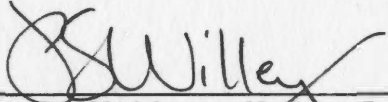


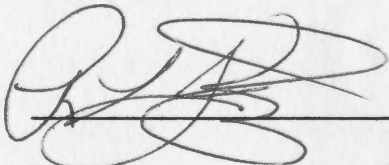
To the Graduate Council:

I am submitting herewith a thesis written by Stephen Patrick Langdon entitled "Porotic Hyperostosis and Artificial Cranial Deformation in Dallas Society." 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.



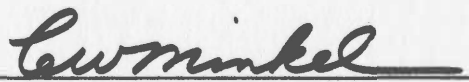
P. S. Willey, Major Professor

We have read this thesis
and recommend its acceptance:



Maria O. Smith

Accepted for the Council:



Vice Provost and
Dean of the Graduate School

POROTIC HYPEROSTOSIS AND
ARTIFICIAL CRANIAL DEFORMATION
IN DALLAS SOCIETY

A Thesis
Presented for the
Master of Arts Degree
University of Tennessee
Knoxville

Stephen Patrick Langdon
August 1989

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Finally, I thank my wife, Michelle, who helped me keep my sanity when adversity was at its greatest. I dedicate this work to her.

ABSTRACT

The purpose of this study is to evaluate, test, and amplify Lewis and Kneberg's (1946) observation that the severity of porotic hyperostosis at Hiwassee Island is related to the degree of cranial deformation. Statistical tests indicate a moderate, although non-significant, correlation between the two conditions. It is believed that this correlation may be explained by the differential treatment of infants, rather than a direct causality.

A sample of 364 crania from four Dallas Phase sites are examined. Age, sex, and status distributions of porotic hyperostosis, cribra orbitalia, and cranial deformation are examined in a biocultural framework that emphasizes the interaction among biology, culture, diet, and disease. Porotic hyperostosis and cribra orbitalia are evaluated by severity and activity, and cranial deformation is scored by degree and type.

High incidences of both cribra orbitalia and porotic hyperostosis indicate endemic iron deficiency anemia in Dallas society.

As expected, high status individuals exhibit lower frequencies of both conditions, suggesting preferential access to iron- and protein-rich food sources. Cribra orbitalia (representing infant anemia) is least common in mound males, suggesting prolonged or more frequent access to

mother's milk and other dietary supplements. Early childhood anemia (represented by calvarial porotic hyperostosis), however, is less frequent in females, suggesting preferential access to foods by virtue of sex role initiation and proximity to cooking pots, or that females are less susceptible to dietary stress. Another possibility is that females are weaned earlier than males and suffer anemic stress at an earlier age.

Artificial cranial deformation resulting from cradleboard use is virtually omnipresent. Both intentional and unintentional types are more common in village individuals, indicating increased use of the cradleboard by low status laborers. The higher frequency of intentional deformation in village individuals, especially males, suggests the use of different cradling apparatus for different infants.

Because porotic hyperostosis, cribra orbitalia, and cranial deformation are conditions most frequently occurring in childhood, differences based on status strongly suggest that status in Dallas society is largely ascribed. Intentional deformation in a few high status males, however, suggests achievement of status occurred among males.

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CHAPTER 1

INTRODUCTION

STATEMENT OF PURPOSE

In their extensive monograph on Hiwassee Island, Lewis and Kneberg (1946) make many observations of the biology and pathology of the human skeletal remains. In a discussion of the site's Late Mississippian Dallas component they note an association between artificial cranial deformation and osteoporosis symmetrica (Lewis and Kneberg 1946:162):

Many of the crania that show the most severe osteoporotic conditions are markedly deformed. The deformation... appears to have been unintentional in most cases, and to have resulted from the use of a hard cradle during infancy. The most severe cases we have already mentioned seem to be associated with nutritional deficiency.

While this observation is provocative, an explanation is lacking. Lewis and Kneberg make no attempt to quantify, systematically test, or explain the relationship, treating it as an anecdotal observation.

In the three decades since Hiwassee Island was published, numerous archaeological studies have examined artificial cranial deformation and/or porotic hyperostosis in sites dating to the Dallas Phase. None of these, however, address the possible correlation.

The purpose of this thesis is to evaluate the proposed correlation between cranial deformation and porotic hyperostosis using a large skeletal sample from the Dallas Phase, and to offer an explanation of why it does or does not exist.

RESEARCH ORIENTATION

Because porotic hyperostosis results from pathological processes and cranial deformation is a cultural modification resulting from mechanical forces, a direct causal link between the two is unlikely. Rather, any correlation between the two is believed to be indirect and coincidental, reflecting differential treatment of individuals based on their age, sex, or status.

Research for this thesis, then, is predicated on two assumptions. The first states that information about culture, subsistence, and biological stress can be inferred through osteological analysis (Buikstra 1976; Huss-Ashmore et al. 1982). The second asserts that the archaeological record can be used to determine the status of once-living peoples (Binford 1971; Peebles and Kus 1977).

Biocultural Approach. Because the variables under study are cultural and biological, an approach that recognizes the synergistic relationship among biology,

culture, and the environment is required (Parham 1982; Rathbun et al. 1980). This biocultural perspective views human cultural systems as adaptations that buffer the effects of stress produced by the environment (Figure 1; Goodman et al. 1988). The cultural system, in turn, produces additional stresses on the population and the individual, such as differential access to food resources or warfare.

Stress is defined as the "physiological disruption of an organism due to environmental perturbations," and is commonly reflected in the skeleton as disease or growth disturbances (Huss-Ashmore et al. 1982:396). Both skeletal biology and paleopathology are founded on our ability to observe and interpret the impact of environmental and cultural stress in bone. By examining the presence and patterning of pathological conditions in the individual and across the population we can make inferences about the types of stress affecting a prehistoric population and judge the success of particular adaptive strategies (Huss-Ashmore et al. 1982).

The same principles can also be used to look for and explain variability within a society or sample. The dietary hypothesis as proposed by Buikstra (1976:39) states that individuals belonging to the superordinate class in a society have preferential access to food

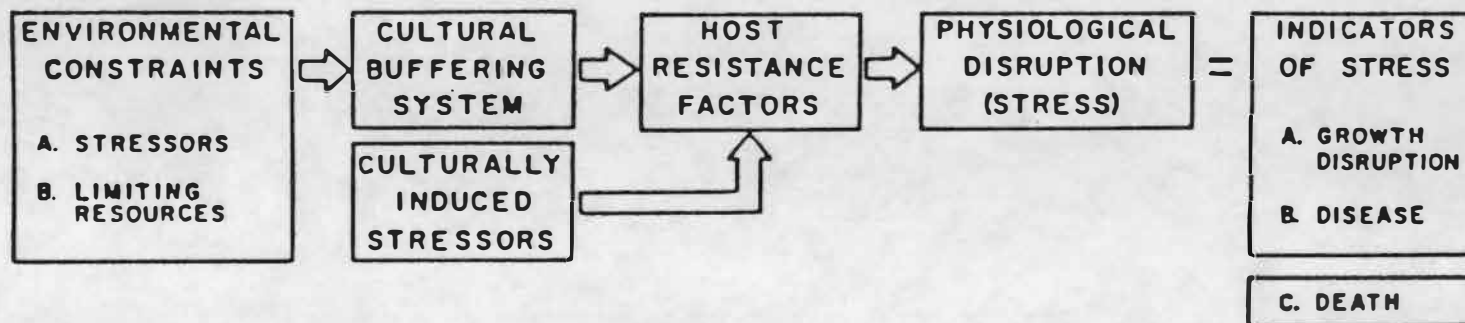


Figure 1. Stress model as applied to archaeological populations.

Sources: Goodman et al. 1988, Huss-Ashmore et al. 1982.

resources and, thus, exhibit fewer indicators of dietary or environmental stress. We can take this assertion one step further to also reflect the degree of pathological involvement, where diseases and growth arrests are not only more frequent in low-status peoples, but also more severe. This hypothesis, however, is not limited to status-based distinctions, but can be expanded to describe and explain differences in the frequency and occurrence of disease and growth disruptions by age and sex.

Status. Status is defined by Linton (1936:113) as the position or office an individual holds within his society. In reality, an individual holds several statuses (e.g. father, shaman, warrior), each pertinent to a different social sphere, culminating in an overall status or social persona. In this study, the term status represents the overall rank or position held by an individual in terms of membership in a sociopolitical caste or group (i.e. high or low status). This bipartite status distinction is typical of stratified chiefdom societies present in the Mississippian period (Service 1962; Smith 1978).

Binford (1971) asserts that the status or social persona held by an individual in life extends into death and is reflected in mortuary patterning (Buikstra 1976; Peebles and Kus 1974). It is possible, then, to use the

archaeological record to determine the status of the individual, and in turn, to infer the level of sociocultural complexity held by the society (Buikstra 1976; Hatch 1974, 1976; Peebles and Kus 1977).

Peebles and Kus (1977) provide both a theoretical framework and methodology for examining status from an archaeological perspective. They list five areas that can be examined to assess status: mortuary practices, settlement type, subsistence sufficiency, organized productive activities, and society-wide organizational activities. A similar model proposed by Hatch (1974) places emphasis on mortuary patterning and grave accompaniment artifacts, and Buikstra (1976) introduced the use of skeletal biology and paleopathology.

These models have been employed in numerous studies of status and sociopolitical organization in Mississippian populations, including the Dallas Phase, and will be discussed in detail in the next chapter, following a description of the Mississippian archaeological manifestation.

CHAPTER 2

ARCHAEOLOGICAL SETTING

The late prehistoric period of the southeastern United States is dominated by Mississippian culture. The core area of the Mississippian covered much of the region between St. Louis, Missouri, and Natchez, Mississippi, and its influence ranged into Ohio, Georgia, and the Caddo region of Texas (Muller 1978). The Mississippian began in the Central Mississippi Valley near Cairo, Illinois, and dates from A.D. 800-1500 (Morse and Morse 1983; Smith 1978), but may have persisted more recently in some regions (Lewis and Kneberg 1946; Whiteford 1952).

MISSISSIPPIAN PERIOD

The Mississippian culture has been defined by material culture traits, social organization, and environmental adaptation. The earliest designations employed the presence of substructure mounds with burials and certain pottery technologies (Muller 1978), or the presence of "Southern Cult" artifacts. Peebles and Kus (1977) classify it in terms of subsistence strategy and social organization. A more eclectic definition is provided by Smith (1978:486):

Those prehistoric human populations existing in the eastern deciduous woodlands during the time period A.D. 800-1500 that had a ranked form of social organization and a specific complex adaptation [that] involved maize horticulture and selective utilization of a limited number of species groups of wild plants and animals.

Smith (1978) also emphasizes settlement patterns. While settlement varies slightly by region and time, the norm is fortified villages located on fertile river bottomlands in the Mississippi, Tennessee, Cumberland, and Ohio River basins. Village size is also variable, ranging from expansive urban centers such as Cahokia and Moundville to small, upland settlements (Morse and Morse 1983, Smith 1978).

Mississippian society is organized at Service's (1962) chiefdom level of sociocultural complexity. Archaeological evidence suggests the presence of a superordinate and subordinate class. Peebles and Kus (1977) used five criteria to examine status and sociocultural complexity at Moundville, Alabama site. They discovered sufficient evidence in all five categories to support the contention of a stratified society with ascribed status.

Many studies have involved the use of biocultural parameters in conjunct with mortuary patterning to examine status differentiation following Buikstra's (1976) dietary hypothesis model. Blakely (1980) and Blakely and Beck

(1981) looked at skeletal pathology and trace elements at Etowah, Georgia to infer a ranked social organization. These studies, and others of the Dallas Phase (to be discussed later), verify the existence of sociopolitical stratification in Mississippian society.

DALLAS PHASE

In East Tennessee, the Late Mississippian is divided into two components. The distinction was first noted by Webb (1938:367), who identified two archaeological manifestations in the Norris Basin based on the presence of "small-log" and "large-log" structures. A similar distinction was found in the Chickamauga Basin by Lewis and Kneberg (1941, 1946) who identify an early Hiwassee Island Focus (small-log) followed by the Dallas Focus (large-log).

The Dallas Focus, later designated a Phase by Faulkner (Boyd 1984), is found throughout the portion of the Great Valley formed by the Tennessee River and its tributaries (Figure 2). Radiocarbon dates for Dallas occupation are from A.D. 1250-1550 (Hatch et al. 1983), although archaeological and ethnohistorical evidence suggest the culture may have extended until 1750, well into the Historic Period (Lewis and Kneberg 1946; Richardson 1988; Whiteford 1952).

