FLUORINE AND NITROGEN SKELETAL DATING: AN EXAMPLE FROM TWO OHIO ADENA BURIAL MOUNDS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

LEONARD RICHARD PIOTROWSKI, B.A., M.A.

* * * * *

The Ohio State University

1985

Reading Committee: Approved By
William S. Dancey, Ph.D.
Paul Sciulli, Ph.D.
Chung-Min Chen, Ph.D.
William Sumner, Ph.D.

William S. Dancey, Advisor
Department of Anthropology
Copyright by
LEONARD RICHARD PIOTROWSKI
1985
ACKNOWLEDGEMENTS

I wish to acknowledge the aid of The Ohio State University Department of Physics, and the faculty and staff at the Van DeGraaff Accelerator Laboratory who helped make this research possible. Special thanks go to Dr. Petra Schmalbrock who developed the technique used here and devoted many hours of her time to the project. I wish to also thank Dr. Richard Boyd, Director of the Van DeGraaff Laboratory who offered the use of his facility and made possible the entire project.

Thanks are due also to the staff of the Ohio Historical Society who provided access to their collections and the skeletal samples necessary to the analyses. Special thanks go to Martha Potter-Otto and Brad Baker for their help in the selection of suitable samples and their support during the evaluation by the Museum's Curation Committee.

I wish to also show my appreciation to The Ohio State University Department of Anthropology, and Alumni Research Award Committee, and the Sigma Xi Scientific Society for providing grants to conduct the chemical analyses of this study. In addition, I would like to extend my warmest
regards to the faculty, staff, and students of the Department of Anthropology, The Ohio State University, for their support, encouragement and friendship throughout my years as a graduate student.
VITA

September 26, 1949...... Born

1975................. B.A., The Ohio State University, Columbus, Ohio

1975-1976............. Student Research Assistant, The Mershon Research Center, Columbus, Ohio

1976-1977............. Student Research Assistant, Department of Anthropology, The Ohio State University, Columbus, Ohio

1977.................. M.A. The Ohio State University, Columbus, Ohio

1977-1978............. Teaching Associate, Department of Anthropology, The Ohio State University, Columbus, Ohio

1978-1980............. Field Assistant, Regional Archaeological Preservation Office, The Ohio State University, Columbus, Ohio

1980-1981............. Regional Archaeological Preservation Officer, The Ohio State University, Columbus, Ohio

1980-1985............. Teaching Associate, Department of Anthropology, The Ohio State University, Columbus, Ohio

PUBLICATIONS


FIELDS OF STUDY

Major Field: Anthropology

Studies in Midwestern Archaeology. Professor William S. Dancey
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acknowledgements</td>
<td>ii</td>
</tr>
<tr>
<td>Vita</td>
<td>iv</td>
</tr>
<tr>
<td>List of Tables</td>
<td>ix</td>
</tr>
<tr>
<td>List of Figures</td>
<td>xii</td>
</tr>
</tbody>
</table>

## Chapter

### I. The Chronological Problem in Ohio Area
- Prehistory .................................................. 1

### II. Methodology ........................................... 10
- Research Strategy ........................................ 10
- Fluorine and Nitrogen Dating Methods .......... 19

### III. The Sites and the Skeletal Samples .......... 28
- Description of the Sites .............................. 28
- The Skeletal Samples From the Davis Mound ........ 34
- The Skeletal Remains From Toepfner Mound ......... 39

### IV. Data Analysis ....................................... 47
- Descriptive Statistics .............................. 47
- Spearman Rank Correlations ......................... 58
- Principal Components .............................. 66
V. Factor Decomposition .......................... 83
   Charge/Silicon Affects .......................... 89
   Bone Preservation and Soil Characteristics .... 98

VI. Fluorine and Nitrogen Values in Stratigraphic Context ................. 114
   The Davis Mound .................................. 114
   The Toepfner Mound ................................ 124

VII. Summary and Conclusions .......................... 151

APPENDIXES

A. Raw Data ........................................ 157

Bibliography ....................................... 158
### LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description of Davis Mound Skeletal Samples</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Bone Types For Davis Samples</td>
<td>35</td>
</tr>
<tr>
<td>2.</td>
<td>Description of Toepfner Mound Bone Samples</td>
<td>39</td>
</tr>
<tr>
<td>3.</td>
<td>Anatomical Bone Types From Toepfner Mound</td>
<td>40</td>
</tr>
<tr>
<td>4.</td>
<td>Fluorine and Nitrogen Descriptive Statistics</td>
<td>46</td>
</tr>
<tr>
<td>5.</td>
<td>Results of T-tests and Analysis of Variance</td>
<td>49</td>
</tr>
<tr>
<td>6.</td>
<td>Pooled Descriptive Statistics</td>
<td>50</td>
</tr>
<tr>
<td>7.</td>
<td>Standard Error in the Pooled Descriptive Statistics</td>
<td>50</td>
</tr>
<tr>
<td>9.</td>
<td>Initial Spearman Rank Correlations for Toepfner and Davis Mounds</td>
<td>63</td>
</tr>
<tr>
<td>10.</td>
<td>Initial Spearman Rank Correlations Between Fluorine and Nitrogen</td>
<td>65</td>
</tr>
<tr>
<td>11.</td>
<td>Principal Components Analysis for Combined Data</td>
<td>68</td>
</tr>
<tr>
<td>12.</td>
<td>Factor Matrix for Toepfner Mound</td>
<td>72</td>
</tr>
<tr>
<td>13.</td>
<td>Davis Mound Factor Matrix</td>
<td>78</td>
</tr>
<tr>
<td>14.</td>
<td>Bone Mineral Descriptive Statistics for Toepfner and Davis</td>
<td>87</td>
</tr>
<tr>
<td>15.</td>
<td>Rank Correlations for Charge and Nuclear Measures</td>
<td>90</td>
</tr>
<tr>
<td>16.</td>
<td>Charge and Nuclear Measures Divided into Good</td>
<td>- ix -</td>
</tr>
</tbody>
</table>
and Bad Counts ........................................ 93

18.  Rank Correlations of Charge and the Chemical
     Measures ............................................... 95

19.  Rank Correlations of the Chemical and Nuclear
     Measures ............................................... 96

20.  Rank Correlations of Toepfner Good Counts and
     Davis Bad Counts ................................... 98

21.  Fluorine to Nitrogen Ratios for Toepfner and
     Davis Mounds ........................................ 100

22.  Statistics for Mound Fill and Sub-floor
     Features ............................................... 105

23.  pH Reaction Range for Various Soils from
     Toepfner and Davis ................................ 108

24.  Statistics of the Bone Minerals From Mound
     Fill ..................................................... 109

25.  T-test and Analysis of Variance of the Bone
     Minerals ................................................. 111

26.  Neutron Activation Analysis of Sodium ............ 112

27.  Rank Correlations for Mound Fill and Sub-
     floor Features ........................................ 116

28.  Rank Correlations for Davis Mound Fill, Sub-
     floor, & Long-bones .................................. 118

29.  Rank Correlations for the Bone Minerals at
     Davis .................................................... 121

30.  Fluorine, Nitrogen, and Bone Mineral Ratios
     at Both Mounds ....................................... 126

31.  Permeability and Available Water for Soils at
     Toepfner and Davis .................................. 129

32.  Bank Correlations for Unburned Bone and Log
     Tombs at Toepfner .................................... 132

33.  Bank Correlations Between Fluorine and
     Nitrogen at Toepfner ................................. 135

34.  Bank Correlations with Calcium at Toepfner
     Mound ................................................. 136

- x -
35. Rank Correlations of the Bone Minerals at Toepfner Mound .............. 137
36. Rank Correlations for Rib at Toepfner Mound .. 143
37. Rank Correlations Between Fluorine & Nitrogen at Toepfner ............... 144
38. Rank Correlations of the Bone Minerals for Toepfner .................. 145
39. Rank Correlations of Bone Minerals at Toepfner ....................... 146
40. Original Measurements of Bone Used in This Study ........................ 157
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Typical Van de Graaff Accelerator Low Energy Portion of the</td>
<td>21</td>
</tr>
<tr>
<td>2.</td>
<td>Factor Plot for Combined Data</td>
<td>69</td>
</tr>
<tr>
<td>3.</td>
<td>Factor Plot for Toepfner Mound</td>
<td>73</td>
</tr>
<tr>
<td>4.</td>
<td>Factor Plot for Davis Principal Components</td>
<td>79</td>
</tr>
</tbody>
</table>
Chapter I
THE CHRONOLOGICAL PROBLEM IN OHIO AREA PREHISTORY

The emphasis in modern archaeology on cultural process and the explanation of change contrasts sharply with the way archaeology has been conducted in the Ohio area in years past. A cultural-historical approach has dominated area prehistory for many years, exemplified by the classification, description, and comparison of archaeological phenomena in anthropological terms. The major product of this approach has been archaeological cultures defined by artifact types. The process of defining particular cultural types was made formulaic through the application of standard classification methods such as the Midwestern Taxonomic System (McKern 1939), and the Willey System (1966; see Stoltman 1978). Although productive in the early history of Ohio area archaeology, today they prevent a modern scientific approach to understanding the archaeological record. This typology is the single major barrier that prevents a modern scientific approach to the archaeological record in Ohio.
American archaeology's adoption and institutionalization of the cultural-historical approach in the past was largely due to the dominance of museums in the early history of the discipline. The organizational needs of museums, amassing data from archaeological excavations for decades, demanded comparative and descriptive methods for classification.

Anthropology at the same time was coming to grips with the concept of culture. Archaeology naturally perceived it's record as representative of ancient tribes or cultures studied by the anthropologists. Cultural change was perceived by archaeology in its simplest form: sequential replacement of whole cultures. Time and space analogies existed everywhere in the contemporary world in the form of American Indian tribes. Anthropological techniques that were developed to study the American Indian culture were commonly viewed as directly applicable to the archaeological record.

This strategy was expressed profoundly true in the application of geographical and diffusional studies to material culture. Cultural and historical information was thought to be directly recovered through comparative and descriptive analyses of artifacts. The possibility of finding alternative theories to account for this material record were never really contemplated. The anthropological paradigm based almost exclusively on the normative concept
of culture, and later, on culture area theory, dominated the imagination of archaeologists throughout the major portion of the history of American archaeology. The dependence on analogy to ethnographic cultures handicapped the development of an independent study of the archaeological record based on its own peculiar properties and capacities.

Since the early 1950's, the development of radiocarbon dating has revolutionized the concept of time in archaeology. C-14 dating, along with other developments in dating method, provided an alternative to using cultural forms and artifactual characteristics, as determiners of time relationships. Time in the formulations and ideas about the archaeological record by prehistorians took on a continuous dimension, rather than a ladder-like scheme. It was immediately possible to free archaeological inference concerning cultural relationships from its dependence on cultural forms.

With C-14 dating the spatial scope of chronological comparisons was greatly expanded. Absolute time allowed the calendrical relation of cultural episodes from different parts of the world to be made, regardless of intervening miles, and geographical or cultural barriers. With the introduction of C-14 dating came a greater potential for discriminating patterns in time, which provided archaeologist's with the opportunity to pursue purely archaeological
problems in the archaeological record. Such a freedom offered the excuse to abandon the constricting geographical methods and the monolithic theoretical orientations and adopt a much more open and debated, theory oriented outlook, which included not only anthropological approaches but other approaches as well.

However, developments in methodology and theory have had to struggle with vestiges of the previous paradigm. The struggle, in terms of chronology, can be characterized as a dispute over two views of time: a normative, static concept allied with the earlier approach (McKern 1939; Griffin 1967; Willey 1966; Stoltman 1978) and a dynamic, continuous concept associated with new dating methodologies (see Rowe 1959; Swanson 1959; Binford 1968; Plog 1974; Dunnell 1978). The former has been associated with culture-history, and the latter with the scientific method. The old paradigm produced unchanging cultural units sequentially ordered in time as separate and distinct cultural entities. The new paradigm accentuates the role of processes of change within systems of genealogically continuous social groups.

Although archaeology nationally has changed over the past three decades, developments in Ohio area prehistory have slipped behind. With respect to the new theoretical and methodological trends in prehistory, students and researchers have had to realize only recently the full sig-
nificance and implications of the new paradigm. The historical dominance of classification, description, and formal comparison in research, recovery, and interpretation of the record in the Ohio area permeates nearly every level of work. The scope and nature of the cultural typologies since the beginning of this century has affected the conduct and impeded innovation in archaeological method. The spatial, cultural, and temporal taxonomy was well developed by the 1930's and '40's, and in fact its broadest outlines were discernable in the late 1800's. The record of Ohio area prehistory was recovered during these crucial beginning years and organized within this taxonomic framework. Dissertations on the archaeology of the Ohio area over the last twenty or so years still reflect the implicit acceptance of this static, normative model of regional prehistory. Work is conducted within this taxonomic framework, characteristically involving further description, finer temporal, formal, or geographic segmentation, cultural reconstructions, or theoretical arguments involving relationships in time and space between taxonomic units. The methodology of the new archaeology and even its jargon are employed in this work, but the goals of understanding cultural process are not implemented largely due to the mismatch of method and theory. Radiocarbon dating has been employed merely to confirm the descriptive cultural-
temporal categories. The revolutionary potential of absolute radiometric dating techniques has not altered in any major way the organization and structure of the established record, nor the majority's conception about Ohio area prehistory.

The goals of studying the process and change of human culture calls for a dynamic, systems concept of culture and prehistory, in which time is measured independently from cultural forms and acts as another dimension of the archaeological record analogous to the spatial dimension, that is, a continuous dimension across which archaeological phenomena can be mapped and measured (Rowe 1959; Plog 1974). There are two major barriers to accomplishing this within Ohio area prehistory: (1) the nature of the record itself and (2) the way archaeologists employ dating techniques. As most of the record was recovered before the advent of modern dating techniques, organic materials are usually inadequate or unsuitable for dating purposes, creating a challenge to methodological development. In addition, chronology is not thought of as a theoretical study involving datable materials, the target event of interest, and aspects of the dating method. In fact, chronology has been viewed within the new archaeology as synonymous with history and particularistic, idiographic, individualistic description (see Trigger 1973), an unappetizing kind of
scholarship in the opinion of some archaeologists. The objective evaluation of the characteristics involved in the relationships between dating materials, target events, dating methods, natural and physical conditions of burial context, and recovery, as well as archaeological goals and problems, are necessary preconditions to any archaeological study interested in regional problems dealing with systemic changes in culture and evolutionary or developmental processes (Plog 1974; Dean 1978).

Chronology in Ohio area prehistory, with few exceptions, has either not attempted, or misused, the new techniques for organizing the established record. Where radiocarbon dates have been used, it has been without an awareness of C-14's full potential value. Virtually every study using C-14 dates has done so without critical or explicit evaluation of the measurement's relationship to the condition of the dated material, the target event of interest, and problems concerning the sample's preparation and measurement. Most C-14 dates are used as if they were descriptive characteristics like other taxonomic traits, subordinated in significance to the reconstructed cultural unit.

The established record in the Ohio area consists almost exclusively of the remains of the mound builders who left numerous monuments to their dead over most of south-central Ohio. A major advancement in understanding the
temporal organization within and between separate burial mounds, and within and between the taxonomic burial-cultures, would revolutionize the greater bulk of Ohio area prehistory. This would affect as well a significant change in conception of Eastern Woodlands's development, cultural change, and cultural relationships.

The most consistently recovered item of dating significance for the mound builder history are the remains of the mound builders themselves. The development of bone dating techniques would be invaluable to the problem of systematically reorganizing the chronological record of Ohio area mound builders in concordance with the new theoretical paradigm. This would mean the dismantling of the old cultural-historical sequence and its replacement with independent dating schemes tailored to the theoretical study of systemic culture change and the explanation of the development of culture in Ohio area prehistory. Such an attempt, if successful, has the potential of expanding the scope and refining the scale of Ohio area studies, increasing its flexibility. It is capable of improving our understanding because the bulk of the record still is unorganized by modern temporal means, and currently research has stagnated under the old taxonomies.

This study will focus upon fluorine and nitrogen dating of human skeletal material from the Davis and Toepfner bur-
ial mounds. Davis and Toepfner were selected because they each contained a stratified set of burial features important to the evaluation of the time sensitivity of the fluorine and nitrogen dating technique. Although the fluorine and nitrogen dating techniques are relative dating techniques, they are important to intra-site chronologies, especially since sites are used as analytical units for cultural comparisons and seriations. A major hindrance to the study of temporal patterns of cultural change is the problem of comparing site assemblage types as if they were deposited contemporaneously. Recognizing that sites are accumulations of archaeological materials over extended periods of time, relative dating techniques are valuable aids for understanding their formation, and sorting out chronological links with other sites.

The dissertation is organized in the following manner. The methodology used in developing the research strategy for the entire study opens the discussion. This includes a description of the particular fluorine and nitrogen measuring techniques, followed by a chapter describing the sites and their samples. Next are sections on the research results beginning with preliminary descriptive statistics, followed by a specific analysis of the accelerator problems and bone preservation factors affecting the fluorine and nitrogen measurements, and ending with a chapter on the stratigraphic context of the fluorine and nitrogen dates.
Chapter II
METHODOLOGY

RESEARCH STRATEGY

The dating techniques to be studied here are the relative measurements of fluorine and nitrogen as neither of these methods has been exclusively employed in Ohio (to my knowledge, fluorine and nitrogen assay of bone has never been used), the research project was structured in the form of a series of experiments to test and evaluate the success of each technique in measuring time. In general, only initial experimental situations were planned. As new questions arose from initial results or different measurement problems, additional experiments were conducted.

The fluorine and nitrogen tests are applied to human skeletal materials from two burial mounds. These burial mounds are artificially constructed hills of clay and soil, containing the accumulated remains of several burial events. These separate burial events took place over an extended period of time in one area. The consistent reuse of the same locality, as well as the striking similarities in burial treatment and grave goods from one burial to the
next, indicate a ritualistic use of the area coupled with a systematized belief in death and the afterlife. The ritualistic focus and burial use of the locality over an extended period resulted in the accretion of a large number of graves. Unlike other cemeteries, the development of these sites was vertical rather than horizontal, emphasizing the ritualistic significance of the space itself. Consequently the internal structure of the graves within the mounds is roughly one of superposition, at least as they are expressed at the Davis and Toepflner mounds. This means that the first and oldest graves at each site are overlain by successive layers of progressively younger and newer graves. This feature allows precise determination of a skeleton's relative burial age with respect to other skeletons in the mound, thus affording an opportunity for independently evaluating the fluorine and nitrogen measured ages from the same skeletons.

Although these burial mounds are not typical cemeteries because they contain for the most part only adults and are characterized by a large number of high status individuals at least as this relates to the differential association of grave goods with individual burials, the use of the site is probably by a single community and its lineal descendants. These communities were probably practicing foraging and subsistence economies within restricted territories con-
fined to the boundaries of a single watershed. Although the mound burial phenomena is widespread throughout the middle and upper Ohio Valley at the time range of the Davis and Toepfner sites, this is probably not an indication of mass movements and migrations of people over large areas. Most mound sites throughout the region show general similarities to one another, yet they also manifest indiosyncratic differences which argue for separate group participation in a general system of ritual and belief centered on death and activities associated with burial. This probably reflects a common social purpose for this ritual amongst the participating societies that grows more expansive over time and finally culminates in the massive and extensive network of the Hopewell culture.

This conception is important to the evaluation of the fluorine measurements in that the uptake of this element through the available water system in the living population is likely to remain roughly the same from individual to individual if their seasonal movements are confined to small territories. The redundant and ritualistic nature of mound burial itself argues for a social function whereby conflicts and strains over resources or territory are relieved peacefully through systematized sets of social activities and relations—ships which transform potentially volatile competitive episodes into cooperative and peace-
full interaction. Through the institutionalization of a shared system of ritual and belief, a higher level of integration can be achieved in the social cultural system, which emphasizes local specialization and production in concert with extra-local sharing and exchange systems.

The basis for the network of exchanges is probably personal or family relationships established between local communities by means of a common ritual and belief system made significant through actual or classificatory changes and expansion of the kinship organization, perhaps through marriage exchange. The subsequent kin-network may therefore include new social categories that extend beyond local communities and territorial boundaries, similar to a clan organization within a tribal system. The burial mound itself may be an aspect of this extra-community kin or social network, symbolically representing the social and cultural subsystem responsible for maintaining equilibrium as well as the growth in the cultural system through the integration of previously independent social segments.

Relationships of burials and burial features within single mound sites offer opportunities to investigate problems of change in the ritualistic use of prehistoric burial areas and thus contribute to an understanding of their nature and history. The relative dating measurements of human bone suggest a means of deriving such information. How-
ever, the application of fluorine and nitrogen dating methods to the dating of human skeletal materials is not possible without first examining extraneous variations that may alter the meaning of the measurements. Problems exist such as variations in the materials themselves, in the preservative coating used by museums found on many of the bones, in the geochemical variations of the bone's burial context, and in the analytical procedures themselves as they relate specifically to human bone specimens. It is unknown whether effective results can be obtained for archaeological dating useable on a wide scale. Consequently, the project tried to define the feasibility of these techniques under practical circumstances and identify any potential problem areas that may arise due to their application to Ohio mound data.

The Davis and Toepfner burial mounds were selected for this study because they contain skeletons in stratigraphic order spanning a time frame between late Archaic through late Adena cultural periods (approximately the first millennium B.C.). These mounds collectively represented the longest stratigraphic sequence for these cultural periods in the south-central Ohio area. It should be noted that such extensive stratigraphic records are rare in mound sites in general, and the recovery and recording of such information in a suitable form for any kind of study is
even rarer. The potential overlap in time between the two mounds, based on artifactual similarities, was a second reason for choosing the two sites. The stratigraphically ordered skeletal series from each site provided an independent measure of time against which to evaluate the relative dating techniques. In addition, C-14 dates obtained from wood charcoal and bone collagen formed a second independent time check.

The Davis and Toepfner burial mounds were also chosen because they occur in stable depositional contexts. This is important because the elements under study are sensitive to variations in the geochemical environment, which consequently need to be controlled in order to separate their effects from age effects in the skeletons. Within restricted areas of similar geomorphology, ambient environmental conditions can be assumed to be roughly equivalent for the buried bone in terms of these elements. Thus, the rates of fluorine accumulation (Hagen 1973; McConnell 1962), uranium uptake (Bowie and Davidson 1955; Fitting 1965), and nitrogen loss (Oakley 1970; Ortner et al. 1972) should remain the same within relatively closed geochemical systems. However, at sites where factors such as climate, soil composition, pH, ground water content, and temperature are variable (Garlick 1970; Jelinek and Fitting 1963; Ortner et al. 1972), the relative configuration of these three
elements in bone will vary with differences in the bone/environment interactions. If skeletons from the two mounds are determined to be roughly contemporaneous based on one of the independent dating techniques, then any variations in the elemental content would probably be due to environmental factors, within the limits of standard errors of the measurement. If stratigraphy or C-14 dates indicate non-contemporaneity, then measurement differences are predicted and variations in the measurements should be in accord with their stratigraphic or C-14 date, that is, if there is no environmental variation, again within the limits of the standard errors of the measurement. Determining the degree of tolerance to geochemical variation for dating purposes is an important consequence of this investigation.

Determination of the geochemical effects is also important in discovering how widely the dating techniques can be extended geographically without modification. It will be important to evaluate site-specific differences because the ultimate usefulness of these relative dating techniques will lie in their capacity to be linked together with other independent local sequences to form geographically extensive chronological frameworks (see Haddy and Hanson 1973 for a practical application). If minor variations in the depositional environments are tolerable, measurements between sites can be directly compared. If not, the dif-
ferences in the relative amounts of the elements from different sites will form parts of closed systems that must be linked by other means. Usually this can be accomplished by cross-dating with such techniques as radiocarbon dating of bone collagen (Longin 1970), bone amino-acid racemization rates (Bada, Schroeder, and Carter 1974), and artifact style seriations based on shared similarities. Determining the limits to which these closed systems of rankings can be geographically extended is an important factor in evaluating their usefulness for dating purposes. Comparison of the two study mounds will provide a preliminary benchmark for this determination. Uranium was early considered as a good candidate for experiment but was dropped from more intensive study because of three problems that threatened to be major consumers of time and expense. The first uranium dating method considered made use of Ge(Si) counters ("Geiger" type) to measure the Alpha and Beta decay products of radioactive uranium in prepared bone-powder samples. This technique was extensively tested by the Michigan Memorial--Phoenix Project Number 132 (Jelinek and Fitting 1965). The method was found to be highly variable in its results for a variety of reasons: differences in sample preparations and degrees of washing, sample weight variances, soil inclusions, mechanical difficulties of grinding and the resultant particle size distributions,
surface configurations of the bone powder in relation to
the detector surface, moisture content of the sample and in
the laboratory atmosphere during counting runs, anatomical
and species differences in bone samples, density of bone
variations, variations in chemical and physical conditions
of the bone samples, pH and other chemical or physical dif-
ferences in the burial matrix, and so on (see Jelinek and
Fitting 1963; 1965). Second, the relative recentness in
age of the specimens considered in the present study sug-
gested that the sensitivity of chemical analyses would be
poor because of the low accumulation of uranium in the bone
(bone "absorbs" uranium from ground water over time).

Although neutron activation as a uranium detection tech-
nique avoids these problems, preliminary attempts at The
Ohio State University Nuclear Reactor Lab identified spe-
cial problems of activation time spans and the "noise"
interference of other elements in the bone that obscured
the spectra and masked uranium peaks. The improvement of
the detection and measurement of uranium peaks would take a
long series of experiments, comparing different activation
times, neutron flux rates, and resultant spectra for opti-
mum results. Although this strategy appeared promising, it
also seemed to be time consuming and costly for the present
purposes. For these reasons, efforts were concentrated
instead on the fluorine and nitrogen dating methods.
**FLUORINE AND NITROGEN DATING METHODS**

Two techniques were employed in the measurement of fluorine and nitrogen of bone. The chemical analyses were performed by the laboratories of Hazleton Raltechs, Inc., in Madison, Wisconsin. Their methods of analysis are published by the Association of Official Analytical Chemists (Horwitz 1980). The volumetric titration method was employed for fluorine (Horwitz 1980:392-395); the micro-Kjeldahl technique for nitrogen (Horwitz 1980:15).

The nuclear measurements were performed at The Ohio State University Van de Graaff Accelerator Laboratory.

Both fluorine and nitrogen were targeted for simultaneous measurement using a 3.4-4.0 Mev proton beam. Previous determinations of the fluorine contents of various samples such as teeth, food samples, and bones, have been made using the nuclear reaction $^{19}$F$(p,p')^{19}$F at low beam energies (Haddy and Hanson 1982:38; Kenny 1981; Shroy et al. 1978; Way 1982:228). Fluorine was clearly identifiable in the present samples. The measurement of nitrogen was not entirely successful in these experiments due to its different nuclear properties. Gamma-ray spectra from the bone targets were obtained for a variety of elements using a Ge(Li) detector. Spectra were collected and analysed by means of the Van de Graaff Lab's microcomputer and software. Six clearly definable fluorine peaks were detectable.
for each sample, three at either end of the spectra (see Figure 1).

