CANINE DENTAL MICROWEAR AND LIGHT STABLE ISOTOPIC ANALYSES OF SOME SOUTH AFRICAN HOLOCENE POPULATIONS

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ABSTRACT

This thesis uses light stable isotope analyses as the basis against which to evaluate the efficacy of canine dental microwear in distinguishing different diets between some Holocene populations in southern Africa. It has been recognised for some time that the use of stable isotopes as the basis for dental microwear evaluations may be a valuable method for determining dietary activities. These methods are used together for the first time here.

Three southern African Holocene populations representative of different dietary regimes were sampled for both carbon apatite and canine microwear. The information gleaned from carbon apatite values was supplemented by existing collagen information.

General dietary trends are discernable between the three populations based on isotopic analyses. Coastal hunter-gatherer populations from Matjes River and Oakhurst subsisted largely on a diet of marine foods, supplemented by C_3 or C_4 terrestrial resources. K2 agriculturalists indicated diets based largely on the exploitation of domesticated stock supplemented by wild hunted/gathered/snared foods. Isotopic ratios for inland hunter-gatherers vary depending on geographical location, but largely reflect a diet based on the resources available from the biome of habitation. Two Harrismith burials, thought to be hunter-gatherers, may indicate some contact with sedentary populations.

These dietary trends are not borne out by canine microwear analyses. Canine microwear indicates statistically significant differences only in the concentration of features. These differences are however subject to groupings and probability limits and are therefore not regarded as viable dietary indicators.

Isotopic results for this study substantiate those from previous research in recognising dietary patterns associated with particular Holocene populations in southern Africa. However the analysis of canine dental microwear in human populations is not sensitive enough to detect dietary differences.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Archaeology is chiefly concerned with the reconstruction of human behaviour from material remains. The choice of foods and the methods used to obtain it, is a central feature of the interaction of humans with the environment. A knowledge of dietary activity is therefore essential to any complete investigation of past human populations. Having recognised this, archaeologists have developed diverse methods for recovering dietary information.

The goal of understanding dietary behaviour has stimulated several specialised fields of dietary analysis. These can be generally understood in terms of skeletal information on the one hand, and contextual information on the other (White 1988). Skeletal data deals with those factors that are primarily associated with specific individuals. Tooth wear analyses, chemical analyses and contextual physical anthropology are examples. Cultural artefacts, lithic assemblages, faunal and floral remains are all contextual in nature and detail group activities.

Initial dietary investigative methods were qualitative rather than quantitative in nature. The examination of faunal and floral remains from a particular site provide key aspects of how a population lived, both in terms of environmental information, and dietary factors. However, the assessment of diet based solely on faunal and floral remains are largely subject to preservational constraints. Faunal assemblages usually provide direct information of dietary activities, however certain faunal elements may be introduced into the deposit by agents other than humans. Preservation also limits what skeletal elements survive until excavation. Thus, while faunal analyses may give us information about the presence of a given food item such data are often incomplete. Flora is subject to an even greater sampling error. Plant material survives very infrequently, so that even when the

bones of animals indicate the exploitation of individual species, the plant component in a diet is often invisible.

In order to address the limited information of differential preservation, alternative methods were sought. Analysing skeletal remains may provide information on disease, nutrition and dietary abrasion. More recently, dental microwear and chemical analyses of skeletal remains have been employed to assess dietary activities.

Initial qualitative assessments of gross dental wear indicated the relative consistency of dietary items (Dahlberg & Kinzey 1962; Rensberger 1978; Walker et al 1978; Covert & Kay 1981). This method has been refined into the highly quantitative examination of dental microwear. Most studies have concentrated on molar microwear. These teeth are involved in active mastication and are likely to reflect dietary consistency rather than food manipulation or ingestion (see Teaford 1988; Ungar 1992 for reviews). Recently, incisor microwear investigations have been conducted on a variety of extant and extinct anthropoids (Walker 1976; Ryan 1979; Ryan & Johanson 1989,1981; Kelley 1986, 1990; Ungar 1990;1994;1996; Grine & Ungar 1991; Ungar et al 1991). These studies suggest that anterior dental microwear provides information about diet, as well as allowing inferences relating to ingestion and other manipulatory behaviours not directly discernible from the analysis of molar teeth.

