AN ARCHAEOLOGICAL, ANTHROPOLOGICAL STUDY OF THE HUMAN SKELETAL REMAINS FROM THE OAKHURST ROCKSHELTER, GEORGE, CAPE PROVINCE, SOUTHERN AFRICA

A project in fulfilment
of the requirements for a
MA Degree in Archaeology

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ABSTRACT

Osteological and dental analyses have been widely used to outline a graded response to nutritional and physiological stress in human bone. It is argued that agriculturalists and transitional agro/pastoralists are more stressed than the hunter gatherers who preceded them. This is evinced by mortality profiles, mean age at death and the number and extent of stressors observed in the skeleton such as enamel hypoplasiae, porotic hyperostosis and Harris lines. Agriculturalists and agro/pastoralists are thought to be more prone to these stressors as they relied heavily on root crops and cereals for their nutrients. This exposed them to periods of episodic starvation and physical stress. Hunter gatherers in comparison are thought to have subsisted on a relatively healthy diet, offering more and better quality protein and so reducing the incidence of episodic and general stress. An alternative to this diet-dependent hypothesis is suggested by the analysis of forty-six skeletal remains from the nonagricultural, marine-dependent population of Oakhurst from the South coast of southern Africa. Porotic hyperostosis and enamel hypoplasiae are just as common among these marine-dependent people as among transitional agro/pastoralists. These findings imply that both individual development and population growth rates at Oakhurst were interrupted episodically and generally, and that these interruptions were substantially more common than in living and recently extinct hunter gatherers and pastoralists in southern Africa.

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CHAPTER ONE

INTRODUCTION

The relationship between population growth and 'food' is a complex one. The classic Malthusian view (Malthus 1798 quoted in Weeks 1986) is that the cultivation of land was the cause of population increase by lowering mortality and raising fertility. An opposing view recently discussed by Weeks (1986) suggests that an increase in population size due to decreased mortality, led to a need for more innovative ways of obtaining food. Of necessity this led to greater food production, the advent of agriculture, settled village life, and complex social structures.

These concepts have long occupied the thoughts of demographers. Such thoughts, however, are not the specific domain of the demographer. Archaeological research has long focused on the food quest. Palaeonutrition is a term used by archaeologists which encompasses the reconstruction of prehistoric diets from archaeological remains and the study of those diets in nutritional terms (Van der Merwe in press).

Such research has generated a body of data which forms an essential basis for testing hypotheses about ecological relationships, human adaptation, and changing patterns of human interaction with the nutritional environment. The success of these adaptations can best be evaluated by their effect on the health and nutritional status of the population in question. There are three major foci in palaeonutritional studies. The aspect that can best be reconstructed is the mode of adaptation to the physical environment via tools, settlement patterns and subsistence economy. This is the traditional approach which until recently formed the bulk of archaeological research. More recently, the study of human skeletons to determine the component parts of their diet by means of chemical analysis (Van der Merwe and Vogel 1978, Schoeninger et al. 1983) and the study of deficiency diseases in human skeletons (Huss-Ashmore 1978, Cohen and Armelagos 1984) to assess the nutritional status of prehistoric communities have been attempted. These approaches are complementary, so that hypotheses about diet arrived at by one approach can be tested through results obtained by the other. The conclusions can, in turn, be evaluated in the light of present knowledge of human biology and nutrition and compared with contemporary epidemiological findings.

Case studies of nutritional change, at the skeletal level, have been attempted from diverse geographical locations and among culturally dissimilar groups. These include Sudanese Nubian groups (Armelagos 1968, Armelagos et al. 1982, Huss-Ashmore 1978, Martin 1983), California Indian populations (McHenry 1968, McHenry and Schulz 1976, Mensforth et al. 1978), and within the geographical locations of India (Kennedy 1969, 1978, 1984), the Mediterranean (Angel 1971, 1982), in Europe (Meiklejohn and Constandse-Westermann 1978, Henneberg M and Henneberg R in prep) and in Iran and Iraq (Rathburn 1972, 1975, 1982). Data are not yet available from Sub-Saharan Africa, Lowland America, and from most of North, Central and East Asia (Cohen and Armelagos 1984). The results of these studies suggest that patterns of human interaction and adaptation with the nutritional environment are the products of three sets of stressors (Fig. 1). These are environmental constraints, cultural systems (which may act to buffer the impact of environmental constraints), and host resistance (Cohen and Armelagos 1984:15). Stress, for the purpose of this research, is defined as " the reaction of the animal body to forces of a deleterious

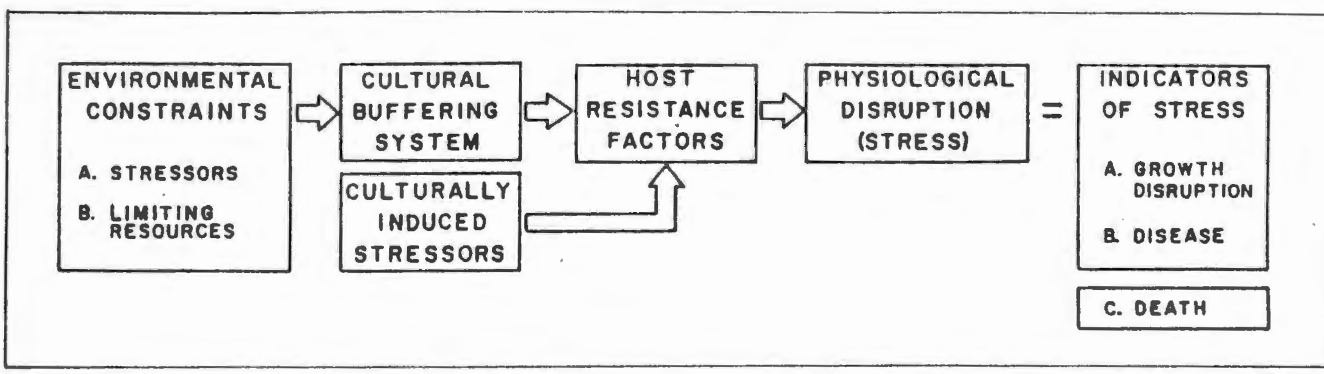


FIGURE 1 : MODEL FOR INTERPRETATION OF STRESS INDICATORS IN PALEOEPIDEMIOLOGICAL RESEARCH (after Cohen and Armelagos 1984)

nature, infections and various abnormal states that tend to disturb its normal physiologic equilibrium" (Basmajian 1976).

Population process

To what extent these data may be tested directly has generated a great deal of debate. A traditional archaeological view is (Childe 1951) that the adoption of agricultural economies resulted in improvements in food technology which improved the quality and reliability of human food supplies, and the overall lessening of labour demands in the food quest. More recently, Cohen and Armalegos (1984) have suggested that agro/pastoralism be added to this category.

A similar argument has been proposed by Hayden (1981) and Butzer (1982) for hunter gathering groups. The adoption of marine foraging, the intensive processing of wild seeds, and the hunting and gathering of small game are seen to be technological changes in foraging economies. The effect of which is thought to have led to improving the buffering of human groups against periodic food crises while simultaneously reducing labour costs (Cohen 1977:2).

The concept has been expanded upon by nutritionists (Barnicot 1969, Yudkin 1969, Yesner 1980 a.b.) and those who utilize the ecological model (Gall and Saxe 1977), who have argued that, in theory, the diets of hunter gatherers ought to be relatively healthy, offering more and better quality protein than the diet of farmers which focused heavily on cereals or root crops. Accordingly, farmers would be more prone to episodic starvation than hunter gatherers (Cohen and Armalegos 1984:2).

Opposing this view, Ammerma (1975) claims that hunter gatherers lived in a hostile environment and as such were exposed to starvation and frequent bouts of episodic stress. This resulted in a low overall growth rate for these populations.

The model

In an attempt to answer processual questions about the cause and result of physiological disruption among the prehistoric peoples of sub-Saharan Africa this thesis attempts to analyse the impact of technological changes on the human food quest. These changes include the adoption of marine foraging, the intensive processing of wild flora, and the hunting and gathering of small game, all of which became intensified relatively late in the human archaeological record.

Data collection may, for the sake of convenience, be grouped under four major headings. These are:

(1)	'Stress' -	episodic infectious specific demographic index
(2)	'Life Habit' -	activity trauma
(3)	'Dietary' -	dentition isotopic growth
(4)	'Time' -	radiometric dating

Using these four sets, data are collected with regard to:

(1) The occurrence, frequency, age and sex distribution of episodic stress which was sufficient to disrupt childhood growth. The specific stress indicators observed are Harris lines of long bones and enamel hypoplasiae of teeth.

(2) The occurrence, frequency, age and sex distribution of generalized indicators of infectious lesions.

(3) The occurrence of indicators which suggest specific nutritional deficiencies.

(4) The occurrence of changes in bone growth, such as cortical thinning and poor mineralization indicative of chronic malnutrition.

(5) Caries of the teeth and other oral pathologies.

(6) The occurrence, location, age and sex distribution of trauma, differentiating, where possible, the incidence of accidental and violence-related trauma.

(7) Muscular development and arthritic degeneration suggestive of work load and physical stress.

(8) Isotopic analysis of bone, indicative of the composition of the diet, and to provide estimates of weaning profiles for juvenile samples.

(9) To provide a temporal dimension and so compare, if present, changes in the frequency and occurrence of stressors over time.

This research, therefore, may be considered as presenting data according to a model of the cause and results of physiological disruption or stress. Data are presented outlining various skeletal indicators that provide a picture of adjustment to the challenges and vagaries of the southern Cape environment. This perspective has emerged in an attempt to answer questions about the severity, duration and periodicity of stress and the effect that this has on human behaviour.

The rest of this thesis is divided into nine chapters. Chapter two is a background to the physical anthropology of the Oakhurst sample. Chapter three deals directly with Oakhurst in prehistory and emphasis is given to those features of geomorphology and climate which would have shaped the environment in which the people of Oakhurst lived. Chapter four is an introduction to the theoretical aspects of studying human bone and chapters five, six and seven outline various pathologies that may be used by the archaeologist to assess the extent and effect of nutritional stress on the human skeleton. The results of this study are given in chapter eight while chapter nine and ten concludes this thesis with a discussion of the implications of the results for future archaeological research in the southern Cape.

CHAPTER TWO

PHYSICAL ANTHROPOLOGY AND THE PEOPLING OF THE CAPE SOUTH COAST

The people of southern Africa

Anthropological studies of the people of southern Africa began in the 10th century (Tobias 1985) when Moslem geographers and merchants documented the physical diversity of the living peoples of the subcontinent. Following the same tradition other trained observers, naturalists, missionaries and physicians began to record their observations. Their observations provided a corpus of what we might call the protohistory of physical anthropology in southern Africa. The writings of these early travelers, from the 10th to the 16th century, speak of two African peoples, the black Negriform and the yellow-skinned, click-speaking people of Africa. Summarized evidence (Wilson 1970) of their geographical distribution suggests that the whole of the Transvaal and Natal and large parts of the Orange Free State and the eastern Cape Province were peopled by black Africans. Most of those areas and the remainder of southern Africa were peopled by numerous yellow-skinned bands and chiefdoms.

By the beginning of the 19th century a continued interest in the indigenous peoples of southern Africa gave rise to the South African Philosophical Society and its primary goal was to "preserve the mental products of the indigenous races of South Africa" (Tobias 1985). Major areas of research were ethnology, linguistics and folklore. The research aims of the society were later expanded and its scope of interest turned to understanding the morphological principles underlying human evolution. A theme of interest stimulated by

Darwin's "Descent of Man" and Henry Morgan's anthropological classification of human behaviour. Much of the effort of the society was therefore directed towards the problem of whether the yellow-skinned people of southern Africa could be differentiated morphologically and culturally from the black Negriform population.

By the mid 1950's a corpus of knowledge had accumulated which claimed, on the one hand, that the San and Khoi could not be differentiated anatomically from each other (Peringuey 1911) while others attested that they could (Schultze 1928, Drennan 1929, 1957). However, Schultze proposed that the San and Khoi were two variants of a single group composed of the 'Khoikhoin', their name for themselves, and 'San', the Khoi Khoi name for the Bushman hence the term Khoisan (Tobias 1985:18). What did seem quite clear however, was that the San and Khoi differed from the South African Negro, and this lead Trevor (1955) to postulate that the Khoi and San be recognized as one of the worlds major races, the Khoisanoid. In his classification of humankind, they were coined the Khoisaniform race and placed on a level of distinctness with the Negriform, Caucasiform, Mongoliform and Australiform racial clusters.

Differentiation within the Khoisan: from types to populations

The earlier studies used a typological approach to Khoisan and Negro studies. This gave rise to a situation where each distinct morphological feature was interpreted as a sign of a specific genetic strain. Since the definition of a type required an assumption of morphological homogeneity in the "pure stock", signs of individual variation were assumed to represent the presence of alien genetic connections. This led Dart (1951, 1952) to postulate Armenoid, Mediterranean and Mongolian influences in the morphology of the living Khoi, while Tobias (1955) cited seven separate genetic lines meeting to create the Khoi and San.

The first hint of dissatisfaction with the typological approach was expressed by Ronald Singer (1958) who condemned the approach as being methodologically incorrect. Where earlier workers sought conformity and atributed deviation from the ideal 'type' to the effects of hybridization Singer and later workers suggested that variation was a normal occurrence in any human population. Aware of the inherent bias in their sample selection researchers began to exclude morphological selection and drew their samples instead from specimens 'known in life'. In order to fulfill the sample selection process specimens for study had to be accompanied by documents that identified the person in life as San, Khoi or Negro. The object of this sample selection was to describe the range of variability among living populations and so help solve the unrepresentative and restricted range of variation created by typological selection.

The first of the new workers to avoid the use of typology in their analyses were Stern and Singer (1967) and their data, when compared with measurements reported by earlier researchers, showed less of a tendency to match the accepted 'typical' characteristics of each group. In the years 1970 through 1980 a number of researchers applied multivariate statistical analyses to the carefully selected 'known-in-life' sample. Rightmire (1970), Howells (1973) and Hausman (1980) applied the technique in an attempt to identify the range and importance of morphological variation of Khoi and San. These studies confirmed Stern and Singers (1967) reported increased range of variation.

The new non-typological techniques were not without problems. Boldsen and Kronborg (1984) working with large uni-variate biological measurements have demonstrated the apparently non-normal distribution of many samples which are generated by some major factor affecting the otherwise normal distribution of populations. Such factors include the influence of diet.

The biocultural model and the origin of the Cape Khoikhoi

Hausman (1982) has suggested that if pastoralism was brought to the Cape coast by small groups of inland Khoikhoi, rather than replacing the aboriginal hunter-gatherers the Khoikhoi and San could have coexisted. Assimilation, both biological and cultural may have occurred. That is, some San would adopt pastoralism while some Khoikhoi may exploit marine resources resulting in some new synthesis of the two economic strategies (Hausman 1982:318).

Hausman (1982) set out to test these hypotheses using a series of crania from Holocene deposits in the Cape. Using mulitvariate statistical analysis of cranial measurements to determine patterns of morphological variation she argued that the traditional distinction between San and Khoikhoi is correct for inland groups. This suggests that the overall similarity of the groups reflects their close biological relationship and common origin. Secondly, the San populations who live along the coast differed from the San populations of the northern Cape. Inland skeletons tend to be smaller in dimensions such as palate breadth, maximum frontal breadth and cranial height. The San forehead is more vertical than that of the Khoikhoi, who have longer, more narrow cranial vaults and a greater glabellar protrusion that contributes to their more rugged appearance (Hausman

1982:322). The notion of a 'strandloper' population living along the coast of southern Africa, first suggested by early scholars (Fitzsimons 1926, Laing and Gear (1929) is therefore revived. These data are taken by Hausman (1982) to represent the traditional San Khoisan division. This, she suggests, holds that culture and geographical criteria do define morphologically distinct groups. In addition to this she suggests that these data provide little evidence for assuming complete population succession on the coast of South Africa.

Much of the variation between San and Khoikhoi that Hausman discusses is due to growth factors. Khoikhoi have been distinguished from San on the basis of stature (Wells 1960), and robusticity (Keen 1947, Thom 1952, Rightmire 1970). Hausman's (1980, 1982) own work has shown that size is not the only discriminating factor. Aspects of craniofacial growth are more related to shape than size. The variables considered in her study include upper facial height, basi-bregmatic height, palate length, basion-prosthion and cranial length. Khoikhoi, particularly males, are longer in all of these dimensions. Given that San morphology is not governed by hormonal control (Van der Walt et al. 1977) the relationship between nutrition and growth, overall size and robusticity requires attention. It is interesting to note that Pucciarelli (1980), Corruccini and Whitley (1981) have demonstrated in rats that cranial morphology reflects nutritionally related growth. One may argue therefore that the larger dimensions observed in Khoikhoi and Coastal San are a function of individuals growing in a better environment. The addition of milk and a constant supply of meat could have improved growth conditions enough to produce some of the morphological differences between Khoikhoi and San.

Oakhurst:environmental testing

The Oakhurst skeletons were recovered from Late Stone Age deposits (Goodwin 1938), but the first physical anthropological description classified them as Khoikhoi (Drennan 1938). This is somewhat problematic and the characteristics of the sample are worthy of extensive re-analysis in view of the archaeological interest in the problem of the origin of the Khoikhoi. If the Khoikhoi were, as currently assumed, a migratory population who relatively recently entered the southern and western Cape together with domesticated stock and pottery, then this implies a new economy and human population which superseded the hunter gatherer economies of the Later Stone Age. The skeletal sample from Oakhurst is considerably older than the earliest dated pottery and domesticated stock occurrences in the southern Cape (Table 4). The earliest date for pastoralism is 1 200 - 1 100 BP (Klein 1986).

Drennan's original analysis is critical to this discussion. If his interpretation of the skeletal anatomy is correct, then a specific Khoikhoi morphology existed before the advent of the herder economy. Although Hausman's models are different from Drennan's, they share the concept of long term regional continuity of the Cape coastal populations. The arrival or transformation of the Khoikhoi is an interesting archaeological problem which requires detailed morphological analysis in the future. Sadly, this kind of metrical analysis is beyond the scope of this study, but what can be done is to examine the Oakhurst skeletons as representatives of a group of people who were the immediate predecessors of the historic Khoikhoi and/or San of the South Cape coast.

If, as the evidence suggests, morphology is strongly controlled by the environmental effects of dietary intake and lifestyle, then it is imperative to understand the lifestyle of these people so that morphological analyses can be tempered with this knowledge.

The problem of who were the people of the Cape coast can be tested by examining the incidence and prevalence of dietary disease, and by noting deficiency and prosperity resulting from, or associated with, changes in lifestyle. Such studies would provide an index of growth, or low growth phases throughout the lifetime of the individual examined. These data may then be tested against epidemological and serogenetic findings and viewed against the palaeoenvironmental-/archaeological record to help determine to what extent environmental influence has shaped human morphology on the South coast. By focusing on known events of cultural change and on the interaction between biological and cultural processes a more dynamic model of Khoisan evolution may be offered. If one succeeds in finding statistically significant associations between nutritional growth/stress one may conclude that these changes are due to changes in the resource/foraging pattern of the group under investigation.

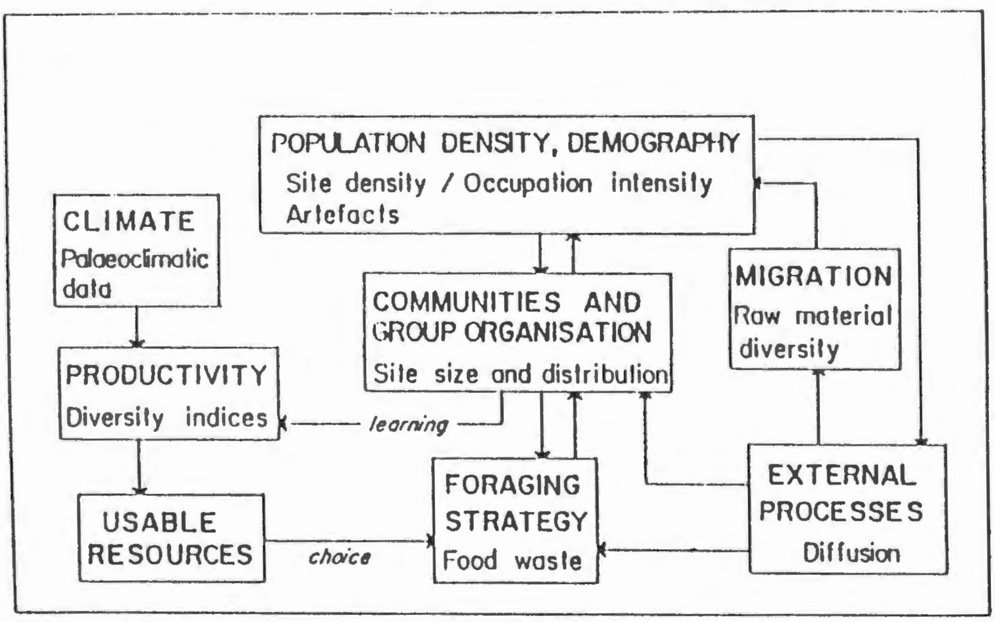
CHAPTER THREE

OAKHURST IN PREHISTORY: THE ENVIRONMENT AND ARCHAEOLOGICAL CONTEXT

The historical development of southern African archaeology is well documented (Parkington 1984, Hall 1987) and something like a general consensus of opinion concerning the prehistoric people (Harpending and Jenkins 1973, Hausman 1982, Morris 1984, Tobias 1985) and the paleoenvironments (Vogel 1983, Deacon H.J. and Thackeray 1983, Deacon, J. et al 1984, Klein 1984) in which they lived has emerged.

It has been suggested (Deacon, H.J. and Thackeray 1983) that the dispersal of people in southern Africa and the rise of local and regional populations may be tested directly against climatic and paleoenvironmental data. There are many criticisms of the ecological approach (Clarke 1972, Mazel 1987) to the effect that it is particularly deterministic. Population distribution, it is argued, may be viewed as ever-changing and that the cause and effects are not necessarily consistent in time and space. This has led Deacon H.J. and Thackeray (1983) to hypothesise that "although climate is an important limiting factor, deterministic correlations between climate, migrations and cultural evolution beg counter-arguments of the human ability to adapt to different climatic conditions with the aid of technology" (Deacon H.J. & Thackeray 1983:376). Thus the model proposed by Deacon H.J. and Thackeray (1983) (Fig.2) draws a relationship between climate, productivity and usable resources on the one hand and foraging strategies, community and group organization and demography on the other.

Two foraging strategies are proposed which are thought to remain archaeologically visible. These are "patch foraging strategies" in



FIRURE 2: FLOW CHART SHOWING THE RELATIONSHIP BETWEEN CLIMATE PRODUCTIVITY AND HUMAN POPULATION (after Deacon HJ and Thackeray A, 1983)

which there is a high reliance on underground plant foods, territorial and ground game, and "mobile mixed strategies" in which more search-time is invested in obtaining larger migratory herd animals" (Deacon, H.J. & Thackeray 1983:377). Interest is therefore focused on the extent to which palaeoenvironmental data can be used to distinguish periods of stress which may have limited the distribution and density of human groups.

Oakhurst

As defined for the purpose of this research, the area extends approximately from 33^{o} 59' to 34^{o} 00'S and 22^{o} 35' to 22^{o} 43'E. It is located on the South coast of the Cape Province between the towns of George and Knysna (Fig.3). Oakhurst is a rockshelter cut into a cliff of Table Mountain sandstone rendered schistose by excessive folding (Goodwin 1938, Martin 1962). Data concerning the human occupation of the Oakhurst rockshelter are drawn from the archaeological and palaeoenvironmental context.

Sources of palaeoenvironmental data

The amelioration of climates after the Last Glacial Maximum from 16 000 BP saw the dispersal of populations over the greater part of southern Africa with a wide geographical dispersal of pre-agricultural peoples being achieved in the earlier Holocene (Deacon and Thackeray 1983:75). By the mid-Holocene there appears to have been a contraction in the human range. This is envinced in temporal discontinuities in the archaeological record (Deacon J. 1974) and the absence of established local populations in the Karroo and grassland biomes between 9 000 and 4 500 BP.

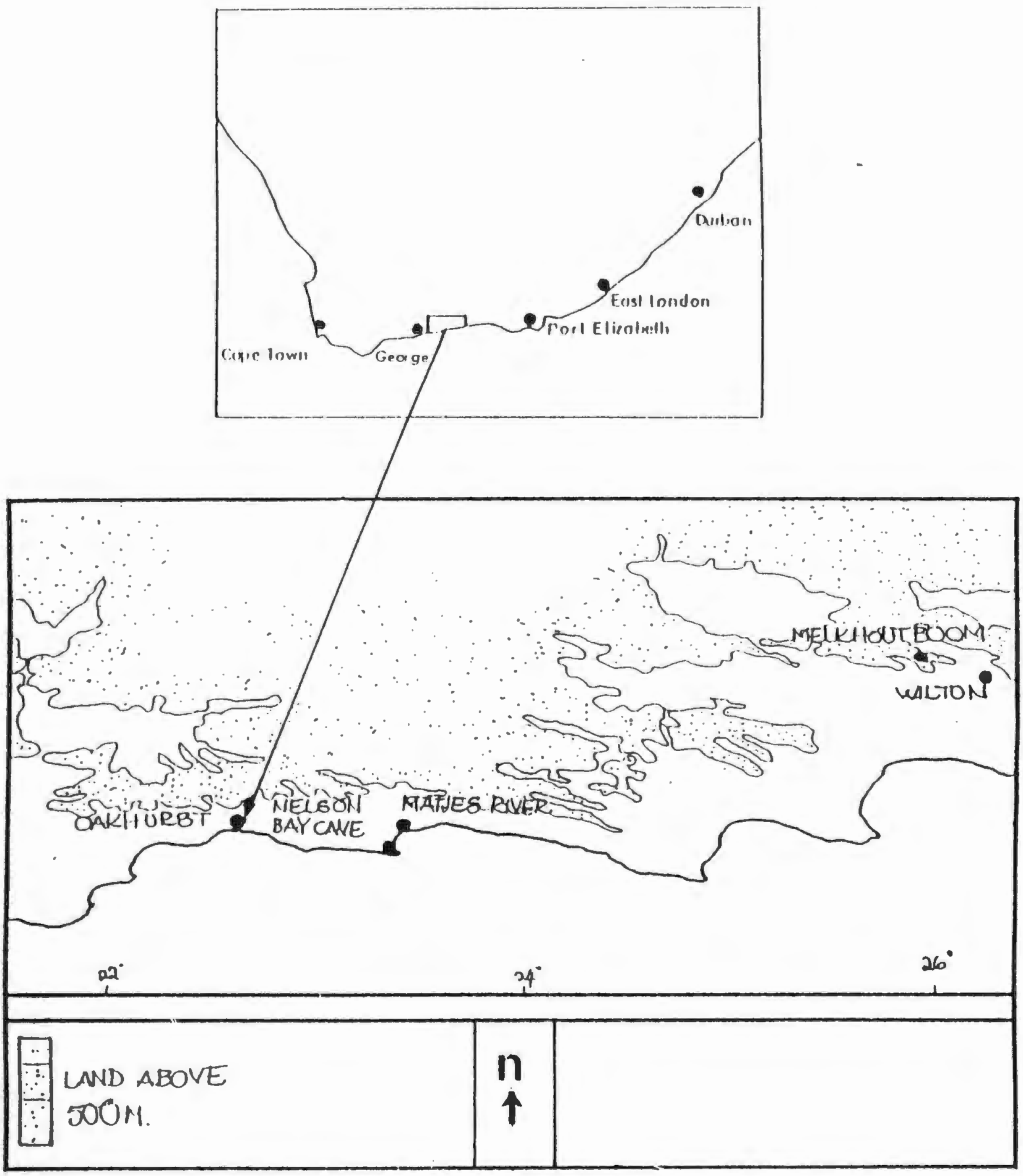


FIGURE 3: GEOGRAPHICAL SETTING OF THE OAKHURST ROCKSHELTER AND OTHER SITES REFERRED TO IN THE TEXT

The eastern Cape forelands (Deacon H.J. 1976) and Orange River basin (Sampson 1974, Humphreys 1979) were repopulated after 4 500 BP. The Transvaal Highveld, however, continued to show little evidence of Stone Age populations in the Late Holocene prior to settlement by Iron Age people. Mason (1981) has documented the occurrence of stone tools in an Iron Age context at Broederstroom and this has led Deacon H.J. to hypothesise that agriculturalists provided resources previously lacking to maintain hunter-gatherer groups in the area (Deacon H.J. and Thackeray 1983:384).

Climate and vegetational cover

The early Holocene has been described (Avery D.M. 1981, Van Zinderen Bakker 1982) as drier and warmer relative to the Late Holocene. Variations in climate occurred, however, on the Gaap escarpment from 9 800 to 7 600 BP., from 3 200 to 2 400 and from 1 300 to 25 BP. when there were periods of increased wetness. The climatic conditions in the eastern and central interior also indicate two relatively moist phases, the first between 7 700 to 6 300 and the second between 3 600 to 1 300 BP. Vegetation cover was diminished in the first, but not the second phase of climatic change (Deacon, J. et al. 1984:400). Pollen spectra from several southern Cape sites (Martin 1968, Scott 1984) indicate vegetation cover which was relatively open and similar to the present in the Late Holocene. Around 7 000 BP., however, forests became prominent and expanded over coastal areas until 2 000 BP. These developments are thought to be related to small temperature or moisture changes. According to Scott (1984) it would appear that from the Cape to the Transvaal regions the present vegetation pattern only developed during the last one or two thousand years.

The geomorphology and climate

The area defined is part of the Touws River floodplain, and has been the subject of a diverse array of hydrological, ecological and geological studies. A review of the literature (Martin 1962, Hill 1975, Birch and Du Plessis 1977, Whitfield et al. 1983), shows the environmental sensitivity of this coastal ecosystem. Evidence concerning coastal formation in the area has been drawn from these studies. In order to appreciate the impact of environmental factors one must go back to the region's pleistocene and holocene past. At the start of the major cycles of glaciation in the northern hemisphere some 45 000 years ago, the sea totally covered the Wilderness embayment, the lakes and Swartvlei lapped the cliff face of a very much older landscape of the Tertiary uplands (Allanson and Whitfield 1983:1).

During the last ice-age (16 000 - 45 000 BP.) the sea was 100 - 120 m lower than it is now. With the withdrawal of the sea due to the accumulation of water in the northern ice-cap, rejuvenation of rivers and streams occurred. They cut deeply into the edge of the Tertiary uplands and began to form an erosive phase over the sandy shores exposed by the receding sea. This process continued until some 10 000 years ago when, at the end of the northern hemisphere glaciation, the sea level began to rise and the sea transgressed over the coastal plain. It is thought that approximately 6 000 years ago the sea level was about 2,5 m above the present level. The sea then fell back to its present position about 4 000 years ago (Whitfield et al. 1983:2).

With the increase in land temperatures, the temperature differential between sea and land would have been larger than it is today. This would result in strong south-westerly winds which were the motive force in the creation of the serried dunes typical of the South Coast.

This movement of sand blocked the estuary of the coastal rivers and their basins began to fill from river flows. As their levels rose they were reconnected to the sea by new estuarine meanders. This tidal phase has lasted throughout the Holocene and continues at present (Allanson and Whitfield 1983:2).

Topography

On the northern boundary of this research area, steeply rising formerly well-forested slopes represent the remains of old sea cliffs. To the South, high consolidated old sand dunes protect the system from on-shore (southerly) winds. The gradient from the most easterly of the chain of lakes, Rondevlei, to the Touws River lagoon, is very slight over a straight-line distance of 13 km. Minor variations in water level therefore can produce slow, but wide-ranging, effects throughout the system (Allanson and Whitfield 1983:2). Martin (1962) has estimated that the system was formed in its present form some 7 000 years ago but that estuarine conditions have existed for only 4 000 to 5 000 years BP (Allanson and Whitfield 1983:2).

Vegetation

The natural vegetation of the area is coastal Maccia or Fynbos vegetation (Acocks 1979), including Restionacea, Ericoid leaved plants and various Compositae. Several hundred Kranz plant species belonging to at least thirteen different angiosperm families have been identified. Southern African grasses, which include both C3 and C4 species are, to a marked degree, separated geographically. Figure 4 demonstrates that C4 grass species are more abundant than C3 grasses over most of the country. The only areas where the C3 grass species predominate are the winter rainfall region of the western Cape and the summits of the Drakensberg and other mountain ranges of the eastern

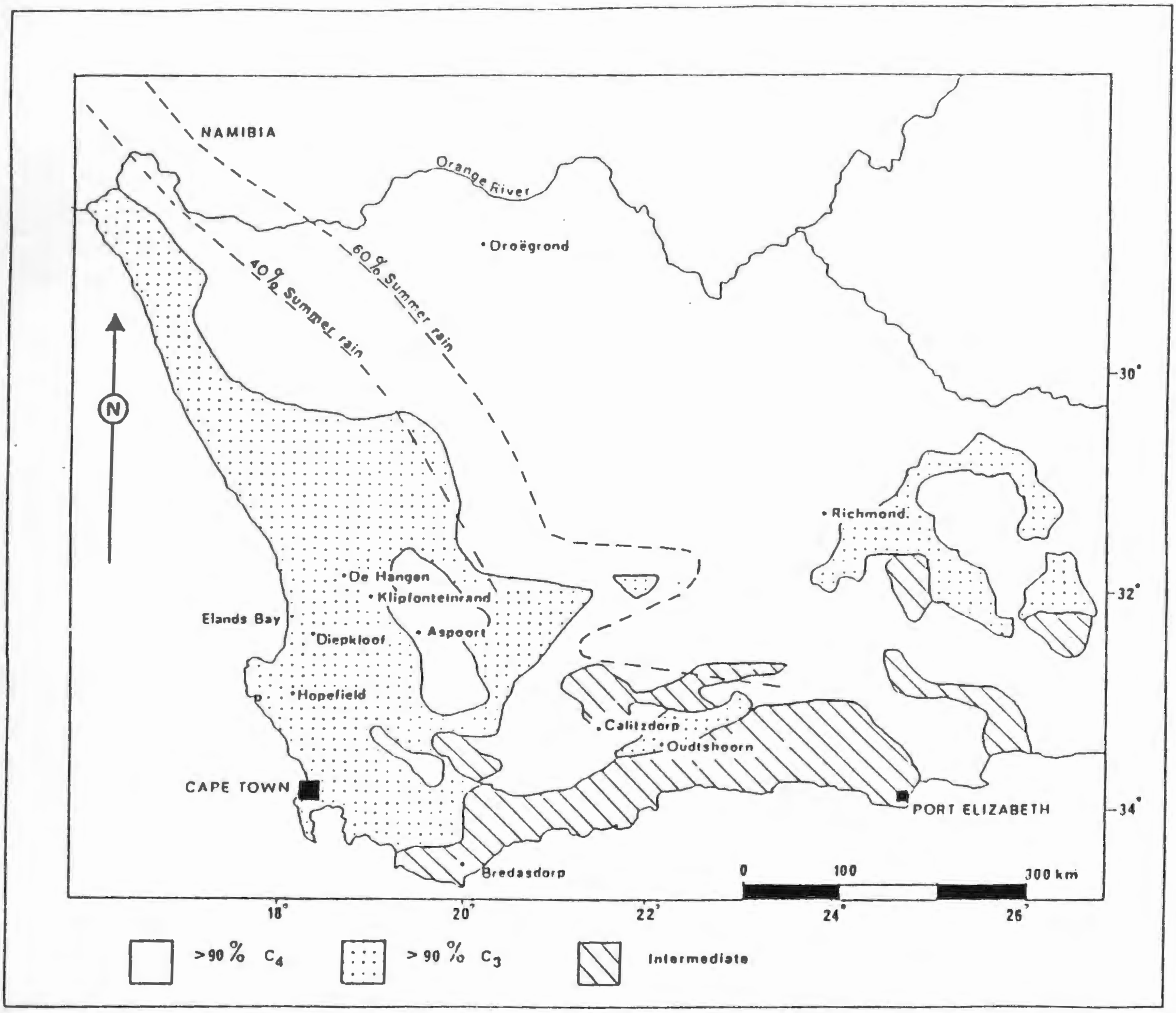


FIGURE 4: DISTRIBUTION OF C_3 AND C_4 GRASS SPECIES IN SOUTH AFRICA (After Vogel et al. 1978)

Cape (Vogel et al. 1978). The vegetation was relatively open in the early Holocene but forests became prominent around 7 000 BP and only expanded further, over the coastal dunes around 2 000 BP.