Several excellent papers have been written since 1947 concerning the history and development of applications of both nitrogen and fluorine dating techniques to bone (Cook 1960; Cook and Ezra-Cohn 1959; Cook and Heizer 1947; 1953a; 1953b; Garlick 1963; Groff 1971; Heizer and Cook 1952; McConnell 1962; Oakley 1947; 1948; 1949; 1951; 1955; 1963a; 1963b; Olsen 1950; Ortner, VonEndt, and Robinson 1972; Stewart 1951; 1952; Zeuner 1960). Haddy and Hanson have recently summarized the premises and conditions upon which nitrogen and fluorine dating of buried bone and teeth are based (1982:37-38). In brief, nitrogen makes up about 5% by weight of living human bone. This is largely in the form of protein collagen, which decomposes with time into amino-acids that can leach away in the burial environment. The rate at which nitrogen decreases with burial time is dependent on such geochemical variables as temperature, soil pH, oxidation, ground water content, and protein attacking micro-organisms. Fluorine dating, on the other hand, is based upon an accumulative process. In general, fluoride ions replace hydroxyl ions in the hydroxyapatite crystal lattice of inorganic bone (Ca10(PO4)6(OH)2), to form the much more stable mineral in burial environments, fluoroapatite ((Ca3F)2(PF4)6Ca4). (In reality, the
Figure 8: Typical Van de Graaff Accelerator Low Energy Portion of the Gamma-ray Spectra of Human Bone.
mineral substance of living bone and teeth is a multi-phase solid composed of amorphous and crystalline calcium phosphates of various kinds (see Dallemagne and Richelle 1973 as well as Weatherell and Robinson 1973:54-55, 66). The source of the fluoride ions is the ground water of the depositional environment in which the bone is buried. The rate at which fluorine accumulates in bone depends upon factors such as temperature, soil pH, fluorine concentrations in the ground water and soil matrix, conditions affecting the amount of ground water available and its rate of percolation across the boney material.

In addition to the geochemical context, determination and evaluation of fluorine and nitrogen values requires consideration of the comparability of different anatomical bone types and the consistency of nitrogen and fluorine concentrations within and between bone types (Haddy and Hanson 1982:37-38). The chemical alterations involve essentially surface processes that produce depth gradients of nitrogen concentration (Hare 1980:217) and fluorine (Coote et al. 1982). Individual bone profiles are affected by permeability characteristics unique to every specimen and bone type. For instance, profile differences may be expected between compact and cancellous bone, or human and nonhuman bone (Ortner et al. 1972:519), or between thin and thick bones (Haddy and Hanson 1982:37). The porosity
of different bone types affect nitrogen and fluorine cross-sectional distributions from the outside to the inside. Thus, nitrogen content is expected to be lower at the surface and higher internally because of surface loss, and fluorine just the converse. These factors are important in choosing particular anatomical bone types or portions of each bone specimen for measurement. This is especially important in the evaluation of the accelerator determinations because of the physics involved with the proton beam/target/detector interaction.

The detection limits for any element in bone using the accelerator techniques are dependent on proton energies, the efficiency of the gamma-ray detector, and the amount of interference between other constituent elements in the bone. The detection depth or penetrance into the bone is dependent upon beam energies primarily. The proton beam usually cannot penetrate entirely through a bone target thicker than 0.25 mm. Thus, at low beam energies of 1.5 Mev, 90% of the gamma-ray yield for fluorine in bone comes from the first 15 microns nearest the surface facing the beam; at 2.5 Mev, 90% of the detected gamma-rays come from the first 35 microns of bone (Coote et al. 1982:218), and with beam energies of 4.0 Mev, as much as 75 microns of bone is penetrated by 90% of the beam. In contrast, nitrogen generated gamma-rays for a beam energy of 4.0 Mev will
virtually all come from just the first 19 microns of the bone surface. Therefore, within the range of beam energies marking the detection limits for any element under study, varying the beam energy throughout this range will produce a kind of depth probe of the bone, where higher energies will penetrate deeper into the target surface. However, the physics of some elements offer better opportunities than others to take advantage of this phenomenon, for instance, fluorine nuclear microprobe ranges versus nitrogen at low beam energies.

In addition, actual chemical gradients in whole bone are normally far greater than the ranges of the nuclear microprobe. Fluorine distributions in prehistoric bones have been shown to vary between thousands and tens of thousands of microns in depth (Badone and Parquhar 1982; Coote et al. 1982:216-217), making the depth profiles from the nuclear microprobe of less than a hundred microns insignificant in relationship. Little useful information can be obtained from varying beam energies alone as suggested by Haddy and Hanson (1982:39). However, Coote et al. (1982) have been successful in obtaining fluorine depth profiles by combining the nuclear microprobe, using special steering and focusing techniques, with perpendicularly cut bone specimens that expose progressively deeper bone material to the beam spot. Gamma-ray yields for nitrogen of less than 20
microns for similar beam energies make depth profiles nearly useless even with specially prepared perpendicular bone cuts. This weak bone penetrance of the proton beam's energy resonant for nitrogen may make the results of this measurement problematic for dating purposes, since the first 20 microns of the bone surface has experienced the highest protein loss, and nitrogen quantities in this range may be extremely small except for very recent bone specimens. In sum, any accelerator techniques using low energy proton beams must be evaluated with respect to the shallow surface penetrance of the bone targets, coupled with an awareness of the greater depth profiles of actual fluorine and nitrogen gradients in fossil bones.

Another methodological concern is with the inconsistency of nitrogen and fluorine concentrations from one bone to the other: nitrogen varies from a high percentage by weight in immature bone to a low in aged individuals and initial fluorine concentrations can vary with rates of dietary consumption. With this in mind, as well as the depth profile problems mentioned above, both Haddy and Hanson's study and the present one have selected only adult skeletons and similar anatomical bone types as sample material. However, it is important to point out some significant differences between the Ohio research presented here, and Haddy and Hanson's Moundeville, Alabama study.
Although Haddy and Hanson recognize the importance of comparable bone types and proximate geoenvironmental contexts for the evaluation of results, their analysis is based on nineteen bone specimens, from seven different mounds, and from seven different parts of the skeleton (7 ulnae, 5 tibias, 2 clavicles, 2 metatarsals, 1 femur, 1 ilium, and 1 rib). Much tighter control of inter- and intra-mound variations in burial contexts and much reduced variability in anatomical bone types was achieved in the present study.

The accelerator technique used by Haddy and Hanson called for the use of ground bone samples pressed into aluminum planchets 2 mm. thick, in contrast to the use of whole, unaltered bone here. Grinding bone into powder obviously results in the mixture of original bone depth gradients for fluorine, which cannot be recovered using different proton beam energies suggested by them in their paper (1982:39), nor by the special bone cutting techniques of Coote et al. (1982). As a consequence, the resultant fluorine measurements are some unknown mixture of the real fluorine content. The technique developed at The Ohio State University Van de Graaff Laboratory by Dr. Petra Schmalbrock allowed the mounting of whole bone specimens directly in the beam line because of a special target holder. Even though proton beam penetration is very small at the low beam energies used here (indeed, extremely small
for nitrogen), the technique has provided useful data because the kinetic and diagenetic processes that any fossil bone experiences over time affect the concentrations of fluorine and nitrogen through the surface. Therefore, the technique is an appropriate one in detecting these changes.
Chapter III
THE SITES AND THE SKELETAL SAMPLES

The skeletal samples included in this study come from two burial mounds located in Franklin County, Ohio. Each of the samples are described below following a brief summary of the location and excavation of the mounds.

DESCRIPTION OF THE SITES

The William H. Davis mound was located on a gravel ridge north of U.S. Route 40, east of Columbus on a bluff overlooking Big Walnut Creek, in Franklin County, Ohio (Latitude 39 degrees 57 minutes, Longitude 82 degrees, 50 minutes). It was totally excavated in 1959 by the Ohio Historical Society (see Baby 1959 and Baby and Mays 1959).

The mound was threatened by ground leveling activities associated with a housing development. As curator at the Ohio Historical Society, Raymond Baby was able to organize a salvage excavation, but not before bulldozers had already stripped the top of the mound to an unknown depth. At the time Baby first saw Davis mound it was twenty feet high and eighty feet in diameter. He recorded measurements for the
surface elevation of the mound but was unable to complete a map because of time. In general, this is true of most of the internal features of the mound as well, where location-al coordinates are meticulously recorded, but only a few rough, free-hand sketch diagrams are available. The only completed mound profiles drawn in the field came at the beginning of the excavation when no burial features were encountered.

The excavation of Davis mound, like most of the mounds excavated by Baby, utilized the so-called "Chicago" method. A base line was established off the periphery of the mound, and a perpendicular bisecting axis laid from this base line across and through the top of the mound pointing to grid "north." To the left and right of this perpendicular bisector (the zero line) were parallel grid lines five feet apart, labelled with their distances from the zero line and a left or right designation (i.e., 0, R1, and R2 stood for 0 feet right, 5 feet right, and 10 feet right respectively). Lines perpendicular to the zero line and parallel to the base line were established at 5 foot intervals froming grid squares designated by the coordinates of the grid's southwest corner (i.e., 5L1, 5L2, and 5L3 indicated 5 feet "north" and 5 feet left, 5 feet "north" and 10 feet left, and 5 feet "north" and 15 feet left respectively). The grid designation was a field strategy to simplify and speed
the work. Comprehending the system in the field notes afterwards was more difficult.

The first step in the excavation of the mound was the digging of a trench through the base line squares in search of the mound skirt. Usually the first trenches across the central zero line failed to identify anything but sterile dirt. This was part of the excavation strategy, the result of placing the base line outside the boundaries of the site. Eventually, moving the trench line along the zero axis towards the mound center resulted in the identification of the mound edge in a bulk profile. At that point it was mapped and the lowest elevation noted. This mound "floor" largely determined the subsequent process of the excavation. New units would be opened to the front of the excavation direction to a depth corresponding to the mound floor. Thus, the mound was "emptied" like a container one square at a time.

No complete profiles were drawn at Davis in the central part of the mound where burial features were numerous. In addition, only the central mass of the mound was completely excavated. Many portions of the mound edge were not investigated. This was largely influenced by the salvage nature of the operation. Information recorded for the burial features, however, was detailed enough to carry on an examination of the stratigraphic relations of the individual mound burials.
Toepfner mound was two hundred feet in diameter and thirty feet high, located on the floodplain of the Scioto River, two miles above the junction with the Olentangy River within Columbus City limits, also in Franklin County, Ohio (Latitude 39 degrees, 58 minutes, and Longitude 83 degrees, 2 minutes). The two mounds are only about ten miles from one another.

Excavation at the Toepfner mound began in the fall of 1953 and was completed during the spring of 1954 by the Ohio Historical Society (see Baby 1953-54). Toepfner had been previously threatened with destruction in 1946 when the owner, Mr. Pope, advertised the lot for sale (Toepfner mound was then called the Pope Mound, and previous to that, the Anderson Mound). Richard G. Morgan, curator of archaeology and the Ohio Historical Society Museum, developed public support with persuasive arguments for Toepfner's incalculable value to Ohio prehistory. With the help of the Dublin Road Neighborhood group he was able to delay the owner's plans for several years. Although a resolution was drafted by the Dublin Road Neighborhood group asking the Ohio Historical Society and the State of Ohio to purchase the land in order to "be preserved as a place of beauty and historical interest," this never came about. When matters once again came to a head in mid-1953, Raymond Baby had to conduct a salvage excavation, although given time from the
new land owner (Mr. Toepfner) to complete the operation. Heavy construction equipment was donated by the land owner to strip the mound of trees and to excavate everything but the main central core of the mound which was some thirty feet high. The mound's diameter was originally two hundred feet.

The Toepfner excavation was recorded in the same manner as Davis mound. The determination of the stratigraphic relationships from the written record was aided by the concentration of work in the central core of the mound due to the way the bulldozers were employed in the initial preparations. When cold weather set in late in 1953 a small wooden building was built over the portion of the mound still unexcavated. Work continued up to freezing conditions and was finished early in the spring of 1954 after the thaw.

These two mounds were selected for the present study because they contain stratigraphically ordered burials and together span a time period ranging from late Archaic to late Adena. The stratigraphic relationship of the burial features and the skeletons within them was determined from the original field notes. For the most part this was a straightforward task at Toepfner of collecting the correct notations for a particular feature from the various day entries in the notes. This was due to the superimposed
nature of the log tombs over the central sub-floor grave pit. Some analysis was necessary, using Baby's description and observations, to determine the stratigraphic relations of the three sub-floor pits at Toepfner, but the notes make clear Feature #12's intrusion by subsequent grave pits through the disturbance of the bark covered gravel ring which surrounded it (see below).

Davis, on the otherhand, was not as straightforward. Burial features were much smaller, less well preserved (not as visible archaeologically), and not as tightly focused on a single central axis. The field notes were somewhat less clear than Toepfner's on a day-to-day basis, but complete coordinates of the position of each burial feature, and their contents were recorded, including many sketch maps and profile drawings. From these it was possible to reconstruct a three dimensional map of the mound structure, and to determine the stratigraphic relationships of all major features. This map was compared against the observations in the field notes until congruence was affirmed completely.

For the stratigraphic relations at both mounds, decisions were made to include a feature or skeleton in the sample only after complete analysis of all the data, including the matching of skeletal numbers in the museum collection with their provenience in the skeletal inventory
and the field notes, produced no ambiguities or alternative positions. In other words, the rank order for each of the mound's skeletal series are the best that can be expected from an examination of the field notes, and, in my opinion, Baby's field records provided excellent conditions to accomplish this, although at times this turned out to be very tedious.

A total of 22 samples are described below, nine from Davis mound, and thirteen from Toepfner mound. The relevant data for the Davis samples are shown in Table 1 and 2 and for the Toepfner mound in Tables 3 and 4.

**THE SKELETAL SAMPLES FROM THE DAVIS MOUND**

The bone series from Davis Mound came almost entirely from a single stratified, sub-floor burial pit (Feature #4), which was intruded from above by the earliest Adena burial in the central mound area (Burial #22). Many of these sub-floor Archaic-type burial pits at the Davis site demonstrate excellent bone preservation because of well-drained gravel and sand subsoil. However, the burials generally in the mound fill at Davis were in advanced states of deterioration probably due to the relatively impermeable clay with which it was constructed (see Table 1).

Within Feature #4, very well preserved bone samples were found from a series of fourteen superimposed flexed burials
Table 1

Description of Davis Mound Skeletal Samples

Abbreviations in the following table refer to:
unk=unknown; ext=extended; sem-flx=semi-flexed; flx=flexed.

<table>
<thead>
<tr>
<th>Stratigraphic Position</th>
<th>Feature &amp; Burial #</th>
<th>Bone Condition</th>
<th>Burial Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>F.1, B#3</td>
<td>Very Poor</td>
<td>unk</td>
</tr>
<tr>
<td>8</td>
<td>F. X, B#11</td>
<td>Very Poor</td>
<td>ext</td>
</tr>
<tr>
<td>7</td>
<td>F. X, B#18</td>
<td>Very Poor</td>
<td>ext</td>
</tr>
<tr>
<td>6</td>
<td>F. 20, B#21</td>
<td>Very Poor</td>
<td>ext</td>
</tr>
<tr>
<td>5</td>
<td>F. 3, B#22</td>
<td>Poor</td>
<td>sem-flx</td>
</tr>
<tr>
<td>4</td>
<td>F. 4, B#22A</td>
<td>Poor</td>
<td>flx</td>
</tr>
<tr>
<td>3</td>
<td>F. 4, B#22D</td>
<td>Poor</td>
<td>flx</td>
</tr>
<tr>
<td>2</td>
<td>F. 4, B#22L</td>
<td>Good</td>
<td>flx</td>
</tr>
<tr>
<td>1</td>
<td>F. 4, B#22N</td>
<td>Good</td>
<td>flx</td>
</tr>
</tbody>
</table>

arranged more-or-less vertically in a deep, circular pit, 2 feet in diameter and 5.5 feet deep. The three burials at the very bottom (Burial's #22L, M, and N), were bundle burials and are among the best preserved of the entire segment. Burial #22L provided a collagen date of \(1180\) BC \(±\) 60 (DIC-2838). Two burials were associated with artifacts, which included three hematite plummetts with Burial #22B, and two triangular mussel shell pendants fused together beneath the temporal region of the skull of Burial #22F.

Burial #22 (Feature #3) was found directly above the last burial in Feature #4 (Burial #22A). It was deposited in a bark-lined, roughly circular pit, just large enough to Accommodate the semi-flexed body (that is, its legs were flexed) and associated with a slate atlatl handle. This
burial was incorporated in or covered by the bark floor of the lowest prepared Adena tomb in the mound, Feature #20. Feature #20 was approximately oval in shape about 9.5 feet long (east-west) and 5.8 feet wide (north-south) and lined with bark strips probably held in place by small poles. Two extended adult burials were located in Feature #20 (Burials #20 and #21). Burial #21 was an extended adult with head toward the northwest. It was buried with a diagnostic early-middle Adena limestone blocked-end tubular pipe with a sandstone pellet, (Dragoo 1963), as well as stemmed points and thick pottery fragments identified elsewhere in the mound by Baby as Fayette Thick (see below). It also had with it a stemmed reamer. Burial #20 appeared to have been placed in the fill covering Burial #21. It was only a partial burial (articulated portions of the skull, cervical vertebrae, left rib cage and left humerus), extended in an east-west direction, with head to the west.

Above the lower extremities of Burial #21 where found Burials #15, #16, and #17 in a complex feature (Feature #2). Feature #2 was an elongate oval pit 8.7 feet long (east-west) and about 6 feet wide (north-south) with a bark floor upon which the burials were lain. Just above this grave were Burials #11, #12, and #18, probably all from an unnumbered feature (designated 'F.X' in the following tables) disturbed in the prehistoric excavation of Feature
2. The recognition of these burials as derived from another feature only came after the definition of Feature #2. These burials were originally extended with heads to the north. Burial #18's remains were pushed into a corner of Feature #2. Another burial (#13) apparently was placed inside Feature #2 after Burials #15, #16, and #17 where interred, since it extended over the lower extremities of Burials #16 and #17. The head of Burial #13 was pointed to the southwest, opposite the general direction of Burials #15, #16, and #17.

A distinctive artifact of Feature #2 was the bottom of a grit-tempered Fayette Thick pot, apparently reused as a bowl, and associated with Burial #15. Many other grit-tempered Fayette Thick pot sherds were found throughout the feature as well. Burial #17 contained additional grave goods: a limestone, two-holed, rectangular gorget; a tubular clay pipe; two stemmed points, one with a straight base similar to the fractured base stem in Feature #3, Burial #21 (Archaic/Cresap-like?), and the other an Adena-stemmed; a large stemmed spear point; and a knife of Flint Ridge flint.

Burial #18 was badly disturbed and not associated with any artifacts, but it was located stratigraphically above Burial #17 and contained enough bone material for an analysis. An isolated skull found next to the left femur of
Burial #15 (Feature #2) is thought to have been from Burial #18 (the rest of the torso was apparently removed during the preparation of Feature #2). However, the excavation and stratigraphic evidence for this was inconclusive.

Located stratigraphically above the remains of Burial #18 and Feature #2 was Feature #1. Feature #1, from which Burial #3 was excavated, contained three individuals in a complex bark-lined grave. The long-bones of Burial #3 were painted with red ochre, and the body was laid out in an extended position within an oval, bark-lined grave over six feet long (east-west) and almost two feet wide (north-south). Included with Burial #3, which provided the bone samples, were a "quatra-concave" slate gorget (Baby 1959:6), a broken Adena-stemmed projectile point, and a pestle located near the body. Also in this grave was the skull of Burial #4 associated with some copper beads. A smaller bundle burial (Burial #5) was attached to Feature #1. It apparently was placed in an oval, bark-lined basin 3.1 feet long (north-south) and 2.3 feet wide (east-west) conforming to a fire-pit filled with charcoal, ash, and fire-cracked rock still in place below it. Associated with Burial #5 was a clay tubular pipe with an expanding stem.

Listed in Table 2 are the bone types used for the two methods of analysis. Most of Davis' samples were provided by long-bones. Preservation of the skeletal remains was
very poor at Davis. Often only crumbling fragments were preserved. The gravel pit burials in Feature #4 were better preserved allowing the use of ribs instead of long-bones. One burial in the stratigraphic sequence could only provide cranial material for dating. Samples in the chemical analysis many times were composed of different skeletal segments in order to obtain the required ounce of material (see Table 2).

Table 2

**Bone Types For Davis Samples**

Abbreviations for the following table refer to:
1-b=long-bone fragments; misc=miscellaneous.

<table>
<thead>
<tr>
<th>Stratigraphic Position</th>
<th>Feature &amp; Burial #</th>
<th>Chemical Analyses</th>
<th>Nuclear Analyses</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>F.1,B#3</td>
<td>1-b</td>
<td>1-b</td>
</tr>
<tr>
<td>8</td>
<td>F.X,B#11</td>
<td>misc 1-b</td>
<td>l-b</td>
</tr>
<tr>
<td>7</td>
<td>F.X,B#18</td>
<td>misc 1-b</td>
<td>l-b</td>
</tr>
<tr>
<td>6</td>
<td>F.20,B#21</td>
<td>1-b</td>
<td>ulna</td>
</tr>
<tr>
<td>5</td>
<td>F.3,B#22</td>
<td>skull</td>
<td>skull</td>
</tr>
<tr>
<td>4</td>
<td>F.4,B#22A</td>
<td>rib &amp; 1-b</td>
<td>rib</td>
</tr>
<tr>
<td>3</td>
<td>F.4,B#22D</td>
<td>misc 1-b</td>
<td>l-b</td>
</tr>
<tr>
<td>2</td>
<td>F.4,B#22L</td>
<td>ribs</td>
<td>rib</td>
</tr>
<tr>
<td>1</td>
<td>F.4,B#22N</td>
<td>ribs</td>
<td>rib</td>
</tr>
</tbody>
</table>

**The Skeletal Remains From Toepfner Mound**

In contrast to Davis Mound, the greatest number of samples came from stratified log tombs in the mound fill at Toepfner. Many of these tombs had been burned prehistorically, which involved the bones of the burials to various degrees.
However, this seems to have worked beneficially towards the preservation of the skeletons. Feature #9, the lowest of the log tomb sequence, superimposes a low bark covered mound capping three bark-lined sub-floor pits (Features #12, #13, and #14). These pits contained relatively large numbers of burials that were mixed extended, bundled, flexed, and cremated (see Table 3).

Table 3

Description of Toepfner Mound Bone Samples

Abbreviations for the following table refer to: crem=cremation; part crem=partial cremation; ext=extended; disart=disarticulated remains.

<table>
<thead>
<tr>
<th>Stratigraphic Position</th>
<th>Feature &amp; Burial #</th>
<th>Bone Condition</th>
<th>Burial Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 B#1</td>
<td>very good</td>
<td>ext</td>
<td></td>
</tr>
<tr>
<td>8 F.1,B#4</td>
<td>part crem</td>
<td>ext</td>
<td></td>
</tr>
<tr>
<td>7 F.2,B#7</td>
<td>part crem</td>
<td>ext</td>
<td></td>
</tr>
<tr>
<td>7 F.3,B#9</td>
<td>crem</td>
<td>disart</td>
<td></td>
</tr>
<tr>
<td>6 F.6,B#22</td>
<td>smoked</td>
<td>bundle</td>
<td></td>
</tr>
<tr>
<td>5 F.8,B#28</td>
<td>very good</td>
<td>ext</td>
<td></td>
</tr>
<tr>
<td>4 F.9,B#31</td>
<td>good</td>
<td>ext?</td>
<td></td>
</tr>
<tr>
<td>3 F.9,B#35</td>
<td>good</td>
<td>ext?</td>
<td></td>
</tr>
<tr>
<td>3 F.9,B#35</td>
<td>good</td>
<td>ext?</td>
<td></td>
</tr>
<tr>
<td>2 F.13,B#78</td>
<td>very good</td>
<td>ext</td>
<td></td>
</tr>
<tr>
<td>1 F.12,B#61</td>
<td>good</td>
<td>bundle</td>
<td></td>
</tr>
<tr>
<td>1 F.12,B#65</td>
<td>good</td>
<td>ext?</td>
<td></td>
</tr>
<tr>
<td>1 F.12,B#66</td>
<td>good</td>
<td>ext?</td>
<td></td>
</tr>
</tbody>
</table>

Three samples were obtained from Feature #12, a sub-floor pit under the central mound. Feature #12 was oval in horizontal profile measuring 11.1 feet long (northwest-southeast) and 8.6 feet wide (northeast-southwest). approx-
imately 2.5 feet deep. It was nestled within a raised gravel and till ring covered with bark which draped down the pit's sides and lined the floor of Feature #12. Ten burials painted with red ochre were found in a poor state of preservation. Three were extended, three were bundles, one flexed, one semi-flexed, one was cremated, and one included only the lower extremities in an extended position. Three were associated with artifacts: Burial #64 (broken Adena-stemmed point, 3 stemmed scrapers), Burial #66 (complete wolf mandible), and Burial #68 (Adena-stemmed point, two leaf-shaped blades, fragments of shell, and a rectangular sandstone gorget).

Feature #13 was a sub-floor pit under the central mound, about 7.8 feet long (northeast-southwest) and 5.5 feet wide (northwest-southeast) and 2 feet deep. Intruding the northwest side of the raised gravel and till ring surrounding Feature #12. It contained seven burials; three cremations, two bundles, and two extended. Burial #78 used here as a sample was one of the two extended burials placed parallel to each other along the north side of the pit, heads to the west. Burial #78 was not associated with any artifacts, but its companion (Burial #72) had 5 copper beads and 2 shell beads. One other Burial (#73) was associated with a curved base modified tubular pipe of clay.
Feature #9 was located above the mound capping the sub-
floor pits, constructed first as a square clay basin and
then lined inside with logs. All the logs of this tomb had
been charred by fire after it was closed, which was typical
of most of the log tombs in the mound. Eight burials and
three isolated skulls were removed from this feature.
Three extended burials were excavated, plus two cremations,
one bundle, one consisting of lower extremities laid out in
perfect anatomical order, and one partially decomposed
reburial (evidenced by displacement of the skull, and miss-
ing both of its tibias and fibulas, as well as its feet). At
least two of these burials were placed on bark and cov-
ered with bark. No artifacts were associated with this
tomb except for a small piece of worked bone (calcined)
associated with a cremation (Burial #36). It should be
noted that bone samples No. 6 and 7 in the accompanying
tables are from the same individual (Burial #35). Feature
#9 covered a small bark-lined and bark-covered burial pit
apparently created by the collapse of the mound roof over
top of Feature #12 below it. Feature #9 has been dated
using wood charcoal from the log-lining to 460 BC±200
(M-521).

Feature #8 (Burial #28) was a roughly oval bark-lined
area measuring 7.5 feet long and 3.2 feet wide located
above Feature #9, containing one extended adult male, lying
in an east-west direction, head to the east. No artifacts were encountered, but two other similar burials were placed on the mound covering Feature #9.

