterion was intended to reduce possible element variability due to intrasite soil differences. Previous researchers have

overwhelmingly adopted the precaution of analyzing and comparing element concentrations in bone from a single locality (e.g. one site) or stratigraphic level (Parker and Toots 1980; Toots and Voorhies 1965; Wessen et al. 1978; Wing and Brown 1979). Differences exist in the range of element levels available to different species in different environments. Element concentrations in local environments are affected by such things as soil pH, groundwater, chemical constituents of the parent rock, weathering sequence, and drainage of the soils (Sillen and Kavanagh 1982; Wing and Brown 1979). These local factors determine the concentration of minerals available to plants, animals and ultimately humans. Comparing individuals from the same locality helps ensure that the background level of elements is nearly uniform.

Type of Grave Floor. The general shape and construction of the walls and capstone(s) of stone box graves seem to seldom vary (Dowd 1986b). The floors of the graves, however, have been prepared in any number of ways. Three distinct floor constructions were observed at Gordon Town. One floor type observed was that of one or more thin limestone slabs. The second type of floor encountered was that of crushed shell-tempered pottery sherds. Reconstruction of the sherds lining graves have produced partial and even, near

complete vessels (Dowd 1986b). The third and most common type of floor observed at the Gordon Town site was an unprepared, natural soil.

All individuals selected for trace element analysis were interred in stone boxes with soil floors. There were a number of reasons for choosing only graves with soil floors. First, the high frequency and widespread distribution of this type of floor throughout the site made it most amenable (with the other criteria) as a selection criterion. Furthermore, the effects of soil on bone deterioration and diagenesis have been identified and extensively studied (Gordon and Buikstra 1981; Hanson and Buikstra 1987; Kyle 1986; Lambert et al. 1979, 1985b; Pate and Hutton 1988). The effect of limestone and shell-tempered pottery sherds on diagenesis, however, is presently unknown. As such, individuals interred on these materials were regrettably excluded from this analysis.

Summary of Human Sample Selection. Table 6 lists the 12 individuals selected for trace element analysis. All 12 individuals are well-preserved, healthy adults. They were interred in the same area of the site and in stone box graves with soil floors. The selection criteria that were met by each of the chosen individuals

were set up to control and/or minimize the individual and environmental modifying factors.

The Faunal Sample. The importance of measuring trace element concentrations in faunal remains from the same site as the human remains cannot be overemphasized (Bumsted 1985; Kyle 1986; Price 1985; Toots and Voorhies 1965; Wessen et al. 1978). Dietary reconstruction from trace element analyses depends on the comparison of human bone element concentrations to the same element concentrations in representative herbivores and carnivores (Bumsted 1985; Kyle 1986). Herbivore and carnivore concentrations establish a range of element levels within which human (as omnivores) bone levels will fall between, dependent, of course, upon the proportion of plant and animal food resources consumed during life (Price 1985).

The faunal material must come from the same site and preferably the same stratigraphic level as the human material (Kyle 1986; Pate and Brown 1985; Toots and Voorhies 1965). Since many chemical elements are unevenly distributed in the environment, this association ensures that the sources of trace elements in the faunal and human material are held constant. Strontium, for example, is unevenly distributed in the lithosphere (Kabata-Pendias and Pendias 1984). As a

Table 6. Individuals Selected for Trace Element Analysis

Burial	Sex	Age	Pathologies	Burial Cluster	Grave Floor
21	M	30-40	none	III	soil
22A	M	30-40	osteoporotic	III	soil
22B	F	40-50	none	III	soil
24	M	40-50	none	III	soil
27	M	30-40	none	III	soil
34A	F	40-50	osteoporotic	IV	soil
36	M	40-50	none	IV	soil
40	F	30-40	none	IV	soil
65	F	30-40	osteoporotic	VI	soil
66	M	30-40	none	VI	soil
72	M	30-40	none	VI	soil
76	F	40-50	none	VI	soil

result, plants and animals living in one area will consume different amounts of strontium than animals in another. Furthermore, as discussed in Chapter II, there are many variables in the local environment (e.g. soil pH, groundwater) that may affect the amount of elements available to plants and animals. Based on this principal one could not legitimately compare element concentrations, for example, in white-tailed deer from one part of the country to those from another (Gilbert 1977; Sealy and Sillen 1988; Sillen and Kavanagh 1982).

Five bones from three species of animals were analyzed for trace element concentrations. Two herbivores, two omnivores and one carnivore were represented. The herbivore sample consists of two skeletal elements from two white-tailed deer (Odocoileus virgineanus), the omnivore consists of two skeletal elements from two black bears (Ursus americanus) and the carnivore was represented by one skeletal element from a single cougar (Felis concolor). Table 7 lists the skeletal elements sampled. All faunal samples were from adults of each species. The diets of each of these animals is distinct and should be reflected by their bone element concentrations. The preferred diet of each species sampled is described below.

Table 7. Faunal Material Selected for Trace Element Analysis

Animal	Sample	Age	Bone	Site Location
Odocoileus virginianus White-tailed deer	1	Adult	Tibia	Fea. 13
	2	Adult	Humerus	Str. III, Fea. 25
Ursus americanus Black bear	1	Adult	Humerus	Str. III, Fea. 25
	2	Adult	Mandible	Fea. 8
Felis concolor Cougar	1	Adult	Radius	Surface, Lot 81

Deer are browsing animals feeding chiefly on the leaves, twigs, and fruits of trees and shrubs and the foliage of herbaceous plants. They also take seeds, fungi, mosses, lichens, succulent grasses, farm crops, and sometimes small amounts of animal food like snails and fish. Over 450 different kinds of plants are known to be eaten by White-tailed Deer ... but of these only relatively few are used extensively (Schwartz and Schwartz 1981:345).

Black bears eat a wide variety of food. Grass, berries, and other fruits, all kinds of seeds including nuts, the inner bark of trees, and roots are their main plant foods. The animal foods are ants, bees and their honey, crickets, grasshoppers, fish, frogs, small rodents, fawns, birds' eggs, and carion of all kinds, including other bears (Schwartz and Schwartz 1981:281).

> Cougars consume a diet primarily composed of meat. Deer is a favorite food, but ... [they will] take small mammals, domestic cattle, and sheep (Schwartz and Schwartz 1981:327).

Trace Elements Chosen for Measurement

The choice of elements to be measured is critical to the overall analysis. A trace element chosen for analysis should meet several criteria. First, an element should be predominantly associated with a particular food or food class (e.g. grains, meats). Secondly, a direct relationship between the element levels in the diet and the element levels in bone should exist. Thirdly, trace element concentrations should be high enough for accurate measurement. And finally, trace elements chosen for analysis should be relatively stable in the post-depositional environment (Beck 1985; Gilbert 1975, 1977; Wessen et al. 1978; Wing and Brown 1979). Satisfaction of the above criteria should enable the researcher to accurately infer dietary practices from trace element concentrations.

Certain elements (e.g. lead) are known to accumulate in bone tissue throughout an organism's life as long as the element is encountered and absorbed (Gilbert 1975). Other trace elements are fixed in bone up to certain levels after which the surplus amounts are

excreted. This is referred to as the "upper limit restriction" (Wing and Brown 1979). Unfortunately, maximum levels of absorption are not known for all of the trace elements. Nevertheless, excluding those elements that are firmly under homeostatic control and accumulate in the body throughout an organism's lifetime, there are a number of elements that are absorbed into bone and the range of these element concentrations in human bone can be assumed to reflect the consumption of the element in vivo (Gilbert 1975).

Based on previous research and the criteria outlined above, five "mineral" elements were chosen for analysis. These elements are strontium (Sr), magnesium (Mg), manganese (Mn), zinc (Zn) and copper (Cu). Sr, Mn, Zn, and Cu are considered "trace" minerals, while Mg is present in the body at a concentration greater than 0.01% and is thus technically a "macro" mineral. Strontium, magnesium and manganese are highly concentrated in plant foods while zinc and copper predominate in animal foods (Schroeder 1973; Schroeder et al. 1966a, 1966b, 1972; Underwood 1977). Table 8 lists the concentrations of these five mineral elements present in various food classes.

From Table 8 it is clear that the highest concentrations of each element are found in nuts. The possible consumption of nuts by a population will

Table 8. Mean Element Concentrations in Parts Per Million (ppm) for Grains, Vegetables, Meats, and Nuts

Element	Grains & Cereals	Vegetables[a]	Meat[b]	Nuts
Manganese	7.00	2.50	0.20	17.00
Magnesium	805.00	307.00	267.00	1970.00
Strontium	3.00	1.90	2.00	60.00
Copper	2.00	1.20	3.90	14.80
Zinc	17.70	6.00	30.60	34.00

[a] Category of vegetables includes values for legumes, tubers, and leafy material.
[b] Category of meats excludes fish and shellfish.
Source: Taken in part from Gilbert 1977:88

obviously affect the interpretation of trace element concentrations. A group that consumes a diet primarily composed of meat foods (resulting in high bone levels of zinc and copper), but also eats a fair quantity of nuts, will exhibit high levels of the plant-associated elements (manganese, magnesium, strontium). A researcher may erroneously conclude from such results that the population relied disproportionately on plant foods. It is thus imperative that the possibility of nut consumption by a population be investigated prior to the analysis of element concentrations.

The post-depositional stability of these trace elements has been measured and results are variable (Gilbert 1975; Hatch and Geidel 1985; Lambert et al. 1979, 1983, 1984, 1985a, 1985b; Price et al. 1985). It

is generally agreed, however, that strontium and zinc are the most stable (less susceptible to mineral enrichment or depletion) in the post-depositional environment (Gilbert 1975; Lambert et al. 1979, 1983, 1984, 1985b; Price et al. 1985). Their stability is lessened, however, in more acidic soils and they may be more susceptible to diagenesis (Lambert et al. 1985a). Reports on the stability of manganese, magnesium and copper in buried bone have been conflictive (Gilbert 1975; Hatch and Geidel 1985; Lambert et al. 1979, 1983, 1984, 1985a, 1985b; Price et al. 1985). Results of analyses using manganese are especially ambiguous. Nelson and Sauer (1984) found manganese concentrations to be stable in neutral or alkaline soils while Lambert et al. (1985a, 1985b) and Price et al. (1985) reported contamination of manganese in buried bone. Gilbert (1975) also reports inconsistent results when analyzing manganese concentrations. Despite the equivocal nature of many reports, most studies have focused on zinc, copper, manganese, magnesium and strontium, singularly or in combination (Blakely and Beck 1981; Brown 1973; Connor and Slaughter 1984; Gilbert 1975; Hatch and Geidel 1985; Katzenberg 1984; Price 1985; Schoeninger 1979; Sillen and Smith 1984; Toots and Voorhies 1965).

Sample Preparation

Bone samples. One of the research goals of this thesis is to compare the trace element concentrations within each individual. Klepinger et al. (1986) compared inter- and intraindividual element concentrations using sections of the tibia, humerus and femur in a small (n=4) sample from Sicily. They reported greater intraindividual variation in nine out of 40 cases (measured 10 elements in four individuals). The implication of their study, however, is unclear since the variation may be due to either diagenesis, the small amount of bone analyzed or physiological mechanisms. Another study, carried out by Grupe (1988), investigated the effect of bone choice on trace element concentrations. She concluded that element concentrations differ between different types of bones within a single individual (i.e. trabecular versus compact). The results of this study identify compact bone as more amenable to trace element analysis due to its decreased susceptibility to diagenetic changes and its high correlation to total skeletal content of specific elements. Lambert et al. (1982) also reported significant differences in trace mineral levels in femora and ribs from the same site. It is clear from these studies that intraindividual variation may be a

complicating factor in the interpretation of trace element studies.

A comparison of element concentrations between two to four bones per individual will be made. The skeletal portions chosen for this comparison are the midshaft area of both the right femur and humerus, the middle section of a middle range rib, and a section of the spinous process of a middle or lower thoracic vertebra. Two of these skeletal elements are primarily composed of trabecular bone (rib and vertebra) and two of compact bone (femur and humerus). Due to the incompleteness of some of the burials, sample sizes of each bone vary. Femur samples were taken from all 12 burials, humerus samples from 11 burials, ribs from 10 burials, and vertebra samples from nine burials. All pairwise comparisons (e.g. femur versus humerus, femur versus rib, femur versus vertebra, etc.) will be made.