The distribution of fauna in prehistory

Faunal remains from the Cape ecozone, composed of the Cape Folded Mountains and adjacent coastal plains in the extreme southern and southwestern parts of the Cape Province, show a gradual shift between 12 000 and about 10 000 BP from predominantly grazers to predominantly browsers. The Cape Zone is unique in being the only zone in which browsers probably outnumbered grazers in both diversity and overall biomass. Species diversity, however, is lower in this ecozone, both overall and locally due to a less complete vegetation mat which was unsuitable as food for larger mammals (Klein 1984:118). In the Cape ecozone all Holocene faunas are dominated by small browsing antelope and ground game. Fauna dating to between 10 000 and 5 000 BP include relatively higher numbers of vaalribbok, mountain reedbuck and roan antelope. Such species are rarer samples post-dating 5 000 BP when the blue duiker appears for the first time (Deacon J. et al. 1084:400). Klein (1980) suggests that this shift implies an increase in forest and woodland habitats in the second half of the Holocene. Such is consistent with Martin (1968) and Scott's (1984) observations.

The Oakhurst fauna

Analyses of the remains of mammals, fish and shellfish from the Oakhurst cave site have been undertaken by Barnard (quoted in Goodwin (1938), Avery (pers.comm) and Cohen (pers. comm.) and the results of these studies are given in Table 1. Only the molluscan sample is taken as representive. The faunal list for this Holocene deposit includes no

TABLE 1: FAUNAL REMAINS IDENTIFIED FROM THE OAKHURST SHELTER

MAMMALIAN & AVIAN FAUNA

Raphicerus sp.
Procavia capensis (rock rabbit)
Cauies
Falies spp.
Viverrid
Phacochoerus (bushpig)
Papio ursinus (baboon)
Morus capensis (Cape gannet)
Bathyergus suillus (Cape mole rat)
Cephalophus monticela (blue duiker)
Accipitridae (hawk or eagle)
Tragelaphus scriptus (bush buck)
Taurotragus oryx (eland)
Phalacrocorax (white breasted cormorant)
Cephalophus (blue duiker)
Moridea (vlei rat)
Genetta sp.
Tortoise sp.
(Avery/Patrick identifications S.A.M. 1985)

PISCES

Sparodon durbanensis (biskop)
Pomatonius saltator (elf)
Myliobatis aquila (eagle ray)
(Barnard identifications S.A.M. 1937: 305)

MOLLUSCA

Donax serra
Perua Perua
Ostrea sp.
Glycimeris
Solen sp.
Turbo sarmaticus
Oxystele merula
Conus sp.
Cypraea edeutola
Bullia digitalis
Burnupena (Cominella)
Nasearina Kraussiana
Tricolia kochi
Haliotis spadicea
Patella cochlear
P. tabularis
P. longicosta
Helcion psuinosus
Siphonaria sp.
Tropidophora ligates (land shells)
Turritella carinifera
Choromytilus edulis

The above faunal remains were identified by KH Barnard from the SA Museum (1937). The collection of mollusca submitted for analysis is considered a representative sample from the uppermost 9ins of the Oakhurst deposit.

species which had not previously been recorded from other South coast sites (Klein 1984). The presence of Taurotragus oryx (eland) and previously only reported in pleistocene contexts (Klein 1984) is noted as is that of the blue duiker which makes its first appearance around 5 000 BP. The presence of eland in a Holocene context may readily be explained by the disturbed nature of the deposit (see Table 2). The blue duiker seems to be consistent with palaeoenvironmental data which indicates an increase in forest and woodland habitats in the second half of the Holocene. Although minimum numbers of individuals have not been calculated, since the sample is too small to be representive, tortoise bone outnumbers all other categories of fauna. This is an interesting observation in view of Klein & Cruz-Uribe's (1987) findings for South coast sites. Bones of the angulate tortoise (Chersine angulata) are abundant at all western Cape sites. They are, however rare at South coast sites like Nelson's Bay Cave and Boomplaas. Klein has attributed this to wet and moist conditions which made the South coast particularly unattractive to this species.

Among the molluscal remains there are twenty edible species, composed of five estuarine and fifteen marine species (Table 1). Three species have been noted for their use as decorative items.

Late Stone Age Technlogies

At the onset, the reader is reminded that the Late Stone Age (LSA) is a term used here to describe a technological unit in keeping with Goodwin and Van Riet Lowe's (1929) original tripartite classification of the Stone Ages of southern Africa. This classification was made on the basis of stone tool manufacture as envinced by the microlithic size and shape of tools. The LSA was subdivided into two main but

0 - 100cm			101 - 200cm			201 - 335cm		
UCT 199	71 cms	6 180 BP	UCT 216	114cm	2 065 BP	UCT 202	279cm	9 100 BP
Charcoal	91cm	3 450	UCT 201	122cm	5 990	UCT 215	292-269cm	9 120
UCT 218D	91cm	5 390	UCT 205	127cm	4 880	C22 burnt bone	259cm	8 950
UCT 200	101cm	7 120	Charcoal	137cm	7 910	UCT 203	280cm	4 100
			UCT 214	144cm	4 900	UCT 203 (child)	280cm	4 870
			UCT 210	155cm	4 530	C23 charcoal	335cm	8 270
			UCT 204	162cm	4 995			
			UCT 212	172cm	5 150			
			UCT 211	172cm	5 330			
			UCT 209	175cm	4 880			

TABLE 2: DEPTH OF GRAVES AND ASSOCIATED RADIOCARBON TESTS

parallel technological industries (Goodwin and Van Riet Lowe 1929, Clark 1959), namely the Wilton and the Smithfield. The latter was further subdivided into five discrete phases from Natal, Pondoland and the southern and western Cape (Inskeep 1967, Deacon H.J. 1972, Deacon J. 1972, 1978, Sampson 1972, 1974). The Wilton was described as one phase which had a wide geographical distribution, being recognized in Zambia, Zimbabwe, Botswana, Namibia and the western and southern regions of South Africa (Deacon J. 1984:224).

Chronologically the Smithfield and Wilton industries were seen to be broadly contemporary. With time, however, it became apparent that the relatively simple Wilton/Smithfield sequence described by Goodwin and Van Riet Lowe was far more complex that this. Excavations on the South Coast at Oakhurst and Matjes River (Dreyer 1933, Goodwin 1938, Louw 1960) and at Ncinginwinde in Transkei (Laidler 1933) and a re-excavation of the Wilton site (Deacon J. 1972) showed that "throughout the Holocene, large scrapers both preceded and succeeded assemblages with smaller scrapers and that the occurrence of significant numbers of segments was restricted in time to the mid-Holocene" (Deacon J. 1984:224).

In addition to these findings it became apparent that in the drier interior of South Africa, the type area of the Smithfield, there were no dated assemblages. This led Deacon, J (1984) to suggest that the low density of assemblages in which segments are prominent led to the classification of all material in the interior of South Africa as Smithfield 'C' rather than as Wilton. Thus the Smithfield and Wilton rather than being contemporary, were chronologically differentiated. Holocene "LSA industries in southern Africa are therefore characterized by changing parameters of scrapers through time and by changes in the relative frequency of backed microlith sub-types, particularly segments. In some instances, these changes are accompanied by shifts in the relative frequencies of raw material" (Deacon, J. 1984:225).

Radiometric dating has demonstrated the great antiquity of the microlithic toolmaking tradition in southern Africa which appears to have begun in the Late Pleistocene (18 000-12 000 BP). In order to distinguish between the Oakhurst Complex industries and these earlier microlithic ones, in the southern Cape at least, Klein (1974), Deacon, H.J. (1976) and Deacon, J. (1978) have termed the Oakhurst Complex the Albany Industry and the preceding microlithic assemblages dated between 18 000 and 12 000 BP, the Robberg (Deacon, J. 1984:225).

There is a broad correspondence of dated technologies (Parkington 1984) throughout southern Africa of the Robberg, Albany/Pomongwe/Oakhurst and Wilton industries which suggests that these substages represent widely diffused norms of technology (Deacon, H.J. and Thackeray 1983:380). Whether these data may be taken to represent cultural diffusion or a response to environmental stimuli, has prompted Deacon, J. (1984) to classify the component parts of stone tool technologies in the following manner. Change in lithic technologies are seen as the by-product of two sets of stimuli. Change from one complex to another implies an adjustment in the size and shape requirements for tools. Where such change is geographically widespread and cross-cuts environmental boundaries, it is thought to represent 'new ideas' which spread through social contact rather than an in-situ response to environmental stimuli. Change within a complex, however, where contemporary samples in different regions have distinctive formal tool frequencies, are thought to reflect functional adaptations to given sets of environmental stimuli, or activities (Deacon, J. 1984:226).

Other items characteristic of L.S.A. technologies include art and items of personal adornment. This may take the form of decorated ostrich eggshell, beads, pendants, marine and fresh water pendants and paintings. Tools made for use in hunting and fishing in the form of bows, arrows, fish hooks and sinkers are recognized. Finally, formal burial of the dead in graves often covered with painted gravestones, and/or boulders accompanied with grave goods are observable (Deacon, J. 1984, Parkington 1984, Hall and Binneman 1987).

Cultural stratigraphy at Oakhurst in relation to the Cape LSA

The stratigraphy (Fig.5) has been described in detail by Goodwin (1938). The deposit consists mainly of well preserved sea-shell and woodash containing carbon fragments and leaf mould. A curious feature of the deposit is the presence of massive white layers of carbonates and charcoal which Goodwin (1938:239) has interpreted as evidence of at least three forest fires. A similar feature of deposit has been noted at Matjes River, Glentyre, Melkhoutboom and Nelson's Bay Cave (Sampson 1974:283). Periods in which there has been more intensive use of the cave are evidenced by a bank of ash (which is thought to have formed a 'protective fireplace' in the cave) concentrations of stone tool and debitage suggestive of a workshop site and eighteen burials associated with grave goods (Goodwin 1938:239).

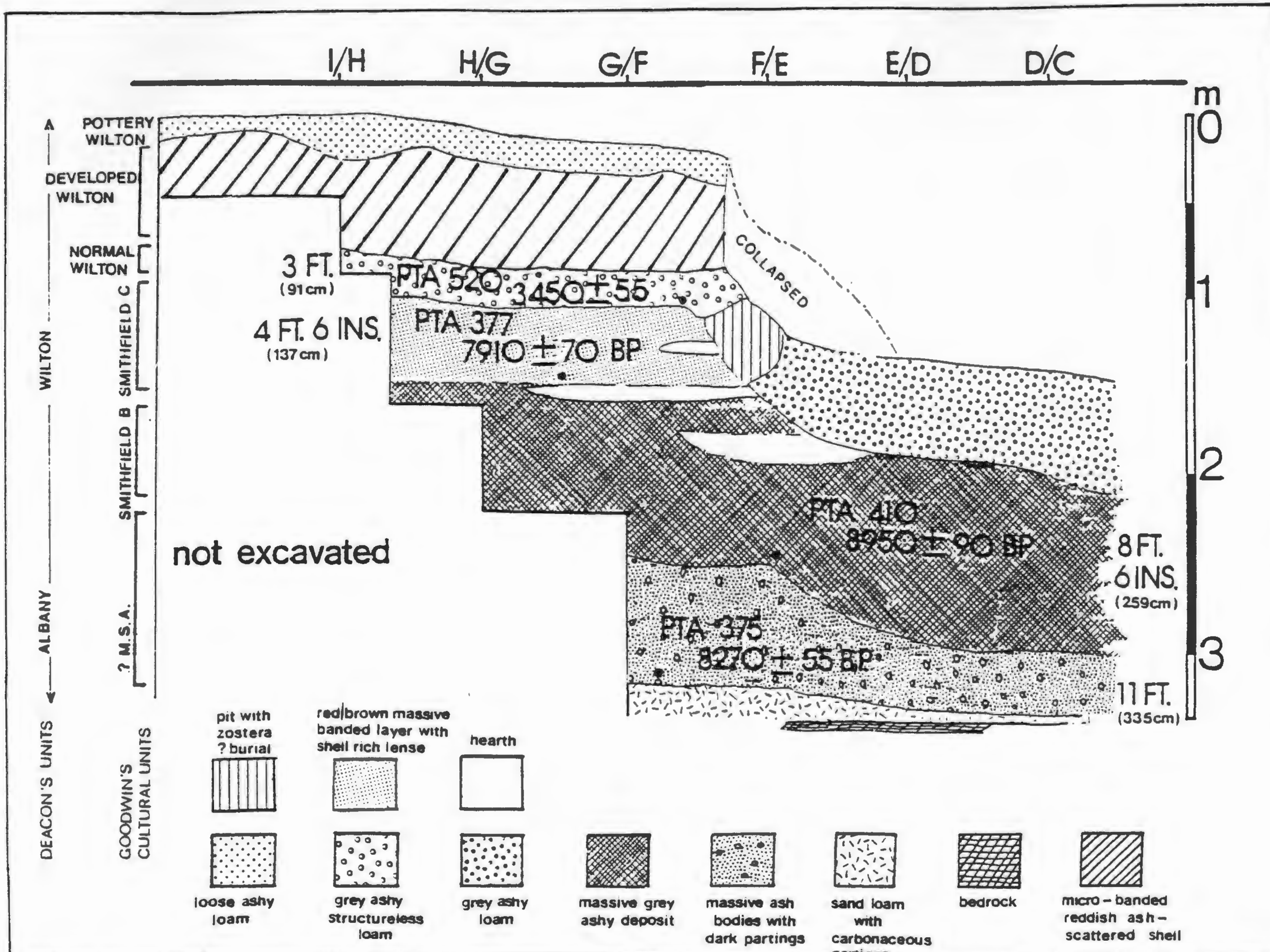


FIGURE 5 : OAKHURST ROCKSHELTER SECTION ALONG END WALL (Adapted from Deacon, H.J., 1976)

The cultural stratigraphy is well documented (Goodwin 1938, Fagan 1960, Schrire 1962, Sampson 1974, Deacon, H.J. 1976) and major technological change is noted between Middle Stone Age (M.S.A.) and L.S.A. artefacts at 335-259cms, Still Bay type implements and a point with typical Mossel Bay trimming are characteristic of this deposit. Technological change within the L.S.A. is noted from 150-90cms, (bracketed between dates of 7 910 and 3 450 BP) as envinced by large implements, lower density of artefacts and a raw material change from chalcedony and fine grained quartz to quartzite. A further technological change characterized by stone crescents, small convex scrapers and shell ornaments is noted from 8-22cms (Goodwin 1938, Deacon, H.J. 1976). From the uppermost layer of the deposit, the last 22cms, there is evidence of pottery, the increased use of shell artefacts, crescents made from black mussel shells Choromytilus edulis, shell ornaments and buttons, ostrich eggshell beads and pendants, bone tools, awls and arrowpoints.

Changes in subsistence

There is some evidence to suggest (Parkington et al. 1986, Hall and Binneman (1987) that human populations in the Late Holocene (4 000 - 3 000 BP) were subjected to economic and social stressors. A response to these stressors was an intensification of ritual elaboration. This is best seen in the rock art of the western Cape and the burial customs and associated grave goods from the South coast. Laughlin and d'Aquili (1979) have commented on the role of ritual in human adaptation and suggest that a frequent cause of ecological stress is brought about by competition of scarce resources. A major function of ritual during ecological stress is to serve as a buffer between extreme environmental change and potential psychological stress. Evidence of ritual elaboration in the archaeological record, therefore, may be used as a useful indicator of economic stress.

The difference between the Smithfield B midden deposits which are rich in Solen species but poor in Fish remains, and the Wilton deposits which contain many kinds of shellfish, Fish and small animals (Goodwin 1938:323), is strong evidence to suggest a change in subsistence economy. This change in subsistence may reflect a human preference for certain foods or a shortage of available resources. The latter hypothesis is favoured here since there is evidence to suggest that the range of foods available for exploitation increased in the late Holocene.

Burial practices and associated grave goods

The Oakhurst burials are the primary source of biological data in this study, so it is useful to review the context of their discovery. The burials, described by Goodwin (1938) and Inskeep (1986), were in general buried in a side-flexed position and placed directly on the natural ground surface. The exception to this is the grave of two new-born babies (U.C.T. 215/G and 215/H) buried on beds of sea-grass, Zostera capensis, and under river-pebble gravestones, and a young juvenile (U.C.T.212) buried beneath eight gravestones. The entire grave had been outlined in sea-grass. Two adult burials (U.C.T.208/193, 204) with gravestones were also uncovered. In each instance several gravestones overlay the burial. At the time of excavation the greatest number of graves lay at a depth of between 127-152 cm from the surface and came from a relatively small area, 210 cm long by 150 cm across. Earlier graves were consistently disturbed by later burials, in some instances more than once (Goodwin 1938:247). Two additional factors gave rise to finding incomplete skeletons, the presence of roots in certain portions of the more exposed deposit, and crushing by overlying material, particularly gravestones.

Forty-six interments were recovered from Oakhurst (Table 3, Appendix 1). Of the forty-six interments there were 8 women, 8 men, 5 unsexed individuals and 25 juveniles. The body position could be identified for 17 individuals (10 adults and 7 juveniles). Fourteen individuals were buried on their right side in a flexed position and 3 individuals on their left side in a flexed position. The remaining material was so disturbed with unkown grave association that burial position was difficult to ascertain. The skeletal series has been increased from Drennan's original twenty-two individuals to include the partial remains of twenty-four other individuals that neither Goodwin nor Drennan had described. This was achieved by including incomplete skeletal remains. In the past only those skeletons with complete crania were considered for study.

Gravegoods from this site include bored stones, ostrich eggshell beads, conus shell beads, nacre beads, tortoise shell bowls, red ochre, ivory palettes, ivory points and ivory arrow heads. These are consistent with gravegoods found elsewhere in the southern Cape. Indeed, the frequency with which artefacts appear in graves is comparable with Inskeep's (1986) findings in which there is a time linked change in southern coastal groups. "Personal ornaments, such as beads and pendants appear in only 10% of Albany graves, rise to 64% in the Wilton, and fall back to 28% in the post-Wilton" (Inskeep 1986:50). There appears to be no great change in the incidence of grave-stones at Oakhurst in all three periods. The reader is however reminded of the disturbed nature of the Oakhurst deposit. Hence such data may be regarded as an approximation only.

	0-11.9 mths	1-4 years	5-9 years	10-14 years	15-19 years	20-29 years	30-39 years	40+ years	no age/sex estimate possible
	UCT 201	UCT 207/I	UCT 205		UCT 213 ♀	UCT 214 ♂	UCT 199 ♂	UCT 202 ♂	UCT 204 3 individ.
	UCT 203	UCT 207/G	UCT 207/H			UCT 218 ♂	UCT 206 no.1 ♂		UCT 218/D 2 individ.
	UCT 209	UCT 212	UCT 208 (10)			UCT 200 ♀	UCT 206 no.2 ♀		
	UCT 213/G	UCT 215/I	UCT 215/B			UCT 205 ♂	UCT 201 ♀		
	UCT 215/P	UCT 208 (9)	UCT 217			UCT 206 no.3 ♀	UCT 203 ♀		
	UCT 216/Q	UCT 210				UCT 209 ♂	UCT 204 no.1 ♀		
	UCT 216/J	UCT 213					UCT 211 ♂		
	UCT 217/K	UCT 215/D					UCT 212 ♀		
	UCT 217/L	UCT 217/F							
	UCT 217/N								
	UCT 217/M								
TOTAL	11	9	5	0	1	6	8	1	5

TABLE 3: NUMBER OF SKELETONS RECOVERED FROM OAKHURST BY AGE AND SEX

MUSEUM No.	ARCHAEOLOGICAL REMARKS	RADIOCARBON DATE	LAB No.
C 19	Charcoal at 91cm	3450 ± 55	Pta 520
C 20	Charcoal at 137cm	7910 ± 70	Pta 377
C 22	Burnt bone near grave 18 259cm	8950 ± 90	Pta 410
C 23	Charcoal at 335cm	8270 ± 55	Pta 375
UCT 199	Collagen/grave 1 71cm	6180 ± 70	Pta 3718
UCT 200	Collagen/grave 2 101cm	7120 ± 60	Pta 4354
UCT 201	Collagen/grave 3 122cm	5990 ± 70	Pta 4426
UCT 202	Collagen/grave 5 279cm	9100 ± 90	Pta 3724
UCT 203	Collagen/grave 5 280cm	4100 ± 60	Pta 4431
UCT 203	Collagen/grave 6 114-145cm	4870 ± 210	AA 2119
UCT 204	Collagen/grave 6a 162cm	4530 ± 70	Pta 4449
UCT 205	Collagen/grave 7 127cm	4880 ± 70	Pta 4347
UCT 206	Collagen/grave 8 152cm	5450 ± 70	Pta 4367
UCT 207	Collagen/grave 9 106cm	4830 ± 250	AA 2115
UCT 209	Collagen/grave 11 175cm	4880 ± 70	Pta 4348
UCT 210	Collagen/grave 12 155cm	4995 ± 215	AA 2117
UCT 211	Collagen/grave 13 172cm	5330 ± 60	Pta 3719
UCT 214	Collagen/grave 18 144cm	4900 ± 60	Pta 4467
UCT 216J	Collagen/grave 6 114-145cm	2065 ± 105	AA 2116

TABLE 4: RADIOCARBON DATES FROM OAKHURST

A note on radiocarbon dates

A major requirement for this study was the need to have the burials placed in a temporal order. Twenty-four individuals were dated by the radiocarbon technique and the dates are recorded in Table 4.

These data show clearly the disturbed nature of the deposit and confirm Goodwin's (1938) observations that earlier interments had been disturbed by later interments (Table 2), in some cases more than once. The pattern of the dates confirms the notion of a South coast focus of people in the mid-Holocene. Dates pertaining to the mid-Holocene (4 000 - 7 000 BP.) are consistent with data observed at Matjes River Rock Shelter (Louw 1960), Byneskranskop (Scheitzer and Wilson 1982), Cape St. Francis (Thackeray and Feast 1974), Klasies River Mouth (Singer and Wymer 1982) and Nelson's Bay Cave (Deacon, J 1984). The pattern of these data are quite distinct in comparison with dates from the Atlantic coast. It is known (Parkington and Hall 1987) that there are no radiocarbon dates from the west coast between 4 300 and 7 800 BP. A similar pattern has been observed to the North and East (Parkington 1980).

A palaeoenvironmental explanation has been proposed (Parkington & Hall 1987) which suggests that conditions were extremely arid, this gave rise to inhospitable coastal conditions with fewer reliable fresh-water seeps.

Life style inferred from archaeological remains

Given the nature of the data presented here the Oakhurst sample may be seen as part of a local population residing on the south coast of southern Africa. They are part of a regional focus of people living on the South coast around 10 000 to 2 000 years ago who appear to have exploited small browsing game, ground game such as tortoise, and shellfish. Fish such as biskop, elf, kabeljauw and steenbras formed part of their dietary intake. These items presumably would have been more readily available when estuarine conditions were formed around 4 to 5 000 years ago. Oakhurst Rockshelter is situated in dense forest, which became prominent around 7 000 years ago, and expanded to the coastal dunes up to 2 000 years ago. This vegetational cover may have provided a useful habitat for the small antelope, small carnivores and larger mammals hunted by the people of the area.

The opportunity to exchange ideas and marriage partners with other local populations may have occurred between the local populations living at Nelson's Bay Cave, Glentyre and Matjes River. Using Wobst's (1976) data, mate exchange requires the maintenance of a dense communication network which is frequently symbolically supported by food sharing, exchange and ritual. This suggests that if the people of Oakhurst and Matjes River, as an example, were regularly exchanging mates, the contemporaneous occurrence of distinct assemblage types at these sites cannot be explained in terms of different ethnic affiliations.

CHAPTER FOUR

RESEARCH DESIGN

Skeletal biology: the theoretical background

The study of palaeopathology has long been restricted to the recognition and diagnosis of disease from past human populations. More recently, the study of pathological conditions has focused on the disease process as a selective agent in the evolutionary history of our species (Angel 1964, 1966, Armelagos and Dewey 1970, Brothwell 1963, Cohen 1975,1977, Huss-Ashmore et al.1982). Features of nutritional stress in prehistoric skeletons have been viewed, and these are being analysed at a population level. The palaeopathologist attempts to describe, to classify, and then interpret the epidemiological parameters of disease in human populations. These parameters have a demographic impact as well. Fertility, mortality and migration are the dynamic elements of demographic analysis. They are the population process that lead to change in the demographic structure and often in the social, economic and political structure of a society as well (Weeks 1986:79).

The realization that skeletal pathologies of archaeological populations may aid in interpreting adaptation has given rise to a number of methods for studying nutritional deficiencies in skeletal populations This chapter, and chapters 5, through 7 outline the theoretical aspects of some of these methods, and are basic to understanding their anthropological application. Accordingly some understanding of bone structure, bone growth, bone chemistry and oral pathology is also required. The reader is asked to bear through, what at first, may appear to be a review of clinical rather than archaeological data. This is necessary in order to appreciate the anthropological implication of these pathologies.

The physiology of bone

The skeleton of all large living vertebrates, undergoes bone specific ontogenetic changes in the numbers and distributions of cells which secrete new calcifiable collagen matrices (osteoblasts) and which resorb pre-existing bone matrix (osteoclasts). The numbers and activities of these cells, which function via tissue remodeling to maintain the external and internal morphology of bone, are also constrained by nutritional and endocrinological influences.

Bone formation also varies according to differing circumstances in different parts of the skeleton. Three patterns of bone formation are recognized. These are: (1) endochondral ossification, where bone deposition is related to the presence of calcified cartilage. This process involves the removal of calcified cartilage by cellular activity and the formation of bone by cells which invade the cartilaginous tissue after it has been resorbed (2) intra-membranous ossification in which relatively large areas of collagenous fibrous tissue appear to calcify very quickly with the production of trabeculae and larger blocks of bone. This process occurs as part of the production of the immature bone of the metaphysis and also of the lamellar bone of the diaphysis in normal skeletal development; and (3) appositional growth where bone formation occurs continuously by the deposition of layers of matrix on pre-existing bone. This process is the one in which new bone formation occurs in the continuous turnover of the mature skeleton (Woods 1972:11).

The composition of fresh bone can vary considerably with age and portion of bone examined. Approximate values suggest that bone is composed of 70% mineral, 20% collagen, 8% water and 2% noncollagenous components. The mineral portion of bone is composed principally of calcium phosphate, which is present in both crystalline and amorphous forms. In adults the dominant form is crystalline hydroxyapatite. Around 40% of mature compact bone mineral is of the nonapatitic form. However, since most amorphous calcium phosphate spontaneously goes to hydroxyapatite in water, most of the mineral in archaeological bone is crystalline (Klepinger 1984:75).

The annual turnover rate for bone varies according to age and type of bone. In general, infants and young children have a higher turnover rate than adults. In adults the normal turnover rate for trabecular bone is estimated to be three to ten times faster than for cortical bone. Although variation does occur, the annual turnover rate for trabecular bone averages 10% and that for cortical bone 2.5%. These differences should be taken into consideration when making comparisons between metabolically dissimilar bones (Klepinger 1984:75).

Many developmental defects observed osteologically are the result of a specific failure of a tissue to appear or disappear at the correct time. It is obvious that skeletal tissues be normal with regard to their structure and composition, and it is no less important that those tissues make their appearance, and be removed, at the correct time and in the appropriate quantity, especially during the period of growth (Woods 1972:16). Since the study of palaeopathology is a retrospective analysis these factors are of particular importance in ones interpretation of skeletal anomalies.

As a dynamically adaptable material, bone form and structure are continually undergoing subtle remodeling in order to conform to its function. The primary function of bone is to provide support and locomotion, storage and regulation of minerals, protection of the brain and spinal cord, and the production of red blood cells (Katz et al. 1984:31). An extensive literature exists on the functional significance of bone, and bone architecture. In this study four levels of structure, or organization are considered.

(1) The molecular level, where collagen, the major organic constituents and other organic components such as lipids, proteoglycans and the like are defined. Bone is a unique tissue in that it contains an inorganic, mineral-like component, hydroxyapatite (OHAp).

(2) The ultrastructural level, where small crystallites of OHAp appear to be in intimate juxtaposition in a highly organized geometrical arrangement with collagen fibrils.

(3) The microstructural level, where fibrillar collagen OHAp crystallite units organize into higher level organizations such as woven, plexiform and Haversian bone.

(4) The macrostructural level where the size and shape of the whole bone are considered (Katz et al. 1984;31). The macrostructural level also includes the organism as a whole, and therefore also deals with demographic aspects of population change.

The utility of studying bone in levels of hierarchical organization is not only of value to those working in the fields of bone chemistry and biomedical engineering but also to those in archaeology. Figure 6 demonstrates the use of human bone in archaeological research and the type of data that may be obtained from such studies. For the sake of continuity and ease of reading, the theoretical aspects of the macro, micro and molecular level are presented in separate chapters. Each chapter is headed with the structural level of analysis followed by a review of the literature and a section devoted to my own research methodology.

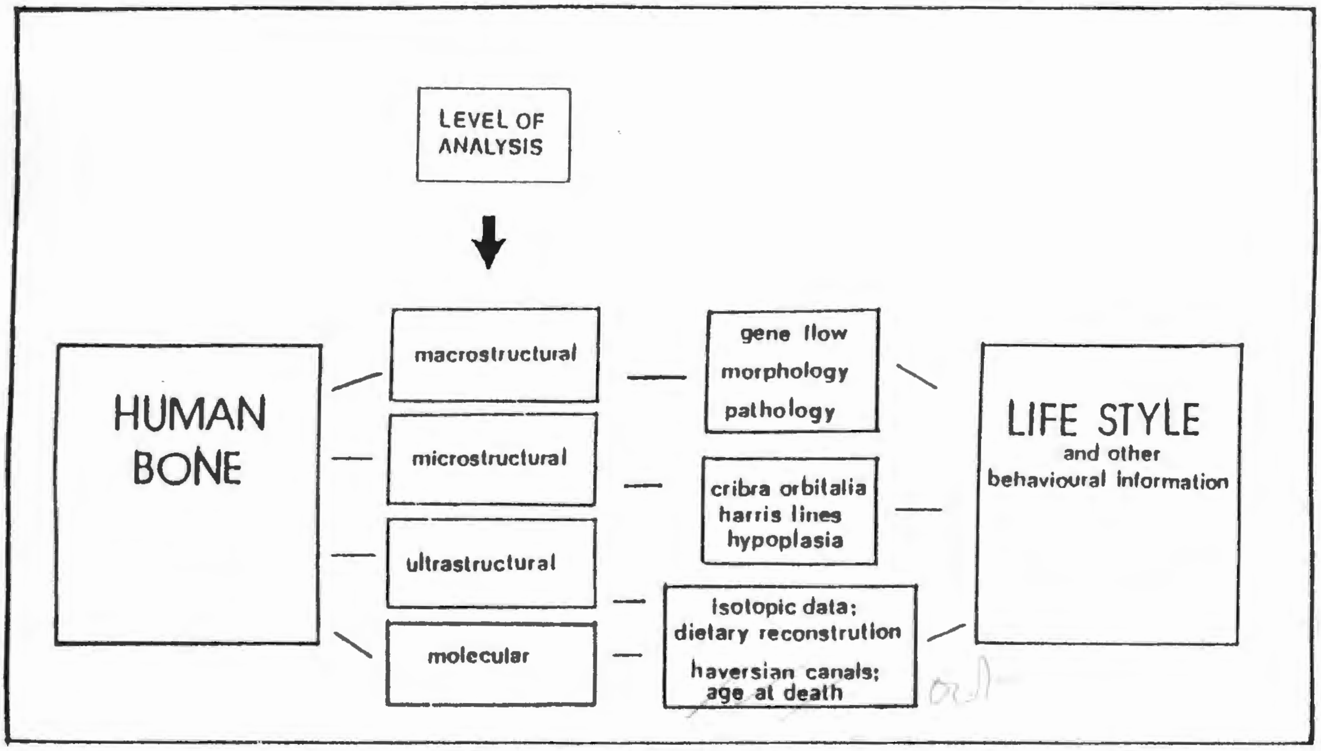


FIGURE 6 : FLOW CHART WHICH OUTLINES THE FUNCTIONAL AND ANALYTICAL SIGNIFICANCE OF HUMAN BONES IN ARCHAEOLOGICAL RESEARCH

CHAPTER FIVE

MACROSTRUCTURAL ANALYSIS

Skeletal morphology, its variation and pathology

The macrostructural level of analysis is, without doubt, not only the best known, but also the most widely used form of analysis in archaeological research (for a synthesis of this approach in South African populations see Tobias 1985). The emphasis of this mode of research is to explain geographical differences between contemporary and archaeological populations (de Villiers 1968, Morris 1984), and to evaluate the notion of 'race' in relation to ecology, climate, cultural and demographic selection (Nurse et al.1978). These topics are taken up in this chapter and as such the macroscopic level of analysis deals with aspects of skeletal biology that relate to demography, gene flow, morphology and gross pathology linked to life habit or life style.

D E M O G R A P H Y

Limiting conditions for the origins of band societies

Artefacts recovered from archaeological sites indicate the presence of human occupation. Assumptions may be made and tested concerning the spatial and temporal distribution of such finds, they may also tell us something of the people who live there (by house or hearth counts) and those who died there (by skeletal remains recovered from burial sites) (Howell 1976). What these data cannot provide however is a detailed account of population growth and the social institutions that arise from such. This lack of concern with cultural behaviour has led to what Wobst (1976) considers a 'worms-eye' view of socio-cultural evolution, and increasingly isolates archaeology from the other social and behavioural sciences (Wobst 1976:49). In order to understand a particular society one needs to know how many people live there, how many people are being born, how many are dying, how many people move in and out of a group and the age structure of the group. In addition to these factors one needs to know about the social, psychological and economic characteristics of the people being studied. Generally speaking, three categories of information are amassed. These are population size and distribution, and the reproductive capacity of the group. These data form the demographic perspective.

The demographic perspective

Given that events in the past are caused by the same processes which are at work in the present, a uniformitarian theory may be applied to palaeodemography. The uniformitarian position implies that "the human animal has not basically changed in its direct biological response to the environment in processes of ovulation, spermatogenesis, length of pregnancy, degree of helplessness of the young and rates of maturation and senility over time" (Howell 1976:26). This does not imply that humans have not changed in the rates of performance of these processes, but only that the process still responds in the same way to variations in environment, including the cultural and technological aspects of human society as part of the external environment. The uniformitarian approach has been applied by Acsadi and Nemeskeri (1970) to help reconstruct the history of performance in mortality and by Weiss (1973) and Hennenberg (1976) to construct model populations by combining life tables derived from anthropological studies with age-specific fertility schedules. The approach adopted in this project makes use of life tables and fertility schedules.

There are three methods with which one may estimate the fertility level of a prehistoric group. Firstly, the number of births in a group may be reconstructed from the average duration of the reproductive period. It is assumed that the average woman gives birth over a period of 30 years (ie: from menarche to menopause). One divides this reproductive period by the length of the interval between the birth of two subsequent children born in a family. If one assumes in the general case that the birth interval is 3 years, then the average woman is capable of giving birth to 10 children in her lifetime. The second method is based on the reconstructed age structure of living females and hypothetical age-specific fertility rates. The third method makes use of morphological changes in the female pelvic bones associated with pregnancies and deliveries (Angel 1969, Ullrich 1975). The second and third method however do not permit one to establish the actual numbers of births in a prehistoric population and at best are rough approximations only. According to Henneberg (1976) the most appropriate approach to the problem of reproduction in earlier human populations is to measure the impact of mortality on the reproductive capacity of populations. To do this a method is constructed from actual prehistoric mortality data coupled with known regularities in procreation observed in contemporary non-Malthusian populations who do not practice modern forms of birth control ("non-Malthusian populations, in the sense that Malthus showed that populations would all eventually have to control their own growth in some manner") (Henneberg 1976:42).

Patterns of procreation in non-Malthusian populations

Patterns of procreation in non-Malthusian populations have been well documented (Lorimer 1954, Pressat 1961, Henry 1972, Henneberg 1976) and it seems clear that fertility rates differ considerably. There are two factors which influence fertility levels. The differences in the ages of onset of menarche, and birth spacing. Other factors, although of less importance, include cultural practices such as sexual and food taboos. Given then that there are a number of factors which influence fertility levels in non-Malthusian populations a common model concerning the set of age-specific fertility rates and birth spacing is not possible. What can, however, be calculated is "the increase of the relative cumulative proportion of births with the age of adults. Based on this regularity in relative cummulated fertility one may construct an archetype of fertility" (Henneberg 1976:42). From this one may estimate the capacity for natural increase among prehistoric populations. Having done this it remains thereafter to study population size, structure and distribution. The data gleaned from these studies give archaeology an analytical concept compatible with the 'society' or 'culture' of ethnology, or with the 'population' of general ecology. At this level of analysis one is more sensitive to socio-cultural processes between interacting local populations than the traditional archaeological approach via cultures, traditions and assemblage types (Wobst 1976:49).

Locational relationships in prehistoric populations

Wobst (1976) introduced 'the mating network' concept which integrates socio-cultural processes with local populations. These data are seen to shape the form and structure of cultural behaviour at individual settlements. Other than providing food and shelter a society must be able to provide its members with a reasonable chance to obtain marriage partners. If there are areas which would inhibit or discriminate against their occupants by their marginal location to a mating network, they will be occupied only if all other possibilities are exhausted. According to Wobst (1974) marginal areas include coastal islands, peninsulas, mountain valleys and tail ends of watersheds. While it is highly probable that many of these areas are capable of supporting local populations in relative comfort, such would strongly inhibit the opportunity for social interaction with other groups.