Feature #6 was a roughly rectangular log-lined tomb, located directly above Feature #8. Feature #7 was a log lined tomb located on the same level as Feature #6, but off the mound's central axis to the east of Feature #6. Feature #7 measured 7.2 feet (north-south) by 6.5 feet (east-west). It was the only unburned tomb in the mound. However, it was affected by the intense fire at Feature #6 that carbonized some of its logs. Charcoal from this tomb was dated to 830 BC ± 410 (C-942), the oldest date from the site. Feature #6, located on the central mound axis, measured 8.4 feet long (north-south) and 6.9 feet wide (east-west) and was extensively burned, especially in the northeast corner. A burial (#20) was placed on top of the southwest corner and apparently cremated in place. Another burial (#27) was banked against the logs of Feature #6, but badly decomposed. Seven burials were encountered inside the tomb, three extended, three cremated, and one bundle, not all having been placed in the grave at the same time. The floor of the tomb was lined with bark on which was placed a woven mat. On this mat were placed four burials: Burial #21 (extended adult covered with fabric and red ochre, head to the south), Burial #22 (bundle lying on the right shoul-
der of #21), Burial #23 (cremation on the woven mat), and Burial #24 (cremation slightly above the lower extremities of #21). Above this group were found Burials #18 (extended adult, head to the north) and #19 (extended adult, head to the south), both covered with fabric. Besides the fabric, no other artifacts were found in association, except for the mound fill capping the tomb: a "typical Adena, grit-tempered rim sherd," small projectile points, animal bones, fire-cracked rock, and other midden debris. A layer of bark covered this small mound, upon which yellow clay was layered and the floor logs of Feature #3 were set.

Feature #3 was a sub-rectangular log tomb covered by a small mound, and extensively burned prehistorically. It contained the remains of two burials: Burial #9 (cremation), and Burial #16 (a neonate or fetus). No artifacts were encountered, but the wood charcoal from the logs provided a date of 320 BC±200 (M-518).

Feature #2 was apparently built on the same mound covering Feature #6 (another tomb, Feature #4, was built on this level as well). It was roofed with at least fourteen identifiable charred logs lying in an east-west direction. Two extended burials were found in it (Burials #7 and #8) partially cremated by the burning of the tomb, and associated with three chert blades, three pieces of sandstone, a worked swan bone, a worked rabbit bone, a broken stemmed
a projectile point, and a fragmented worked shell piece from the fill. Two dates were obtained from the wood charcoal of the roof beams: 350 BC±200 (M-517), and 427 BC±150 (C-923).

Immediately above Feature #2 and #3 was Feature #1, the last log tomb built in the mound. It was burned just as all of the others except Feature #7. Two extended burials (#4 and #5) and one cremated burial (#6) were located in the structure. Burial #4 was associated with a Robbins Steamed point.

The last mound burial (#1) is the best preserved of the entire series. It is of an extended adult female, on her back, head to the west. Apparently no burial preparation or grave goods were associated with this individual. Burial #1 essentially terminates the ritual use of the mound at least with respect to human burial.

It should be pointed out that the dates from Toepfner's log tombs do not fit the expected chronology for Late Adena: they are too young. This has largely been attributed in the past to the use of the "carbon black" method of radiocarbon dating by the University of Chicago and the early dates from the University of Michigan (Griffin 1974a:xv, 1978:62; Michael and Ralph 1971). But in general, the sub-floor bark-lined pits at Toepfner are similar to early-middle Adena burial features (Dragoo 1963), where-
as the log-tomb burial features are typical of the "Robbins Complex" of Late Adena.

The different bone types used in the two analyses at Toepfner are listed in Table 4. Preservation conditions were much better at Toepfner and the majority of the remains included ribs in amounts large enough to perform the measurements. Toepfner in comparison with bone types at Davis mound has a more homogeneous and larger sized sample. These two factors may have some affect on the statistics discussed in the following sections.

Table 4

Anatomical Bone Types From Toepfner Mound

<table>
<thead>
<tr>
<th>Stratigraphic Position</th>
<th>Feature &amp; Burial #</th>
<th>Chemical Analyses</th>
<th>Nuclear Analyses</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>B#1</td>
<td>ribs</td>
<td>rib</td>
</tr>
<tr>
<td>8</td>
<td>F.1,B#4</td>
<td>ribs</td>
<td>rib</td>
</tr>
<tr>
<td>7</td>
<td>F.2,B#7</td>
<td>ribs</td>
<td>rib</td>
</tr>
<tr>
<td>7</td>
<td>F.3,B#9</td>
<td>ribs</td>
<td>rib</td>
</tr>
<tr>
<td>6</td>
<td>F.6,B#22</td>
<td>ribs</td>
<td>rib</td>
</tr>
<tr>
<td>5</td>
<td>F.8,B#28</td>
<td>ribs</td>
<td>rib</td>
</tr>
<tr>
<td>4</td>
<td>F.9,B#31</td>
<td>femur</td>
<td>femur</td>
</tr>
<tr>
<td>3</td>
<td>F.9,B#35</td>
<td>misc l-b, &amp; vert</td>
<td>rib</td>
</tr>
<tr>
<td>3</td>
<td>F.9,B#35</td>
<td>ribs</td>
<td>rib</td>
</tr>
<tr>
<td>2</td>
<td>F.13,B#78</td>
<td>ribs, l-b</td>
<td>rib</td>
</tr>
<tr>
<td>1</td>
<td>F.12,B#61</td>
<td>ribs</td>
<td>rib</td>
</tr>
<tr>
<td>1</td>
<td>F.12,B#65</td>
<td>ribs</td>
<td>rib</td>
</tr>
<tr>
<td>1</td>
<td>F.12,B#66</td>
<td>ribs</td>
<td>rib</td>
</tr>
</tbody>
</table>
Chapter IV
DATA ANALYSIS

Initial descriptive statistics from the fluorine and nitrogen analyses indicated significant differences between Toepfner and Davis mound, and deviations from expected values. Possible sources of these deviations are discussed and a factor analysis is performed to help isolate additional deviations.

DESCRIPTIVE STATISTICS

Table 5 lists the means, standard deviations, and sample sizes for the chemical and nuclear measures of fluorine and nitrogen, including nuclear values calibrated to the specimen's calcium/phosphorus ratio. The raw data for these statistics can be found in Appendix A. The results of T-tests and analysis of variance are reported in Table 6. Tests for homogeneity of variance indicated that chemical fluorine or FPPM (Cochran's C = .7609, p = .185; Bartlett-Box F = 1.614, p = .205; Hartley's F max. = 3.182), nuclear nitrogen or MNO (Cochran's C = .6016, p = .526; Bartlett-Box F = .395, p = .530; Hartley's F max. = 1.510), and the
calcium/phosphorus adjusted nuclear nitrogen values or FNOADJ (Cochran's C = .5293, p=.856; Bartlett-Box F = .031, p=.860; Hartley's F max. = 1.125) all were statistically similar enough to pool their variances in the T-tests. The same test for homogeneity of variance on chemical nitrogen or N% (Cochran's C = .9114, p=.012; Bartlett-Box F = 5.582, p=.019; Hartley's F max. = 10.292), nuclear fluorine or FNO (Cochran's C = .9124, p=.001; Bartlett-Box F = 11.520, p=.001; Hartley's F max. = 10.417), and the calcium/phosphorus adjusted nuclear fluorine values or FNOADJ (Cochran's C = .8986, p=.002; Bartlett-Box F = 10.093, p=.002; Hartley's F max. = 8.861) indicate significant differences in the variances for these measures, and the T-tests were thus based on the separate variance estimates.

The results of the T-tests suggest that all means, except for chemical fluorine (FPPN), are not significantly different from each other between the two mounds. Likewise, the analysis of variance indicates no significant variations between the mounds for the same elements. Thus, all elements, except chemical fluorine, were pooled into a single sample for descriptive purposes only (see Table 7). The relative amounts of standard error from each mound in these pooled values contributing to the total error are listed in Table 8.
Table 5

**Fluorine and Nitrogen Descriptive Statistics**

The following abbreviation refer to: PPM=chemical fluorine in parts per million; N%=chemical nitrogen in % by weight; FNO=nuclear fluorine in gamma counts divided by total gammas; FNOADJ=nuclear fluorine adjusted to the calcium/phosphorus ratio; NNO=nuclear nitrogen measured in gamma counts divided by total gammas; NNOADJ=nuclear nitrogen adjusted to the calcium/phosphorus ratio.

<table>
<thead>
<tr>
<th></th>
<th>PPM</th>
<th>N%</th>
<th>FNO</th>
<th>FNOADJ</th>
<th>NNO</th>
<th>NNOADJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Davis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean</td>
<td>1057.2</td>
<td>0.5933</td>
<td>289.9</td>
<td>168.7</td>
<td>1493.7</td>
<td>854.99</td>
</tr>
<tr>
<td>standard deviation</td>
<td>221.1</td>
<td>0.4183</td>
<td>235.6</td>
<td>140.1</td>
<td>1122.6</td>
<td>621.9</td>
</tr>
<tr>
<td>n</td>
<td>6</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>minimum</td>
<td>826</td>
<td>0.16</td>
<td>68</td>
<td>29.15</td>
<td>557</td>
<td>206.8</td>
</tr>
<tr>
<td>maximum</td>
<td>1280</td>
<td>1.32</td>
<td>797</td>
<td>450.98</td>
<td>3820</td>
<td>2161.53</td>
</tr>
<tr>
<td>Toepfner</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean</td>
<td>1472.6</td>
<td>1.4013</td>
<td>261.6</td>
<td>157.1</td>
<td>2094.7</td>
<td>1287.51</td>
</tr>
<tr>
<td>standard deviation</td>
<td>394.5</td>
<td>1.3420</td>
<td>73.0</td>
<td>47.1</td>
<td>913.6</td>
<td>659.4</td>
</tr>
<tr>
<td>n</td>
<td>8</td>
<td>8</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>minimum</td>
<td>721</td>
<td>0.10</td>
<td>128</td>
<td>79.0</td>
<td>684</td>
<td>387.3</td>
</tr>
<tr>
<td>maximum</td>
<td>2000</td>
<td>3.36</td>
<td>396</td>
<td>248.4</td>
<td>3370</td>
<td>2694.52</td>
</tr>
</tbody>
</table>

Table 6

**Results of T-tests and Analysis of Variance**

D.F.=degrees of freedom. See Table 5 for other abbreviations.

<table>
<thead>
<tr>
<th>Variable</th>
<th>T Value</th>
<th>D.F.</th>
<th>Probability</th>
<th>1-tailed F</th>
<th>D.F.</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPM</td>
<td>2.31</td>
<td>12</td>
<td>0.020</td>
<td>5.3249</td>
<td>1.12</td>
<td>0.0396</td>
</tr>
<tr>
<td>N%</td>
<td>1.60</td>
<td>9</td>
<td>0.072</td>
<td>1.9919</td>
<td>1.12</td>
<td>0.1835</td>
</tr>
<tr>
<td>FNO</td>
<td>0.31</td>
<td>8</td>
<td>0.383</td>
<td>0.1432</td>
<td>1.19</td>
<td>0.7093</td>
</tr>
<tr>
<td>FNOADJ</td>
<td>0.23</td>
<td>8</td>
<td>0.413</td>
<td>0.0775</td>
<td>1.19</td>
<td>0.7837</td>
</tr>
<tr>
<td>NNO</td>
<td>1.38</td>
<td>20</td>
<td>0.091</td>
<td>1.9118</td>
<td>1.20</td>
<td>0.1820</td>
</tr>
<tr>
<td>NNOADJ</td>
<td>1.55</td>
<td>20</td>
<td>0.068</td>
<td>2.3939</td>
<td>1.20</td>
<td>0.1375</td>
</tr>
</tbody>
</table>
Table 7

Pooled Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Deviation</th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Davis FPPM</td>
<td>1057.2</td>
<td>221.13</td>
<td>6</td>
<td>826.00</td>
<td>1280.00</td>
</tr>
<tr>
<td>Toepfner FPPM</td>
<td>1472.6</td>
<td>394.45</td>
<td>8</td>
<td>771.00</td>
<td>2000.00</td>
</tr>
<tr>
<td>Pooled N%</td>
<td>1.0550</td>
<td>1.0596</td>
<td>14</td>
<td>-10</td>
<td>3.36</td>
</tr>
<tr>
<td>Pooled FNO</td>
<td>271.28</td>
<td>148.54</td>
<td>21</td>
<td>68</td>
<td>797</td>
</tr>
<tr>
<td>Pooled FNOADJ</td>
<td>161.50</td>
<td>90.71</td>
<td>21</td>
<td>29.15</td>
<td>450.98</td>
</tr>
<tr>
<td>Pooled NNO</td>
<td>1848.82</td>
<td>1023.95</td>
<td>22</td>
<td>557.00</td>
<td>3820.00</td>
</tr>
<tr>
<td>Pooled NNOADJ</td>
<td>1110.57</td>
<td>665.71</td>
<td>22</td>
<td>206.08</td>
<td>2694.52</td>
</tr>
</tbody>
</table>

Table 8

Standard Error in the Pooled Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>Davis* Standard Error</th>
<th>Toepfner’s Standard Error</th>
<th>Total Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined FPPM</td>
<td>90.27</td>
<td>139.46</td>
<td>102.86</td>
</tr>
<tr>
<td>Pooled N%</td>
<td>.1708</td>
<td>.4745</td>
<td>.2936</td>
</tr>
<tr>
<td>Pooled FNO</td>
<td>80.30</td>
<td>20.25</td>
<td>32.95</td>
</tr>
<tr>
<td>Pooled FNOADJ</td>
<td>49.52</td>
<td>13.05</td>
<td>19.79</td>
</tr>
<tr>
<td>Pooled NNO</td>
<td>374.20</td>
<td>253.37</td>
<td>218.31</td>
</tr>
<tr>
<td>Pooled NNOADJ</td>
<td>207.28</td>
<td>182.89</td>
<td>141.93</td>
</tr>
</tbody>
</table>

These descriptive statistics are useful landmarks for judging the degree of change in the elements at Toepfner and Davis mound in comparison with fresh bone and fossil bones from other sites around the world. For instance, the pooled mean and range of Toepfner and Davis nitrogen measurements are considerably below that of fresh bone, a fact that is not very startling (Berger, Horney, and Libby 1964:1000; Garlick 1970:503; Oakley 1970:41; Ortner, Von
Endt, and Robinson 1972:518; Protsch 1978:32; Sellstedt, Engstrand, and Gejvall 1966:573). What is surprising is the over thirty-fold difference between the lowest and highest nitrogen value in the pooled range. As Haddy and Hanson have pointed out (1982:43), it is safe to assume that all the bones started out with the same amount of nitrogen, between 4% and 5% by weight. If this amount decreased exponentially as Ortner and Von Endt have calculated (1972:516-517) then, as Haddy and Hanson reasoned, "a bone with 1% nitrogen would be more than twice as old as a bone with 3% nitrogen. If this is true, it means that the oldest bone in this study, 1648N, is probably at least twice the age of the newest, possibly putting it in the Moundville I period" (1982:43). In actuality, the difference, using Ortner and Von Endt's formula, in age of bone sample 1648N from the newest bone, 1539S, in the Moundville sample, is more like 2.76 times as old.

The formula devised by Ortner and Von Endt describes the rate of change of nitrogen as $\ln a/a-x = kt$, where $a =$ the initial concentration of nitrogen (arbitrarily set here to 5%), $x$ is the amount of nitrogen released at time $t$, and $k$ is a constant defining the slope of the decay curve (1972:516). Given that the pH, water availability, and mean annual temperature are constant, than the oldest bone in this study, which contains more than thirty times less
nitrogen than the youngest bone, should be approximately 9.8 times older, a prediction that obviously is inaccurate given what is already known about the range and dispersion of Adena mound dates in central Ohio (see Figure 5). Therefore, constant conditions must be violated within and between Davis and Toepfner mounds.

An inspection of Table 6 indicates that significant differences exist between Davis and Toepfner mounds in terms of their chemical fluorine measurements (PPPM, F ratio = 5.3249, p = .0396), whereas a larger amount of the total variation is contributed by within mound variations for all the other variables (no F ratios have probabilities smaller than .1375). Table 8 shows that the greatest amount of error in the chemical determinations of fluorine and nitrogen comes from Toepfner mound, but in the case of the nuclear measurements, it is Davis mound with the largest contributing variation.

When absolute figures are compared with values derived elsewhere, the pooled nitrogen percentages contain values as low as those reported for Predynastic Egyptian sites (Garlick 1970:508-509), as well as Pleistocene aged fossils from Europe (Oakley 1970:41-43). A major factor contributing to this is the mean annual temperature variation between these regions. As Ortner et al. have demonstrated (1972:517), an increase of mean annual temperature of only
7 degrees centigrade at Cairo, Egypt versus Washington, D.C. is enough to increase the rate of nitrogen loss over four times. Consequently, colder mean annual temperatures in European sites contribute to the preservation of Pleistocene aged bone nitrogen. However, the difference in temperature between central Ohio and European fossil localities is not as great as that between Ohio and Egypt. Consequently, other factors must also be contributing to the low nitrogen values in the Ohio mounds.

At the Moundville, Alabama site, Haddy and Hanson recorded only a threelfold difference in nitrogen percentages, from 1.07% to 2.86% (1982:42). Their specimens were collected from seven different mounds, versus only two here. Yet all seven of these mounds were located on the same promontory above the floodplain. The two mounds in the present study, on the other hand, were located in two different geomorphological contexts producing a thirty-fold difference: Davis in the uplands, and Toepflner on a floodplain. This difference contributed to variations in pH and water availability between the two sites, which, with the mean annual temperature, must be considered in the evaluation of the measurements reported here (see below).

In Table 9 nitrogen and fluorine values of North American hominids are listed from the "Catalog of Fossil Hominids" by Heiner Protsch (1978). A comparison with Table 7
reveals considerable differences between the means for fluorine and nitrogen (FPPM and N%) at Toepfner and Davis, with respect to the means of North American Fossil hominids in general: Ohio mounds have lower mean fluorine content, and higher mean nitrogen content. The fossil hominid sample contains specimens with much smaller minimum values for both elements as well. The maximum nitrogen content for the pooled Ohio mounds is nearly twice as high as the fossil hominids; whereas, the maximum fluorine value for the fossil hominids is sixty times greater than the highest value at Toepfner mound.

The Ohio mounds do not demonstrate the same variability in their fluorine measurements as the fossil hominids, as would be expected from a sample that is so widespread, but this is not true for the nitrogen values. The low values for the standard deviation of fossil hominid nitrogen is not so remarkable considering the logarithmic nature of the relationship between time and nitrogen (Cook 1960:230; Ortner et al. 1972:516). Because nitrogen loss is measured in relation to the mass unit of bone and is proportional to the remaining nitrogen, the ratio is greatest initially and reduces with time. As Protsch's table consists largely of purported Pleistocene hominids, some with comparable fluorine and nitrogen dates on associated extinct fauna, and some with Pleistocene absolute dates, the high frequency
Table 9

Fluorine and Nitrogen Measurements for North American Fossils

From Protsch (1978), "Catalog of Fossil Hominids." Means calculated for human bone only. The ranges reported for the Los Angeles and Midland 1 calvaria were counted as if the minimum and maximum values were two measurements. All fluorine values were originally reported in percentages; these were converted into approximate ppm by multiplying the appropriate decimal fraction of each percentage by 1,000,000 to facilitate comparisons with the values reported here.

<table>
<thead>
<tr>
<th>FLUORINE PPM Equivalents</th>
<th>NITROGEN % by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arlington Springs</td>
<td>120,000</td>
</tr>
<tr>
<td>Calaveras skull</td>
<td>2,200</td>
</tr>
<tr>
<td>Calaveras cave skull</td>
<td>2,800</td>
</tr>
<tr>
<td>Calaveras rhinoceros</td>
<td>23,000</td>
</tr>
<tr>
<td>Calaveras mammal</td>
<td>19,700</td>
</tr>
<tr>
<td>Conkling Cavern-human</td>
<td>1,000</td>
</tr>
<tr>
<td>&quot;</td>
<td>1,000</td>
</tr>
<tr>
<td>&quot;</td>
<td>1,800</td>
</tr>
<tr>
<td>&quot;</td>
<td>1,500</td>
</tr>
<tr>
<td>&quot;</td>
<td>4,700</td>
</tr>
<tr>
<td>&quot;</td>
<td>1,400</td>
</tr>
<tr>
<td>&quot;</td>
<td>- Camelus</td>
</tr>
<tr>
<td>&quot;</td>
<td>- Megalonyx</td>
</tr>
<tr>
<td>&quot;</td>
<td>- Equus</td>
</tr>
<tr>
<td>Lagow Sand Pit-recent animal</td>
<td>300</td>
</tr>
<tr>
<td>Tepexpan &quot;man&quot;</td>
<td>15,000</td>
</tr>
<tr>
<td>Laguna Beach, human skull</td>
<td>3,000</td>
</tr>
<tr>
<td>&quot;</td>
<td>3,000</td>
</tr>
<tr>
<td>Los Angeles, human calvaria</td>
<td>1,200-400</td>
</tr>
<tr>
<td>&quot;</td>
<td>1,500-800</td>
</tr>
<tr>
<td>Melbourne 1, tibia</td>
<td>960</td>
</tr>
<tr>
<td>&quot;</td>
<td>- Equus</td>
</tr>
<tr>
<td>&quot;</td>
<td>- Mammothus</td>
</tr>
<tr>
<td>Midland 1, calvaria</td>
<td>8,600-7100</td>
</tr>
<tr>
<td>&quot;</td>
<td>5,900</td>
</tr>
<tr>
<td>&quot;</td>
<td>- Equus tooth</td>
</tr>
<tr>
<td>&quot;</td>
<td>- Equus radius</td>
</tr>
<tr>
<td>&quot;</td>
<td>- modern Lepus</td>
</tr>
<tr>
<td>Macthez 1, pelvis</td>
<td>3,800</td>
</tr>
<tr>
<td>&quot;</td>
<td>- new analysis</td>
</tr>
<tr>
<td>&quot;</td>
<td>- Mylodon</td>
</tr>
<tr>
<td>&quot;</td>
<td>- new analysis</td>
</tr>
<tr>
<td>Stanford 2</td>
<td>2,700</td>
</tr>
</tbody>
</table>
Table 9 Continued.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Torrington</td>
<td>3,760</td>
<td>--</td>
</tr>
<tr>
<td>&quot;</td>
<td>2,860</td>
<td>--</td>
</tr>
<tr>
<td>Tranquillity, human 6071</td>
<td>1,850</td>
<td>--</td>
</tr>
<tr>
<td>&quot;</td>
<td>1,560</td>
<td>--</td>
</tr>
<tr>
<td>&quot;</td>
<td>1,020</td>
<td>--</td>
</tr>
<tr>
<td>&quot;</td>
<td>2,080</td>
<td>--</td>
</tr>
<tr>
<td>&quot;</td>
<td>1,360</td>
<td>0.053</td>
</tr>
<tr>
<td>&quot;</td>
<td>1,100</td>
<td>0.04</td>
</tr>
<tr>
<td>&quot;</td>
<td>1,200</td>
<td>0.06</td>
</tr>
<tr>
<td>&quot;</td>
<td>9,800</td>
<td>0.05</td>
</tr>
<tr>
<td>&quot;</td>
<td>2,280</td>
<td>--</td>
</tr>
<tr>
<td>&quot;</td>
<td>2,100</td>
<td>--</td>
</tr>
<tr>
<td>&quot;</td>
<td>2,360</td>
<td>--</td>
</tr>
<tr>
<td>&quot;</td>
<td>1,280</td>
<td>--</td>
</tr>
<tr>
<td>Yuha 1, tibia</td>
<td>12,000</td>
<td>0.68</td>
</tr>
<tr>
<td>&quot;</td>
<td>14,000</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Mean = 7,559.09
Standard Deviation = 20,253.36
n = 33
Minimum = 400
Maximum = 120,000

and low variability of small nitrogen values probably represents a maxima in the decay curve for this group of fossils.

As Sherburne Cook has pointed out, the detection limit of the micro-Kjeldahl method for nitrogen set around the 0.1 percent level (1960:230). Values lower than 0.2 percent become less and less reliable, and, according to Cook, "differences based upon hundredths of one percent have no meaning." Consequently, the majority of fossil hominid samples approach the limit of detectability. Likewise, a cluster of cremated, partially cremated, and smoked specimens at the Toepfner mound are at or near the 0.1 percent
detectibility limit for the micro-Kjeldahl technique. All of the specimens from the Davis mound are very low as well, except for individuals found in the deep sub-floor pits.

Another comparison of interest is the range of fluorine measurements for the Ohio mounds versus those from the Moundville, Alabama site. Haddy and Hanson obtained a fivefold difference between their lowest and highest fluorine measurement (between 166 and 775 ppm). In contrast, the greatest range of difference found here is a little less than three-times the smallest value at Toepfner mound. If, as Haddy and Hanson claim for their study, a fivefold increase showed "an excellent sensitivity of the methods to the time span over which these burials took place" (1982:43), then the sensitivity of the chemical method used here is somewhat less so.

Unlike nitrogen, the rate of fluorine uptake appears to be more variable and depends a great deal on the amount of fluorine in the area (Parker and Toots 1970:931). Therefore, as Oakley and Hoskins first pointed out (1950), the fluorine dating method is valid only for bones from the same locality or similar soil matrix. Thus, a formula relating the change in fluorine content to the change in time would have to be highly specific to a locality, and more than one may apply to a complex mound structure, given changes in hydrology and geochemical conditions from one
context to the next. Therefore, differences noted between Moundville, Alabama and the Ohio mounds may be due in part to variations in site hydrology and geochemistry. A major goal of this study is to identify these contexts and to evaluate the time sensitivity of the method within and between them.

The time sensitivity of the methods used in this study are evaluated in a number of ways, primary among which is the Spearman rank correlation with an independent time scale. In as much as the fluorine and nitrogen measures were almost immediately discovered to be more than simple time indicators, several intervening factors were isolated and tested as to their effects on the time-related rank correlations. This resulted in the definition of a number of general and specific variables between and within each mound as having significant and potential interactive effects on the kinetic processes and diagenesis of buried bone with respect to the several elements investigated here.

SPEARMAN RANK CORRELATIONS

Many of the following measurements and analyses are not from normal, statistical populations, especially as these measures pertain to time or time related processes. Therefore, non-parametric statistics are more important to the
evaluation of these measurements. Throughout the following analysis it is assumed that most, if not all, variations in the measurements are due to a physical cause, either related to specimen interactions with natural forces in real time, or instrument fluctuation and error, or contamination. It is the object of the following analysis to sort out these variations one from the other, to try and isolate a series of sample rank correlations that maximize the association with the primary, independent time variable, stratigraphic position. In all of the following tables, the maximum expected Spearman rank correlation for fluorine with stratigraphic position is -1.000. The maximum "perfect" rank correlation expected for nitrogen with stratigraphic position is +1.000. Both of these values are based on the fact that fluorine will accumulate with time and nitrogen will decay with time. The sign of the correlation is an arbitrary factor of counting stratigraphic rank from the bottom to the top of each mound, that is, the lowest burial is scored 1 for stratigraphic position, and numbers increase with each superimposed burial.