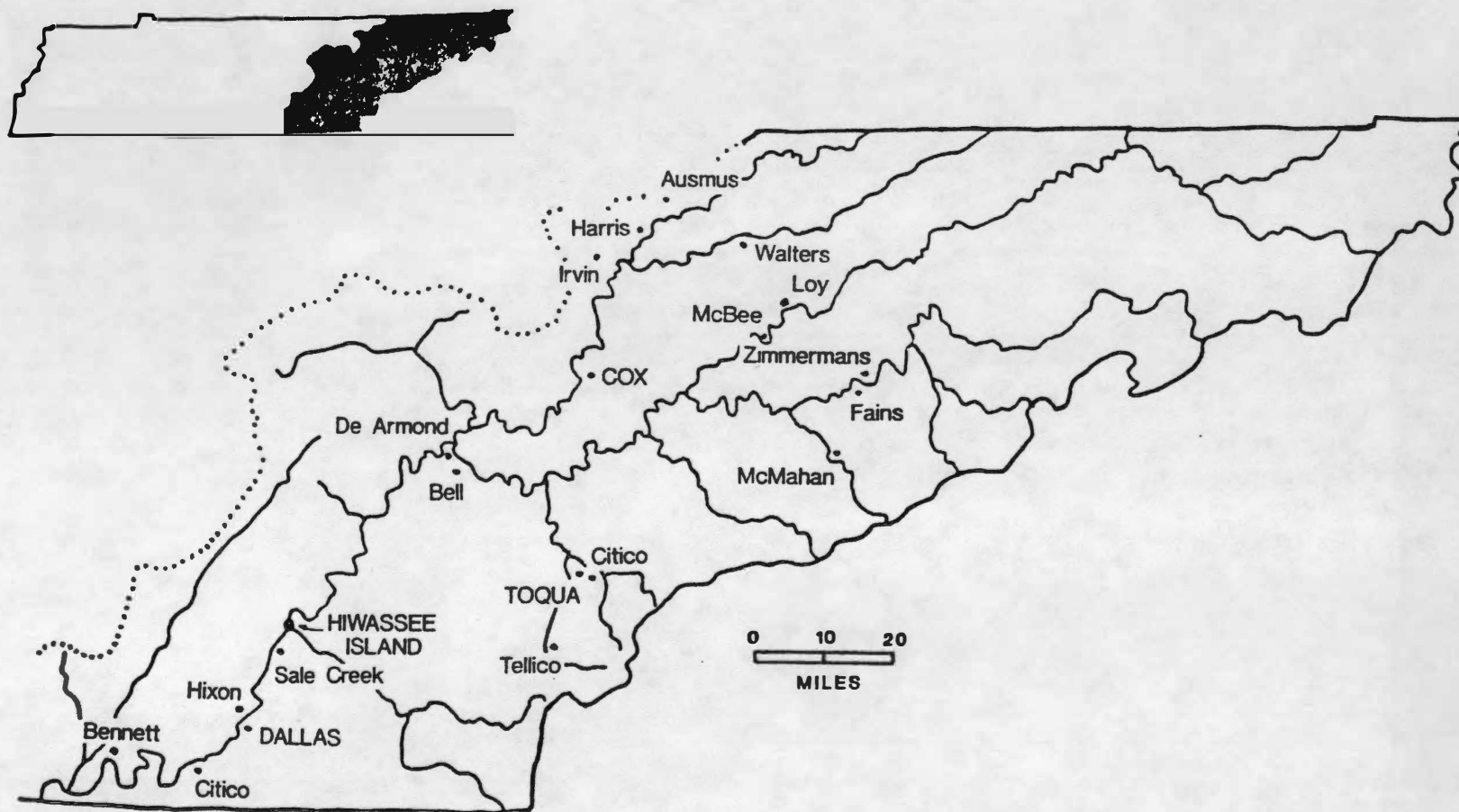


Figure 2. Map of East Tennessee showing location of Dallas Phase sites.

Settlement and subsistence follow the "typical" Mississippian pattern as outlined by Morse and Morse (1983) and Smith (1978). The Dallas community was usually a medium-sized village/ceremonial center dominated by an open plaza and one or more substructure mounds and was usually fortified with palisades and bastions. Villages are found throughout the East Tennessee ridge and valley system on the river bottomlands (Hatch et al. 1983; Parham 1982). The smaller, upland settlements occurring at the same time are attributed to the Mouse Creek Phase (Boyd 1984).

Dallas dead were buried under the floors of village house structures or in the substructure mounds. Individuals were interred in small pits, usually in a flexed position. Grave goods are often found in accompaniment, and burials are sometimes multiple.

Dallas subsistence was based on cultivation of corn, beans, and squash, and was supplemented by exploitation of wild food resources. Deer, turkey, bear, fish, waterfowl, and mollusks formed a large portion of dietary protein (Bogan 1982). Numerous wild plant species including nuts, berries, and seeds were also extensively utilized (Lewis and Kneberg 1946; Smith 1978).

Both archaeological and ethnohistorical evidence indicate a stratified society with a superordinate and subordinate group. Early ethnographic accounts of the

Southeast (Adair 1775; Hodges 1907; Swanton 1946) indicate that the Creeks, Choctaws, and other tribes in East Tennessee were organized into stratified chiefdoms. The distinction is especially evident when these tribes are compared with the Cherokee, whose sociopolitical system was more egalitarian (Owsley 1984).

This distinction was first demonstrated archaeologically by Hatch (1974), who examined mortuary patterning and artifact distribution in several Dallas sites. Hatch (1974:242-245) found that a dichotomy existed where individuals buried in mounds exhibited more signs of high status than those buried in the village. That is, ceremonial or valued trade objects are more often associated with males and mound burials while utilitarian items are found in accompaniment of females and village burials. He later (Hatch 1976) determined that Dallas society was characterized as a Type 2 chiefdom, where the primary distinction is between a superordinate class of the paramount chief, assistant chiefs, and their families and a class of commoners.

A similar mound-village dichotomy was discovered by Scott (1983) who examined mortuary patterning at Toqua using a model of energy expenditure. Bogan's (1982) reconstruction of diet from faunal remains indicates preferred access to meat foods by high status individuals.

Analyses of Dallas skeletal biology also support the presence of high and low status groups. Hatch and Willey (1974) found that males of high status (mound) were significantly taller than low status (village) males, but no significant differences were reported in females. Other analyses have employed the assumptions of Buikstra's (1976) dietary hypothesis. Studies of trace element concentration (Hatch and Geidel 1983), cortical thickness and Harris lines (Hatch et al. 1983), and skeletal biology and pathology (Parham 1982; Parham and Scott 1980) have found that low status individuals tend to exhibit greater frequencies of disease and growth disturbances than those of high status.

In any chiefdom society, status can be ascribed or achieved, and both occur simultaneously in most instances (Service 1962). Whether status in Dallas society is primarily achieved or ascribed is not clear, and is subject to much debate. Archaeological evidence is inconclusive, with studies suggesting both ascription (Hatch 1974, 1976; Hatch et al. 1983; Hatch and Willey 1974) and achievement (Parham 1982, Scott 1983) as the avenue of status determination. Most likely, both avenues of status determination were operational in Dallas society.

SAMPLE

The crania of 364 individuals from four Dallas Phase sites in East Tennessee are examined (Table 1; Figure 2). Materials were excavated from areas threatened by rising waters of the Chickamauga, Melton Hill, and Tellico reservoirs Resulting from Tennessee Valley Authority (TVA) dam construction. The skeletal materials examined in this study are currently curated at the Frank H. McClung Museum at the University of Tennessee, Knoxville (Chapman 1988).

Cox Mound (5AN19) and Village (18AN19). The Cox site is located on the east bank of the Clinch River near Clinton, Tennessee. The site was first investigated by H.M. Sullivan and A.P. Taylor, who excavated the mound, and reported by Webb (1938) as part of his Norris Basin Survey. The village component was subsequently excavated in 1960 (McNutt and Fisher n.d.). A total of 247 individuals was recovered from the site.

Dallas (7,8HA1). The Dallas site is located on the east bank of the Tennessee River near Harrison, Tennessee, and contains both mound and village components. Archaeological evidence suggests occupation from A.D. 1300-1550 (Richardson 1988). Excavations were carried out by C.H. Nash in 1936-1937. Lewis and Kneberg (1941)

Table 1. Demographic Distribution of Dallas Phase Sample.

Site	Inf	Child	Adol	Adults			Total
				M	F	?	
Cox	2	13	9	34	22	5	85
Dallas	5	21	10	31	39	2	108
Hiwassee Is.	3	17	8	16	30	2	76
Toqua	3	17	8	37	29	1	95
Total	13	68	35*	118	120	10	364

* Includes 10 males and 11 females.

reported the site and analyzed the skeletons of 279 individuals.

Hiwassee Island (37,38,42,46,63,78,VT1MG31).

Hiwassee Island is located at the mouth of the Hiwassee River where it enters the Tennessee River in Meigs County and is about 20 miles upriver from the Dallas site. The island contains several mounds and has Woodland, Mississippian, and Historic components. J.W. Emmert visited the site in 1885 for the Bureau of American Ethnology (BAE) and reported 24 mounds, excavating five (Thomas 1891, 1894). Moore (1915:394-395) noted six mounds during his exploration, and M.R. Harrington 16 mounds in 1919 (Lewis and Kneberg 1946). Six mounds were standing on the site when Nash supervised excavations in 1937-1938. An extensive analysis of the archaeology and skeletal biology of the site based on Nash's investigation was published by Lewis and Kneberg (1946) who reported 188 Dallas burials recovered from two village sections and several mounds.

Toqua (40MR6). The Toqua site is on the south bank of the Little Tennessee River about five miles east of Vonore, Tennessee (Polhemus 1987). The site contains both Dallas and Cherokee components. Dallas occupation is dated by radiocarbon to A.D. 1300-1600. Emmert visited the site in 1884, reporting two mounds (Thomas 1894:379-

388). He excavated 71 burials: their whereabouts unknown. Barnes (n.d.) investigated part of the village component in the 1930's. Emmert's Big Toco and Calloway Mounds correspond to Mounds A and B, respectively, excavated by Polhemus and Schroedl in 1975-1978 (Polhemus 1987). The skeletal remains of over 500 individuals collected during the Barnes and Schroedl excavations are in the McClung collections, but only the latter are included in the present analysis.

CHAPTER 3

BIOCULTURAL VARIABLES AND METHODOLOGY

In this chapter the variables under study are discussed. First, the occurrence of porotic hyperostosis is discussed in detail, with emphasis on etiology and pathogenesis. Next, a discussion of artificial cranial deformation is presented. Finally, osteological and statistical methods are provided.

POROTIC HYPEROSTOSIS AND CRIBRA ORBITALIA

Porotic hyperostosis is a pathological condition of the skull manifest as pitting or spongy bone growth of the exterior vault (Figures 3, 4, and 5). The condition is described as a thickening of the vault from an expansion of diploic bone and a thinning of the cortical bone of the outer table (Ortner and Putschar 1981:258). Severity ranges from slight pitting or foramina to a gross outgrowth on trabecular bone (El Najjar et al. 1976).

Cribra orbitalia is a similar condition (Hengen 1971) in which bony changes occur in the orbital roof (Figure 6). The relationship between porotic hyperostosis and cribra orbitalia is unclear, but they are believed to result from similar pathogenic and etiological factors (Steinbock 1976:242-248; Stuart-Macadam 1987a, 1987b).



Figure 3. Adult male (7HA1:107) with slight, healed porotic hyperostosis on frontal.



Figure 4. Adolescent male (38MG31:137) with moderate, active porotic hyperostosis on posterior parietals.



Figure 5. Adolescent male (38MG31:40) with severe, healed porotic hyperostosis on posterior parietals.



Figure 6. Infant (38MG31:54) with severe, active cribra orbitalia.

This relationship is discussed following an outline of pathogenesis and etiology.

Both conditions have been described in the past using a variety of terms: symmetrical osteoporosis (Hrdlička 1914), cribra parietalia (Williams 1929), hyperostosis spongiosa, porotic hyperostosis (Angel 1967), cribra cranii (Henschen 1961), usura orbitae (Møller-Christensen and Sandison 1963), and cribra orbitalia.

Paleopathological convention separates porotic hyperostosis into three categories based on location. Porotic hyperostosis occurs on the frontal, parietal, and occipital bones of the ectocranial vault. Cribra orbitalia denotes changes in the orbital roof, and cribra cranii, changes on the endocranium. This standard terminology is employed for the present study.

Pathogenesis. Porotic hyperostosis and cribra orbitalia result from similar mechanical processes of skeletal response to marrow expansion. As marrow and diploic bone of the skull are hypertrophied, they exert pressure on the outer table, thinning the cortical bone (Steinbock 1976:219):

The hyperblastic cellular marrow between the tables of the skull widens the diploic space and thins the outer table.

The new bone formed is arranged parallel to the marrow blood vessels that are perpendicular to the inner table.

This radial arrangement of new bone growth produces the characteristic "hair-on-end" appearance of the vault in x-ray (Aksoy et al. 1966; Britton et al. 1960). Cribra orbitalia results from similar hyperplasia in the orbital roof where the diploe expand downward into the orbital cavity (Hengen 1971).

As the cortical bone is eroded, the ectocranium and orbital roof may take on a porotic or spongy appearance. These small pores in the outer table are foramina for blood vessels that have enlarged as a product of marrow hyperplasia (Hengen 1971:62; Williams 1929:857). In the most severe cases the outer table is completely eroded and is superseded by hypoerostotic growth of the diploe. Skeletal changes occur almost exclusively in the frontal, parietal, and occipital bones in the area between the temporal lines, as the temporalis muscle provides sufficient pressure on the cranium to prevent hyperostosis in that region.

While marrow hyperplasia can occur in individuals of all age groups (Britton et al. 1960), skeletal changes are more common in infants and young children than in adults. In adults, the red, hematopoietic marrow is restricted to the skull, vertebrae, ribs, pelvis, and clavicles (Ascenzi 1976) and at least 50 percent of the total marrow space is filled with yellow marrow, which functions as a fat reserve (Woodward and Holodny 1960). The fatty deposits

of yellow marrow are sensitive to the needs of erythroid and myeloid tissue (Ascenzi 1976) and can be stimulated to begin hemopoiesis under pathological stress such as anemia (Tavassoli et al. 1974). In adults, then, expansion of the red marrow is absorbed by the buffer of yellow marrow. Yellow marrow is first seen microscopically at seven years, but is not visible as fat globules until 12-14 years (Ascenzi 1976). Because infants and young children possess virtually no yellow marrow, the expansion of hemopoietic red marrow must occur at the expense of skeletal integrity (Ascenzi 1976; Oski and Naiman 1972). This has lead to the conclusion that porotic hyperostosis and cribra orbitalia are skeletal remnants of a childhood condition (Stuart-Macadam 1985).

For marrow hyperplasia to create skeletal lesions in adults, one of the following must occur. It is possible that an episode of diploic hypertrophy beginning in childhood is not overcome by the body's compensatory mechanisms, but rather persists into adulthood. Another possibility is that an episode of marrow expansion is so severe that the induction of hemopoiesis in yellow marrow is not sufficient compensation, and skeletal lesions may be produced. In any case, it is necessary to determine whether the observed porotic hyperostosis is active or healed at death, and only active lesions can be considered

positive evidence of active marrow proliferation in adulthood.

Etiology. The occurrence of porotic hyperostosis and cribra orbitalia has been attributed to many diseases. Past studies have found both conditions associated with rickets, endocrine and toxic disorders (Hrdlička 1914), tuberculosis (Williams 1929), syphilis (Henschen 1961), leprosy (Møller-Christensen and Sandison 1963), and anemia (Angel 1967). Williams (1929:860) offers a scenario where the cradle boarding of infants may produce porotic hyperostosis.

Pressure produced on the occiput of the Indian baby resting on a head board would tend to create a venous hyperemia in the parietal and frontal regions, the venous outlets of the posterior region being impeded.

Williams (1929:858), however, stresses that porotic hyperostosis probably reflects a general marrow disorder brought on by nutritional deficiency (Lewis and Kneberg 1946).