According to Birdsell (1957), Lee and De Vore (1976), Damas (1969) and Wobst (1974) minimum bands range in size from 15 to 75 people. The norm in this distribution appears to be around 25 people. This unit tends to maintain a territory through habitual use, by the presence of natural barriers and its close approximation to other groups. In order for any member of this group, upon reaching maturity, to find a compatible marriage partner a given local group would have to engage in mate exchange with 18 other local groups. Wobst (1974) has hypothesized that if these local groups are placed in a hexagonally packed arrangement so that each group has 6 nearest neighbours, some interesting observations arise.

Firstly, mating networks which are closed, in the sense that the participating local groups derive virtually all of their mates from the same set of personnel, would be essentially congruous. As population density decreases, the marginal groups would be placed in a more and more unfavorable distance relationship relative to the groups in the center of the network. At low population density it is questionable whether local groups could maintain themselves in this way. It seems more profitable therefore, for local groups to develop their own mating network, that is a network which does not coincide with those of any of their neighbours. Local groups would be able to achieve identical spatial relationships to their pool of potential mates. There are two important points here. One is that the communication network required of any given group would be of minimal size. The second point to be observed is that this situation gives rise to continuously distributed, partially overlapping mating networks. This concept has been tested in contemporary populations by Harpending (1975) and Henneberg (1979) who have calculated the marriage distance for the Zu/wasi San in Botswana and Namibia. Their results demonstrate that the average distance between the centers of neighboring territories was about 65 km. This implies that genetically closed local breeding isolates could not materialize under these conditions since the chain of mate exchange would lack clear breaks and boundaries. The importance of this observation is that prehistoric groups with distinct assemblages and ritual elaboration cannot have arisen before a certain population density threshold was reached over wide areas.

These demographic findings may go a long way to explain why linear environments, such as sea coasts were not exploited as a set of resources until very late in human history and why specialized exploitation of various sets of land resources seem to have a longer history.

In ones final analysis of population processes it becomes quite clear that fertility, mortality and the sex ratio of a given group are important evolutionary parameters. The smaller the breeding population, the greater the short-time fluctuations in inbreeding and fertility. Thus, in order to make up for reproductive loss resulting from these fluctuations, women have to be more fertile and draw their mates from partially overlapping networks.

In the following sections a method is set out for estimating the age and sex of an individual, followed by a method for estimating the biological state index of a population so that the reproductive possibilities and an estimation of the biological dynamics of Holocene populations may be understood.

Estimation of age and sex in prehistoric populations/methodology

The assessment of skeletal maturity is a method, based on changes in the developing skeleton, which may be easily viewed and evaluated. Each morphological change, or stage, is assigned a specific point score and the result is a skeletal maturity score to which a biological age may be assigned. Given that there are 80 separate ossification centers and far more than one thousand details of appearance, modeling, epiphyseal union and obliteration of epiphyseal lines some simplification of this endless possible detail is necessary. Recognizing the limitations inherent in using only one area of the body in maturity assessments, Garn et al.(1971) have agreed on twenty morphological traits which have the best predictive efficiency in both sexes.

Age, in a prehistoric population is expressed in developmental, or maturity assessment categories. When dealing with prehistoric populations however it is difficult to be sure that significant developmental changes took place at the same time, and that they showed the same group variability as in contemporary populations (Brothwell 1981:64). Acheson (1966) however, has proposed that in theory such criteria should be universal and could be applied to all children and should not be affected by disease states. This view is supported by physical anthropologists (Malina 1971) concerned with the utility of skeletal maturity assessment in understanding human growth and development within the context of the maturity process. The estimation of an individuals age, and sex for that matter, are an important characteristics since they determine ones place in the system of production and reproduction and, ones ability to participate in the transmission of information (Henneberg and Strzalko 1983:161).

Age-related variation in skeletal morphology is due to genetic, environmental and nutritional influences and a substantial amount of work has been done in an attempt to document the impact of these variables on skeletal maturation. Weiner and Thambipillai (1952), Angel (1976) and Pucciarelli (1980) to name but a few, have made extensive studies on the effects of 'race', sex and nutrition and suggest that any estimate of age structure in earlier populations, living in various eco-cultural conditions, should be accepted with these data in mind. What follows therefore is merely a guideline.

Criteria used for age estimation/methodology

There are a number of criteria that may be used, and I have selected, for the purpose of this study, to restrict myself to Ferembach et al. (1980) and Brothwell's (1981) recommendations for age diagnosis.

The body part characteristics used in age diagnosis are delineated into three developmental categories: children, juveniles and adults. Following Ferembach's et al. (1980) approach, the following criteria were used to ascertain age in the Oakhurst sample. Firstly, tooth calcification and tooth eruption patterns, followed by epiphyseal fusion, suture closure, phases of relief of the facies symphaseos (symphysis pubis) and phases of relief of the spongiosa structure of the femur and humerus head.

Birth - 13 years : children

The most valuable indication of age in children is tooth development as this presents precise stages which can be divided into discrete and narrow age categories. Dental observations involve:

(1) tooth calcification stage, using the scheme originally developed by Schour and Massler in 1941 (Fig. 7).

(2) and tooth eruption stage (Fig. 8).

Other aging features for children include the ossification of the skull and post - cranial skeleton. The major landmarks in skeletal ossification according to Ferembach et al. (1980) include:

(1) Closure of the posterior fontanelle (0-3 months);

(2) Body and greater wing of sphenoid fusion (6-9 months);

(3) Unision of two halves of the mandible (9-12 months);

(4) In the course of the second year of life the anterior fontanelle and the frontal sutures close (in exceptional cases the suture remains open as a metopic suture) and both halves of the vertebral arches grow together;

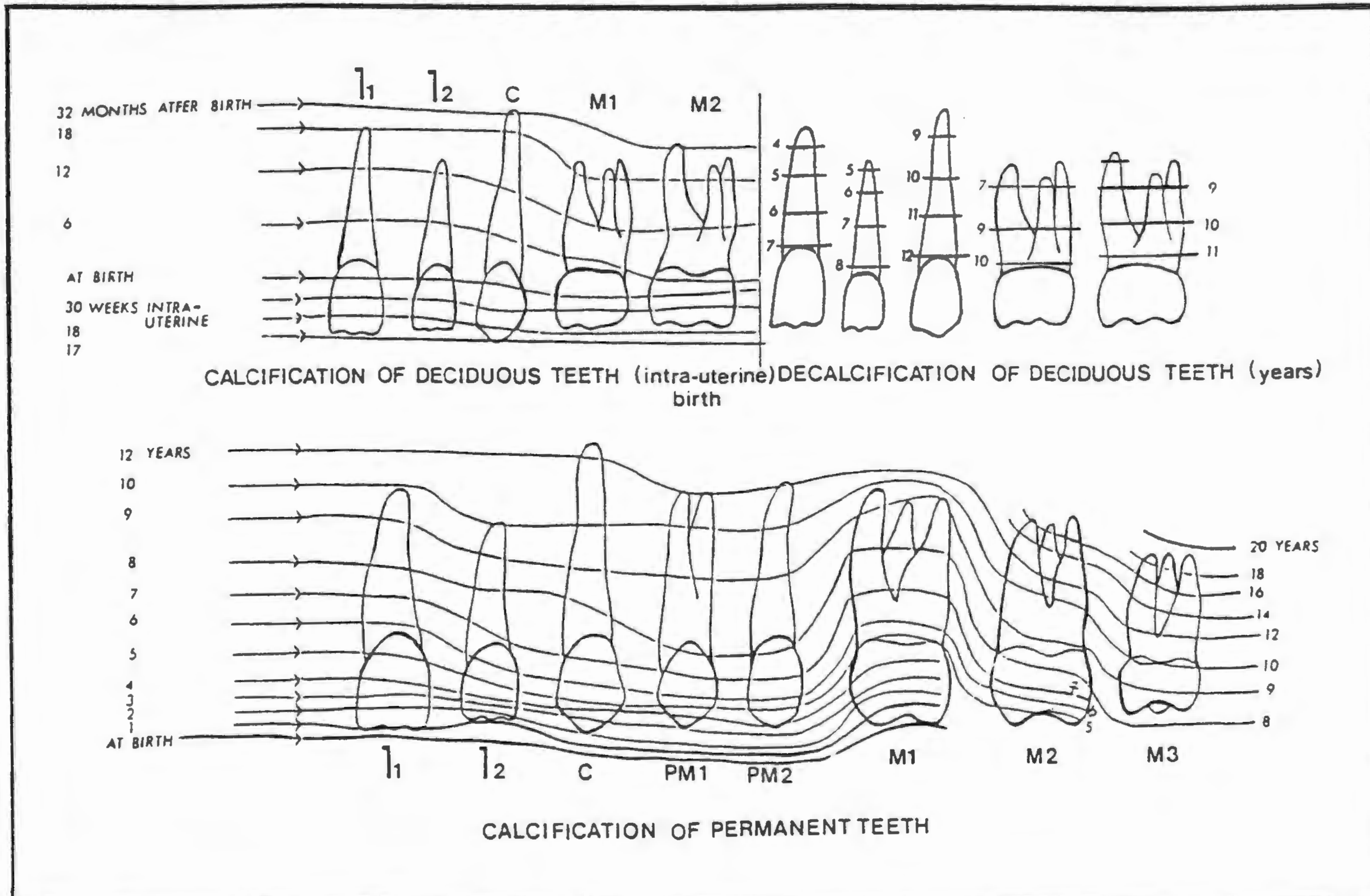


FIGURE 7: CHRONOLOGY OF TOOTH DEVELOPMENT AND CALCIFICATION RATES OF THE DECIDUOUS AND PERMANENT TEETH IN GROSS LABIAL VIEW, WITH THE DEVELOPMENTAL LINES AND PERIODS INDICATED ON THE RIGHT AND LEFT. (After Schour & Massler 1941)

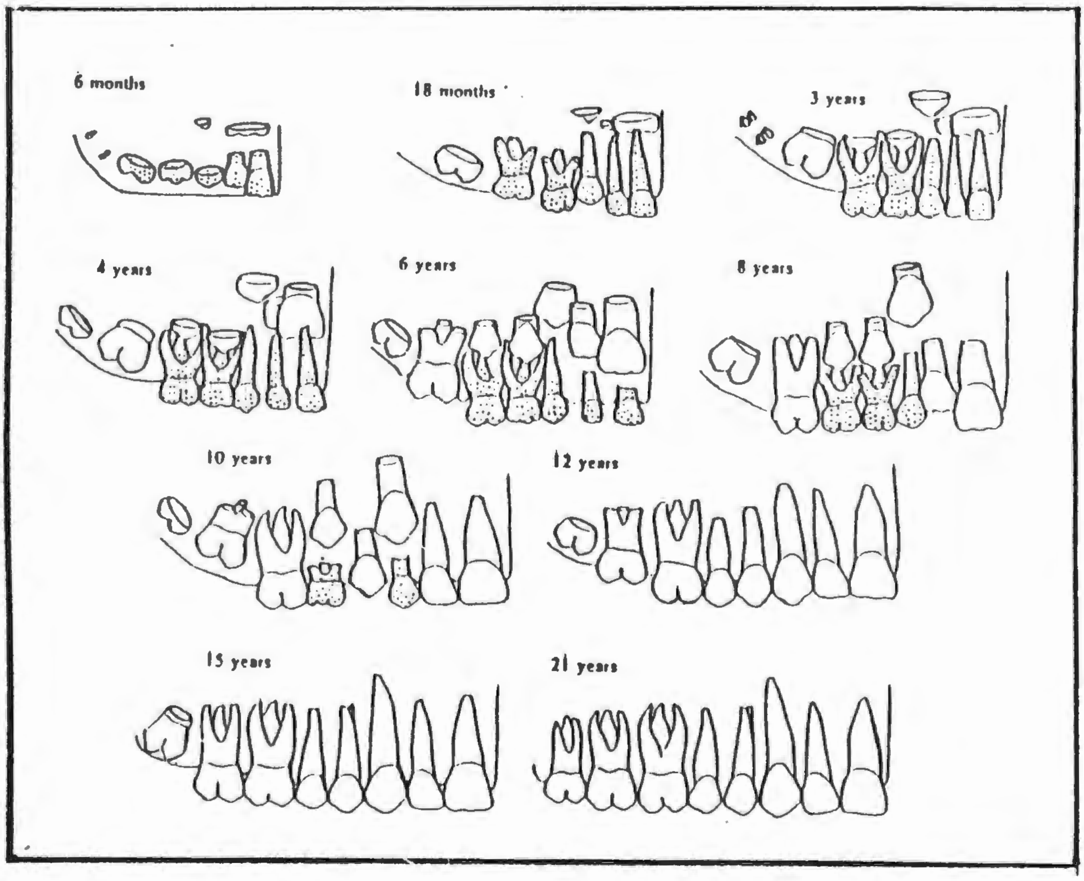


FIGURE 8: AVERAGE DEVELOPMENTAL STAGES OF THE HUMAN DENTITIONS FROM 6 MONTHS TO 21 YEARS OF AGE. STIPPLED TEETH REPRESENT THE DECIDUOUS DENTITION. (After Brothwell 1981)

(5) By the end of the third year the pars lateralis and the pars basalis of the os occipitale have united;

(6) In the fourth year of life the vertebral arches fuse with the vertebral body;

(7) Towards the end of the sixth year, the fissure between the squama and the pars lateralis of the occipital bones close, and simultaneously the pubic and the ischial part of the hip boners lateralis of the occipital bones close, and simultaneously the pubic and the ischial part of the hip bone fuse together at the ischio-pubic ramus (Ferembach et al. 1980: 530-531).

14 years to 25 years

In this age category epiphyseal union (Fig. 9) is the most important age indicator. Ossification of the pelvis, scapula, sternum, sacrum and the phalanges are also reliable indicators of developmental maturation. X-ray examination of epiphyseal lines, which are observable for approximately one to two years after ossification, may accurately determine age.

Adulthood

The method described by Nemeskeri et al. (1960), in which phases of relief of the facies symphaseos (symphysis pubis) and the spongiosa structure of the femur and humerus head are of some importance in this age category. Having stated this, however, it needs mention that significant differences do occur within these categories. The influence of births on the age changes of the pubic symphysis in women (see for example Stewart 1970, Ullrich 1975) as well as differences due to population and social differences in the aging process depending on heredity and environmental factors, such as nutrition, disease and workload (Hart et al. 1984, Binderman et al. 1984) must be considered.

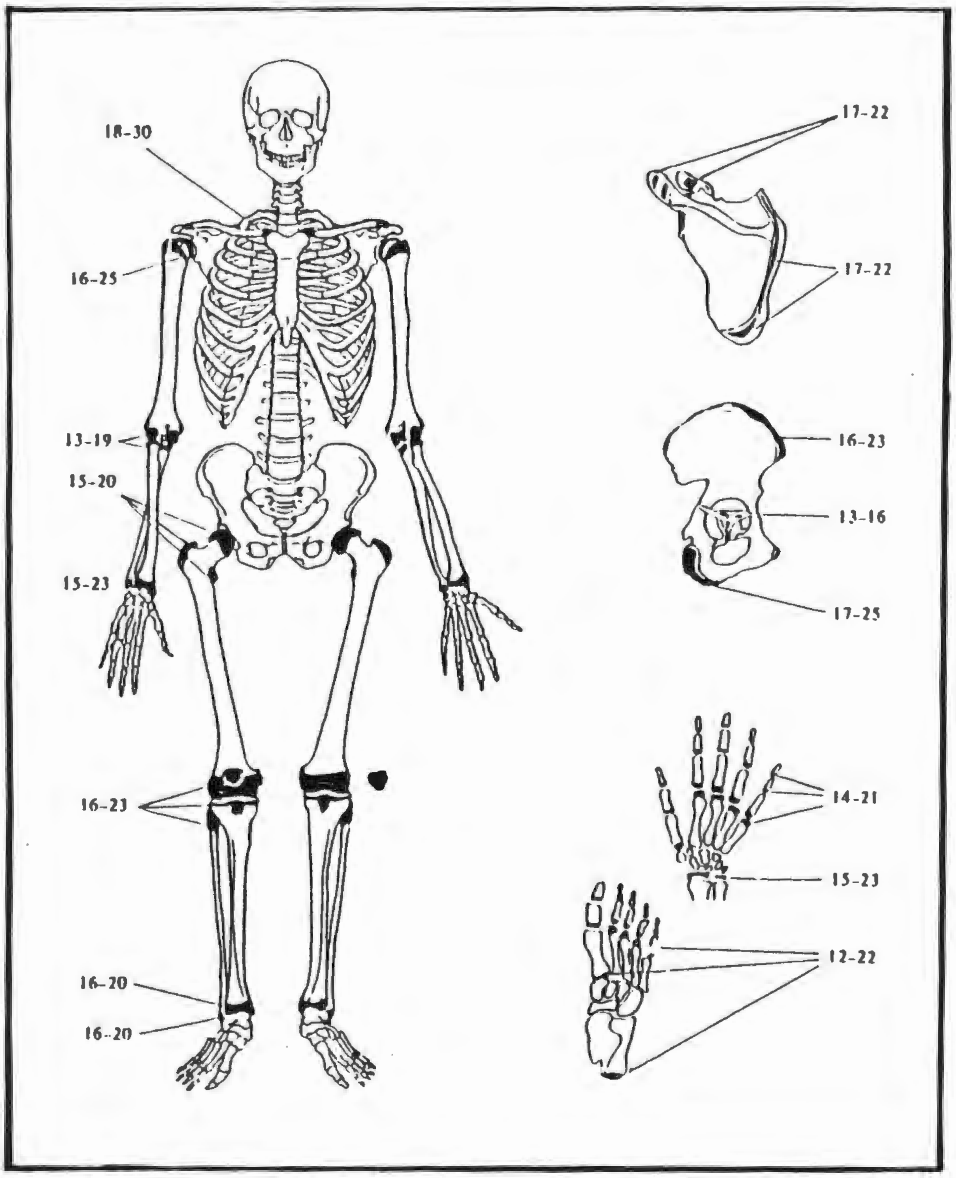


FIGURE 9 : TIMES OF EPIPHYSEAL UNION OF VARIOUS PARTS OF THE SKELETON. ALL NUMBERS REPRESENT YEARS, THE DIFFERENCE BETWEEN EACH PAIR SHOWING THE TIME SPAN WITHIN WHICH THE PARTICULAR EPIPHYSES UNITE. (After Brothwell 1981)

Following Ferembach's et al. (1980) recommendations "four major characteristics are used. Several phases of the aging process have been described. They are:-

(1) The relief of the facies symphaseos. Because of the changes of the faces by birth this characteristic should be employed only for men; if it is utilized on women the results obtained are better for younger women than for older women;

(2) The spongiosa structure of the femur head (Fig. 10) using X-ray techniques, and following Bergot and Bocquet's (1976) recommendations is useful;

(3) The spongiosa structure of the humerus head using X-rays;

(4) The obliteration of the endocranial skull sutures according to Broca's recommendations" (Ferembach et al. 1980:533). The method, however, is not without problems.

Necrason et al. (1966) has suggested that a large range of variability can be expected in the determination of an individual age-at-death, while Masset (1971) has calculated that the estimated figures are too low for the upper age categories, especially over 60 years.

Determination of sex/methodology

With regard to the sexing of skeletal material it is now generally recognized that the value of certain features varies with the group under investigation (see for example de Villiers 1968 work on South African populations) and that considerable overlap in the range of variation exists both at the intra and interpopulation level. Ideally therefore it is useful to be familiar with a large series of skeletons from a particular ethnic group. In this way one may note the degree of variation that exists within a given group.

The following guidelines for sex determination, using Ferembach et al's (1980) criterion are adopted in this study. To date there are no South

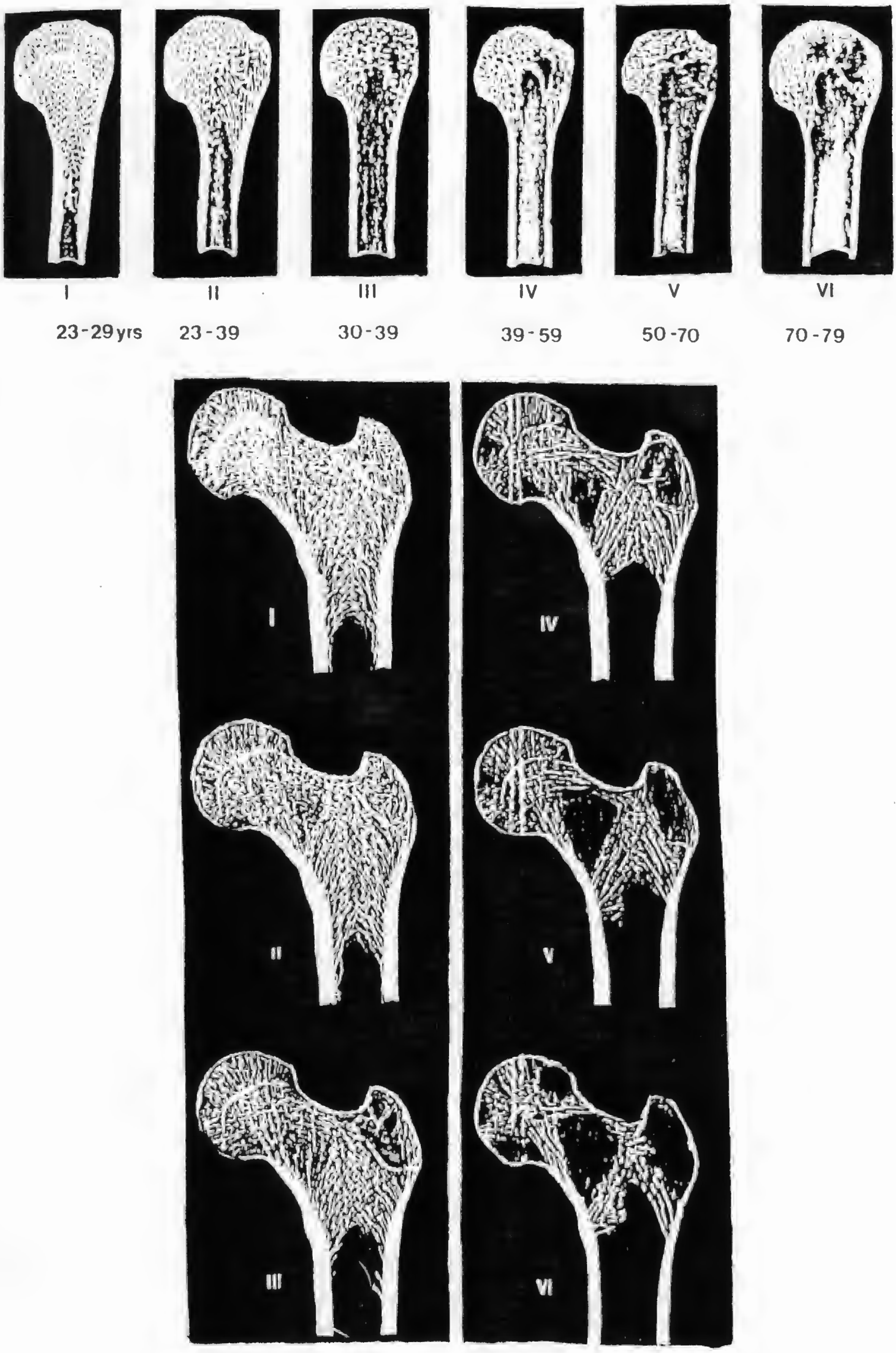


FIGURE 10 : VARIATIONS IN CORTICAL AND CANCELLOUS BONE IN RELATION TO AGE. (After Nemeskéri *et al.* 1960)

African criterion that one may make reference to without first submitting the skeletal material for metrical analysis.

Morphological traits: pelvis

Only those characteristics depending on visual examination (Fig. 11) are used here. Metrical analyses are not considered. In relation to the female pelvis, the male pelvis is higher, the pelvis major is less broad, the crisa iliaca is bent more conspicuously in an S-form; the fossa iliaca is higher and less broad; the foramen obturatum is oval (in the female triangular); the angulus pubis is narrow and A-formed (in the female broader and more rounded-off); the incisura ischiadiaca major is narrow, the os ischii lower; the corpus ossis ischii broader, the spina ischiadica is more levelled-off (more pointed in the female);the horizontal branch of the pubic bone (ramus superior ossis pubis) is, on the average, more prismatic in the male, in the female more roof-shaped. The male pelvis has no, or only a narrow and shallow, sulcus praeauricularis (it is deep and broad in the female) and simple arc compose (Ferembach et al. 1980: 518-519).

The cranium and mandible

In general the male skull may be distinguished from the female by the following characteristics:

(1) It is generally larger and heavier;

(2) Muscular ridges, such as temporal lines and nuchal crests, are larger;

(3) The supraorbital ridges are more prominent and the frontal sinuses larger;

(4) The external occipital protuberance and mastoid processes are more developed;

(5) The upper margin of the orbits is more rounded;

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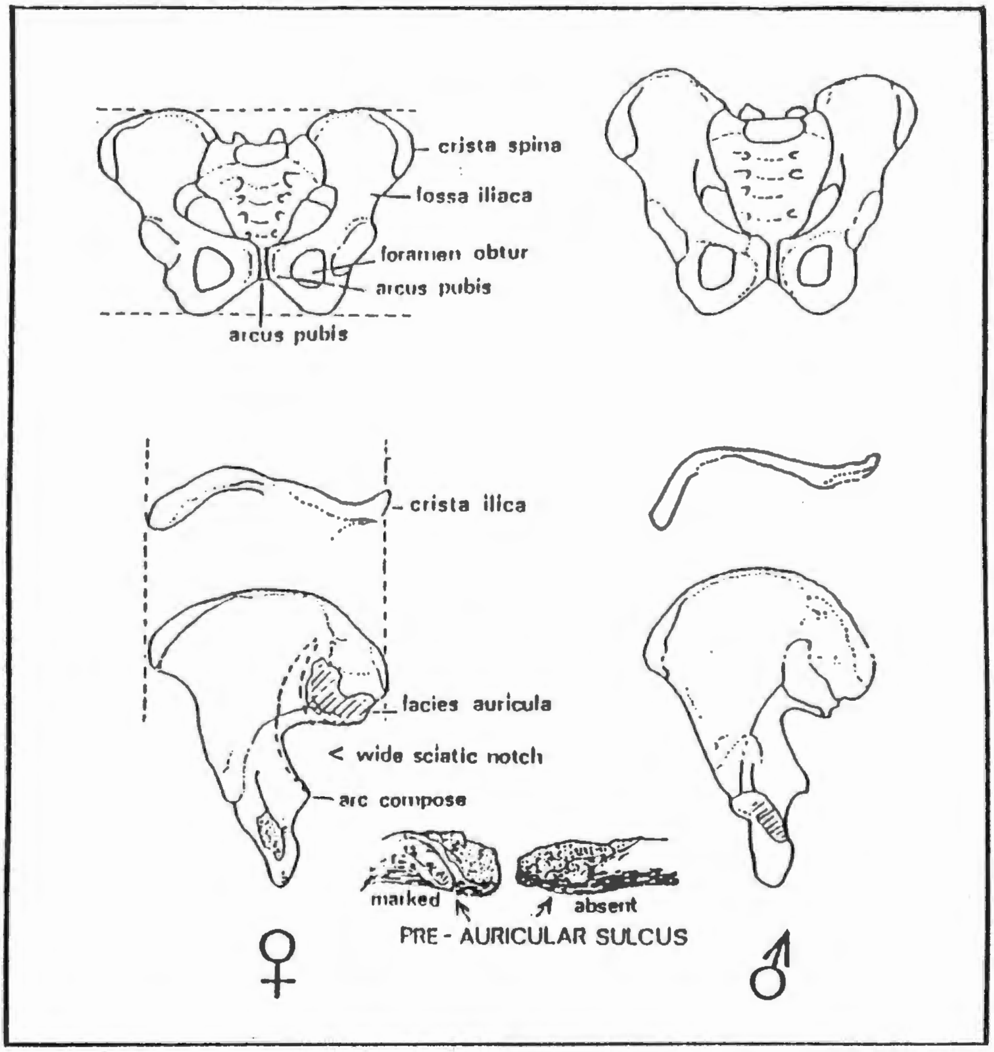


FIGURE 11: PRINCIPAL SEXING FEATURES OF THE PELVIS (After Fernbach et al 1980 and Brothwell 1981)

(6) The palate is larger;

(7) The ramus of the mandible is broader with heavier corpus mandibulae;

(8) The posterior root of the zygomatic process extends for some distance past the external audiotory meatus as a well-defined ridge;

(9) The mandible is more robust with more developed and flaring gonial regions;

(10) The ramus of the mandible is broader and longer in males with a better developed coronoid process;

Appendicular skeleton

The remaining bones of the appendicular skeleton, including the scapula, clavicle, sternum, vertebrae and sacrum are considered less significant in the determination of sex. The differences seem to be small and a great degree of overlapping between males and females in different population groups occurs. Accordingly, these body parts were only used in sex determinations along with pelvic and cranial observations.

Estimation of mortality profiles/methodology

To describe a population state one makes use of fertility data and of life tables derived from mortality and fertility data. These factors are interrelated with the biological state of the population by way of feedback loop systems. The behaviour of the entire set of feedback loops can be described by measuring the biological state index (Henneberg et al. 1978:191).

Thus using the data on frequency of death (dx) in a population, as well as the loss of reproductive potential due to individuals prematurely dying in specific age categories (sx), one may calculate the biological state index according to the formula: $Ibs = 1 - \sum_{x=00}^{x=\infty} dx\,sx$

Where dx is the frequency of death at a given age, sx refers to the probability of not having given the complete number of births characteristic for individuals surviving to senility at a given age (x) and w refers to the age at death of the oldest member of the group. The index is composed therefore of two groups of data; the frequency of deaths of immature individuals (for whom, at sx = 1, the sum of products dx x sx equals the sum of the values dx) and weighted by the probabilities sx 1 the mortality of adults.

Thus Ibs may be written in the form $Ibs = 1 - \left(do-14 + \sum_{x=14}^{x=\infty} dx\,sx\right)$

where do-14 the frequency of deaths of reproductively immature individuals, when assumed puberty age is 14. The sum $\sum_{x=14}^{x=\infty} dx\,sx$ computed for $\sum_{x=14}^{x=\infty} dx = 1$ and subtracted from unity is the potential gross reproduction rate (R pot) expressing the natality possibilities in a population with given mortality conditions (Henneberg & Piontek 1975:195). Additional methodological details of the construction of this coefficient, as well as its application in palaeobiological studies of human populations are discussed by Henneberg (1976).

D I E T A R Y

Life style inferred from dental caries and oral pathology

It is a paradox that teeth, which are so quickly destroyed in contemporary populations, have an extraordinary ability to resist the destructive influences of time. Teeth which are millions of years old have provided information about caries and dental health. The frequency and distribution of dental caries and dental wear in prehistoric and modern hunter-gatherer populations has gained much attention (Drennan 1929, Van Reenen 1966, Molnar 1971, Walker 1978, du Plessis 1986) and the information gleaned from these studies may be seen as a unique source of information concerning diet since it is the result of a direct interaction between the teeth of these individuals and the food they consumed. In turn dental analysis offers an independent check against the reconstruction of subsistence based economies based on the analysis of floral, faunal and artefact observation.

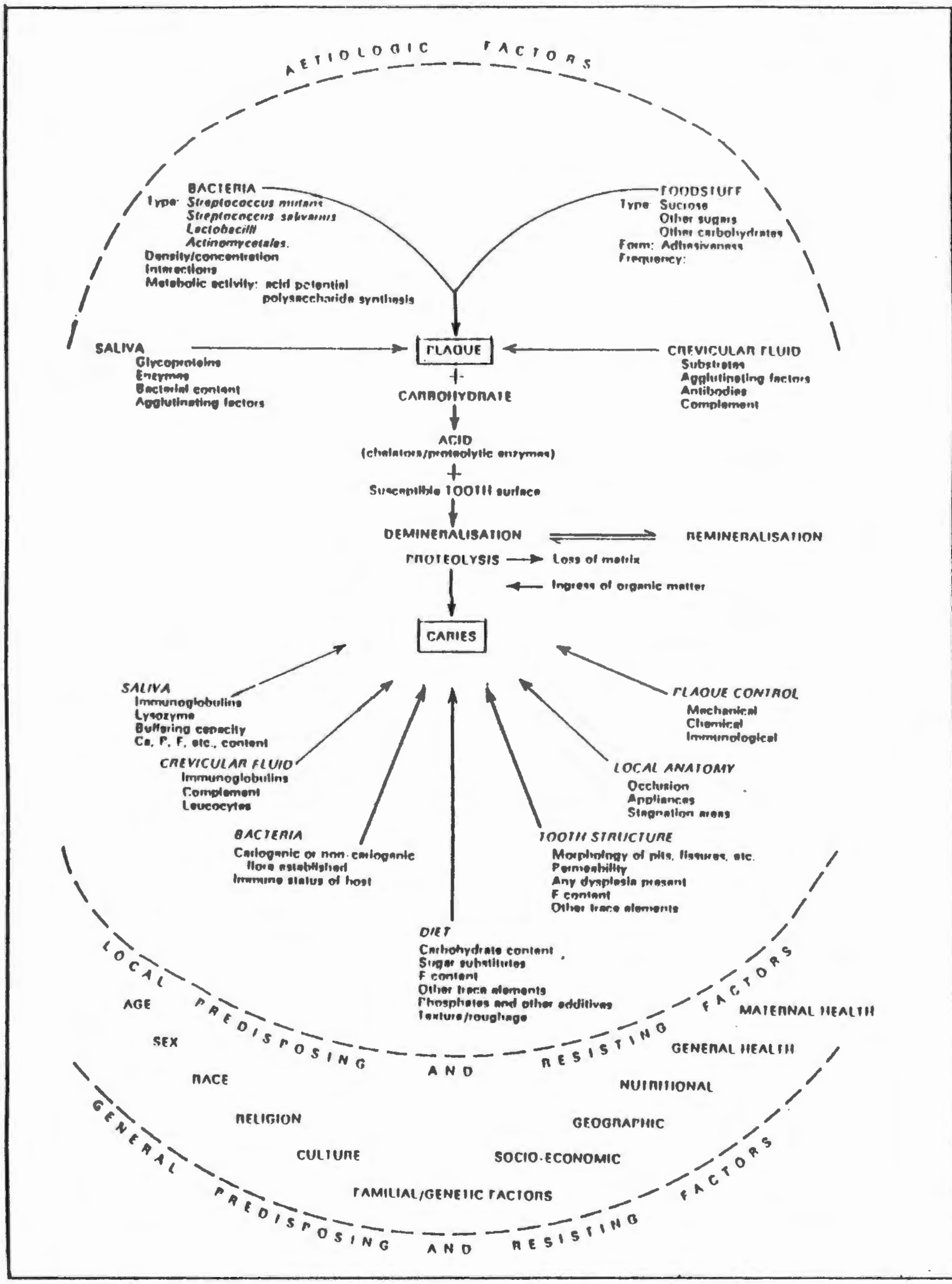
The pathology of dental caries

An oversimplified, but essentially accurate concept of the aetiology and pathogenesis of dental caries has existed for more than a century (Silverstone et al. 1981:6) and has come to be known as the chemico-parasitic or acidogenic theory. In essence, this states that bacteria present in the mouth interact with retained food particles to produce substances capable of dissolving enamel. The three essential components of the caries process are thus immediately appreciated, namely the presence of a susceptible tooth, the presence of micro-organisms and contributing dietary factors. Many other factors, both local and systemic, however influence the likelihood of caries developing and its speed of progression. Caries is a multifactorial disease. These factors and their interactions are presented schematically in Figure 12 to demonstrate the complexity of the issue.

Dental caries has been defined (Shafer et al. 1963:308) as a disease of the calcified tissues of the teeth, characterized by a demineralization of the inorganic portion, and a destruction of the organic substance of the tooth. It is considered the most prevalent chronic disease affecting humankind, since once it occurs, its manifestations persist throughout life. Occasionally persons who have had no carious lesions, throughout their lives, are designated caries-free. To date no satisfactory explanation of their immunity has been found. It is known however, that individuals who suffer from a rare autosomal recessive defect, called hereditary fructose intolerance (HFI) have remarkably few caries and indeed are often caries free (Linden and Nisell 1964).

Diet and dental caries

Diet has been associated, either in the prevention or promotion of dental caries for centuries and in the total field of research into aetiology diet has probably received more attention than any other subject. Diet is defined as the habitual nourishment of a person, group or population. Nutrition, on the other hand, is the act or process of being nourished, human nourishment in normal circumstances coming from the constituents of the diet. The distinction between diet and nutrition needs to be kept clear (Silverstons et al. 1981:32). The diet of any society is woven into the fabric of its culture, hence the archaeological interest in the evidence and distribution of caries. The food that people consume is influenced by geography, climate, tradition, religion and cost. In all societies, the process of eating



<u>FIGURE 12:</u> DIAGRAM SHOWING THE MULTIPLICITY OF FACTORS WHICH INFLUENCE THE INITIATION AND RATE OF PROGRESS OF DENTAL CARIES

is more than merely a way of taking in nourishment, it is a social act. The point is made by way of indicating that dietary practices, whether they are seen as good or bad, are deeply ingrained and are not easily changed while living conditions remain stable. Lasting dietary changes are usually accompanied by fundamental changes in a way of life.