A wedge-shaped transverse section was removed from the posterior midshaft of the right femur and anterior midshaft of the humerus. A transverse section, approximately 2 cm in length, was removed from the midsection of each rib and the distal portion of the spinous process on each thoracic vertebra. All bone was sectioned using a fine-tooth steel-blade "X-acto" saw with 16 teeth per inch. Following removal, each bone section was scraped clean of any adhering metal blade

fragments with a piece of sterilized glass and bagged in individual plastic bags for transport to the Brehm Animal Science building on the University of Tennessee Agricultural campus, Knoxville. Dr. John P. Hitchcock, Associate Professor in Animal Sciences and Linda C. Miller, Research Associate in Animal Sciences undertook the sample preparation and trace element assay.

Bone preparation for Atomic Absorbtion. Each individual bone sample was prepared in the manner described below. First the bone samples were placed in a Whirlpack ultrasonic cleaner with 20 ml of pure (deionized) water and sonicated for approximately 5-7 minutes to remove any surface contaminants. After sonication the bone samples were removed from the Whirlpack and thoroughly rinsed in pure water. The samples were then placed on aluminum drying pans and dried for 24 hours at 115^{o} centigrade. The samples were subsequently removed from the oven and allowed to equilibrate in a desiccator overnight. The next day the samples were weighed into oven-dried and weighed Coors crucibles at two grams of bone per crucible. The bone samples were next placed into a muffle furnace and ashed at 600^{o} centigrade for 14 hours. Following ashing the samples were covered with 10 ml concentrated HCl and allowed to digest over the weekend. The samples were

then washed out of the crucibles with ultra-pure water and taken to an initial dilution of 25 ml. From this point the samples were diluted accordingly and were submitted to a 551 Instrumentation Laboratory AA-AE Spectrophotometer. Absorbance readings were recorded for each sample.

Atomic Absorbtion Spectrometry

Atomic absorption spectroscopy (AAS) was chosen as the method of analysis for several reasons. First, AAS is widely used and accepted in the analysis of biological materials including bone tissue (Slavin 1968; Szpunar et al. 1978; Varma 1984). Atomic absorption also offers great versatility and precision. It can be used to determine concentrations of 60-70 mineral elements in trace to macro amounts (Reynolds and Aldous 1970; Slavin 1968). Furthermore, sample preparation is straight forward and analysis quickly performed. The equipment necessary to applying atomic absorption is also readily available on most university campuses as well as in the community at large. More technically, because AAS is a direct measurement of ground state free atoms, it is less susceptible to various forms of interference, including temperature and spectral variation (Reynolds and Aldous 1970; Varma 1984). Spectral interferences are reduced because of the specific nature of the atoms of a particular element.

The atoms of a specific element can only absorb radiation of a particular wavelength; conversely, a specific light frequency can only be absorbed by a specific element. It is important to note, however, that spectral interferences are more likely to occur during the assay of certain elements. This issue will be further addressed in the results and discussion section. Inaccuracy due to temperature variation during the analysis is unlikely since in AAS the atoms need only be heated to a ground state instead of to a higher state of excitation as in atomic emission spectroscopy (Ebdon 1982; Reynolds and Aldous 1970).

Atomic absorption is based on the ability of ground-state atoms to "absorb" light radiation of a specific wavelength that corresponds to the wavelength emitted when going from a ground-state (an atom, ion or molecule at its lowest energy level) to an excited state of higher energy (Brown 1974; Reynolds and Aldous 1970; Skoog and West 1986; Slavin 1968). The application of AAS to a material requires the sample to be converted to an atomic vapor. This is accomplished by heating the sample in a flame. At this point the ground state atoms of a specific element are able to absorb radiation of their own distinct wavelength. Generally hollow cathode lamps treated with the element to be measured or multi-element lamps treated with several elements provide the

spectral lines to be absorbed by the sample. Single lamps were used in this analysis because of their greater accuracy. Each lamp will emit only the spectrum of the desired element or elements. Thus when the spectrum of a specific elements is passed through the flame containing the specific atoms of the element to be measured, a portion of the light will be absorbed. The portion of the light absorbed will correspond to the concentration present in the sample (Reynolds and Aldous 1970; Skoog and West 1986).

A readout of the percent of light absorbed by the ions is obtained and the concentration of the specific element is determined by comparing percent absorption to a calibration curve. Standard solutions of each element are used to construct calibration curves unique to each element.

Statistical Analyses

Statistical testing of all data was accomplished using analysis of variance (ANOVA) procedures and Student's T-test for small samples of less than 30. All programs were available in the Statistical Analysis System (SAS) package (SAS Institute, Inc. 1985).

The first research goal of this thesis requires the comparison of mean trace mineral concentrations of the femora, humeri, ribs and vertebrae in order to assess intraindividual differences. An analysis of variance

was applied to this research problem. A number of assumptions regarding the sample to be tested are necessary when an ANOVA is applied. First, all observations must be independent - one measurement must not affect another measurement. Second, the sample must be from a population that is normally distributed. And thirdly, the variances of the samples being compared must be equal. Each of these assumptions, except for the first one, was met. Element concentrations in bone are, as has been discussed, determined by numerous intrinsic factors. Technically, then, the element concentrations to be compared are not independent. However, by using the ABSORB option offered in the analysis of variance procedure (PROC GLM) (SAS Institute, Inc., 1985), the effects of the individual on element concentrations were controlled for. Intraindividual variation will subsequently be compared to interindividual differences by comparison of coefficients of variation and ranges of concentrations.

With regard to the second research goal of this thesis, the mean concentrations of each element of the human sample will be compared to the mean concentrations of each element of the herbivore, omnivore and carnivore samples in order to assess the trophic level the Gordon Town sample is most similar to.

The comparisons described above will address the research goals presented in the introduction; however, a number of additional analyses must be performed prior to the fulfillment of the main research goals. First of all, trace mineral concentrations between males and females will be compared in order to assess possible concentration differences related to gender. A Student's T-test for small samples will be applied for this comparison. Results for males and females will be pooled for all subsequent analyses if the differences are not statistically significant. Comparison of mean element concentrations between age categories will also be run. Since there were only two age groups represented by this sample (30-40 years of age and 40-50 years of age) Student's T-tests were appropriate. Again, results will be pooled if no significant differences are found to exist between age groups. Finally, an ANOVA was performed to assess any differences in mean element concentrations due to burial in a particular grave cluster. The results of the ANOVA will highlight any significant concentration differences that may exist between individuals due to burial location. By testing for differences in mean element concentrations due to gender, age and intrasite environmental factors, the possible effect of these

factors on the trace mineral concentrations may be identified and thus controlled and considered in the interpretation of the concentrations for the fulfillment of the two main research goals of this thesis.

CHAPTER V

RESULTS AND DISCUSSION

The results of the trace mineral analysis of the Gordon Town skeletal sample will be presented in three sections. The first section will present the results of tests used to determine the presence and degree of intrinsic and extrinsic complicating factors such as age, gender and interment within a particular burial cluster. The second section will present the results of statistical tests performed to address the first research goal of this thesis, namely inter- versus intraindividual variation with respect to trace element concentrations. The third and final section will present the results of tests that address the second research goal, the inference of dietary information from the trace mineral concentrations of the Gordon Town individuals.

Concentrations of manganese, magnesium, strontium, calcium and zinc were determined for each individual in two to four different bones. The measured levels were determined from the dissolved bone ash and reported in parts per million (ppm). Mean percent bone ash from the dry bone samples was 82.77%. The individual trace

element concentrations for the human and animal samples are presented in Appendix Tables 1A and 2A.

All statistical analyses will be performed on mean bone concentrations. Table 9 presents the means, standard deviations, and coefficients of variation for each element per each bone class analyzed from the human sample. Concentrations in from two to four bones for each of five elements are reported. The coefficient of variation (c.v.) is especially important at this stage of the analysis. The c.v. is used to measure the amount of variability present in a population of measurements. If the coefficient is high there is a great deal of variation between the measurements. Schoeninger (1979) suggests that a coefficient of about 20% may be expected for a population that is ingesting the same diet. This 20% variation reflects elemental differences due to individual and environmental factors of variation. Price et al. (1985b) have reported a somewhat higher coefficient of 34.4%.

The coefficients of variation from Table 9 range from 10.58% to 178.345%. The highest coefficients are associated with the trace mineral manganese (range: 108.752% -178.345%). Certainly the high degree of variability may suggest dietary differences between the sexes or between individuals of different ages. However, this explanation is unlikely in this instance.

Table 9. Descriptive Statistics For Trace Element Concentrations (ppm) of the Gordon Town Skeletal Sample.

Element	Bone	N	Mean	Std. Dev.	C.V.
Manganese	Femur	12	61.678	109.999	178.345
	Humerus	11	300.433	435.171	144.848
	Rib	10	409.325	455.151	108.752
	Vertebra	9	404.079	507.220	125.525
Magnesium	Femur	12	890.333	189.124	21.242
	Humerus	11	823.000	87.072	10.580
	Rib	10	870.900	168.027	19.293
	Vertebra	9	1024.222	250.582	24.466
Strontium	Femur	12	16.423	3.114	18.964
	Humerus	11	16.170	4.338	26.824
	Rib	10	15.307	2.121	13.855
	Vertebra	9	17.305	3.557	20.557
Copper	Femur	12	5.250	0.957	18.233
	Humerus	11	6.192	1.336	21.583
	Rib	10	7.195	2.118	29.442
	Vertebra	9	8.897	2.386	26.815
Zinc	Femur	12	134.011	44.741	33.386
	Humerus	11	164.889	88.570	37.380
	Rib	10	193.953	54.943	28.328
	Vertebra	9	178.658	70.010	38.187

All other elements have coefficients that range from 10.58% to 38.187%. They are significantly lower than the values seen for manganese. When the questionable stability of manganese in the post-depositional environment is recalled (Gilbert 1975; Lambert et al. 1985a, 1985b; Price et al. 1985), this high degree of variability is not surprising. Unfortunately, the great variation and range of values for manganese effectively render the results of this element unreliable. Subsequent analyses of trace mineral concentrations will thus disregard manganese. Any interpretations based on such a variable element would be suspect and of questionable value.

It will also be noted from Table 9 that the mean concentrations for strontium are unnaturally low (femora = 16.42 ppm, humeri = 16.17 ppm, ribs = 15.31 ppm, vertebrae = 17.31 ppm). Prior research has seldom reported strontium levels below 100 ppm and never less than 60 ppm in humans. It is believed that interferences during the atomic absorption analysis may account for these low values. One possible source of interference is the type of flame used during the analysis. At the time of this analysis an air-acetylene flame was used. Most element concentrations can be determined in an air-acetylene flame; however, numerous interferences have been documented in certain

elements, especially the alkali metals (including strontium). Interference due to the flame is generally related to insufficient atomization of the solution or the occurrence of noticeable ionization. The Animal Sciences laboratory where the atomic absorption analysis took place has recently purchased a nitrous oxide-acetylene flame. This type of flame is, for the most part, free from interferences and is thus more suitable for use with those elements, including strontium, that experience difficulties with the air-acetylene flame (Miller personal communication 1989, Welz 1985). The other four elements analyzed experienced no interferences in an air-acetylene flame. Other possible sources of interference with regard to strontium determination are the presence of silicon and phosphates in the vaporized solution (Miller, personal communication 1989).

The unnaturally low levels of strontium recorded by this analysis cannot be used to supplement a dietary interpretation, however, the strontium levels may still be used in the assessment of gender and age effects, differences due to intrasite burial location, as well as inter- versus intraindividual comparisons. The interferences that acted on the atomic absorption of strontium are systematic and constant and thus the absolute trace mineral concentrations of each individual

were affected by a constant factor (Miller, personal communication 1989). The strontium concentrations recorded for the Gordon Town sample can thus be considered relative (as opposed to absolute) concentrations and be used when appropriate.