Studies in clinical medicine indicate that porotic hyperostosis is a consequence of anemic stress (Ascenzi 1976). Anemia is defined as subnormal levels of hemoglobin or red blood cells (Osiki and Naiman 1972), often due to the high turnover of abnormal erythrocytes (Steinbock 1976). The presence of abnormal red blood cells and/or low hemoglobin levels diminishes the body's

ability to transport oxygen through the circulatory system. To compensate, the body increases production of red blood cells, often involving the physical expansion of the hematopoietic marrow (Ascenzi 1976), and will increase iron absorption in the digestive tract (Layrisse et al. 1968). As discussed earlier, this marrow hypertrophy is believed to be responsible for the described skeletal changes. Supporting this contention, radiographic analyses demonstrate that changes in the calvarium and orbital roof characteristic of porotic hyperostosis and cribra orbitalia occur in individuals with clinically diagnosed anemia (Aksoy et al. 1966; Britton et al. 1960; Ortner and Putschar 1981:252).

Anemias fall into one of three classes: loss of blood, increased destruction of blood, or defective formation of blood (Castle 1943; Retznikoff 1943). Generally, either the rate of blood production falls or increased blood production fails to compensate for excessive loss or destruction.

Anemia resulting from loss of blood includes only acute hemorrhage; chronic blood loss is classified as defective formation of blood (Retznikoff 1943). Because of the protracted and variable nature of acute blood loss, this type of anemia is not expected to produce skeletal changes, and is not considered in this study.

Increased destruction of blood or hemolysis involves the increased turnover of blood cells. These conditions include the sickle-cell hemoglobinopathies, deficiencies in glucose-6-phosphate dehydrogenase (G-6-PD) and pyruvate kinase, and rare conditions of hereditary spherocytosis, cyanotic congenital heart disease, and polycythemia vera (Oski and Naiman 1972; Retznikoff 1943; Steinbock 1976).

Anemias due to defective formation of blood include the thalassemias and deficiency anemias (Oski and Naiman 1972; Retznikoff 1943). Of these, iron deficiency anemia is the most common in the world today (Davidson and Passmore 1969). Iron deficiency occurs when the "physiological requirements for iron exceed iron absorption capabilities" (Finch 1976:286) and is directly linked to subnormal production of hemoglobin and erythrocytes. The resulting blood is hypochromic and microcytic, meaning that hemoglobin levels are low and the red blood cells are reduced in size. Factors leading to iron deficiency include chronic hemorrhage, chlorosis and menstruation, defective absorption, decreased dietary intake, childhood nutritional deficiency, gastrointestinal distress, and removal of iron from the mother by the fetus (Retznikoff 1943).

Each of the anemias listed above can produce skeletal changes, but each presents a different pattern of skeletal involvement in the crania and postcrania offering the

possibility of accurate diagnosis (Angel 1964, 1967, 1978; Ascenzi 1976; Huss-Ashmore et al. 1982; Steinbock 1976). Further, because congenital hemoglobinopathies are virtually absent in the pre-Columbian New World (Livingstone 1967:94) and the lesions tend not to fit the patterns associated with classic hereditary anemias, porotic hyperostosis and cribra orbitalia in American Indians are attributed to iron deficiency anemia.

Iron deficiency in the New World may be attributable to any of several agents. Infestation by parasitic hookworms or ascarids can result in anemia through chronic hemorrhage in the intestinal tract (Angel 1967; Rathbun et al. 1980; Stewart 1969), but may be unlikely in eastern deciduous woodland populations because chenopodium, an intensively exploited plant group, is rich with anti-helminthic compounds (Hancock 1986). Blood and iron loss through menstruation, pregnancy, and lactation are a normal fact of life, but cannot account for the endemic proportions of porotic hyperostosis and cribra orbitalia in prehistoric populations. In general, anemia in the New World is seen as a nutritional problem, involving inadequate dietary intake and malabsorption.

In the Americas, the case for anemia resulting from dietary iron deficiency is not difficult to demonstrate. Williams (1929) first noted that the distribution of

porotic hyperostosis mimics that of intensive agriculture, and evidence of anemia in non-agricultural populations is extremely rare (Hancock 1986; Lallo et al. 1977), but porotic hyperostosis incidence is high in areas where maize is a dietary staple (El Najjar and Robertson 1976; El Najjar et al. 1975, 1976, 1982).

The diet of Mississippian peoples in general, and Dallas society in particular, is characterized by intensive cultivation of maize, beans, and squash. These staples are supplemented by the harvesting of wild plant foods, fresh water mollusks, fish, and some migratory water fowl, but other meat sources such as deer and bear are utilized to a much lesser degree (Lewis and Kneberg 1946; Smith 1978).

The dietary staple of corn (Zea mays) contains a moderate amount of iron but has high levels of phytic acid, a chemical compound that binds iron at the molecular level, inhibiting its absorption by the intestine (Finch 1976). As such, corn is one of the poorest sources of dietary iron, lagging far behind animal flesh and many other plant foods (see Anderson et al. 1986; Exler 1987; Haytowitz and Matthews 1984; Leveille et al. 1983; McCarthy and Matthews 1984; Posati 1979). These corn-based phytates may also reduce the amount of dietary iron available from meat resources (Layrisse et al. 1968). Corn and beans are both high in carbohydrates, low in

protein, and virtually lacking in ascorbic acid, a condition that furthers reduces absorption of iron. Further, the typical Southeastern cooking practice where foods are excessively boiled or roasted, reduces the content of folic acid and vitamin B12, which are necessary for proper red blood cell development (Davidson and Passmore 1969; Hancock 1986).

Regardless of corn consumption, the heavy reliance on plant foods and shellfish, rather than animal flesh, produces a diet that is high in carbohydrates, phosphorous, and calcium, but low in protein and iron. Plant foods contain non-heme iron which is less easily absorbed than the heme iron found in red meats (Parham 1982) and is most affected by phytic acid. The high calcium and phosphorous intake acts to inhibit iron absorption (Parham and Scott 1980; Wintrobe 1967). Diets low in protein and high in starch usually lack essential amino acids that ease in iron absorption (El Najjar and Robertson 1976; Katz et al. 1974; Von Endt and Ortner 1982). Low levels of ascorbic acid and high intake of tannin, as found in many nuts, can also diminish normal iron absorption capabilities (Steinbock 1976). Further complicating matters, Hancock (1986) has demonstrated that traditional cooking practices among Southeastern Indians, involving extended roasting or boiling, significantly reduces the nutritive quality of the diet.

Considerations. It was discussed earlier that infants and young children are more likely to exhibit skeletal changes subsequent to marrow expansion. It must also be stressed that subadults are highly susceptible to iron deficiency anemia. The healthy infant is born with an excess of iron, but these stores are usually depleted by three-to-four months of age, when iron requirements must be met entirely from extrasomatic sources (Ascenzi 1976; Finch 1976; Stuart-Macadam 1985). Up to 50% of infants, however, may be born anemic from fetal hemorrhage (Oski and Naiman 1972), with depleted iron stores and excessive iron requirements. It is also reported that infants born of iron deficient mothers may exhibit either normal or deficient iron stores at birth (Kaneshige 1981; Oski and Naiman 1972). Breast milk provides sufficient iron for the healthy infant until five or six months of age (Owen et al. 1981), even when the mother is malnourished (Jelliffe and Jelliffe 1978), but may be inadequate for those individuals born with anemia. In any case, iron deficiency anemia will occur by age 9-24 months without proper dietary supplementation.

Among Dallas individuals, then, we would expect high incidences of anemia and, by association, porotic hyperostosis and cribra orbitalia. The supplementary or weaning diet in this society is basically composed of watery corn gruel (Adair 1775; Boyd 1984), with small

amounts of premasticated foodstuffs. This iron-poor diet would appear to complicate the tendency toward anemia in the infant.

These physiological and dietary inadequacies in iron nutrition are further compounded by the infant's susceptibility to infection (Lallo et al. 1977). Mild infection or fever in the neonate have been demonstrated to reduce the body's ability to absorb dietary iron (Reeves et al. 1984; Retznikoff 1943), or may result in excessive iron loss through chronic gastrointestinal disease (diarrheal complaint), parasitic infection, or other intestinal blood loss (Steinbock 1976). These nutritional deficiencies, in turn, increase the individual's susceptibility to infection, creating a vicious cycle. It is thus noted that iron deficiency anemia is produced not solely by dietary iron deficiency, but by the synergistic interaction of numerous etiological factors (Steinbock 1976:238).

Because porotic hyperostosis and cribra orbitalia represent episodes of anemia occurring in infancy and childhood, skeletal lesions in adults generally represent childhood iron deficiency anemia. Similarly, sex differences in the distribution of skeletal lesions in adults are interpreted to reflect differential iron nutrition and anemia in subadult males and females.

Another group at high-risk to iron deficiency anemia are premenopausal females. During menstruation, pregnancy, childbirth, and lactation the female undergoes repeated acute anemic stress from the increased demand for iron by the fetus or excessive loss with bleeding (Retznikoff 1943). The cost of pregnancy in terms of iron is very high: it is reported, variously, that infants of iron deficient mothers may be born with normal iron stores (Oski and Naiman 1972) or with deficient stores (Kaneshige 1981). The production of nutrient-rich breast milk also occurs at the mother's expense (Jelliffe and Jelliffe 1978). Despite the discrepancies in the clinical literature, the preference for the maintenance of fetal iron levels and infant nutrition over those of the mother may be more important in the development of iron deficiency anemia in adult females than poor dietary iron intake (Palkovich 1987).

To determine positive evidence of anemia in adult females it is necessary to determine whether the lesions are active or healed. Active lesions are assumed to indicate anemia active at death, but healed lesions suggest that anemic stress was not active at death. It is expected, then, that active vault and orbital lesions will be more commonly active in adult females than in adult males.

It must be noted that the degree of skeletal involvement may not reflect the severity of anemic stress. Steinbock (1976) and Stuart-Macadam (1987a, 1987b) emphasize that orbital and vault lesions are quite variable: individuals with severe anemia may exhibit no skeletal changes while others with only slightly lowered hematocrits have exhibited extreme hyperostosis.

Porotic Hyperostosis and Cribra Orbitalia. The exact relationship between cribra orbitalia and calvarial porotic hyperostosis is unclear, although they appear to result from similar pathogenic and etiologic factors. In both cases, marrow hyperplasia as consequence of anemia is believed to produce the characteristic skeletal changes (Hengen 1971; Steinbock 1976). There is, however, no strong association between the two, and both occur independently (Ortner and Putschar 1981; Parham 1982; Steinbock 1976; Stuart-Macadam 1987a, 1987b). Hengen (1971) suggested that cribra orbitalia is a precursor to calvarial porotic hyperostosis, and clinical studies have demonstrated that vault lesions tend to occur first in the frontal bone and progress posteriorly (Lallo et al. 1977). Specifically, orbital lesions occur in infancy while vault changes take place during early childhood (Sebes and Diggs 1979; Stuart-Macadam 1985). As such, the presence of cribra orbitalia is interpreted to reflect anemic stress

occurring in the one to two year age group, while porotic hyperostosis identifies anemia occurring approximately two to six years of age.

It is possible that the anemia producing cribra orbitalia results from different etiological processes than those associated with porotic hyperostosis. Because orbital lesions commonly develop in infancy and approximately 50% of term infants are born with reduced iron stores due to fetal blood loss, neonatal anemia must strongly reflect health factors of the intrauterine environment. The probability of acquiring anemia should be equal for all sex and status groups, unless dietary supplementation is preferentially administered. Porotic hyperostosis, on the other hand, is associated with weaning in early childhood, and probably reflects dietary factors of iron deficiency more directly. Given this situation, fewer age and status differences are expected in the incidence of cribra while vault lesions should be more variable. Any sex or status differences in the expression of cribra orbitalia, however, must be interpreted as reflecting the adequacy of iron intake or dietary supplementation.

CRANIAL DEFORMATION

Artificial cranial deformation is a cultural practice that distorts the normal contours of the skull vault, particularly in the antero-posterior dimension, by flattening the occipital and/or frontal regions of the skull. The practice is common in both the Old and New Worlds (Brothwell 1981:48; Hodges 1907:96). The methods employed to deform the skull generally involve binding of the infant's head or use of hard boards or stone tablets as in cradleboarding (Hodges 1907).

Cranial deformation is classified as either intentional or unintentional following the guidelines of Brothwell (1981), Hodges (1907), and Neumann (1942). In cases where only the posterior vault is affected (e.g. lambdoid, obelionic, and occipital) the deformation is considered an unintentional result of cradle use in infancy. Intentional or cosmetic deformation, however, usually involves flattening of the frontal or parietal bones in addition to the occipital, and is believed to reflect some conscious effort to alter the normal cranial contours by cradling or binding of the skull .

Cradling produces a distinct pattern of cranial deformity. As pressure is applied to the occipital or occipital and frontal bones, the skull tends to bulge to the sides to compensate for brain and vault growth.

Cradleboarding affects dimensions of the vault, cranial base, and face (Anton 1989; Berryman and Owsley 1984), especially maximum length and breadth (Figures 7 and 8).

Neumann (1942) developed the most widely used system for classifying artificial deformation. He lists seven types defined by the direction of force applied to the skull and the regions of the vault that are flattened. All types can result from the use of a hard cradle during infancy (Adair 1775; Hodges 1907; Lewis and Kneberg 1946). A similar typology was developed by Dembo and Imbelloni in 1938 from a sample of South American crania (Loveland 1980).

Various accounts of American Indian deformation are in the ethnographic and archaeological literature. Adair (1775:7-8) provides the following descriptions:

The Choktah Indians flatten their fore-heads, from the top of the head to the eye-brows with a small bag of sand;

[They] fix the tender infant on a kind of cradle, where his feet are tilted, above a foot higher than a horizontal position, - his head bends back into a hole, made on purpose to receive it, where he bears the chief part of his weight on the crown of the head, upon a small bag of sand.

Hodges (1907:358) describes the Apache custom.

The cradle distorts the head by flattening the occiput as a natural consequence of contact between the resistant pillow and the immature bone.



Figure 7. Comparison of deformed (adult female, 8HA1:42) and undeformed (adult male, 7HA1:107) crania, top view.