The role of carbohydrates

Various studies into the prevalence of dental caries in prehistoric, historic and contemporary populations suggest that members of societies who have a relatively low caries index manifest a remarkable increase in caries after exposure to refined diets. The presence of processed or refined sugar has been thought to be responsible for this loss of caries immunity, and numerous studies confirm this belief. In contemporary populations sucrose consumption in preschool children and adolescents is generally accepted as being promotive of dental caries (Yudkin 1969, Bowen 1978, Du Plessis 1986).

While diet and the role of dental caries has received much attention, diet alone is not the only constituting factor in the carious process. Although no single theory has yet been put forward which will explain completely all aspects of the epidemiology, histopathology and chemistry of dental caries, there have evolved from various investigations three main theories, the acidogenic theory, the proteolytic theory and the proteolysis-chelation theory.

Dental caries: a theory

The acidogenic theory postulates that the initiation and progression of carious lesions is brought about primarily by the destruction of the tooth substance at the site of the lesion by microbially produced acids. Two distinct processes are involved. The primary action is removal of the soluble protein fraction of the organix matrix of the enamel and demineralisation of the tooth substance by acids, the organic residue being subsequently liquified by the enzymes of proteolytic bacteria (Farmer and Lawton 1966).

The proteolytic theory on the other hand infers that the initial carious attack occurs as a progressive alteration of the organic matrix of the enamel and a projection of micro-organisms into the tooth substance. The subsequent loss of mineral salts is accounted for by the effect of acids resulting from the protein breakdown and mechanical disintegration following the loss of organic matrix (Schatz et al. 1957).

Dissatisfied with the acidogenic and proteolytic theory, Schatz et al. (1957) advanced the proteolysis-chelation theory which seeks to explain the loss of mineral salts as a process of chelation. This theory is attractive in that it reconciles the conflict between whether it is destruction of matrix or mineral which is the key event, by proposing that both occur simultaneously and interdependently.

The estimation of dental health/methodology

Crowding of teeth, a condition which occurs when there is a reduction in the size of the mandible without a corresponding reduction in the size of teeth (Bass 1971) was noted where it occurred. Molar cusp, tooth eruption patterns, shovel-shaped teeth and artificial deformation of teeth was also recorded. Dental health, alveolar pathologies, and the incidence of caries were recorded plus any abnormalities of tooth form and size. Mandibles and maxilla with deciduous and permanent dentition were radiographed. Intra-oral radiographs were taken using a General Electric 1000 intra-oral x-ray unit. Panoramic radiographs were taken using a General Electric Panelipse x-ray machine. X-omatic regular intensifying screens and x-omat RP panoramic film was used. A 22 seconds exposure at 55-65 KV was used throughout.

The recording of caries in this project was to document all macroscopically observable caries. A carious lesion was recognized as a macroscopic necrotic defect of a tooth surface. Each tooth was scored for the absence or presence of a carious lesion. When present each tooth was scored for according to the tooth surface involved, and caries which exposed the pulp and those which exposed the pulp with only the root remaining intact. When the lesion involved more than one surface no attempt was made to identify the surface first attacked. The incidence of caries was counted separately for each tooth and tooth type to give an indication of the distribution of caries within the sample.

L I F E S T Y L E

Skeletal morphology and activity induced pathology

Descriptions of arthritic change in anthropological skeletal series are well documented and have been described as a function of seed grinding activities (Angel 1966), heavy labour (Angel 1971), temporo-mandibular dysfunction (Pfeiffer 1977) and as a measure of status based on levels of energy expenditure (Tainter 1980). Routine observation of osteo-arthritis within populations have also been measured at the general level of analysis (Brothwell 1961). The important feature of this pathology is that it allows one the opportunity to observe skeletal response to both general (traumatic) and habitual behaviour. Habitual behaviour, or activity related patterns, are those activities which place an abnormal amount of stress for an abnormally long period of time on the skeleton. This in turn has implications with regard to environmental influences and cultural uniqueness.

Osteoarthritis is defined (Merbs 1983:16) as a common, progressive, chronic, non-inflammatory disease of the diarthrodial joints which cause increasing disability with advancing age. Since the disease is intimately connected with the aging process, so closely in fact that the "normal" is frequently indistinguishable from the "pathological", that the two must be considered as a whole. A number of criteria are important in an evaluation of this condition. These are age of onset, degree of involvement, and the ability to distinguish between arthritic changes caused by mechanical stress placed on a joint by habitual activity, and those joint changes due to inflammation or developmental error. It is widely recognized that the term "osteoarthritis" is a misnomer insofar as it implies an inflammatory process. A more accurate designation, "degenerative joint disease", is not used here, since the former designation is still widely accepted. Tarnopolsky (1950) has compiled 54 synonyms for osteoarthritis, including, osteoarthrosis, degenerative arthritis, hypertrophic arthritis, arthritis deformans, deforming arthropathy and partial chronic articular rheumatism.

Arthritis of the vertebral bodies is discussed under a separate heading, osteophytosis. While the articulations between the vertebral bodies are arthrodial (a joint permitting gliding movement) rather than diarthrodial (a synovial joint), it has been argued (Merbs 1983:16) that their degeneration does not meet the requirements of what can be called "osteoarthritis". However, since the process involved is similar to that involved in osteoarthritis the justification for discussing arthritis of the vertebral bodies under the separate heading osteophytosis is based more on morphology than any basic difference in pathology.

Etiology

There are three macroscopic changes which take place in osteoarthritis. The first consists of a cystic area of rarefaction which develops immediately beneath the joint surface. Sokoloff (1966) has described the etiology of this process and suggests that within these areas the marrow undergoes mucoid or fibrous degeneration, trabeculae disappear and the entire area is enriched by a rim of reactive new bone and compact fibrous tissue. Such cysts usually open directly at the bony surface of the joint giving the bone a porous appearance. The second change is connected with new bone formation in the form of exophytic growth along the margins of the articular cartilage and in fossae located within joint capsules. These changes are often referred to as lipping. The correct name however is marginal osteophytosis. Osteophytes generally follow one or two growth patterns. They either protrude into the joint space, or they develop within capsular and ligamentous attachments to the joint margins. Either way, the direction of the osteophyte is governed by lines of mechanical force exerted on the area of growth and generally correspond to the contour of the joint surface from which it protrudes. Morphologically the osteophyte consists of true bone that merges imperceptively with the other cortical and cancellous tissue of the subchondral bone. It is frequently capped by a layer of hylaine and fibro-cartilage which becomes continuous with the adjacent synovial lining.

The third osteoarthritic sign is commonly referred to as eburnation, a name derived from the ivory-like appearance of the affected bone. This occurs as a portion of the bony articular surface is denuded of cartilage. The bone is rubbed smooth and assumes a glistening, polished appearance. With the passage of time, the smooth surface becomes roughened, worn and excoriated. The area of bone under the greatest mechanical stress begins to groove and remodeling of the bone surface occurs. This results in gross deformity. Such deformities are most commonly seen on the superior articular facets of the second cervical vertebra where they are curvilinear, reflecting the rotational movement at the joint. The distal end of the femur also demonstrate such deformities, reflecting the flexion-extension movement which takes place at the knee (Merbs 1983:18).

Osteophytosis

The vertebral disk consists of the annulus fibrous, the nucleus pulposus and two hyaline cartilage plates. The fibers of the annulus are attached to the ring epiphyses of adjacent vertebral bodies and to the margins of the hyaline plates. The outermost fibers of the annulus blend with the longitudinal ligaments of the vertebral column. The nucleus pulposus is semi-gelatinous and highly plastic and it is held in place by the annulus and the cartilage covered vertebral bodies. Intervertebral disks serve several functions (Ross and Wilson 1972), the most important of which are shock absorption and movement. The spinal column, commencing with the thoracic curve of embryonic origin, undergoes secondary flexion with the formation of cervical and lumbar curves as a child begins to hold its head upright and to stand erect.

According to Stewart (1966) the basic pattern of osteophytosis seen in humans, a concentration of degenerative changes affecting the inter-vertebral disk in each of the three regions of the movable column, cervical, thoracic and lumbar, appears to be related to the curvature of the spine. With age, disks of the vertebral column tend to become fibrocartilaginous and the structural differentiation between the annulus (which provides stability by binding the vertebral bodies together) and the nucleus (which equalizes pressure by serving as an axis of movement between adjacent vertebrae) frequently disappears. In addition to this the water content of the nucleus decreases, and this along with the above factors, results in permanent thinning of the disk.

Anthropological application

Anthropological studies of osteophytosis have centered around anatomical variation within the individual, pattern variation within and between populations, and as an indicator of age. However, while the first two variables provide useful information as an indicator of a population's health, the latter criterion is less useful. According to McKern and Stewart (1957), Stewart (1958) and Howells (1965) osteophytosis as a morphological feature on which to assess age has limited use, since no more than 51% of the age variance appears to be predictable. Osteophyte development in relation to sex and population group has produced some interesting observations. Gunness-Hey's (1982) study among the Koniag Eskimo, suggest that males are more prone to osteophytosis than females (92% to 63%). Both sexes show however the greatest involvement in the thoracic region. Nathen (1975) studies of European and African-Americans demonstrates that the distribution of osteophytes are more numerous on the anterior aspect rather than the posterior aspect of the disk. Cervical disks are more frequently involved than any other, and the small difference between race and sex, while noted, were not statistically significant. Stewart's (1947, 1966) study among Alaskan Eskimos, Pueblo Indians and European Americans suggest that the lumbar region of the spine showed the greatest involvement of the inferior joint margins in all three groups.

The importance of activity induced pathology in prehistoric groups

Much of the pathology seen in an individual is the product of his/her genotype, embryonic development, chance exposure to pathogens, or activity-induced pathology. The importance of activity-induced pathology rests in its non-randomness within a sample, which reflects the non-random nature of the activity itself. While it is true that the actions performed and the postures assumed by any one individual during a single day will differ from those of any other day, strong similarities do exists. The same kinds of actions will be performed over and over again, particularly if they are culturally defined as 'correct', or necessary to survival, and the same will be true of posture. Interest is thus focused on habitual behaviour.

An evaluation of generalized osteoarthritis and osteophytosis/methodology

Osteoarthritic degeneration of a joint is here defined by the presence of three signs, lipping (osteophyte development), porosity (erosion, development of pseudocysts) and eburnation (polishing). The presence of any of these three signs was taken to mean that the joint had been affected by osteoarthritis (degenerative joint disease).

For ease of general comparison, joints were divided into individual articular facets. Each facet was given a score on the basis of, observation possible, pathology present or absent, intensity of pathology: trace, moderate and severe. Each of the three signs was scored individually. The scoring procedure for osteophytosis (degenerative disk disease) was the same as that for osteoarthritis. The only difference here is that the score was based upon a single sign 'lipping'.

While recording the presence or absence of the above pathologies (both macroscopically and radiographically) any additional peculiarities of the articular surface of developmental, traumatic, or pathological origin which may have affected the normal functioning of a joint was scored. Fractures and other pathologies affecting parts of a bone, other than an articular surface were also recorded. These observations provide a catalogue of skeletal disorders. However, they do not form an integral part of this study and are only recorded to ensure a complete record for each individual.

CHAPTER SIX

THE MICROSTRUCTURAL ANALYSIS

Human bone as a marker of age and metabolic stress

Microstructural analysis of bone has yielded many interesting observations, and in view of these data a strategy of research particularly useful for archaeological manipulation has arisen. Although there would appear to be no common terminology for this type of study, skeletal biology and palaeohistology are used here to refer to a method which analyses the growth and remodeling of bone. The value of this method lies in its relative success in extracting valuable metabolic information about the individual.

Bone Structure as metabolic and systemic indicators

Microscopic analysis can be used to identify growth arrest and repair of bone. Indeed, evidence of a number of physiological and developmental adjustments occurring in contemporary human populations make it possible to discern the outline of a graded response to these forms of stress.

Pathological conditions generally encountered in skeletal material reflect disturbances of growth and repair in bone and may manifest itself occasionally as arthritis, but more commonly as lines of arrested growth (Harris Lines), porotic hyperostosis, periosteal reactions, reduction of stature, and in teeth, enamel hypoplasia and enamel hypocalcification.

In the following pages an attempt will be made to outline the theory, method and epidemiological significance of each of these conditions.

EPISODIC STRESS

Lines of arrested growth as markers of episodic stress

Lines of arrested growth have been used by anthropologists to demonstrate episodic stress. The technique has been widely applied (Cohen and Armelagos (1984) and show a broad correlation between nutritional stress and systemic growth disruptions. Lines of arrested growth are often called Harris Lines in recognition of the work produced by Harris (1926,1931,1933).

In 1927 Eliot et al. conducted histological studies on long bones displaying lines of arrested growth. The authors concluded that transverse lattice formation might be regarded as temporary halting of cartilage growth but with continuation of osteoblastic activity. Harris (1931) supported this view and presented a historical review of the literature, along with case histories and illustrations of various clinical conditions which suggested that transverse strata first appear as calcification in proliferation zones of cartilage.

In 1933, Todd and his associates described radiographic changes in the growing ends of long bones which they attributed to disturbances in growth caused by mild gastrointestinal upset due to food or respiratory allergy. In this respect Todd distinguished between 'scorings' which consisted of transverse lines of increased density as opposed to 'scars' which he considered to be produced by infectious disease and injuries (Cohen and Friedmar 1937:1).

Etiology and mechanism of formation of lines of arrested growth

Lines are commonly associated with episodes of disease in childhood, and possibly adolescence, due to increased mineralization, or increased mineral density of bone (expressed as grams per cubic centimeter of bone). Structurally, lines of arrested growth, or transverse lines since they often appear on the transverse diameters of certain long bones, tibia and fibula, are strata of denser and thicker bony trabeculae that form the metaphyses of growing long bones parallel to the epiphyseal disc. As the long bone grows and the length of the bone increases they later appear on the diaphyses but the distance between the lines remain constant so that chronologies for the ages of line formation can be determined (Garn et al. 1968:58). The mechanics of how these lines form are well known and have been described in the literature (Harris 1931,1933, Follis and Park 1952, Pratt and McCane 1964, Woodall 1968).

Much of the remodeling that occurs when such lines are laid down takes place at the epiphyseal disc, and although the process is initiated by the onset of differential chondroblastic and osteoblastic activity, lines actually appear during a recovery period after growth resumes. However, this explanation is a limited one, since it has been shown (Schwager 1968) a new line may appear even though no disease was reported in the previous six months.

The precise etiology of transverse lines is varied and controversial, however, their formation has often been associated with episodes of stress, malnutrition (including protein-calorie malnutrition), anemia and hypervitaminosis D (Wolbach 1947, Platt and Stewart 1962, Pratt and McCance 1964, Blumberg and Kerley 1966, Garn et al.1968, Marshall 1968, Blanco et al.1974, McHenry 1968). Psychogenic stress has also been cited as an explanation of transverse lines (Sontag and Comstock 1938), as has food allergy in children (Cohen et al. 1937).

Of interest is the findings of Dreizen et al. (1964) who found no difference in the incidence of line formation between well-nourished and malnourished children, although they did find that lines in long bones of children with nutritive failure persisted longer than in adequately nourished children. A review of the literature dealing with the correlation of illness with transverse lines has also produced controversial results. Gindhart (1969) documented a correlation between line formation and numerous diseases, including chicken pox, whooping cough, measles, influenza and even smallpox inoculations. She concluded that disease episodes were followed by line formation in about 25% of cases. Marshall (1968) also found a relationship between disease episodes and line formation but reported that the incidence of line formation and illness were not correlated. In conclusion then, these studies seem to indicate that transverse lines may be considered as general indicators of stress associated with some disruption in the normal metabolism. However, they also emphasize the controversial nature of the data base and suggest that line formation and specificity of cause must remain inferential. Despite the fact that lines may form as a result of factors other than disease or nutritional stress has led many researchers to use line formation frequencies to investigate the health status of various palaeopopulations (Wells 1961, 1967, Buikstra and Kearley 1966, McHenry 1968, Cassidy 1972, Allison 1974, Buikstra and Cook 1981). The same general approach is adopted here.

Age at which lines form

Lines of arrested growth have been used as natural bone markers to measure growth and changes in growth at the surfaces of every bone. Using a pair of lines, one proximal and one distal, on a typical long bone, it is theoretically possible to fractionate growth and growth rates and to compare growth at the articulating surfaces of adjacent bones. Thus using multiple lines, or serially appearing lines, long-term analyses of bone growth and changes in bone growth are possible. The proximal contribution to appendicular growth is determined by subtracting the metaphysial growth and the epiphysial growth at the distal end from the overall increase in the length of bone (Garn et al.1968:79). Both in the clinical setting, and of importance to the archaeologist, the presence, or absence of these lines help one ascertain to what extent childhood illnesses constitute permanent impairments and possibly lead to disabilities of aging, accelerated aging and diminution in the length of life.

Stability of lines

According to Garn et al. (1968) and his associates, lines of arrested growth come and go. The results of their longitudinal study at the Fels Research Institute demonstrate that, typically, new lines appear on the distal tibia in early childhood but not in preadolescent and adolescent groups. Such lines that persist into adulthood, in some instances well into the fifth decade of life, are those lines laid down in early childhood. New lines, which appear after the first year, appear in peaks in the second and third year and diminish after the fifth year. An interesting observation is that new lines occur more commonly in boys than in girls. Garn et al. (1968) suggests that this observation may be consistent "with the common belief that boys are more vulnerable to environmental insults during the growing period, or it simply may reflect the somewhat greater rate of subperiosteal apposition and linear growth of bone in boys" (Garn et al. 1968:66).

In addition to these finding it appears that whilst new lines are systematically more common in boys, they do not persist as long in boys as in girls. Boys therefore show more new lines over the same period of time, but the lines do not persist as long, possibly because of enhanced remodeling of bone. Girls, on the other hand show fewer lines, but the lines persist longer, which in part may explain the greater prevalence of lines on the distal tibia in women.

Until Garn and his associates published the results of their Fels studies, a long-standing and apparently unresolved problem was the dimensional stability of lines. Do lines hold their position over time, do they move, or is the remodeling process such that the distance would appear to drift? Garn's results, from a sample of 54 children, aged from 1 year to 17 years, was to confirm that lines stayed 'put' on bones. The survey was further extended to include 120 adult women and 86 males. In keeping with the hypothesis that lines make there first appearance in early childhood, it was observed that only a few lines, less than 25 mm from the inferior articular surface, were present. Twentyfive percent were 65 mm or more from the articular surface in women, and over 60% were 65 mm or more in men. On the basis of these findings, Garn was to conclude that most of the lines observed refer to events that transpired long before adolescence, and in the case of lines 110 mm or more above the articular surface, to events in infancy or even earlier (Garn et al. 1968:76).

Differential remodeling

Lines of arrested growth disappear as a result of both a decrease in mineral density (grams per cubic centimeter) and a reduction in width. Tibial lines, however, disappear in an entirely different manner.

Single, or multiple transverse lines of increased density on the distal end of the tibia apparently move away from the later aspect and disappear at the medial aspect. This process is indicative of appositional growth occurring on the lateral aspect of the distal tibia, and the resorptive phase on the medial aspect, which implies differential remodeling and cortical drift (Garn et al.1986:81).

This phenomenon is of considerable methodological importance since in the final analysis the meaning of differential resorption and apposition on the distal end of the tibia, is determined by the morphological nature of the structures which appear as lines on radiographs. Lines of arrested growth in bones may be interpreted as discs, sheets, rings, washers, or a combination of lines. Such may be the result of: (a) uniform extension of compact bone at the endosteal surface into the marrow cavity, (b) localized hypermineralized cortex, or (c) discontinuous projections of compact bone into the marrow cavity. In order to test which hypothesis is correct, and indeed verify which lines encountered on a radiograph constitute lines of arrested growth required some experimental radiographic work by Garn et al. (1986), the results of which were to demonstrate that hypothesis C is, in fact, correct. Lines of increased density caused by bands or spicules of bone within the marrow cavity are visualized when the bands or spicules are at right angles to the central ray, but are not visualized, or visualized only as a single spot when they are parallel to the central ray. Lines of increased density, on the other hand, disappear when the bone is rotated axially. This implies that they are are formed by lattice networks, rings or discs.

Estimation of lines of arrested growth/methodology

Given the physiological parameters and the histological processes of the development of lines of arrested growth as described in this thesis one may assume that the skeletal remains recovered from Oakhurst may be thought of as reflecting the overall health status of these prehistoric people at the time of their death. Accordingly radiographic analyses of the Oakhurst sample should reveal stress markers if present.

Technique

Dry bones were placed in the anteroposterior position and roentgenograms of the bones taken. A Gafmed Fast Screen was used throughout, as was Medmark standard radiographic film. The field focus distance was held constant at 120 cms and a fine focal spot of 0,6mm used (G.Bowie pers. comm.). Radiographs were viewed using a standard light screen. Radiographs were viewed twice, by an independent clinician in each instance. Using lines, either singular or multiple, and following Garn's (1968) method the distance between the articulating end of each bone to the line, or lines of arrested growth were noted and recorded in millimeters. The length, frequency, age at occurrence and the morphological character of these lines was then compared to Garn's et al. (1968) comparative American data as South African data are not available (R. Seggie, B. Heselson and N. Beyers pers. comm.).

The etiology of enamel hypoplasiae and there use as markers of systemic stress

Hypoplastic deficiencies of enamel thickness may be used by the archaeologist as a method to document systemic growth disruptions and stress insults on the human body. Enamel defects are divided into a number of separate entities. Hereditary enamel hypoplasia, and hereditary idiopathic enamel hypomineralization defects (Winter and Brooks 1975). During the first phase of enamel formation there is, in successive layers, the deposition of the enamel matrix (organic material and water 65% and mineral salts 35%) which starts at the amelodentinal junction and progresses to the surface. This appositional type of growth results in the formation of concentric layers, or rings. The hard tissues of the teeth thus form by the deposition of a new layer on the old, the enamel from within outward and the dentine from without inward. Since the deposition of these layers is regular, their chronological sequence can be determined.

During the second phase of enamel formation, the organic material and water are mostly removed and replaced by mineral salts which eventually constitute about 96% of the matrix. This maturation starts at the tip of the cusp and progresses towards the cervix in cross relation to the incremental lines. If there is a disturbance of the first phase in which the matrix is being formed, the result is enamel hypoplasia in which the enamel is deficient in quantity and irregular, though the substance is hard. If the disturbance is during the second phase of maturation of the enamel, the quality is affected in that it is deficently mineralized and soft, this is termed enamel hypomineralization (Stones 1962:164).

The layers of enamel and dentine are extremely sensitive to variations in metabolic processes during their formation and calcification. Any alteration in the internal environment of the body is therefore recorded in the incremental layers developing at that time. Such hypoplasias cannot be removed by systemic factors (Massler et al. 1941:35). This is because the formative cells have receded and lost their connection with the matrix itself. In the dentine the encapsulated dentinal fibrils, protoplasmic processes from the odontoblasts in the pulp, give "vitality" to that tissue but the matrix is nonvital. Hence systemic variations remain permanent and unaltered and therefore constitute a permanent record of metabolic fluctuations.

Only external factors such as caries, erosions and abrasions can erase such records from the teeth (Massler et al.1941:35). The etiology of hereditary enamel hypoplasia and idiopathic enamel hypomineralization is unknown and at best there is usually a marked hereditary factor involved where members of a family are similarly affected (see Cameron and Bradford 1957, Pinborg 1970,).

Hypoplasia due to trophic disturbances

Unlike hereditary defects, which begin at birth, and affect the entire tooth crown, hypoplasias which result as some disturbance of general metabolism will result in a defect occurring on only one or adjacent teeth. Such defects on these teeth will reflect the relative completeness of crown development at the time of the stress (Sarnat and Schour 1941, Lindemann 1958, Farmer and Lawton 1966, Pinborg 1970).

Pathogenesis

The specific etiology of environmentally related (systemic, chronologic, linear) enamel hypoplasia is not clearly understood. However, Massler et al. (1941) have hypothesized that if a systemic disturbance is sufficiently severe, not only the calcification of the matrix but the cells active at the time in the deposition of the matrix will be affected. The result may be a lack of matrix formation, and may be reflected in the presence of interglobular dentine in the dentine (Massler et al. 1941:42).

Gottlieb (1941) and Kreshover (1944) conclude that a mineralized material like enamel is laid down in previously formed organic matrix so that when calcium is deposited immediately, the normal structure of enamel is achieved. If the deposition of calcium is delayed, the matrix may collapse with a resultant defective formation of the enamel at this site. There is enough evidence to suggest that this condition originates from the destructive changes in the ameloblasts which are to be found in all stages of degeneration. Early changes include the cubical shape of the ameloblast and the abnormal formation of an enamel-like substance within, or adjacent to the ameloblasts, the nuclei of which undergo karyolysis and pyknosis. Cystic changes occur in the ameloblast and streaks of irregular enamel-like material project downwards from the vacuolated area, and the final stage is the complete destruction of the ameloblast. When this occurs enamel formation ceases, so that in this area there are notch like defects (Farmer and Lawton 1966:178).

Histopathology

Thin sections prepared from hypoplastic teeth show that the enamel is seen to be deficient in the areas that are being mineralized during the disturbance. These defects follow the incremental lines. The extent of the affected area of enamel depends on the duration of the disturbing factor. As an example, in infectious diseases, there is only a horizontal narrow zone, but in prolonged nutritional deficiencies a .pa wide area is affected. The amelodentinal junction, instead of being a well defined line is, sometimes, but not always, irregular. Enamel tufts, which are probably a sign of defective mineralization, may be more numerous than usual. The enamel spindles, which are the prolongation of the dentinal tubules into the enamel, are well marked (Stones 1962:179-180).

Clinical features of hypoplasia

Hypoplastic defects may manifest themselves as either pits or horizontal grooves on the enamel. During short duration illnesses, pits, or grooves, form a narrow horizontal line across the teeth, the remaining portion appearing normal. In prolonged deficiency diseases a large area of the affected tooth, or teeth, may be involved by these irregularities.

Hypoplasias have been experimentally induced in rats exposed to a number of insults, including fluorine administration (Schour and Ham 1934), strontium administration (Irving and Weinmann 1948), rickets (Irving 1943), fever (Kreshover and Clough 1953), under and overnutrition (Becks and Furata 1941) and hormonal disruptions (Schour et al. 1937, Baumel et al. 1954).

A similar response has been noted in human populations. Lindemann (1958) found a high correlation between gastro-intestinal disturbances, which may be due to incorrect feeding, bad hygienic conditions or infection of the gastro-intestinal tract. The clinical manifestations of such disturbances are colic, constipation, diarrhoea and vomiting.

Scurvy, both infantile and adult, is due to a deficiency of vitamin C in the diet. Teeth which are hypoplastic due to this condition show irregular pits scattered over the tooth surface. Stones(1962) considers that a period of some six months must pass before symptoms of this deficiency manifest itself. Rickets, a deficiency of vitamin D may also produce hypoplastic insults. Taylor and Day (1939) observed that in certain districts of the Punjab that in cases where severe rickets was present, that teeth were extremely well formed with little obvious hypoplasia and only slight caries. In South Africa, however, Staz (1943) reported that in a group of Indian children 52% had varying degrees of hypoplastic defects which he attributed to deficiencies of calcium and vitamin D. Other factors that may affect dental formation include hormonal disturbances, hypocalcaemia. Infant tetany, usually the result of hypoparathyroidism, occurs between the ages of three months and two years. Exanthema, or infective fever with skin eruptions, can affect the mineralizing enamel. The usual fevers which involve the teeth are measles, scarlet fever and diptheria (Stones 1962:176). Any tooth may be affected, depending on the age at which the illness occurs, however Sarnat and Schour (1941) have observed it most frequently in the permanent incisors, canines, and first molars. With regard to age at occurrence, they report that the defect has not developed in the prenatal period, but that in two-thirds of the cases it occurs during the first twelve months after birth, and in one-third it happens between thirteen and thirty-four months. In two percent of cases the defects occur later, between thirty-five and eighty months, and then the second molars are also involved. Marshall's (1936) studies however, led him to conclude that teeth are not always affected by the exanthema (skin eruption). He considers this to be related to the severity of disease, and the resistance of the patient. Mineralization of teeth is an intermittent process with alternate periods of rest so that if there is a short acute bout of fever during the period of rest the tooth will not be affected.

A recent review of the epidemiology of dental defects by Cutress and Suckling (1982) confirms the nonspecific nature of defective enamel, and indeed, somewhat overwhelmingly suggests nearly one hundred factors associated with hypoplastic teeth, Of interest however, is a recent reanalysis (Goodman and Armelagos 1985) of the "time development" hypothesis. It was suggested that the frequency of enamel defects is dependent on which tooth crowns are developing at the time the insults are most active.

The biological process which is assumed to underlie this hypothesis is one of consistent magnitude and response to physiological disruption. These factors form the basis for archaeological interpretation as general stress indicators.

Estimation of enamel hypoplasias/methodology

Following Goodman's et al. (1980, 1984) criterion, hypoplasias are defined as circumferential lines, bands or pittings of decreased enamel thickness. Where present, hypoplasias were recorded by tooth type and morphological type. Teeth and enamel crowns were thoroughly cleaned in order to remove calculus and foreign substances. Macroscopic observation of hypoplasias was conducted using a zoom binocular microscope. This method of viewing minimized the likelihood of misclassifying and confusing hypoplasias with other features of the dental enamel.

In order to approximate the developmental age of an individual which displayed such defects the location of lines from the cemento-enamel junction was measured using a thin tipped caliper to 0.1mm. The location measurement was then converted to a time at development based on the chronology of dental calcification units prepared by Schour and Massler (1981) (Fig. 7). This method divides the deciduous and permanent dentition into zones corresponding to developmental periods during which the tooth crown is developing.

G E N E R A L I S E D   S T R E S S

General stress, for the purpose of this thesis, is defined as the reaction of the human body to forces of a deleterious nature, infections and various abnormal states that tend to disturb the body's normal physiologic equilibrium. Episodic stress, as evinced by Harris Lines and enamel hypoplasia, is more specifically related to interruptions in the growth process.

The etiology of porotic hyperostosis as a marker of systemic stress

Earlier medical and anthropological reports on porotic hyperostosis were published under a variety of descriptive terms. Among the first descriptions, and proposed etiologies of the condition, was that given by Welcker (1888) quoted in Mensforth et al. (1978) who concluded that certain Mediterranean groups were more susceptible to this disease than others. He referred to the condition as cibra orbitalia.

The condition was later described by Hrdlicka (1913) and Williams (1929) who referred to the condition as symmetrical osteoporosis, by Muller (1935) as osteoporosis of the cranium, by Henschen (1961) as cribra cranii, and by Putschar (1966) as spongy hyperostosis. Nathan and Hass (1966) have observed the presence of cribra orbitalia in apes and monkeys. They conclude however, that the more advanced degrees of development observed in human skulls are not found.

Clinical appearance

Porotic hyperostosis is found localized in the anterior parts of the orbital roof, and the pericranial surfaces of the frontal, parietal and occipital bones. The temporal, sphenoid and facial bones are less frequently involved (Mensforth et al. 1978:4). The lesion is characterized by a coral, cribiform, or sieve-like porosity with marginal hypervascularity.

There are two hypotheses which attempt to explain the etiology of porotic hyperostosis. The first hypothesis proposes that the condition is the result of a hemolytic anemia resulting from a balanced polymorphic adaptation to falciparum malaria (Angel 1964,1966b,1967). In the Old World, excluding southern Africa, the temporal and geographic distributions of the lesion seems to confirm this hypothesis.

The second hypothesis considers the role of chronic iron-deficiency anemia. Iron-deficiency anemia is seen to be the most prevalent nutritional deficiency throughout the world (Robbins 1974). Porotic hyperostosis, likewise, has a widespread distribution in both the old and the new world (El-Najjar et al.1976, Hengen 1971) and corresponds well with the distribution of dietary staples characterized by foodstuffs low in bioavailable iron (Mensforth et al.1978:6-7).

Epidemiological studies (Witts 1966, Kilpatrick 1970) have demonstrated that iron-deficiency anemia is so prevalent throughout the world that it is now regarded as an excellent index of the nutritional health of a population. The biological process which is assumed to underlie this hypothesis is one of consistent magnitude and response to physiological disruption. Clinical and experimental studies have documented consistent age/sex specific risk factors in the etiology of iron deficiency anemia (Heath and Patek 1937, Hallberg et al. 1970). Among the most important risk factors "are rate of growth, which primarily affects infants and adolescents, and physiological blood loss due to the onset of menstruation in adolescent females or to menstruation and pregnancy in adult females. Infants and children in particular can exhibit an age-specific syndrome referred to as hypochromic microcytic iron-deficiency anemia" (Mensforth et al 1978:13).

Iron-deficiency anemia

In developing countries, iron-deficiency anaemia contributes significantly to patterns of infant and child morbidity and mortality (Akel 1963, Ashworth et al.1973, Burks et al.1976, Grantham-McGregor et al.1974). The clinical manifestations of the disease have been well researched (Josephs 1953, Finch 1968, W.H.O. 1968), and include erythroid marrow hyperplasia, reduced serum iron and elevated latent iron-binding capacity of the serum.

The age distribution of these anemias commonly affect infants between the ages of 6-24 months. In premature and low birthweight infants the anaemia occurs at an earlier age and is more pronounced (Mensforth et al. 1978:13). The pathogenesis of iron-deficiency anemia in infants is rarely attributable to a single etiology. Constitutional factors such as iron stores at birth, birthweight and rate of growth (Josephs 1956) are thought to 'precondition' the infant to a borderline nutritional status.

Given that in certain parts of the world cultural practices (Gordon et al. 1963), determine the age of an infants weaning from the mother, weaning may generate a prolonged dependence on foods low in bioavailable iron such as milk, unfortified cereals and carbohydrates. Heath and Patek (1937), Josephs (1953) have demonstrated that these foodstuffs can contribute to poor iron retention in diets. In addition to these factors, the high frequency of respiratory and gastrointestinal infections, common among infants and children dramatically affect the bioavailability of iron, and the biological resistance of the host. What follows therefore is a brief discussion of the constitutional factors, diet and infectious disease which will demonstrate the nature of their synergistic interaction and their potential role in the aetiology of porotic hyperostosis.

Iron store at birth

Smith (1972) has demonstrated that both prenatal and postnatal events contribute to the iron economy of the infant for the first six months of life. Prenatal factors affecting ironstores include the length of gestation, maternal iron deficiency and hemorrhage.

Maternal events such as prematurity, twinning and multiple births all help reduce the quantity of iron available to the neonate. While important clinically, placental hemorrhage and maternal iron deficiency are not considered major epidemological variables in anemia (Mensforth et al.1978:14).

MacKay (1931) concludes that at birth, both full-term and premature infants are born with iron concentrations relatively proportional to body weight. Thereafter, from about nine days to two months, all infants experience anemia (what Smith (1972) describes as normochromic normocytic anaemia) which profoundly influences the infants iron economy for the fist six months of life. The phenomenon is referred to as the "physiologic anaemia of infancy" and is considered a fundamental adaption to the extrauterine environment. Haavardsholm - Finne and Halvorsen (1972) have outlined, in detail, the physiological events which give rise to this adaption. At birth, the lungs replace the placenta as the source of oxygen. Arterial oxygenation rises from 45 to 95%. In response to this abrupt change the body depresses erythropoiesis (the production of red blood cells). As circulating red blood cells expire and body size increases, hemoglobin levels decline. The iron released from the destruction of red blood cells during the first two months of life is the primary source of hemoglobin (iron) for the first six months of life, or until this source is depleted by rapid growth.

While full-term infants double their birth weight in the first six months of life, premature infants may increase their weight four to six times in the same period. This rapid growth has been referred to as "catch up growth". Given that iron stores are relative to body weight, this rapid growth spurt in premature infants predisposes them to anemia. In conclusion therefore, the age of onset is determined by absolute iron stores at birth, and rate of growth (Mensforth et al.1978:16).

Diet

Martinez-Torrse & Layrisse (1974) and Wretlind (1970) have demonstrated that the bioavailability of dietary iron varies not only with the food source eaten, but varies considerably within the same food source depending on how the food was grown, and how it is prepared. Heme iron is more readily absorbed than ferrous iron, and ferrous iron is better absorbed than ferric iron. Meat products contribute more iron in absorbable form and generally enhance iron absorption from vegetable foodstuffs. Hwang & Brown (1965), Kuhn et al. (1968) and Davies (1970) suggest that the bioavailability of iron is also influenced by dietary constituents such as chelating agents, which can either promote or inhibit iron absorption. Ascorbic acid (vitamin c) is a chelating agent that promotes iron absorption by providing a water soluble iron complex. Phytates, phosphates, carbonates and oxalates on the other hand strongly inhibit the absorption of dietary iron by effectively binding it into insoluble macromolecules. The importance of these agents and the effect they exert on the bioavailability of iron cannot be overemphasized. Under normal circumstances the body exerts a strict control over iron balance and iron economy through conservation, reutilization and by rigid control of the processes by which iron losses are replenished. Heinrich (1970) suggests that infants can absorb approximately 10% of their dietary iron and that the absorption of bioavailable iron in the infant is comparable to that in the adult male. Iron deficient infants far exceed this amount and may adsorb two or three times the normal amount of iron as a means of compensating for iron loss and depletion (Mensforth et al. 1978:17).