Some important problems are noteworthy right from the beginning. First of all, each measurement whether it be in parts per million, percent by weight, or proportional gamma counts, are all sensitive to mass effects. That is, each individual measurement is a ratio of that element to the
total bone mass. Therefore, each value is relative to the total bone mass unit, and any condition or factor that alters the bone mass unit, regardless if it is time-related or associated with the target elements under study, will have an effect on the recovered value of these elements. So, for instance, the alteration of the inorganic composition of a specimen, although not necessarily directly affecting organic protein, will none-the-less cause the artificial inflation of nitrogen values because of the reduction of overall bone mass against which it is measured. The solution would be to use only absolute measures of the mass or volume of each of these elements. But until these techniques are developed, or the reporting of these kinds of measures becomes standard practice, analysis must also be performed on the concomitant changes in the bone mass units of each specimen to properly evaluate variations in the target elements, especially as these variations may be perceived as time-related.

Second, the accelerator method employed here is highly experimental. Work was conducted without any direct parallels with which to judge its performance and success. Also, no direct external standard was methodologically desirable for the experiment, and therefore, results are not related to a widely recognized set of standard units of measure. The method made use of internal sets of standards
whereby the targets in the study could be calibrated within themselves. Because the highest desire was to develop a set of relative dating measures, such a technique was not viewed as a handicap.

Three major methods were used to calibrate the gamma spectra, only one of which is directly observable in the following tables. The first was an aluminum "foil" standard, of very thin thickness, that was placed directly across the beam path, and contributed to the output of every target spectra. Thus each spectra contained lines from this aluminum target, and all other elements from each specimen could be measured with respect to it. The second calibration technique was a count of the total beam charge, by which each peak in the spectrum could be made a proportion of the total beam energy output. Fluctuations in beam charge could be plotted against real time, and machine trends of increasing or decreasing charge could be compensated for by various curve-fitting formula. It should be noted that machine fluctuations in things like belt speed, and charging or discharging effects on the target or the amplifying and recording equipment was a major problem in the experiments, and considerably affected the results in some instances (see below).

Connected with machine "mechanical" difficulties is the problem produced by the beam inadvertently striking a sili-
con quartz window at the end of the beam line, used to visually orient the targets. Spectra obtained in such situations contained inflated silicon peaks. Silicon has been identified as a minor inorganic constituent in modern calcified tissues (Weatherell and Robinson 1973:59-60), as well as fossil bones (Parker and Toots 1970:926). Therefore, it became difficult to isolate true bone silicon from window charge effects.

Finally, a calibration technique was employed after the total beam charge calibration was calculated, using the ratio of calcium/phosphorus from the spectral analyses. These are recorded in the following tables as FNOADJ (adjusted nuclear fluorine) and NNOADJ (adjusted nuclear nitrogen). This was based on the observation and theoretical conclusion that the most stable structure in bone is the hydroxyapatite crystal, especially the calcium/phosphorus matrix. If true, each bone specimen itself contained its own internal standard, and perhaps a means for eventually producing an absolute standard as well. Connected with this is the remarkable homogeneity of the calcium/phosphorus ratio discovered in this study, and also observed in the data of other reported bone analyses (see Price and Kavanagh 1982 and Table 25).

Initial Spearman rank correlations (Spearman's rho) are listed in Table 10 for chemically determined fluorine
(FPPM), chemically determined nitrogen (N%), nuclear fluoride (FNO), and nuclear nitrogen (NNO) (see Blalock 1979:434-436 for computations). Toepfner mound for all measures indicate low, negative rank correlations with stratigraphic position. Davis mound demonstrates high negatives for all measures. But nitrogen values across the board are of the wrong sign from expected at both mounds. However, Davis' rank correlations for fluorine, chemical and nuclear, show strong negative values in line with expected.

Table 10

<table>
<thead>
<tr>
<th>RANK</th>
<th>x FPPM</th>
<th>N%</th>
<th>FNO</th>
<th>NNO</th>
<th>FNOADJ</th>
<th>NNOADJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toepfner</td>
<td>-.1796</td>
<td>-.3353</td>
<td>-.0513</td>
<td>-.4903</td>
<td>-.1247</td>
<td>-.4876</td>
</tr>
<tr>
<td>n=8</td>
<td>n=8</td>
<td>n=13</td>
<td>n=13</td>
<td>n=13</td>
<td>n=13</td>
<td>n=13</td>
</tr>
<tr>
<td>Davis</td>
<td>-.6000</td>
<td>-.8286</td>
<td>-.4524</td>
<td>-.6500</td>
<td>-.5000</td>
<td>-.7000</td>
</tr>
<tr>
<td>n=6</td>
<td>n=6</td>
<td>n=8</td>
<td>n=9</td>
<td>n=8</td>
<td>n=9</td>
<td>n=9</td>
</tr>
<tr>
<td>p=.104</td>
<td>p=.021</td>
<td>p=.130</td>
<td>p=.029</td>
<td>p=.104</td>
<td>p=.018</td>
<td></td>
</tr>
</tbody>
</table>

A second Spearman rank correlation between the fluorine and nitrogen measurements themselves allows a comparison with the Moundville, Alabama data generated by Haddy and Hanson (see Table 11). The first thing to notice is the poor correlations for the nuclear measures (FNO x NNO, and
Only one (Toepfner's FNO x NNO correlation) is negative, the direction that is predicted for this relationship. Chemical measures of fluorine and nitrogen are much better in this regard. It should be recalled that the chemical determinations of fluorine and nitrogen showed the greatest amount of variance at Toepfner mound (see Table 8), and coupled with the above results seems to indicate a significant association with stratigraphic placement. On the other hand, Davis mound demonstrated the greatest variance in the nuclear measurements, but the Spearman rank correlations suggest that this variation is not due to stratigraphic position, and therefore, to burial time.

It should be pointed out that Moundville's nitrogen values were obtained using the same technique used in this study (the micro-Kjeldahl technique described in Ortner et al. 1972), but the method used to determine fluorine was a variation of the proton inelastic scattering technique developed at the Brookhaven National Laboratory Van de Graaff accelerator (Haddy and Hanson 1982:38). In comparison with this, the initial nuclear values obtained here are a disappointment.

Even though Toepfner's FPPM x N% correlation is the highest in the table, its level of probability is significantly higher than the Moundville results, suggesting a
### Table 11

**Initial Spearman Rank Correlations Between Fluorine and Nitrogen**

<table>
<thead>
<tr>
<th></th>
<th>FPPM x NNO</th>
<th>FNO x NNO</th>
<th>PNOADJ x NNOADJ</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Combined Samples</strong></td>
<td>-0.4176</td>
<td>0.2316</td>
<td>0.3217</td>
</tr>
<tr>
<td>n=13</td>
<td>n=29</td>
<td>n=29</td>
<td></td>
</tr>
<tr>
<td>p=.078</td>
<td>p=.113</td>
<td>p=.044</td>
<td></td>
</tr>
<tr>
<td><strong>Toepfner</strong></td>
<td>-0.5714</td>
<td>-0.2091</td>
<td>0.0440</td>
</tr>
<tr>
<td>n=8</td>
<td>n=13</td>
<td>n=13</td>
<td></td>
</tr>
<tr>
<td>p=.069</td>
<td>p=.247</td>
<td>p=.443</td>
<td></td>
</tr>
<tr>
<td><strong>Davis</strong></td>
<td>-0.3000</td>
<td>0.2381</td>
<td>0.4762</td>
</tr>
<tr>
<td>n=5</td>
<td>n=8</td>
<td>n=8</td>
<td></td>
</tr>
<tr>
<td>p=.312</td>
<td>p=.285</td>
<td>p=.116</td>
<td></td>
</tr>
<tr>
<td><strong>Moundville</strong></td>
<td>-0.5545</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>n=11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p=.038</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Large proportion of random chance in this particular rank ordering. Even though the rank correlations for the same two variables in the combined sample and the Davis mound sample are lower, they indicate an important trend towards a negative relationship, the one expected on empirical and theoretical grounds. However, as will be seen in the following pages, there is a strong suggestion that even in the chemical measurements of fluorine and nitrogen, there are intervening and interactive factors affecting the present quantities of these elements in bone that are not directly related to their ages. This can be seen in the lack of homogeneity and consistency in the nuclear rank correla-
tions in both tables and in the variations between the chemical values from each mound and the combined mound data.

The nature of these interactive effects are not immediately knowable from the study of the rank correlations alone, although manipulations of the samples by sub-setting to isolate clusters of characteristics hypothetically thought to be a factor in the values is a viable option. However, it is time consuming and sometimes leads the analysis down blind-alleys. Consequently, a factor analysis of the two mounds and the combined data was instituted as a starting point. The analyses reported here is a Principal Components Analysis (Harman 1976), although the resulting factor matrix was confirmed by an unweighted least squares extraction as well (Harman and Jones 1966). The results of this analysis, and subsequent analyses, have important implications for the Moundville data as well, which may affect the interpretation of Haddy and Hanson's initial conclusions.

**Principal Components**

Three Principal Component Analyses were performed, one for each mound and one for the combined mound data. The first three factors for each sample are described below. Both general and mound specific factors were identified as
influences on the data. Factor 1 for all three Principal Component Analyses proved to be a complex, interactive system of relationships between a number of variables. Subsequent analyses involved the decomposition of these relationships into definable parts that affected the Spearman rank correlations. In this section, each of the three samples will be described in terms of the first three factors and briefly compared with one another. More detailed analysis will follow in the next sections.

The first three factors for the combined mound data are listed in Table 12. The factor plot for this table is depicted in Figure 2. The variable clusters in Table 12 are based on their factor loadings and their spatial relationships found on the factor plot. Factor 1 in the table indicates a high number of variable loadings clustered in a number of different ways. The most important associations involve MNO and MNNOADJ, along with N%, in a negative relationship to the charge and silicon cluster. Of note as well is the low negative association of FNOADJ with respect to the charge/silicon cluster. The charge/silicon cluster probably represents an important machine factor in the measurements of MNO and MNNOADJ, but somewhat less on a factor for FNOADJ. However, the very strong negative coefficient for N% suggests that nitrogen in general may have an accidental relationship to the charge/silicon cluster,
since the micro-Kjeldahl technique for determining nitrogen was independent of the accelerator analysis.

Table 12
Principal Components Analysis for Combined Data

The following abbreviations apply to this and subsequent tables: \( \text{N\%}=\text{chemically determined nitrogen in percent by weight}; \) \( \text{PPPM}=\text{chemically determined fluorine in parts per million (PPM)}; \) \( \text{NNO}=\text{nuclear determined nitrogen in terms of gamma count proportions}; \) \( \text{NNOADJ}=\text{NNO calibrated by the calcium/phosphorus ratio (Ca/P)}; \) \( \text{FNO}=\text{nuclear determined fluorine in terms of gamma count proportions}; \) \( \text{FNOADJ}=\text{FNO calibrated by the calcium/phosphorus ratio (Ca/P)}. \) Absolute values of coefficients less than 0.3000 are suppressed in the following tables in order to make them more readable.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Factor 1 Coefficients</th>
<th>Factor 2 Coefficients</th>
<th>Factor 3 Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Eigenvalues = 4.28761</td>
<td>3.50038</td>
<td>0.179203</td>
</tr>
<tr>
<td></td>
<td>% Variance = 33.0</td>
<td>26.9</td>
<td>13.8</td>
</tr>
<tr>
<td>Charge</td>
<td>-0.68963</td>
<td>--</td>
<td>-0.49962</td>
</tr>
<tr>
<td>Silicon</td>
<td>-0.55288</td>
<td>--</td>
<td>-0.48084</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>-0.39971</td>
<td>0.77387</td>
<td>--</td>
</tr>
<tr>
<td>Calcium</td>
<td>-0.56685</td>
<td>0.67297</td>
<td>--</td>
</tr>
<tr>
<td>Sodium</td>
<td>-0.43197</td>
<td>-0.65520</td>
<td>--</td>
</tr>
<tr>
<td>N%</td>
<td>-0.93180</td>
<td>--</td>
<td>-0.34077</td>
</tr>
<tr>
<td>PPPM</td>
<td>--</td>
<td>--</td>
<td>0.87800</td>
</tr>
<tr>
<td>NNOADJ</td>
<td>-0.89567</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>NNO</td>
<td>-0.85982</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>FNOADJ</td>
<td>-0.30855</td>
<td>0.82094</td>
<td>--</td>
</tr>
<tr>
<td>FNO</td>
<td>--</td>
<td>0.81059</td>
<td>--</td>
</tr>
<tr>
<td>Ca/P</td>
<td>0.34808</td>
<td>--</td>
<td>0.53111</td>
</tr>
</tbody>
</table>
Figure 2: Factor Plot for Combined Data
Another strong cluster of Factor 1 involves the elements phosphorus, calcium, and sodium, with moderately low factor loadings. There is strong reason to believe these associations represent a bone mineral association, in contrast to bone organics, which are positively aligned with the charge/silicon cluster but negatively associated with the nitrogen and fluorine measures. Although the calcium/phosphorus ratio is not spatially clustered with this bone mineral group, its coefficients are very similar. The lack of spatial clustering of the Ca/P ratio with the other bone minerals indicates that neither calcium nor phosphorus dominates the relationship, which is significant given the fact that these are fossil bones. This means that neither calcium nor phosphorus is differentially discriminated against in the fossilization process more than the other, and, by implication, they retain a more-or-less stable chemical relationship with one another throughout their burial history.

Factor 2 for the combined data is almost as important as Factor 1 in explaining the variation between the variables (eigenvalue of 3.5 versus 4.3, and % variance of 26.9% versus 33.0% respectively). Factor 2 emphasizes moderately high coefficients for the bone mineral cluster, and rather strong association with FNO and FNOADJ, demonstrating even higher factor loadings. The implication is of a strong
relationship of the nuclear fluorine content with the nuclear bone mineral values.

The third factor for the combined data has a comparatively low eigenvalue and percent variance (1.79 and 13.8% respectively), indicating a lack of relative significance for the combined data as a whole, at least in relation to Factors 1 and 2. However, it does indicate a negative relationship between N% and PPPM, as would be theoretically expected. It also indicates a moderately strong charge/silicon association with N%, in contrast to the negative association in Factor 1, and a moderately strong association of the calcium/phosphorus ratio with PPPM, in contrast to the association of the calcium/phosphorus ratio with the bone mineral cluster in Factor 1. The latter trend is understandable in that fluorine becomes incorporated in the inorganic fraction of the bone mass. The relationship of the charge/silicon cluster to PPPM may be a factor of its association with the calcium/phosphorus ratio, for all three are based on nuclear measurements, and positively co-vary with PPPM. What seems to be most significant about Factor 3 is a definite clustering, and clearly negative relationship, of the chemically determined values of PPPM and N%.

The factor matrix for Toepfner mound is listed in Table 13. Figure 3 is the plot of each variable in factor
space. Although Factor 1 in the table consists of the same clusters as in the combined table, factor loadings are much different. The first difference of note is the much larger eigenvalue and % variance in Toepfner's Factor 1 (6.39 and 49.2%), indicating the greater importance of this factor at Toepfner versus the combined data in general. But like the table for the combined data, Toepfner's Factor 1 is a complex interaction of many variables.

Table 13

<table>
<thead>
<tr>
<th>Factor Matrix for Toepfner Mound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor 1 Coefficients</td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>Eigenvalues</td>
</tr>
<tr>
<td>% Variance</td>
</tr>
</tbody>
</table>

Variables

- Calcium
- Phosphorus
- Sodium
- Ca/P ratio
- Charge
- Silicon
- MNOADJ
- NNO
- %
- FPPM
- FNOADJ
- FNO
Figure 3: Factor Plot for Toepfner Mound
The most significant aspect of Factor 1 is the bone mineral cluster of calcium, phosphorus, and sodium. Closely associated, although again not spatially clustered with them, is the calcium/phosphorus ratio. The charge/silicon cluster indicates a moderate positive relationship to the bone mineral variables but not as dominating a feature as in the combined data. Again the nitrogen variables have high, negative coefficients with respect to the bone mineral cluster and the charge/silicon cluster. However, the relationship appears to be strongest with the bone mineral cluster, unlike in the combined data. This implies that nitrogen's proportion of the total bone mass decreases with increasing bone mass, and, in general, is less a consequence of beam charge than in the combined data. This particular relationship is suggested because several of Toepfner mound's bone specimens demonstrated significantly reduced chemical nitrogen values (N%) at or near the limit of detectability. Therefore, in order to maintain the negative relationship with bone inorganics, given these low values for N%, bone mineral must be of a higher proportion in the total bone mass. This has been associated with burned bone in the present study, which occurs only at the Toepfner mound (see below). This combination of factors supports the information from Table 8 that demonstrated a high degree of variability in the chemical nitrogen meas-
urements at Toepfner mound. As we shall see, Davis mound demonstrates just the opposite tendencies. N% at Toepfner mound is again unclustered with the nuclear nitrogen measurements but nearer the FPPM measure, where they both demonstrate large and significant negative coefficients with one another, as expected.

Factor 2 at Toepfner mound has significantly reduced eigenvalues and % variance (2.5 and 19.3% respectively) whether one compares it with Factor 1 at Toepfner, or the factors in the combined data. The nuclear fluorine values are also highly associated but unclustered with the chemical fluorine values. This feature is characteristic of Factor 2 for the combined data as well, although it is significantly stronger at Toepfner mound. As we shall see, too, Toepfner mound is nearly the sole contributor of this feature in Factor 2 of the combined data. A very low negative silicon coefficient is also recorded for Toepfner's Factor 2, decoupled from any charge association. The indication is that a decrease in fluorine, whether detected nuclearly or chemically, is inversely related to silicon, which, given fluorine's predicted increase with time, means a steady loss of silicon. This is highly suggestive of the possibility that silicon is present in the bone matrix base and decays, like nitrogen, with time to be lost in the environment. But this is in contrast to the conclusions
based on Factor 1 at Davis, (see below) and its low loading factor must temper any generalizations.

Factor 3 at Toepfner has eigenvalues and % variance only slightly lower than the combined data. It shares with Factor 3 of the combined data a charge and silicon cluster, but one with very different coefficient combinations. Instead of being nearly equal in association, charge has nearly twice as much contribution to Toepfner's Factor 3 as silicon. And too, Toepfner's Factor 3, similar to the combined data, is associated with a very low negative calcium coefficient, indicating a slightly negative relationship of beam charge with the bone minerals. Unlike the combined data, however, Toepfner's Factor 3 has no strong FPPM/N% cluster; it is instead a significant factor in Factor 1 as point out previously.

The factor matrix for Davis mound is depicted in Table 14, and the factor plot in Figure 4. The interpretation of these statistics should be cautious because the number of factor variables exceeds the sample size. However, correction measures were applied to the factor matrix and the resultant clusters and associations of variables at the Davis mound reflect the same patterns found in the Combined data and the Toepfner mound data, giving confidence to the resultant coefficients. Factor 1, like Toepfner mound, has a very high eigenvalue (6.07), which accounts
for 46.7% of the variance. But the factor loadings are again different. The strongest cluster at Davis is the nuclear fluorine measures, in contrast to the bone minerals at Toepfner, and charge/silicon cluster for the combined data. For the first time there is a clear association of the nuclear fluorine with nuclear nitrogen measures, with fairly high values, but unfortunately it is in the positive direction, exactly opposite from prediction. This is an interesting result given the high degree of variance found in Table 8 for Davis mound. Even though there tends to be relatively more variability in the nuclear measures at Davis, both fluorine and nitrogen strongly co-vary with one another. A reason for this peculiar trend will be presented below.

Chemical nitrogen demonstrates an even stronger positive association with the nuclear fluorine measures, but is not clustered spatially with it nor with the nuclear nitrogen measures. The chemical fluorine value is a very low positive number that tends in the right direction but is not anywhere near as strong as found in Factor 1 at Toepfner mound nor Factor 3 in the combined data. However, Factor 3 here at Davis salvages this relationship somewhat.

FPPM, though, appears to have a different history at Davis versus nuclearly determined fluorine, as well as most of the other variables. Bone mineral elements again clus-
Table 14

**Davis Mound Factor Matrix**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Factor 1 Coefficients</th>
<th>Factor 2 Coefficients</th>
<th>Factor 3 Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.07396</td>
<td>3.27706</td>
<td>1.69088</td>
</tr>
<tr>
<td>% Variance</td>
<td>46.7</td>
<td>25.2</td>
<td>13.0</td>
</tr>
</tbody>
</table>

**Variables**

| FNO       | .93671                | --                     | --                     |
| PNOADJ    | .93621                | --                     | --                     |
| N%        | .89653                | --                     | -.36208               |
| NNOADJ    | .75072                | .61826                 | --                     |
| NNO       | .71232                | .63849                 | --                     |
| Phosphorus| .78996                | --                     | --                     |
| Calcium   | .70629                | --                     | .62879                |
| Sodium    | .66743                | --                     | --                     |
| Ca/P ratio| --                    | --                     | .81109                |
| Charge    | --                    | -.97129                | --                     |
| Silicon   | .31843                | -.68238                | --                     |
| PPPM      | .32303                | .79873                 | .52758                |

Text:

...ter with moderately high coefficients, positively related to the trends in nuclear fluorine and nitrogen: all seem to vary together as with the total bone matrix, unlike the situation at Toepfner mound. Silicon is again decoupled from charge in Factor 1, but, unlike Factor 2 at Toepfner, it is positively associated with fluorine. This seems to imply the very converse of the conclusion reached for Toepfner mound, that is, silicon accumulates with burial...
Figure 4: Factor Plot for Davis Principal Components.
time instead of being an element of the original bone matrix. But again, the very low factor loading must be considered in the determination of the significance of this conclusion. However, the possibility exists, based on this evidence, that silicon is both an aspect of the bone mass base, and the diagenetic accumulation in the voids and spaces of buried bone (see Parker and Toots 1970: 926, 930).

Factor 2 at Davis mound has an eigenvalue and % variance somewhat in line with the combined data, but significantly larger than Toepfner's Factor 2 (3.23 and 25.2% respectively). Unlike Toepfner's Factor 2 or the combined data, Davis' Factor 2 shows a clear and strong negative association of the charge/silicon cluster and $\text{NO}/\text{NOADJ}$ cluster. This appears to indicate that as charge increases, silicon's value increases, perhaps due to target miss-alignment that allowed part of the beam to strike the quartz window, and perhaps this is associated with random variations in the nuclear nitrogen values. Given nitrogen's low level of detectability at Davis, higher beam charge ratios would tend to increase the noise level in the gamma spectra, which may tend to obscure nitrogen peaks and the resolution of nuclearly determined nitrogen. At any rate, the association seems to indicate some problem with the nitrogen measure at Davis. The moderately high negative association
of chemical fluorine with beam charge seems completely accidental. It is unlikely that its presence in Factor 2 is a product of a positive association with the nuclear nitrogen cluster, because in Factor 1 it indicated a very weak association, and other clusters with stronger associations to the nuclear nitrogen cluster in Factor 1 do not appear in Factor 2. Thus, the evaluation of subsequent relationships of FPPM to nuclear measures at Davis, especially the nitrogen cluster, should be in light of its fortuitous co-variation with beam charge.

Factor 3 at Davis mound demonstrates eigenvalues and % variance in line with Factor 3 of the combined data (1.69 and 13.0%), and retains the negative association of chemical nitrogen and fluorine in combination with the calcium/phosphorus ratio, although all are unclustered spatially at Davis mound. Both FPPM and the calcium/phosphorus ratio vary together, with moderate coefficients of association, but whose values are reversed from the situation in the combined table. The calcium/phosphorus ratio dominates Davis Factor 3, indicating a strong bone mineral influence on the other variables. Calcium shows the next highest coefficient, signaling its dominance in the relationships. Chemical nitrogen, although its negative sign is in the direction of prediction, has a very low association with the other variables, very similar to the condition in the
combined table, indicating affects on these elements that diverge from expected. It was seen in Table 5 that Davis mound had overall smaller mean and range values for N% than Toepfner mound. However, these low Davis nitrogen values do not show significant negative correlations with fluorine or the bone minerals in Factor 3 as would be expected if age were the only determinative factor. This is likely due to a concomitant reduction in the bone mineral as well, a conclusion supported by soil pH variations identified within and between the two mounds (see below and Table 22 as well as Table 23). Further confirmation of the non-time related variability of Davis nitrogen values is provided by the unexpected positive associations of nitrogen with fluorine in Factor 1 at Davis.

Factor 3 is very much different from the corresponding factor at Toepfner mound, where the charge/silicon cluster was weakly associated with a negative calcium coefficient. Charge effect does not seem to play a factor in Factor 3 at Davis, and thus the bone minerals seem to be immune from the moderately strong co-variation of the nuclear nitrogen values in Factor 2.
Before examining the temporal sensitivity of the fluorine and nitrogen measurements in their stratigraphic context some special problems must first be examined. The question at this point involves the significance of the different factor loadings and clusters for understanding the differences observed earlier in the rank correlations between and within Toepfner and Davis mounds. A general characteristic relating to Factor 1 in all the tables involves the association of the bone mineral group (calcium, phosphorus, sodium, and the calcium/phosphorus ratio) with the characteristic behavior of fluorine and nitrogen in the two mounds. Although the direction (or sign) and the strength of the relationship is variable, the association is significant in each case, and fundamentally important to all subsequent interpretations. The association can be stated as a system (the bone matrix base) whose constituent parts (fluorine, nitrogen, and the bone minerals) are each functions of the other bone constituents, relative to the mass of the surviving bone matrix, and whose terminal configuration is a
factor of the burial environment and the exposure time. Eventually we would like to isolate the conditions of exposure time that affect the quantities of fluorine and nitrogen from other factors, but in the mean time we must begin with an understanding of the interactive influences of the bone matrix base and environmental alterations. Both are important aspects of the problem of evaluating the time sensitivity of fluorine and nitrogen at Toepfner and Davis mounds.

The general model for the interactive bone matrix system in a burial environment, as it affects the relative measure of fluorine, nitrogen, and the bone mineral cluster, is a simple one. As already indicated, fluorine accumulates in the apatite crystal of the bone matrix at a rate that is closely controlled by local hydrological conditions. Nitrogen, as a part of bone protein, decays with time, and is lost to the environment at an exponential rate. The bone mineral matrix as well suffers alterations with time due to weathering and chemical erosion. As long as we hold two of the three bone constituents constant in the bone matrix base, as well as the burial environment processes, we can safely say that changes in the third constituent proceeds in the predicted manner. However, in the process, apparent values of the other two constituents, as determined by the techniques used here, will change, even though
their absolute quantities are held constant. This is because the measurements are determined as proportions of the total bone matrix. As one element's ratio in the matrix changes, all the other proportions will change as well.