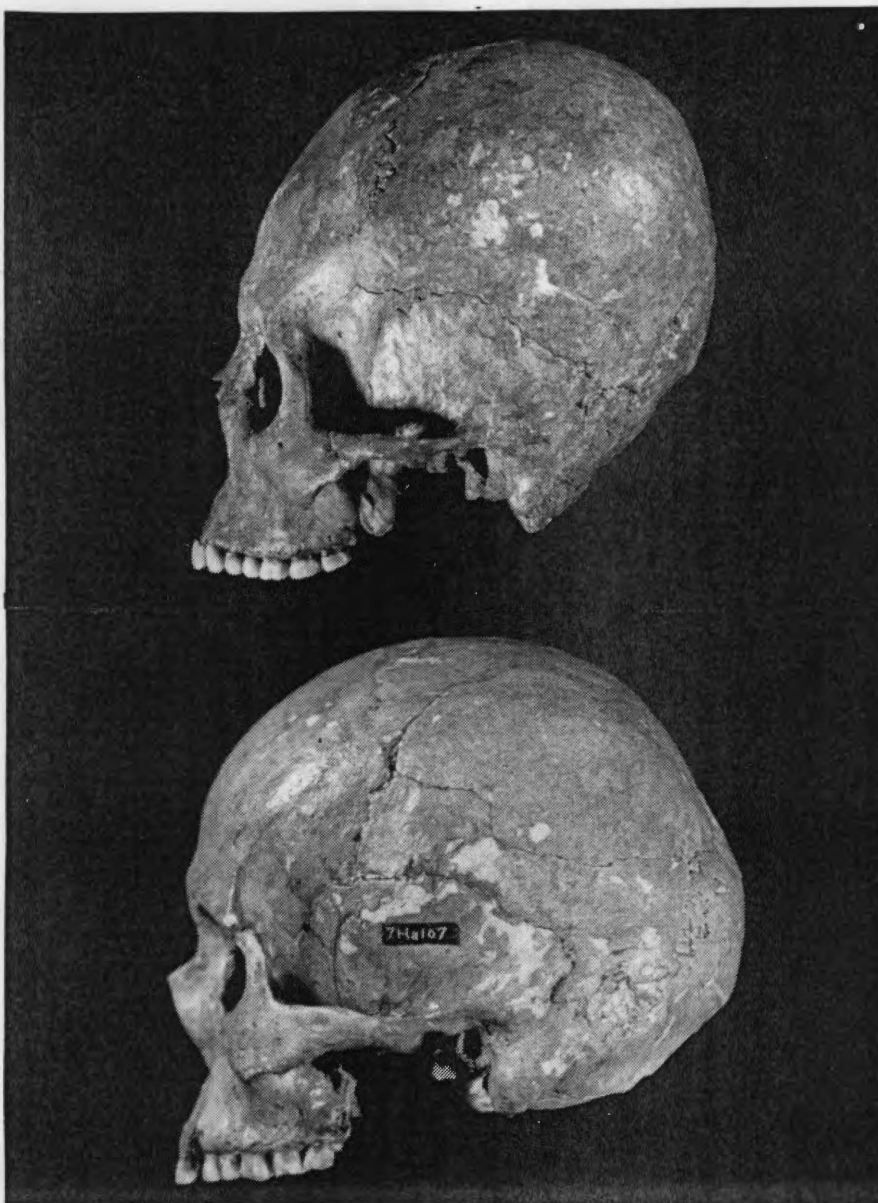


Figure 8. Comparison of deformed (adult male, 8HA1:42) and undeformed (adult male, 7HA1:107) crania, side view.

Swanton (1946) supplies several additional accounts obtained from first-hand observations and early ethnographies, and numerous drawings of cradle use are provided by Catlin (1984).

Unlike the modern-day version, the Indian cradle is primarily used to transport the infant, rather than as a sleeping place. As such, infants are often strapped to the cradle when the mother is laboring in the fields, but the baby is allowed to roam freely when at home (Catlin 1984; Hodges 1907).

Deformed skulls have been reported in numerous archaeological populations from South America (Hrdlička 1914), the Great Basin (Cassels 1972), Northwest Coast (Hodges 1907; Hrdlička 1905), and the Southeast (Berryman and Owsley 1984; Lewis and Kneberg 1946; Loveland 1980; Neumann 1942; Parham 1982).

Previous studies of Mississippian populations reveal high frequencies of cranial deformation. Parham (1982:89) reports cradleboarding in 81.5% of the Toqua sample, and Owsley et al. (1984) 93.55% of Averbuch. Parham found no difference in frequency between the sexes, but low-status individuals were more commonly deformed.

Whether cranial deformation in Mississippian peoples is the unintentional result of cradle use or, rather, was intentionally practiced for cosmetic reasons is unclear. Lewis and Kneberg (1946:165) concluded that deformation in

the Dallas component at Hiwassee Island is largely unintentional. In his analysis of Toqua, however, Parham (1983:91) reports that Dallas is typified by intentional deformation, with the highest frequencies in the low status group.

METHODS

Age and Sex. Assessments of age and sex are based on field notes and osteological records filed at McClung Museum. In cases of questionable or unclear records, age and sex are determined using standard criteria.

Individuals are sorted into one of four age categories: infants (0-2 years), children (2-12 years), adolescents (12-18 years), and adults (greater than 18 years).

The age of infants, children, and adolescents is based on teeth, long and cranial bones, and epiphyses. Dental development is assessed using the standards of Moorrees et al. (1963a, 1963b), and dental eruption follows Ubelaker's (1988) chart for Non-Whites. Age based on diaphyseal length employs the standards of Merchant and Ubelaker (1977). Epiphyseal fusion is evaluated following the summaries by Bass (1971), Krogman and Iscan (1986), and Ubelaker (1988). Development of the temporal (Weaver 1979) and occipital (Redfield 1970) bones is examined also.

Adult age is primarily determined by full epiphyseal closure (Bass 1971; Krogman and Iscan 1986; Ubelaker 1988), suture closure (Mann et al. 1987; Meindl and Lovejoy 1985; Redfield 1970), and the presence of degenerative changes (Ortner and Putschar 1981; Stewart 1958; Ubelaker 1988). Further refinement of age classification other than as Adult is not attempted.

Sex is determined for adults and older adolescents using the pelvis and skull. Sex determination of infants, children, and younger adolescents is problematic and inaccurate, and is not attempted. Pelvic morphology is assessed using the standards of Anderson (1962), Phenice (1969), and Bass (1971). The presence of so-called scars of parturition of the dorsal pubes (Angel 1969) and ilium (Iscan and Derrick 1984) are also employed. Morphological assessment of the cranium follows Bass (1971) and Krogman and Iscan (1986).

Status. The status of each individual is determined by burial location. In Dallas society, individuals are buried in pits in the village house floors or the mounds (Lewis and Kneberg 1946). Following the work of Hatch (1974, 1976), Blakely (1980), Peebles and Kus (1977), Bogan (1980), and Scott (1983), individuals recovered from mounds and the immediate mound periphery are designated high status (superordinate). These individuals include

burials found in Dallas substructure mounds and pits intrusive into the Hamilton burial mounds. Burials located in the village component of the site are considered low status, or belonging to the subordinate dimension. In this methodology, individuals found in Structure 3 at Toqua and a similar structure at Dallas (Polhemus 1987) are classified as low status in accordance with Parham's (1982) results.

Porotic Hyperostosis and Cribra Orbitalia. Changes in the outer cortex of the orbital roof and skull due to cribra orbitalia and porotic hyperostosis are evaluated by severity. The scale used is a synthesis of standards developed by Berryman (1984), Nathan and Haas (1966), and Stuart-Macadam (1985). The extent of porosity and diploe expansion are evaluated using the following rating system.

None:	Absent; cortex smooth
Slight:	Porotic Stage; scattered, fine foramina
Moderate:	Cribrotic Stage; larger pits and/or clusters of pits, may form a trabecular structure.
Extreme:	Trabecular Stage; hyperostotic outgrowth with sponge-like appearance. Outer cortex may not be discernible in affected areas.

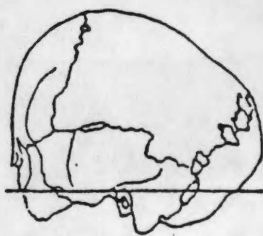
Porotic hyperostosis and cribra orbitalia are also examined for state of activity. The condition is considered active when lesions are sharp-rimmed and

healing or healed where resorption or remodeling of the bone is present.

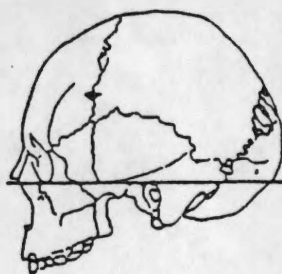
Skulls with pathological conditions other than cranial porosity are excluded from observation, as are specimens where observations are hindered by preservative used to coat the skull, or the vault is excessively fragmented or incomplete.

Cranial Deformation. Cranial deformation is classified by type and scored on an ordinal scale. The type of deformation is identified using Neumann's (1942) classification scheme. Neumann's typology defines seven types of artificial deformation based on flattening of the occipital, frontal, and parietal bones in varying combinations and directions (Figure 9). Following conventional practice, deformation is considered unintentional when only the posterior vault is flattened. In individuals where the frontal region is also flattened, deformation is scored as intentional (see Brothwell 1981; Hodges 1907; Neumann 1947; Parham 1983).

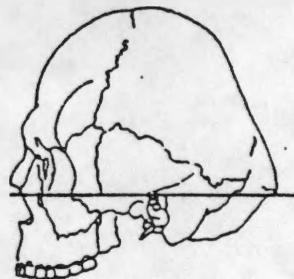
The degree of deformation is scored using standards developed by Berryman and Owsley (1984) and Owsley et al (1984) for the Averbuch skeletal series. Skulls are determined to exhibit slight, moderate, or extreme deformation (Figure 10). In cases where part of the vault is missing, deformation is scored as present but degree-



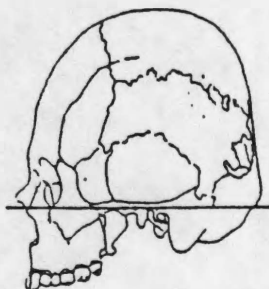
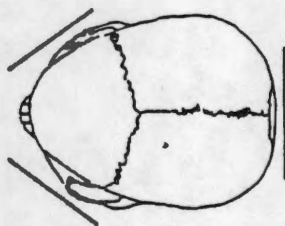
Obelionic



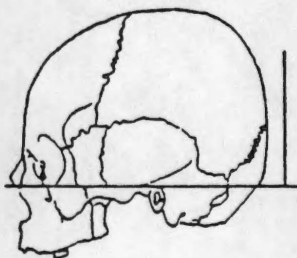
Natural Lambdoid



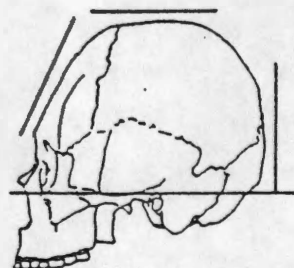
Artificial Lambdoid



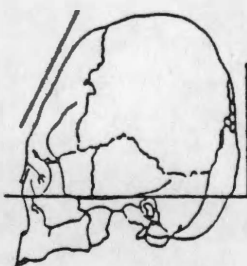
Occipital



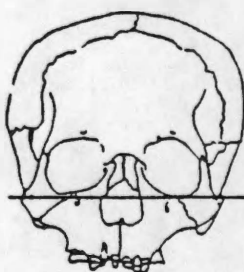
Bifronto-Occipital



Fronto-Parieto-Occipital



Fronto-Vertico-Occipital



Parallelo-Fronto-Occipital

Figure 9. Types of artificial cranial deformation found in the Southeast.

Source: Neumann 1942:307.

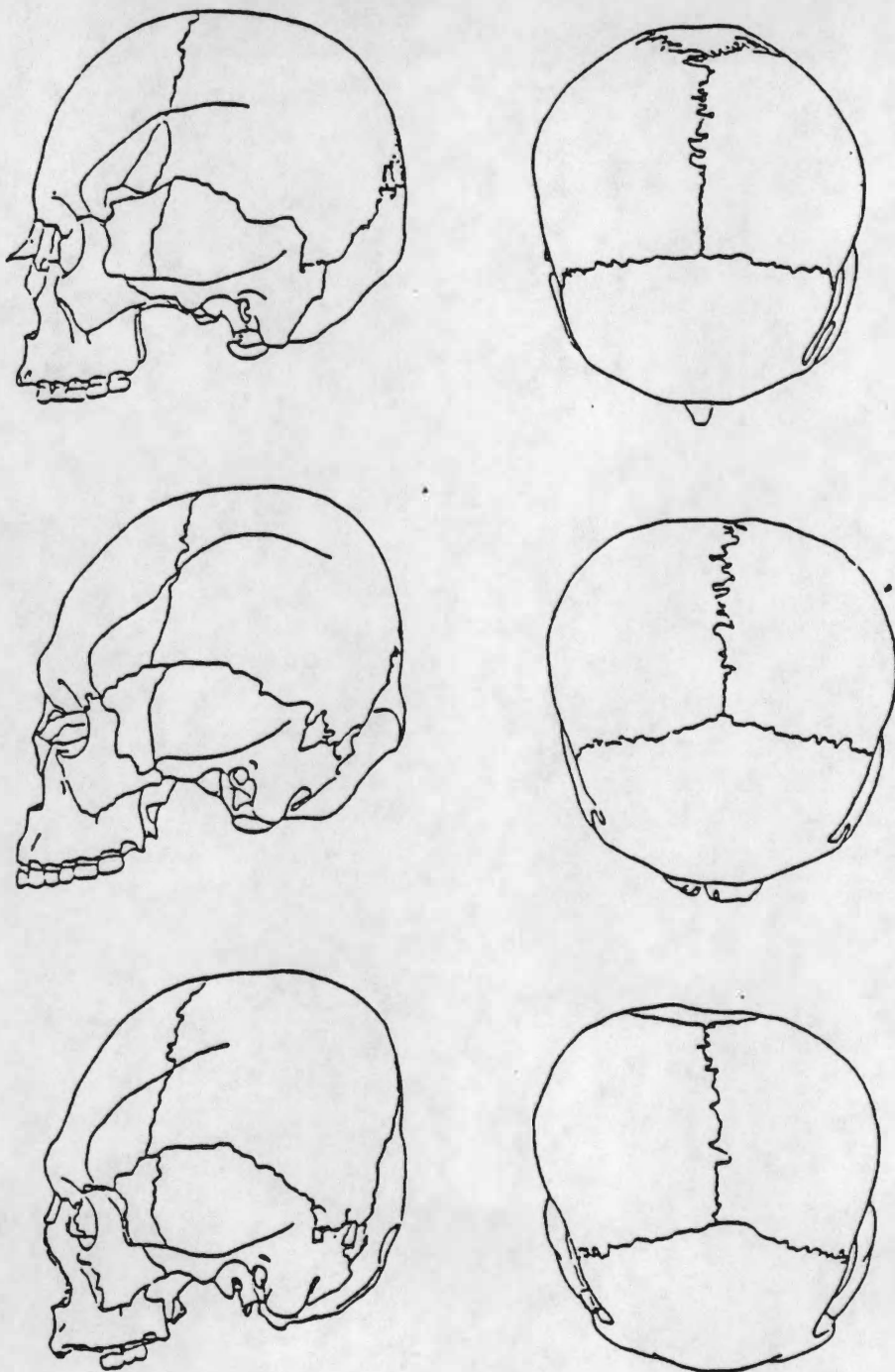


Figure 10. Examples of slight (top), moderate (middle), and extreme (bottom) cranial deformation.