A final, and equally important clinical observation (Mac Kay 1931, Fullerton 1937, Ashworth et al. 1973, Granthan - McGregor et al.1974), is that a consistent association between anaemia and artifical or prolonged milk feeding and weaning diets of maize or corn grules are frequently found in association with a high frequency of anemia in infants. Lanzkowski & McKenzie (1959), Martinez-Torres & Layrisse (1974) suggest that this situation occurs, in part, to the relatively high phosphorous content which inhibits the absorption of dietary iron from milk and corn.

The role of infectious disease

Among infants and children from six months to approximately two to three years of age, constitutional and dietary factors precondition this section of the population to a relatively unstable iron metabolism. In addition to these factors, infants in this age group also experience a high frequency of systemic illness, namely respiratory and gastrointestinal infections which contribute significantly to morbidity and mortality. Given these data it is important to examine the role of infectious disease in relation to iron economy and the anaemia of infection. In order for bacterial and viral pathogens to survive and multiply in mammalian host tissue, iron as a nutrient source is required. Brubaker et al.(1965) and Bullen et al. (1968) have demonstrated that iron enhances the growth and virulence of bacterial pathogens. This occurs by virtue of the fact that many pathogens posses the ability to synthesize siderophores which enable the microbe to compete with the host for iron to meet the growth demands of the microbe.

A consistent observation among clinicians (Cartwright et al.1946, Greenberg et al.1947, Kuhns et al.1950) is that infectious episodes are accompanied by dramatic reductions in serum iron. This reduction in serum iron is seen as a physiological response which deprives pathogens of essential iron and has been termed host "nutritional immunity". Mild and severe infections in infants result in a markedly lowered hemoglobin level which may remain for several weeks to months after the infectious episode. Such infants are prone to develop additional respiratory and gastrointestinal infections. Chandra (1973) and Masawe (1973) have demonstrated that this is particulary true of infants who suffer from protein-calorie malnutrition.

Two additional factors which profoundly influence the bioavailability of dietary iron are cultural practices and environmental variables. Gordon et al.(1967) has shown that weaning practices, featuring age-and sex specific food restrictions and taboos, can contribute significantly to patterns of chronic malnutrition. Environmental variables such as hookworm infestation leads to intestinal bleeding and therefore blood loss, in turn this gives rise to chronic iron-deficiency anaemia. In conclusion then, anaemia may be seen as a homeostatic mechanism which functions to balance iron economy for nutrititional needs, and host "nutritional immunity" against infectious disease on the other. Mensforth et al. (1978) summation of these physiological responses is, that porotic hyperostosis is a consequence of iron-deficiency anemia, and that periosteal reaction a result of infectious disease and may exhibit a close relationship in a single population.

Periosteal reactions

Periosteal reactions are characterized by a smooth, irregular, or spiculated layers of new bone which appear as a 'scab' over the normal cortex of bone. Radiographically the lesion appears in a solid, laminated or spiculated pattern. Such lesions occur as a result of an elevation of the fibrous outer layer of the periosteum when blood vessels are stretched or compressed. A subperiosteal haemorrhage then occurs which greatly reduces the blood supply to the bone. Infectious agents such as pus, intrusive agents such as neoplasm or trauma, and vascular blood flow may stimulate a periosteal reaction. This leads to an impairment of normal cortical metabolism and results thereafter in necrotic tissue damage Mensforth et al.1978:9).

Morse (1969) has demonstrated that periosteal reactions are a common response of bone to overlying soft tissue infections. In addition to this Lallo et al.(1977) suggests that not only are periosteal reactions a result of chronic infection, but that they are commonly found in association with porotic hyperostosis. It is, on the basis of these findings that a proposed synergistic relationship between the two types of skeletal lesions are thought to exist. The implications of which have a profound affect on infant and child morbidity. Gordon et al.(1967) has outlined a pattern of infant morbidity which exhibit a consistent age-specific relationship with infectious disease. Three important stress-related periods are identified. The first is birth to one month in which death of the infant is attributed to prematurity, birth injuries, congenital anomalies, asphyxia, atelectasis (collapsed lung) and infections. In the second age class, 1 to 12 months, the most common infectious diseases are bronchitis, pneumonia, otitis media and gastroenteritis. The third period is from one to four years during which the frequency of malnutrition increases as the frequency of infectious disease begins to decrease (Mensforth et al.1978:12). The critical period for the infant therefore in terms of the synergistic stresses imposed by nutritional deficiency and infectious disease is 6 to 24 months. It is during this time that both malnutrition and infectious disease have their greatest impact on levels of infant and child morbidity and mortality in a population.

Estimation of porotic hyperostosis and periosteal reactions/methodology

Following Mensforth's (1978) criteria, five age classes were defined on the known age-specific distribution of iron-deficiency, anaemia and infectious disease in infants and children. These age classes are: from 0-6 months, 6-12 months, 1-3 years, 3-5 years and 5-10 years. Adults, for the purpose of this research were considered as one group.

Cranial material was examined macroscopically for evidence of porotic hyperostosis. In addition to this, both cranial and postcranial material were observed for periosteal reactions. Lesions were scored as present or absent. If present, lesions were classified as remodeled or unremodeled on the basis of the quality and extent of resorptive bone activity. Knip (1971) has identified four main types (degrees of development) of porotic hyperostosis. One, a porotic type which is characterized by a scattered array of isolated fine apertures. The second, a cribrotic type which is a conglomerate of larger but still isolated apertures. The third, a trabecular type is characterized by confluent apertures which result in the formation of bone trabeculae. The fourth, and final type is referred to as closed trabecular. It is characterized by closed apertures but the surface is crossed by sulci and depressions.

Unremodeled lesions are defined as sharp and clearly defined margins in the cribriform structure of hyperostotic bone. The cribriform mesh characteristically display a microporosity visible upon close macroscopic examination. Remodeled lesions are defined as a smooth lamellar texture with bone filling of the peripheral pores. The microporosity, characteristic of unremodeled lesions is absent in the cribiform mesh of remodeled lesions.

Periosteal reactions were scored as either present or absent and remodeled or unremodeled lesions. A lesion was considered remodeled if a redistribution of the new subperiosteal bone became incorporated into the normal cortex or table of the affected bone, and if there were signs of hypervascularity and loss of normal bone contour.

Lesions were scored as unremodeled if they displayed a fibrous, vascular, porous and somewhat irregular new layer of bone which gave the appearance of a 'scab' over the normal cortex or table of the bone (Mensforth <u>et al</u>. 1978:24).

In keeping with the model outlined in this thesis, remodeled lesions were used to indicate episodes of stress which had subsequently healed. Unremodeled lesions were used to indicate an active disease which was occurring in an individual at the time of his/her death.

Summary of the microstructural level of analysis

This chapter demonstrates clearly that specific diagnostic skeletal markers of nutritional stress are not possible. Skeletal response to these stressors are generalized and systemic. However, by virtue of the systemic nature of these responses, rather than search for single diagnostic criteria, bone growth patterns, remodeling, infection and repair may be used to accurately document the occurrence of stress markers at different parts of the life cycle. In turn these data may be used to help construct a demographic profile of morbidity within a population.

CHAPTER SEVEN

MOLECULAR AND ULTRASTRUCTURAL ANALYSIS

Dietary reconstruction: stable carbon isotopes

At the molecular and ultrastructural level collagen and hydroxyapatite are used to reconstruct human dietary intake. Examples of studies using these techniques include Van der Merwe and Vogel 1978, Schoeninger et al. (1983), Sealy & Van der Merwe (1985), Sealy (1986), Ambrose and De Niro (1986) and Lee Thorpe & Van der Merwe's (1987) use of bone collagen to determine the stable carbon and nitrogen isotopic ratios of animal tissue. This method facilitates the identification and quantification of foods consumed in prehistory since the lack of overlap in isotopic ratios of certain plants and the passing of these characteristic ratios to consumers allows dietary tracing. In this way important behavioural modifications associated with the exploitation of new food resources may be inferred.

The basis for this type of research rests on the fact that carbon has two stable isotopes, ^{12}C ^{13}C, which are assimilated at different rates by living organisms. Averaged out over the entire globe, the ratio of ^{12}C ^{13}C ^{14}C is about 100:1,1. The proportions of ^{12}C and ^{13}C may change since ^{12}C, smaller and lighter than ^{13}C, reacts a little faster in chemical reactions.

A major source of fractionation (change in ^{13}C and ^{12}C ratio) is the photosynthetic fixation of atmospheric CO2 by green plants. Three photosynthetic pathways are recognized, each fractionating atmospheric carbon dixoide to a different extent. They are called the C^3, C^4 and CAM pathways (Sealy 1986). The importance of these photosynthetic pathways to the archaeologist lies in the fact that these mechanisms fix atmospheric ^{12}C and ^{13}C to different extents and that these differences are quantifiable.

Isotopic theory

Atmospheric carbon dioxide has a ^{13}C value of about -7‰. This means that it is depleted in ^{13}C by seven parts per thousand relative to a universal standard, the marine limestone from the Pedee formation (PDB standard) in South Carolina, which has been assigned a value of 0‰ (Graig 1953,1957).

The PDB standard, like all marine limestones, is relatively rich in ^{13}C so that most natural substances have negative ^{13}C values calculated as:

$$\delta^{13}C \text{ sample} = \left(\frac{^{13}C/^{12}C \text{ sample}}{^{13}C/^{12}C \text{ standard}} - 1\right) \times 1000\%.$$

Both C^3 and C^4 plants during photosynthesis fix ^{12}C in preference to ^{13}C, the selection is considerably more severe in the ^{13}C process. C^3 plants include nearly all trees and shrubs and grasses found in temperate environments, whilst C^4 include tropical grasses and a few dicotyledonous plants (Park and Epstein 1960). In the C^3 cycle total fractionation is about -19,5 . The foliage of C^3 plants have an average value of -26,5‰, with a range of - 20 to 35‰ (Calvin and Benson 1948) compared with the average of - 12,5‰ for C^4 plants with a range of -9 to -16‰ (Smith and Epstein 1970).

Factors which influence the carbon dioxide cycle, other than local differences in the carbon dioxide cycle, also influence the $\delta^{13}C$

values of plants, even within one photosynthetic pathway. Temperature, moisture availability, salinity, light intensity and the nutrient state of the soil all have an affect on the $\delta^{13}C$ values of plants. In ones interpretation of isotopic data it must be borne in mind that δC^3 plants grow in a wider range of habitats than C^4 plants and are therefore exposed to more variation in all these factors. This probably contributes to their greater $\delta^{13}C$ range (Vogel 1978).

Terrestrial food webs

Animals cannot derive their carbon from atmospheric carbon dioxide but must ingest it in a more complex form, such as glucose, which is furnished by plants. Animals thereafter metabolically fractionate the ingested isotope which leads to an enrichment of $\delta^{13}C$ in their tissues. Each tissue has a characteristic fractionation factor. For bone collagen this enrichment has been measured at values from 1 per mil to 6 per mil. Notwithstanding this, the isotopic values for collagen are thought to clearly reflect those of the diet (Parker 1964). On the basis of these findings the technique has been employed to measure prehistoric diet in Woodland North America (Van der Merwe and Vogel 1978), and Southern Africa (Sealy 1986) to detect the introduction of intensive maize cultivation (C^4 plants) in a C^3 environment (De Niro and Epstein 1981, Van der Merwe et al. 1981). In the South African context Sealy (1984, 1986) has applied the technique to differentiate the bone collagen of marine and terrestrial feeders, and to determine to what extent these food sources were exploited by prehistoric human populations. Sealy's results indicate that the mean $\delta^{13}C$ value of marine based foods consumed by people living on the coast consuming shellfish, crayfish, fish, seal and seabird meat is -15.6 + 1.3‰ (range = -12.3 to 19.4). Terrestrial plants have a mean $\delta^{13}C$ of -25.4 + 1.8‰

(range = - 22.3 to 29.2‰) while terrestrial animal meat has a mean of -23.6 + 1.3‰ (range = 20.9 to 25.8‰). It is clear that a marine based diet has an isotopic signature substantially different from a terrestrially based one, this difference would be reflected in the bones of people consuming these foods.

It is generally acknowledged that seawater bicarbonate, the carbon dioxide source for marine plants, is enriched in $\delta^{13}C$ by about 7 parts per mil relative to atmospheric carbon dioxide, which is fixed by land plants. This difference is maintained through the trophic levels, the outcome being that marine resources are $\delta^{13}C$ enriched, compared to terrestrial food chains based on C^3 plants and produce values similar to those of C^4 plants. In the absence of C^4 plants as potential dietary constituents, carbon isotope values for human bone collagen may be used to estimate the relative amounts of terrestrial and marine food in diets. Lee Thorp (1983) and Sealy (1984, 1986) however have demonstrated a number of interesting observations within the isotopic model. As an example, browsing animals have been shown to have similar $\delta^{13}C$ values in different environments and therefore may not be used as environmental indicators. Marine animals on the other hand may only show changes in their $\delta^{13}C$ values if the sea temperature changes. An increase in the proportion of C^4 grasses on the coastal plain in prehistoric times is thought to have occurred and therefore ought to be reflected in the $\delta^{13}C$ values of prehistoric grazers or mixed feeders. Sealy (1986) has proposed that such a change however would also be the one most likely to invalidate conclusions about prehistoric diets based on the modern dichotomy between the isotopic signatures of marine and coastal terrestrial foods (Sealy 1984:127).In an attempt to resolve the marine, terrestrial dichotomy Sealy (1984,1986), Silberbauer (1979) and

Chisholm et al. (1982) have considered the role of stable nitrogen isotopes in dietary reconstruction.

Stable nitrogen isotopes

The potential archaeological application of this technique rests primarily in the estimation of the relative dietary contribution of legumes versus nonlegumes and terrestrial versus marine resources. Around 78% of the atmosphere is nitrogen. In its molecular form it is chemically inert and cannot be used by most organisms, which acquire their nitrogen in a combined form such as nitrate, ammonia or amino acids. In order to make use of molecular nitrogen, as a utilisable compound, involves the process of nitrogen fixation, 90 of which is biological. Biological fixation is carried out by symbiotic or free-living microorganisms (Klepinger 1984:88). Plants that fix nitrogen via the activities of symbiotic bacteria have a nitrogen isotope ratio similar to that of the atmosphere. Non-nitrogen fixing plants derive their nitrogen in usable form from the soil. Such plants therefore have an isotopic composition similar to the soil in which they are grown. Animals fed on diets which differ in isotopic composition reflect these changes in their tissue. Table 5a,b list the values for a number of plant, marine animal and marine organisms compiled for southern African species. The $\delta^{15}N$ values range from = 7.1 to 19.4‰. Algae have an average $\delta^{15}N$ value of =3.5‰; planktonic organisms + 7.6‰; filter feeders + 8.4 and carnivorous organisms, scavengers and detritus feeders + 11.0 (Sealy et al. 1987).

De Niro and Epstein (1981) have demonstrated that $\delta^{15}N$ values estimated from bone collagen decrease over time in archaeological samples. This they attributed to an increase in the proportion of legumes (or animals

ORGANISMS COLLECTED AT OUDEKRAAL KELP BED, CAPE PENINSULA

	$\delta^{15}N$ ‰	
Carnivorous organisms, scavengers, detritus feeders		
Jasus (crayfish: eats mussels, rocky subtidal scavenger)	10.1	
Pachymetapon (hottentot fish: predator)	12.9	
Marthasterias (starfish: eats mussels)	10.1	
Henricia (starfish: eats detritus and organic fragments)	12.2	Average = 11.0
Patiria (starfish: eats detritus and organic fragments)	11.7	
Burnupena (whelk: rock-pool scavenger)	9.6	
Argobuccinum (whelk: eats worms)	11.1	
Cubomedusae (jellyfish)	10.2	
Filter-feeders		
Pentacta (sea-cucumber)	8.8	
Aulacomya (ribbed mussel)	6.8	Average = 8.4
Pyura (red bait)	9.5	
Planktonic organisms		
Phyto- and zooplankton	6.2	Average = 7.6
Mysids	9.1	
Primary producers		
Gigartina (red weed)	0.9	
Pachymenia (red weed)	-0.9	Average = 3.5
Laminaria (kelp)	3.2	
Ecklonia (kelp)	7.3	

TABLE 5a: AVERAGE $\delta^{15}N$ VALUES FOR ORGANISMS COLLECTED FROM THE CAPE PENINSULA (After Sealy et al 1987)

PLANTS

	$\delta^{15}N$
Collected at Cape Point 8/5/86	
Carpabrotus edulis	1.3
Rhus laevigata	2.6
Leucadendron xanthoconus	1.7
Asteraceae (gen. & sp. unknown)	1.4
Collected at Churchhaven 11/5/86	
Carpabrotus edulis	1.2
Rhus sp. #1	-3.5
Rhus sp. #2	-2.9
Rhus sp. #3	-0.2

MARINE ANIMALS FROM THE SOUTH-WESTERN CAPE

ANIMAL	LOCALITY	$\delta^{15}N$ ‰	TISSUE
Arctocephalus pusillus (Cape fur seal)	Cape Peninsula	15.9	bone collagen
Arctocephalus pusillus (Cape fur seal)	Vredenburg Peninsula	19.3	bone collagen
Arctocephalus pusillus (Cape fur seal)	Vredenburg Peninsula	19.4	meat
Spheniscus demersus (Jackass penguin)	Vredenburg Peninsula	16.1	meat
Phalacrocorax capensis (Cape cormorant)	Elands Bay	14.6	meat
Morus capensis (Cape gannet)	-	13.7	meat
Liza cf. *ramada* (haarder fish)	Elands Bay	18.0	meat
Lithognathus lithognathus (white steenbras fish)	Cape Peninsula	15.3	meat
Jasus lalandii (crayfish)	Vredenburg Peninsula	11.8	meat
Patella granatina (limpet)	Elands Bay	8.0	meat
Patella granularis (limpet)	Elands Bay	8.4	meat
Patella argenvillei (limpet)	Elands Bay	7.2	meat
Haliotis midae (perlemoen, abalone)	Vredenburg Peninsula	7.1	meat
Choromytilus meridionalis (black mussel)	Elands Bay 11/11/81	8.2	meat
Choromytilus meridionalis (black mussel)	Elands Bay 1/3/82	8.9	meat
Choromytilus meridionalis (black mussel) n=7	Elands Bay 24/5/82	8.1	meat
Choromytilus meridionalis (black mussel) n=2	Elands Bay 10/7/82	8.8	meat
Choromytilus meridionalis (black mussel) n=8	Elands Bay 15/7/82	8.7	meat
Choromytilus meridionalis (black mussel) n=9	Elands Bay 12/9/82	8.4	meat
Whale (species unknown)	-	13.5	bone collagen
Whale (species unknown)	Elands Bay	12.7	bone collagen

TABLE 5b: $\delta^{15}N$ VALUES FOR PLANT AND MARINE ANIMALS FROM THE SOUTH-WESTERN CAPE (After Sealy *et al* 1987)

that consumed them) in the diet. This trend, however is not substantiated by the archaeological data. This may be attributed to the relatively small sample, or the as yet unproven assumptions about fractionation values in humans and lack of significant diagentic shift.

Before turning ones attention to the 'marine' problem, it ought to be borne in mind that the isotopic composition of non-nitrogen fixers reflects the isotopic composition of the soil in which they are grown. It is questionable, therefore, to what extent collagen $\delta^{15}N$ values can be compared both on a spatial and temporal dimension. The higher $\delta^{15}N$ values observed in marine organisms are a result of denitrification with a high fractionation factor, and the continuous input of isotopically enriched organic matter, such as blue-green algae which are capable of nitrogen fixation. Nitrogen enrichment increases with each link in the food chain. Thus, there is an isotopic enrichment with trophic levels in both terrestrial and marine food chains, but marine organisms have significantly higher $\delta^{15}N$ content than their terrestrial counterparts because of higher rates of nitrogen fixation (Capone and Carpenter 1982).

Schoeninger et al.(1983) have investigated the effect of dietary marine resources on human bone collagen. Their observations suggest that it is prudent to measure both the $\delta^{13}C$ and the $\delta^{15}N$ values of bone collagen. This, they suggest, will produce a more reliable reconstruction of aspects of the diet, rather than analysis based on only one isotope. As an example, they refer to the $\delta^{13}C$ values of humans whose diet consist of equal amounts of C^4 and C^3 plants, and terrestrial mammals which would mimic those obtained from a completely marine diet. In addition to this $\delta^{15}N$ values from humans subsisting on large amounts of tropical reef organisms do not necessarily reflect the marine origins of their diet.

These problems must not be seen to invalidate the isotopic model but rather enhance it in the true Popperian sense. While it cannot be denied that there are limitations to the application of isotopic models they are no greater than those that exist in more traditional archaeological models.

Trace elements: strontium analysis

Also at the molecular and ultrastructural level, and of considerable palaeodemographic value, is the data gleaned from strontium/calcium analysis. The technique has been used to determine (a) the proportion of meat and vegetables consumed in a diet by comparing human and animal bones from the same site (Szpunar et al. 1978); (b) to compare the dietary portion of meat and vegetables between sites (Brown 1973); (c) to estimate dietary change over time (Lambert et al.1979); (d) to determine the social status of individuals within a society (Blakely and Beck 1981); (e) and to estimate weaning profiles in prehistoric populations (Rehnberg et al. 1969, Sillen and Smith 1984).

For the purpose of this research, the technique has been applied to the Oakhurst sample to infer weaning patterns in juvenile skeletons. Sillen and Smith (1984) have hypothesized that human milk is exceptionally low in strontium/calcium ratio, but solid foods have relatively high ratios. In theory, therefore, it ought to be possible to examine the pattern of dietary supplementation and the age of weaning in prehistoric groups by reference to strontium/calcium ratios in juvenile skeletons.

Theoretical aspects of strontium analysis

Strontium and calcium behave throughout the geological cycle in much the same way because of their similarity in electron configuration, ionization energy and ionic size. Calcium and strontium however, are not necessarily present in the same ratio between geographic regions, nor is either element distributed evenly throughout the physical environment. The initial distribution of strontium in soils determines the amount available for uptake by plants. The amount of strontium in ground water is a blend of the amount of strontium within different soils in a drainage basin. It is this combination which determines the amount of strontium available for plant uptake (Schoeninger 1979:297).

Strontium uptake by plants and animals

Bowen and Dymond (1955) suggest that there is little discrimination against strontium in favour of calcium by plants. At the cellular level of uptake, the concentration of strontium in leaves and stems differs. Plants have a closed system without mechanisms for the excretion of trace elements. However, continued movement of strontium from soil through the plant stem into the leaves and storage organs results in a higher concentration of the element in the leaves than in the stems. In addition to this, various plant-types (grasses versus shrubs) accumulate different amounts of strontium.

The amount of strontium deposited in the body parts of animals depends on the amount of the element available, and on biological factors. Odum (1957), Ophel (1963), Schroeder et al.(1972) and Kulebakina (1975) have observed differences in the concentration of strontium in vertebrates and invertebrates. Strontium becomes concentrated in the flesh of marine and fresh water molluscs and crustaceans, and marine vertebrates have higher levels of strontium in their skeletons than terrestrial vertebrates (Rosenthal 1963, Berg 1972).

Strontium metabolism

The majority of dietary strontium is excreted renally, with additional small amounts being lost due to lactation and placental transfer in females (Comar and Wasserman 1963), however, a small, but constant percentage of strontium passes into the bloodstream and this becomes available for incorporation into bone mineral. Since virtually all of the strontium stored in the body is found in the skeletal system it follows that animal flesh provides no strontium when it is included in a diet.

A herbivore's diet, on the other hand, provides a large amount of strontium since plant material contains about three times the amount of strontium as does animal flesh. A small percentage of the herbivore's dietary strontium is deposited in its skeletal system. An omnivore from the same geographic region should have even lower bone strontium values since the meat in its diet contains virtually no strontium. A carnivore on the other hand should show the least amount of bone strontium since more of its diet is meat (Schoeninger 1979:298).

Since virtually all of the strontium retained in the skeleton is sequestered in the mineral portion of bone some understanding of how strontium is distributed within an individual and between individuals of a species ought to be considered.

Although most authors agree that the amount of ionic exchange decrease within hydroxyapatite during its maturation process the exact nature of this change is much debated. Neuman <u>et</u> <u>al</u>. (1963) and Termine and

Posner (1967) suggest that this lowering of exchangeability may be due to improved crystallization. McLean and Urist (1968) on the other hand suggest it may be due to increasing bone mineralization, or a combination of these two factors. Whatever the cause, the result is that once bone crystal maturity is attained strontium is not selectively removed from the bone mineral.

Hodges et al. 1950, Thurber et al. (1958), Yablonski (1973) and Wessen (1977), analysis of bone strontium levels indicate that there is no difference in strontium levels between individuals other than that expected from measurement error, whilst Bang and Baud (1972), found that strontium was evenly distributed in bone from all areas of the body. Accordingly, it would appear that bone mineral in any portion of the body reflects in the same manner towards strontium. The area where most debate occurs is focused around the age dependence differences in strontium incorporation. Lengeman (1963), Lough et al. (1963), Loutit (1967) and Brown (1973), report that bone strontium levels are higher in children than in adults. Hodges et al. (1950), Torekian and Kulp (1956), Alexander and Nusbaum (1956) and Szpunar (1977) however, believe that there is no age dependent difference except in fetal bone. Still others, Bedford et al. (1960), Sowden and Stitch (1957) believe that bone strontium levels are higher in adults than in children.

In view of the controversial nature of the data base, and with specific reference to the age dependence difference of strontium/calcium ratios in juveniles and adults, the Oakhurst sample will be used for comparative analysis and interpretation.

Strontium/calcium ratios in juvenile skeletons: weaning profiles/methodology

A sample from all juveniles represented in the population plus five control adult samples were submitted for strontium/calcium analysis to determine weaning profiles.

Sample preparation

Each sample was broken into small fragments and 4-5 mg weighed with a Perkin-Elmer AD4 electrobalance. The samples were digested with 100ul concentrated nitric acid (Atistar) in 12x75mm borosilicate glass culture tubes at 140 . The samples were brought to dryness, and redissolved in 1ml 0.2n HNO_3. These solutions provided stocks from which allquot samples for analysis could be removed. The digestion procedure was performed in duplicate for each specimen. When the differences in strontium/calcium ratio between duplicates was greater than 10% repeat digestions of the specimen, again in duplicate, were analyzed (Sillen and Smith 1984).

Strontium and calcium ratios

Concentrations of strontium in the preparation were measured with a Perkin-Elmer 5000 Atomic Absorbtion Spectrophotmeter fitted with a graphite furnace. Strontium reference standards were prepared from commercially available reference solutions (BDH Spectrosol). Concentrations of calcium in the solution were measured with flame atomic absorption spectrophotometry employing a Varian Techron AA6 spectrometer. From each stock solution 100ul samples were diluted x1000 in a dilutant containing 0.1% lanthanum, as $LaCl_3$.

Stable carbon isotope analysis

A 15mg sample from each individual, adult and juvenile, represented at Oakhurst was submitted for isotopic analysis. All measurements were derived from bone collagen.

Sample preparation

Bone collagen was extracted by decalcifying whole bone in 1% to 5% hydrochloric acid. Decalcification was completed within seven days. Thereafter the collagen was soaked in distilled water which was changed daily until all traces of hydrochloric acid had been removed from the sample. The sample was then freeze-dried and ready for analysis.

Gas production and purification

Sample combustion was carried out in sealed glass tubes as described by Sofer (1980) and applied by Sealy (1984). A 5mg sample, excess copper oxide (at least 0.5g) and a twist of silver wire were loaded into 6mm O.D. tubes which were then evacuated to less than 10-2 Torr, sealed with a glassblower's torch and combusted, at a temperature of 800c, in a furnace overnight. Thereafter, the tube was removed from the furnace, and inserted into a 'cracker' of the type described by Desmarais and Hayes (1976) and applied by Sealy (1984). The cracker is attached to a stainless steel gas-separation line and the whole line evacuated to 10-4 Torr. Carbon dioxide and nitrogen yields were measured on a manometer, and gas frozen into a clean tube. Thereafter, the tube is sealed off and is ready for insertion into another cracker on the mass spectrometer (Sealy 1984:93).

Measurement on the mass spectrometer

The micromass 60 ZE mass spectrometer used for 13C measurements is a 90 sector double-collector instrument with a dual inlet system. All measurements are done against a laboratory reference gas that has been related to the Chicago PDB marine limestone standard by calibration against six NBS isotopic reference materials, NBS 16,17,18,19,20 and 21 (Sealy 1984:93).

CHAPTER EIGHT

RESULTS OF STUDIES AT THE MACROSCOPIC LEVEL OF ANALYSIS

Demographic results: mortality profiles/life tables

The mortality curve (dx) (Fig. 13) value for the Oakhurst sample is characterized by a bimodal curve, with one mode in child deaths and the other in old age: in addition, there is a low frequency of deaths in the subadult category. The probability of dying (Qx) (Fig. 14) value supports the above statement and an overall comparison of the life expectancies (ex) (Fig. 15) curve and 95% confidence intervals (ex) (Fig. 16a,b) yield similar results.

This index summarizes mortality, reproductive potential and longevity. This means that an average newborn infant in the Oakhurst population had a 27% chance of fully participating in the reproductive dynamics of the group. Forty-six percent of all live born survived to sexual maturity, while 54% of individuals died prematurely as subadults, and 24% in infancy (Fig. 17). Adults in the group who reached the age of 20 years had, on average, an additional calculated 13.2 years left to live (Henneberg pers. comm.). In total, 3.7% of the Oakhurst sample survived to age 40 years (Fig. 18), thus being able to participate fully in total reproduction and exchange of ideas in the extended family. The total growth rate (1.6%) calculated from the net reproductive rate was sufficient to preserve the continuity of the group. During their lifetime two individuals would produce on average of 7.4 children. The birth interval was approximately 6-7 years.

Life style results: osteoarthritis

Nine individuals (64%) of the adult sample show evidence of osteo-arthritis. The sample is too small to make gender comparisons statistically meaningful. The age distribution of the disease is within the 25-30 years age category. Osteoarthritis of the appendicular skeleton (Fig. 19, Table 6) is concentrated far more in the feet (40%) than in the hands in both sexes. The area of heaviest involvement is on the first metatarsophalangeal joint.

Hands

Osteoarthritic involvement of the hand (2 individuals, one adult male and one female :9% of the sample) is on the right side only. The area of involvement includes the proximal end of the 2nd and 3rd metacarpal which articulates with the trapezoid and capitate bone of the hand.

Hip

Osteoarthritis of the hip occurred in two individuals (9% of the adult sample). One individual shows involvement of both hips, while another had involvement of the left hip only. One individual falls within the 18-22 and the other the 30 year age category. Arthritic changes were noted radiographically on the surfaces and margin of the acetabulum rather than on the femoral head. All changes are of a minor sort (Seggie, pers.comm. Department of Radiology, Groote Schuur Hospital).

Vertebral column

The distribution of osteophytosis of the vertebral column is similar in the two sexes, although men (5 individuals 35.7% of the adult sample) are slightly more affected than women (4 individuals 28.3% of the sample). The number of males and females is too small to make statistically meaningful comparisons. The regions affected with the greatest frequency in both sexes are mid-cervical, upper thoracic and lumbar (Fig. 20, Table 6). Within this pattern several modes of distribution are of note. Major modes occur at level cervical 4-5, thoracic 1-4, lumbar 1-2 and lumbar 4-5. Lipping, for example, occurs more frequently and with greater intensity on the superior surface of a joint than on the inferior aspect.

Other gross disorders seen in the skeleton

One individual (U.C.T. 199/180) is thought to have suffered from neuro-fibromatosis (Dr N. Hesselson, Department of radiography, Groote Schuur Hospital). The spine shows a sharp, angular kyphoscoliosis with dyplasia (formation of abnormal tissue) of the vertebral bodies (Fig. 21) and erosion of the vertebral bodies (Fig. 22).

Neurofibromatosis is a hereditary disturbance of mesodermal and neuroctodermal tissue. The prime lesions are neurofibromas of the peripheral and central nerves. Frequently associated findings are cafe-au-lait spots, skin neurofibromas, plexiform neurofibromas, bone deformities and angular kyposcoliosis which is severe and may led to paraplegia, localized gigantism and elephantoid hypertrophy (Davidson and Mac Leod 1973:1030).

Traumatic lesions

The only evidence of traumatic lesions not associated with an inflammatory disease process, is a healed fracture of the radius in an 18-22 year old male (U.C.T. 213) (Fig. 23). The radius shows post-fracture bone growth around the fracture point. This indicates that the injury occurred long before death. There is no evidence of infection while the bone was healing.

Dietary results: the frequency of caries and other dental anomalies

Forty-two percent of the Oakhurst sample, adult and juvenile data pooled, had dental caries. Although the incidence of caries appeared higher in men (4 individuals: 9% of the sample) than in women (3 individuals: 6.8%) than in unidentified individuals (2 individuals: 4% of the sample) the sample is too small to make statistically meaningful comparisons. The age distribution frequency suggests that the incidence of caries was lowest in children and adolescents and highest in adults in the 25-30 year age category (Table 7a,b,c).

The incidence of caries was greatest in the canines, M1, M3, PM1, M2, PM2, respectively. Central and lateral incisors were not found to be carious in this sample. Interproximal caries occurred in 32% and occlusal caries in 34% of all caries susceptible teeth. Mandibular teeth were less susceptible to caries, 7% occlusal, 9% interproximal, than maxillary teeth, 27% occlusal and 23% interproximal.

Dental anomalies

Severe irregularities in the arrangement of teeth occurred in 2 individuals. Crowding of teeth (Fig. 24) was found in two women (UCT 200 and 213) in the 19-25 years age class. A generalized spacing of teeth was not found in this sample. White flecking of enamel was not found, but staining of the roots was observed in 4 individuals. The brown stain observed is thought to be an artefact of preservation rather than the mottling associated with fluoride staining (Owen, pers.comm. Department of Prosthodontics, University of Western Cape.).

Deformation of teeth in the form of interproximal grooves was observed in 1 individual (U.C.T. 218) (Fig. 25). The grooves are consistent in width (1.5-2.2 mm) and direction (linguo-labial) and are confined to the right and left maxillary molars, 2nd and 3rd. The grooves are not associated with a carious surface. The microscopic appearance (Fig. 26) is characterized by numerous tiny parallel striations running linguo-labially along the groove.

Discussion of results at the macroscopic level

Demography

The trends in mortality noted for the Oakhurst sample do not differ significantly from those previously reported for prehistoric and Medieval European populations (the distribution of deaths - dx and ex for these groups are given in Table 8).

A possible criticism of the data presented here is that the sample under investigation spans some 7 000 years and may therefore not be considered representative. The method has, however, been tested with some accuracy and applied by Bocquet-Apple (1985) and Hennenberg and Piontek (1975). Hennenberg and Piontek (1975) have computed the biological state index for some twenty-two groups commencing with Neanderthal groups and ending with contemporary Polish communities. According to their calculations it may be hypothesized that in the course of human history improvements in the upper limit of adaptive possibilities, rather than the biological state index, of the group improves. If one considers the R pot data given in Table 9 it is clear that it is an improvement in the biological situation of adults which is a long way in advance of the decline in children's mortality. Using this data it is hypothesized that human groups conform to three stages of growth. In the first stage, there is a low R pot value and considerable subadult mortality, the general biological state of the population is poor, less than half of individuals born have the opportunity to complete their reproductive years. In the second stage, there occurs an improvement in life conditions for adults, the values R pot are higher, and an increase in birth numbers are possible. This, in turn, at essentially unchanged mortality conditions for children, involves a high frequency of deaths in the ages 0-14 years. The biological state of the population is poor, as it was in the first stage. In the third stage, R pot approaches the ideal value (1.0) and the biological state index is high. this stage is seen to be specific to highly developed/civilized populations.

In the first and second stage natural selection discriminates against traits unfavourable for juveniles rather than for adults. In the third stage, birth control counteracts selection through differential fertility and largely diminishes the action of natural selection of the human organism (Hennenberg and Pionek 1975).

It is clear from the data presented here that the Oakhurst sample conforms to stage 1 of the biological state index, having a low R pot value and considerable subadult mortality. The results however, based on so few samples from different time periods, and a possible sex bias, are necessarily partial. The conclusions drawn may be considered approximations only. Two features of note in the Oakhurst sample are however the unusually long birth spacing interval for the group and the confidence intervals calculated for life expectancy in the 20-29 year age category.