As discussed earlier there are numerous metabolic and extraneous variables that may alter the trace mineral concentrations from those that solely reflect the dietary intake of the individual. The disrupting factors discussed earlier included gender, age, overall health, interaction of minerals within the body, burial location, and post-depositional environment. Possible differences of trace element concentrations due to gender, age, and burial location were tested statistically in order to identify their possible effect.

Elemental Differences Due to Gender

The first factor to be tested was sex. As discussed in Chapter II, significant differences in the element concentrations between males and females may be attributable to either physiological or dietary factors. In a population that consumes the same diet, for example, pregnant or lactating females may exhibit higher levels of strontium than other females in the population because strontium is discriminated against in favor of calcium by the placenta and mammary cells. Two

times as much calcium as strontium is secreted into milk (Comar et al. 1957; Twardock 1963). Divergent element concentrations between the sexes may also result from differential access to specific food classes. In these instances it is more common to see lower levels of protein-related minerals like copper and zinc in females, suggesting greater access to protein foodstuffs by males (Brown 1973; Lambert et al. 1979).

Table 10 presents the results of two sample t-tests to determine if any significant differences exist between element concentrations in males and females. The research hypothesis states that there are significant differences in element concentrations between males and females. This hypothesis is rejected at the .05 and even .10 significance level. There are no statistically significant differences between the four element concentrations in males and females at Gordon Town.

In all bones but the femur, strontium exhibits the lowest p-values. In all cases females exhibit higher mean bone strontium levels than males. This is not unusual given the above discussion. Women in the two age-groups represented, 30-40 and 40-50 years of age, are still capable of reproducing, although at 40 to 50 years of age a woman is reaching the end of her child-bearing years. The slightly higher bone strontium

Table 10. Results of Student's T-test For Differences Between Males and Females by Bone and Trace Elements

Bone	Element	Sex	N	Mean	STD	T	DF	P
Femur	Mg	M	7	830.86	84.92	-1.1440	4.6	0.3095
		F	5	973.60	269.60			
	Sr	M	7	15.90	3.17	-0.6682	10.0	0.5191
		F	5	17.15	3.23			
	Cu	M	7	5.22	1.09	-0.1302	10.0	0.8990
		F	5	5.29	0.86			
	Zn	M	7	124.99	31.60	-0.8135	10.0	0.4349
		F	5	146.64	60.54			
Humerus	Mg	M	7	829.71	95.29	0.3228	9.0	0.7542
		F	4	811.25	82.60			
	Sr	M	7	14.97	3.05	-1.2514	9.0	0.2423
		F	4	18.28	5.90			
	Cu	M	7	6.28	1.62	0.2635	9.0	0.7981
		F	4	6.04	0.80			
	Zn	M	7	167.03	51.29	0.1447	9.0	0.8882
		F	4	161.15	85.86			
Rib	Mg	M	6	839.83	141.56	-0.6952	8.0	0.5066
		F	4	917.50	215.58			
	Sr	M	6	14.78	2.17	-0.9622	8.0	0.3641
		F	4	16.10	2.07			
	Cu	M	6	7.27	1.71	0.1242	8.0	0.9042
		F	4	7.09	2.93			
	Zn	M	6	195.87	63.34	0.1272	8.0	0.9019
		F	4	191.09	48.50			

Table 10 (Continued)

Bone	Element	Sex	N	Mean	STD	T	DF	P
Vertebra	Mg	M	6	1088.17	259.46	1.0962	7.0	0.3093
		F	3	896.33	214.62			
	Sr	M	6	15.98	3.00	-1.7842	7.0	0.1176
		F	3	19.96	3.51			
	Cu	M	6	8.36	2.50	-0.9436	7.0	0.3768
		F	3	9.97	2.13			
	Zn	M	6	167.01	28.60	-0.4675	7.0	0.6847
		F	3	201.95	127.83			

levels in females could also be interpreted as dietary differences. As stated earlier differential access to food resources usually results in higher levels of plant associated elements in females. This explanation is unlikely however, since statistically significant differences are not present between males and females in strontium or other elemental concentrations. Dietary inferences from these results will be discussed in greater detail later in the chapter.

The results of this analysis of gender differences are important for two reasons. First of all, the lack of statistically significant differences enables the pooling of males and females for all subsequent analyses. This will allow for the largest possible sample size. Secondly, these results suggest equal access, with respect to gender, to a variety of food classes.

Elemental Differences Due to Age

Table 11 presents the results of two-sample t-tests to determine age-related concentration differences. As with gender there are no statistically significant differences between the element concentrations of 30-40 year olds and 40-50 year olds. The lowest p-value ($p=0.1457$) is seen in copper concentrations in ribs. This value is suggestive of some difference between the two groups. A low p-value constitutes evidence to

Table 11. Results of Student's T-test For Differences Between Age Groups by Bone and Trace Element.

Bone	Element	Age Group	N	Mean	STD	T	DF	P
Femur	Mg	30-40	7	822.86	74.09	-1.3229	4.4	0.2505
		40-50	5	984.80	266.47			
	Sr	30-40	7	15.92	3.18	-0.6514	10.0	0.5295
		40-50	5	17.14	3.23			
	Cu	30-40	7	5.08	1.01	-0.6924	10.0	0.5045
		40-50	5	5.48	0.93			
	Zn	30-40	7	141.85	56.22	0.7012	10.0	0.4991
		40-50	5	123.04	22.49			
Humerus	Mg	30-40	7	845.00	101.29	1.1229	9.0	0.2905
		40-50	4	784.50	40.61			
	Sr	30-40	7	15.29	2.70	-0.8833	9.0	0.4000
		40-50	4	17.72	6.57			
	Cu	30-40	7	6.28	1.66	0.2487	9.0	0.7823
		40-50	4	6.03	0.62			
	Zn	30-40	7	176.91	70.18	0.8435	9.0	0.4208
		40-50	4	143.85	43.41			
Rib	Mg	30-40	6	839.17	134.01	-0.7111	8.0	0.4972
		40-50	4	918.50	223.01			
	Sr	30-40	6	15.04	2.07	-0.4709	8.0	0.6503
		40-50	4	15.71	2.45			
	Cu	30-40	6	8.01	2.17	1.6115	8.0	0.1457
		40-50	4	5.98	1.52			
	Zn	30-40	6	201.02	68.83	0.4764	8.0	0.6465
		40-50	4	183.35	30.19			

Table 11 (Continued)

Bone	Element	Age Group	N	Mean	STD	T	DF	P
Vert.	Mg	30-40	5	1088.00	297.78	0.8376	7.0	0.4299
		40-50	4	944.50	184.28			
	Sr	30-40	5	16.61	3.04	-0.6293	7.0	0.5492
		40-50	4	18.17	4.43			
	Cu	30-40	5	9.08	2.89	0.2382	7.0	0.8185
		40-50	4	8.67	1.99			
	Zn	30-40	5	206.22	37.97	1.3970	7.0	0.2051
		40-50	4	144.20	12.33			

reject the null hypothesis of no differences between age-groups. Overall, however, the results corroborate research that reports more stable element concentrations in adults as compared to children (Hodges et al. 1950; Lambert et al. 1979; Sowden and Stitch 1957; Tanaka et al. 1981) although certain element levels decreased or increased slightly with age.

It is interesting to note, however, that there are no significant differences between the older and younger age groups simply because as one grows older, bone mass typically decreases. This would obviously have a negative effect on bone mineral content. Lambert et al. (1979) plotted 10 element concentrations against age. Four of the elements (Mn, K, Al, Fe) showed extremely high levels in the very young, followed by a sharp decrease in childhood and a continued increase with age. They concluded, based on additional studies, that the bones of the very young and the elderly are more susceptible to diagenesis thus explaining the increased element levels in these two groups. This trend is not seen here. A comparison of the mean bone element concentrations between the older and younger group does not show any consistent pattern, except in zinc. With respect to zinc, the older individuals exhibit lower mean concentrations. This may reflect a physiological effect since some elements are known to decrease with

age (e.g. calcium). Underwood (1977:6) reports the results of a study that found decreasing zinc concentrations after the age of 40.

Elemental Differences Between Burial Clusters

The 12 individuals selected for analysis represent three distinct burial clusters. A one-way analysis of variance was performed in order to determine if there are significant differences in the element concentrations of individuals from three burial clusters. In this instance, an analysis of variance looked at the differences between the burial clusters to determine if they are greater than would be expected by chance.

The results of the one-way analysis of variance are presented in Table 12. The research hypothesis states that significant differences in element concentrations exist between the burial clusters. A low p-value would confirm this hypothesis. The research hypothesis is rejected at the .05 level in all but one instance: mean bone strontium concentration of the femora. There are three other instances where there are some difference between burial clusters noted. These instances are Mg-humeri p = 0.0915), Sr-humeri (p = 0.1363), and Zn-rib (p = 0.0999). It is unknown at this point whether these differences are an artifact of small sample sizes or real differences. The majority of the element

Table 12. Results of an Analysis of Variance of Differences Between Individuals From Different Burial Clusters

Element	Bone	DF	F-value	P
Mg	Femur	1, 10	0.10	0.7607
	Humerus	1, 9	3.57	0.0915@
	Rib	1, 8	0.15	0.7130
	Vertebra	1, 7	0.00	0.9708
Sr	Femur	1, 10	17.14	0.0020*
	Humerus	1, 9	2.68	0.1363
	Rib	1, 8	0.70	0.4276
	Vertebra	1, 7	0.30	0.6014
Cu	Femur	1, 10	0.56	0.4707
	Humerus	1, 9	0.20	0.6677
	Rib	1, 8	0.11	0.7472
	Vertebra	1, 7	0.05	0.8352
Zn	Femur	1, 10	1.85	0.2042
	Humerus	1, 9	0.01	0.9253
	Rib	1, 8	3.46	0.0999@
	Vertebra	1, 7	1.52	0.2578

* Significant at the 0.05 level
@ Significant at the 0.10 level

concentrations, however, do not differ significantly between burial clusters. Individuals from all areas will thus be pooled for all subsequent analyses.

Research Goal #1: Intra-individual Variation

Table 13 presents the results of a one-way analysis of variance to test for differences between two to four bones within a single individual. From the table we see that for all four elements significant differences in elemental concentrations occur between the bones of an individual. The ANOVA tests the null hypothesis that there are no differences in the mean elemental levels between the different bones tested. A low p-value is evidence to reject the null hypothesis and accept the research hypothesis that there are significant elemental differences between the bones of an individual. The ANOVA does not tell us, however, which element concentrations differ between which bones. To determine this the CONTRAST procedure in SAS (SAS Institute, Inc. 1985) was applied. The contrast procedure performs multiple comparisons (of the researcher's choice) using the independent variables from the analysis of variance in order to determine where the significant differences lie. Since the goal is to determine if significant elemental differences exist within an individual, comparisons were made between the elemental

Table 13. Summary Table of Analysis of Variance of Mean Bone Element Concentrations Within Individuals

Element	d.f.	F-value	P
Magnesium (Mg)	12	4.14	0.0008*
Strontium (Sr)	12	6.31	0.0001*
Copper (Cu)	12	3.53	0.0024*
Zinc (Zn)	12	3.17	0.0049*

* Significant at the 0.01 level

concentrations of the different bones. The contrasts performed were between:

1) the femora & humeri and the ribs & vertebrae. This comparison is essentially between the two general types of bone, compact versus trabecular.

2) the femora and humeri. This comparison is between the two compact bones.

3) the ribs and vertebrae. This contrast compares the two trabecular bones.

4) the femora and the ribs. This comparison is between the larger compact bone and one of the trabecular bones.

5) the femora and the vertebrae. This contrast compares the larger compact bone and the other trabecular bone.

6) the humeri and the ribs. This contrast compares the smaller compact bone and one of the trabecular bones.

7) the humeri and the vertebrae.
This comparison is between the smaller compact bone and the other trabecular bone.