For instance, if fluorine accumulation were the only process acting on the bones in this study, we would observe an increase in the value of fluorine in relationship to its stratigraphic rank. In as much as fluorine also adds to the bone matrix base, albeit in very small quantities, we can expect to see a concomitant decline in the measured proportions of nitrogen and the other bone minerals. A rank correlation between fluorine and nitrogen would be perfectly negative. We may be tempted to conclude that both elements are measuring a time relationship when in reality only one is varying. The same is true if we were to hold constant fluorine accumulation and the bone minerals and let nitrogen change with time. We would expect, if this scenario were true, to find similar but inverse rates of change to be reflected in all of these constituents, if an alteration process is working only on one of them, simply because our methods of measurement rely on relative proportions with respect to the total bone matrix base. Evaluation of these elemental changes and their statistical significance should be accomplished with this in mind.
When the bone mineral elements are altered, keeping for the moment, fluorine and nitrogen constant, we may expect the proportion of nitrogen in the bone matrix to increase. Forcing fluorine to remain constant would also cause an apparent increase in its ratio to the total bone matrix. Fluorine is functionally related to the absolute amount of apatite mineral, because it can accumulate only as a substitution in the crystallite lattice. Consequently, its absolute quantity is directly affected by the absolute quantity of the bone mineral. In this special case, a reduction in bone mineral proportions reduces fluorine ratios as well, producing an even larger apparent nitrogen affect than previously suggested.

In real burial situations, all three variables can undergo processes of change simultaneously, creating a tremendously difficult puzzle to unravel. To illustrate the problem, compare the bone mineral statistics in Table 41 with the fluorine and nitrogen values in Table 5. Both the chemical and nuclear measurements at Toepfner mound have higher mean values and higher standard deviations. These values do not necessarily imply that nitrogen is higher in quantity, and thus the bone is younger or better preserved, because the bone mineral elements are lower for Toepfner as well, perhaps contributing to an apparent increase in nitrogen values. In conjunction with this is the opposite
tendencies of chemical fluorine and nuclear fluorine values at Toepfner, with respect to their corresponding values at Davis.

<table>
<thead>
<tr>
<th></th>
<th>Calcium</th>
<th>Phosphorus</th>
<th>Sodium</th>
<th>Calcium/Phosphorus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined Data</td>
<td>Mean = 6876.71</td>
<td>3.9238</td>
<td>100.27</td>
<td>1.77300</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation = 1783.33</td>
<td>1.04011</td>
<td>34.14</td>
<td>.33912</td>
</tr>
<tr>
<td></td>
<td>n = 30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Toepfner</td>
<td>Mean = 6575.85</td>
<td>3.88146</td>
<td>106.46</td>
<td>1.68072</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation = 1620.73</td>
<td>.72584</td>
<td>35.20</td>
<td>.16145</td>
</tr>
<tr>
<td></td>
<td>n = 13</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Davis</td>
<td>Mean = 7957.33</td>
<td>4.50667</td>
<td>109.52</td>
<td>1.84094</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation = 2278.38</td>
<td>1.51060</td>
<td>34.26</td>
<td>.58349</td>
</tr>
<tr>
<td></td>
<td>n = 9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>

Another compounding difficulty is the difference in behavior of the bone matrix burial system for different bone types. Hard, dense cortical bone would tend to respond differently from thin bones, or animal bone from human bone. Moreover, a sequential affect within single bones can be expected as density changes from the outside to the inside, because the forces of alteration in the
environment are directional in nature, tending to concentrate activity at the surfaces. As a result, the comparison of these different bone types from various burial situations may be misleading. For instance, the comparison of chemically determined nitrogen and fluorine are based on the whole bone, sometimes including more than one bone specimen and bone type (to make-up the required sample sizes for laboratory measurement). Nuclear measures, on the other hand, determine only the surface content of the elements and involve only one bone specimen.

A strategy is followed in later analyses that tries to isolate sub-samples in the bone series from each mound that contain similar degrees of bone mineral preservation, with similar bone types in order to minimize the non-temporal effects on fluorine and nitrogen content. This involves, for example, differences between unburned and burned bone at Toepfner mound, or rib bone versus long-bone. In addition, much of the preceding reasoning has gone into the calibration of nuclear fluorine and nitrogen values by the calcium/phosphorus ratio in the PNOADJ and NNOADJ measurements. The desire was to reduce the proportional affects of bone mineral variations on the target elements.

A second analytical strategy that characterizes the succeeding sections, is the isolation of environmental factors as sources of variation in the sample. Thus, soil pH, and
sub-mound versus mound fill areas were used to sub-set the skeletal series for comparison and evaluation. Small overall sample sizes in the sub-sets have hindered some aspects of the analysis, but the work is not final. Hypotheses generated by the following results can be tested against future research, and used to evaluate and define the optimal conditions for employing these methods for dating purposes.

**CHARGE/SILICON AFFECTS**

Accelerator fluctuations have a significant affect on the interpretation of the nuclear measurements. The Factor 2 results for the Combined Data in Table 12 indicated a significant negative association of nuclear nitrogen and the charge/silicon cluster, which is reflected in Davis mound's Factor 2 as well (Table 14). This association is corroborated by strong Spearman rank correlations between beam charge and \( \text{NNO} (-.5500, \ n=9, \ p=.06) \) and \( \text{NNOADJ} (-.4667, \ n=9, \ p=.103) \). Although not as apparent in Toepfner mound, Factor 1 (Table 13) shows a similarly high negative Spearman rank correlation of nuclear nitrogen with beam charge (\( \text{NNO: -.5172, n=13, p=.035; NNOADJ: -.5089, n=13, p=.038} \)). Toepfner's fluorine values apparently are immune to the beam charge problem (see Table 16).
### Table 16

**Rank Correlations for Charge and Nuclear Measures**

<table>
<thead>
<tr>
<th>Charge</th>
<th>x</th>
<th>PNO</th>
<th>FNO</th>
<th>NNO</th>
<th>MNO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined Data</td>
<td>-0.0469</td>
<td>-0.0478</td>
<td>-0.6834</td>
<td>-0.6404</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=29</td>
<td>n=29</td>
<td>n=30</td>
<td>n=30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p=.404</td>
<td>p=.403</td>
<td>p=.000</td>
<td>p=.000</td>
<td></td>
</tr>
<tr>
<td>Toepfner</td>
<td>-0.1556</td>
<td>-0.2118</td>
<td>-0.5172</td>
<td>-0.5089</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=13</td>
<td>n=13</td>
<td>n=13</td>
<td>n=13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p=.306</td>
<td>p=.244</td>
<td>p=.035</td>
<td>p=.038</td>
<td></td>
</tr>
<tr>
<td>Davis</td>
<td>0.5000</td>
<td>0.4286</td>
<td>-0.5500</td>
<td>-0.4667</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=8</td>
<td>n=8</td>
<td>n=9</td>
<td>n=9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p=.104</td>
<td>p=.145</td>
<td>p=.062</td>
<td>p=.103</td>
<td></td>
</tr>
</tbody>
</table>

When target spectra and samples were inspected for possible mechanical or machine variations, several samples were found to have beam spots (physically marked on the bone by a black residue) that were off center near the edge, which corresponded with unusually high silicon counts. The obvious conclusion was that a large part of that target's spectra was produced by gammas from the observation window behind the target at the end of the beam line, rather than the bone sample itself. Other bone samples could be determined as suspect in their results due to problems encountered during the actual run, for instance, fluctuations in the beam current level observed during the acquisition of a spectra. Other targets may have not been hit at all, because of mis-alignment of the heavy aluminum target holder that absorbed the entire beam and showed up
in the spectra as lower than expected values for the thinner aluminum foil standard. This was usually confirmed visually by a distinct beam spot on the bone. At least one sample was so thin over a portion of the beam that it was likely that the beam penetrated entirely through. Two samples were also of powdered bone, loosely consolidated in tantalum foil envelopes, and considered unreliable in their results.

All these considerations and the physics involved were included in a determination of "Good Counts" containing reliable data. In this and subsequent analyses of the data, the "Good Counts" are contrasted against the "Bad Counts." The only systematic relationship of these subsets to the overall target "population" is that initial set-up and alignment problems occurred with the first few targets (which came largely from Davis Mound), and beam current fluctuations occurred near the end of the run, affecting a few Toepfner samples. Most of Toepfner's samples occurred during the middle of the run, where initial problems of alignment and set-up were eliminated, and the beam current and machine performance were constant and optimal, given overall conditions.

Implications for Davis mound gathered from Table 16 are that the charge and accelerator beam effects have a strong influence on both nitrogen and fluorine determinations.
Nitrogen is likely being washed out of the spectra due to its low values and association with high noise levels with increasing beam charge strength, thus producing its negative correlation with increasing beam charge levels. Fluorine nuclear measurements at Davis are, in contrast, enhanced by increasing beam charge, although the correlation is not as significant. Nuclear fluorine determinations at Toepfner, however, appear to be free of this problem. The charging problem has been controlled somewhat in the following data analysis by the segregation of those samples with high charge effects from the target "population" (i.e., Good Counts versus Bad Counts).

The number of Good Count samples was too small at Davis mound to do a rank correlation. However, the number of Bad Count specimens was large enough. These are listed in Table 17 in comparison to the Total Bad Counts for the Combined Data. The Bad Counts for the Combined Data and Davis mound are similar in that the Bad Counts indicate high negative rank correlations with charge. The segregation of the target "population" into Good Counts and Bad Counts did not eliminate, however, nitrogen's dependence on charge and beam current factors for the Combined or Toepfner data. In fact the rank correlations for nitrogen for the Combined and Toepfner Good Counts are higher than Davis' Bad Counts. The only conclusion possible at this point is that NNO and
NNO measures in all instances of this study have some systematic contribution from the accelerator source to the bone measurement, probably as a result of low, absolute nitrogen in the targets, and the inability of nitrogen peaks to be distinguished from spectral background (see Figure 1). Toepfner nuclear fluorine seems still to be free of this problem.

Table 17

Charge and Nuclear Measures Divided into Good and Bad Counts

<table>
<thead>
<tr>
<th>Charge</th>
<th>FNO</th>
<th>FNOADJ</th>
<th>NNO</th>
<th>NNOADJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined Good Counts</td>
<td>-.2819</td>
<td>-.2843</td>
<td>-.7868</td>
<td>-.6814</td>
</tr>
<tr>
<td>n=17</td>
<td>p=.137</td>
<td>p=.134</td>
<td>p=.000</td>
<td>p=.001</td>
</tr>
<tr>
<td>Toepfner Good Counts</td>
<td>.0167</td>
<td>-.0667</td>
<td>-.6167</td>
<td>-.5500</td>
</tr>
<tr>
<td>n=9</td>
<td>p=.483</td>
<td>p=.432</td>
<td>p=.038</td>
<td>p=.062</td>
</tr>
<tr>
<td>Total Bad Counts</td>
<td>.1401</td>
<td>.2732</td>
<td>-.5392</td>
<td>-.5365</td>
</tr>
<tr>
<td>n=12</td>
<td>p=.332</td>
<td>p=.195</td>
<td>p=.092</td>
<td>p=.029</td>
</tr>
<tr>
<td>Davis Bad Counts</td>
<td>.3000</td>
<td>.3000</td>
<td>-.5429</td>
<td>-.5429</td>
</tr>
<tr>
<td>n=6</td>
<td>p=.312</td>
<td>p=.312</td>
<td>p=.133</td>
<td>p=.133</td>
</tr>
</tbody>
</table>

A possibility exists that nitrogen in general is in part accidentally associated with beam charge. Table 18 lists rank correlations between beam charge and the two chemical measurements. Such correlations cannot be related to the
accelerator because they were independently made at another laboratory using a chemical technique. However, the high correlations of fluorine and nitrogen with charge in both analyses may be the result of underlying factors in the target samples themselves. To test this possibility, rank correlations were conducted between the techniques for the two measures, to clarify their relationships (see Table 19). The results indicate a significant relationship between the two independent measures of nitrogen and fluorine at Toepfner mound, but not at Davis mound. The implication is that the Toepfner mound nuclear measures are as reliable an indicator as their chemical counterparts. Moreover, these nuclear measurements are good indicators of the whole bone's content of fluorine and nitrogen, and not just the surface. These relationships are strongest for nitrogen in the adjusted nuclear values for the total Toepfner sample, and for fluorine in the unadjusted nuclear values for the total Toepfner sample.

Conversely, the nuclear measures at Davis show no relationship to their chemical counterpart. They appear to vary randomly with respect to one another. Therefore, their is a strong indication that major differences exist between the nature of the bone surface, versus the total bone sample mass at Davis mound. This is likely due to factors of preservation (see below). However, what it
### Table 18

**Rank Correlations of Charge and Chemical Measures**

<table>
<thead>
<tr>
<th>Charge</th>
<th>( x )</th>
<th>FPPM</th>
<th>N%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Combined Data</strong></td>
<td>( .3566 )</td>
<td>( -.4196 )</td>
<td>( n=12 )</td>
</tr>
<tr>
<td><strong>Combined Good Counts</strong></td>
<td>( .2857 )</td>
<td>( -.7143 )</td>
<td>( n=7 )</td>
</tr>
<tr>
<td><strong>Toepfner Total</strong></td>
<td>( .5000 )</td>
<td>( -.5714 )</td>
<td>( n=8 )</td>
</tr>
<tr>
<td><strong>Toepfner Good Counts</strong></td>
<td>( .7714 )</td>
<td>( -.6000 )</td>
<td>( n=6 )</td>
</tr>
<tr>
<td><strong>Combined Bad Counts</strong></td>
<td>( -.7143 )</td>
<td>( .2143 )</td>
<td>( n=7 )</td>
</tr>
<tr>
<td><strong>Davis Total</strong></td>
<td>( -.6000 )</td>
<td>( .3143 )</td>
<td>( n=6 )</td>
</tr>
<tr>
<td><strong>Davis Bad Counts</strong></td>
<td>( -.9000 )</td>
<td>( .4000 )</td>
<td>( n=5 )</td>
</tr>
</tbody>
</table>

Indicates for the present is that the charge effects on fluorine and nitrogen nuclear measurements are significant, and not just a product of accidental associations of the real, absolute nitrogen and fluorine content with it. As bone deterioration at the surface seems to be involved versus the overall bone mass, proton beam penetration of this
Table 19

**Rank Correlations of the Chemical and Nuclear Measures**

<table>
<thead>
<tr>
<th></th>
<th>N% x NNO</th>
<th>N% x NNOADJ</th>
<th>FPPM x PNO</th>
<th>FPPM x PNOADJ</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Combined Data</strong></td>
<td>.6794</td>
<td>.7495</td>
<td>.2354</td>
<td>.1429</td>
</tr>
<tr>
<td>n=14</td>
<td>n=14</td>
<td>n=14</td>
<td>n=14</td>
<td>n=14</td>
</tr>
<tr>
<td>p=.004</td>
<td>p=.001</td>
<td>p=.209</td>
<td>p=.313</td>
<td></td>
</tr>
<tr>
<td><strong>Combined Data</strong></td>
<td>.6071</td>
<td>.7500</td>
<td>.7500</td>
<td>.6786</td>
</tr>
<tr>
<td>Good Counts</td>
<td>n=7</td>
<td>n=7</td>
<td>n=7</td>
<td>n=7</td>
</tr>
<tr>
<td>p=.074</td>
<td>p=.026</td>
<td>p=.047</td>
<td>p=.047</td>
<td></td>
</tr>
<tr>
<td><strong>Toepfner Total</strong></td>
<td>.7381</td>
<td>.8095</td>
<td>.6467</td>
<td>.8810</td>
</tr>
<tr>
<td>n=8</td>
<td>n=8</td>
<td>n=8</td>
<td>n=8</td>
<td>n=8</td>
</tr>
<tr>
<td>p=.018</td>
<td>p=.007</td>
<td>p=.042</td>
<td>p=.176</td>
<td></td>
</tr>
<tr>
<td><strong>Toepfner</strong></td>
<td>.5429</td>
<td>.7143</td>
<td>.6000</td>
<td>.4857</td>
</tr>
<tr>
<td>Good Counts</td>
<td>n=6</td>
<td>n=6</td>
<td>n=6</td>
<td>n=6</td>
</tr>
<tr>
<td>p=.133</td>
<td>p=.055</td>
<td>p=.104</td>
<td>p=.164</td>
<td></td>
</tr>
<tr>
<td><strong>Combined Data</strong></td>
<td>.3214</td>
<td>.2143</td>
<td>-.1071</td>
<td>-.4286</td>
</tr>
<tr>
<td>Bad Counts</td>
<td>n=7</td>
<td>n=7</td>
<td>n=7</td>
<td>n=7</td>
</tr>
<tr>
<td>p=.241</td>
<td>p=.322</td>
<td>p=.410</td>
<td>p=.169</td>
<td></td>
</tr>
<tr>
<td><strong>Davis Total</strong></td>
<td>.2000</td>
<td>.4286</td>
<td>-.0857</td>
<td>-.0857</td>
</tr>
<tr>
<td>n=6</td>
<td>n=6</td>
<td>n=6</td>
<td>n=6</td>
<td>n=6</td>
</tr>
<tr>
<td>p=.352</td>
<td>p=.198</td>
<td>p=.436</td>
<td>p=.436</td>
<td></td>
</tr>
<tr>
<td><strong>Davis</strong></td>
<td>.0000</td>
<td>.0000</td>
<td>-.4000</td>
<td>-.4000</td>
</tr>
<tr>
<td>Bad Counts</td>
<td>n=5</td>
<td>n=5</td>
<td>n=5</td>
<td>n=5</td>
</tr>
<tr>
<td>p=.500</td>
<td>p=.500</td>
<td>p=.252</td>
<td>p=.252</td>
<td></td>
</tr>
</tbody>
</table>

The table above shows the rank correlations for various measures, with the p-values indicating the significance of the correlation. The table includes data for combined and specific categories, with the number of observations (n) and significance (p) provided for each correlation.

Weathered layer encounters much more variation in available fluoride and nitrogen (compare standard deviations for PNO and PNOADJ, and NNO and NNOADJ in Table 5). Total bone fluoride and nitrogen content are reduced as well for Davis
as indicated by the chemical analysis of the whole bone sample (see Table 5 for PPPM and N% differences). In sum, the generally poorer preservation condition of Davis bone samples, and the higher weathering factors at the surfaces of Davis samples, seem to have produced some low gamma counts that are not significantly above the noise threshold of the general spectra to avoid confusion with the charge related background. It should be pointed out that even under the worst conditions, charge effects do not display higher than moderate rank correlations, with usually only poor statistical significance.

Rank correlations for Toepfner Good Counts and Davis Bad Counts are listed in Table 20. Sample sizes were too small to also run statistics for Toepfner Bad Counts, and Davis Good Counts. A comparison of Davis mound values indicates that almost the entire sample's rank correlations are the result of Bad Counts, or are associated with some accelerator discrepancy. This may not be a great influence, but it is relatively more important in Davis rank correlations than Toepfner. Toepfner Good Counts indicate some improvement in the rank correlations for fluorine, but little change for nitrogen, although the correlation has increased in the expected negative direction with respect to stratigraphic rank. The Spearman rank correlations with Good or Bad Counts for the two chemical analyses have to be consid-
ered entirely spurious and random, although they shift towards expected values as well.

Table 20

<table>
<thead>
<tr>
<th>Rank</th>
<th>X</th>
<th>FPPM</th>
<th>N%</th>
<th>FNO</th>
<th>NNO</th>
<th>FNOADJ</th>
<th>NNOADJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toepfner Good Counts</td>
<td>-.3143</td>
<td>-.1429</td>
<td>-.2845</td>
<td>-.4937</td>
<td>-.3180</td>
<td>-.4519</td>
<td></td>
</tr>
<tr>
<td>n=6</td>
<td>n=6</td>
<td>n=9</td>
<td>n=9</td>
<td>n=9</td>
<td>n=9</td>
<td>p=.272</td>
<td>p=.394</td>
</tr>
<tr>
<td>Davis Bad Counts</td>
<td>-.3000</td>
<td>-.7000</td>
<td>-.4000</td>
<td>-.3714</td>
<td>-.4000</td>
<td>-.3714</td>
<td></td>
</tr>
<tr>
<td>n=5</td>
<td>n=5</td>
<td>n=5</td>
<td>n=6</td>
<td>n=5</td>
<td>n=6</td>
<td>p=.312</td>
<td>p=.094</td>
</tr>
</tbody>
</table>

**Bone Preservation and Soil Characteristics**

Although Toepfner bone mineral and nuclear fluorine values are lower and more variable than Davis (Table 5 and Table 15), previous analysis of the data plus subjective evaluation of the skeletons (based on the amount of the remains, degree of bone structural integrity, relative bone quality, etc.) revealed that the Toepfner series was in better condition. How then do we interpret the differences in the measurements? One way is to begin with the implications of Factor 1: the values of all bone mineral elements (including fluorine) and bone organics (nitrogen) must be viewed with respect to changes in the overall bone mass, since each is standardized to the total bone mass.
Therefore, Toepfner can demonstrate better bone preservation than Davis, and yet manifest lower mean nuclear fluorine and other bone mineral values, and higher mean nuclear values for nitrogen than Davis. These fluorine and nitrogen variations are probably due to greater overall bone mass proportions at Toepfner (compare FPPM and N% in Table 5), with a larger proportion of it (measured by the accelerator) consisting of organic material. The higher proportion of organic material at Toepfner can be seen in the comparison of FNO to NNO ratios between the two mounds (Table 21). The lower nuclear fluorine to nitrogen ratios at Toepfner indicate that Toepfner has relatively lower proportions of bone mineral with respect to the entire bone mass than Davis. The relative contribution of fluorine and other bone minerals to the bone mass is reduced with respect to organic materials and nitrogen even though the absolute values for all quantities of these elements per specimen may be greater at Toepfner in comparison to Davis specimens because of better preservation conditions. However, this relationship appears to be restricted only to the surface of the bones, for the opposite is indicated for FPPM/N% ratios. The whole bone at Toepfner indicates a higher proportion of mineral than protein at Toepfner, with more variation between individual specimens as well. The FPPM/N% ratio would tend to contradict the bone preservation conclusion.
Table 21

Fluorine to Nitrogen Ratios for Toepfner and Davis Mounds

<table>
<thead>
<tr>
<th></th>
<th>F N%</th>
<th>FNO / NNO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toepfner</td>
<td>Mean = 6035.6789</td>
<td>0.1593214</td>
</tr>
<tr>
<td></td>
<td>Standard</td>
<td>6818.7953</td>
</tr>
<tr>
<td></td>
<td>Deviation</td>
<td>n = 8</td>
</tr>
<tr>
<td>Davis</td>
<td>Mean = 5165.0047</td>
<td>0.2450229</td>
</tr>
<tr>
<td></td>
<td>Standard</td>
<td>5870.5159</td>
</tr>
<tr>
<td></td>
<td>Deviation</td>
<td>n = 5</td>
</tr>
</tbody>
</table>

Why is there so much variation between chemical and nuclear data within the mounds and between the mounds? The answer to this question is not simple nor fully understandable given the extent of the present analysis, but some answers can be gathered. These involve general differences between the two burial sites, and specifically, within site differences in the contexts and prehistoric treatments of individual skeletal remains.

Factor 1 at Davis mound indicates a strong, positive relationship between nuclear (surface) fluorine values, and all nitrogen measurements, including N% (see Table 14). As previously observed, nuclear nitrogen measurements have moderate high rank correlations with beam charge, which is confirmed by the loadings for NNO and NNOADJ, on the one
hand, and charge and silicon, on the other, for Factor 2 at Davis mound. The inverse sign relationship indicates that with increasing beam charge, nuclear nitrogen values tend to decrease. This is consistent with the conclusion that nitrogen values at Davis are very low, as compared with Toepfner mound (see Table 5 and Table 15), in both surface bone, and the overall bone matrix.

Another aspect of Factor 1 at Davis is the high positive bone mineral association of phosphorus, calcium, and sodium. What this seems to indicate is a general mound tendency for surface bone mineral to decrease along with surface fluorine content, and total bone nitrogen, from the surface as well as the interior. Internal fluorine content is affected significantly less by this process, as indicated by a lower coefficient for Factor 1. Consequently, it shows an opposite tendency, that is, a slight tendency to increase with increasing bone deterioration, especially the organic proportion.

These variables from Factor 1 at Davis also display a moderately high negative correlation with stratigraphic rank (see Table 10). The stratigraphic rank correlations indicate that both fluorine and nitrogen, whether measured by chemical or nuclear means, increase with depth. This trend in rank correlations is unexpected for nitrogen, and in fact can only occur as a result of co-variations in
total bone mass against which its values are standardized. Comparisons between the burial contexts of the two mounds provides some clues to the possible forces involved with differential alterations of overall bone mass and their effects on mineral and organic bone measurements with respect to it.

The soil characteristics at the upland Davis site are very much different from the floodplain locality at Toepfermer. Both burial areas are, however, underlain by a calcareous sub-stratum that consists of glacial till. The soils generated from this till is a loam or clay loam called an udorthent. Universally, these soils are characterized as mild to moderately alkaline, very well drained, having high permeability, and rapid runoff (McLoda and Parkinson 1980:60-61). These soils are likely to contain less fluo-
rine than the overlying silt-loams and clay-loams found throughout the region (Robinson and Edgington 1946:347). The gravel hills, knolls, kames, and outwash terraces of Ohio have been recognized for their unusually good skeletal preservation for some time (Moorehead 1894:194, 1895:317), largely as a factor of their soil properties. A striking current example of the effects of alkaline conditions on bone preservation comes from the recovery of an 8,000 year old human being from a Florida peat bog by the University of Florida, demonstrating remarkable tissue preservation
(see Schmeck 1985:22). Dr. William Hauswirth of the University of Florida has been able to recover DNA from these remains, and suggests that bone chemistry may itself tend to protect DNA from degeneration as well, that is, the bone mineral would act like a shield to protect the bone organisms from weathering effects. Some bones that appear to be entirely mineralized have been shown to have retained considerable amounts of protein (see Ascenzi for a thorough bibliographic listing, 1955:557; also Cook and Heizer 1947; Oakley 1970:37).

Laboratory experiments have indicated that collagenase, an enzyme that degrades collagen, disappears rapidly in strong acid conditions (pH below 4 or 5), is highest in neutral or slightly alkaline conditions (pH 7 to 8), and may persist in particular situations with very high alkaline conditions (pH 9) (see Garlick 1970:504). Thus, the pH value alone does not account for the preservation of bone in alkaline contexts. Other factors that may inhibit bone degradation must limit the production of microorganisms. Deep rapid burial of the remains below the active humus level would be one way to avoid these kinds of micro-organisms. This appears to be the case in the subfloor pit burials at both Davis and Toepfner mounds. In addition, deep burial in the calcareous gravels would have an additional bonus of stabilizing annual fluctuations in
temperature and humidity, factors that can also contribute to bone degradation and protein destruction (Garlick 1970:505). This is confirmed in the descriptive comparisons of sub-floor and mound fill measurements at both sites (see Table 22). Note that the largest differences occur at Davis mound, suggesting far more active bone degrading agents in the mound fill versus the other three sub-areas. Protein degrading agents can be largely accounted for in the differences between the pH and other soil characteristics at Davis in comparison with Toepfner mound.

Also, note that the fluorine content of sub-floor burials at Davis is significantly higher, both chemically and nuclearly, than the mound fill. Given that the udorthent soils contain less fluorine than the silt-loams above, this fact may reflect a time component. Although Toepfner's sub-floor samples demonstrate the same tendency, the difference is much more attenuated.