Source: Berryman and Owsley 1984:8.4.

indeterminate. Skulls with deformation or warping attributable to post-mortem processes are excluded from observation.

Statistics. One-tail binomial z-tests are employed to test for differences in incidence by sex and status. Age differences are assessed using a chi-square (χ^2) test of association. The Yates' correction for small sample size (χ^2_c) is employed following the recommendations of Thomas (1986:298). The phi (ϕ) or tau-b (τ_b) coefficient is used to aid in the interpretation of chi-square in cases of large overall sample size, where the probability of false rejection by chi-square is increased (Fleiss 1981; Thomas 1986).

Associations that involve ordinal level data (degree of involvement) are organized into cross-classification tables. The strength of association is then measured using various correlation coefficients.

Correlations involving one nominal and one ordinal variable are evaluated using the phi, tau-b, and lambda (λ) measures of strength of association. The phi coefficient is restricted to 2x2 tables while tau-b applies to any size table. Both are correlation coefficients that are based on chi-square, but are not confounded by large sample size (Fleiss 1981; Thomas 1986). Lambda measures the proportional reduction in

error (PRE) gained when one variable is used to predict another (Ott et al. 1987).

Correlation between two ordinal level variables is measured using gamma (γ). Gamma is a PRE measure that measures the strength and direction of association between two variables, where a score of one or negative-one indicates perfect association and zero, no association.

Statistics are computed using the PROC FREQ command and TABLES subroutine in SAS (SAS Institute 1986). This procedure produces chi-square, phi, lambda, and gamma measures for data arranged in tabular form. A test of significance is also calculated for each statistical measure and $\alpha=0.10$ is chosen as the critical level of significance.

CHAPTER 4

RESULTS AND DISCUSSION

In this chapter, the distribution of porotic hyperostosis and cranial deformation in the Dallas Phase sample is discussed by age, sex, and status. The variables are examined by incidence (i.e., frequency of occurrence) and degree of involvement (severity). In addition, discussions include evaluations of activity of skeletal lesions of porotic hyperostosis and cribra orbitalia and type of cranial deformation. Variability among sites is mentioned.

Statistical analysis indicates that the severity of porotic hyperostosis shows no significant association or correlation with the degree of cranial deformation (Figure 11). It appears that skeletal evidence of anemia is unrelated to cradleboarding of infants, either directly or indirectly.

POROTIC HYPEROSTOSIS AND CRIBRA ORBITALIA

Calvarial porotic hyperostosis is present in 64.47% of the total sample and the sites range from 55.57% to 74.77% (Table 2). Cribra orbitalia is less frequent (40.74%) and exhibits a great deal of intersite variability (Table 3). The high incidence of both vault

SAS

TABLE OF POROSIS BY CRADLE

POROSIS	CRADLE				
FREQUENCY					
EXPECTED					
PERCENT					
ROW PCT					
COL PCT	1	2	3		TOTAL
1	37	21	6		64
	34.8	22.1	7.1		
	45.68	25.93	7.41		79.01
	57.81	32.81	9.38		
	84.09	75.00	66.67		
2	7	6	2		15
	8.1	5.2	1.7		
	8.64	7.41	2.47		18.52
	46.67	40.00	13.33		
	15.91	21.43	22.22		
3	0	1	1		2
	1.1	0.7	0.2		
	0.00	1.23	1.23		2.47
	0.00	50.00	50.00		
	0.00	3.57	11.11		
TOTAL	44	28	9		81
	54.32	34.57	11.11		100.00

$$\chi^2 = 1.096; \text{ d.f.}=4; \text{ p}>.9000$$

$$\gamma = 0.321; \text{ p}=0.209$$

Figure 11. Degree of cranial deformation compared with severity of porotic hyperostosis.

Table 2. Incidence of Porotic Hyperostosis by Site, Age, Sex, and Status.

Category	Cox		Dallas		Hiwassee Is.		Toqua	
	N*	%	N	%	N	%	N	%
Overall	72	55.55	107	74.77	76	65.76	94	58.51
Age								
Inf	1	0.00	5	20.00	3	0.00	3	33.33
Child	13	46.15	21	80.95	17	29.41	17	23.53
Adol	8	37.50	10	60.00	8	75.00	8	62.50
Adult	50	62.00	71	78.87	48	81.25	66	68.19
Sex								
Males	28	75.00	32	87.50	19	84.21	39	79.62
Females	22	40.91	43	69.77	32	81.75	32	56.25
Status								
Low	50	64.00	23	77.38	66	69.70	81	58.02
High	22	36.36	84	65.22	10	40.00	13	61.53

*N - Sample size.

% - Percent affected.

Table 3. Incidence of Cribra Orbitalia by Site, Age, Sex, and Status.

Category	<u>Cox</u>		<u>Dallas</u>		<u>Hiwassee Is.</u>		<u>Toqua</u>	
	N*	%	N	%	N	%	N	%
Overall	61	9.84	88	29.55	64	60.94	84	59.52
Age								
Inf	2	50.00	4	25.00	2	50.00	3	66.67
Child	7	28.58	10	60.00	15	66.67	13	84.62
Adol	5	20.00	8	62.50	6	83.34	8	75.00
Adult	47	4.26	66	21.21	41	56.10	60	51.67
Sex								
Males	28	10.71	29	24.14	16	50.00	37	48.65
Females	19	0.00	40	25.00	28	67.86	28	60.71
Status								
Low	42	11.90	70	27.14	57	61.40	72	62.50
High	19	5.26	18	38.89	7	57.14	12	41.67

*N - Sample size.

% - Percent affected.

and orbital hyperostosis suggests that iron deficiency anemia was endemic in Dallas society (Palkovich 1987; Parham 1982). These incidences are considerably greater than those reported for the Averbuch site, the Mouse Creek Phase, or a sample of Overhill Cherokee (Table 4), suggesting a greater emphasis on plant foods by Dallas people.

Considerable intersite variability is noted. The low overall incidence cribra orbitalia at Cox may suggest that meat resources were more extensively utilized at certain sites, especially those settlements located off the main river channels (Boyd 1984). This interpretation is problematic, however, given the low incidence of orbital lesions at the large, main channel Dallas site, and the similar incidences of porotic hyperostosis at all four sites.

As previously discussed, cribra orbitalia generally forms in infancy while vault lesions do not arise until two-to-five years of age. Given the higher frequency of calvarial hyperostosis in the Dallas Phase, anemia is probably more common in young children than in infants.

Orbital and vault lesions are active at death in approximately 25%-30% of observed individuals (Table 5), suggesting that iron deficiency anemia had a considerable impact on the mortality and morbidity of the Dallas population. Active lesions are much less common in adults

Table 4. Incidence of Porotic Hyperostosis and Cribra Orbitalia Compared with Other Archaeological Samples.

Site	<u>Porotic Hyperostosis</u>		<u>Cribra Orbitalia</u>	
	Sample	Percent	Sample	Percent
Dallas Phase	349	64.47	297	40.74
Toqua ^a	192	64.58	168	50.00
Averbuch ^b	402	41.79	295	24.75
Cherokee ^c	41	7.30	56	28.60
Moundville ^d	162	0.00	162	9.26

^aParham (1982).

^bBerryman (n.d.).

^cOwsley (1984).

^dPowell (1988).

Table 5. Activity of Calvarial and Orbital Lesions by Age, Sex, and Status.

Category	Sample Size	Active Lesions		Statistics
		Number	Percent	
POROTIC HYPEROSTOSIS				
Overall	219	57	26.00	-
Age				
Infants	2	2	100.00	$\chi^2 = 17.332^*$ $P = 0.106$
Children	30	14	46.67	
Adolescents	20	10	50.00	
Adults	167	31	18.56	
Sex				
Males	92	22	23.91	z= 0.41
Females	82	15	18.29	
CRIBRA ORBITALIA				
Overall	114	35	30.70	-
Age				
Infants	5	4	80.00	$\chi^2 = 42.799^*$ $P = 0.424$
Children	27	21	77.78	
Adolescents	17	4	23.53	
Adults	65	6	9.23	
Sex				
Males	36	3	8.33	z= 0.56
Females	41	5	12.20	

* Significant at $p < 0.0002$.

than subadults, supporting the hypothesis that porotic hyperostosis and cribra orbitalia represent childhood anemia, and that said anemia is often a transitory condition which can be overcome by the body's compensatory mechanisms.

In most cases, the degree of skeletal involvement of either porotic hyperostosis or cribra orbitalia is slight (80.00% and 71.07%, respectively) or moderate (18.67%, 20.66%), with severe (1.33%, 8.26%) lesions occurring infrequently. The severity of lesions in the Dallas sample is virtually identical to that reported for Averbuch (Table 6). In both samples, orbital lesions tend to be more severe than vault lesions. While the degree of skeletal involvement of porotic hyperostosis and cribra orbitalia may not directly reflect the severity of anemic stress (Steinbock 1976; Stuart-Macadam 1987a, 1987b), these results do suggest that anemia occurring in infancy tends to be more severe as measured by the degree of diploic expansion.

Age Distribution. As expected, lesions of cribra orbitalia and porotic hyperostosis are active in the majority of subadults, but less frequently active in adults (Table 5). These results support the notion that orbital and vault lesions reflect skeletal changes associated with anemia occurring in infancy or childhood

Table 6. Degree of Porotic Hyperostosis and Cribra Orbitalia Compared with Averbuch.

Degree	Averbuch ^a		Dallas Phase	
	Sample	Percent	Sample	Percent
Porotic Hyperostosis				
Slight	137	81.55	180	80.00
Moderate	28	16.67	42	18.67
Severe	3	1.79	3	1.33
Total	168	-	225	-
Cribra Orbitalia				
Slight	49	67.12	86	71.07
Moderate	16	21.92	25	20.66
Severe	8	10.96	10	8.26
Total	93	-	121	-

^aBerryman (n.d.).

(Stuart-Macadam 1985). Further, mortality associated with anemia is more prevalent in subadults, given the higher frequency of active lesions in the younger age groups.

Cribra orbitalia occurs most frequently in infants and young children (Tables 3 and 7), and incidence decreases with age. Porotic hyperostosis, on the other hand, occurs most frequently in adults, with greatly reduced incidences in subadults (Tables 2 and 8). In both cases the association is significant. It appears that anemia in infancy may contribute more to the mortality and morbidity of Dallas society than does anemia occurring in early childhood.

For both porotic hyperostosis and cribra orbitalia, the degree of skeletal involvement expresses a moderate (but nonsignificant) negative correlation with age (Table 9). Lesions tend to be more severe in the younger age groups, possibly reflecting the infant's increased susceptibility to skeletal changes subsequent to anemia and marrow expansion.

Sex Differences. Porotic hyperostosis is more common in males than in females (Table 8) and this relationship is constant for all sites (Table 2). Cribra orbitalia, on the other hand, exhibits no statistically significant sex difference, although it appears to be more common in females (Table 7), and exhibits greater intersite

Table 7. Incidence of Cribra Orbitalia in the Dallas Phase Sample.

Category	Sample Size	Cribra Orbitalia		Statistics
		Number	Percent	
Total Sample	297	121	40.74	-
Age				
Infants	11	5	45.45	$\chi^2 = 21.813^{**}$ $\tau_b = 0.073$
Children	45	29	64.44	
Adolescents	27	17	62.96	
Adults	214	70	32.71	
Sex				
Male	110	36	32.73	z = 1.13
Female	115	46	40.00	
Status				
Low (Village)	241	104	43.15	z = 1.75*
High (Mound)	56	17	30.36	
Low				
Males	81	30	37.04	z = 0.35
Females	101	40	39.60	
High				
Males	29	6	20.69	z = 1.54
Females	14	6	42.86	
Males				
Low	81	30	37.04	z = 1.61
High	29	6	20.69	
Females				
Low	101	40	39.60	z = 0.23
High	14	6	42.86	

* Significant at $p < 0.10$.

** Significant at $p < 0.05$.

*** Significant at $p < 0.0002$.

Table 8. Incidence of Porotic Hyperostosis in the Dallas Phase Sample.

Category	Sample Size	<u>Porotic Hyperostosis</u>		Statistics
		Number	Percent	
Total Sample	349	225	64.47	-
Age				
Infants	12	2	16.67	$\chi^2 = 28.505****$ $T_b = 0.082$
Children	68	32	47.06	
Adolescents	34	20	58.82	
Adults	235	171	72.77	
Sex				
Male	118	95	80.51	z = 2.83***
Female	129	83	64.34	
Status				
Low (Village)	281	190	67.62	z = 2.50**
High (Mound)	68	35	51.47	
Low				
Males	86	70	81.40	z = 1.60*
Females	109	78	71.56	
High				
Males	32	25	78.13	z = 3.77****
Females	20	5	25.00	
Males				
Low	86	70	81.40	z = 0.40****
High	32	25	78.13	
Females				
Low	109	78	71.56	z = 4.00
High	20	5	25.00	

* Significant at $p < 0.10$.

** Significant at $p < 0.01$.

*** Significant at $p < 0.0025$.

**** Significant at $p < 0.0002$.

Table 9. Degree of Porotic Hyperostosis, Cribra Orbitalia, and Cranial Deformation by Sex, Status, and Age.