Table 14 presents the results of the contrast procedure. The results do not follow a strong pattern. Significant elemental concentration differences at the traditional 0.05 level were seen in nine of 28 instances. Significant differences at the .10 level added five more instances for a total of 14 of 28 (50%).

The results of the intraindividual differences may be interpreted in several ways. One way to interpret the results in Table 14 is to consider the individual bones (e.g. femur, humerus, rib, vertebra) that were compared. It was previously mentioned that Grupe (1988) compared the trace element levels between compact bone and trabecular bone. She found significant differences between the element concentrations of the two bone types. The results of this study are also suggestive of this. When the mean bone element concentrations were compared between the compact (femora, humeri) and trabecular (ribs, vertebrae) bones (col. 1), significant differences at the 0.05 level were found in Cu and Zn levels. Differences at a lower confidence level were found in Sr and Mg ($p < 0.3000$). Even though the p-values of Sr and Mg aren't low enough to be included in the 95% confidence level it is clear that some

Table 14. Results of Analysis of Variance For Differences Between Bones.

Element	F/H vs R/V #1	F vs H #2	R vs V #3	F vs R #4	F vs V #5	H vs R #6	H vs V #7
Mg	0.2054	0.5242	0.0167*	0.4972	0.0631#	0.9476	0.0206*
Sr	0.2756	0.9599	0.0621#	0.0766#	0.8334	0.0782#	0.8737
Cu	0.0003*	0.1507	0.0171*	0.0188*	0.0001*	0.3049	0.0015*
Zn	0.0299*	0.1483	0.3814	0.0073*	0.0697#	0.1644	0.6232

* Significant at 0.05 (n=9)
\# Significant at 0.10 (n=5)

differences do exist. Similarly, the differences between the two compact bone samples (femora, humeri - column 2) are not as pronounced as the differences between the two trabecular bones (ribs and vertebrae - column 3). Mean mineral levels of Sr and Mg are not even close to being significantly different in the compact bones. Significant elemental level differences between each of the compact bones and each of the trabecular bones (columns 4-7) are also observed. Differences between the mineral levels of the femora and either of the trabecular bones (columns 4 and 5) are generally more significant than those between the humeri and each of the trabecular bones (columns 6 and 7).

Therefore, when analyzed with respect to the type of bones compared (compact vs trabecular) the results of this study agree with those of Grupe (1988): trace element concentrations in compact bone differ significantly (in most cases) from those in trabecular bone.

This situation may be related to bone turnover rates (Snyder et al. 1975). For normal adult individuals, the turnover rate for trabecular and cortical bone is set at 10% per year and 2.5% per year, respectively (Snyder et al. 1975:75). This disparity in turnover rate would be reflected in higher element concentrations in trabecular bones (ribs and vertebrae

in this study) than in compact bones (femora and humeri in this study). A review of Table 9 (p. 78) is consistent with this idea.

Another way to interpret the results presented in Table 14 is to look at which minerals are the most variable between the bones of an individual. In referring to Table 14, the element that is most variable within the skeleton is Cu - significant differences exist between copper concentrations in all comparisons. Zinc is also somewhat variable although only two contrasts are significant at the .05 level. Magnesium is the next variable element and strontium appears to be the least variable with regards to distribution throughout the skeleton.

Variability throughout the skeleton may be a function of element distribution within a single bone. Lambert et al. (1983) used a scanning electron microscope to determine the distribution of several elements in femoral cross-sections of archaeological bone. Their results found that the distribution of Sr and Zn were homogenous throughout the section. Manganese was concentrated along the outer surface of the sections, and Mg, in some instances, built up along the outer surface as well. The distribution of copper within a bone section was not determined. What the study suggests is that the stability of certain elements

in the postdepositional environment is questionable and appears to be related to elemental distribution throughout the bone. Build-up along the outer bone surface, as noted in Mn and to some degree Mg, is suggestive of enrichment by foreign ions from the burial environment. The pervasive distribution of Sr and Zn, on the other hand, suggest they undergo little postdepositional alteration. These concepts would be reflected in the current analysis by acceptance of the null hypothesis of no difference between the bones of an individual in the cases of Sr and Zn ($p > 0.05$) and a rejection of the null hypothesis for Mg and Mn ($p < 0.05$). The results from this study (Table 14) do not fully agree with the results of Lambert et al. (1983). Strontium was the least variable element within an individual. Zinc was more variable than expected and Mg less so.

The results of this aspect of the thesis may also be due to variation in susceptibility to diagenesis. As mentioned earlier, smaller more porous bone is more susceptible to diagenesis than dense compact bone. Differences in susceptibility to diagenesis would also manifest in significant differences in element concentrations between compact and trabecular bones.

It is clear from the results of this segment of the trace element analysis that there are a number of

possible explanations for the variable levels between different bones within an individual.

Intra-individual Variation Compared to Inter-individual Variation

Table 15 presents the ranges and coefficients of variation (c.v.) of element concentrations for the sample overall (n=12) and for each individual burial. The overall sample concentrations are represented by the femur. The range was determined by subtracting the lowest femur concentration for each element from the highest femur concentration. The range for each element within an individual was determined by subtracting the lowest concentration (of either the femur, humerus, rib, or vertebra) from the highest concentration (of either the femur, humerus, rib, or vertebra). The ranges and c.v.s were compared to determine if there was greater variation in element concentrations between the femora of all 12 individuals than in element concentrations within a single individual. In 11 of 48 (22.9%) instances the c.v. is greater within a single individual than the c.v. of all 12 individuals. In nine of 48 (18.75%) cases the range of element concentrations within an individual exceeded the range between all 12 individuals.

On an individual level nine of the 12 individuals exhibited greater intraindividual variability than

Table 15. Range (in ppm) and Coefficient of Variation (C.V.) for Element Concentrations of the Femora From the Gordon Town Sample (Inter-individual) and the Femora, Humeri, Ribs and Vertebrae Within Each Burial.

	Element			
	Mg	Sr	Cu	Zn
Interindividual (n=12)				
Range	760.00	8.90	2.50	154.80
C.V.	21.24	18.96	18.22	33.39
Burial 21				
Range	397.00	6.40	3.70*	149.30
C.V.	18.73	16.43	22.97*	39.22*
Burial 22A				
Range	10.00	2.20	0.40	0.60
C.V.	0.93	12.78	7.39	0.25
Burial 22B				
Range	79.00	1.00	0.50	27.10
C.V.	7.09	4.53	6.67	18.03
Burial 24				
Range	255.00	2.30	3.20*	90.50
C.V.	13.54	6.39	21.36*	27.37
Burial 27				
Range	126.00	2.80	4.30*	60.30
C.V.	9.19	8.90	26.84*	20.16
Burial 34A				
Range	339.00	5.50	6.50*	31.30
C.V.	6.13	14.85	47.62*	11.26
Burial 36				
Range	123.00	3.00	1.30	81.00
C.V.	6.13	9.44	8.14	20.77
Burial 40				
Range	62.00	0.60	5.70*	101.90
C.V.	3.58	2.34	37.25*	16.40
Burial 65				
Range	72.00	1.90	31.60*	229.20*
C.V.	4.39	5.60	5.56	65.27*

Table 15 (Continued)

	Element			
	Mg	Sr	Cu	Zn
Burial 66				
Range	655.00	4.20	7.50*	229.17*
C.V.	27.58*	4.83	40.62*	65.27*
Burial 72				
Range	298.00	7.50	1.90	62.00
C.V.	19.52	21.51*	15.43	15.64
Burial 77				
Range	146.00	8.40	3.40*	85.20
C.V.	7.89	15.55	27.67*	27.91

* Greater intra-individual Range and/or greater C.V. than inter-individual Range and/or C.V.

interindividual variability. The reasons for this variability are unknown. It has been suggested that the inhomogeneity of bone may be responsible. Another factor that may influence variability is, once again, susceptibility to diagenesis. Interindividual variability was determined using the femur, a bone that is regarded as more stable in the postdepositional environment than the rib or vertebra (Lambert et al. 1982). The variability within an individual, however, was determined by comparing the element levels in from two to four bones representing cortical and trabecular bones. As discussed earlier, trabecular bone is hypothesized to be more susceptible to diagenesis than compact bone. With this in mind it is interesting to note that the two burials where only the compact bones (femur and humerus) were sampled (Burial 22A, 22B), intraindividual variation does <u>not</u> exceed interindividual variation. Regardless of the explanation for the presence of high intraindividual variability, the occurrence of the variability is unsystematic and unpredictable. For this reason interindividual comparisons of element concentrations should be done using the same bone.

Research Goal #2: Inferences Regarding Dietary Practices and Subsistence Behavior of the Gordon Town Inhabitants

One of the primary goals of the trace element analyses of human bone has been the reconstruction of subsistence practices and dietary behavior of the sample under study (Brown 1973; Connor and Slaughter 1984; Price 1985; Schoeninger 1979; Schoeninger and Peebles 1981). This goal is dependent upon the recovery of representative herbivores and carnivores from the same site as the human remains. By comparison of element concentrations in human bone to concentrations in herbivores and carnivores, the relative proportion of plant and animal food resources in the human diet may be determined.

Analysis of representative herbivores and carnivores are necessary to the accurate interpretation of diet because they provide the end points of a range of element concentrations between which humans, as omnivores, will fall. As outlined earlier two herbivores (white-tailed deer), two omnivores (black bear), and one carnivore (cougar) from the Gordon Town site were analyzed. Table 16 presents the descriptive statistics of the element analysis of the faunal material. Individual concentrations are reported in Appendix Table 2A.

Table 16. Descriptive Statistics for Element Concentrations (ppm) of the Gordon Town Site Faunal Sample

Animal	N	Element	Mean	Std. Dev.	C.V.
White-tailed deer	2	Mg	1028.990	208.243	20.238
	2	Sr	20.86	1.485	7.119
	2	Cu	6.264	0.188	3.003
	2	Zn	111.910	19.021	16.997
Black Bear	2	Mg	1039.805	122.436	11.775
	2	Sr	19.195	2.397	12.488
	2	Cu	7.747	0.091	1.168
	2	Zn	237.345	94.307	39.734
Cougar	1	Mg	1050.890	--	--
	1	Sr	23.400	--	--
	1	Cu	9.533	--	--
	1	Zn	114.860	--	--

It is appropriate to mention that the role of carnivore remains in trace element studies is problematic. Carnivore remains are infrequently recovered at most archaeological sites (Price 1985). When carnivore remains are present, their numbers are low. This situation precludes an accurate assessment of the range of local element concentrations in carnivores. Different carnivores consume different meat diets. The type of meat they consume will affect their bone element concentrations (Sealy and Sillen 1988). If a carnivore consumes herbivores or omnivores that possess high levels of certain elements the carnivore will exhibit higher bone element levels than a carnivore that ingests a diet with lower element levels.

A preliminary inventory of the Gordon Town faunal remains identified a single carnivorous species (cougar) represented by one bone. While the recovery of even one carnivore is fortunate since it suggests to some extent the carnivore element levels present at Gordon Town, a sample size of one severely limits the usefulness of the information derived from it. A sample size of one obviously does not enable one to assess the range of variation present in carnivores in general and the possibility exists that the element concentrations measured in this animal may not be representative of carnivores overall. This situation makes it difficult

to estimate the range of local concentrations found in carnivores. The other two faunal species analyzed are represented by two animals each. This small sample size is not an ideal situation, however, financial constraints necessitated such a situation.

One final note before the analysis continues. It will be recalled that the Sr concentrations of both the human and animal samples are abnormally low. Interferences during the chemical analysis may be responsible for the low concentrations. Miller (1988, personal communication), however, suggested the factor(s) of interference were systematic and constant across the sample. This situation enabled the Sr values to be considered relative values and interpreted accordingly. While the percentage of dietary intake of food resources high in Sr cannot be inferred from the Sr concentrations of the human sample, the relative relationship between element concentrations of humans, herbivores, nonhuman omnivores, and carnivores can be assessed.