Also, note that the fluorine content of sub-floor burials at Davis are significantly higher, both chemically and nuclearly, than the mound fill. Given that the udorthent soils contain less fluorine than the silt-loams above, this fact may reflect a time component. Although Toepfner's sub-floor samples demonstrate the same tendency, the difference is much more attenuated.
Table 22

Statistics for Mound Fill and Sub-floor Features

(* DATA UNAVAILABLE FOR CALCULATION *)

<table>
<thead>
<tr>
<th></th>
<th>FPPM</th>
<th>%N</th>
<th>PNO</th>
<th>NNO</th>
<th>Ca/P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Davis Mound Fill</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean = 982.3</td>
<td>178.225</td>
<td>967.0</td>
<td>1616.904</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>210.6</td>
<td>127.78</td>
<td>337.69</td>
<td>88.975</td>
<td></td>
</tr>
<tr>
<td>n = 3</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Davis Sub-floor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean = 4992.0</td>
<td>419.75</td>
<td>2152.0</td>
<td>1711.498</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>5523.1</td>
<td>237.05</td>
<td>1264.05</td>
<td>140.853</td>
<td></td>
</tr>
<tr>
<td>n = 3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Toepfner Mound Fill</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean = 1443.0</td>
<td>249.33</td>
<td>1896.78</td>
<td>1677.46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>385.45</td>
<td>64.56</td>
<td>934.25</td>
<td>182.76</td>
<td></td>
</tr>
<tr>
<td>n = 7</td>
<td>7</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Toepfner Sub-floor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean = 1680.0*</td>
<td>265.25</td>
<td>2540.0</td>
<td>1680.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>*</td>
<td>45.95</td>
<td>503.39</td>
<td>54.51</td>
<td></td>
</tr>
<tr>
<td>n = 1</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

The soil types in the vicinity of Davis mound are of two types: Cardington silt-loam and Alexandria silt-loam. The Cardington soils likely occupied upper mound and mound crest positions. They are very strongly acid in the upper portions to mildly alkaline in the lower parts. Its permeability is slow, with a seasonally high water table of 24 to 36 inches. It contains moderately low organic matter, and experiences a high degree of frost action (McLoda and Parkinson 1980:19).
Alexandria silt-loam soils occupy slope positions of 12 to 18%, and probably were found along the mound sides. It is a well drained soil, very strongly acid in the upper portions, to neutral in its lower parts. It has moderately slow permeability, and puddles and crusts over easily (McLoda and Parkinson 1980:12).

In contrast, Toepfnier's floodplain soils consist of the Genesee and Medway types. Genesee silt-loam soils probably characterized the upper mound sections at Toepfnier. They are only slightly acidic to moderately alkaline from upper to lower portions, and are characterized by a deep well drained matrix, with moderate permeability and slow runoff. Its floodplain locality guarantees high available water content almost anytime of the year (McLoda and Parkinson 1980:35).

Medway silt-loams probably occupied the sloping sides of Toepfnier mound. Eldean soils of 6 - 18% slope were not considered representative of the original material available for the construction of Toepfnier mound. However, it is likely that these soils developed later on the mound slopes. Eldean soils are only slightly more acidic than Medway soils, between 5.6 and 7.8 pH (0 - 35 inches in depth), and neutral to moderately alkaline between 35 and 70 inches (McLoda and Parkinson 1980:178). But it can be assumed that by the time these conditions developed in the
mound slopes, graves and tombs were already buried deep, and the increase in the surface soil acidity was of decreased significance to the overall diagenetic processes in the vicinity of the remains. The upper portions of Medway soils are slightly acidic, while lower portions are moderately alkaline, just as the Genesee soils. Permeability is moderate, water capacity high, and runoff is slow. Medway has a low shrink swell coefficient and a deep root zone (McLoada and Parkinson 1980:43).

The major difference between Davis soils and Toepfner soils are their higher acid content (pH less than 6.1; see Table 23). Relatively higher acid contexts would be the number one reason for the de-mineralization of bone in any environment (Garlick 1980:506; Gilbert 1977:90; Ortner et al. 1977:519; Spiess, Curran, and Grimes 1985:150). Nearly a century ago, Warren K. Moorehead noticed the association of Ohio's silt-loam soils with poor skeletal preservation (1894:194). Today many laboratories de-calcify bone specimens with acid in order to isolate the organic fraction for analysis. There is no quantitative way to measure the absolute amounts of bone mineral from any of the specimens in this study to directly demonstrate this condition. However, other lines of evidence will support this conclusion regarding the differences between Davis and Toepfner mounds.
Table 23

**pH Reaction Range for Various Soils from Toepffer and Davis**

Data obtained from McLoda and Parkinson 1980:177-178.

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Depth From Surface (inches)</th>
<th>pH Reaction Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardington Silt-loam</td>
<td>0 - 6</td>
<td>4.5 - 7.3</td>
</tr>
<tr>
<td></td>
<td>6 - 34</td>
<td>4.5 - 7.8</td>
</tr>
<tr>
<td></td>
<td>34 - 70</td>
<td>7.4 - 8.4</td>
</tr>
<tr>
<td>Alexandria Silt-loam</td>
<td>0 - 8</td>
<td>4.5 - 7.8</td>
</tr>
<tr>
<td></td>
<td>8 - 42</td>
<td>4.5 - 7.3</td>
</tr>
<tr>
<td></td>
<td>42 - 70</td>
<td>7.4 - 8.4</td>
</tr>
<tr>
<td>Genesee Silt-loam</td>
<td>0 - 9</td>
<td>6.1 - 7.8</td>
</tr>
<tr>
<td></td>
<td>9 - 37</td>
<td>6.1 - 8.4</td>
</tr>
<tr>
<td></td>
<td>37 - 70</td>
<td>7.4 - 8.4</td>
</tr>
<tr>
<td>Medway Silt-loam</td>
<td>0 - 15</td>
<td>6.1 - 8.4</td>
</tr>
<tr>
<td></td>
<td>15 - 30</td>
<td>6.1 - 8.4</td>
</tr>
<tr>
<td></td>
<td>30 - 70</td>
<td>6.6 - 8.4</td>
</tr>
</tbody>
</table>

Proportions of the three bone mineral elements, calcium, phosphorus, and sodium, show remarkably similar values as measured by the accelerator (see Table 24). This is because the measurements are not absolute quantities of the three elements, but their proportions in relation to the entire bone matrix. What is interesting to note at this point is that the proportions of the three elements in bone, regardless of other factors and variations, remain roughly stable with time (compare Table 15 Ca/P ratio with McConnell's Ca/P ratio for bovine cortical bone (1.683), and hydroxyapatite (1.667) (1962:241)). This conclusion is
significant because of previous debates in the literature concerning the alteration of calcium and phosphorus ratios due to the introduction of carbonates in the bone mineral lattice with time (see Dallemagne and Richelle 1973:31; Gruner and McConnell 1912; McConnell 1938, 1952, 1960a, 1960b, 1962; Zapanta-LeGeros 1965).

Table 24

<table>
<thead>
<tr>
<th>Statistics of the Bone Minerals From Mound Fill</th>
<th>Calcium</th>
<th>Phosphorus</th>
<th>Sodium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Davis Mound Fill</td>
<td>7043.60</td>
<td>4.32</td>
<td>109.76</td>
</tr>
<tr>
<td>Mean</td>
<td>1962.45</td>
<td>1.10</td>
<td>28.15</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>n</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Toepfner Mound Fill</td>
<td>6970.22</td>
<td>4.12</td>
<td>111.95</td>
</tr>
<tr>
<td>Mean</td>
<td>1728.93</td>
<td>0.73</td>
<td>39.12</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>n</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>

I am not prepared with these data, nor with an adequate knowledge of bone crystal chemistry, to join in a critique of whether or not human calcified tissue consists of hydroxyapatite crystals, or carbonate hydroxyapatite (dahlite). Most researchers seem convinced that calcified human tissue consists of a multi-phase mineral structure consisting of amorphous and crystalline calcium phosphate. Because carbonates in the crystallites have not been verified by published research, the proposed affects on the
fluorine accumulation and structural properties in fossil bone appear to be premature (see Dallewagne and Richelle 1973). However, the change in the chemical and crystal structure during burial can be examined in the present data. Laboratory experiments have demonstrated that calcium and phosphorus exchange occurs in calcified tissues (Underwood and Hodge 1952). But the proportions of these two elements appear to be rather stable with time.

The results of the Student's T-test for difference in means, and Analysis of Variance of the bone minerals for Davis and Toepfler mounds indicates they have no significant differences (Table 25). What this signifies is that the mineral crystal lattice of bone at the two different sites appears to be the same despite significant differences in preservation and deterioration factors, as well as time, at least as it is so far equated with stratigraphic position. Even as human bone has altered in the different contexts already identified, and others to be defined below, the mineral fraction of the remains maintains similar elemental proportions, and perhaps its original crystal lattice structure. Further comparative research in this area will prove illuminating to this problem.

A final point of interest that is worth mentioning at this time is the consistent association of sodium in this study with inorganic crystal elements in bone. Several
Table 25

T-test and Analysis of Variance of the Bone Minerals

<table>
<thead>
<tr>
<th></th>
<th>Calcium</th>
<th>Phosphorus</th>
<th>Sodium</th>
<th>Ca/P Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-Test</td>
<td>1.67</td>
<td>1.30</td>
<td>.20</td>
<td>.33</td>
</tr>
<tr>
<td>p=.055</td>
<td>p=.104</td>
<td>p=.42</td>
<td>p=.37</td>
<td></td>
</tr>
<tr>
<td>(pooled estimate)</td>
<td>(pooled estimate)</td>
<td>(pooled estimate)</td>
<td>(pooled estimate)</td>
<td></td>
</tr>
<tr>
<td>F(1,20)</td>
<td>2.789</td>
<td>1.6916</td>
<td>.0410</td>
<td>.1121</td>
</tr>
<tr>
<td>p=.1111</td>
<td>p=.2082</td>
<td>p=.8416</td>
<td>p=.7413</td>
<td></td>
</tr>
</tbody>
</table>

Studies have reported the association of sodium with the inorganic portion of bone and teeth (Dallemagne and Richelle 1973:25, 26; IAEA Information Sheet 1981:4; Lambert, Szpunar, and Buikstra 1979: 117-128; Parker and Toots 1970:926; Price and Kavanagh 1982:74-75; Weatherell and Robinson 1973:59-60; Zipkin 1973:496). Reported values have ranged from 0.75 ppm from prehistoric ribs and longbones from Wisconsin (Price and Kavanagh 1982:75) to as high as 8740 ppm in modern enamel (Weatherell and Robinson 1973:59). Neutron activation analysis at The Ohio State University Nuclear Reactor Laboratory on a rib from Burial #1 at Toepfner mound produced results intermediate to these extremes (see Table 26).

Although studies have linked the sodium content in fossil bone to biological processes during life and not to accumulative processes during fossilization, opinions have
Table 26

**Neutron Activation Analysis of Sodium**

<table>
<thead>
<tr>
<th>Sodium in ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>Burial #1, Toepfner (Rib)</td>
</tr>
<tr>
<td>Cortical Bone = 2670 ± 4%</td>
</tr>
<tr>
<td>Cortical Bone = 2839 ± 4%</td>
</tr>
<tr>
<td>Cancellous Bone = 2638 ± 4%</td>
</tr>
<tr>
<td>Bovine Bone Standard</td>
</tr>
<tr>
<td>NBS Orchard Leaves Standard</td>
</tr>
</tbody>
</table>

differed as to the reason for the variations found in fossil bone sodium. Lambert, Szpunar, and Buikstra (1979:123, 125, 127-128) have concluded that sodium's fluctuations among age grades in the burial populations at the Gibson and Ledder's mound sites have resulted from dietary factors. Parker and Toots on the other hand, although acknowledging that sodium probably enters the bone structure primarily during the life of an animal, note that qualitative levels of sodium in fossil and modern bone are the same, and sodium is associated with the apatite structure of bone (1970:926, 929). Consequently, variations in fossil bone sodium may be linked to variations in fossil bone apatite content. Interestingly, findings here support the latter conclusion, that is, sodium seems to be closely allied to the apatite crystal and shares a similar diagenetic fate as the rest of the bone minerals. Therefore,
variations in the sodium content of fossil bones may not be
direct measures of dietary differences of the organisms in
life but may be related to subsequent diagenetic changes in
the burial environment as well.
Chapter VI

FLUORINE AND NITROGEN VALUES IN STRATIGRAPHIC CONTEXT

The stratigraphic relationship of the fluorine and nitrogen measurements for Toepfner and Davis are analysed using Spearman rank correlations. Sources of variability in the fluorine and nitrogen dating capability are examined and evaluated. Variations within mounds as well as between mounds are examined, and factors which detract from the time sensitivity of the fluorine and nitrogen measurements are isolated and discussed.

THE DAVIS MOUND

To return to our evaluation of the time sensitivity of fluorine and nitrogen in the bone samples, we may safely say that the two mounds have very different geochemical environments that have contrasting effects on the states and conditions of various bone elements of the remains buried within them. Also within each mound itself are two broad, contrasting geochemical environments defined by the mound fill and the underlying udorthent gravels. How do
these general differences affect the Spearman rank corre-
lations for the two methods of measuring fluorine and nitro-
gen?

A summary of the results of dividing the total mound
samples into mound fill and sub-floor features is presented
in Table 27. The sub-floor pits below Toepfner contain too
few samples to calculate rank correlations. Davis mound's
small sample prevents a further breakdown into Good Counts
versus Bad Counts so only total mound fill and sub-floor
rank correlations are listed. The Bad Counts for Toepf-
ner's mound fill sample is also too small for statistical
evaluation.

A comparison of Table 27 with Table 10 indicates an
overall improvement, in the expected direction, of Spearman
rank correlations for both fluorine and nitrogen nuclear
measures, and Davis mound fill specimens show some surpris-
ing turn-abouts. Focusing upon the Davis mound results
first, we notice that sample sizes are too small for ideal
analyses, but some interesting trends are noticeable: FNO
and FNOADJ are probably relatively good measures, as indi-
cated by their high coefficients in Factor 1, but FPPM is
not highly associated with them, indicating a difference
between surface (cortical) bone and total bone (cortical
plus cancellous). However, NNO, NNOADJ, and N% are all
highly associated with each other in Factor 1, but are the
Table 27

**Rank Correlations for Mound Fill and Sub-floor Features**

<table>
<thead>
<tr>
<th>Rank</th>
<th>x</th>
<th>FPPM</th>
<th>%N</th>
<th>FNO</th>
<th>NNO</th>
<th>FNOADJ</th>
<th>NNOADJ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toepfner Mound Fill</td>
<td>-.0360</td>
<td>-.3243</td>
<td>-.2689</td>
<td>-.3530</td>
<td>-.3361</td>
<td>-.3109</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=7</td>
<td>n=7</td>
<td>n=9</td>
<td>n=9</td>
<td>n=9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p=.469</td>
<td>p=.239</td>
<td>p=.242</td>
<td>p=.176</td>
<td>p=.188</td>
<td>p=.208</td>
<td></td>
</tr>
<tr>
<td>Toepfner Mound Fill</td>
<td>-.1000</td>
<td>-.2000</td>
<td>-.5766</td>
<td>-.3784</td>
<td>.5406</td>
<td>-.2883</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=5</td>
<td>n=5</td>
<td>n=7</td>
<td>n=7</td>
<td>n=7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Davis Mound Fill</td>
<td>-1.0000</td>
<td>-.5000</td>
<td>-.4000</td>
<td>-.7000</td>
<td>.0000</td>
<td>-.6000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=3</td>
<td>n=3</td>
<td>n=4</td>
<td>n=5</td>
<td>n=4</td>
<td>n=5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p=.000</td>
<td>p=.333</td>
<td>p=.300</td>
<td>p=.094</td>
<td>p=.500</td>
<td>p=.142</td>
<td></td>
</tr>
<tr>
<td>Davis Sub-floor</td>
<td>.4000</td>
<td>-1.0000</td>
<td>-.4000</td>
<td>-.5000</td>
<td>-.4000</td>
<td>-.5000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=4</td>
<td>n=4</td>
<td>n=5</td>
<td>n=5</td>
<td>n=5</td>
<td>n=5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p=.300</td>
<td>p=.000</td>
<td>p=.252</td>
<td>p=.196</td>
<td>p=.252</td>
<td>p=.196</td>
<td></td>
</tr>
</tbody>
</table>

Wrong expected sign in relationship with fluorine in the same factor (i.e., they are both positive). This Factor 1 association appears to be explainable in part by contrary rank correlations within both nuclear fluorine (cortical bone) and chemical tested fluorine (cortical and cancellous bone) between mound fill and sub-floor specimens. In as much as nuclear nitrogen rank correlations change very little whether they are calculated for the total mound, mound fill only, or the sub-floor features, a great deal of the co-variation in Table 27 for nitrogen and fluorine in Fac-
tor 1, especially at the surface in the cortical bone, is explainable by the sub-mound specimens having higher fluorine accumulation with respect to the mound fill remains. FNOADJ demonstrates only a random association with stratigraphic position, and FNO a reverse trend from expected (that is, it decreases with stratigraphic rank in the mound fill!). However, total bone nitrogen and fluorine show stronger negative rank correlations with the mound fill, where they are also associated with nuclear nitrogen following the same trend. This combination of geochemical environmental differences and cortical versus total bone characteristics explains much of the apparent associations in the Factor 1 loadings, as well as the rank correlations. Yet one more variable is important to sorting out the relationships at Davis mound: the type of bone used in the analysis.

A significant proportion of the bone samples from Davis mound were of long-bones, which typically have thick, dense, cortical areas with rather extensive internal masses of cancellous material. Acids in the upper mound section of Davis mound tend to decompose the thick, cortical mineral structure and expose the more permeable internal bone to hydrologic action and other decomposing agents. In the sub-floor environment, this heavy outer bone would tend to be preserved, protecting the internal bone structures from
alterations by the geochemical environment, while presenting thick, dense cortical bone mineral to the hydrological system for exchange to occur. This combination of interactive affects is illustrated in Table 28.

Table 28

<table>
<thead>
<tr>
<th>Rank</th>
<th>x</th>
<th>FPPM</th>
<th>N%</th>
<th>FNO</th>
<th>NNO</th>
<th>FNOADJ</th>
<th>NNOADJ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Davis Total</td>
<td>-0.6000</td>
<td>-0.8286</td>
<td>-0.4524</td>
<td>-0.5000</td>
<td>-0.6500</td>
<td>-0.7000</td>
<td></td>
</tr>
<tr>
<td>n=6</td>
<td>p=0.104</td>
<td>p=0.021</td>
<td>p=0.130</td>
<td>p=0.104</td>
<td>p=0.029</td>
<td>p=0.018</td>
<td></td>
</tr>
<tr>
<td>Mound Fill</td>
<td>-1.0000</td>
<td>-0.5000</td>
<td>-0.4000</td>
<td>-0.0000</td>
<td>-0.7000</td>
<td>-0.6000</td>
<td></td>
</tr>
<tr>
<td>n=3</td>
<td>p=0.000</td>
<td>p=0.333</td>
<td>p=0.300</td>
<td>p=0.500</td>
<td>p=0.094</td>
<td>p=0.142</td>
<td></td>
</tr>
<tr>
<td>Sub-floor</td>
<td>-0.4000</td>
<td>-1.0000</td>
<td>-0.4000</td>
<td>-0.4000</td>
<td>-0.5000</td>
<td>-0.5000</td>
<td></td>
</tr>
<tr>
<td>n=4</td>
<td>p=0.300</td>
<td>p=0.000</td>
<td>p=0.252</td>
<td>p=0.252</td>
<td>p=0.196</td>
<td>p=0.196</td>
<td></td>
</tr>
<tr>
<td>Long-bone</td>
<td>-0.8000</td>
<td>-0.8000</td>
<td>-0.6000</td>
<td>-0.6000</td>
<td>-0.2000</td>
<td>-0.3143</td>
<td></td>
</tr>
<tr>
<td>n=4</td>
<td>p=0.100</td>
<td>p=0.100</td>
<td>p=0.142</td>
<td>p=0.142</td>
<td>p=0.352</td>
<td>p=0.272</td>
<td></td>
</tr>
</tbody>
</table>

Total bone, as measured by the chemical method, in the mound fill, indicates higher fluorine uptake with stratigraphic rank in respect to the sub-floor specimens, as well as the mound in general and total long-bone specimens. Higher fluorine values for the whole bone reflects the effects of acids exposing the internal structure of the bone. Nuclear nitrogen rank correlations are higher neg-
atives than chemical nitrogen in the mound fill, probably because of greater degradation of the surface bone versus internal bone. Likewise, nuclear fluorine shows positive or random associations with stratigraphic rank, probably due to cortical bone deterioration as well.

On the other hand, the chemical fluorine measurement indicates a positive rank correlation with stratigraphic depth in the sub-floor samples. This seems to indicate the progressive isolation of internal bone structures from the hydrological exchange processes due to the preservation of the cortical bone covering. The cortical bone now demonstrates a significant increase in fluorine accumulation over the mound fill specimens, probably due to the retention of bone mineral at the surface where hydroxyl groups in the crystal lattice can exchange with fluorine in the ground water. Chemical nitrogen values indicate stronger negative rank correlations with stratigraphic depth, a sign that total bone protein is more likely to be preserved with increasing distance from the acidic environment of the mound above, and the decreased risk of cancellous bone contact with degrading micro-organisms, variations in temperature, and exposure to oxygen provided by the conservation of the cortical surface.

One anomaly in this explanation is the nuclear nitrogen trends in Table 28. Instead of cortical nitrogen decreas-
ing positively with rank as expected in the mound fill, it is a high negative, comparable to the total mound rank correlations for NNO and NNOADJ. Conversely, where we would now expect cortical nitrogen to be greater in the sub-floor specimens with respect to the mound fill, rank correlations are still rather high negative, although less so than would be predicted. Further, the long-bone sample, four out of six of which come from the mound fill, indicate greater cortical nitrogen content with respect to all other categories, as would be predicted, but cortical fluorine seems to be increasing with depth, which is not predicted for the mound fill because of mineral degeneration.

It must be kept in mind that the sample sizes are small, and Davis experiences relatively strong beam charge effects on the nuclear measurements. The conclusions derived here can be presented as no more than suggestive at this time, although there are strong theoretical and corroborative data to suggest the model for fossilization at the Davis mound is fairly accurate. In general, the chemical measures are more reliable indicators of overall trends between the mound fill and sub-floor features. The nuclear measures can be viewed as only suggestive of corresponding variations in the surface bone material.

A final comparison can be made in support of the Davis fossilization model, using the three bone minerals of cal-
cium, phophorus, and sodium previously discussed, the calcium/phosphorus ratio, and the chemical nitrogen values (see Table 29). As would be expected, mound fill acids reduce the amount of cortical mineral, exposing cancellous bone to degrading agents that reduce the overall nitrogen content measured for the total bone (N%). Thus, calcium, and the calcium/phosphorus ratio are the lowest negative correlations with respect to stratigraphic rank in comparison to the total mound sample and the sub-floor specimens. This tends to suggest that cortical mineral is decreasing with depth in the mound fill, in contrast to the sub-floor trend.

Table 29

<table>
<thead>
<tr>
<th>Rank</th>
<th>x Calcium</th>
<th>Phosphorus</th>
<th>Ca/P Ratio</th>
<th>N%</th>
<th>Sodium</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Davis Total</td>
<td>-.2333</td>
<td>-.3667</td>
<td>-.3500</td>
<td>-.8286</td>
<td>.1167</td>
</tr>
<tr>
<td>n=9</td>
<td>n=9</td>
<td>n=9</td>
<td>n=7</td>
<td>n=9</td>
<td></td>
</tr>
<tr>
<td>Mound Fill</td>
<td>-.1000</td>
<td>-.5000</td>
<td>-.2000</td>
<td>-.5000</td>
<td>-.6000</td>
</tr>
<tr>
<td>n=5</td>
<td>n=5</td>
<td>n=5</td>
<td>n=3</td>
<td>n=5</td>
<td></td>
</tr>
<tr>
<td>Sub-floor</td>
<td>-.3000</td>
<td>.3000</td>
<td>-.6000</td>
<td>-1.0000</td>
<td>.3000</td>
</tr>
<tr>
<td>n=5</td>
<td>n=5</td>
<td>n=5</td>
<td>n=4</td>
<td>n=5</td>
<td></td>
</tr>
<tr>
<td>p=.312</td>
<td>p=.312</td>
<td>p=.142</td>
<td>p=.000</td>
<td>p=.312</td>
<td></td>
</tr>
<tr>
<td>Long-bone</td>
<td>-.2571</td>
<td>-.5429</td>
<td>-.0857</td>
<td>-.8000</td>
<td>-.0286</td>
</tr>
<tr>
<td>n=6</td>
<td>n=6</td>
<td>n=6</td>
<td>n=4</td>
<td>n=6</td>
<td></td>
</tr>
<tr>
<td>p=.311</td>
<td>p=.133</td>
<td>p=.436</td>
<td>p=.100</td>
<td>p=.479</td>
<td></td>
</tr>
</tbody>
</table>
Nitrogen from the total bone, as would be expected from improved bone preservation with depth at Davis, shows a moderately high negative value with stratigraphic position in the mound fill, but is more positive with respect to the total mound values for chemical nitrogen, or the sub-floor specimens, or even total long-bone. With respect to chemical nitrogen trends in general, mound fill specimens tend to decrease in conjunction with decreasing cortical bone calcium and calcium/phosphorus ratios. Conversely, chemical nitrogen values in the sub-floor specimens increase relatively in parallel with increasing cortical calcium and calcium/phosphorus ratios. Sample sizes are too small to directly evaluate the rank correlations of these elements. So again, the data are only suggestive. Yet they are consistent with theoretical expectations.

Long-bone calcium/phosphorus ratios in Table 29 appear to be insignificant and random with respect to stratigraphic position, probably because of the inverse association of cortical bone destruction with stratigraphic depth in the mound fill versus the increasing cortical bone preservation in the sub-floor pits below. Consequently, these two trends would cancel each other's pattern of rank correlation when lumped together. However, total nitrogen in the table tends to have a single overall pattern of increase with depth, regardless of mound position, perhaps due to
the attenuation of protein degrading agencies with deeper burial.

Finally, it should be noted that phosphorus and sodium do not share the same pattern of changes with calcium nor the calcium/phosphorus ratio. Within the mound fill alone, both tend to increase with stratigraphic depth, and both tend to reverse this pattern in the sub-floor specimens, i.e., they seem to decrease slightly with depth. Comparison of the rank correlations for the total mound and the long-bone alone appears to show no significant relationships, however, and it is difficult to explain. Perhaps these two elements, under certain conditions, behave similarly and in contradistinction to the behavior of calcium in burial environments. Perhaps exchange processes are working on these elements as well as the degradation processes. In that case, it may be accentuated in the high acidic environment of the mound fill, and more significant in relation to phosphorus than sodium. Clarification of this will have to await further evaluation and comparative research.