Variable	Porotic Hyperostosis	Cribra Orbitalia	Cranial Deformation
Sex	$\phi = -0.056^*$ $\lambda = 0.000$	$\tau_b = 0.031$ $\lambda = 0.000$	$\tau_b = 0.019$ $\lambda = 0.000$
Status	$\gamma = -0.060$	$\gamma = 0.136$	$\gamma = -0.324$
Age	$\gamma = -0.243$	$\gamma = -0.395$	-

* None of the above correlations are statistically significant at $\alpha = 0.10$.

variability (Table 3). Taken in whole, these results suggest that males undergo anemic stress in early childhood, but infancy provides equal risks for both sexes.

No sex differences in the distribution of porotic hyperostosis or cribra orbitalia among adults are present in the activity of lesions (Table 5) or the degree of skeletal involvement (Table 9). Given the increased demands for iron in the premenopausal female, we would expect a greater frequency of active lesions in adult females from the Dallas sample. The lack of any such difference reinforces the hypothesis that anemia in adults is not always manifest as porotic hyperostosis or cribra orbitalia due to the buffering effects of yellow marrow. It is also possible that women can compensate for this increased stress by enhancing iron absorption, thus negating the deleterious effects of anemia.

Status Differences. In direct confirmation of the dietary hypothesis, the incidences of both porotic hyperostosis and cribra orbitalia are greater in individuals of low status (Tables 2 and 3). In both cases the differences are statistically significant (Tables 7 and 8). Surprisingly, no status differences are observed in the frequency of active lesions, and neither does the degree of skeletal involvement for either condition

correlate with burial in the mound or village (Table 9) though both were expected to be greater in the low status group. In terms of iron nutrition, the diet of high status individuals appears to have been better suited to limit the deleterious effects of anemia on the skeletal system, suggesting preferential access to meat foodstuffs among the superordinate class. Similar conclusions are reported by Hatch and Geidel (1983) and Hatch et al. (1983), who examined trace elements and Harris lines, respectively.

Sex and Status. Individuals are sorted into one of four categories based on sex and status: mound males, mound females, village males, and village females. Vault lesions are more common in males, regardless of status, but status differences are significant only for females (Table 8). It is observed that the incidence of porotic hyperostosis is lowest in mound females, suggesting that early childhood anemia is least common in high status females.

A vastly different picture arises, however, in the distribution of cribra orbitalia. Orbital lesions occur in high frequencies for all sex-status groups except mound males (Table 7). No status differences are observed in the females and low status individuals express no sex differences: the low incidence of cribra orbitalia in

high-status males accounts for all the observed status differences. These results suggest that high status males experience greatly reduced anemic stress during infancy compared to other individuals.

Interpretation of these results is problematic. During infancy, it appears that infant males of high status are receiving preferential treatment in terms of iron nutriture, probably resulting from greater access to mother's milk either by prolonged or more closely spaced feedings, or more nutritious dietary supplements. Given the high mortality rate associated with infant anemia and cribra orbitalia, this may reflect a conscious or unconscious effort to increase the fitness of males in the superordinate class. Increased investment in the health of infant males, particularly those of high status, further suggests that status was primarily ascribed.

During childhood and weaning, however, females, especially those of high status, appear to be under considerably less anemic stress than their agemates. This may reflect increased dietary consumption of meats and other iron-rich foods. If sex role differentiation begins at an early age, female children may gain preferential access to food resources by virtue of their association with adult females and proximity to cooking pots, whereas male children are being deprived because they are now associating with the adult males. Another

possibility is that females are weaned in infancy while males are weaned in early childhood, and experience anemic stress at an earlier age than males. Both interpretations suggest preferential nourishment of males during infancy and a relaxation of this preference during childhood.

It is also possible that female children are better adapted to handle the stress of anemia associated with weaning and dietary iron deficiency. Hatch and Willey (1974) and Parham (1982) reached similar conclusions while investigating stature and porotic hyperostosis, respectively, and other investigators have noted that stress appears to affect females less than males (see Greulich 1951; Greulich 1953; Stini 1972).

CRANIAL DEFORMATION

Artificial cranial deformation occurs in 90.48% of the Dallas sample. Incidence varies from a low of 84.48% at Cox to 96.34% at Toqua (Table 10). This incidence is similar to that reported for other sites from Tennessee (Table 11).

In most instances the deformation is slight (49.16%) or moderate (35.29%), rather than extreme (15.15%). This stands in contrast to the results from Kaufmann-Williams, a prehistoric Caddoan site from East Texas (Loveland 1980)

Table 10. Incidence of Cranial Deformation by Site, Sex, and Status.

Category	<u>Cox</u>		<u>Dallas</u>		<u>Hiwassee Is.</u>		<u>Toqua</u>	
	N*	%	N	%	N	%	N	%
Overall	58	84.48	88	86.36	66	93.94	82	96.34
Sex								
Males	30	86.67	30	76.67	18	94.44	36	97.22
Females	21	85.71	40	92.50	31	93.55	29	93.10
Status								
Low	34	82.35	69	89.86	57	94.74	72	97.22
High	24	87.50	19	73.68	9	88.89	10	90.00

*N = Sample size.

% = Percent affected.

Table 11. Incidence of Cranial Deformation Compared with Other Archaeological Samples.

Site	Sample Size	Number Deformed	Percent
Dallas Phase	294	266	90.48
Toqua ^a	151	123	81.46
Averbuch ^b	80	76	95.00
Kaufmann-Williams ^c	58	56	96.40

^aParham (1982).

^bBerryman (n.d.).

^cLoveland (1980).

and Averbuch (Table 12), where extreme deformation is most frequent.

The type of deformation is determined for 221 individuals (Table 13). Occipital flattening is most common, followed by fronto-verticooccipital, lambdoid, obelionic, and fronto-parieto-occipital. Intentional types of deformation (32.58%) occur less frequently than unintentional types (67.42%). Table 14 demonstrates that the rate of intentional deformation in Dallas society is close to that of Averbuch, but far removed from Kaufmann-Williams.

These results contradict those of Lewis and Kneberg (1946) and Parham (1982). The moderate incidence of intentional deformation does not agree with Lewis and Kneberg's (1946:163) statement that intentional deformation was "rarely if ever practiced" by Dallas people. Conversely, while intentional deformation is "ubiquitous among all Dallas sites" (Parham 1982:90), it is considerably less common than unintentional deformation. The present studies supports an intermediate position: both intentional and unintentional cranial deformation occur in Dallas society, with intentional types occurring less often.

A chi-square is calculated to test for an association between the degree and type of deformation. Results are significant ($\chi^2=23.58$, d.f.=8, $p<0.005$). This

Table 12. Degree of Cranial Deformation Compared with Other Archaeological Samples.

Degree	Kaufmann- ^a Williams		Averbuch ^b		Dallas Phase	
	Sample	Percent	Sample	Percent	Sample	Percent
Slight	9	16.07	14	18.42	117	49.16
Moderate	21	37.50	26	34.21	84	35.29
Extreme	26	46.43	36	47.37	37	15.55
Total	56	-	80	-	238	-

^aLoveland (1980).

^bBerryman (n.d.).

Table 13. Type of Cranial Deformation by Site.

Type	Cox		Dallas		Hiwassee Is.		Togua	
	f*	%	f	%	f	%	f	%
Obelionic	2	6.25	8	12.70	2	3.64	0	0.00
Lambdoid	5	15.63	20	31.75	8	14.55	11	15.49
Occipital	17	53.13	15	23.81	24	43.64	37	52.11
F-P-O	0	0.00	0	0.00	1	1.82	0	0.00
F-V-O	8	25.00	20	31.75	20	36.36	23	32.39
Total	32	-	63	-	55	-	71	-

*f = Frequency.

% = Percent of total.

Table 14. Comparison of Type of Deformation with Other Archaeological Samples.

Type	<u>Dallas Phase</u>		<u>Toqua^a</u>		<u>Averbuch^b</u>		<u>Kaufmann-^c Williams</u>	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Obelionic	12	5.43	0	0.00	0	0.00	0	0.00
Lambdoid	44	19.91	15	12.20	4	8.16	0	0.00
Occipital	93	42.08	27	21.95	29	59.18	0	0.00
F-P-O	1	0.45	0	0.00	0	0.00	0	0.00
F-VO	71	32.13	81	65.85	16	32.65	2	3.57
P-F-O	0	0.00	0	0.00	0	0.00	54	96.43
Total	221	—	123	—	49	—	56	—

^aParham (1982).

^bBerryman (n.d.).

^cLoveland (1980).

relationship is expected: in groups where deformation is intentional it will also be more severe, reflecting the conscious desire to alter the normal shape of the head.

Sex Differences. Cranial deformation is present in 88.60% of males and 91.74% of females (Table 15), but this difference is not significant ($z=0.81$, $F(z)=0.7909$, $p>0.20$). Neither does the degree of deformation exhibit any correlation with sex (Table 9).

In females, the most common type of deformation is occipital, while males exhibit fronto-verticooccipital most frequently (Table 16). The difference in the incidence of intentional deformation between males (41.86%) and females (30.00%) is statistically significant ($z=1.69$, $F(z)=0.9545$, $p<0.05$). Sex differences are not observed in mound-buried individuals, but the incidence of intentional deformation in the low status group is significantly greater in males (Table 17). These results disagree with those of Parham (1982), who found intentional deformation equally common between the sexes.

Between the sexes, then, only the type of deformation is significantly different. It appears that males of low status are receiving special treatment as infants to cosmetically alter the shape of the cranium, while deformation in other individuals tends to be the unintentional result of cradleboard use.

Table 15. Incidence of Cranial Deformation in the Dallas Phase Sample.

Category	Sample Size	<u>Cranial Deformation</u>		Statistics
		Number	Percent	
Total Sample	294	266	90.48	-
Sex				
Male	114	101	88.60	z= 0.81
Female	121	111	91.74	
Status				
Low (Village)	232	214	92.24	z= 1.99*
High (Mound)	62	52	83.87	
Low				
Males	83	77	92.77	z= 0.08
Females	101	94	93.07	
High				
Males	31	24	77.42	z= 0.67
Females	20	17	85.00	
Males				
Low	83	77	92.77	z= 2.29*
High	31	24	77.42	
Females				
Low	101	94	93.07	z= 1.20
High	20	17	85.00	

* Significant at $p < 0.025$.

Table 16. Type of Cranial Deformation by Sex.

Type	Males		Females	
	Freq.	Percent	Freq.	Percent
Obelionic	3	3.49	6	6.00
Lambdoid	12	13.95	26	26.00
Occipital	35	40.70	38	38.00
F-P-O	0	0.00	1	1.00
F-VO	36	41.86	29	29.00
Total	86	-	100	-

Table 17. Comparison of Intentional Cranial Deformation by Sex and Status.

Status	Males		Females		Sex Differences
	Sample Size	Percent Affected	Sample Size	Percent Affected	
Low	69	44.93	85	31.76	z= 1.68*
High	17	29.41	15	20.00	z= 0.61
Status Differences	z= 1.16		z= 0.18		

* Significant at $p < 0.05$.

Status Differences. Table 15 reveals that cranial deformation among low status individuals (92.24%) is significantly greater than in the high status group (83.67%) when burial location is considered ($z=1.99$, $F(z)=0.9767$, $p<0.025$). This distinction is true for males, but is not statistically significant in females (Table 15). These results agree with those of Parham (1982), suggesting that cradling of infants was more common in individuals of low status.

The degree of deformation exhibits a moderately negative, but nonsignificant, correlation with status (Table 9). The crania recovered from villages tend to be more severely deformed than those excavated from mounds.

In a similar manner (Table 18), the low status group possesses a higher incidence of intentional deformation than high status individuals ($z=1.67$, $F(z)=0.9525$, $p<0.05$). Differences between the status groups are not significant, however, when sorted by sex (Table 17).

In Dallas society, artificial cranial deformation is more common, more often intentional, and generally more severe in low status individuals than in the superordinate group. The reason for this association is unknown, but may be partially explained by the observed correlation between degree of deformation and intentional types. It

Table 18. Type of Cranial Deformation by Status.

Type	<u>Village</u>		<u>Mound</u>	
	Freq.	Percent	Freq.	Percent
Obelionic	10	5.46	2	5.26
Lambdoid	36	19.67	8	21.05
Occipital	73	39.89	20	52.63
F-P-O	1	0.55	0	0.00
F-VO	63	34.43	8	21.05
Total	183	-	38	-

logically follows that groups practicing intentional deformation would deform the skull to an extreme extent.

An explanation for why crania are intentionally deformed is not readily available, but it is probably practiced for aesthetic or cosmetic reasons. Adair (1775) states that members of the Choctaw tribe considered their broad, flattened heads more attractive than those of the long-headed Europeans.

The lower incidence of intentional types of deformation in mound individuals suggests that status was primarily ascribed, but some avenue for achievement must have been possible given the presence of several intentionally deformed crania recovered from the mound (Parham 1982:91-92). It is possible that intentional deformation was considered a desirable quality in those low status males who functioned as warriors, and the presence of intentionally deformed skulls in the mound indicates achievement of status through prowess in battle. It may be possible to test this hypothesis by looking at grave goods to determine if mound males with intentional deformation are accompanied by utilitarian items, tools for hunting or warfare, or "administrative" goods.

CHAPTER 5

SUMMARY AND CONCLUSIONS

As stated in the introduction, the goal of this thesis is to examine certain pathology and cultural practices in Dallas society to evaluate status differences related to diet and differential treatment of infants in Dallas society. Following a paradigm of biocultural interaction and the precepts of the dietary hypothesis, porotic hyperostosis, cribra orbitalia, and artificial cranial deformation are analyzed by age, sex and status.

OVERALL SAMPLE

Porotic Hyperostosis. The high incidence of both porotic hyperostosis and cribra orbitalia in the sample indicates that iron deficiency anemia was endemic in Dallas society. The great number of lesions that were active at death suggests that this anemia had profound effects in infant mortality and was a major health problem for adults as well. It is easy to see that the diet of the Dallas Indian was quite deficient in the nutrients required to prevent nutritional anemia, given the low iron and low protein composition of a maize based subsistence. The high incidence of active lesions in the younger age ranges supports the hypothesis that cribra orbitalia and

calvarial porotic hyperostosis are largely skeletal manifestations of childhood anemia.