Chemical analyses are also highly useful methods for determining dietary activity. Under certain circumstances, the analysis of light stable isotopes, both carbon and nitrogen, provides an understanding of what types of foods form the basis of an individuals' diet. In contrast to dental microwear analyses, this approach provides a long-term indicator of diet. For instance, in agricultural populations, the milling of cereal grains introduces a gritty element into the diet that should leave distinct microwear features on the teeth, however, microwear analyses will not provide information about what cereal is being consumed. The distinctive isotopic signatures of plants that form the basis of isotopic analyses may help determine more specifically what type of cereal is being eaten.

Chemical investigations also record those components of the diet that may be invisible to microscopic detection. Meat may not leave any distinctive microwear features (van Valkenburgh et al 1990), but the analysis of stable isotopes may in some instances detect this component of the diet. Isotopic analyses has been successfully employed to reconstruct prehistoric human diets (van der Merwe et al 1978; Ambrose & DeNiro 1986; Lee-Thorp 1989; Sealy 1997; Sealy et al 1992; Lee-Thorp et al 1989), as well as investigations of seasonal transhumance of past hunter-gatherers (Sealy & van der Merwe 1986), the introduction of domesticated plants into diet (for example: Vogel & van der Merwe 1977; van der Merwe et al 1981; Lee-Thorp et al 1993) and marine dependence (for example: Chisholm et al 1982; Schoeninger & DeNiro 1983; Sealy et al 1987; Schoeninger et al 1983). The analysis of light stable isotopes is thus a complimentary method for investigating prehistoric diets that may enable a more comprehensive understanding of the dietary regime of early humans.

A second avenue of chemical investigation is the analysis of trace elements. Strontium is a trace element that is taken up from soil and incorporated into bone mineral. Plant material provides about three times as much strontium as does animal flesh. Therefore, in a given foodweb a herbivore's diet will reflect larger amounts of this trace element than an omnivore, while a carnivore will reflect the least strontium (Schoeninger 1979). Strontium analyses have been used to determine proportions of meat and vegetables in a populations' diet (Szpunar et al 1978), to compare these proportions between sites (Brown 1973), to estimate dietary change over time (Lambert et al 1979), to determine the social status of individuals' within a society (Blakely & Beck 1981), to estimate weaning profiles in prehistoric populations (Rehnberg et al 1969; Sillen & Smith 1984) and to determine predator-prey relationships (Sillen & Lee-Thorp 1994; Sillen & Hall 1995; Sillen 1992).

Where faunal assemblages provide information about particular species exploitation, chemical and microwear analyses help to understand those components of the diet that are typically invisible during excavation. While both of

these methods are well known and well established, they have not yet been used together. Yet they are complimentary tools that should ideally be used jointly to provide a more comprehensive understanding of dietary activity.

1.2 Aims

This study aims to investigate the efficacy of canine dental microwear as a means of determining dietary activity against the background of reconstructed diets from isotopic and conventional methods. Molar microwear and recently, incisor microwear have received extensive attention. However, the analysis of canine dental microwear is less well understood. A major part of this research is to determine what information anterior microwear provides us with and to establish whether this is a reliable means of understanding dietary activity. Canines have been selected for a number of reasons. Firstly, canine microwear has received little attention, so there is little knowledge of their efficacy in determining dietary information. Secondly, previous studies (Manning 1995) have suggested noticeable differences between species with different diets. Finally, canines are assumed to function in a similar manner to the incisors, thus providing information about ingestion and food manipulation. However, because they are peripheral to the anterior functional unit, they may provide different information to the incisors.