Connected with these possible exchange processes the determination by Parker and Toots (1970:926, 930-931) of the presence of yttrium in the solid apatite phase of bone. They believe, among others, that yttrium enters the crystal structure in an exchange process with calcium during fossi-
lization, similar to the behavior of fluorine with the hydroxyl ion. Other free ions in the soil matrix, including rare earths and trace metals, may play some role as well. Only a few studies have been carried out on soil/bone elemental relationships (Lambert et al. 1979; Parker and Toots 1970), with most of the archaeological interest focused on possible contaminants in dietary analyses and not apatite exchange processes (see Lambert et al. 1985, manuscript for publication, Richard Yerkes personal communication). One last point of interest here is the association of soil acidity with ionic exchange in bone (Gilbert 1977:90). Soil acidity is a relatively significant factor in the mound fill at Davis, and thus any of the proposed soil ions that can join in an exchange process with bone minerals will be encouraged to do so in such an environment.

The Toepfner Mound

Although overall bone condition is better at Toepfner, indicated not only by subjective criteria, but also by higher chemical fluorine and nitrogen values, higher and less variable nuclear nitrogen values, and less variable nuclear fluorine values (Table 5), these indications conceal significant variations within the mound's skeletal series. These variations affect the Spearman rank correla-
tions with respect to stratigraphic placement, and thus their consistency as time indicators. Different ratios of fluorine and nitrogen are compared between the two mounds in Table 30, which circumvents somewhat the interactive effects of each element's proportion of the total bone matrix base found in Table 5. The chemical fluorine and nitrogen ratio is higher, which could indicate better preservation (higher bone mineral content leading to higher fluorine ratios with respect to the organic fraction) or to greater time exposure (fluorine content increases while nitrogen decreases) or both. The nuclear fluorine and nitrogen ratios indicate just the converse, which does not aid in the discrimination of possible causes. The fact that the chemical measures indicate whole bone processes, and nuclear measures reflect surface bone processes, are significant, though. The two are expressed quite differently at the two mounds, suggesting significant differences in geochemical interactions and bone structure.

The behavior of the calcium/phosphorus proportion with respect to nuclear fluorine and nitrogen is unusual. Since we already have determined that the acid content of Toepfer ner mound is somewhat reduced with respect to Davis mound, we would expect the bone mineral fraction to be higher (better bone preservation) and thus to dominate these ratios more. Davis mound shows the higher values. This is
Table 30

**Fluorine, Nitrogen, and Bone Mineral Ratios at Both Mounds**

<table>
<thead>
<tr>
<th></th>
<th>FPPM / N%</th>
<th>FNC / NNO</th>
<th>Ca/P / FNO</th>
<th>Ca/P / NNO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toepfner</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean = 6035.68</td>
<td>16335</td>
<td>7.1026</td>
<td>1.04937</td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deviation = 5818.79</td>
<td>10597</td>
<td>2.1940</td>
<td>0.65286</td>
<td></td>
</tr>
<tr>
<td>n = 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Davis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean = 5165.00</td>
<td>22892</td>
<td>9.8720</td>
<td>1.58813</td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deviation = 2541.67</td>
<td>14634</td>
<td>7.1538</td>
<td>0.81286</td>
<td></td>
</tr>
<tr>
<td>n = 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Possible if Toepfner mound specimens are on the average older than Davis mound (thus increasing the effect of fluorine in the first ratio), but just on taxonomic criteria alone, Davis mound burial features appear to be Early Adena/Late Archaic in nature. The early typological date is supported by a bone collagen date of 1180 BC ± 60 (DIC-2838) from Burial #22L, Feature #4, from the sub-floor pit at Davis. The earliest date at Toepfner is from a log tomb (Feature #7) of 830 BC ± 410 (C-942), a controversial date based on the carbon black method. These log tombs typologically have been placed in Late Adena. The other dates for Toepfner range only between 320 and 460 BC.

Another factor that may affect the discrepancy in fluorine values is the differences in water availability, percolation rates, and fluorine concentration in the water at
the two sites. The first two are significant factors of the floodplain environment of Toepfner mound (see Table 31). The relative differences in the fluorine content within the mounds was not investigated here, and would be particularly difficult to evaluate now since neither mound is still standing. However, assuming that flooding conditions did not inundate Toepfner mound (at least not normally), then the source of water for both sites should be the same, natural rainfall. Fluorine variations should all result from soil fluorine differences at the two sites. Tests of the local soil extant at these two sites today may help clarify this question but were not performed for this study.

Robinson and Edgington (1946) have measured the fluorine content of soil profiles from 137 samples from around the United States, averaging around 292 ppm (1946). They have concluded that, in general, heavier silt-loam soils contain more fluorine than lighter sandy soils. It was pointed out that the probable sources of fluorine in these soils are muscovite, biotite, and other micaeous minerals found in most clays (Robinson and Edgington 1946:347). If the assumption that clay availability in floodplain soils is greater than upland soils can be justified, than perhaps a source of fluorine variation is suggested.

The report goes on to point out that fluorine content in soils increases with depth, probably as the result of
leaching from surface soils. In addition, fluorine uptake in plants is very low (Robinson and Edgington 1946:349–351), usually less than 10 ppm, therefore, little of this element will be brought up to the surface from lower areas by root action, and redeposited on the surface. Consequently, floodplain soils, by the periodic addition of alluvial clays, and the repeated leaching of fluorine from these renewed surface deposits, would appear to have the greatest opportunity of accumulating more fluorine than upland soils, especially in the C horizon (1946:346).

The C horizon for Davis' Cardington silt-loam ranges from 34 - 70 inches; in Toepfner's Genesee soils it ranges between 23 - 70 inches. Likewise, Toepfner's Medway soils have a slightly shallower C horizon than Davis' Alexandria silt-loam, (39 - 70 inches versus 42 - 70 inches respectively). However, the implication is that the local soils available to the builders of Toepfner mound probably contained greater amounts of fluorine than the Davis mound soils.

Statistics for nuclear fluorine in Table 5, given that Toepfner is typologically "younger" than Davis in general, show that the two mounds are very close in their values, perhaps supporting the idea of greater fluorine availability in the floodplain soils. The lower standard deviations may reflect the homogeneity of the fluorine ion availabili-
## Table 31

<table>
<thead>
<tr>
<th>Depth (In)</th>
<th>Permeability (In/Hr)</th>
<th>Available Water (In/In)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Davis</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardington</td>
<td>0 - 6</td>
<td>0.6 - 2.0</td>
</tr>
<tr>
<td>Silt-loam</td>
<td>6 - 34</td>
<td>0.2 - 0.6</td>
</tr>
<tr>
<td></td>
<td>34 - 70</td>
<td>0.2 - 0.6</td>
</tr>
<tr>
<td>Alexandria</td>
<td>0 - 8</td>
<td>0.6 - 2.0</td>
</tr>
<tr>
<td>Silt-loam</td>
<td>8 - 42</td>
<td>0.2 - 0.6</td>
</tr>
<tr>
<td></td>
<td>42 - 70</td>
<td>0.2 - 0.6</td>
</tr>
<tr>
<td><strong>Toepfner</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Genesee</td>
<td>0 - 9</td>
<td>0.6 - 2.0</td>
</tr>
<tr>
<td>Silt-loam</td>
<td>9 - 37</td>
<td>0.6 - 2.0</td>
</tr>
<tr>
<td></td>
<td>37 - 70</td>
<td>0.6 - 2.0</td>
</tr>
<tr>
<td>Medway</td>
<td>0 - 15</td>
<td>0.6 - 2.0</td>
</tr>
<tr>
<td>Silt-loam</td>
<td>15 - 30</td>
<td>0.6 - 2.0</td>
</tr>
<tr>
<td></td>
<td>30 - 70</td>
<td>0.6 - 2.0</td>
</tr>
</tbody>
</table>

...ty inside Toepfner as well, perhaps reflecting greater water availability and fluoride concentration. However, this latter characteristic may only be the result of similar bone preservation conditions or similar bone type (see below) or a shorter use time of the site relative to Davis mound.

The last ratio between the calcium/phosphorus proportion and the nuclear nitrogen fraction is again interesting because of the ambiguities it presents with respect to expected results. Nuclear nitrogen values (or surface
organic amounts) would be expected to be higher given somewhat younger "age" predicted by the cultural classification for Toepfner. The greater collagenase microbial activity predicted from lower acidity levels would tend to counter this effect. Higher soil alkalinity would also tend to preserve the bone minerals as well, which, combined with bone protein decay, should increase the bone mineral-to-nuclear nitrogen ratio.

Two conditions that appear to affect this relationship, as well as the Spearman rank correlations, are the greater use of rib bone in the measurements at Toepfner versus long-bone at Davis and the higher frequency of burned or heat exposed bone at Toepfner. Rib bone would be expected to be less resistant than the denser, more compact long-bone to protein degradation; and temperature increases would tend to breakdown the stable collagen polypeptide chains into less organized gelatin, which is readily attacked by "proteolytic enzymes" (Garlick 1970:504). Therefore, the lower calcium/phosphorus-to-nuclear nitrogen ratio observed for Toepfner mound may be the result of greater than expected protein loss in rib bone, burned bone, or both. This higher protein loss is substantiated in Spearman rank correlations for sub-sets of the Toepfner series.
Spearman rank correlations for the combined Toepfner sample, and sub-sets of the total series by Good Counts, log tomb location, and unburned versus burned bone are compared in Table 32. Notice that there is not much difference in the trends of the individual correlations until Toepfner's unburned bone is tested. The rank correlations for chemical fluorine and nitrogen attain moderately high values, in the predicted direction, whereas the nuclear measurements are reduced from a primarily negative association with stratigraphic rank to no more than a random fluctuation with depth of burial. This situation remains essentially the same for Toepfner's unburned and Good Count sub-samples (note that the samples for the chemical fluorine and nitrogen measures are identical in both statistics). An analysis of just the unburned bone in Toepfner's log tombs still indicate a moderate correlation of the chemical data, in the predicted direction, with stratigraphic rank, and, although the strength of the correlations are not much improved, for the nuclear the relative positions for nuclear fluorine and nitrogen with respect to stratigraphic placement tend towards predicted (i.e., FNO is more negative than NNO, as is FNOADJ in relation to NNOADJ). However, in this latter statistic, sample sizes are too small for safe evaluation.
### Table 32

**Rank Correlations for Unburned Bone and Log Tombs at Toepfer**

<table>
<thead>
<tr>
<th>Rank</th>
<th>x</th>
<th>PPPM</th>
<th>N%</th>
<th>FNO</th>
<th>NNO</th>
<th>PNOADJ</th>
<th>WNOADJ</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>-.1796</td>
<td>-.3353</td>
<td>-.0513</td>
<td>-.4903</td>
<td>-.1247</td>
<td>-.4876</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=8</td>
<td>n=8</td>
<td>n=13</td>
<td>n=13</td>
<td>n=13</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Toepfer</strong></td>
<td>-.3143</td>
<td>-.1429</td>
<td>-.2845</td>
<td>-.4937</td>
<td>-.3180</td>
<td>-.4519</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=6</td>
<td>n=6</td>
<td>n=9</td>
<td>n=9</td>
<td>n=9</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Log Tombs</strong></td>
<td>-.0360</td>
<td>-.3243</td>
<td>-.2689</td>
<td>-.3530</td>
<td>-.3361</td>
<td>-.3109</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=7</td>
<td>n=7</td>
<td>n=9</td>
<td>n=9</td>
<td>n=9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>p=.469</td>
<td>p=.239</td>
<td>p=.242</td>
<td>p=.176</td>
<td>p=.188</td>
<td>p=.208</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Good Counts</strong></td>
<td>-.1000</td>
<td>-.2000</td>
<td>-.5766</td>
<td>-.3784</td>
<td>-.5406</td>
<td>-.2883</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=5</td>
<td>n=5</td>
<td>n=7</td>
<td>n=7</td>
<td>n=7</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Unburned Bone</strong></td>
<td>-.8000</td>
<td>.6000</td>
<td>-.0085</td>
<td>.0000</td>
<td>.0766</td>
<td>.0085</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=4</td>
<td>n=4</td>
<td>n=9</td>
<td>n=9</td>
<td>n=9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>p=.100</td>
<td>p=.200</td>
<td>p=.491</td>
<td>p=.500</td>
<td>p=.422</td>
<td>p=.491</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Toepfer</strong></td>
<td>-1.5000</td>
<td>.5000</td>
<td>-.1539</td>
<td>-.0513</td>
<td>-.0513</td>
<td>-.2052</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=3</td>
<td>n=3</td>
<td>n=5</td>
<td>n=5</td>
<td>n=5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Several implications can be drawn from this comparative table. The first is that the time sensitivity of fluorine and nitrogen is enhanced in whole, unburned bone, as reflected in the improved chemical data correlations. Secondly, that time sensitivity of fluorine and nitrogen at the surface is unaffected by the same sub-setting of...
unburned bones, but that a false negative nitrogen correlation is eliminated, a result probably due to the influence of burned or heat affected bone specimens in the combined Toepfner mound data. Thus, it seems that generally the chemical data of the whole bone for the Toepfner mound is a more reliable indicator of time than the nuclear data from just the surface of the bone. This was the initial indication seen in Table 11 between the total rank correlation of chemical fluorine with chemical nitrogen. Yet it is clear that individually, each of these measurements is not equally time sensitive in the total mound series until the unburned bone is separated out for analysis. Finally, there is a suggestion in the table that Toepfner's log tomb series may improve somewhat on the surface bone indicators of time, perhaps indicating slightly better preservation conditions versus other burial features in the mound. This will again appear in the following analysis of Toepfner's rib bone series. Perhaps the carbonized logs and the fired clay walls, floor, and ceilings of Toepfner's burned log tombs produced a protective environment for the remains within.

A third implication of the data is that, despite the independent Spearman rank correlations of the various measurements with stratigraphic rank, the fluorine and nitrogen rank correlations may be insignificant, or the exact oppo-
site from predicted (see Table 33). Deviations from expectation for the fluorine and nitrogen correlations are due to the interactive relationships of the individual elements with respect to the total bone matrix base, described at the beginning of this section, which defines each measurement relative to the total bone mass. For instance, chemical and fluorine values can show moderate negative correlations with each other, as predicted, for most sub-sets of the Toepfner series, but random correlations with one another for unburned bone, and a positive correlation for unburned bone recovered from log tombs. These variations in the chemical measures between burned and unburned bone apparently is due to changes in the bone mineral fraction of the total bone matrix base used in the measurement ratios for chemical fluorine and nitrogen. This is illustrated by a rank correlation of the calcium proportion of the bone with respect to chemical fluorine and nitrogen for the combined Toepfner sample, unburned bone, and unburned bone recovered from log tombs (Table 34).

As can be seen by a comparison of Table 33 and Table 34, the apparent correlations between chemical fluorine and nitrogen are a factor of fluorine’s relationship to the bone mineral cluster. The data in Table 35, show a definite trend for the bone minerals to decrease in rank correlation (with respect to stratigraphic position) from the
Table 33

**Rank Correlations Between Fluorine and Nitrogen at Toepfner**

<table>
<thead>
<tr>
<th></th>
<th>FPPM x N%</th>
<th>FNO x NNO</th>
<th>FNOADJ x NNOADJ</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Toepfner Combined</strong></td>
<td>-.5714</td>
<td>-.2091</td>
<td>.0440</td>
</tr>
<tr>
<td>n=8</td>
<td>p=.069</td>
<td>n=13</td>
<td>p=.247</td>
</tr>
<tr>
<td><strong>Toepfner Good Counts</strong></td>
<td>-.4857</td>
<td>-.0667</td>
<td>.2167</td>
</tr>
<tr>
<td>n=6</td>
<td>p=.164</td>
<td>n=9</td>
<td>p=.432</td>
</tr>
<tr>
<td><strong>Toepfner Log Tombs</strong></td>
<td>-.6786</td>
<td>-.2000</td>
<td>.1167</td>
</tr>
<tr>
<td>n=7</td>
<td>p=.047</td>
<td>n=9</td>
<td>p=.303</td>
</tr>
<tr>
<td><strong>Toepfner Log Tombs Good Counts</strong></td>
<td>-.6000</td>
<td>-.0357</td>
<td>.2143</td>
</tr>
<tr>
<td>n=5</td>
<td>p=.142</td>
<td>n=7</td>
<td>p=.470</td>
</tr>
<tr>
<td><strong>Toepfner Unburned Bone</strong></td>
<td>.5000</td>
<td>-.2500</td>
<td>-.0167</td>
</tr>
<tr>
<td>n=4</td>
<td>p=.500</td>
<td>n=9</td>
<td>p=.258</td>
</tr>
<tr>
<td><strong>Toepfner Unburned Bone Good Counts</strong></td>
<td>.0000</td>
<td>-.3214</td>
<td>.0714</td>
</tr>
<tr>
<td>n=4</td>
<td>p=.500</td>
<td>n=7</td>
<td>p=.241</td>
</tr>
<tr>
<td><strong>Toepfner Log Tombs</strong></td>
<td>.5000</td>
<td>-.5000</td>
<td>.1000</td>
</tr>
<tr>
<td>n=3</td>
<td>p=.333</td>
<td>n=5</td>
<td>p=.196</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>p=.436</td>
</tr>
</tbody>
</table>

Combined data, to unburned bone, and finally to unburned bone recovered from log tombs. The chemical fluorine and nitrogen rank correlations for the same groups in Table 33 trend in the exact opposite direction, from a moderately high negative value for the combined data, to an essentially random correlation for the Toepfner unburned sub-set, to
<table>
<thead>
<tr>
<th>Calcium x</th>
<th>Calcium x</th>
<th>Calcium x</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPPM</td>
<td>N%</td>
<td>Phosphorus</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td>Toepfner</td>
<td>.5476</td>
<td>-.8810</td>
</tr>
<tr>
<td>Combined</td>
<td>n=8</td>
<td>n=8</td>
</tr>
<tr>
<td>p=.080</td>
<td>p=.002</td>
<td>p=.000</td>
</tr>
<tr>
<td>Toepfner</td>
<td>.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>Unburned</td>
<td>n=4</td>
<td>n=4</td>
</tr>
<tr>
<td>p=.500</td>
<td>p=.000</td>
<td>p=.018</td>
</tr>
<tr>
<td>Toepfner</td>
<td>-.5000</td>
<td>1.0000</td>
</tr>
<tr>
<td>Unburned</td>
<td>n=3</td>
<td>n=3</td>
</tr>
<tr>
<td>Log Tombs</td>
<td>p=.333</td>
<td>p=.333</td>
</tr>
</tbody>
</table>

A moderately positive value for the Toepfner log tomb group. The immediate conclusion is that the negative correspondence between the rank correlations of fluorine and nitrogen are not necessarily an indication of their time sensitivity, as Haddy and Hanson have concluded (1982:41, 43), but may be influenced by fluctuations in the total bone mineral content as well.

Thus, as calcium and the other bone minerals tend to decrease with stratigraphic depth in Toepfner mound, the nitrogen proportion tends to increase, and the fluorine ratio tends to decrease, causing the negative correlation between FPPM and N% in Table 33. However, for the unburned bone series, calcium and the bone minerals tend to decrease significantly less, with essentially little change in the
Table 35

Rank Correlations of the Bone Minerals at Toepfner Mound

<table>
<thead>
<tr>
<th>Rank</th>
<th>Calcium</th>
<th>Phosphorus</th>
<th>Sodium</th>
<th>Ca/P Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toepfner Combined</td>
<td>.2909</td>
<td>.3324</td>
<td>.4882</td>
<td>.2438</td>
</tr>
<tr>
<td></td>
<td>n=13</td>
<td>n=13</td>
<td>n=13</td>
<td>n=13</td>
</tr>
<tr>
<td></td>
<td>p=.167</td>
<td>p=.134</td>
<td>p=.045</td>
<td>p=.211</td>
</tr>
<tr>
<td>Toepfner Unburned</td>
<td>-.4256</td>
<td>-.1447</td>
<td>-.1795</td>
<td>-.4937</td>
</tr>
<tr>
<td></td>
<td>n=9</td>
<td>n=9</td>
<td>n=9</td>
<td>n=9</td>
</tr>
<tr>
<td></td>
<td>p=.127</td>
<td>p=.355</td>
<td>p=.322</td>
<td>p=.088</td>
</tr>
<tr>
<td>Toepfner Unburned</td>
<td>-.7182</td>
<td>-.7182</td>
<td>.4104</td>
<td>-.7182</td>
</tr>
<tr>
<td></td>
<td>n=5</td>
<td>n=5</td>
<td>n=5</td>
<td>n=5</td>
</tr>
<tr>
<td></td>
<td>p=.086</td>
<td>p=.086</td>
<td>p=.246</td>
<td>p=.086</td>
</tr>
</tbody>
</table>

Nitrogen content (perhaps even an improvement with depth as indicated in Table 34), and the fluorine content with respect to bone mineral tends to fluctuate randomly. Nitrogen's stability and fluorine's fluctuation appears to have caused the random correlation between chemical fluorine and nitrogen for the Toepfner unburned sample in Table 33. Finally, the bone mineral rank correlation with stratigraphic position for the sample of unburned bones in log tombs reaches the highest, significantly negative correlations for all data (sodium is an anomalous exception here), and the nitrogen decay trend remains essentially the same with respect to bone mineral variations, but fluorine is decreasing in proportion to increasing bone mineral variations, but fluorine is decreasing in proportion to
increasing bone mineral content with depth in the unburned bone for the log tombs. As both fluorine and nitrogen are decreasing together with respect to the increasing bone mineral fraction in Table 34, their rank correlations together reflect a positive association, as seen in Table 33.

Reasons for these multi-variable, interdependent fluctuations are difficult to unravel, because different processes are working simultaneously on different aspects of the bone mineral matrix. Some general features can be pointed out here. For instance, the combined Toepfner sample seems to be affected more by the influence of the burned bones, which tend to present from the beginning of burial a bone structure with little of its original integrity and greatly reduced protein content. Degrading factors would naturally be accelerated in these specimens, resulting in higher bone mineral losses which may constrain the maximum uptake of fluorine. Unburned bone, especially in a protected log tomb environment, may resist the degrading aspects of the environment on the bone mineral portion thus enhancing the uptake and accumulation of fluorine as a proportion of the total bone matrix, which is reflected in its higher rank correlations with depth in Table 32. Although the trend of the decay curve for nitrogen in Table 34 seems to be more or less consistent and independent of variations in the
bone minerals seen in Table 35, or the relationships of fluorine to calcium, the total bone matrix base appears to affect its rank correlations with respect to depth as seen in Table 32. Thus, nitrogen demonstrates rather low negative correlations for all sub-sets of the data, except for the unburned bone, where it starts to follow the predicted positive trend with stratigraphic rank. Even though nitrogen appears to retain a more-or-less consistent change relationship with stratigraphic position, as suggested by Cook (1970:230) and Parker and Toots (1972:516), this is not immediately apparent until the influence of the bone mineral variations are isolated in relationship to it.

The data for the nuclear measures are less clear cut and suggestive than the chemical data. Nevertheless, a comparison between the rank correlations of FNO x NNO, and FNOADJ x NNOADJ in Table 33 indicate that the calcium/phosphorus ratio plays a small, but definite role in the individual nuclear fluorine and nitrogen measurements. In Table 32 the unburned bone sub-sets effect the general trend of the rank correlations with stratigraphic depth, by making them more positive (that is, improving the preservation and retention/accumulation of both elements near the surface), and standardizing these values with respect to the calcium/phosphorus ratio in the FNOADJ and NNOADJ columns improves this tendency even more. It must be pointed out that these
values and their differences are very small, and the sample sizes in many of the previous comparisons test the limit of the statistics. Consequently, these results should be considered only as suggestive of a trend and not indicative of a fact.

Before leaving this particular analysis, it should be noted that the highest fluorine/nitrogen correlation in Table 33 occurs for the chemical measures among bones from Toepfner’s log tombs. Despite this large rank correlation, larger than the rank correlation found for the Moundville data (Spearman’s rho = .5545, n=11, p=.0375), the individual rank correlations of chemical fluorine and nitrogen with stratigraphic position are quite poor (Table 32). Again, this is a result of an interaction with bone mineral proportions. The rank correlation between calcium and chemical fluorine is .6429 (n=7, p=.060), and with chemical nitrogen is -.8214 (n=7, p=.012). Therefore, the proportional interactive effects of bone mineral with the two target elements has created an apparent association consistent with theoretical expectation, although individual rank correlations of the elements with respect to their stratigraphic position tell a different story. The assessment of these time sensitive variations against an independent time frame is a superior methodology in comparison to the method of calculating the rank correlations between the nitrogen
and fluorine measurements alone used by Haddy and Hanson, at least by the evidence obtained here, and should be practiced in any future study involving these or other time measuring methods.

The last characteristic of the Toepfner bone series to be investigated is the effect of rib bone on the time sensitivity of the fluorine and nitrogen measures. The breakdown of various sub-sets of the Toepfner samples and their rank correlations with stratigraphic placement are listed in Table 36. It will be noticed that there is a general improvement in the correlations within the rib specimens with respect to the total mound data. But the figures for nitrogen are not in the positive direction as predicted, although they tend that way. For instance, chemical data for unburned, Good Count Toepfner ribs indicate a moderate negative correlation for fluorine, and a somewhat lower negative correlation for nitrogen. With respect to the same correlations for all of Toepfner ribs in the row above, this indicates an improvement in the statistic in the predicted direction, i.e., chemical fluorine is getting more negative, and chemical nitrogen more positive. The unburned, Good Count Toepfner rib sub-sample, also parallels the chemical fluorine and nitrogen relationship seen for the total Good Count sample in the table. This trend in the improvement in the chemical data for the rib sub-
sample is supported by the moderately high negative correlations between FPPM and N% seen in Table 37, although the interpretation of this statistic should be cautioned. A strong positive correlation between calcium and chemical fluorine, and a strong negative correlation between calcium and chemical nitrogen may be contributing to the negative association of FPPM and N% in Table 37 (see Table 38). However, calcium and other bone minerals show no strong correlations with stratigraphic position (Table 39), therefore the changes in rank correlation with respect to stratigraphic depth for chemical fluorine and nitrogen noted in Table 36 probably represent a true time relationship rather than an interactive effect with changing bone mineral proportions.