Cribra orbitalia occurs most frequently in infants while the greatest incidence of porotic hyperostosis occurs in adults. Mortality associated with iron deficiency appears to be greater in cases of neonatal or infant anemia, arising from biological factors of intrauterine hemorrhage, rather than in early childhood where anemic stress is the product of an iron-poor weaning diet.

Cribra orbitalia is slightly more common in females but porotic hyperostosis occurs most frequently in males. It appears that males are receiving preferential access to food resources during infancy but females are better off in early childhood. Several explanations are possible. Females may be weaned in infancy while males are weaned in early childhood and, thus, females would experience anemic stress at an earlier age. It is also possible that young boys lose access to preferred foods as they adopt traditional male roles and leave the circle of women, while girls are not deprived of access to the cooking pots. Both of these interpretations suggest preferential treatment of males during infancy. A third possibility is that both males and females are weaned at the same age but females are better equipped to handle dietary stress than males.

Cranial Deformation. The high incidence of cranial deformation indicates that cradleboarding is a common cultural practice in Dallas society. Unintentional types of deformation outnumber intentional types two-to-one, and flattening of crania in Dallas society appears to be largely the unintentional result of cradleboard use. Intentional deformation is common enough, however, to indicate a possible conscious effort to cosmetically alter the appearance of the head in some individuals.

STATUS

It is generally agreed upon that Mississippian societies are organized at the chiefdom level, where a division exists between the ruling class and the commoners, and status is usually ascribed (hereditary chiefdom). In Dallas society, this distinction is noted archaeologically by the burial of high status individuals in mounds and interment of low status individuals within the village. This mound-village dichotomy is employed to analyze differential treatment of infants and children as well as preferential access to dietary resources for the two groups.

Porotic Hyperostosis and Status. In terms of overall incidence, porotic hyperostosis and cribra orbitalia are more frequent in village individuals, meeting expectations

of the dietary hypothesis. Iron deficiency anemia is believed to occur more frequently in low status individuals due to their limited access to protein and iron rich foodstuffs, especially meats.

Cribra orbitalia is least frequent in mound males while porotic hyperostosis occurs infrequently in mound females. The distribution of orbital lesions is interpreted as reflecting a conscious investment in high status males to stave off neonatal or infant anemia through access to a more nutritious diet. This preferential treatment of high status male infants suggests ascription of status, where male heirs are valued.

Cranial Deformation and Status. Cranial deformation occurs most commonly in low status individuals, indicating greater use of the cradleboard in the village. This distribution may reflect division of labor along status lines: village females spend more time in the fields and thus utilize the cradle more often than high status women, who would tend to work at home where cradling is not practiced.

Intentional types of deformation occur most frequently in low status individuals and males and least frequently in high status females, suggesting that crania of subordinate males are deformed for cosmetic purposes,

while this appearance is less desirable in high status individuals and females. Cranial deformation appears to be a marker of the subordinate class, suggesting that status was primarily ascribed.

The moderate incidence of intentional deformation in mound males suggests that a fair number of low status males had achieved high status. Achievement of status by males may result from prowess in battle or the hunt, or through marriage to a high ranking female. The former hypothesis can be tested through an analysis of grave goods to determine if high status individuals with intentional deformation are buried with artifacts associated with hunting or warfare, or with ceremonial objects.

GENERAL CONCLUSIONS

The results of this investigation have demonstrated that porotic hyperostosis and artificial cranial deformation are moderately correlated, but this relationship is not statistically significant. Systematic testing found no evidence supporting the contention of Lewis and Kneberg (1946) that Dallas individuals with severe porotic hyperostosis also exhibit extreme cranial deformation.

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APPENDICES

APPENDIX A
CODING FORMAT

SITE

05AN19	Cox
18AN19	
07HA1	Dallas
08HA1	
37MG31	Hiwassee Island
38MG31	
42MG31	
46MG31	
63MG31	
78MG31	
VT1MG31	
40MR6	Toqua

BURIAL

#	Burial Number
---	---------------

AGE

1	Infant (0-2 years)
2	Child (2-12 years)
3	Adolescent (12-18 years)
4	Adult (>18 years)

SEX

1	Male
2	Female
3	Indeterminate

CRADLE (Deformation)

0	Absent
1	Slight
2	Moderate
3	Extreme
4	Present, degree indeterminate
Blank	Not observable

1	Obelionic
2	Lambdoid
3	Occipital
4	Bifronto-Occipital
5	Fronto-Parieto-Occipital
6	Fronto-Verticooccipital
Blank	Indeterminate/Absent

POROSIS, CRIBRA

0	Absent
1	Slight
2	Moderate
3	Severe
Blank	Not observable

PHSTATE, COSTATE (Activity)

A	Active
H	Healed
Blank	Indeterninate/Absent

APPENDIX B

RAW DATA

SAS

8:47 MONDAY, APRIL 10, 1989

1

OBS	SITE	BURIAL	AGE	SEX	STATUS	CRADLE	TYPE	PROSIS	PHSTAT	CRIBRA	COSTATE
1	05AN19	1	4	1	2	1	2	0		0	
2	05AN19	2	4	1	2	4		0		0	
3	05AN19	3	3	1	2	1		0		1	H
4	05AN19	4	4	1	2	2	3	1	H	0	
5	05AN19	5	4	2	2	3	6	0		0	
6	05AN19	7A	4	1	2	2	3	1	H	0	
7	05AN19	8	4	1	2			1	H		
8	05AN19	9	4	1	2	1	3	1	H	0	
9	05AN19	10	2	3	2	1	1	0		0	
10	05AN19	11A	4	2	2	4		0			
11	05AN19	13	4	1	2			1	H	0	
12	05AN19	14	4	2	2	2	6	0			
13	05AN19	16	4	1	2	1		1	H		
14	05AN19	17	4	1	2	4		1	H		
15	05AN19	19	3	2	2	1	2	0			
16	05AN19	20	4	1	2	0		0		0	
17	05AN19	21	4	2	2	2	6	0		0	
18	05AN19	23	4	1	2	2	6	1	H	0	
19	05AN19	28	4	1	2	4				0	
20	05AN19	32	4	1	2	4				0	
21	05AN19	32A	4	3	2	4				0	
22	05AN19	34	4	2	2	1	3	0			
23	05AN19	36	4	3	2			0		0	
24	05AN19	37	2	3	2	3	3	0			
25	05AN19	38	4	2	2	1	3				
26	05AN19	41	4	2	2	0		0		0	
27	05AN19	42	4	1	2					0	
28	05AN19	45	4	1	2	0				0	
29	18AN19	6	4	1	1	2	3	0		0	
30	18AN19	7B	4	1	1	2	6	1	H		
31	18AN19	10A	4	2	1	1	3	1	A	0	
32	18AN19	33	3	2	1					0	
33	18AN19	39	4	1	1					0	
34	18AN19	40	4	2	1			1	H	0	
35	18AN19	48	4	1	1	0		1	H	0	
36	18AN19	54	4	1	1	2	3	2	H	0	
37	18AN19	57	4	1	1	4		0			
38	18AN19	60	3	3	1	0		0		0	
39	18AN19	63	4	1	1					0	
40	18AN19	66	4	1	1	3	3				
41	18AN19	67	4	2	1	2	3			0	
42	18AN19	68	4	2	1	3	6	1	H	0	
43	18AN19	69	4	1	1	1	2	1	A	0	
44	18AN19	70	4	1	1	4		1	H	0	
45	18AN19	74	4	1	1	2	6	2	A		
46	18AN19	75	3	1	1	1	3	2	A	0	
47	18AN19	76	4	1	1	2	3	1		2	H
48	18AN19	77	4	2	1	2	3	2	A	0	
49	18AN19	78	4	1	1	2	3	2	H	0	

SAS

8:47 MONDAY, APRIL 10, 1989²

O B S	S I T E	B U R I A L	A G E	S E X	S T A T U S	C R A D L E	T Y P E	P O R O S I S	P H S T A T E	C R I B R A	C O S T A T E
50	18AN19	80	4	2	1	1	1	0		0	
51	18AN19	91	2	3	1			0			
52	18AN19	92	4	3	1			0			
53	18AN19	85	2	3	1			1	A	1	A
54	18AN19	82	2	3	1			2	A	2	A
55	18AN19	83	1	3	1					1	A
56	18AN19	84	3	2	1			0			
57	18AN19	104	3	3	1			1	H		
58	18AN19	105	4	1	1	1	3	1	H	0	
59	18AN19	108	4	1	1	4		0		0	
60	18AN19	111	2	3	1	4		2	A	0	
61	18AN19	112	3	3	1			0		0	
62	18AN19	115A	1	3	1			0		0	
63	18AN19	119	4	2	1	0		1	H	0	
64	18AN19	120	4	2	1	4		0		0	
65	18AN19	128	4	1	1	4		1	H	0	
66	18AN19	130	2	3	1			0		0	
67	18AN19	131	4	2	1	2		0		0	
68	18AN19	132	4	2	1			1	H	0	
69	18AN19	135	4	1	1			1	A	2	A
70	18AN19	137	4	2	1	0		1	H	0	
71	18AN19	140	4	2	1	2	6	1	H	0	
72	18AN19	141	4	2	1	2		1	H	0	
73	18AN19	145	2	3	1			0			
74	18AN19	149	4	3	1			2	H		
75	18AN19	150	2	3	1			1	H		
76	18AN19	151	4	1	1	0		1	H		
77	18AN19	161	2	3	1			1	A	0	
78	18AN19	166	4	2	1	2	3	0		0	
79	18AN19	169	2	3	1	4		0			
80	18AN19	170	4	2	1	1	2	0		0	
81	18AN19	175	2	3	1			0		0	
82	18AN19	189	4	3	1	0		2	A	0	
83	18AN19	190	2	3	1			1	H		
84	18AN19	203	4	1	1	2	2			0	
85	18AN19	204	3	3	1			2	A		
86	07HA1	3	4	2	1	0		1	H	0	
87	07HA1	4	4	2	1	2	6	0		0	
88	07HA1	9	3	3	1	0		1	H	0	
89	07HA1	27	2	3	1			1	H		
90	07HA1	6	4	1	1			1	H	1	H
91	07HA1	15	4	2	1	1	1	2	H	0	
92	07HA1	7	4	1	1	3	6	1	H	0	
93	07HA1	17	2	3	1			1	H		
94	07HA1	19	2	3	1	4		2	H		
95	07HA1	8	4	2	1	1	1	1	H	0	
96	07HA1	22A	4	1	1	2	6	1	H	0	
97	07HA1	29	2	3	1	4		1	H		
98	07HA1	35	4	2	1	1	2	1	H	0	

SAS

8:47 MONDAY, APRIL 10, 1989³

O B S	S I T E	B U R I A L	A G E	S E X	S T A T U S	C R A D L E	T Y P E	P O R T S I S	P H S T A T E	C R I B R A	C O S T A T E
99	07HA1	36	4	1	1			1	H	0	
100	07HA1	41	4	2	1	1	2	1	H	0	
101	07HA1	44	4	1	1	2	1	0		0	
102	07HA1	45	3	3	1	0		0		2	H
103	07HA1	46	4	2	1	1	2	1	H	0	
104	07HA1	47	3	3	1	2		3	A	3	A
105	07HA1	54	4	2	1			1	H	0	
106	07HA1	55	4	2	1	1	1	1	H	0	
107	07HA1	56	4	1	1	1	1	1	H	0	
108	07HA1	64	2	3	1	1	1	1	H	0	
109	07HA1	67	4	2	1	1	6	1	H	0	
110	07HA1	75	2	3	1	2	3	2	A		
111	07HA1	73	4	2	1	3	2	2	H	0	
112	07HA1	74	4	2	1	4		1	A	1	H
113	07HA1	77	4	1	1	2	6	1	H	0	
114	07HA1	83B	4	1	1	2	6	0		0	
115	07HA1	87	2	3	1	4		1	H		
116	07HA1	89	4	2	1	1	1	0		1	H
117	07HA1	97	3	3	1			0		0	
118	07HA1	92	2	3	1			1	H	0	
119	07HA1	93	4	2	1			1	A	0	
120	07HA1	103	4	2	1	1	2	1	H	0	
121	07HA1	107	4	1	1	0		1	H	0	
122	07HA1	112	4	1	1			1	H		
123	07HA1	113	4	2	1	0		0		0	
124	07HA1	114	4	1	1	2	6	1	H		
125	07HA1	115	2	3	1	4		1	H	0	
126	07HA1	117	4	1	1	1	2	1	H	0	
127	08HA1	34	2	3	2			1	H		
128	08HA1	38	2	3	2			0		0	
129	08HA1	16	4	1	1	1	3	2	H	0	
130	08HA1	25	2	3	2			2	H		
131	08HA1	24	1	2	1			0		0	
132	08HA1	5	4	2	2	1	3	1	H	0	
133	08HA1	44	4	1	2	0		1	H	0	
134	08HA1	32	1	3	2	4		0		2	A
135	08HA1	33	1	3	2			0		0	
136	08HA1	6	4	2	1	1	3	1	H	1	H
137	08HA1	45	4	1	2	0		1	A	0	
138	08HA1	23	4	2	1	1	2	1	H	0	
139	08HA1	53	4	1	2	0		1	H		
140	08HA1	62	4	1	2	4		2	H		
141	08HA1	10	4	2	1	1	3	1	H	0	
142	08HA1	11	2	3	1	4		2	H	1	H
143	08HA1	19	4	2	2	1	2	0		0	
144	08HA1	28	4	2	1	2	2	1	H	0	
145	08HA1	50	4	2	2	1	3	0			
146	08HA1	55	4	1	2	0		2	H	1	H
147	08HA1	69	4	3	1	1	3	2	H	0	