Lee (1972), Sussman (1972) and Howell (1976) have noted that the birth interval among the Kung in southern Africa is 3 years. This is considered a long birth interval and is attributed to the need to invest considerable effort in each child through long lactation and need to carry small children on group moves. The reduction in fertility noted at Oakhurst may be understood as an adaptive strategy using the critical fat hypothesis. While prolonged and heavy lactation suppress ovulation various studies around the world (Menken et al.1981) suggest that this stage may last as long as 18 months. It has not been known to produce intervals of 3, 6 and 7 years. The critical fat hypothesis developed by Frisch (1974, 1978) in essence may be summed up by stating that the large women require a greater amount of fat to reach menarche than short slim women. According to this hypothesis, large women are able to build up necessary fat deposits from their food supply, while slimmer women who are less well nourished, or who cope with environmental stresses tend to be smaller in final stature and to reach critical fatness, and therefore menarche, at later ages. The female reproductive capacity is therefore dependent on fat deposits. If the process is to continue, women who lose their fat deposits later in life become first anovulatory and, if weight loss continues, ammenorrheia.

The Frisch hypothesis seems to explain the long birth interval observed in the Oakhurst sample. It would however be an oversimplification to state that scarcity of food led directly to reduction in critical fat levels. Rather, a number of environmental and cultural constraints, such as choice of food and caloric cost, maintain or rebuild fat deposits and therefore have a profound effect on the length of the birth interval.

Discussion of results: arthritis

The incidence of arthritis in this archaeological series is not significantly higher than those previously reported by Morris (1984) for his hunter gatherer series at Riet River (chi square 5.4975 sig at >.05) or his historic Khoi sample from Kakamas (chi square .38181 sig at >.05).

While the sample under investigation is small, there do seem to be a number of trends worthy of discussion. Men show higher levels of osto-arthritis and vertebral osteophytosis. The trimodal distribution of osteophytosis in the vertebral column appears to correlate closely with the three primary curves of the column and is taken to represent the bipedal posture of the sample. Thus the distribution of vertebral osteophytosis may be seen to reflect the mechanics of the vertebral column: the greater the center of the disc from the line of weight transmission, the greater the stress placed upon it and the greater the likelihood of degeneration occurring. The degree of 'lipping' involvement of the superior and inferior joint margins is interesting and corresponds well with Merbs (1983) findings. Apophyseal facets are shaped differently with regard to the superior and inferior surface and vertebral movement, particulary flexion and extension, tends to restrict vertebral movement. Thus the greater the frequency of lipping observed on the superior margin of vertebral discs may be seen as a direct result of mechanical stress.

The most important activities associated with arthritic changes of the hand is thought to be clothing manufacture. This includes the preparation and cutting of skins and the sewing of garments. Skin preparation involves the scraping away of fat and other adherent tissue with a sharp implement and softening of the skin with the teeth. Both of these activities appear to have left distinctive marks on the skeletal system. If skins were cut with the implement presumably held in the dominant hand, the the distinctive feature of this cutting action is medial flexion of the wrist. Sewing on the other hand, would involve primarily the radial side of the hand, and this is exactly the pattern of osteoathritis seen in the Oakhurst sample. It is clear that side comparisons of pathology are an important element in the interpretation of specific activity patterns.

Discussion of Results

Dental health

The incidence of caries per individual in this sample is not significantly higher than those previously reported by Morris (1984) (Table 10) for his hunter gatherer series at Riet River (chi-square 1.289 sig >.05), or his Historic Khoi sample from Kakamas (chi-square 1.289 sig >.05). However, when one considers the total number of carious teeth, the Oakhurst sample shows considerably higher values than those reported by Morris (1984) for Kakamas (chi-square 44.46 sig <.001), Riet River (chi-square 9.800 sig <.001) and those observed by Van Reenen (1966) for 'Wild Bushmen' (chi-square 167.47 sig <.001) and 'Farm Bushmen' (chi-square 183.85 sig <.001).

In reporting the incidence of caries in the Oakhurst sample the following general trends require discussion. It seems clear from this study that the incidence of caries is similar in men and women. This trend may be considered unusual. It has been noted, in contemporary studies, that the permanent dentition of women show a higher incidence of caries than males (Bibby 1975, Kelly and Harvey 1974, de Plessis 1986).

There are numerous studies (Rose et al. 1984, Walker and Erlenoton 1986) where the distribution of caries by sex has been used as an indicator of carbohydrate consumption. Women are thought to have "snacked" more frequently than men, simply because they collected food. This simple correlation between food consumption and the incidence of caries needs to be reinvestigated in view of the known biological difference which exists between males and females. The difference between the sexes in the incidence of caries is due in part to the earlier eruption of permanent teeth in females; on average some 5 months earlier. However, even when the age difference in timing of eruption is controlled for, females still have a higher caries index than males, which cannot at present be explained (Sloman 1941, Carlos and Gittelsohn 1965). In considering the frequency of sugar intake and "snacking" it would appear that here too there is insufficient and often confusing epidemiological evidence to suggest that sucrose intake is the main cause of caries (Richardson & Cleaton-Jones 1988).

The idea that frequent "snacking" aids the caries process is therefore called into question. This view is upheld by the many workers who have been unable to demonstrate that between-meal snacking is associated with an increase in dental caries (Bibby 1940, Walker and Cleaton-Jones 1978, Walker 1986). One may ask the questions, therefore, is the snack-eating habit as harmful as thought, and does total sucrose/carbohydrate intake play a meaningful role in caries development? Is there any point in archaeologists using this as an index of food consumption?

Fluoride in drinking water reduces caries considerably (McInnes, et al. 1982) and its influence by far supercedes that of differences in daily dietary intake of sucrose. Caries was a common occurrence in the sample studied, and suggests that the people of Oakhurst did not ingest flouride in amounts sufficient to protect their teeth. The incidence of caries among the Oakhurst sample is higher than those reported by Morris (1984) for hunter gathers living in southern Africa.

Sealy et al. (1987) have demonstrated that caries is absent in the teeth of skeletons with 13 - 13 to 11.0 but increase in those skeletons with 13c values of -18.0- 15.0. There is no apparent correlation with stable carbon isotope values and caries in this sample (Table 11). The average value for c 13 and teeth with carious lesions is -12.96 and -13.8 for those without caries. Using the Student t test $t = 1.22$, $p = 0.230$.

A type of tooth damage observed in the Oakhurst sample corresponds with those found in prehistoric peoples from California (Schulz 1977) and South Dakota (Ubelaker et al. 1969). The relevant characteristics of these dental anomalies are the presence of grooves in all adult dentitions, the occurrence of both isolated and bilaterally aligned grooves, and the absence of any correlation with caries loci. It has been suggested elsewhere (Schulz 1977:90) that this pattern reflects a habitual activity of adults of both sexes and all ages. The use of teeth in various craft functions is well known (Molnar 1972) and includes the use of teeth during some stages of basketry manufacture (Kroeber and Barrett 1960). The grooved surfaces produced by these behaviours are, however, occlusal and not interproximal. This has led Ubelaker et al. (1969) to suggest that the habitual therapeutic or palliative use of wooden probes to remove food residues could account for the pattern of grooves described here. More recently Wallace (1974) has proposed that the tooth-pick hypothesis is not a reasonable aetiology and that grooving results from hydraulic patterns of grit-laden saliva forced between the teeth after gingival recession in older adults. These arguments are inconclusive. Since the occurrence of approximal grooves in the incisor teeth of fossil buffalo (von Koenigswald 1972), bovids from archaeological sites (Plogg pers. comm.) and in a variety of atrodactyls (Parmalee et al. 1969, Hawksley et al. 1973) have been reported. Additional detailed research is required to solve the problem of interproximal grooving.

General summary of macroscopic analysis

In general, the Oakhurst sample indicates a pattern of demography and disease seen in many other hunter gathering groups. Two features of the data show a distinctive pattern (1) the relatively long birth interval calculated from the net reproductive rate, and (2) the high caries incidence seen in the total number of teeth.

RESULTS OF STUDIES AT THE MICROSTRUCTURAL LEVEL OF ANALYSIS

Episodic stress results: lines of arrested growth

The frequency and distribution of transverse lines of arrested growth in the Oakhurst sample are given in Table 12a,b. Fifty per cent of the sample have at least one line (Fig. 27a,b) and one individual as many as nine insults per long bone. The longest that any line was observed to persist in these data was 29 years. This was a line in a 30-year old woman which is though to have formed in the first year of her life. Only one individual, aged 3-5 years, had a line that appears to have formed during fetal development. In all other age categories lines appear to have formed early in infancy, from birth to 3 years. There is no significant difference (Chi square 5.600 = $p>.05$) between the incidence of growth arrest lines in adults and juveniles.

In analysing total numbers of lines in adults and juveniles, only the two individuals in the age category birth to 6 months had lines which formed during or just preceding the year of death. Data are not presented for allometric growth since only single distal lines are present in each sample. The mean number of growth arrest lines (calculated by dividing the total number of lines with the total number of individuals) was 3.0, suggesting that growth arrest in this sample was infrequent. Lines were distributed periodically, suggesting that their cause was a regularly recurring stress such as an annual hunger period or the result of some systemic illness.

The frequency and distribution of enamel hypoplasia

Forty-seven (10 individuals, adult and juvenile data pooled) percent of the sample showed evidence of enamel hypoplasia (Fig. 28). There appears to be no gender bias in the distribution of these defects: women 14% (3 individuals), men, 14% (3 individuals) and 19% (4 individuals) in unsexed juveniles (Table 13). The variation in the frequency of enamel hypoplasia by tooth type is shown in Figure 29. The highest frequency of defects are found on the mandibular lateral incisors, followed by the mandibular 2nd molar and the maxillary canine (Fig 30). At the microlevel of analysis, teeth which show several hypoplastic insults per tooth from a single individual are predominantly the mandibular canine and 2nd molar.

If one compares the chronological distribution of hyoplasia by developmental intervals for all teeth (Fig. 31) mandibular incisors show a peak frequency of insults between the age category 4-5 years, mandibular canines between 4-7 years and maxillary 2nd molars between 5-8 years of age. Canines, both mandibular and maxillary, show the highest frequency of hypoplastic defects overall. According to the distribution frequency of hypoplasias for the Oakhurst sample, two developmental phases place the individual at risk. These are from 18 week <u>in utero</u> to 1 year and 4-8 years of age.

Generalised stress results: porotic hyperostosis

Sixty-one percent (11 individuals) of the Oakhurst sample showed evidence of porotic hyperostosis (Fig. 32, Table 14), 39% juvenile (7 individuals) and 22% adult (4 individuals). The lesions observed were of slight to moderate involvement. Lesions were localized mainly in the anterior or middle parts of the orbital roof and more lateral than on the medial plane. Twenty-eight percent of individuals show involvement of both orbits and 33% show involvement in one orbit only. Extraorbital lesions, such as those affecting the frontal, parietal or occipital bone, as well as periosteal reactions, were not observed. Orbital lesions occurred with the greatest frequency in the 0-6 months (3 individuals, 16%), 1-3 year (4 individuals, 22%) and 20-40 year (4 individuals, 22%) age category (Table 15). The frequency of remodeled and unremodeled lesions show no apparent age specific trend. Twenty-eight percent of the sample had unremodeled lesions which was indicative of an active disease process occurring in an individual at the time of their death. Following Knips (1971) classification, 50% (11 individuals) of the sample had porotic type and 11% (2 individuals) trabecular type lesions.

Discussion of results: at the microstructural level

The most useful information to be gained at this level of analysis is that rather than searching for single diagnostic criteria to document episodic stress, the occurrence of stress markers at different parts of the life cycle may be examined and then compared to the mortality schedule of the group. In turn these data can be evaluated against environmental data to provide a "picture" of the nutritional status of the group.

Comparative South African data on the frequency and distribution of lines of arrested growth are not available. However, Dickel et al (1984) have calculated the average number of Harris Lines in Early, Middle and Late Central California populations. The Oakhurst sample is significantly less stressed than the data computed for hunter gatherers from the Early Horizon ($P < 0.20$) and the seed collecting, marine dependent sample from the Middle ($P < 0.05$) and Late Horizon ($P < 0.001$).

Comparative South African data are not available to compare the frequency and distribution of enamel hypoplasia. Using Dickel's et al.

(1984) data for California Indian populations it would appear that the Oakhurst sample was considerably more susceptible to these stressors. Using the Fishers exact probability test the Early Horizon sample have a value of p =.00635 (sig. at <.001). Middle Horizon samples have a value of p=.000073 (sig. at <.001) and the Late Horizon p=.000169 (sig. <.001).

The chronological distribution of linear enamel hypoplasias in the Oakhurst sample supports the hypothesis that many of these dental defects are a result of nutritional disturbances and infectious diseases experienced around the time of weaning in the 4-8 year age category (Schulz and McHenry 1975, Goodman and Armelagos 1985). The distribution of hypoplastic disturbances in infancy (2% of the sample) is more difficult to explain. The most likely explanation for these hypoplastic defects is a proposed deficiency of calcium and vitamin D in the pregnant mother which may have been brought about by gastro-intestinal disturbances (Lindeman 1958).

The Oakhurst data seem to confirm Goodman and Armelagos's (1985) findings that earlier developing teeth, such as incisors, have earlier peak frequencies of defects (4-5 years), while later developing teeth - canines - show peak frequencies at 5-7 years and molars have subsequent peak frequencies at 6-9 years. These data seem to confirm the hypothesis that frequency differences among teeth are due to differences in time development. Teeth which are developing during periods in which host resistance is low and environmental insults are great, are more likely to be hypoplastic. However, not all differences in overall frequencies of hypoplasia by tooth type presented here are explained by difference in time development. The time-development hypothesis neither explains the increased frequency of defects found on the mandibular lateral incisor, when compared to other incisors and first molars.

The Oakhurst results confirm the hypothesis that anterior teeth are more hypoplastic than posterior teeth and that in all teeth, hypoplasias are most common in the middle and cervical thirds. Precise epidemiological interpretation of the Oakhurst data is hampered by a number of factors. Until recently it was assumed that by studying all available permanent teeth, except for the highly variable third molar (Swardstedt 1966), one had a method to check that the underlying stress was systemic, rather than local, in origin. This was achieved by showing the same episode recorded on different teeth, or "best teeth" analysis which includes the use of maxillary central incisors and mandibular canines. As an example, in the Dickson Mounds study (Goodman et al. 1980) 95% of systemic stresses were recorded on one or both of these teeth. In contrast the Oakhurst sample shows only 11% of defects on these teeth. In part these data may be explained in the light of Goodman and Armalagos (1985) findings that some teeth are more susceptible to ameloblastic disruption than others. Thus the frequency of hypoplasia may be directly related to developmental stability. Teeth which are more developmentally stable will be more susceptible to ameloblastic disruption, whereas teeth which are less developmentally stable will be more resistant.

Dietary intake and anaemia

The 0-6 month age group at Oakhurst conforms to the iron deficiency anaemias observed by Brittion et al. (1960), Sax (1963) and Wilson et al. (1967). Around six months of age children have depleted the iron stores accumulated in utero and must depend on sufficient dietary intake of iron to satisfy growth requirements. Clearly these demands were not met at Oakhurst. Factors that diminish the intra-uterine accumulation of iron are prematurity, twinning, gastroenteritis, milk allergy and parasitic infestations. These predispose a child to the onset of iron deficiency anaemia. Thus the porotic hyperostosis observed in early childhood at Oakhurst may be a result of prolonged milk feeding and weaning diets low in available iron (Ashworth et al. 1973). This situation is thought to occur because of the relatively high phosphorous context of certain plant foods (Martinez-Torres and Layrises 1974), which inhibits the absorption of dietary iron from milk. Infants are also susceptible to anaemia because of diarrhoeal infections they often contract when weaned from sterile food and ingest drinking water contaminated with microorganisms (Gorden et al. 1963, Keusch and Katz 1979, Mata et al. 1980).

The results from the third age category (25-40 years) may be readily explained, at least for two individuals, as iron deficiency anaemia associated with childbearing and menstrual blood loss and the hematopoietic effort to meet the fetal demand during pregnancy. Inadequate dietary intake will aggravate these conditions and iron deficiency anaemia will develop (Mensforth et al. 1978).

The two adult males in the sample may have suffered from iron deficiency anaemia as a result of intestinal parasites. If sufficient dietary iron is not absorbed, then anaemia develops. One individual (U.C.T. 211/184) had remodeled lesions suggesting that dietary iron was sufficient to deal with this stressor. The second individual (U.C.T. 199/180), however, had unremodeled lesions which demonstrate that porotic hyperostosis was one of many biological stressors present at the time of his death. This individual had gross arthritis and carious lesions suggesting that this individual suffered from poor health and was particularly at risk to dietary and infectious stressors.

Discussion of porotic hyperostosis: macroscopic and microscopic predators

The frequency of porotic hyperostosis in the Oakhurst sample is greater than those previously reported for southern African populations (Morris 1984). Interpopulation comparisons suggest that the sample from Oakhurst show significantly higher levels of porotic hyperostosis than the hunter gatherers from Riet River (chi-square 25.824 sig. <.001) and Historic Khoi from Kakamas (chi-square 21.372 sig. <.001).

The frequency and distribution of porotic hyperostosis in the Oakhurst population is attributed to two factors, inadequate nutrition at critical stages in the life cycle, and microscopic predicators. The reason that one may be so sure of these interpretations is based on the historical evidence of the distribution (or lack of documented evidence for particular diseases) in the African subcontinent. In addition to these factors it is unlikely that the people of Oakhurst received dietary iron supplements, obtained from leached out minerals, from surrounding rock formation. The area in which the Oakhurst Rockshelter is situated is composed largely of limestone and sandstone which are not particularly high in ferrous oxides (Le Roux, Department of Geology, University of Cape Town).

The most important transmissible disease of humankind in the region, which may give rise to anaemia, is malaria, treponematosis in the form of yaws in the tropical moist areas and non-veneral syphilis in other areas, brucellosis, tick-bite-fever, trypanosomiasis and schistosomiasis. Brucellosis, trypanosomiasis and tick-bite-fever are thought to be fairly recent introductions into the subcontinent and are associated with the arrival of agriculturalists since they require an ungulate reservoir for their transmission. The spread of the disease depends on conditions suitable for its vector, the tsetse fly. The tsetse fly is widely distributed in Africa between the latitude 14° North and 29° South. Between the limits of latitude mentioned, the species of Glossina are widely but not universally distributed, though one or more occur wherever the environment is suitable. These insects are completely absent from several large areas which include the whole littoral of the Red Sea and the Gulf of Aden, the highlands of Abyssinia, the whole of South Africa except a small area in Zululand, all of South West Africa and most of Bechuanaland and the south of Angola (Buxton 1955:36).

Schistosomiasis has spread gradually through Africa from a probable original focus in the Nile valley. The snail intermediate hosts are present in almost all rivers and streams, but it is unclear how they first became infested with the responsible worm. It is unlikely, however to have been before the arrival of agriculturalists and their settlement along river banks, as a human host is necessary for the cycle.

Malaria is endemic in the better watered, more tropical regions of the African continent but is unknown on the highveld or lowveld of southern Africa. (Nures et al. 1985). Treponematsis, in the form of yaws is confined to tropical regions (Murry et al. 1956) while non-veneral syphilis is confined to the Kalahari. In addition to this, the characteristic Mulberry molars and saber-shin tibia associated with the disease process was not observed in the Oakhurst sample.

Hemlminths (parasitic worms) and burrowing insects are responsible for severe iron-deficiency anaemia, and may once have been a more potent cause of disease than they are now. However, burrowing insects, such as the sac of Tunga (jigger flea) gives rise to acute secondary infections. There is no evidence of infection in the skeletal remains recovered from Oakhurst.

Thus, despite the assumed high-protein, iron rich diet of the Oakhurst people, intestinal parasites may have caused iron deficiency. Firstly, most fish are not a particularly good source of iron (We Leung and Flores 1961), mussels have a high iron content but are low in heme iron (Abdon and del Rosario 1980, Walker and Snethkamp 1984) and therefore have a lower bioavailability than that of red meat. The meat of sea mammals and small game would provide a rich source of highly absorbable heme iron (Wu Leung and Flores 1961) but may have been consumed less frequently than shellfish and fish depending on their availability. A possible scenario is that fish-borne parasites may have played a significant role in the frequency and distribution of porotic hyper-ostosis. Studies of kelp bed fish species show that many fish are heavily infested with laval round worms. These parasites are known to infect people who eat raw, or partially cooked fish (Jackson 1975, Dailey <u>et al</u>. 1982). Fish-borne parasites invade the digestive tract and cause vomiting, diarrhoea, ulceration and blood loss in the stool. Some fish and most sea-mammals host a tape worm (<u>Diphyllobothrium pacificum</u>) (Baer 1969, Patruccor <u>et al</u>. 1983, Araujo <u>et al</u>. 1983) and when ingested by humans gives rise to diarrhoea and megablastic anaemia.

It is interesting to note that the association of porotic hyperostosis and periosteal reactions, a common response to infectious disease (Gordon et al. 1963) is not present in the Oakhurst sample. The mild severity of the porotic hyperostosis and the concentration of lesions in the orbital roof strongly suggest iron deficiency anaemia. An alternative explanation of the lower frequency of porotic hyperostosis in adults than in children is that lesions acquired early in life gradually disappear in adults through bone remodeling (Vanier 1967, Mosely 1974, Stuart-MacAdam 1982).

General summary of microstructural analysis

The results gleaned at the microstructural level of analysis are interesting and provide processural data useful at two levels. Firstly, it is not surprising that the frequency of lines of arrested growth are minimal. Protracted bouts of episodic stress was not a feature at Oakhurst. This conforms to what we know about food preference and the range of food available to hunter gatherers (Lee 1969). Starvation seems improbable, less favoured food resources, in descending order of preference, would have been consumed to ward off starvation and malnutrition.

The second level of information to be gained concerning episodic stress seems almost contradictory. The incidence of enamel hypoplasia is fairly high. However this is regarded as protracted metabolic insults consistent with child weaning practices and concominant childhood disease rather than periods of episodic starvation. What is surprising about the data is that which pertains to levels of generalized stress. The incidence of porotic hyperostosis and the length of the birth interval are unusual. The precise etiology of porotic hyperostosis in this sample is unknown. However, one may consider the role of fish borne parasites and make deductive comments relating to the general health of individuals who consumed foods both low in bio-available iron and contaminated with parasites. These factors may have contributed to the long birth interval by profoundly affecting fat stores, ovulation and health in general.

RESULTS AT THE MOLECULAR LEVEL OF ANALYSIS

Isotopic data

The results are given in Table 16 for δ13c and δ15N valves versus age and sex. The average value for δ13c is 13.75, (standard deviation:1.50). The average value for δ15N is 12.31 (standard deviation:2.41). The small variability of these values suggests that the Oakhurst people consumed a marine diet which did not change significantly over the 6,000 year time period studied (Fig. 32). These data are consistent with Chisholm et al. (1982) and Schwarcz et al. (1985) findings for other small populations. These results for inter-population variation place a limit on the maximum variability of the diet-to-collagen isotopic fractionation for humans and suggests that this variability is characteristic for human populations (Lovell et al. 1986). There is no evidence of significant correlation of the 13c values with age and sex. The distribution of the two groups as a whole is statistically normal (using the two-tailed t test T .101 p=9199). Lovell et al. (1986) suggest that this is a general characteristic of any human population subsisting on a uniform diet.

The nitrogen values presented in Table 16 do not separate out marine from terrestrial meat. This is an interesting observation in view of Sealy et al.'s (1987) findings that prehistoric people who ate predominately terrestrial diets have lower N15 values than those with largely marine diets.

Strontium/calcium results

The strontium, calcium concentrations of the Oakhurst skeletons, plotted by age are given in Figure 34. Strontium values range from 2.6 ppm to 30.0 ppm. The data given here are best interpreted in terms of those developed previously for the historic Arab population at Dor by Sillen and Smith (1984).

Discussion of results at the molecular level

The δ13C values for Oakhurst, while indicative of a marine diet (δ13c average value -13.75‰) compares favourably with Sealy's findings for a marine based diet (average δ13c value - 12.3 to 19.4‰) . These data may, however, represent a subsistence strategy which relied heavily on the consumption of terrestrial animal flesh or animal protein at the expense of carbohydrates. This kind of dietary regime would appear more C4 in its isotopic composition than a diet composed of equal amounts of animal protein and plant carbohydrates (Sealy pers. comm.). It is unlikely (but not impossible), that people would move out of the high rain-fall area where C4 plants are less abundant. The perceived marine diet of the Oakhurst people may therefore be interpreted as a terrestrial diet rich in animal protein but low in carbohydrate, or a diet composed of marine foods and adequate amounts of carbohydrate. The latter interpretation is more acceptable to this author and the data on Oakhurst pathology clearly suggests a balanced diet. Protein consumption appears to have been adequate in the Oakhurst sample since there is no evidence of rickets (lack of extension and widening of the epiphyses), osteomalacia or osteoporosis. Carbohydrate consumption also seems to have been adequate since there is no evidence of defective dentine and no enlargement of the costochondral junction (Davidson and MacLeod 1973).

Discussion of strontium/calcium results

In general the shape of the curve for strontium/calcium is similar to that seen at Dor, as well as those developed for modern populations using radiogenic 90 strontium. It is apparent that the strontium/calcium value for the foetal/newborn category is low when compared to the rest of the population. This result conforms to data based on studies of mothers and stillborn children in modern populations (Beninson et al. 1964), Knizhnikov and Marei 1967) and experimental studies demonstrating a discrimination against strontium at the level of the placenta (Comar et al. 1955, Hartsook and Herschberger 1973). The strontium/calcium values in the Oakhurst study are seen to gradually increase with individuals in the 1 to 4 year age range having among the highest values for the entire population. By age four strontium/calcium levels have leveled out. There are, however, certain specific details in the Oakhurst sample that differ from the Dor data. These differences are of interest since they may reflect a different weaning pattern than that seen in historical herding populations. Three year olds at Oakhurst were not as far advanced in dietary supplementation than the three year olds at Dor. By age three years juveniles at Dor had strontium/calcium values similar to the adult population (Sillen and Smith 1984). The Oakhurst juveniles, on the other hand, by age four-eight years had values lower than those of the adult Oakhurst sample. This suggests that dietary supplementation was delayed. Why this should be so may be a complex mix of cultural practices and physiological response.

By the age of 6 months, weaning has commenced in most children in contemporary populations (Ebrahim 1983). In developing countries however breast milk may be crucial for the first 2 years of life (Morley and Woodland 1979). In those countries there is usually a strong relationship between duration of breast feeding and the birth interval. The mean birth interval is about two years. Breast feeding delays pregnancy in several ways. Firstly, women who breast feed have an extended period of amenorrhoea. This is related to failure of ovulation, so that pregnancy is unlikely (Salber 1968). In addition to this the suckling infant sucks more frequently, the stimulus of the sucking infant on the nipple inhibits ovulation through a complex hormonal pathway. Secondly, many communities have traditions which discourage intercourse while breast feeding is continued. The same may have applied in prehistory. Thirdly, many communities do not measure the birth interval in years alone. It may be measured in terms of behaviour of the young child (Morley and Woodland 1979:128).

Lastly, the question of adequacy of breast milk as the sole nutrient for the older infant must be addressed. It has been suggested that after the third month of life the output of breast milk is not enough to meet the energy and protein requirements of the growing infant (F.A.O./W.H.O. 1973 quoted in Ebrahim 1983:85). Growth in height and weight are most severely affected between three to twelve months, the slowing of growth in the first year of life accounts for 91% of the deficit in body weight and 90% of the deficit in length at the age three years. Though the rate of growth approaches normal in the second and third years, when growth is slowing down, the lost ground is never recovered and the deficit remains (Ebrahim 1983:86).

General summary of molecular level of analysis

Knowledge of diet yields information about human social and economic organization, health and way of life. In this thesis diet has been reconstructed using stable carbon isotopes and trace elements and has provided a method for reconstructing the relative amounts of marine and terrestrial food sources in the diet of the people living at Oakhurst.

Strontium and calcium ratios have allowed one to calculate the estimated time of infant weaning from parental care.

Archaeological data and molecular analysis indicate that the Oakhurst people seem to have exploited molluscs and fish as a primary source of nourishment. The uniform marine diet suggested by isotopic analysis is interesting and allows one an opportunity to compare dietary and demographic results. Given the uniform marine diet reported here it is hypothesized from this data that marriage partners were obtained from areas abounding the coast. It is reasonable to suggest that men or women from the interior of southern African would have consumed a predominantly terrestrial diet. Upon marriage these people would move to the coast to reside with their respective partners. This would be reflected in the isotopic signature of the individual, which in this sample, it is not. The notion that groups of people obtained marriage partners from other coastal regions is therefore supported by the isotopic data given. In addition to this the radiocarbon data provided for this sample seems to support a regional focus of people living along the South coast of southern Africa. The hiatus observed from the Cape Interior to the southern fringes of the Kalahari. and the northern edge of the Cape Folded Belt suggests that this area was unsuitable for large scale human habitation (Deacon and Thackeray 1983). Radiocarbon dates from Oakhurst cover this hiatus and suggest that people were concentrated along the coast of South Africa.

When one compares the samples dated in time an interesting observation is evident. Those samples which fall between 9-5 000 BP appear to be more stressed than those from 4-2 000 BP. The sample is very small and not amenable to statistical testing, however, a consistent trend at each level of analysis (Table 17) is apparent. One may do no more than speculate the reason for such a trend in the data. It is interesting however to note that in the time period 9-5 000 BP vegetational cover in the Oakhurst area was diminished and that estuarine conditions had not yet formed. In the 4-2 000 BP time slot estuarine conditions prevailed and vegetational cover was optimal. These factors would have helped provide a wider range of food sources than had previously existed and so diminish nutritional stress.

General comments

The most significant findings at the molecular level of analysis may be divided into two categories, those which pertain to dietary stability, and the length of the weaning period in infants.

The isotopic data presented in this thesis supports the idea that the people of Oakhurst subsisted on a marine based diet. This is supported by archaeological data from the site. Large amounts of marine fauna have been identified which far outweigh all other categories of fauna. There is no evidence for seasonal variation within this food-collecting strategy.

The weaning profile for Oakhurst is interesting in itself but the more so when considered in light of the birth spacing interval and the frequency and distribution of enamel hypoplasia in the sample. These data outline a graded response to environmental and cultural stress at the general level.