Although there is an indication of an improvement amongst the rib bone specimens in the time sensitivity of the chemical data (and therefore, for the whole bone measurement), a similar improvement is not seen in the nuclear values (and therefore, for the surface measurements), until the comparison of ribs from the log tombs at Toepfner (see Table 36). Nuclear nitrogen values for the combined data, Toepfner Good Counts, and Toepfner ribs, show moderate negative correlations with depth, even in the adjusted category (NNOADJ), but the nuclear fluorine values (FNO and FNOADJ) show rather low negative correlations over the same
Table 36

**Rank Correlations for Rib at Toepfner Mound**

<table>
<thead>
<tr>
<th>Rank</th>
<th>x PPPM</th>
<th>N%</th>
<th>FNO</th>
<th>NNO</th>
<th>FNOADJ</th>
<th>NNOADJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toepfner</td>
<td>-.1797</td>
<td>-.335</td>
<td>-.0513</td>
<td>-.4903</td>
<td>-.1247</td>
<td>-.4876</td>
</tr>
<tr>
<td>Combined</td>
<td>n=8</td>
<td>n=8</td>
<td>n=13</td>
<td>n=13</td>
<td>n=13</td>
<td>n=13</td>
</tr>
<tr>
<td>Toepfner</td>
<td>-.3143</td>
<td>-.1429</td>
<td>-.2845</td>
<td>-.4937</td>
<td>-.3180</td>
<td>-.4519</td>
</tr>
<tr>
<td>Good Counts</td>
<td>n=6</td>
<td>n=6</td>
<td>n=9</td>
<td>n=9</td>
<td>n=9</td>
<td>n=9</td>
</tr>
<tr>
<td>Toepfner</td>
<td>-.3784</td>
<td>-.3243</td>
<td>-.1083</td>
<td>-.4874</td>
<td>-.2299</td>
<td>-.5058</td>
</tr>
<tr>
<td>Ribs</td>
<td>n=7</td>
<td>n=7</td>
<td>n=11</td>
<td>n=11</td>
<td>n=11</td>
<td>n=11</td>
</tr>
<tr>
<td></td>
<td>p=.201</td>
<td>p=.239</td>
<td>p=.376</td>
<td>p=.064</td>
<td>p=.248</td>
<td>p=.056</td>
</tr>
<tr>
<td>Toepfner</td>
<td>-.5000</td>
<td>-.2000</td>
<td>-.286</td>
<td>-.5000</td>
<td>-.5357</td>
<td>-.5000</td>
</tr>
<tr>
<td>Ribs</td>
<td>n=5</td>
<td>n=5</td>
<td>n=7</td>
<td>n=7</td>
<td>n=7</td>
<td>n=7</td>
</tr>
<tr>
<td>Unburned</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toepfner</td>
<td>-.3189</td>
<td>-.3189</td>
<td>-.5218</td>
<td>.0290</td>
<td>-.8117</td>
<td>.0290</td>
</tr>
<tr>
<td>Ribs</td>
<td>n=6</td>
<td>n=6</td>
<td>n=6</td>
<td>n=6</td>
<td>n=6</td>
<td>n=6</td>
</tr>
<tr>
<td>Davis</td>
<td>-.8000</td>
<td>-.8000</td>
<td>-.6000</td>
<td>-.2000</td>
<td>-.6000</td>
<td>-.0857</td>
</tr>
<tr>
<td>Long-bones</td>
<td>n=4</td>
<td>n=4</td>
<td>n=5</td>
<td>n=6</td>
<td>n=5</td>
<td>n=6</td>
</tr>
<tr>
<td></td>
<td>p=.100</td>
<td>p=.100</td>
<td>p=.142</td>
<td>p=.352</td>
<td>p=.142</td>
<td>p=.436</td>
</tr>
</tbody>
</table>

Samples. The relationship is exactly opposite from predicted and contrary to the trend noted for the chemical, whole bone measurements of fluorine and nitrogen. The implication is that surface nitrogen, and therefore, surface proteins, are in a better state of preservation with increasing depth in the mound. However, an intervening factor in this pattern is the occurrence of fire altered bone in the log tombs in the upper part of the mound, which has apparently artificially decreased the protein propor-
Table 37

<table>
<thead>
<tr>
<th></th>
<th>FPPM x N%</th>
<th>FNO x NNO</th>
<th>FNOADJ x NNADJ</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Toepfner Combined</strong></td>
<td>- .5714</td>
<td>- .2091</td>
<td>.0440</td>
</tr>
<tr>
<td></td>
<td>n=8</td>
<td>n=13</td>
<td>n=13</td>
</tr>
<tr>
<td></td>
<td>p=.069</td>
<td>p=.247</td>
<td>p=.443</td>
</tr>
<tr>
<td><strong>Toepfner</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Good Counts</strong></td>
<td>- .4857</td>
<td>- .0667</td>
<td>.2167</td>
</tr>
<tr>
<td></td>
<td>n=6</td>
<td>n=9</td>
<td>n=9</td>
</tr>
<tr>
<td></td>
<td>p=.164</td>
<td>p=.432</td>
<td>p=.288</td>
</tr>
<tr>
<td><strong>Toepfner Ribs</strong></td>
<td>- .5714</td>
<td>- .0319</td>
<td>.2091</td>
</tr>
<tr>
<td></td>
<td>n=8</td>
<td>n=11</td>
<td>n=11</td>
</tr>
<tr>
<td></td>
<td>p=.090</td>
<td>p=.463</td>
<td>p=.269</td>
</tr>
<tr>
<td><strong>Toepfner Ribs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Good Counts</strong></td>
<td>- .6000</td>
<td>.2143</td>
<td>.4286</td>
</tr>
<tr>
<td></td>
<td>n=5</td>
<td>n=7</td>
<td>n=7</td>
</tr>
<tr>
<td></td>
<td>p=.142</td>
<td>p=.322</td>
<td>p=.169</td>
</tr>
<tr>
<td><strong>Unburned</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Toepfner Ribs</strong></td>
<td>- .6000</td>
<td>-.0857</td>
<td>.2571</td>
</tr>
<tr>
<td></td>
<td>n=6</td>
<td>n=6</td>
<td>n=6</td>
</tr>
<tr>
<td></td>
<td>p=.104</td>
<td>p=.436</td>
<td>p=.311</td>
</tr>
<tr>
<td><strong>Log Tombs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Davis Long-bone</strong></td>
<td>- .5000</td>
<td>.3000</td>
<td>.7000</td>
</tr>
<tr>
<td></td>
<td>n=3</td>
<td>n=5</td>
<td>n=5</td>
</tr>
<tr>
<td></td>
<td>p=.333</td>
<td>p=.312</td>
<td>p=.094</td>
</tr>
</tbody>
</table>

The correlation of that part of the Toepfner series with respect to bone specimens found in the lower mound. Thus, a subset of the bone series containing only unburned ribs (see Table 36), indicates that the nuclear fluorine and nitrogen measures are nearly equal in their stratigraphic correlations, but ribs from the log tombs alone (66% of which are heat affected), show that nuclear fluorine has a much stronger negative correlation with stratigraphic rank ver-
Table 38

**Rank Correlations of the Bone Minerals for Toepfner**

<table>
<thead>
<tr>
<th></th>
<th>Ca x FPM</th>
<th>Ca x N%</th>
<th>Ca x NNO</th>
<th>Ca x Phos</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Toepfner</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combined</td>
<td>.5476</td>
<td>-.8110</td>
<td>-.0605</td>
<td>-.6429</td>
</tr>
<tr>
<td>n=8</td>
<td>p=.080</td>
<td>p=.002</td>
<td>p=.422</td>
<td>p=.009</td>
</tr>
<tr>
<td><strong>Toepfner Good Counts</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n=6</td>
<td>.6000</td>
<td>-.9429</td>
<td>-.0833</td>
<td>-.5000</td>
</tr>
<tr>
<td>p=.104</td>
<td>p=.002</td>
<td>p=.416</td>
<td>p=.085</td>
<td>p=.005</td>
</tr>
<tr>
<td><strong>Toepfner Ribs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n=5</td>
<td>.5357</td>
<td>-.8214</td>
<td>.0091</td>
<td>-.7636</td>
</tr>
<tr>
<td>p=.108</td>
<td>p=.012</td>
<td>p=.489</td>
<td>p=.003</td>
<td>p=.033</td>
</tr>
<tr>
<td><strong>Toepfner Ribs Good Counts</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n=5</td>
<td>.8000</td>
<td>-.9000</td>
<td>-.1786</td>
<td>-.7686</td>
</tr>
<tr>
<td>p=.052</td>
<td>p=.019</td>
<td>p=.351</td>
<td>p=.047</td>
<td>p=.026</td>
</tr>
<tr>
<td><strong>Toepfner Ribs Log Tombs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n=6</td>
<td>.5429</td>
<td>-.7143</td>
<td>-.0286</td>
<td>-.8286</td>
</tr>
<tr>
<td>p=.133</td>
<td>p=.055</td>
<td>p=.479</td>
<td>p=.021</td>
<td>p=.104</td>
</tr>
<tr>
<td><strong>Davis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long-bone</td>
<td>.2000</td>
<td>-.8000</td>
<td>-.6000</td>
<td>.2571</td>
</tr>
<tr>
<td>n=4</td>
<td>p=.400</td>
<td>p=.100</td>
<td>p=.142</td>
<td>p=.311</td>
</tr>
</tbody>
</table>

Sus a now more positive correlation between nitrogen and depth than observed previously (compare for instance Good Counts for log tombs and unburned log tomb specimens in Table 32, with the total log tomb series, or the combined mound data). It is clear from these data that the subjective determination of better bone preservation in Toepfner's log tombs (i.e., although the skeletons are tremendously fragmented, a greater quantity of bone and
## Table 39

**Rank Correlations of Bone Minerals at Toepfner**

<table>
<thead>
<tr>
<th>Rank</th>
<th>x</th>
<th>Calcium</th>
<th>Phosphorus</th>
<th>Sodium</th>
<th>Ca/P Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toepfner Combined</td>
<td>.2909</td>
<td>.3324</td>
<td>.4882</td>
<td>.2438</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=13</td>
<td>n=13</td>
<td>n=13</td>
<td>n=13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p=.167</td>
<td>p=.134</td>
<td>p=.045</td>
<td>p=.211</td>
<td></td>
</tr>
<tr>
<td>Toepfner Good Counts</td>
<td>.0669</td>
<td>.1506</td>
<td>.2605</td>
<td>-.0502</td>
<td></td>
</tr>
<tr>
<td>Good Counts</td>
<td>n=9</td>
<td>n=9</td>
<td>n=9</td>
<td>n=9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p=.432</td>
<td>p=.349</td>
<td>p=.249</td>
<td>p=.449</td>
<td></td>
</tr>
<tr>
<td>Toepfner Ribs</td>
<td>.1885</td>
<td>.2437</td>
<td>.5162</td>
<td>.2575</td>
<td></td>
</tr>
<tr>
<td>Ribs</td>
<td>n=11</td>
<td>n=11</td>
<td>n=11</td>
<td>n=11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p=.289</td>
<td>p=.235</td>
<td>p=.052</td>
<td>p=.222</td>
<td></td>
</tr>
<tr>
<td>Toepfner Ribs</td>
<td>-.0357</td>
<td>.0000</td>
<td>.2703</td>
<td>-.0357</td>
<td></td>
</tr>
<tr>
<td>Good Counts</td>
<td>n=7</td>
<td>n=7</td>
<td>n=7</td>
<td>n=7</td>
<td></td>
</tr>
<tr>
<td>Unburned</td>
<td>p=.470</td>
<td>p=.500</td>
<td>p=.279</td>
<td>p=.470</td>
<td></td>
</tr>
<tr>
<td>Toepfner Ribs</td>
<td>.0580</td>
<td>-.2319</td>
<td>.2319</td>
<td>.0580</td>
<td></td>
</tr>
<tr>
<td>Log Tombs</td>
<td>n=6</td>
<td>n=6</td>
<td>n=6</td>
<td>n=6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p=.457</td>
<td>p=.329</td>
<td>p=.329</td>
<td>p=.457</td>
<td></td>
</tr>
<tr>
<td>Davis Long-bone</td>
<td>-.2571</td>
<td>-.5429</td>
<td>-.0286</td>
<td>-.0857</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=6</td>
<td>n=6</td>
<td>n=6</td>
<td>n=6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p=.311</td>
<td>p=.133</td>
<td>p=.479</td>
<td>p=.436</td>
<td></td>
</tr>
</tbody>
</table>

The proportion of skeletal parts were recovered relative to other burial areas of the mound derives largely from the mineral bone structure, whereas the organic constituents are significantly depleted.

The conclusion to be drawn from is that nuclear nitrogen measures from the surface of rib bone are a poor indicator of time, regardless of whether or not one controls for heat affects, but that surface determined nuclear fluorine may be significant, especially if burned or heat altered bone
is separated from unaffected bone specimens. This latter conclusion is supported by the data in Table 37 and Table 38. No significant correlations are noted between the nuclear fluorine and nitrogen measures themselves, suggesting their independence from one another. The nuclear fluorine measures show a lack of correlation with the bone mineral proportion as well, signifying their independence from the total bone matrix effect on the fluorine measurement. Since the bone minerals show no substantial correlation with stratigraphic depth (Table 39), then the moderate rank correlations for nuclear fluorine found in Table 36 in the unburned, Good Count Toepfner ribs, and the ribs from the log tombs, probably indicate true time indicators.

Nuclear nitrogen values in Table 38 show moderate to moderately high negative correlations with bone mineral proportions, which peak in the log tomb sub-sample with its high ratio of heat altered specimens. Because the distribution of the heat altered specimens is uneven, (concentrating in the tombs of the upper mound) this has a tendency to enhance the negative correlations for the nuclear values for the larger samples of the combined data, Toepfner's Good Counts, and total ribs found in Table 36. It seems safe to conclude that, because the bone minerals show no significant time sensitivity with stratigraphic depth,
and because nitrogen fractions are closely tied to the bone minerals in a negative way, that the moderate negative correlations for nuclear nitrogen with respect to stratigraphic depth are a spurious result of the unequal distribution of burned or heat altered bone specimens in the mound.

A comparison of the Spearman rank correlations between Davis' long-bones and Toepfner's rib bones with stratigraphic rank indicate that surface nuclear measures may be more time sensitive for the thicker, denser long-bones at Davis (given an understanding of the effects of heat on the Toepfner log tomb correlations), and unburned ribs may be a better time indicator for the total bone chemical measure. This latter conclusion is supported by the fluorine/nitrogen correlations in Table 37, where Toepfner's ribs show consistently higher values with better probabilities than Davis' long-bones. The individual chemical data for the Davis long-bones show high negative correlations with stratigraphic depth, despite a moderate negative correlation between themselves. The individual chemical data for the Davis long-bones show high negative correlations with stratigraphic depth, despite a moderate negative correlation between themselves, is largely due to the moderately high negative chemical nitrogen correlation with the bone mineral fraction (Table 38), which is related to improving preservation conditions with depth at Davis mound. Davis'
chemical fluorine appears independent of this interaction, and may be a better measure of stratigraphic depth for long-bone than rib bone. Perhaps this is a function of the difficulty of accumulating fluorine in the greater bone mass of long-bone, so that any variations between specimens, no matter how small, is the result of time exposure to the fluorine ion in the surrounding geochemical envelope.

Perhaps the greater resistance of the denser cortical bone of Davis' long-bone also plays a role in the greater time sensitivity of the nuclear measures their, versus the rib bone specimens at Toepfner. However, Table 37 indicates that both nuclear measures tend to vary together, decreasing with depth, especially after they are standardized for the calcium/phosphorus ratio (FNOADJ x NNOADJ). Nuclear fluorine values at Davis mound are heavily influenced by the bone mineral proportion of the sample in a negative way, as indicated by Table 38, that is, as the bone mineral fraction increases the fluorine proportion decreases with respect to it. Because the bone minerals tend to increase in proportion with stratigraphic depth, as seen in Table 39 with respect to Toepfner mound tendencies, and because the ratio of nuclear fluorine tends to decrease with respect to the bone mineral proportion, the nuclear fluorine and nitrogen values have a combined affect of
decreasing together, at least viewed from the total mound structure. As was pointed out previously, there are major differences between the mound fill and sub-mound characteristics of the bone specimens at Davis (Table 28).

Although sample sizes would be too small to investigate this problem any further here, the implication is that the higher acid content in the upper mound is working to degrade the bone mineral there, which may leave little crystal mass left to accumulate fluorine. However, the better bone preservation in the sub-floor pits would reverse this process. The difference observed between sub-floor specimens with high accumulated fluorine, because of better bone mineral preservation, and mound fill samples with little accumulated fluorine, due to dissolved bone minerals, may produce the general characteristics found in the data. It may turn out that another long-bone sample with more homogeneous preservation patterns may not demonstrate the same nuclear fluorine time sensitivity as the Davis sample.
Chapter VII
SUMMARY AND CONCLUSIONS

The fluorine and nitrogen content of skeletal remains in stratigraphic profiles from two mound samples were analysed and compared, using two different measuring techniques, one chemical and one nuclear. Results indicated that useful fluorine and nitrogen measurements could be obtained for relatively dating mound burial features in central Ohio, given certain conditions and limitations. In general, fluorine variations were found to be a better all round dating technique than nitrogen in the mound burial contexts used here, which dated to the first millenium B.C. of south-central Ohio. The amount of remaining nitrogen in most remains was usually so low that it approached the limit of detectability in many cases. Therefore, the sensitivity of nitrogen variations to time was significantly reduced in comparison with fluorine.

A significant variable relating to the comparability of fluorine and nitrogen dates was found to be the physical burial environment. Variations in soil pH, water availability, fluorine ion content of soils, and chances of
microbial activity were significantly linked to differences in upland and floodplain geomorphology, and variations in statistics. Silty-loam soils in general were found to be significantly more acidic and higher in fluorine content than sub-mound sand and gravel soils. Floodplain silt-loams were found to be less acidic, and possibly higher in fluorine content than upland soils. Upland silt-loams, because of lower pH, were less likely to be associated with microbial degrading processes, but more likely to be related to bone mineral degeneration. Rapid and deep burial of individuals contributed to the preservation of organic material in some bones approaching 3000 years in age. Extended reuse of these grave features implies that previous interments were marked and protected from microbial attack by coverings or removable roofing of some sort, which allowed new additions to the grave.

Significant variations in the fluorine and nitrogen content of long-bone and rib bone were discovered. In general, chemical analysis of long-bones for nitrogen were more sensitive than the chemical analysis of fluorine. The thick cortical bone tended to protect internal bone protein from degradation, while slowing the rate of fluorine uptake. Rib bone, on the other hand, showed a greater sensitivity to fluorine, because of the thinner overall cross-sections and cortical layer, but tended to have relatively
reduced nitrogen content. Thus chemical methods, which measured the whole bone, tended to be a more appropriate method for thinner bones, but the nuclear measures, because they probe the surface, were more appropriate for thicker, cortical bone.

Various prehistoric burial treatments were found to have effects on the time sensitivity of the target elements. Heat alteration was responsible for significant protein losses in bone, but was also associated with better mineral preservation. This condition was also related to the burning of log tombs, which perhaps created a closed environment by fire-hardening clay walls, ceilings, and floors. This protected environment, containing the burned and carbonized remains of the individuals and the log tomb itself, provided relatively good preservation for inorganic bone constituents. Other grave preparations, such as clay linings, or bark layers and coverings, as well as deep pit excavations in gravelly soil, probably enhanced bone preservation in general.

A major variable influencing the interpretation of bone element variations was found to be the interaction of organic and inorganic diagenetic processes, and their resultant effects on relative element measurements. This interrelationship was determined to be important because of the way bone elements are measured using current methods.
Each value, whether chemically or nuclearly measured, depends on a relationship of the element to the total bone mass. Thus, changes in total bone mass will have concomitant effects on fluorine and nitrogen values that could be falsely attributed to a direct diagenetic process involving only these two elements. Consequently, it was concluded that an analysis of the co-variation in the mineral component of bone should be conducted simultaneously with fluorine and/or nitrogen analyses to avoid the effects of confusing changes in overall bone mass with temporal change.

Finally, it was demonstrated that a negative rank correlation between nitrogen and fluorine was not determinative of a significant time relationship. Intervening effects from bone mass alterations significantly interacted with separate processes of fluorine uptake and nitrogen degradation to obfuscate the correlation. A better evaluative methodology was found to be the use of an independent time scheme against which individual target elements can be rank correlated and resultant depth profiles compared. Stratigraphic position was used in this study, along with Spearman rank correlations, to evaluate the time sensitivity of the target elements. A methodology using an independent time scheme for comparison was found to be the only valid way of assessing true time sensitivity of the target elements, and is generalizable to the evaluation of other similar time/
dating studies, regardless of whether they are relative or absolute measures, or even typological/seriation analyses. The use of independent time frames for the comparison and evaluation of the results of other chronological schemes in archaeology is felt to be a significant and important aspect of developing a processual and holistic systems approach to the record.

The fluorine and nitrogen dating methods investigated here will not cause any great stir, nor will their results alter in any major way the taxonomic cultural paradigm presently used in Ohio. The main reason for the investigation of these dating techniques has been to demonstrate their usefulness as one means of sorting out the mound burial record. The results do not solve any cultural problems, nor can one dissertation think to accomplish more. However, the point is to focus attention on the goals of a new chronology for the mound burial record, and indicate practical and pragmatic ways in which it can be implemented. This latter objective can be stated a success. Applications to other parts of the record come immediately to mind. For instance, the relative dating of remains from the so-called Hopewellian charnel houses, or the Glacial Kame ossuaries and cemeteries; or the time relationships of midden bone from Fort Ancient villages, or the contemporaneity and stratigraphic relations of bone tools from the
"unstratified" rock-shelters of southeastern Ohio; or the relationships of individuals within single burial features or within stratified mound features; or even sorting the burial relationships of curated museum collections and fitting them to the maps and notes of old site reports. All these are possible, and some may even advance the goals of a new chronology. The development of intra-site dating techniques, independent of cultural typologies, are important to the evaluation and use of seriations and the cultural concepts dependent on them. In this way, fluorine and nitrogen dating can play a significant role in the future development of Ohio area chronology, and contribute to a further understanding of prehistory in general.
Appendix A

RAW DATA

Table 40

Original Measurements of Bone Used in This Study

<table>
<thead>
<tr>
<th>Stratigraphic Burial #</th>
<th>Rank</th>
<th>F (ppm)</th>
<th>N (%) (gamma)</th>
<th>F (gamma)</th>
<th>N (gamma)</th>
<th>Ca/P (gamma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Davis Mound</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>996</td>
<td>1493.4</td>
</tr>
<tr>
<td>11</td>
<td>8</td>
<td>826</td>
<td>--</td>
<td>154</td>
<td>557</td>
<td>1700.4</td>
</tr>
<tr>
<td>18</td>
<td>7</td>
<td>--</td>
<td>.16</td>
<td>97.9</td>
<td>692</td>
<td>1720.02</td>
</tr>
<tr>
<td>21</td>
<td>6</td>
<td>841</td>
<td>.52</td>
<td>393</td>
<td>1060</td>
<td>1536.7</td>
</tr>
<tr>
<td>22</td>
<td>5</td>
<td>1281</td>
<td>.28</td>
<td>68</td>
<td>1530</td>
<td>1634.0</td>
</tr>
<tr>
<td>22A</td>
<td>4</td>
<td>1220</td>
<td>.48</td>
<td>260</td>
<td>1200</td>
<td>1582.9</td>
</tr>
<tr>
<td>22D</td>
<td>3</td>
<td>906</td>
<td>.80</td>
<td>440</td>
<td>688</td>
<td>1578.99</td>
</tr>
<tr>
<td>22L</td>
<td>2</td>
<td>1270</td>
<td>1.32</td>
<td>797</td>
<td>3820</td>
<td>1767.3</td>
</tr>
<tr>
<td>22N</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>162</td>
<td>2900</td>
<td>1916.8</td>
</tr>
<tr>
<td>Toepfner Mound</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>13</td>
<td>771</td>
<td>2.98</td>
<td>128</td>
<td>2310</td>
<td>1619.6</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>1460</td>
<td>.10</td>
<td>195</td>
<td>1240</td>
<td>1761.95</td>
</tr>
<tr>
<td>7</td>
<td>10.5</td>
<td>1600</td>
<td>.54</td>
<td>300</td>
<td>1830</td>
<td>1960</td>
</tr>
<tr>
<td>9</td>
<td>10.5</td>
<td>2000</td>
<td>.11</td>
<td>317</td>
<td>767</td>
<td>1740.2</td>
</tr>
<tr>
<td>22</td>
<td>9</td>
<td>1780</td>
<td>.17</td>
<td>236</td>
<td>684</td>
<td>1765.9</td>
</tr>
<tr>
<td>28</td>
<td>8</td>
<td>1420</td>
<td>3.36</td>
<td>307</td>
<td>3330</td>
<td>1235.8</td>
</tr>
<tr>
<td>31</td>
<td>7</td>
<td>--</td>
<td>--</td>
<td>328</td>
<td>1420</td>
<td>1661.1</td>
</tr>
<tr>
<td>35</td>
<td>5.5</td>
<td>1070</td>
<td>1.95</td>
<td>196</td>
<td>3370</td>
<td>1716.3</td>
</tr>
<tr>
<td>35</td>
<td>5.5</td>
<td>--</td>
<td>--</td>
<td>237</td>
<td>2120</td>
<td>1636.3</td>
</tr>
<tr>
<td>78</td>
<td>4</td>
<td>1680</td>
<td>2.00</td>
<td>317</td>
<td>2540</td>
<td>1688.3</td>
</tr>
<tr>
<td>61</td>
<td>2</td>
<td>--</td>
<td>--</td>
<td>277</td>
<td>2480</td>
<td>1606.6</td>
</tr>
<tr>
<td>65</td>
<td>2</td>
<td>--</td>
<td>--</td>
<td>276</td>
<td>1860</td>
<td>1759.9</td>
</tr>
<tr>
<td>66</td>
<td>2</td>
<td>--</td>
<td>--</td>
<td>191</td>
<td>3280</td>
<td>1697.4</td>
</tr>
</tbody>
</table>
BIBLIOGRAPHY


Baby, Raymond S. 1953-54 Unpublished Field Notes From Coepeapner Mound. On File at the Department of Archaeology, Ohio Historical Society, Columbus, Ohio.

Baby, Raymond S. 1959 Excavation Field Notes of the William H. Davis Mound, Franklin County #38--1959. On File at the Department of Archaeology, Ohio Historical Society, Columbus, Ohio.


Heizer, Robert F., ed. 1962 *Man's Discovery of His Past*. Prentice-Hall, Inc.


Lambert, Joseph B., C.P. Szpunar, and Jane E. Buikstra. 1979 *Chemical Analysis of Excavated Human Bone from Middle and Late Woodland Sites*. Archaeometry 21(2):115-129.


Pearson, G.W., J.R. Pilcher, and M.G.L. Baille. 1983 High-
precision 14C Measurements of Irish Oaks to Show the 
Natural 14C Variations from 200 BC to 4000 BC. 

Academic Press.

Price, Douglas T. and Maureen Kavanagh. 1982 Bone 
Composition and the Reconstruction of Diet: Examples 
from the Midwestern United States. Midcontinental 

Protsch, Reiner R. 1975 The Absolute Dating of Upper 
Pleistocene Sub-Saharan Fossil Hominids and Their Place 
in Human Evolution. Journal of Human Evolution 
4:297-322.

Protsch, Reiner R. 1978 Catalog of Fossil Hominids of 

Protsch, R. and H. de Villiers. 1975 Bushman Rock Shelter: 
Chronology and Morphology of a Child's Mandible. 

Rainey, F. and E. Ralph. 1959 Radiocarbon Dating in the 


Bowe, John Howland. 1959 Archaeological Dating and 
Cultural Process. Southwestern Journal of Anthropology 

Schmeck, Harold M., Jr. 1985 Intact Genetic Material 
Extracted From an Ancient Egyptian Mummy. The New York 
Times. April 16, pp. 19, 22.

Sellstedt, J. L. Engstrand, and N.-G. Gejvall. 1966 New 
Application of Radiocarbon Dating to Collagen Residue in 

Shroy, R.E., H.W. Kranner, K.W. Jones, J.S. Jacobson, and 
L.J. Heller. 1978 Determination of Fluorine in Food 
Samples by the 19F(p, p') 19F Reaction. Nuclear 
Instruments and Methods 149:313.

Stewart, T.D. 1951 Antiquity of Man in America 