Figures 3 - 6 illustrate the mean bone element concentrations of humans and each species of animal analyzed and, with Tables 9 and 16 (pp. 78, 103), facilitate a comparison between the different animals with respect to the different mineral elements. Several interesting relationships are illustrated. What is most

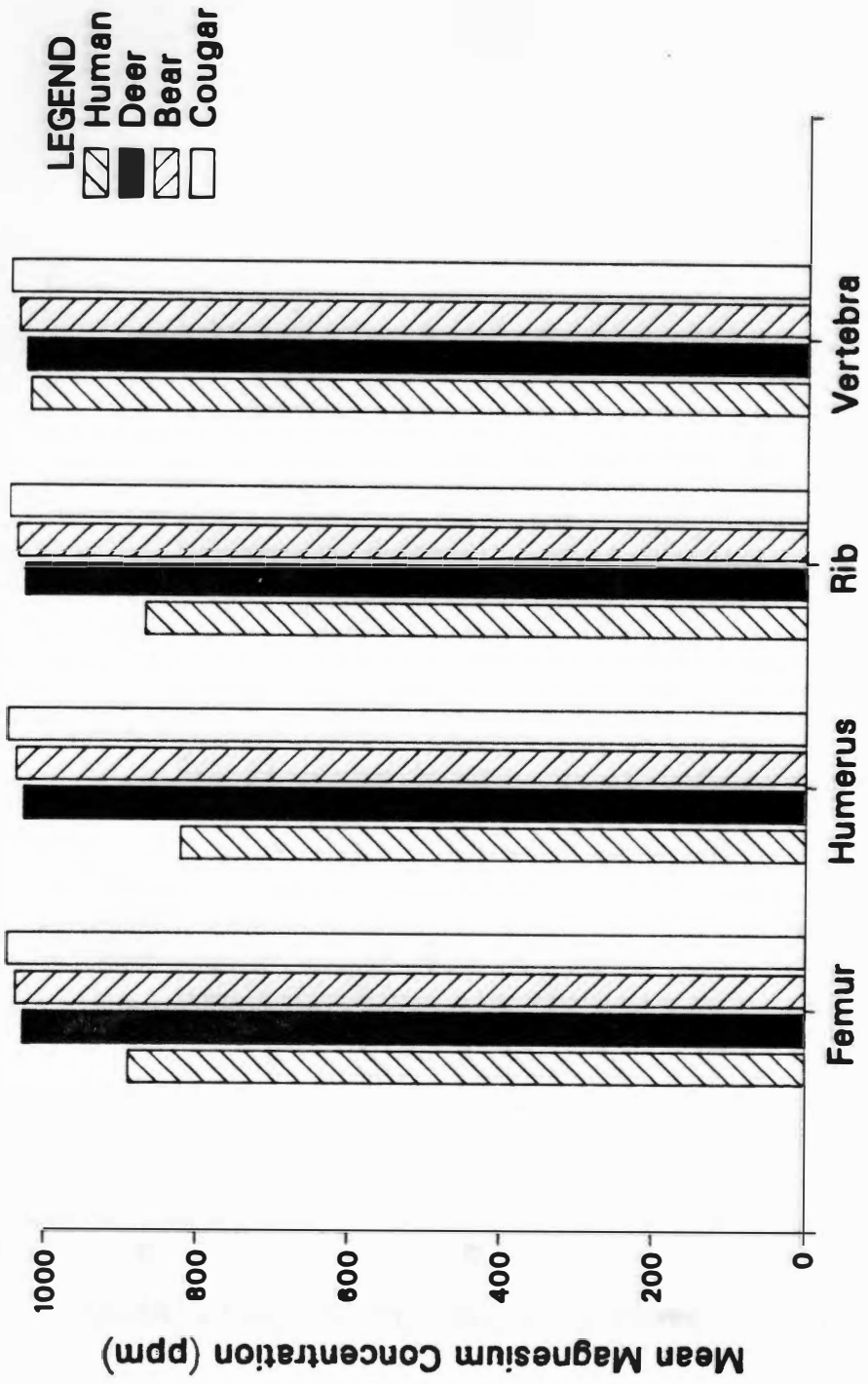


Figure 3. Comparison of Mean Bone Magnesium Concentrations in Human, Deer, Bear and Cougar Samples.

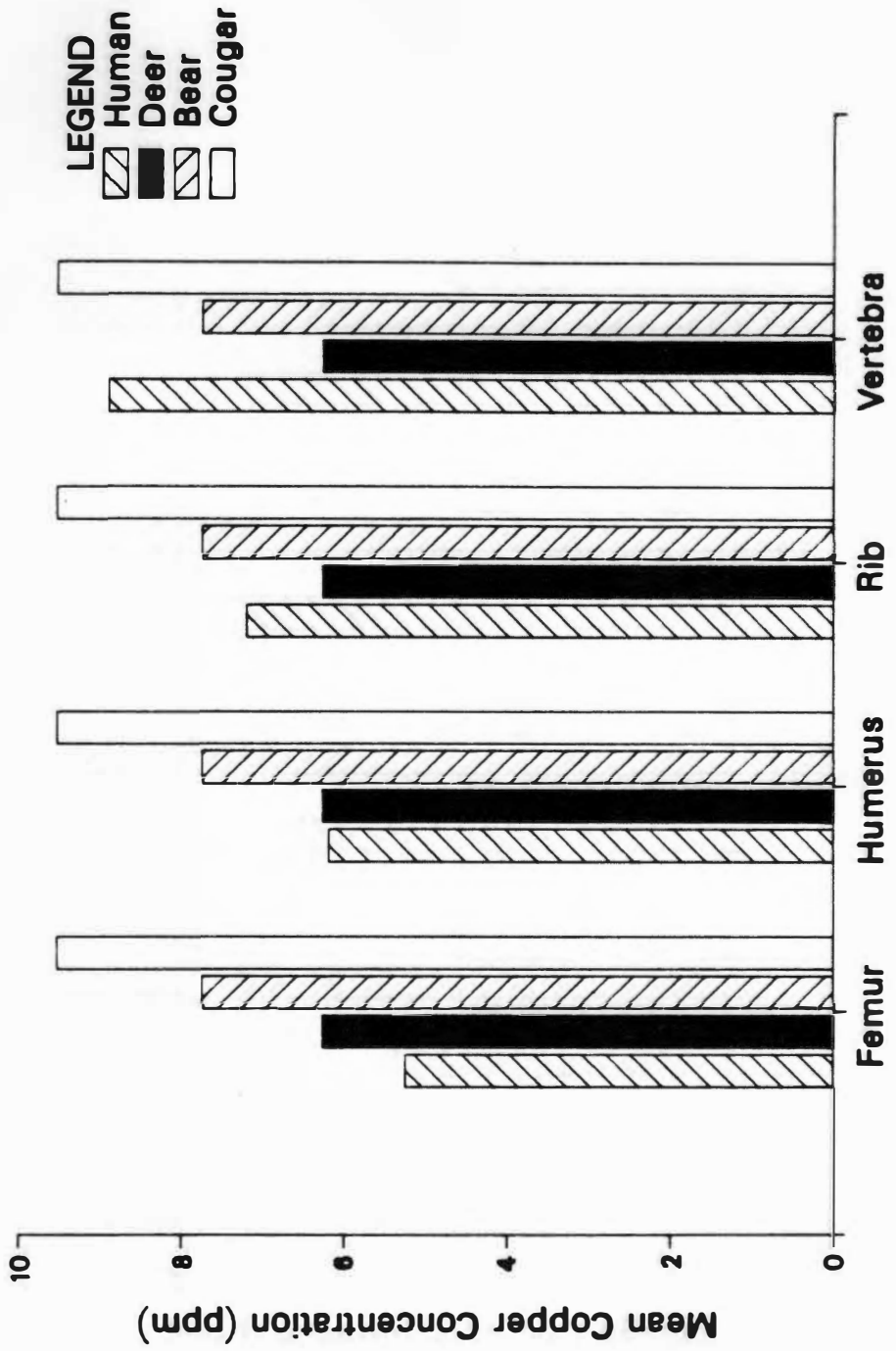


Figure 5. Comparison of Mean Bone Copper Concentrations in Human, Deer, Bear and Cougar Samples.

striking (and disturbing) is that the cougar (carnivore) possesses the greatest concentrations of those elements commonly associated with plant and grain resources -- Mg and Sr -- and thus herbivores. This situation is completely unexpected. These high levels may be explained in a number of different ways. First, the levels measured in the cougar may accurately reflect dietary intake and variation. This is highly unlikely since both Mg and Sr are primarily absorbed into bone (Mertz 1986; Underwood 1977) and are thus discriminated against as one ascends the food chain. Herbivores, since they consume plants (which are high in Sr and Mg), should have a higher concentration of plant-related minerals than carnivores who eat primarily meat resources (since Mg and Sr are absorbed primarily into skeletal structures, there would be less Sr and Mg available to carnivores since they eat primarily flesh, not bone). The high levels of Sr and Mg may also be due to individual variation. Comparison with other cougar remains would have shed some light on this problem. At this point these unusual, and perhaps unreliable, elemental concentrations, cannot be used to infer dietary composition (proportional reliance on plant vs animal food resources) of the human diet.

The concentrations of both Zn and Cu are more in line with expectations. High concentrations of both of

these elements are indicative of a diet primarily composed of meat resources. The cougar, as expected, has the highest level of Cu. Conversely, the white-tailed deer sample contained the lowest concentration of Cu (in the ribs and vertebrae). The black bear sample exhibits the highest mean bone concentration of Zn; cougar exhibits the second highest concentration of zinc. This is not totally unexpected since omnivores may ingest a diet that is high in meat resources depending on what food resources are available to them. Omnivores such as black bears also consume vast amount of nuts, a food source rich in zinc and other trace minerals and one that is generally not consumed by carnivores.

The white-tailed deer samples as the representative herbivore, exhibit the lowest mean bone concentrations of the fauna in all but one mineral (Sr). Low concentrations of both Cu and Zn are expected; however, the low concentration of the plant-related element, Mg, is unexpected and unexplainable.

In summary, the element concentrations recorded for the faunal remains are unusual and in some instances unexpected. The unusualness of the element concentrations in a number of instances, in addition to the small sample size, affect the accuracy with which dietary inferences can be made from this sample. It is

possible to suggest which classes of food resources were consumed by the Gordon Town sample but not the proportion of plant foods versus animal foods.

The histograms presented in Figures 3-6 suggest, for humans, a varied diet that most likely consisted of a judicious mixture of both plant and animal resources. It is clear from the results that the human diet at Gordon Town consisted of some proportion of meat. The mean bone element concentrations of humans with respect to Zn and Cu are higher in most instances than mean bone concentrations in the white-tailed deer (the exceptions being Cu concentrations in the femur and humerus). The proportion of meat in the diet, however, was not overwhelming since the Cu concentrations in human bone are well below the levels in the cougar as well as the black bear (omnivore). Zinc, the other meat related mineral, is higher in humans than the cougar. This may appear puzzling at first glance, however, it is reasonable with respect to the population being analyzed. Zinc levels will be discussed below.

With respect to the proportion of plant foods consumed by the Gordon Town inhabitants, the element concentrations are indicative of some exploitation of plant resources. The human concentrations of the plant-associated minerals are lower than those measured in the white-tailed deer, black bear, and cougar. Keeping in

mind the unusual concentrations of Sr and Mg in the cougar bone sample, these results suggest a diet that contains a lesser degree of plant consumption than seen in a strictly herbivorous diet.

The consumption of a varied diet by the Gordon Town inhabitants is further supported by the concentrations of the plant associated minerals relative to concentrations of the meat associated minerals. If a population were disproportionately exploiting plant resources, the concentrations of plant related elements would be high in relation to lowered levels of meat associated elements. If the reverse situation was practiced (primary reliance on animal foodstuffs), high concentrations of the meat associated elements would be present at the expense of plant element concentrations. The presence of high, or at least comparable, levels of both the plant and meat associated elements would thus be indicative of a varied, mixed diet. Comparable levels may also indicate significant consumption of nuts and mollusks (Beck 1985; Schoeninger and Peebles 1981). A quick review of Table 8 (p.65) confirms the elevated element concentrations in nuts. A significant consumption of nuts is further supported by the higher zinc concentrations in the human and black bear samples than in the cougar. It is possible that these high zinc levels simply reflect the consumption of nuts.