All microwear studies are comparative in nature. One way to tackle the problem of whether canine microwear provides any information about dietary activity would have been to examine the molar teeth of the selected populations. This would establish characteristic differences between the groups based on the different foods they were eating. Then one could examine the canines wear features against this information.

This study attacks the problem from a different angle. We know from previous studies that molar microwear differentiates between agriculturalists and hunter-gatherers (Pastor et al 1992; Teaford 1991; Pastor 1992; Holly Smith 1984). But this leaves key aspects of the diet unknown. Instead of using molar microwear as the basis against which to investigate canine microwear, this study employs

isotopic signatures as the baseline against which to examine whether canine microwear is an effective method of dietary analysis. By establishing characteristic isotopic patterns for archaeologically well-described Holocene populations one can establish a basis from which to evaluate the information gleaned from dental microwear analyses. Research on these populations also provides supplementary information about the diets and lifestyles of Southern African people over the last ten thousand years.

Three southern African Holocene groups have been selected to investigate the efficacy of canine dental microwear as a dietary indicator (these groups are discussed more fully on Chapter 2). These specimens were selected for a number of reasons. Firstly, the South African Holocene is well understood and researched. Secondly, differentiating coastal hunter-gatherers from agriculturalists based on subsistence activities, is a fairly simple task. Thirdly, samples from the Holocene are *relatively* abundant. The comparatively limited sample sizes for this study should be briefly discussed here. Finding and identifying skeletons of inland hunter-gatherers with certainty is extremely difficult. The open nature of inland sites severely limits preservation and identifying inland populations is problematic. A second limiting factor is finding specimens that not only adhere to geographic and subsistence criteria, but then also have the relevant teeth necessary for inclusion in this study. Satisfying these criteria limits the number of specimens available for analysis.

Three groups have been examined (Figure 1). The first group consists of Holocene coastal hunter-gatherers. The Cape south coast has been extensively studied using both chemical and conventional archaeological analyses, providing a sound foundation for microwear investigations. Coastal skeletal material is abundant and well dated and has the added advantage of being locally available. The second group are inland Holocene hunter-gatherers. Inland skeletal remains are less abundant than their coastal contemporaries. Those adhering to the selection criteria discussed above have been included here. The premise is that if isotopic results suggest different diets between coastal and inland hunter-gatherers, these differences should also be characterised by distinctive microwear patterns.

The third group consists of established Iron Age farmers from the interior. At about 2000BP various food-producing groups emerged in South Africa. These populations were characterised by ceramic manufacture, iron metallurgy and raising non-indigenous domesticated animals and cereal crops (Phillipson 1977). Such a lifestyle was well established by ca. 800AD. This study examines specimens from K2 a site dating to ca. 1100AD. The K2 people were established agriculturalists with signs of social stratification and complex leadership (Huffman 1996). The major shift in technology from hunter-gatherer to active farmer implies a shift in diet. This change in subsistence should be borne out by both microwear and isotopic analyses.

Excavations of the selected sites provide faunal data and thus some information on the types of foods being exploited. Geographic location immediately suggest some resources that are more likely to be exploited than others, thus at the coast, it is likely that people exploited sea-food resources because of the ease of access and availability. Such exploitation is not expected for inland populations. Similarly, agriculturalists are presumed to subsist primarily on cultivated crops and domesticated stock. Understanding the faunal remains from the various sites should support such expectations, providing the first approximations regarding the diet of these respective populations.

Conventional archaeological and dental microwear investigations provide information largely about a collective group of people. That is, faunal and material analyses tell us something about how a group of people lived, interacted, and organised their space. While isotopic techniques provide information about individuals relating to their singular life-histories and subsistence behaviour, this method can also be used as the basis from which to make firmer inferences about group dietary activities.

1.3 Questions

This project addresses four broad issues:

1) Are there quantitative canine microwear differences between the three identified populations?