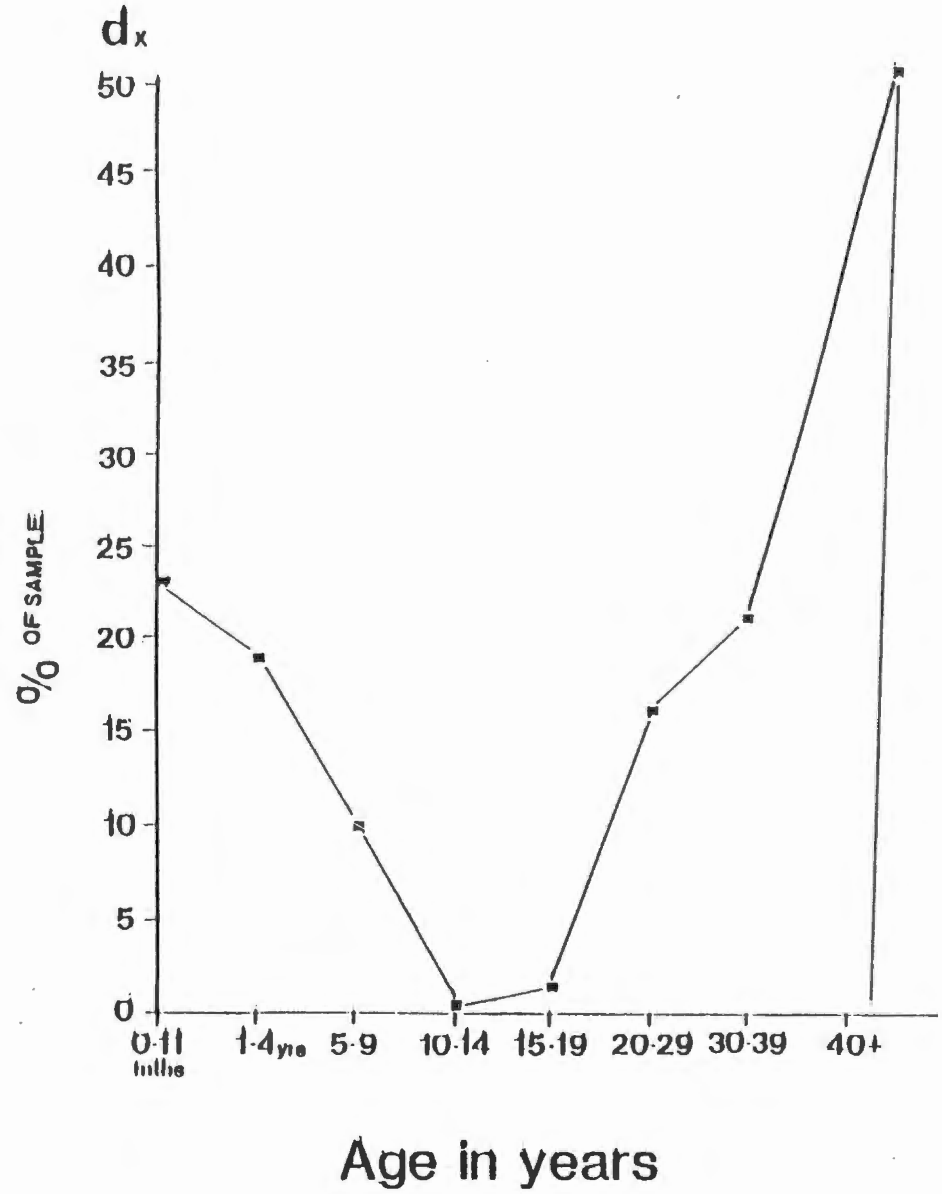


FIGURE 13 : PROPORTION OF THOSE DYING IN EACH AGE COHORT AT OAKHURST

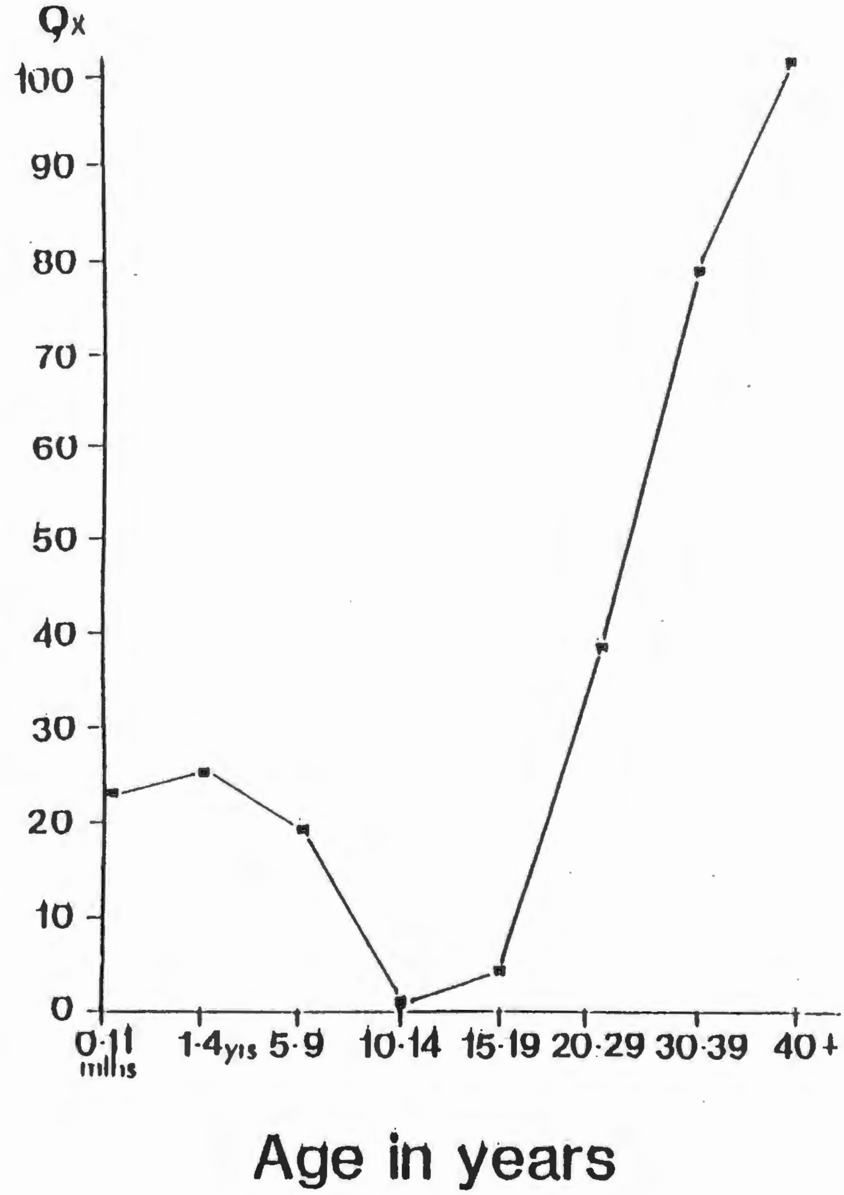


FIGURE 14 : PROBABILITY OF DYING IN EACH AGE COHORT AT OAKHURST

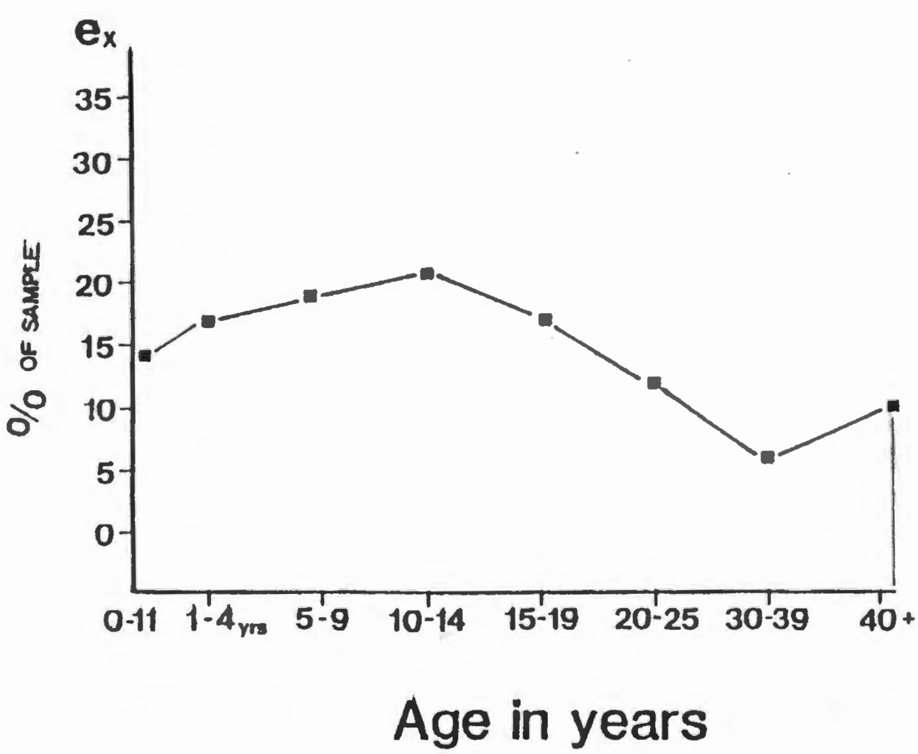


FIGURE 15: LIFE EXPECTANCY IN EACH AGE COHORT AT OAKHURST

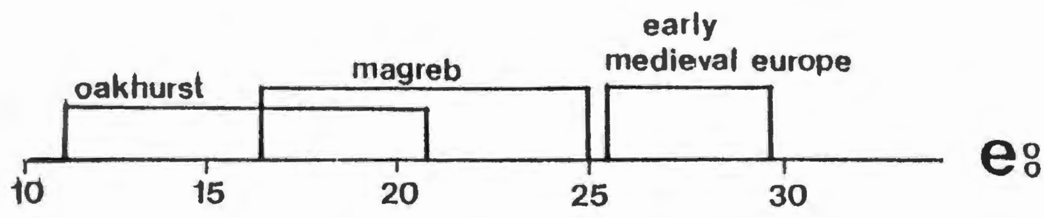


FIGURE 16a: 95% CONFIDENCE INTERVALS FOR NEWBORN LIFE EXPECTANCY

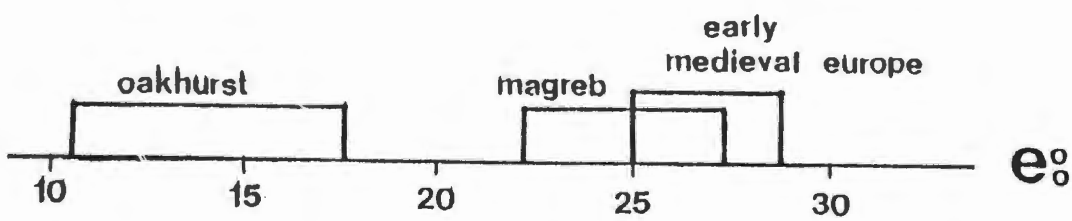


FIGURE 16b: 95% CONFIDENCE INTERVALS FOR 20-29 YR LIFE EXPECTANCY

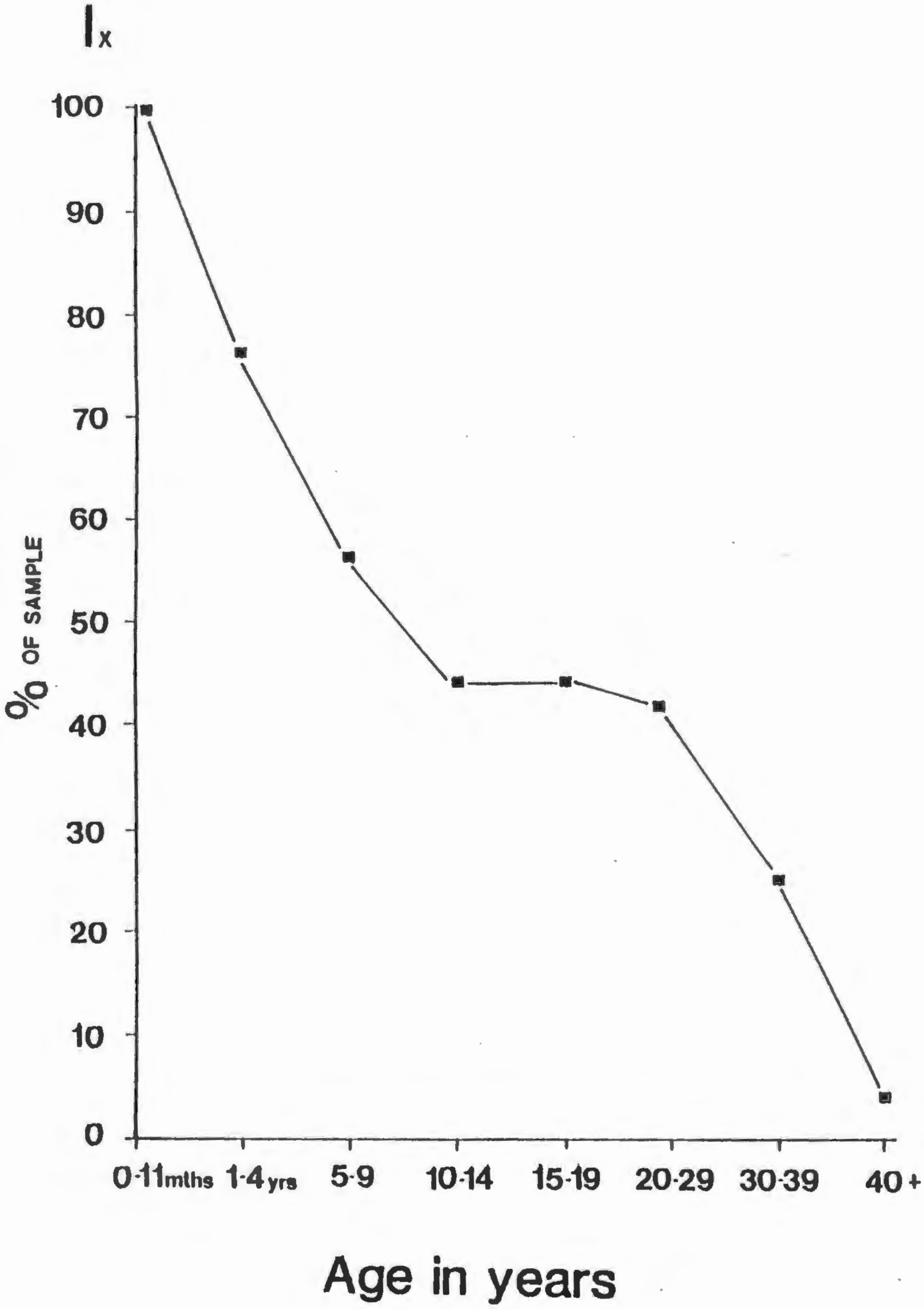


FIGURE 17 : PROBABILITY OF SURVORSHIP IN EACH AGE COHORT AT OAKHURST

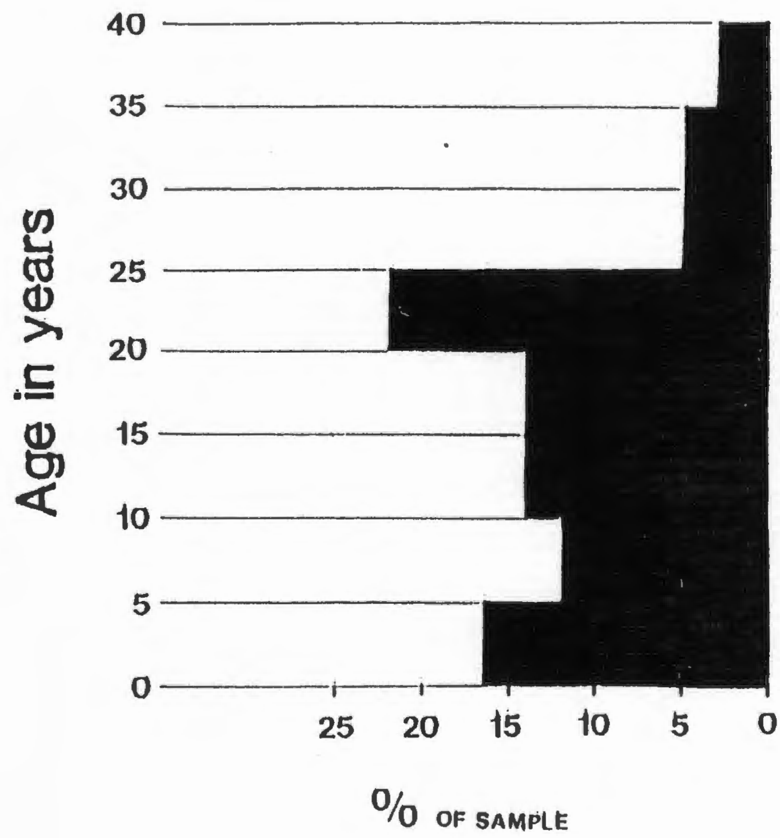


FIGURE 18: AGE STRUCTURE OF THE OAKHURST SAMPLE

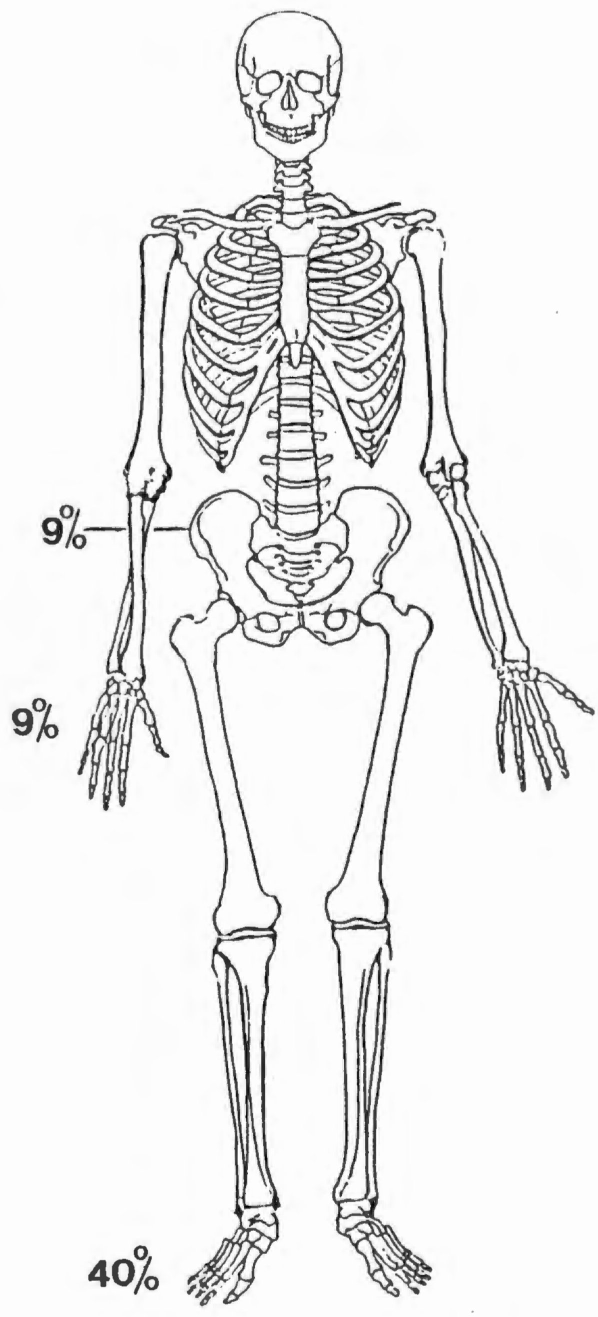


FIGURE 19: DISTRIBUTION OF ARTHRITIS PER JOINT OF THE APPENDICULAR SKELETON

(ADULTS ONLY)

	NUMBER OF INDIV. WITH ARTHRITIS	TOTAL NUMBER OF INDIVIDUALS	AGE CLASS	% OF TOTAL
MALES	5	6	25-30 yrs	83
FEMALES	4	8	25-30 yrs	50
TOTAL	9	14		64.2

* Total joints available (adults only)

	Individuals with arthritis of vertebral column	*%	Individuals with arthritis of hip	*%	Individuals with arthritis of hands	*%	Individuals with arthritis of feet	%
MALES	5	35.7	0	0	1	4.5	5	18
FEMALES	4	28.3	2	9	1	4.5	4	22.7
UNSEXED JUVENILES	0		0		0		0	
TOTAL	9	64.0	2	9	2	9	9	40.7

TABLE 6: SUMMARY DATA ON THE DISTRIBUTION OF ARTHRITIS

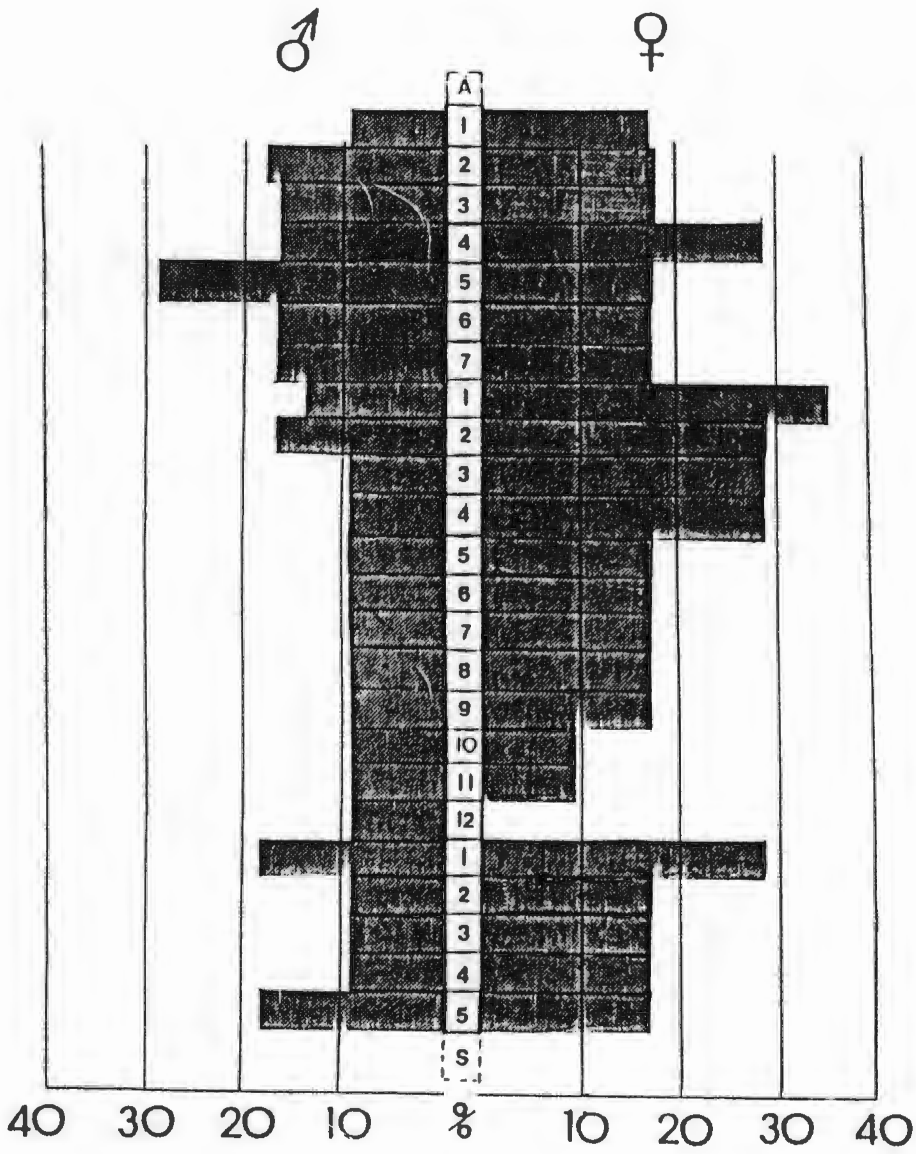


FIGURE 20 : DISTRIBUTION OF OSTEOPHYTOSIS OF THE VERTEBRAL COLUMN

(* per total number of vertebra examined Adults only)

FIGURE 21: LATERAL VIEW OF VERTEBRAL COLUMN, NOTE LIPPING, NARROWING OF DISC SPACE AND KYPHOSIS (UCT 199)

FIGURE 22: EROSION OF VERTEBRAL BODY ASSOCIATED WITH NEUROFIBROMATOSIS (UCT 199)

FIGURE 23: HEALED FRACTURE OF THE LEFT RADIUS, VENTRAL VIEW (UCT 202)

AGE GROUP	No. OF AFFECTED INDIVIDUALS	TOTAL No. OF INDIVIDUALS *	% OF TOTAL IN AGE CLASS
0 - 1 yr	0	4	0
1 - 4 yr	0	4	0
5 - 9 yr	1	1	100
10 - 14 yr	0	0	0
15 - 19 yr	1	1	100
20 - 29 yr	5	7	71
30 - 39 yr	1	3	33
40 + yrs	1	1	100
	9	21	42%

TABLE 7a: SUMMARY DATA ON THE DISTRIBUTION OF CARIES BY AGE

* Only individuals with mandible and/or maxilla are included in this study

	TOTAL No. OF TEETH	No. OF CARIOUS TEETH	% OF SAMPLE
I1	10	0	0
I2	16	0	0
C	27	2	74
PM1	20	6	30
PM2	19	4	21
M1	18	8	44
M2	19	5	26
M3	15	6	40

TABLE 7b : SUMMARY DATA ON THE DISTRIBUTION OF CARIES (ADULTS ONLY) BY TOOTH TYPE

	TOTAL No. OF TEETH	No. OF CARIOUS TEETH	% OF SAMPLE
I1	21	0	0
I2	21	0	0
C	23	0	0
PM1	26	0	0
PM2	26	0	0
M1	6	1	16
M2	8	0	0
M3	0	0	0

TABLE 7c: SUMMARY DATA ON THE DISTRIBUTION OF CARIES (JUVENILES ONLY) BY TOOTH TYPE

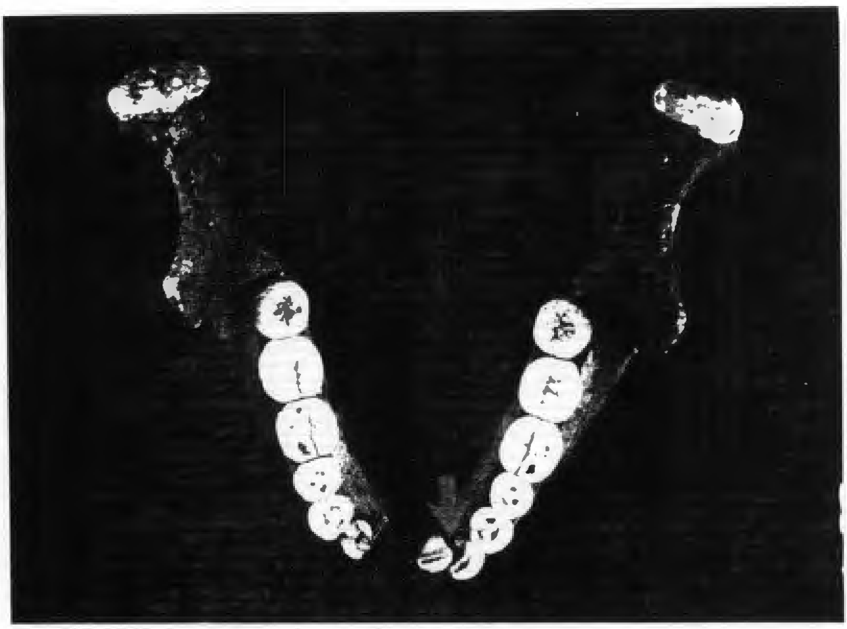


FIGURE 24: CROWDING OF MANDIBULAR TEETH I_2/C IN THE PERMANENT DENTITION (UCT 200)

FIGURE 25: DEFORMATION OF MAXILLARY MOLAR (M_2M_3) (UCT 218)

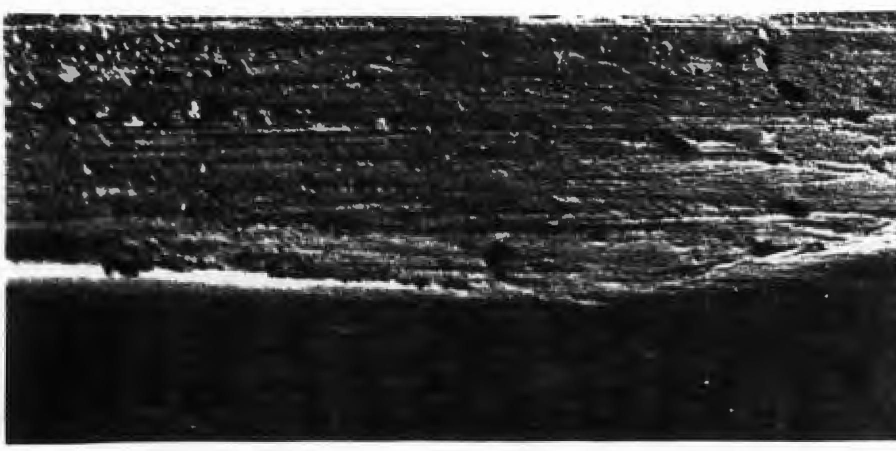


FIGURE 26: MICROSCOPIC APPEARANCE OF M_2. NOTE PARALLEL STRIATIONS WHICH RUN LINGUO-LABIALLY ALONG THE GROOVE (UCT 218, magnification x 200)

	Maghreb		Grossbrem-bach		Sulecin		Keszthely Dobogo		Espenfeld		Hungarian Model		Szczepanowa ♂		Szczepanowa ♀		*Oakhurst	
	dx	ex	dx	ex	dx	ex	dx	ex	dx	ex	dx	ex	dx	ex	dx	ex	dx	ex
0– 6 Infants I	49,0	22,1	19,2	21,4	31,8	24,3	22,5	35,1	36,7	19,2	32,8	29.7	53,3	20,2	52,0	21,6	19,5	19,6
7–14 Infants II	5,2	33,0	21,2	19,8	2,6	28,3	5,8	37,3	12,5	22,7	6,6	35,5	7,8	33,7	6,3	34,9	10,8	21,7
15–19 Juveniles	3,0	28,3	5,8	18,3	3,2	21,3	3,3	32,0	4,5	19,2	4,2	30,9	1,8	31,7	3,1	31,5	2,1	17,4
20–29 Adults	11,6	25,2	21,2	15,2	21,7	17,2	8,3	28,4	18,8	15,9	7,8	28,1	5,8	28,1	7,8	28,8	16,6	13,7
30–49 Mature	14,7	22,6	28,9	11,7	33,3	13,7	28,3	21,7	21,8	13,3	22,8	21,7	15,3	22,4	13,5	24,6	21,0	8,2
50–59 Senile I	6,7	13,9	3,9	5,0	4,8	10,3	16,7	12,1	5,2	5,9	13,7	12,1	6,1	14,3	5,7	15,3	No data	
60 + Senile II	9,8	10,0	-	-	2,6	10,0	15,0	10,0	0,5	10,0	12,2	10,0	9,9	10,0	12,6	10,0	No data	

TABLE 8 : COMPARATIVE DATA ON LIFE AND DEATH EXPECTANCY FOR SOME MODERN AND PREHISTORIC GROUPS (after Hennenberg & Piontek 1975)

* Male and female pooled

POPULATION	I_{bs}	R_{pot}	SOURCE OF MORTALITY DATA
Oakhurst	.26	.58	This study
Neandertal	.26 - .32	.56	Vallois 1937, Acsadi, Nemeskeri 1970
Upper Paleolithic	.30	.49	Vallois 1937
Mesolithic	.30	.42	Vallois 1937
Maghreb type (epipaleolithic)	.35	.75	Acsadi, Nemeskeri 1970
Nea Nikomedeia (Early Neolithic)	.23	.58	Angel 1969
Volni (Neolithic)	.44	.69	Acsadi, Nemeskeri 1970
Germany, Neolithic	.48	.66	Ullrich 1972
Alsonemedi (Copper Age)	.51	.80	Acsadi, Nemeskeri 1970
Grossbremback (Early Bronze)	.32	.53	Ullrich 1972
Lerna (Middle Bronze Age)	.30	.66	Angel 1969
Sulecin (Late Bronze Age)	.42	.64	Piontek 1975
Intercisa-Brigetio (I - IV c AD)	.43	.68	Acsadi, Nemeskeri 1970
Valachians (IV c AD)	.40	.56	Nicotaescu, Wolski 1972
Keszthely-Dobogo (Late Roman Era)	.60	.83	Acsadi Nemeskeri 1970
Sopronköhida (IX c AD)	.50	.93	Acsadi, Nemeskeri 1970
Artand (IX c AD)	.58	.78	Ery 1967
Espenfeld (XI-XII c AD)	.31	.60	Bach, Bach 1971
Czarna Wielka (XI-XII c AD)	.44	.65	Modrzewska 1958
Hungarian model (XI-XII c AD)	.49	.80	Acsadi, Nemeskeri 1970
Reckahn (XII-XIV c AD)	.47	.66	Schott 1964
Villages in parish Szczepanowo (Poland, middle of XIX c AD)	.32	.79	Authors unpublished data
Poland 1960-1966	.94	.99	Rocznik ... 1968

TABLE 9: R_0 AND I_{bs} ESTIMATIONS IN SOME EARLIER HUMAN POPULATIONS. I_{bs} and R_{pot} FOR MODERN POLAND ARE GIVEN FOR COMPARISON

Henneberg, M. & Strzalko, J. 1983.

	n	% INDIVID WITH CARIES	TOTAL No. OF TEETH	% TEETH CARIOUS	AVERAGE No. CARIOUS TEETH PER MOUTH	SOURCE
OAKHURST	9	42.0	361	9.0	4.0	This study
RIET RIVER	47	41.7	1061	4.3	1.0	Morris 1984
KAKAMAS	43	18.8	989	1.3	0.3	Morris 1984
GRIQUA	26	42.3	575	5.2	1.2	Morris 1984
"WILD BUSHMEN"	104	7.7	3335	0.5	0.2	Van Reenen 1964
"FARM BUSHMEN"	221	12.2	7052	0.8	0.3	Van Reenen 1964
COLESBURG	53	22.6	1211	2.6	0.6	Drennan 1929

TABLE 10: SUMMARY DATA ON THE INCIDENCE OF CARIES FROM VARIOUS SOUTHERN AFRICAN SAMPLES

SPECIMEN WITH CARIES	C13 VALUE	SPECIMEN WITHOUT CARIES	C13 VALUE	SPECIMEN WITHOUT CARIES	C13 VALUE
UCT 199	- 13.23	UCT 200	- 14.23	UCT 216 (D)	- 10.43
UCT 204	- 14.46	UCT 201	- 12.35	UCT 217 (K)	- 15.44
UCT 206(2)	- 12.32	UCT 202	- 13.39	UCT 217 (M)	- 15.88
UCT 208 (grave 10)	- 10.88	UCT 203	- 16.65	UCT 217 (N)	- 13.31
UCT 211	- 13.94	UCT 204 (grave 11)	- 13.59	UCT 217 (F)	- 14.07
UCT 214		UCT 205(2)	- 12.57	UCT 217 (L)	- 14.14
UCT 218(6D)	- 11.96	UCT 206(1)	- 12.38		
		UCT 207(H)	- 13.78		
AVERAGE C13 VALUE	- 12.96	UCT 207 (I)	- 14.01	AVERAGE C13 VALUE	- 13.8
		UCT 207 (G)	- 11.12		
		UCT 208 (grave 9)	- 15.04		
		UCT 210 (10_c)	- 12.43		
		UCT 213 (grave 16/2)	- 15.89		
		UCT 215(F)	- 16.44		
		UCT 215(D)	- 11.67		
		UCT 215 (grave 10)	- 15.74		
		UCT 215	- 13.75		

TABLE 11 : INCIDENCE OF CARIES vs CARBON ISOTOPE VALUES

AGE GROUP	INDIVIDUALS WITH LINES	No. OF LINES	MEASURED DISTANCE (mm) FROM DISTAL END OF TIBIA	AGE WHEN FORMED (yrs)
0-6 mths	UCT 217(K)	4	3, 6, 7, 11	birth -
0-6 mths	UCT 213(B)	3	4, 6, 8	birth -
1-4 yrs	UCT 210(E)	1	7	6 mths - 1yr
1 yr	UCT 217(C)	2	3, 4	birth - 6mth
1-4yrs	UCT 217(F)	1	1	intrauterine
1-4yrs	UCT 207(G)	1	5	1 yr
5-9yrs	UCT 207(H)	5	2, 4, 5, 6, 7	6mths - 1yr
5-9yrs	UCT 208	9	3, 4, 5, 6, 8, 9 10, 11, 13	6mths - 2yrs
20-29 yrs	UCT 214	5	20, 25, 27, 28, 30	2, 2½, 3, 3, 4
20-29 yrs	UCT 206L (1st indiv)	3	10, 13, 20	1, 1½, 2
30-39 yrs	UCT 206K (2nd indiv)	4	4, 8, 9, 14	6 mths, 1, 1, 2

TABLE 12a: SUMMARY DATA ON THE FREQUENCIES AND DISTRIBUTION OF RADIOPAQUE TRANSVERSE LINES. OAKHURST ADULTS AND JUVENILES

AGE GROUP	No. OF AFFECTED INDIVIDUALS	*TOTAL No. OF INDIVIDUALS	% OF TOTAL IN AGE CLASS
0 - 6 mths	2	4	50%
1 - 4 yrs	4	5	80%
5 - 9 yrs	2	2	100%
10 - 25 yrs	0	0	0
25 +	3	11	27%
TOTAL	11	22	50%

TABLE 12b: DISTRIBUTION AND FREQUENCY OF HARRIS LINES IN THE TIBIA OF THE OAKHURST SAMPLE

* Since tibia are used with the greatest predictive frequency the total number of individuals in each age class has been reduced to include individuals with tibia only. Individuals who presented with growth arrest lines in femora, humeri and metacarpals are not included in this sample.

b

a

FIGURE 27a: OBLIQUELY ORIENTATED STRANDS WITHIN THE MARROW CAVITY OF THE LEFT TIBIA

FIGURE 27b: CROSS SECTION OF THE LEFT TIBIA SHOWING LINES OF ARRESTED GROWTH: RADIOLOGICAL EXAMINATION

FIGURE 28: ENAMEL HYPOPLASIA OF THE DECIDUOUS DENTITION (UCT 208)

	No. OF INDIVIDUALS WITH HYPOPLASIA	TOTAL No. IN CATEGORY	% OF TOTAL
MALES	3	6	50%
FEMALES	3	6	50%
JUVENILES	4	9	44%
TOTAL	10	21	47%

TABLE 13: DISTRIBUTION OF ENAMEL HYPOPLASIA

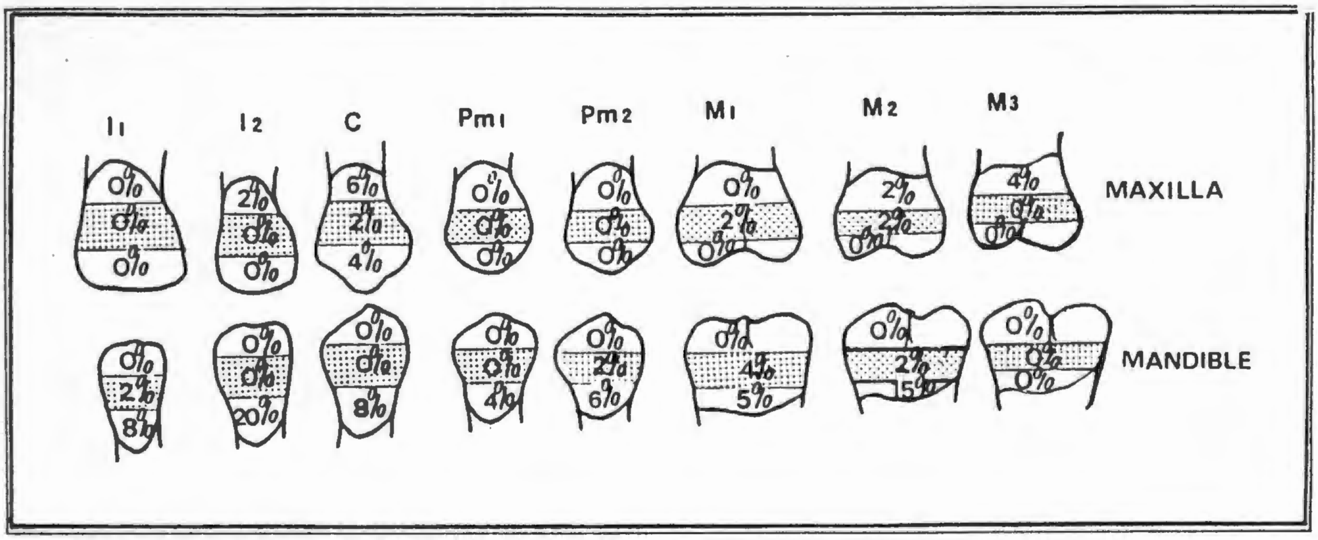


FIGURE 29: PERCENTAGE OF ENAMEL HYPOPLASIA BY INCISAL, OCCLUSAL, MESIAL AND CERVICAL CROWN THIRDS BY TOOTH TYPE (ADULT AND JUVENILE DATA POOLED)