The varied diet suggested by the trace element concentrations of the Gordon Town sample is in accord with the physical location of the Gordon Town site. As discussed earlier, the Gordon Town site is located in the outer portion of the Nashville Basin and the village inhabitants likely had access to a great variety of food resources. It was further suggested that the Gordon Town people were less dependent on maize horticulture than contemporary floodplain groups by virtue of their upland location and the lack of evidence for cultivated fields. It appears likely, then, when the results of the trace element analysis are coupled with the site location and physical environment, that the Gordon Town inhabitants took advantage of the great variety of food resources available to them and that maize was only one component of the overall diet.

CHAPTER VI

SUMMARY

The trace element analysis of archaeological human bone has been primarily applied to questions related to dietary practices and subsistence behavior of past populations. This thesis investigated two aspects of trace element analysis of human bone. The first research goal examined the intraindividual variation of trace mineral concentrations as compared to the degree of elemental variation present between all 12 individuals. The second research goal attempted to infer dietary behavior and subsistence practices from the trace element concentrations of the Gordon Town sample.

Prior to addressing the two research goals, the effects of several possible complicating factors were assessed and, if necessary, controlled for. A few of the factors, such as overall health of the individual, bone preservation, and type of grave floor were controlled for in the selection of the human sample to be analyzed. The effects of the other factors, age, sex, and intrasite burial location, were tested for statistical significance. Results indicated no significant differences in bone element concentrations between males and females, individuals in the two age

groups (30 - 40 years and 40 - 50 years), and individuals buried in different areas of the site. Individuals from these distinct groups were pooled for all subsequent analyses following statistical testing.

Once the effects of the complicating factors had been assessed, the research goals were addressed. With respect to the comparison of intraindividual variation, it was established that significant differences existed between the two to four bones compared within each individual (Table 13, p. 92). There were several explanations offered for these differences. First, the differences may be explained by looking at the type of bone analyzed - trabecular or compact. Two bones of each type of skeletal tissue were analyzed. In general, the element concentrations in the trabecular bones were more variable than those in the compact bones. This situation may be related to different turnover rates in trabecular and cortical bone (10% and 2.5%, respectively). Differential susceptibility to diagenesis may also account for the significant element differences documented between compact and trabecular bones - various studies have concluded that smaller, more porous bones are more susceptible to postdepositional leaching and/or enrichment of minerals. The dissimilarity between the bone element concentrations may also be explained by looking at the

elements themselves. Certain elements appear more variable than others. Copper concentrations were significantly different in all comparisons (Table 14, p. 94). Zinc levels were also variable but not to the extent that copper was. Strontium was the least variable element in all comparisons. The results determined in this experiment were not wholly consistent with what Lambert et al. (1983) concluded - that Sr and Zn were the least variable elements. In this instance Zn was somewhat more variable than expected and Mg was less variable than expected.

With respect to intra- and interindividual bone element concentrations, it was demonstrated that in approximately 14 of 28 instances (50%) intraindividual variation of element levels was greater than interindividual differences (Table 15, pp. 99-100). These results have an impact on the methodology of trace element analyses on bone. They suggest that the element concentrations of one bone cannot legitimately be compared to the element levels of a different bone - in other words, the trace element concentrations of a femur of one individual cannot be compared to the trace element concentrations of a rib of another individual.

The second research goal attempted to infer the dietary practices of the Gordon Town inhabitants from the trace element concentrations in their bones.

Absolute or even relative proportions of plant versus animal foodstuffs in the diet were impossible to determine primarily because of the unusual element composition of the carnivore sample and the inaccurate strontium concentrations. It was concluded from the relative element levels, however, that the Gordon Town inhabitants consumed a diet composed of a variety of both plant and animal foodstuffs. This conclusion is in accordance with what was hypothesized earlier and is supported by the probable available food resources (Table 4, pp. 46-49) in the outer portion of the Nashville Basin during the occupation of the Gordon Town site.

The consumption of a varied diet by the Gordon Town people is in contrast to the primary and disproportionate reliance on maize by Late Mississippian floodplain inhabitants. The conclusions reached by the analysis of the trace element concentrations of the Gordon Town inhabitants are obviously limited since little supporting archaeological evidence was collected. However, with respect to subsistence behavior and local resource exploitation, the results of this aspect of the thesis are suggestive of a successful Late Mississippian, Middle Cumberland Culture adaptation to an upland environment. The overall good health and adequate diet of the Gordon Town people are intriguing

and warrant more systematic investigations of Late Mississippian upland sites.

REFERENCES CITED

REFERENCES CITED

Bass, W.M.
1987 Human Osteology. Missouri Archaeological Society, University of Missouri, Columbia.

Beck, L.A.
1985 Bivariate Analysis of Trace Elements in Bone. Journal of Human Evolution 14:493-502.

Behler, J.L.
1979 The Audubon Society Field Guide to North American Reptiles and Amphibians. Knopf, New York.

Bender, M.M., D.A. Baerreis and R.L. Steventon
1981 Further Light on Carbon Isotopes and Hopewell Agriculture. American Antiquity 46:346-353.

Blakely, R.L. and L.A. Beck
1981 Trace Elements, Nutritional Status, and Social Stratification at Etowah, Georgia. Annals of the New York Academy of Sciences 376:417-431.

Boyd, D.C.M.
1984 A Biological Investigation of Skeletal Remains From the Mouse Creek Phase and a Comparison with Two Late Mississippian Skeletal Populations From Middle and East Tennessee. Unpublished Masters Thesis, Department of Anthropology, University of Tennessee, Knoxville.

Braun, E.L.
1950 Deciduous Forests of Eastern North America. Hafner Press, New York.

Brown, A.B.
1973 Bone Strontium Content as a Dietary Indicator in Human Skeletal Populations. Unpublished Ph.D. dissertation, Department of Anthropology, University of Michigan, Ann Arbor.

Brown, A.B.
1974 Bone Strontium as a Dietary Indicator in Human Skeletal Populations. Contributions to Geology 13:85-87.

Brown, A.B. and R.L. Blakely
1985 Biocultural Adaptation as Reflected in Trace Element Distribution. Journal of Human Evolution 14:461-468.

Brown, I.W.
1981 A Study of Stone Box Graves in Eastern North America. Tennessee Anthropologist VI:1-26.

Bull, J. and J. Ferrand Jr.
1977 The Audubon Society Field Guide to North American Birds: Eastern Region. Knopf, New York.

Bumsted, M.P.
1985 Past Human Behavior from Bone Chemical Analysis Respects and Prospects. Journal of Human Evolution 14:539-551.

Burleigh, R. and D. Brothwell
1978 Studies on Amerincian Dogs, 1: Carbon Isotopes in Relation to Maize in the Diet of Domestic Dogs from Early Peru and Ecuador. Journal of Archaeological Science 5:355-362.

Burt, W.H. and R.D. Grossenheider
1976 A Field Guide to the Mammals. The Peterson Field Guide Series Third Edition. Houghton Mifflin, Boston.

Butler, B.M.
1981 Sellars: A Small Mound Center in the Hinterlands. Tennessee Anthropologist 6: 37-60.

Chaplin, R.E.
1971 The Study of Animal Bones from Archaeological Sites. Seminar Press, New York.

Cleland, C.E.
1976 The Focal-Diffuse Model: An Evolutionary Perspective on the Prehistoric Cultural Adaptations of the Eastern United States. Midcontinental Journal of Archaeology 1:59-75.

Comar, C.L., L. Russell and R.H. Wasserman
1957 Strontium-Calcium Movement from Soil to Man. Science 126:485-492.

Connor, M. and D. Slaughter
1984 Diachronic Study of Inuit Diets Utilizing Trace Element Analysis. Arctic Anthropology 21:123-134.

Crites, G.D.
1984 Late Mississippian Paleoethnobotany in the Nashville Basin: The Evidence from Averbuch. In Averbuch: A Late Mississippian Manifestation in the Nashville Basin. Volume I, Observations, W.E. Klippel and W.M. Bass eds., pp. II.12.1-23.

DeNiro, J.J. and S. Epstein
1978a Influence of Diet on the Distribution of Carbon Isotopes in Animals. Geochimica et Cosmochimica Acta 42:495-506.

1978b Carbon Isotopic Evidence for Different Feeding Patterns in Two Hyrax Species Occupying the Same Habitat. Science 201:906-908.

1981 Influence of Diet on the Distribution of Nitrogen Isotopes in Animals. Geochimica et Cosmochimica Acta 45:341-351.

DeSelm, H.R.
1959 A New Map of the Central Basin of Tennessee. Journal of the Tennessee Academy of Sciences 34:66-72.

Dice, L.R.
1943 The Biotic Provinces of North America. University of Michigan Press, Ann Arbor.

Dinan, E.H.
1988 A New Application of Strontium Analysis For Discriminationg Wild and Domesticated Fauna. Unpublished Master's Thesis, Department of Anthropology, University of Missouri, Columbia.

Dowd, J.T.
1986a Gordontown: Not Just Another Destroyed Site. Tennessee Anthropological Association Newsletter 11: 1-2.

1986b Stone Box Graves: Abnormalities and Patterns. Paper presented at the 43rd Annual Meeting of the Southeastern Archaeological Conference, Nashville, Tennessee.

1987 Gordontown Site Update. Tennessee Anthropological Association Newsletter 12: 2-6.

Ebdon, L.
1982 An Introduction to Atomic Absorption Spectroscopy. Heyden and Son Ltd., Philadelphia.

Edwards, M.J., J.A. Elder and M.E. Springer
1974 The Soils of the Nashville Basin. The United States Department of Agriculture Soil Conservation Service, in cooperation with the University of Tennessee Agricultural Experiment Station, Knoxville.

Eisenberg, L.E.
1986 Adaptation in a "Marginal" Mississippian Population from Middle Tennessee: Biocultural Insights from Paleopathology. Unpublished Ph.D. dissertation, Department of Anthropology, New York University.

1987 The Gordon Town Site Revisited. Physical Anthropology News 6: 16-17.

1988 Some Preliminary Observations on the Association Between Late Prehistoric Health and Settlement Pattern Diversity in the Middle Cumberland Region of Tennessee. Paper presented at the 50th Anniversary Meeting/45th Annual Meeting of the Southeastern Archaeological Conference, New Orleans.

n.d. Paleopathological Analysis of the Gordon Town Skeletal Population. In preparation.

Fenneman, N.M.
1938 Physiography of the Eastern United States. McGraw-Hill, New York.

Ferguson, R. (editor)
1972 The Middle Cumberland Culture. Publications in Anthropology, No. 3, Vanderbilt University Publications, Nashville.

Fogarty, M.E.
1984 The Nashville Basin: Prehistoric Resource Availability. Ms. on file, Department of Anthropology, University of Tennessee, Knoxville.

Frick, T.A.
1939 Slope Vegetation Near Nashville Tennessee. Journal of the Tennessee Academy of Science 14:344-420.

Gilbert, R.I., Jr.
1975 Trace Element Analyses of Three Skeletal Amerindian Populations at Dickson Mounds. Ph.D. Dissertation, Univeristy of Massachusetts, Amherst.

Gilbert, R.I., Jr.
1977 Applications of Trace Element Research to Problems in Archaeology. In Biocultural Adaptation in Prehistoric America, R.I. Blakely, ed., pp. 85-100. Southern Anthropological Society Proceedings, No. 11, University of Georgia Press, Athens.

Gilmore, M.R.
1931 Vegetal Remains of the Ozark Bluff-Dweller Culture. Papers of the Michigan Academy of Science, Arts, and Letters 14:83-102.

Gordon, C.C. and J.E. Buikstra
1981 Soil pH, Preservation, and Sampling Bias at Mortuary Sites. American Antiquity 46:566-571.