2) How can such differences be interpreted in terms of dietary behaviour?

3) How can the expected isotopic differences between the three identified populations be interpreted?

4) Are microwear patterns related to isotopic variations associated with specific diets?

Question 4 assumes specific and quantifiable relationships in microwear and isotopic values that are distinctive to each population and is only applicable if answers to questions 1 and 3 are affirmative.

1.4 Summary

Analysis of the three selected populations for carbon, and in some instances, nitrogen isotopes, should provide an understanding of the foods being exploited by these groups. This forms the basis for dental microwear investigations. Using these two methods not only verifies the efficacy of canine microwear as a dietary indicator, but provides information about these different populations. Thus supplementing what little is known of inland hunter-gatherers and the more detailed investigations of the other sites being examined.

Chapter 2 outlines the various populations examined in this study and contextualises them in terms of dietary resources available for exploitation as seen through the archaeological excavation.

Chapter 3 discusses the background of both dental microwear and chemical analyses. Chapter 4 looks at the methodology of these techniques while Chapter 5 outlines the results for this research. Chapter 6 discusses the results for this study and whether canine microwear is an effective indicator of dietary activity.

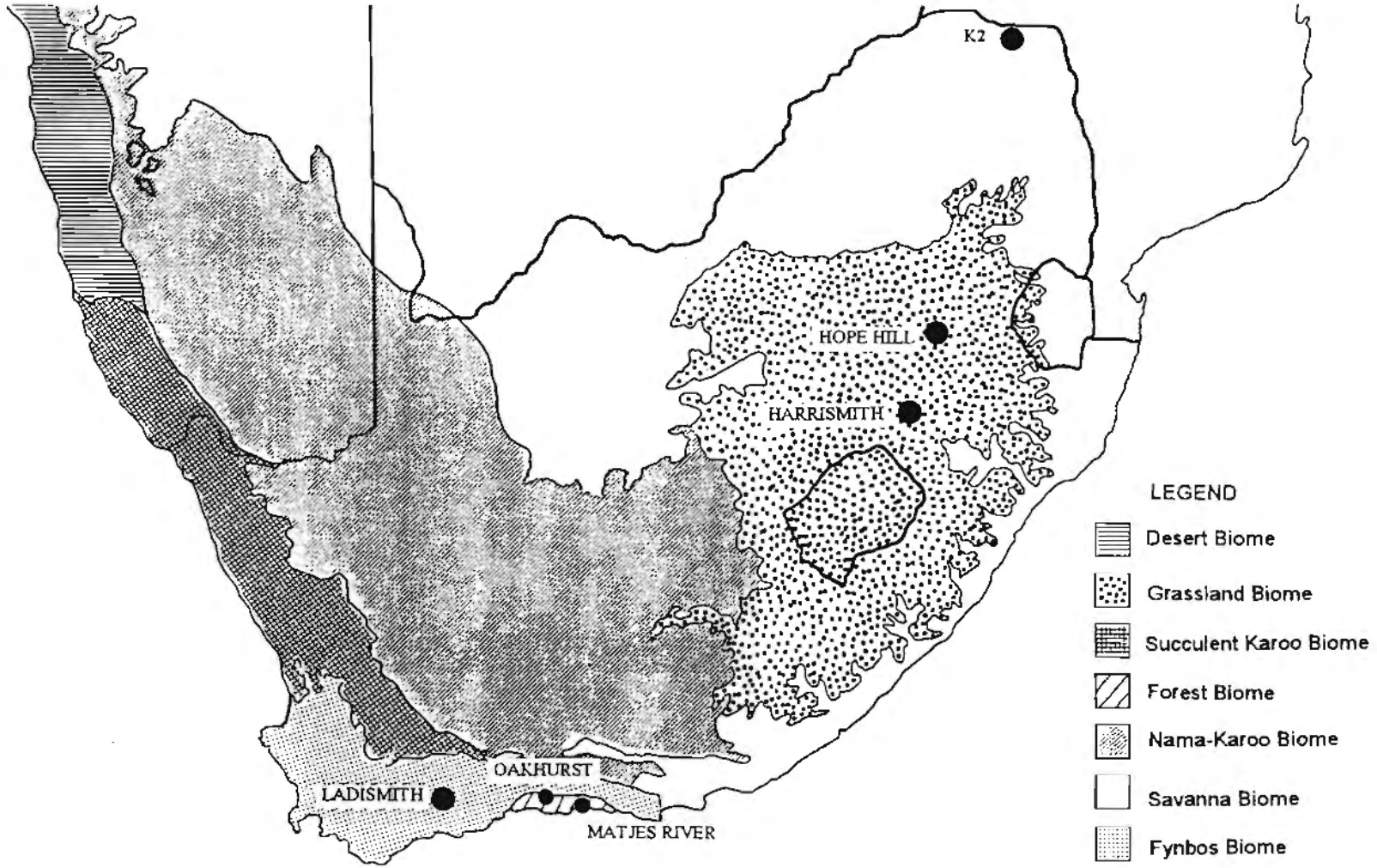


***FIGURE 1*: LOCATION OF ARCHAEOLOGICAL SITES AND BIOMES OF SOUTHERN AFRICA**
(Adapted after Rutherford & Westfall 1986).

CHAPTER 2

HUMAN POPULATIONS EXAMINED

Three different human populations are examined in this study (Figure 1). Each one is representative of a different dietary regime. In the case of the hunter-gatherer groups, these dietary differences are seen both in the geographic locations of the sites, as well as the faunal assemblages. There are two sites which