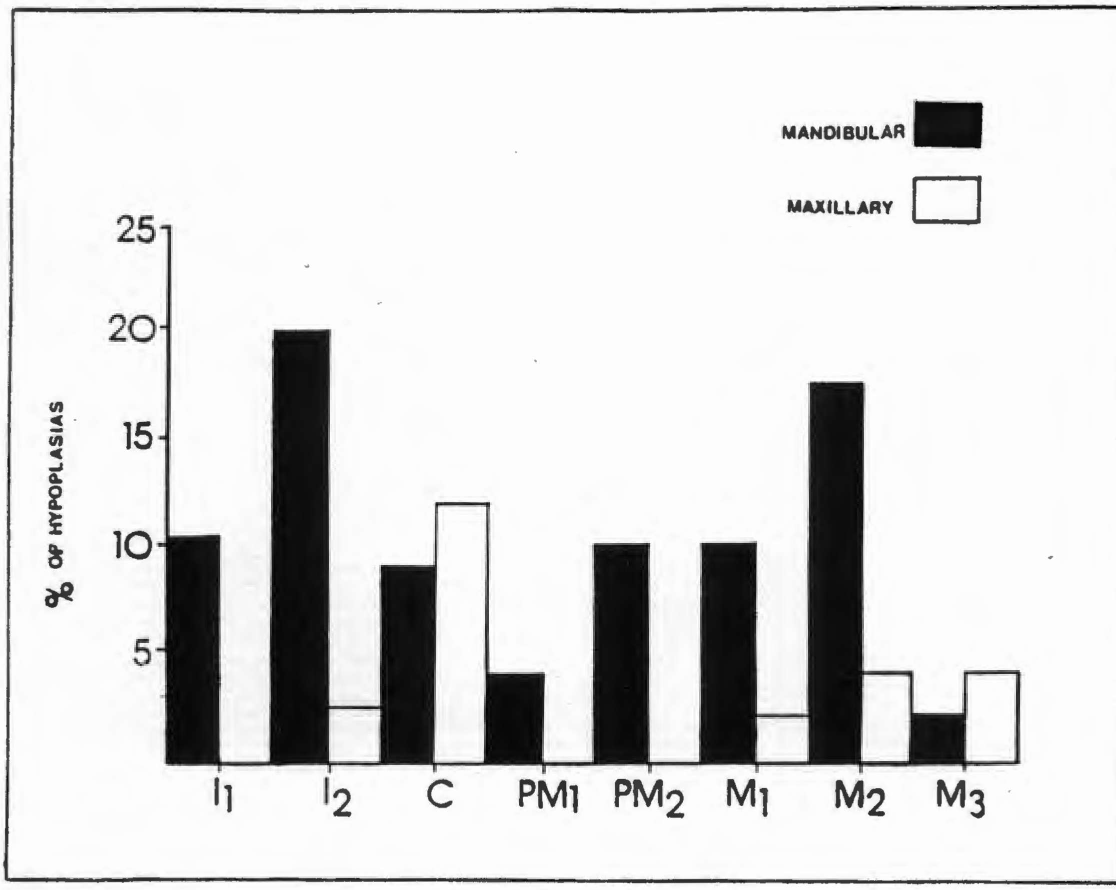


FIGURE 30: PERCENTAGE OF ENAMEL HYPOPLASIA BY MANDIBULAR AND MAXILLARY TOOTH TYPE

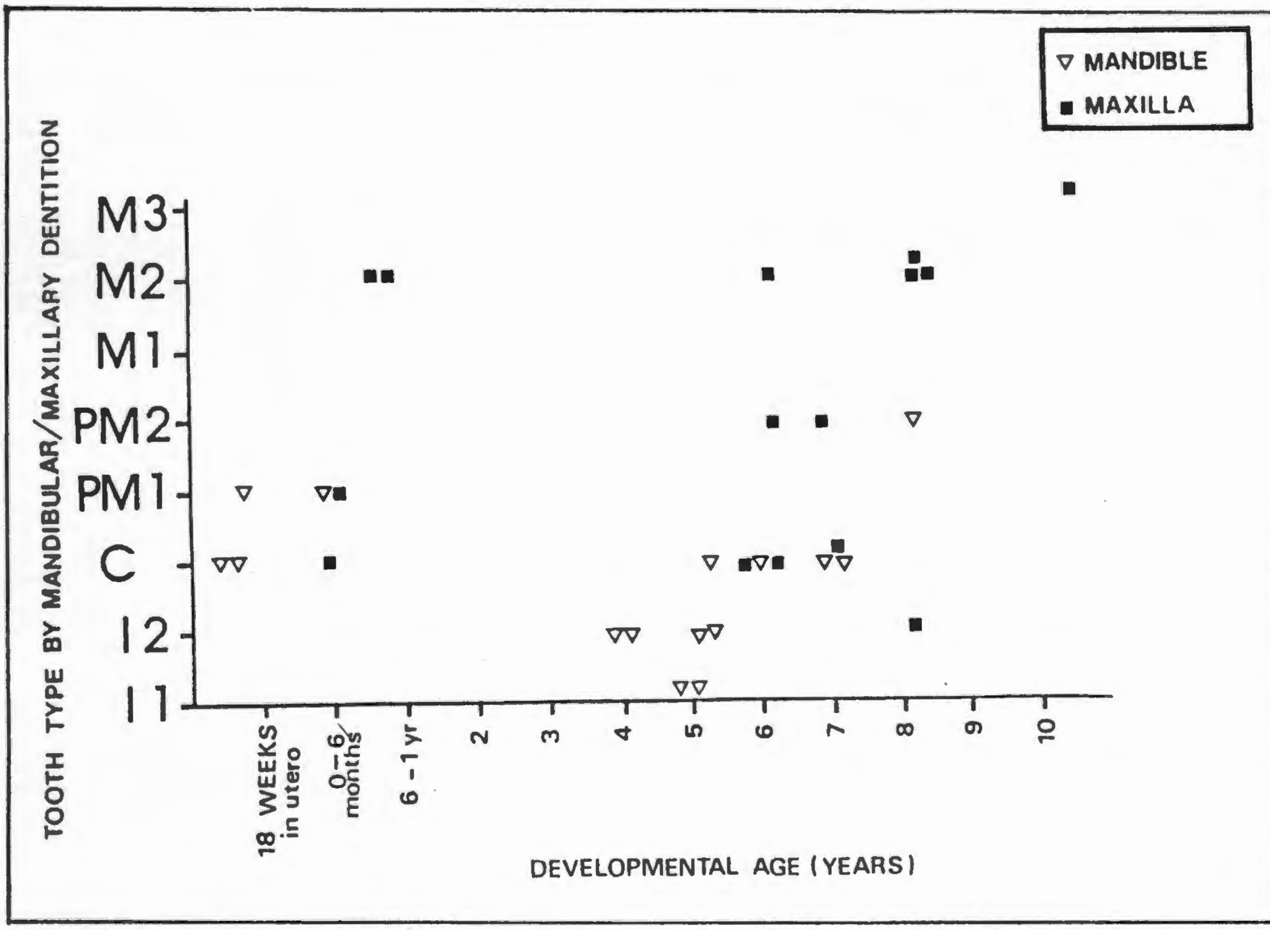
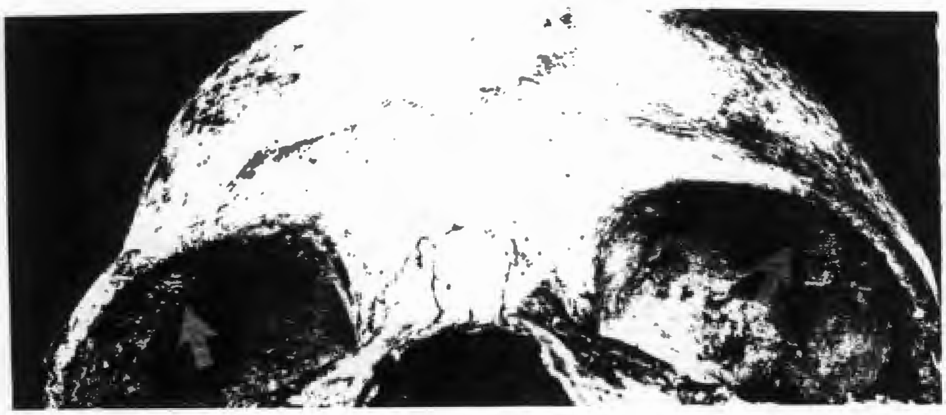


FIGURE 31: DISTRIBUTION OF ENAMEL HYPOPLASIA BY DEVELOPMENTAL YEARS



<u>FIGURE 32</u>: POROTIC HYPEROSTOSIS (cribra orbitalia) IN AN ADULT FROM OAKHURST. NOTE THE PATTERN OF VASCULARIZATION (TRABECULAR TYPE) IN WHICH THE POROTIC OPENINGS HAVE COALESCED INTO A PATTERN OF LARGE, IRREGULAR HOLES (UCT 211)

	No OF INDIVIDUALS WITH POROTIC HYPEROSTOSIS	% OF TOTAL
MALES	2	11
FEMALES	2	11
UNSEXED JUVENILES	7	39
TOTAL:	11	61

	No OF INDIVIDUALS WITH REMODELLED LESIONS	%	No OF INDIVIDUALS WITH UNREMODELLED LESIONS	% OF TOTAL
MALES	2	11	0	6
FEMALES	1	6	1	0
UNSEXED JUVENILES	3	16	4	22
TOTAL:	6	33	5	28

TABLE 14: SUMMARY OF THE DISTRIBUTION OF POROTIC HYPEROSTOSIS IN THE OAKHURST SAMPLE

AGE GROUP	No. OF AFFECTED INDIVIDUALS	*TOTAL No. OF INDIVIDUALS	% OF TOTAL IN AGE CLASS
0 - 6 mths	3	3	100%
6 - 1 yr	0	0	0
1 - 3 yrs	4	4	100%
3 - 15 yrs	1	1	100%
15 - 20 yrs	1	1	100%
20 - 25 yrs	1	5	20%
25 - 30 yrs	0	3	0
30 - 40 yrs	2	2	100%
TOTAL	11	18	61%

TABLE 15: FREQUENCY AND DISTRIBUTION OF POROTIC HYPEROSTOSIS IN THE OAKHURST SAMPLE

* Only individuals with complete orbits were used for this study

MUSEUM NO.	CARBON	NITROGEN	AGE/SEX
UCT 199	-14.23	12.81	30-39 ♂
UCT 200	-12.35	15.98	20-29 ♂
UCT 201	-14.04	11.34	30-39 ♀
UCT 202	-13.39	12.27	40 + ♂
UCT 203	-16.65	9.26	30-39 ♀
UCT 204 (nr grave 11)	-13.59	13.24	30-39 ♀
UCT 204	-14.46	10.09	4-5
UCT 205(1)	no collagen	-	-
UCT 205(2)	-12.57	12.17	20-29 ♂
UCT 206(1)	-12.38	14.66	30-39 ♂
UCT 206(2)	-12.32	11.1	30-39 ♀
UCT 207(H)	-13.78	12.97	5-9
UCT 207(I)	-14.07	12.26	1-4
UCT 207(G)	-11.12	16	1-4
UCT 208 (grave 10)	-10.88	10	5-9
UCT 208 (grave 9)	-15.4	10.86	1-4
UCT 209	-12.34	13.65	20-29 ♂
UCT 210 (10c)	-12.43	15.49	1-4
UCT 211	-13.94	10.67	30-39 ♂
UCT 212	no collagen	-	-
UCT 213	no collagen	-	-
UCT 213 (grave 16/2)	-15.89	9.52	15-19
UCT 213 (grave 16/3)	no collagen	-	-
UCT 214	no collagen	-	-
UCT 215P	-16.44	12.03	0-11.9mths
UCT 215D	-11.67	14.73	1-4
UCT 215 (grave 10)	-15.74	9.79	5-9
UCT 215 (I)	-13.75	12.31	1-4
UCT 216 (Q)	-10.43	16.48	0-11.9mths
UCT 217 (K)	-15.44	10.96	0-11.9mths
UCT 217 (M)	-15.88	12.14	0-11.9mths
UCT 217 (N)	-13.31	15.93	0-11.9mths
UCT 217 (F)	-14.07	12.26	1-4
UCT 217 (L)	-14.14	12.8	0-11.9mths
UCT 218 (6D)	-11.96	5.15	20-29 ♀
UCT 218 (6B)	no collagen	-	-
UCT 218 (D)	no collagen	-	-

TABLE 16: CARBON AND NITROGEN ISOTOPIC DATA FOR THE OAKHURST SAMPLE

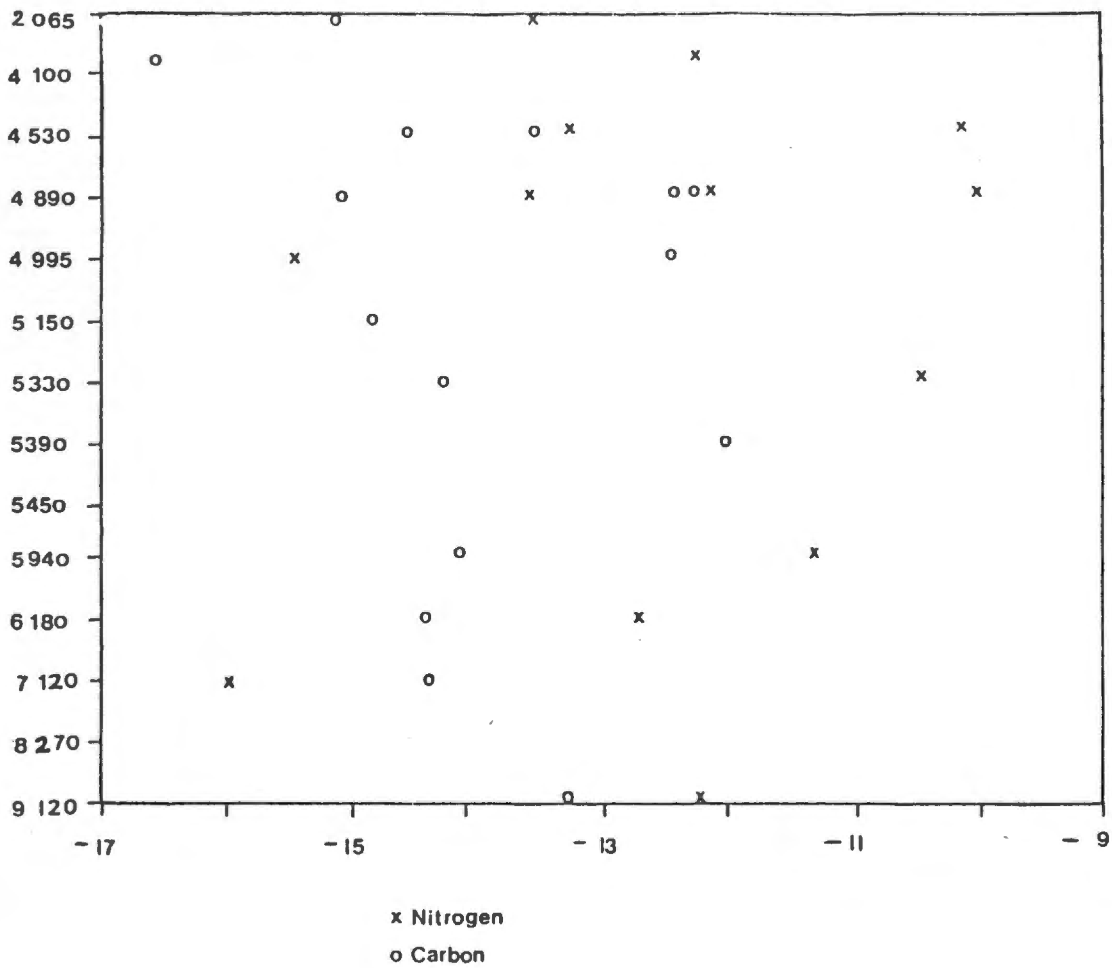


FIGURE 33: DISTRIBUTION OF $\delta^{13}C$ and $\delta^{15}N$ THROUGH TIME (YEARS BEFORE PRESENT).

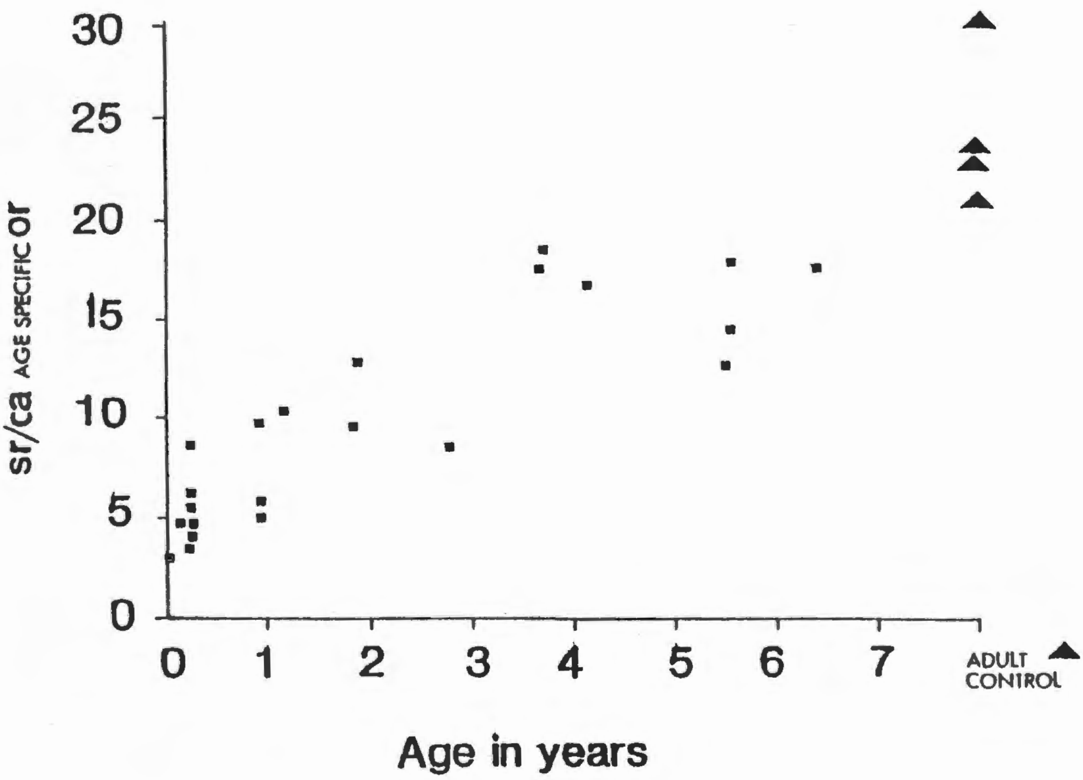


FIGURE 34: ESTIMATED DIETARY Sr/Ca AT OAKHURST

	9 - 5150 BP		% of total	4 - 2000 BP		% of total
POROTIC HYPEROSTOSIS *	n	3	33%	n	2	25%
	without	6		without	6	
	total	9		total	8	
CARIES *	n	3	33%	n	2	25%
	without	6		without	6	
	total	9		total	8	
ENAMEL HYPOPLASIA *	n	4	44%	n	2	25%
	without	5		without	6	
	total	9		total	8	
ARTHRITIS *	n	6	60%	n	4	50%
	without	3		without	4	
	total	9		total	8	

TABLE 17: COMPARISON OF FREQUENCY OF EPISODIC AND GENERAL STRESS IN TIME

* Only individuals with a radiocarbon date are included in this table

CHAPTER NINE

DISCUSSION

POPULATION, HEALTH AND SUBSISTENCE

The main thrust of this thesis was to explore the usefulness of dental and osteological observations and assess how best they may be used to reconstruct prehistoric lifestyle of the Oakhurst people. The importance of lifestyle data is that it may have the potential to illustrate ecological, demographic and dietary transformations in living standards. In this study the use of lifestyle analysis has been useful in distinguishing periods of stress which may have limited the distribution and density of human groups in southern Africa.

The incidence of stress at the general level of analysis documented in the Oakhurst sample is expressed by the frequency and distribution of porotic hyperostosis and demographic data. The incidence of these stressors is significantly higher than that previously reported for hunter/gatherer, pastoralist groups. Where possible the results of this thesis have been compared with similar osteological analysis carried out in southern Africa. Where comparative South African data is unavailable the Oakhurst data is compared with data from similar studies undertaken on California Indian populations.

Much of the demographic data reported here is similar to that given for other prehistoric populations. What differs however is the unusually long birth spacing interval and the confidence intervals calculated for life expectancy in the 20-29 year age category. Both indices suggest a more stressful environment for the people of Oakhurst. The incidence of porotic hyperostosis is higher than that reported by Morris (1984) for hunter gatherers and historic Khoi in southern Africa.

These data, by presenting the case of clearly stressed hunting and gathering people at Oakhurst refute Gall and Saxe's (1977) hypothesis that hunter/gatherers were always less stressed than the pastoralist/agriculturalist who preceded them. The results of this thesis support Ammerman's (1975) hypothesis that hunter/gatherers could live in a hostile environment. However, they differ from Ammerma's (1975) results in as much that hunter/gatherers did not live in an environment where they were exposed to starvation and frequent bouts of episodic stress; rather, hunter/gatherers were exposed to general stress as a result of overdependence on marine resources. In this respect the hunter/gatherers of the south coast of southern Africa differ little from agriculturalists who relied heavily on cereals or root crops. The people of Oakhurst increased their efficiency of resource exploitation, particularly if efficiency is measured in production per unit space per unit time as well as seasonal stabilization of food intake. However, while subsistence economies in this region utilized a broad spectrum of resources they increasingly emphasized a few major staples that shared the attributes of abundance and seasonal concentration in a specific territory.

An interesting trend in the data collated from Oakhurst (Table 15) although not amenable to statistical testing is the suggestion that the skeletal sample analysed between 9 and 5 000 BP shows a higher incidence of porotic hyperostosis, caries, enamel hypoplasia and arthritis. These findings are interesting in view of the palaeo-ecological and demographic data reviewed in this thesis and support the notion of a demographic move from the Karoo, Orange River Basin and grassland biomes to the south coast of southern Africa. The stimulus for this move is undoubtedly related to climatic and environmental conditions which led to diminished vegetational cover and a corresponding lower animal cover. As an example, a rise of 1 metre in sea level would have a catastrophic effect on available resources. Tidal surges and flood waters would destroy shellfish communities and render less plant and animal life for exploitation. In addition to this it has recently been reported (Boyd 1988) that an increase in atmospheric carbon dioxide stimulates the growth of C3 plants. Plants grow more quickly and larger under such conditions. However, they are less nutritious. Given that iron and minerals are difficult to absorb (Natvig and Villar 1973, Wadell 1974) from vegetable sources under normal conditions, plant nutrients played a limited role in the overall nutritional input. It is suggested that these factors may very well have been responsible for the increase in general stress observed in groups living along the South coast between 9 000 and 5 000 BP.

Around 4 000 years ago the sea level reached its present level and estuarine conditions prevailed. Forest encroachment into coastal areas continued until 2 000 BP and this may have had a beneficial input into plant nutrition in as much that forests return carbon dioxide to the earth. The introduction of fish and small terrestrial animals around 4 - 2 000 BP. would also have increased the number of dietary items available for exploitation and this presumably was important in reducing nutritional stress.

In the absence of population pressure, when people enter an unpopulated region, they tend to minimize efforts and maximize nutritional quality and reliability. The inhabitants of Oakhurst, it is suggested, turned to marine foraging as a means of subsistence in the face of dwindling terrestrial resources due to environmental factors. This led to reliability of food supplies and the overall lessening of labour demands and helped buffer human groups against periodic food crises. The only problem with this food collecting strategy was that it led to overdependence on a staple which did not provide all the necessary vitamans and minerals necessary for healthy physiological functioning. A direct consequence of this overdependence on a food staple was lower fertility, and perhaps parasitic infestation and infection, which would influence longevity and infant/juvenile mortality. This could result in low overall growth and low to moderate increase in population size. Such an interpretation would demonstrate therefore that human populations, rather than being static entities, are dynamic groups influenced strongly by their environment.

Food collecting strategies

Students of archaeology are familar with Lee's (1965) concept of the affluent society in which hunter/gatherers may select food from a seemingly endless larder. The concept, however, is called into question (Hawkes and O'Connell 1981) when evaluated in terms of total energy expenditure and the net energy gain after deduction of the energy expended in food procurement and preparation. The concept has been expanded upon by Buchannan (1987) for marine dependent groups and by Henneberg (1984) for Iron Age people from Poland. In this light Lee's affluent society may be viewed in a different way. It is this relatively simple notion of intake and output that is vitally important in understanding morphological traits such as cranial shape and stature. Stature is the trait with which we are most familar when dealing with growth and nutrition. There are, however, a number of other traits which reflect growth. Pucciraelli (1980) has demonstrated that aspects of craniofacial growth reflect nutritionally related growth. Using these concepts it is suggested here that the proposed morphological differences observed in the Oakhurst skeletons by Drennan (1938), Rightmire (1970), Hausman (1980) may be equated with life style and changes in foraging strategies rather than genetic differences. Since less gross energy is required in marine based strategies it is suggested that the people of Oakhurst reached their genetic potential for height.

The repeated demonstration of nutritional influences on growth and development (Frisancho et al. 1970 a.b.), plus the possibility of nutritional variation between any two populations, prompts a reconsideration and re-evaluation of the different effects of malnutrition during childhood and adolescence. A debate has emerged over the meaning and interpretation of such findings as the small body size and delayed maturation of undernourished children (Stini 1972) and of the significance of the apparent age sex differences in response to stress.

Bielick and Welon (1983) have proposed that a 6cm difference in stature within the same population, represents the range of 'ecosensitivity' of its inhabitants. This means that those individuals at the lower end of the stature range have not reached their genetic potential for height while those at the upper end of the range have. One must consider whether the phenotypic expression of height both at the lower and upper limits of the range are traits that were selected for due to environmental demands imposed on the individual. Morphological variation and its resultant effect on a variety of functions, such as work capacity and reproduction has been relatively well investigated (Mueller 1979, Frisancho et al. 1973) and the necessity of considering the possible role of nutrition as an intervening variable between environmental input and a growth outcome cannot be emphasised enough. In order to evaluate nutritional influence one must understand what nutritional variation can and cannot produce in terms of effect on human growth before one considers the people of southern Africa as distinct genetic types.

The study of stature and cranio-facial traits needs to be re-evaluated in light of the 'ecosensitivity' hypothesis. Additional information pertaining to the nature and extent of human skeletal stressors, both episodic and general, needs to be collated from diverse geographical locations and from culturally similar and dissimilar groups. Stable carbon isotopes, nitrogen and strontium values are also required in order to test the archaeological data. These data are however relatively unimportant without some form of absolute dating. Large numbers of radiocarbon dates are therefore required. Only in this way may one make some qualitative hypothesis concerning human evolution and adaptation to the environment, both biologically and culturally.

CHAPTER TEN

CONCLUSION

In general, we may conclude the following:

(1) Life table data suggests that the hunter/gatherer sample studied had, on average, a life expectancy of 33 years. The reproductive span of the hunter/gatherer female is estimated liberally as from 6 to 7 years of age, a period of 19 years. With a 6 to 7 year spacing between births a woman, on average, could produce only three infants that might reach sexual maturity. As the infant and juvenile mortality rate was 50% only 1.5% individuals would reach adulthood. This is the number which is necessary for the population to maintain numerical equilibrium and suggests that the Oakhurst sample were capable of moderate natural increase. It is clear that birth spacing is an important factor limiting the growth of human populations.

(2) Radiocarbon data provide a window into the past and demonstrates that the Oakhurst Rockshelter was used throughout the Early and Late Holocene with no breaks in occupation. This suggests that the South coast of southern Africa provided a favourable habitat for Holocene groups. It is also proposed that groups living in the arid interior between 9-4 000 BP moved to the South coast to exploit more favourable resources associated with forest and estuarine habitats.

(3) Stable isotope and nitrogen data from human skeletons suggest that marine foods were the major constituents of the diet. These data confirm the results of zooarchaeological analysis from the Oakhurst cave. Isotopic analysis suggests that these dietary proportions apply

to the entire annual round and not just the seasonal use of the coast. Isotopic analyses suggest that a marine dependent diet was a consistent subsistence base throughout the Holocene. Strontium data suggests that dietary supplementation was delayed and that children were being weaned from their mothers at age 4 years. Human milk, however, may have continued to supplement the diet of children until the age of 8 years.

(4) There is relatively little variation among the isotopic values given for this sample. Infant and juvenile data are internally consistent and similar to those of adults. There is also relatively little variation among the isotopic values for males and females, which suggests that this was a relatively egalitarian society.

(5) The predominantly coastal diet consumed by the Oakhurst people, while it appears a healthy one, gave rise to a number of health problems, particularly for juveniles and women. It is argued here that a heavy reliance on marine foods led to iron deficiency anaemia which was further compounded by diarrheal infections from eating raw or partially cooked fish contaminated with parasites. A pattern of dietary stress, more general than episodic is evidenced by the frequency and distribution of porotic hyperostosis. This stressor is thought to outline a graded response to systemic stress from a prolonged reliance on an unbalanced diet rather than periods of food shortage.

(6) The frequency and distribution of dental caries is not considered relevant as a dietary tracer, given the natural tendency of women having a higher caries index than men. One could argue that since the males in this sample show a higher incidence of caries than women that

this is evidence of 'snacking'. The complex aetiology of caries, however, refutes this and it is suggested that an increase in carious lesions in the Oakhurst sample reflects poor oral hygiene which is an individual trait not amenable to testing.

(7) There is little evidence of traumatic pathologies among the Oakhurst sample. The pathologies noted are associated with habitual behaviour, or life style.

(8) When the sample is divided in time it would appear that people living in the Early Holocene were more stressed than people living in the Late Holocene.

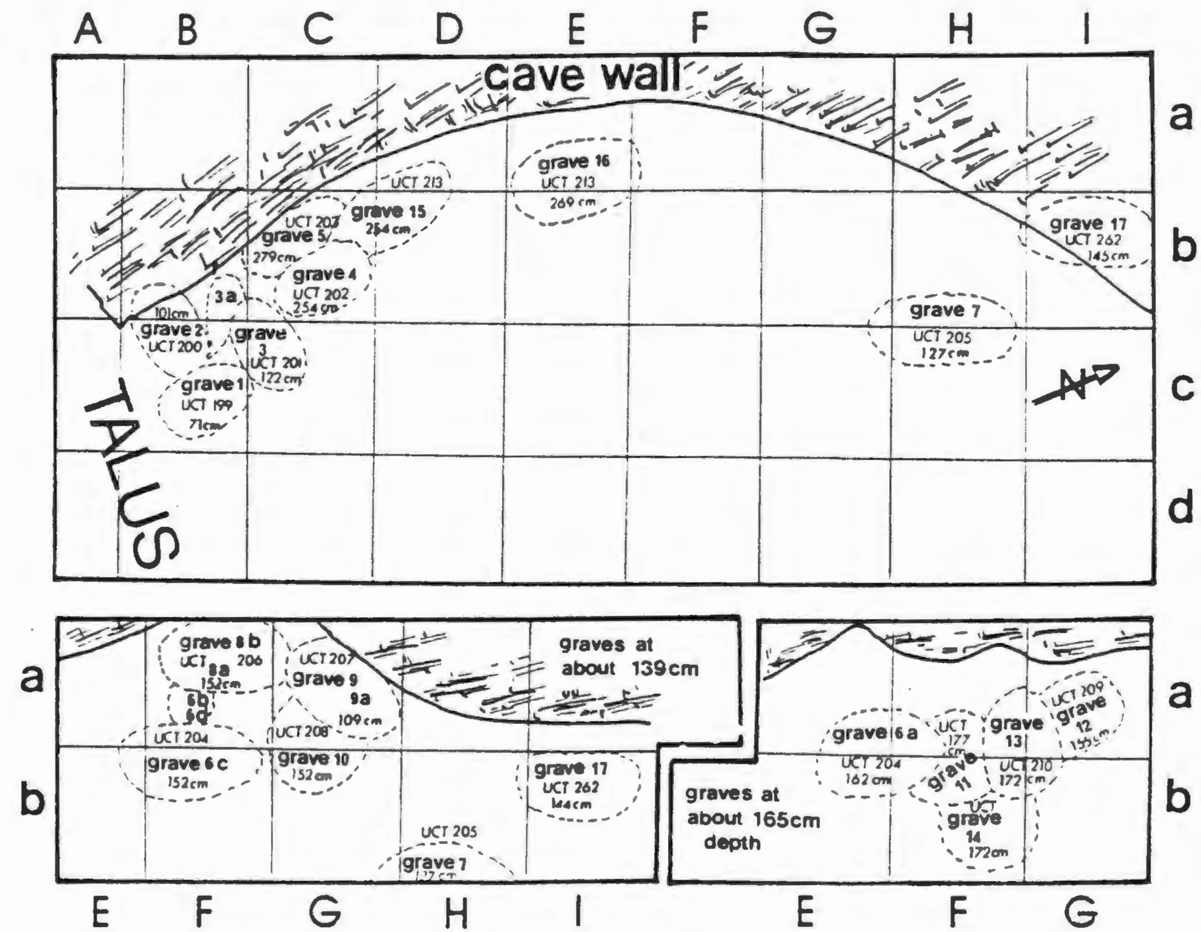


FIGURE 35: SKETCH PLAN SHOWING POSITION AND DEPTH OF GRAVES AT OAKHURST (Adapted from Goodwin 1938)

GRAVE No.	MUSEUM No.	STRATOGRAPHIC LOCATION: Depth	ARCHAEOLOGICAL CONTEXT/REMARKS
GRAVE 1	UCT 199/180	71cms	Excavated from talus southern end of the shelter. Flexed burial, left side facing east, head to south. Disturbed burial.
GRAVE 2	UCT 200/182	101cms	Fully flexed burial, on right side. Disturbed burial.
GRAVE 3 and 3a	UCT 201/183	122cms	Smithfield B or C - also disturbed skull of second individual. Fully flexed lying on right side facing south, head to east. The entire skeleton was intact and undisturbed.
GRAVE 4			Missing, never accessioned.
GRAVE 5	UCT 202/185	279cms	Disturbed burial Smithfield B. Sacrum and skull marked signs of red ochre.
GRAVE 6	UCT 203/191 216J/194	114-145cms	Disturbed grave. The remains of six individuals were recovered from this section. The entire grave lined with sea-grass. Wilton artifacts.

APPENDIX 1 SKELETAL MATERIAL RECOVERED FROM OAKHURST ROCKSHELTER (Adapted from Goodwin 1938)

GRAVE No.	MUSEUM No.	STRATOGRAPHIC LOCATION: Depth	ARCHAEOLOGICAL CONTEXT/REMARKS
GRAVE 6a	UCT 204	162cms	An earlier interment underlying 6. Three gravestones covered the burial, all with red ochre. Skeleton lay on right side, facing east, head to south.
b	UCT 218B-D	152cms	Wilton artifacts, a bored stone and four conus shells found
c	UCT 190	152cms	O.E.S.Bracelet 1½ins wide.
d	217E/191	152cms	
	217C/189	152cms	
	215P	152cms	
GRAVE 7	UCT 205	127cms	Child burial, body flexed and lying on right side, facing east, head to south. A number of shells, <u>Donax serra</u>, lay along the spinal column. A girdle consisting of a single strand of ostrich eggshell beads was strung round the waist. Wilton artifacts.
7a	UCT 217M/187		Complete skeleton of an adult.
GRAVE 8	UCT 217N/188	106cms	Disturbed child burials
	UCT 2151/195	116cms	
	UCT 206/181	152cms	Disturbed adult burials. Possible Wilton burial. One fully flexed burial, lying on the right side facing west, with head to north, buried under nine gravestones. Individual found with a pierced oval of nacre and a piece of ochreous shale, also a mountain-tortoise shell at the nape of the neck.
GRAVE 9	UCT 215G & H	109cms 106cms	Double burial, probably twins, fully flexed. Both lying on right side, facing east, head to south. Lying in a grave lined with sea grass.
	UCT 207G/197 207H/196		Probably Wilton.
9a	215/195	46cms	Body lying on right side, facing west, head to north and lying in sea-grass. The presence of two pierced shells in the neck region suggest that burial was Wilton. Disturbed burial.

GRAVE No.	MUSEUM No.	STRATOGRAPHIC LOCATION: Depth	ARCHAEOLOGICAL CONTEXT/REMARKS
GRAVE 10	UCT 208/193	152cms	Fully flexed, lying on left side, head to the south-east, facing north-west. Several gravestones overlayed the body. Hundreds of ostrich eggshell beads and a spherical bored stone found in association with this grave. Skeleton appears to have been buried on top of a heap of shell Donax serra.
GRAVE 11	UCT 209/186	177cms	Disturbed burial. Skeleton lay on its right side, skull to south-west, facing south-east. A slate palette was found with this skeleton.
GRAVE 12	UCT 210	155cms	Disturbed burial. Buried under and before grave 9 and next to grave 10. Also disturbed by grave 13. Child burial. Four col-conus shells were found around the neck, a spoon-shaped nacre shell at nape of the neck, another at the throat. At the base of the spine was a third. A few ostrich eggshell beads in filling suggests that the burial was either Smithfield C or Wilton.
GRAVE 13	UCT 211/184	172cms	Disturbed burial. Skeleton lay on right side, head to west, facing south. Skeleton buried on a heap of Donax shells. An ivory palette, split into fragments and about 30 double-pierced nacre ovals were found about the neck. Red ochre was visible on the limbs and skull.
GRAVE 14	UCT 212	172cms	Disturbed burial. Skeleton lay on right side, facing south-east, the spinal column pointing south-west. Half flexed. Five gravestones overlay the body, two of which were river boulders, both show use as lower grindstones and bear red ochre paint, no design. Child burial.

GRAVE No.	MUSEUM No.	STRATOGRAPHIC LOCATION: Depth	ARCHAEOLOGICAL CONTEXT/REMARKS
GRAVE 15	UCT 213/192	254cms	Disturbed burial. Fully flexed. Lying on right side, head to north, facing west. Ostrich eggshell beads. A bored limpet shell and red ochre found in association with the burial. Smithfield B artefacts.
GRAVE 16	UCT 213	269cms	Skeleton of a child which lay on its left side, head to south, facing west, flexed. Skeleton buried in red ochre. Second burial, disturbed, of a child.
GRAVE 17	UCT 262	144cms	Skeleton lay on right side, head to north, facing west. The shell of a water-tortoise covered the left arm. One or two fragments of nacre - not accessioned.
GRAVE 18	UCT 214	145cms	Disturbed burial. Fragments of an earlier skeleton used as infilling for this grave.

FIGURE 36 : VIEW OF THE OAKHURST DEPOSIT LOOKING NORTH (After Goodwin 1938)

FIGURE 37: GRAVE 1 (UCT 199/180)

FIGURE 38: GRAVE 3 (UCT 201/183)

FIGURE 39: GRAVE 6 (UCT 203/191)

FIGURE 40: GRAVE 6A (UCT 217/189)

A

FIGURE 41: GRAVE 7 (UCT 205)

FIGURE 42: GRAVE 15 (UCT 213/192)

FIGURE 43: GRAVE 17 (UCT 262)

FIGURE 44: GRAVE 13 (UCT 210)

FIGURE 45: GRAVE 13 (UCT 211/184)

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