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OBS	SITE	BURIAL	AGE	SEX	STATUS	CRA DLE	TYPE	PORDSIS	PHSTATE	CRIBRA	COSTATE
148	OBHA1	42	4	1	1	3	6	1		3	H
149	OBHA1	58	2	3	1			0			
150	OBHA1	86	4	2	1	1	6	0		0	
151	OBHA1	21	4	2	2	2	3	0		0	
152	OBHA1	27	2	3	2	1	2	1		1	A
153	OBHA1	43	4	1	2	0		0		0	
154	OBHA1	49	4	1	2	1	6	1	H	0	
155	OBHA1	65A	1	3	1			2	A		
156	OBHA1	68	2	3	1	1	2	0		1	A
157	OBHA1	66	4	1	1	1	6	1	A	1	H
158	OBHA1	70	4	1	1	2	6	1		0	
159	OBHA1	71	4	2	1	0		0		1	A
160	OBHA1	73	1	3	1			0		0	
161	OBHA1	81A	4	3	1			0		0	
162	OBHA1	79	4	2	1	1	6	1	H	1	H
163	OBHA1	80	3	2	1	1	2	1	A		
164	OBHA1	84	4	2	1	1	6	1	H		
165	OBHA1	92	2	3	2	1		1	A	1	A
166	OBHA1	98	4	2	2	1		0		0	
167	OBHA1	102A	2	3	1	2		0			
168	OBHA1	104	2	3	1			1	A	2	A
169	OBHA1	103	4	2	1	2	6	1	H	0	
170	OBHA1	107B	4	2	1	1	2	0		0	
171	OBHA1	118	4	2	1	3	3	1	A	0	
172	OBHA1	105	4	2	1	2	2	1	A	0	
173	OBHA1	115	3	1	1	3	3	0		0	
174	OBHA1	116	4	2	1	1	3	1	A	1	H
175	OBHA1	121	2	3	1			1	A	1	A
176	OBHA1	117	3	3	1	1	1	1	H		
177	OBHA1	119	4	1	1	3	6			0	
178	OBHA1	120	4	2	1	3	2	0		0	
179	OBHA1	122	4	1	1	2	6	1	H	0	
180	OBHA1	126	4	1	1	2	2	1	A	0	
181	OBHA1	132	2	3	1	1	2	2	A		
182	OBHA1	130	4	1	1	3	6	1	H	0	
183	OBHA1	133	4	2	1	1	2	1	H	0	
184	OBHA1	135	3	1	1	1	3	2	A	2	H
185	OBHA1	136	3	2	1	2	2	0		1	H
186	OBHA1	143	4	2	1	2	6	1	A	1	H
187	OBHA1	144	4	2	1	2		1	H	0	
188	OBHA1	151	4	2	2	3	3	1	H	1	H
189	OBHA1	155	4	1	2	2	6	1	A	2	H
190	OBHA1	156	4	1	2	1	2	1	A	0	
191	OBHA1	159	3	2	2	1	3	1	A	2	H
192	OBHA1	160	4	1	1	2	3	1	A	1	H
193	OBHA1	162	4	1	1	0		1	A	0	
194	37MG31	2	4	1	2	3	6	2	H		
195	37MG31	20	4	1	2	1	1	2	H		
196	37MG31	23	2	3	2	4		0		1	

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O B S	S I T E	B U R I A L	A G E	S E X	S T A T U S	C R A D L E	T Y P E	P O R T O S I S	P H S T A T E	C R I B R A	C O S T A T E
197	38MG31	8	4	2	1	3	6	0		0	
198	38MG31	13	4	1	1	1	2	1	H	0	
199	38MG31	14	3	2	1	3	6	0		2	H
200	38MG31	18	2	3	1	3	6	0		1	H
201	38MG31	23	4	1	1	2	6	0		1	H
202	38MG31	24	4	2	1	2	6	1	H	1	H
203	38MG31	27	3	1	1	2	6	1	H	1	H
204	38MG31	29	3	3	1	1	3	1	A	0	
205	38MG31	32	4	2	1	2	6	0		1	
206	38MG31	33	2	3	1	3	3	1	A	3	H
207	38MG31	46	1	3	1	2	3	0			
208	38MG31	34	4	1	1	0		1	A	1	H
209	38MG31	37	4	2	1	0		1	A	1	H
210	38MG31	38	4	1	1	1	3	1	H	0	
211	38MG31	39	4	1	1	4		0		0	
212	38MG31	40	3	1	1	4		3	H	1	H
213	38MG31	41	4	2	1	3	6	1		1	H
214	38MG31	42	4	1	1	1	6	1	A	1	H
215	38MG31	52	2	3	1	2	3	0		1	A
216	38MG31	54	1	3	1			0		3	A
217	38MG31	53	4	2	1	2	3	1	H	1	H
218	38MG31	66	2	3	1			0		3	H
219	38MG31	56	2	3	1	0		0		0	
220	38MG31	57	2	3	1	3	3	0		3	A
221	38MG31	59	3	3	1			0		1	A
222	38MG31	64	4	1	1	2	3	2	H	1	H
223	38MG31	68	4	1	1	2	6	1	H	0	
224	38MG31	69	4	1	1	2	3	1	H		
225	38MG31	94	2	3	1	4		2	H		
226	38MG31	97	4	1	1	1	3	1	H	0	
227	38MG31	83	4	2	1	1	3	1	H	0	
228	38MG31	111	2	3	1	3	2	3	A		
229	38MG31	98	4	2	1	1	3	0		0	
230	38MG31	99	2	3	1	1	3	1		1	A
231	38MG31	84	1	3	1			0		0	
232	38MG31	85	4	2	1	1	3	1	H	1	H
233	38MG31	93	4	2	1	2		1	H	0	
234	38MG31	96	4	2	1	4		1	H	1	H
235	38MG31	104	4	2	1	1	2	1	A	2	H
236	38MG31	107	4	2	1	1	6	1	H	1	
237	38MG31	109	4	2	1	2	5	2	H	1	H
238	38MG31	115	4	2	1	3	6	1	H	0	
239	38MG31	116	4	2	1	2	3	1	H	1	H
240	38MG31	122	2	3	1	3	6	0		0	
241	38MG31	121	4	1	1	2	6	1	A	0	
242	38MG31	133	2	3	1			0		1	A
243	38MG31	137	3	1	1	1	3	2	A	1	H
244	VT1MG31	2	4	2	1	1	3	1	H	1	H
245	VT1MG31	7	4	2	1	1	2	1	H	0	

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O B S	S I T E	B U R I A L	A G E	S E X	S T A T U S	C R A D L E	T Y P E	P O R T O S I S	P H S T A T E	C R I B R A	C O S T A T E
246	VT1MG31	9	4	2	1	1	6	1	H	1	H
247	VT1MG31	10	4	2	1	1	6	1	H		
248	VT1MG31	11	4	2	1	1	2	1	H	0	
249	VT1MG31	12	4	1	1			2	H	0	
250	VT1MG31	14	3	2	1	1	3	1	H		
251	VT1MG31	20	3	3	1			1	H		
252	VT1MG31	21	2	3	1			0		0	
253	VT1MG31	23	4	2	1	2	2	2	H		
254	VT1MG31	24	4	2	1	3	6	1	H	0	
255	VT1MG31	27	4	1	1	1	3	1	H	1	H
256	VT1MG31	28	4	2	1	3	3	0		1	H
257	63MG31	9	2	3	1			0		0	
258	63MG31	22	4	2	1	2	2	1	H		
259	63MG31	23	4	2	1	2	6	2	H	1	
260	63MG31	20	2	3	1	1	3	1	A	2	A
261	63MG31	19	4	2	1	3	3	1	H	0	
262	63MG31	14	4	2	1	2	1	1	A	2	A
263	63MG31	26	4	3	2	4		0			
264	63MG31	27	4	1	2	2	6	0		0	
265	42MG31	39	4	2	2	0		1	H	1	H
266	42MG31	50	2	3	2	1	2	0		0	
267	46MG31	119	4	2	2			0		1	H
268	46MG31	120	4	3	2	2	3	1	H	0	
269	78MG31	5	2	3	2	1	3	0		3	A
270	40MR6	151	4	1	2	1	3	1	H	1	H
271	40MR6	155	4	1	2	1	2	1	A	0	
272	40MR6	150	4	2	2	2	3	0			
273	40MR6	158A	4	1	2			1	A	0	
274	40MR6	162	4	2	1	1	3	2	H	1	
275	40MR6	163	3	1	1	2	6	1	H	2	A
276	40MR6	165	3	2	1	1	2	1	A	1	H
277	40MR6	166	4	2	1	2	2	1	H	1	
278	40MR6	167	4	2	1	3	6	1	H	1	H
279	40MR6	169	4	3	1	1	2	1	H	1	H
280	40MR6	173	4	1	2			1	H	0	
281	40MR6	174	4	1	1	1	6	1	H	0	
282	40MR6	177	4	2	1	2	3	2	H	0	
283	40MR6	187B	4	2	1	1	6	1	H	1	H
284	40MR6	188	2	3	1			0		1	A
285	40MR6	191	4	2	1			2	H	2	H
286	40MR6	193	4	2	1	2	6	1	H	0	
287	40MR6	195A	4	2	1	1	2	1	H		
288	40MR6	200	4	2	1	3		0		2	H
289	40MR6	203	2	3	1			0		2	A
290	40MR6	209	4	1	1	2	3	1	H	1	A
291	40MR6	211	2	3	1	3	3	0			
292	40MR6	217	4	2	1	1	3	1	A	1	A
293	40MR6	222	2	3	1	1	3	0		1	A
294	40MR6	229	4	1	1	3		1	H	0	

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O B S	S I T E	B U R I A L	A G E	S E X	S T A T U S	C R A D L E	T Y P E	P O R T O S I S	P H S T A T E	C R I B R A	C O S T A T E
295	40MR6	223A	3	1	1	2	6	0		1	H
296	40MR6	230B	4	1	1	2	3	0		0	
297	40MR6	236	4	2	1	1		0		0	
298	40MR6	238	3	2	1	2	3	1	H	0	
299	40MR6	239	4	1	1	4		2	A	0	
300	40MR6	241	4	2	2	0		0		0	
301	40MR6	243	4	1	1	2	3	0		0	
302	40MR6	244	4	1	1	1	2	1	H	0	
303	40MR6	246	4	2	1	1	2	1	H	0	
304	40MR6	250	4	1	1	3	6	0		0	
305	40MR6	254	4	1	1	2	3	1	H		
306	40MR6	255	4	2	2	1	2	1	H	1	H
307	40MR6	257	3	3	1			1	H	0	
308	40MR6	258	2	3	1			0		0	
309	40MR6	262	3	1	1	1	6	1	A	1	H
310	40MR6	263	4	2	1	1	3	0			
311	40MR6	264	2	3	1	2	3	0		2	A
312	40MR6	280	4	1	1			1	A	1	H
313	40MR6	325	4	2	1	1	3	0		1	H
314	40MR6	332	4	1	1	2	3	1	H	0	
315	40MR6	330	4	1	1	1	2	1	H	1	H
316	40MR6	338	4	1	1	1	6	2	H	2	H
317	40MR6	343	4	1	1	0		1	H	0	
318	40MR6	345	4	1	1	1	6				
319	40MR6	347	2	3	1			2	H	3	H
320	40MR6	354	2	3	1	1	3	0		1	A
321	40MR6	355	1	3	1	2	6	0		2	H
322	40MR6	357	4	1	1	2	3	1	H	1	H
323	40MR6	359	4	2	1	1	3	0		0	
324	40MR6	362	2	3	1	2	3	1	H	2	H
325	40MR6	363A	4	1	1	1	6	1	H	0	
326	40MR6	364	4	1	1			1	H	1	H
327	40MR6	365A	4	2	1	2	3	0		1	H
328	40MR6	367	4	2	1	1	3	1	H		
329	40MR6	370A	2	3	1	1		0		1	
330	40MR6	374	2	3	1	2	3	0			
331	40MR6	387	3	2	1			0		3	A
332	40MR6	388	4	2	1	1	6	1	H	0	
333	40MR6	394	4	1	2	1	3	1	H	0	
334	40MR6	405A	2	3	1	3	6	0		2	A
335	40MR6	411A	4	1	1	1	6	0		0	
336	40MR6	414	4	2	1	2	3	0		0	
337	40MR6	419	4	1	1	2	3	0			
338	40MR6	420C	4	1	1	1	2	2	A	1	H
339	40MR6	424A	1	3	1	1		1	A	1	A
340	40MR6	425	4	2	1	1	3	0		1	H
341	40MR6	431	2	3	1	2	3	1	A		
342	40MR6	435	4	1	1	1	3	1	H	2	H
343	40MR6	438	4	1	1	1	3	1	H	1	H

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O B S	S I T E	B U R I A L	A G E	S E X	S T A T U S	C R A D L E	T Y P E	P O R T S I S	P H S T A T E	C R I B R A	C O S T A T E
344	40MR6	450	4	2	1	0		0		1	H
345	40MR6	453A	4	1	1	2	6	0		1	H
346	40MR6	7	4	1	1	1	6	2	H	0	
347	40MR6	9	4	2	1	3	6	0		0	
348	40MR6	12	2	3	1	1	6	1	A	1	A
349	40MR6	8A	4	2	1	2	3	1	H	0	
350	40MR6	10	2	3	1	2		0			
351	40MR6	13	4	1	1	1	3	0		0	
352	40MR6	132	4	2	2	1	3	0		1	H
353	40MR6	34	2	3	1	1		0		2	H
354	40MR6	38	3	3	1	1	3	0		1	H
355	40MR6	77	4	2	1			1	H	3	A
356	40MR6	137	4	1	2	1	3	1	H	2	H
357	40MR6	75	2	3	2			0		0	
358	40MR6	93	4	1	1	3	2	2	H	0	
359	40MR6	94	4	2	1	3	6	2	H	1	H
360	40MR6	95	4	1	1	3	6	1	H	1	H
361	40MR6	103	4	1	2	1	3	0		1	H
362	40MR6	104	1	3	1	3	6	0		0	
363	40MR6	131	4	1	1	2	6	1	H	1	H
364	40MR6	136	4	1	2	1	3	1	H	0	

VITA

Stephen Patrick Langdon was born in Lockport, New York, on April 12, 1964. In 1982 he graduated with Honors from Lockport Senior High School. The following fall he entered the State University of New York at Binghamton to study anthropology. He received a Bachelor's degree from SUNY-Binghamton in May, 1986.

Stephen entered the graduate program in Anthropology at the University of Tennessee, Knoxville, in Fall 1986. He received his Master of Arts degree with a major in Anthropology in August, 1989.

Mr. Langdon is currently studying for his doctorate in Anthropology and serves as Director of the Human Osteology Laboratory at UTK. He is a member of the American Anthropological Association and the Tennessee Anthropological Association.

He is presently married to Michelle Millenbruch Langdon and resides in Knoxville with his wife and surrogate children.