were selected to represent coastal hunter-gatherers; Matjes River Cave and Oakhurst Rock Shelter. Oakhurst was chosen firstly because of its proximity to the coast, secondly because there is a relatively large body of skeletal remains easily accessible for analysis and finally because it falls within the Holocene. Oakhurst has also been well researched and documented. Matjes River Cave is the second of the two coastal hunter-gatherer sites selected for examination. Where Oakhurst is well understood in terms of stratigraphy, Matjes River is less so, resulting in confusion about stratigraphy and skeletal provenience. Despite these limitations, the Matjes River sample adheres to the same criteria as those from Oakhurst. Namely the proximity of the site to the coast, the accessibility of skeletal remains for analysis, and the control over relative chronological range.

The site of K2 was selected as representative of an agricultural community. This implies a semi-sedentary group practising mixed farming and cultivating cereal crops (Phillipson 1977). Although contemporaneous sites in southern Africa indicate a reliance on hunted or gathered foods by agriculturalists, K2 faunal remains suggest that cattle keeping and exploitation was a dominant activity (Voigt 1983). This factor was paramount in selecting this site for analysis, as such a reliance on domestic stock minimises any potential confusion with transitional hunter-gatherer groups. As with the two coastal sites, K2 provides sufficient skeletal samples that are well provenienced and dated.

The sites of Harrismith, Hope Hill Shelter and several isolated burials from the Ladismith area, all represent inland hunter-gatherers. These skeletal

remains were less easy to trace. Geographical positioning played the most important role in their selected. As with the other sites, the samples selected are not all that are available, however, the need to sample maxillary canines for microwear analysis, decreases the sample quantities to those with suitable anterior teeth.