Green, T.J. and C.A. Munson
1978 Mississippian Settlement Patterns in Southwestern Indiana. In Misissippian Settlement Patterns, B.D. Smith, ed., pp. 293-330. Academic Press, New York.

Griffin, J.B.
1967 Eastern North American Archaeology: A Summary. Science 156:175-191.

Grupe, Gisela
1988 Impact of the Choice of Bone Samples on Trace Element Data in Excavated Human Skeletons. Journal of Archaeological Science 15:123-129.

Ham, A.W. and D.H. Cormack
1979 Histophysiology of Cartilage, BOne, and Joints. J.B. Lippincott Company, Philadelphia.

Hanson, D.B. and J.E. Buikstra
1987 Histomorphological Alteration in Buried Human Bone from the Lower Illinois Valley: Implications for Paleodietary Research. Journal of Archaeological Science 14:549-563.

Hare, P.E.
1980 Organic Geochemistry of Bone and Its Relation to the Survival of Bone in the Natural Environment. In A.K. Behrensmeyer, ed., Fossils in the Making: Vertebrate Taphonomy and Paleoecology, pp. 208-219. University of Chicago Press, Chicago.

Harn, A.D.
1978 Mississippian Settlement Patterns in the Central Illinois River Valley. In Mississippian Settlement Patterns, B.D. Smith, ed., pp. 233-268. Academic Press, New York.

Hatch, J.W. and R.A. Geidel
1985 Status-specific Dietary Variation in Two World Cultures. Journal of Human Evolution 14:469-476.

Haywood, J.
1823 The Civil and Political History of the State of Tennessee. Tenase Company, Knoxville, 1969 reprint edition.

Hetzel, B.S. and G.F. Maberly
1986 Iodine. In Trace Elements in Human and Animal Nutrition, W. Mertz, ed., pp. 139-208.

Hodges, R.M., N.S. MacDonald, R. Nusbaum, R. Stearns, F. Ezmirlian, P. Spain and C. McArthur
1950 The Strontium Content of Human Bones. Journal of Biological Chemistry 185:519-524.

Hudson, C.M.
1976 The Southeastern Indians. University of Tennessee Press, Knoxville.

Huss-Ashmore, R., A.H. Goodman and G.J. Armelagos
1982 Nutritional Inference from Paleopathology. In Advances in Archaeological Method and Theory, vol. 5, edited by Michael B. Schiffer, pp. 395-474. Academic Press, New York.

Jenny, H.
1941 Factors of Soil Formation. McGraw-Hill, New York.

Jolley, R.L.
1983 Mississippian Adaptations to the Middle Cumberland Drainage of Central Tennessee. Midcontinental Journal of Archaeology 8:73-90.

Jones, J.
1876 Explorations of the Aboriginal Remains of Tennessee. Smithsonian contributions to Knowledge, No. 259. Washington, D.C.

Jones, V.
1936 The Vegetal Remains of Newt Kash Hollow Shelter. (In) Rockshelters of Menifee County Kentucky. University of Kentucky Reports in Archaeology and Anthropology 3:147-165.

Kabata-Pendias, A. and H. Pendias
1984 Trace elements in Soils and Plants. CRC Press, Boca Raton, Florida.

Katzenberg, M.A.
1984 Chemical Analysis of Prehistoric Human Bone from Fove Temporally Distinct Populations in Southern Ontario. National Museum of Man Series. Archaeological Survey of Canada, No. 129.

Klepinger, L.L.
1984 Nutritional Assessment from Bone. Annual Review of Anthropology 13:75-96.

Klepinger, L.L., J.K. Kuhn and W.S. Williams
1986 An Elemental Analysis of Archaeological Bone from Sicily as a Test of Predictability of Diagenetic Change. American Journal of Physical Anthropology 70:325-332.

Kline, G.W. and G.D. Crites
1979 Paleoethnobotany of the Ducks Nest Site: Early Mississippian Plant Utilization in the Eastern Highland Rim. Tennessee Anthropologist 4:82-100.

Klippel, W.E. and W.M. Bass
1984 Averbuch: A Late Mississippian Manifestation in the Nashville Basin. Vol. I, Observations; Vol. II, Descriptions. Submitted to the National Park Service in accordance with the provisions of contract CX 5000-9-5943 between the University of Tennessee and the National Park Service.

Klippel, W.E. and A. Reed
1984 Locational Analysis of the Late Mississippian Sites in the Nashville Basin. In Averbuch: A Late Mississippian Manifestation in the Nashville Basin, Volume I, Observations, W.E. Klippel and W.M. Bass eds., pp. I.2.1-16.

Krogman, W.M. and Y. Iscan
1986 The Human Skeleton in Forensic Medicine. Charles C. Thomas, Springfield.

Kuhne, E.R.
1939 A Guide to the Fishes of Tennessee and the Mid-South. Tennessee Department of Conservation, Division of Fish and Game, Nashville.

Kyle, J.H.
1986 Effect of Post-burial Contamination on the Concentrations of Major and Minor Elements in Human Bones and Teeth - The Implications for Paleodietary Research. Journal of Archaeological Science 13:403-416.

Lambert, J.B., S.V. Simpson, J.E. Buikstra and D.K. Charles
1984 Analysis of Soil Associated with Woodland Burials. In Archaeological Chemistry III, edited by Joseph B. Lambert. American Chemical Society, Washington, D.C.

Lambert, J.B., S.V. Simpson, J.E. Buikstra and D. Hanson
1983 Electron Microbe Analysis of Elemental Distribution in Excavated Human Femurs. American Journal of Physical Anthropology 62:409-423.

Lambert, J.B., C.B. Szpunar and J.E. Buikstra
1979 Chemical Analysis of Excavated Human Bone From Middle and Late Woodland Sites. Archaeometry 21:115-129.

Lambert, J.B., S.V. Simpson, C.B. Szpunar and J.E. Buikstra
1985a Bone Diagenesis and Dietary Analysis. Journal of Human Evolution 14:477-482.

Lambert, J.B., S.V. Simpson, S.G. Weiner and J.E. Buikstra
1985b Induced Metal-Ion Exchange in Excavated Human Bone. Journal of Archaeological Science 12:85-92.

Lambert, J.B., S.M. Vlasak, A.C. Thometz and J.E. Buikstra
1982 A Comparative Study of the Chemical Analysis of Ribs and Femurs in Woodland Populations. American Journal of Physical Anthropology 59:289-294.

Larson, L.H., Jr.
1972 Functional Considerations of Warfare in the Southeast during the Mississippi Period. American Antiquity 37:383-392.

Levey, Martin (editor)
1967 Archaeological Chemistry: A Symposium. University of Pennsylvania Press, Philadelphia.
Lincoln, F.C.

1939 The Migration of American Birds. Doubleday, Dorn, New York.

Liston, M.A.
1987 Nonmetric Dental Traits of the Gordon Town (40DV6) Skeletal Population. Ms. on file, Department of Anthropology, University of Tennessee, Knoxville.

Martin, D.L. and G.J. Armelagos
1985 Skeletal Remodeling and Mineralization as Indicators of Health: An Example from Prehistoric Sudanese Nubia. Journal of Human Evolution 14:527-537.

McLean, F.C. and M.R. Urist
1968 Bone: Fundamentals of the Physiology of Skeletal Tissue. University of Chicago Press, Chicago.

Mertz, W. (editor)
1986 Trace Elements in Human and Animal Nutrition - Fifth Edition, Volume 2. Academic Press, New York.

Michels, J.W.
1973 Dating Methods in Archaeology. Seminar Press, New York.

Miksicek, C.H.
1987 Formation Processes of the Archaeobotanical Record. In Advances in Archaeological Method and Theory, vol. 10, edited by Michael B. Schiffer, pp. 211-247. Academic Press, New York.

Miller, R.A.
1974 The Geologic History of Tennessee. Tennessee Division of Geology, Bulletin 74.

Munson, P.J., P.W. Parmalee and R.A. Yarnell
1971 Subsistence Ecology of Scovill, A Terminal Middle Woodland Village. American Antiquity 36:410-413.

Myer, W.E.
1928 Two Prehistoric Indian Villages in Middle Tennessee. U.S. Bureau of American Ethnology, 41st Annual Report, 1919-1924, pp. 485-614. Washington, D.C.

Myster, S.M. (Thurston)
n.d. The Human Burials From the Gordon Town Site (40DV6). Submitted to the Department of Conservation, Division of Archaeology, Nashville, in preparation.

Nelson, D.A. and N.J. Sauer
1984 An Evaluation of Post Depositional Changes in the Trace Element Content of Human Bone. American Antiquity 49:141-147.

North, O.
1981 Soil Survey of Davidson County, Tennessee. U.S. Dept. of Agriculture Soil Conservation Service in cooperation with the University of Tennessee Agricultural Experiment Station.

Parker, R.B. and H. Toots
1980 Trace Elements in Bones as Paleobiological Indicators. In Fossils In The Making: Vertebrae Taphonomy and Paleoecology, edited by A.K. Behrensmeyer and A.P. Hill, pp. 197-219. University of Chicago Press, Chicago.

Pate, D.F. and K.A. Brown
1985 The Stability of Bone Strontium in the Geochemical Environment. Journal of Human Evolution 14:483-491.

Pate, D.F. and J.T. Hutton
1988 The Use of Soil Chemistry Data to Address Post-mortem Diagenesis in Bone Mineral. Journal of Archaeological Science 15:729-739.

Peebles, C.S.
1978 Determinants of Settlement Size and Location in the Moundville Phase. In Mississippian Settlement Patterns, B.D. Smith, ed., pp.396-416. Academic Press, New York.

Peebles, C.S. and S.M Kus
1977 Some Archaeological Correlates of Ranked Societies. American Antiquity 42:421-448.

Price, J.E.
1978 The Settlement Pattern of the Powers Phase. In Mississippian Settlement Patterns, B.D. Smith, ed., pp. 201-231. Academic Press, New York.

Price, T.D.
1985 Late Archaic Subsistence in the Midwestern United States. Journal of Human Evolution 14:449-459.

Price, T.D. and M. Kavanagh
1982 Bone Composition and the Reconstruction of Diet: Examples from the Midwestern United States. Midcontinental Journal of Archaeology, 7:61-79.

Price, T.D., M.J. Schoeninger and G.J. Armelagos
1985 Bone Chemistry and Past Behavior: An Overview. Journal of Human Evolution 14:419-447.

Putnam, F.W.
1883a The Stone Graves of Brentwood, Tennessee. Kansas City Review of Science 6: 526-529.

1883b Stone Graves of the Cumberland Valley. Science 1:292.

Reynolds, R.J. and K. Aldous
1970 Atomic Absorption Spectroscopy: A Practical Guide. Charles Griffin and Company, London.

Rice, O.W.
1965 Relationship of pH, Phosphorus, and Potassium of Soil Layers Among Fifty Soil Series in Tennessee. Unpublished Master's Thesis, Department of Soil Sciences, University of Tennessee, Knoxville.

Robison, N.D.
1982 A Critical Review of Mississippian Hunting Patterns and Their Antiquity. Tennessee Anthropologist 7:62-74.

Romanoski, S.M.
1984a Analysis of the Faunal Remians from the Averbuch Site. In Averbuch: A Late Mississippian Manifestation in the Nashville Basin, Volume 1, Observations, W.E. Klippel and W.M. Bass eds., pp. I.13.1-27.

1984b Fauna from the Averbuch Site. In Averbuch: A Late Mississippian Manifestation in the Nashville Basin, Volume 2, Descriptions, W.E. Klippel and W.M. Bass eds., pp. II.1.1-46.

SAS Institute, Inc.
1982 SAS User's Guide, 1985 edition. SAS Institute, Inc., Raleigh.

Schiffer, M.B.
1976 Behavioral Archaeology. Academic Press, New York.

1987 Formation Processes of the Archaeological Record. New Mexico Press: Albuquerque.

Schoeninger, M.J.
1979 Diet and Status at Chalcatzingo: Some Empirical and Technical Aspects of Strontium Analysis. American Journal of Physical Anthropology 51:295-310.