During the Holocene (last 10 000 years) the Cape coast was extensively occupied by people who exploited the coastal resources heavily (Deacon 1982; Parkington 1984; Thackeray 1981; Wadley et al 1992). Such exploitation can be seen in the faunal remains from both Matjes River and Oakhurst where the collection of shellfish and fish increases dramatically with time. In contrast, inland hunter-gatherers, by dint of their geography, are not expected to exploit marine resources and seasonal travel to the coast is unlikely (Sealy & van der Merwe 1986). Inland hunter-gatherers are thus expected to rely more heavily on hunted game and wild plant foods. There are two major complications with this group. Firstly, remains of inland hunter-gatherers in southern Africa are extremely rare. It is thought that the interior during the Holocene was too arid to permit comfortable occupation and thus coastal habitation increased (Deacon 1982; Wadley et al 1992). It may also be the case that the normally exposed nature of inland sites has caused the decomposition of burials which may be appropriate for analysis. Secondly, determining whether inland people are hunter-gatherers or affiliated in some way with more sedentary groups is problematic. Analysing the isotopic composition of their bones or teeth, should help to clarify these issues, as well as looking at the associated faunal and cultural remains.

The following chapter discusses the sites outlined above in some detail. These discussions are however, largely limited to information about subsistence behaviour and skeletal remains.

2.1 OAKHURST ROCK SHELTER

Oakhurst Rock Shelter is situated on the Oakhurst farm about 22km east of George (Figure 2). The rockshelter is in an enclosed valley about 6 metres above the Klein Keurbooms stream. Oakhurst is east facing and situated in dense, virgin forest with access to the coast hampered by the stream cutting

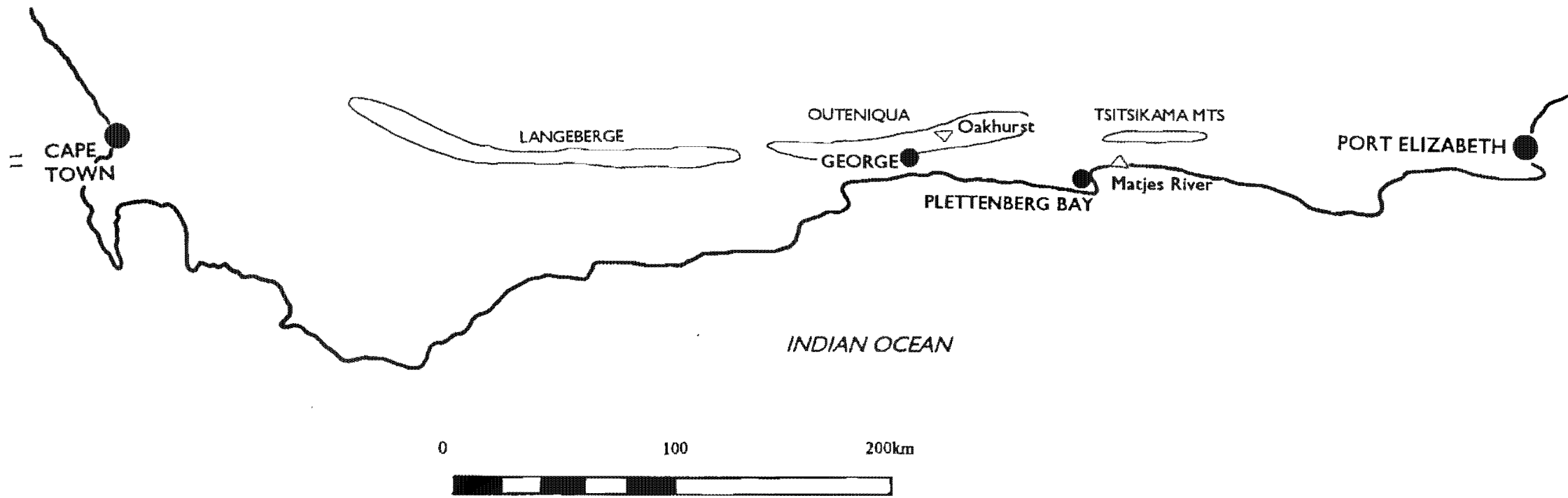


FIGURE 2: LOCATION OF MATJES RIVER CAVE AND OAKHURST ROCK SHELTER

through a narrow gap in the rocky cliff. The shelter has been cut from overhanging cliffs of quartzite from the Cape Supergroup, it is 17 metres in length with the talus situated on the southern and eastern sides of the cave, and forest coming right up to this slope (Goodwin 1938; Deacon 1979).

2.1.1 Stratigraphy

Oakhurst Cave was excavated by Professor A.J.H Goodwin from 1932 to 1935 (Figure 3). Excavations were restricted to the southern section, partly due to the disturbance of the eastern section by tree roots. The deposit consisted mainly of well-preserved sea shell and woodash containing carbon fragments and leaf mould. Extensive layers of white carbonates and charcoal were attributed by Goodwin (1938) to at least three forest fires. Similar features were noted at other nearby sites including Matjes River, Glentyre, Melkhoutboom and Nelson's Bay Cave. However, it has been suggested that the probability of these carbonate layers resulting from forest fires is unlikely, as Oakhurst is situated in a perennially damp forest making it doubtful that fires could move successfully through this vegetation. However, had this happened, it is more reasonable to assume that charred lumps of wood would have marked such an occasion, and not fine ash (Schrire 1962). Evidence of human occupation includes 18 burials with associated grave goods, remnants of a protective fireplace at the entrance of the cave, and stone tools and debitage indicating workshop activities (Goodwin 1938; Patrick 1989).

Oakhurst is an open shelter, which probably did not provide much protection until the floor level had been built up. This may account for the absence of continual occupation before the Smithfield B. Differences in rain action was noticeable in the deposit. The consolidated nature of the lower levels suggested exposure to rainfall, while in the upper levels, those protected from water, the deposit remained loose and unconsolidated (Patrick 1989).

The first 172cm of deposit contained the most cultural remains, with the lower layers of the Smithfield B and the underlying deposit containing few artefacts, small quantities of burnt bone and fragmented quartz, as well as occasional hearths (Goodwin 1938).