Schoeninger, M.J. and C.S. Peebles
1981 Effect of Mollusc Eating on Human Bone Strontium Levels. Journal of Archaeological Science 8:391-397.

Schroeder, H.A.
1973 The Trace Elements and Man. The Devin-Adair Company, Connecticut.

Schroeder, H.A., J.J. Balassa and I.H. Tipton
1966a Essential Trace Metals in Man: Manganese. Journal of Chronic Diseases 19:545-571.

Schroeder, H.A., A.P. Nason, I.H. Tipton and J.J. Balassa
1966b Essential Trace Metals in Man: Copper. Journal of Chronic Diseases 19:1007-1034.

Schroeder, H.A., I.H. Tipton and A.P. Nason
1972 Trace Metals in Man: Strontium and Barium. Journal of Chronic Diseases 25:491-517.

Schutte, K.H.
1964 The Biology of the Trace Elements. J.B. Lippincott Company, Philadelphia.

Schwarcz, H.P., J. Melbye, M.A. Katzenberg and M. Knyf
1985 Stable Isotopes in Human Skeletons of Southern Ontario: Reconstruction Paleodiet. Journal of Archaeological Science 12:187-206.

Schwartz, C.W. and E.R. Schwartz
1981 The Wild Mammals of Missouri. University of Missouri Press and Missouri Department of Conservation, Columbia.

Sealy, J.C. and A. Sillen
1988 Sr and Sr/Ca in Marine and Terrestrial Foodwebs in the Southwestern Cape, South Africa. Journal of Archaeological Science 15:425-438.

Shaver, J.M. and M. Dennison
1928 Plant Succession Along Mill Creek. Journal of the Tennessee Academy of Science 3:5-13.

Shipman, P., A. Walker and D. Bichell
1985 The Human Skeleton. Harvard University Press, Cambridge, Massachusetts.

Sillen, A. and M. Kavanagh
1982 Stontium and Paleodietary Research: A Review. Yearbook of Physical Anthropology 25:67-90.

Sillen, A. and P. Smith
1984 Weaning Patterns as Reflected in Strontium-Calcium Ratios of Juvenile Skeletons. Journal of Archaeological Science 11:237-245.

Skoog, D.A. and D.M. West
1986 Analytical Chemistry: an Introduction. Saunders College Publishing, Philadelphia, Pennsylvania.

Slavin, W.
1968 Atomic Absorbion Spectroscopy. Interscience Publishers - John Wiley and Sons, New York.

Smith, B.D.
1975 Middle Mississippi Exploitation of Animal Populations. Anthropological Papers 57. Museum of Anthropology, University of Michigan.

Smith, B.D. (editor)
1978a Mississippian Settlement Patterns. Academic Press, New York.

Smith, B.D.
1978b Variation in Mississippian Settlement Patterns. In Mississippian Settlement Patterns, B.D. Smith, ed., pp. 479-503. Academic Press, New York.

Smith, B.D.
1986 The Archaeology of the Southeastern United States: From Dalton to de Soto, 10500 - 500 B.P. Advances in World Archaeology 5:1-92.

Snow, D.
1976 The Archaeology of North America. Thames and Hudson Ltd., London.

Snyder, W.S., M.J. Cook, L.R. Karhausen, E.S. Nasset, G.P. Howells and I.H. Tipton
1975 Report of the Task Group on Reference Man ICRP Publication 23. Pergamon Press, Oxford.

Sowden, E.M. and S.R. Stitch
1957 Trace Elements in Human Tissue. Part 2: Estimation of the Concentrations of Stable Strontium and Barium in Human Bone. Biochemical Journal 67:104-109.

Spencer, R.F. and J.D. Jennings
1965 The Native Americans. Harper and Row, Publishers, New York.

Szpunar, C.B., J.B. Lambert and J.E. Buikstra
1978 Analysis of Excavated Bone by Atomic Absorption. American Journal of Physical Anthropology 48:199-202.

Tanaka, G.I., H. Kawamura and E. Nomura
1981 Reference Japanese Man--II: Distribution of Strontium in the Skeleton and in the Mass of Mineralized Bone. Health Physics 40:601-614.

Thruston, G.P.
1897 The Antiquities of Tennessee. Robert Clark Co., Cincinnati, Ohio.

Thurston, S.M. (Myster)
1987 A Preliminary Analysis of Dental Pathologies of the Gordontown (40DV6) Skeletal Sample. Ms. on file Department of Anthropology, University of Tennessee, Knoxville.

Toots, H. and M.R. Voorhies
1965 Strontium in Fossil Bones and the Reconstruction of Food Chains. Science 149:854-855.

Twardock, A.R.
1963 Studies on the Movement of Calcium and Strontium Across the Bovine Mammary Gland. In The Transfer of Calcium and Strontium Across Biological Membranes, edited by R. H. Wasserman, pp. 327-340. Academic Press, New York.

Ubelaker, D.H.
1978 Human Skeletal Remains. Aldine Publishing Company, Chicago, Illinois.

Underwood, E.J.
1958 Trace Elements in Animals. In Trace Elements, edited by C.A. Lamb, O.G. Bentley and J.M. Beattie, pp. 33-46. Academic Press, New York.

1971 Trace Elements in Human and Animal Nutrition, 3rd edition. Academic Press, New York.

1977 Trace Elements in Human and Animal Nutrition, 4th edition. Academic Press, New York.

van der Merwe, N.J.
1982 Carbon Isotopes, Photosynthesis, and Archaeology. American Scientist 70:596-606.

van der Merwe, N.J. and J.C. Vogel
1978 ^{13}C Content of Human Collagen as a Measure of Prehistoric Diet in Woodland North America. Nature 276:815-816.

van der Merwe, N.J., A.C. Roosevelt and J.C. Vogel
1981 Isotopic Evidence for Prehistoric Subsistence Change at Parmana, Venezuela. Nature 292:536-538.

Varma, A.
1984 CRC Handbook of Atomic Absorption Analysis, Vol. I and II. CRC Press, Boca Raton, Florida.

Von Endt, D.W. and D.J. Ortner
1984 Experimental Effects of Bone Size and Temperature on Bone Diagenesis. Journal of Archaeological Science 11:247-253.

Ward, T.
1965 Correlation of Mississippian Sites and Soil Types. Southeastern Archaeological Conference, Bulletin 3:42-48.

Weiss, L. (editor)
1983 Histology: Cell and Tissue Biology. Elsevier Biomedical, New York.

Welz, B.
1985 Atomic Absorption Spectrometry. Verlag Chemie, West Germany.

Wessen, G., F.H. Ruddy, C.E. Gustafson and H. Irwin
1978 Trace Element Analysis in the Characterization of Archaeological Bone. In: Archaeological Chemistry II, edited by G. Carter. American Chemical Society, Washington, D.C.

White, E.M. and L.A. Hannus
1983 Chemical Weathering of Bone in Archaeological Soils. American Antiquity 48:316-322.

Willey, G.R. and P. Phillips
1958 Method and Theory in American Archaeology. University of Chicago Press, Chicago.

Wing, E.S. and A.B. Brown
1979 Paleonutrition: Method and Theory in Prehistoric Foodways. Studies in Archaeology, Academic Press, New York.

Zurer, P.S.
1983 Archaeological Chemistry. Chemical and Engineering News, Feb. 21, pp.26-44.

APPENDIX

RAW DATA ON HUMAN AND ANIMALS SAMPLES

Table 1A. Trace Element Concentrations (ppm) of the Gordon Town Site Human Bone Samples.

Burial	Sex	Age	Area	Bone	Mn	Mg	Sr	Cu	Zn
21	M	1	3	Femur	12.99	847.00	13.838	6.558	95.799
				Humerus	337.59	813.00	16.144	7.010	245.130
				Rib	314.10	970.00	15.544	6.340	150.970
				Vertebra	298.76	1210.00	20.210	10.029	144.630
22A	M	1	3	Femur	16.41	754.00	13.440	4.130	169.380
				Humerus	129.65	764.00	11.212	3.720	169.980
22B	F	2	3	Femur	12.25	828.00	15.207	5.007	92.740
				Humerus	116.33	749.00	16.213	5.503	119.840
24	M	2	3	Femur	21.15	945.00	15.176	5.958	119.040
				Humerus	90.29	803.00	15.963	5.649	126.120
				Rib	247.95	766.00	13.661	6.591	209.490
				Vertebra	25.14	1021.00	15.006	8.846	179.580
27	M	1	3	Femur	5.50	817.00	13.363	4.559	102.010
				Humerus	79.93	691.00	15.753	8.901	158.460
				Rib	172.80	699.00	14.571	6.368	162.340
				Vertebra	199.74	813.00	12.967	6.730	161.740
34A	F	2	4	Femur	17.13	1454.00	18.414	5.845	154.470
				Rib	169.90	1234.00	16.827	4.890	142.700
				Vertebra	200.71	1115.00	22.366	11.396	123.220
36	M	2	4	Femur	224.82	865.00	14.624	6.482	131.460
				Humerus	170.01	833.00	11.636	6.880	208.820
				Rib	366.11	918.00	13.712	7.834	178.500
				Vertebra	185.39	956.00	13.741	6.920	140.820
40	F	1	4	Femur	34.93	882.00	14.403	5.127	120.950
				Humerus	69.14	926.00	14.306	7.156	114.260
				Rib	229.01	864.00	14.939	10.779	165.280
65	F	1	6	Femur	353.12	872.00	15.485	6.377	247.550
				Humerus	932.73	817.00	15.537	5.420	289.870
				Rib	1113.65	816.00	13.990	8.088	253.650
				Vertebra	1190.48	888.00	15.927	10.977	349.440

Table 1A (Continued)

Burial	Sex	Age	Area	Bone	Mn	Mg	Sr	Cu	Zn
66	M	1	6	Femur	29.05	894.00	20.830	4.771	93.000
				Humerus	1350.42	950.00	20.115	6.509	88.570
				Rib	1342.86	1004.00	18.683	10.505	317.740
				Vertebra	1375.81	1549.00	19.212	12.229	157.120
72	M	1	6	Femur	4.73	694.00	20.046	4.069	164.250
				Humerus	18.23	954.00	13.945	5.263	172.120
				Rib	49.71	682.00	12.497	5.965	156.150
				Vertebra	69.05	980.00	14.739	5.421	218.190
76	F	2	6	Femur	8.06	832.00	22.255	4.117	117.480
				Humerus	10.44	753.00	27.051	6.098	120.610
				Rib	87.16	756.00	18.647	4.592	202.710
				Vertebra	91.64	686.00	21.578	7.523	133.180

Table 2A. Trace Element Concentrations (ppm) of the Gordon Town Site Animal Bone Samples.

Animal	Age	Bone	Mn	Mg	Sr	Cu	Zn
White-tailed deer	Adult	Tibia	11.58	881.74	19.810	6.131	98.460
	Adult	Humerus	46.70	1176.24	21.910	6.397	125.360
Black bear	Adult	Humerus	170.67	953.23	20.890	7.683	304.030
	Adult	Mandible	613.80	1126.38	17.500	7.811	170.660
Cougar	Adult	Radius	234.91	1050.89	23.400	9.533	114.860

VITA

Susan Mary Thurston Myster was born in Minneapolis, Minnesota on December 28, 1961. She attended elementary and secondary schools in that same city. In June of 1980 she graduated from Park Center High School. The following August she entered Hamline University, and in May 1984 graduated Cum Laude with honors in Anthropology.

From May 1984 to August 1985 Susan worked as a research and field assistant in the Minnesota State Archaeologist's Office. In September of 1985 she entered graduate school at the University of Tennessee, Knoxville and began working toward a Master of Arts degree in Anthropology. This degree was awarded in May 1989.

Susan married James E. Myster on June 4, 1988. She is a member of Phi Beta Kappa, Pi Gamma Mu, the American Association of Physical Anthropologists, the Tennessee Anthropological Association, and the Southeastern Archaeological Conference.