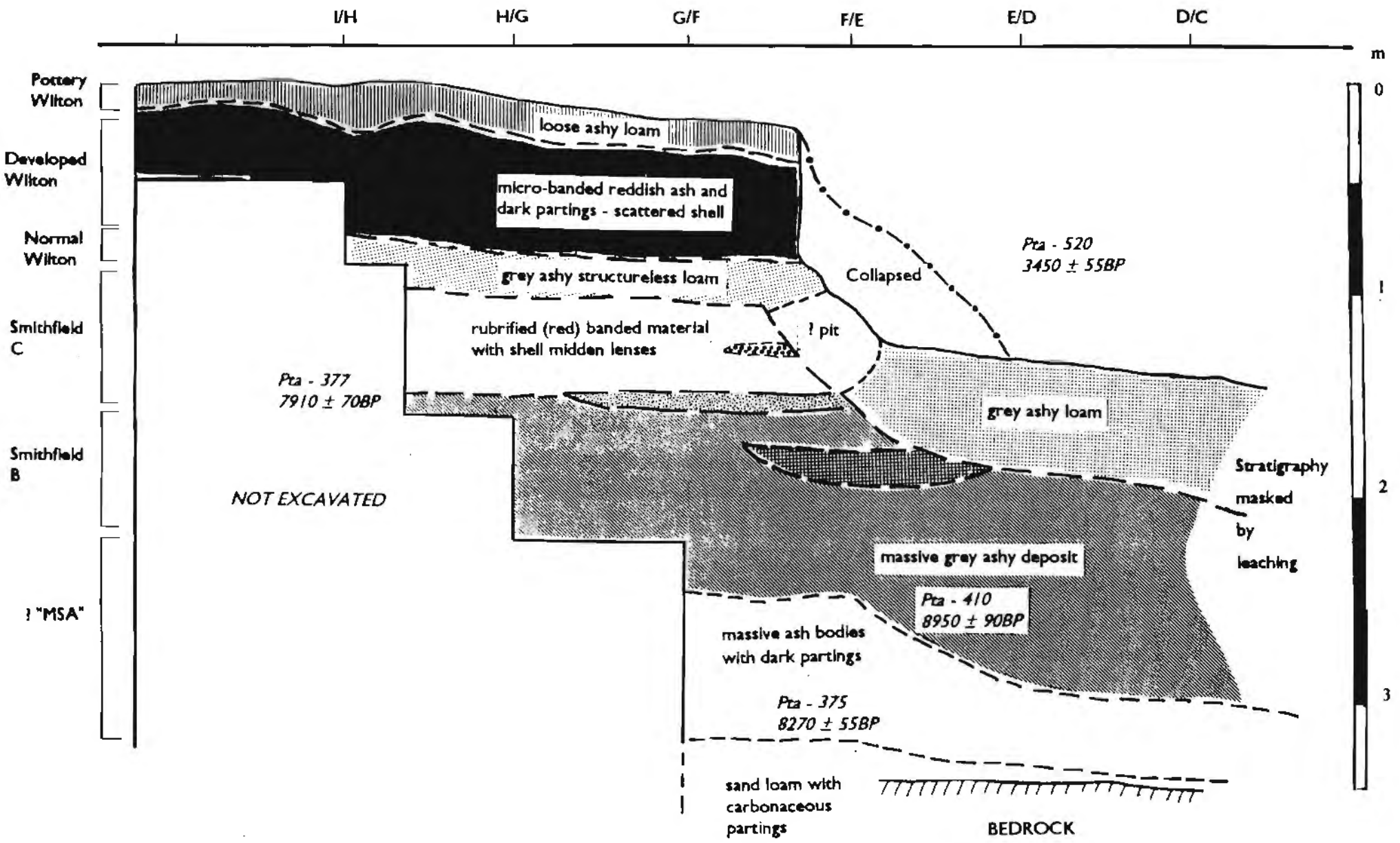


FIGURE 3: OAKHURST ROCK SHELTER - SECTION ALONG EAST WALL
(After Deacon 1976).

The stratigraphy of Oakhurst has been given the following cultural designations:

Depth (cm)	Cultural Designation	Subsistence Strategy
0-22	Pottery Wilton	Large quantities of fish bones suggesting extensive exploitation of marine resources. Small buck bones suggest hunting of large game (Goodwin 1938).
22-89	Developed Wilton	Large number of fish bones, indicating an effective means of capture (Goodwin 1938).
91	Normal Wilton	
91-152	Smithfield C	*Donax serra* in the upper layers replaced by *Mytilus sp.* lower down. Insignificant fish remains suggesting no effective method of capture. Shells as a food source are less common in these lower levels (Goodwin 1938).
152-195	Smithfield B	Lower deposit suggests sporadic occupation becoming more permanent when deposit is built up and provides protection from the elements. Consists mainly of Oyster and Razer (*Solen sp*) shells. Few fish bones (Goodwin 1938).
Below 195	Cape Flats Complex/ MSA	Little known except tool assemblage suggests these earliest layers cover part of the MSA (Goodwin 1938).

Table 1: Oakhurst Subsistence Strategy and Stratigraphy (After Patrick 1989; Goodwin 1938).

2.1.2 Burials

Burials were, with few exceptions, buried in a side-flexed position directly on the natural ground surface. Most of the burials came from a small area 210cm×150cm, with earlier burials consistently disturbed by later ones (Figure 4; Goodwin 1938; Inskeep 1986).

The frequency of grave goods appeared to be chronologically variable and is comparable with Inskeep's (1986) findings of a time linked change in southern coastal burials. Grave goods included bored stones, ostrich egg shell beads, conus shell beads, nacre beads, tortoise carapace bowls, red ochre, ivory palates, ivory points and arrowheads. Personal adornments appeared infrequently in Albany graves, increasing considerably in the Wilton graves and decreasing again in the post-Wilton graves (Inskeep 1986). The accuracy of

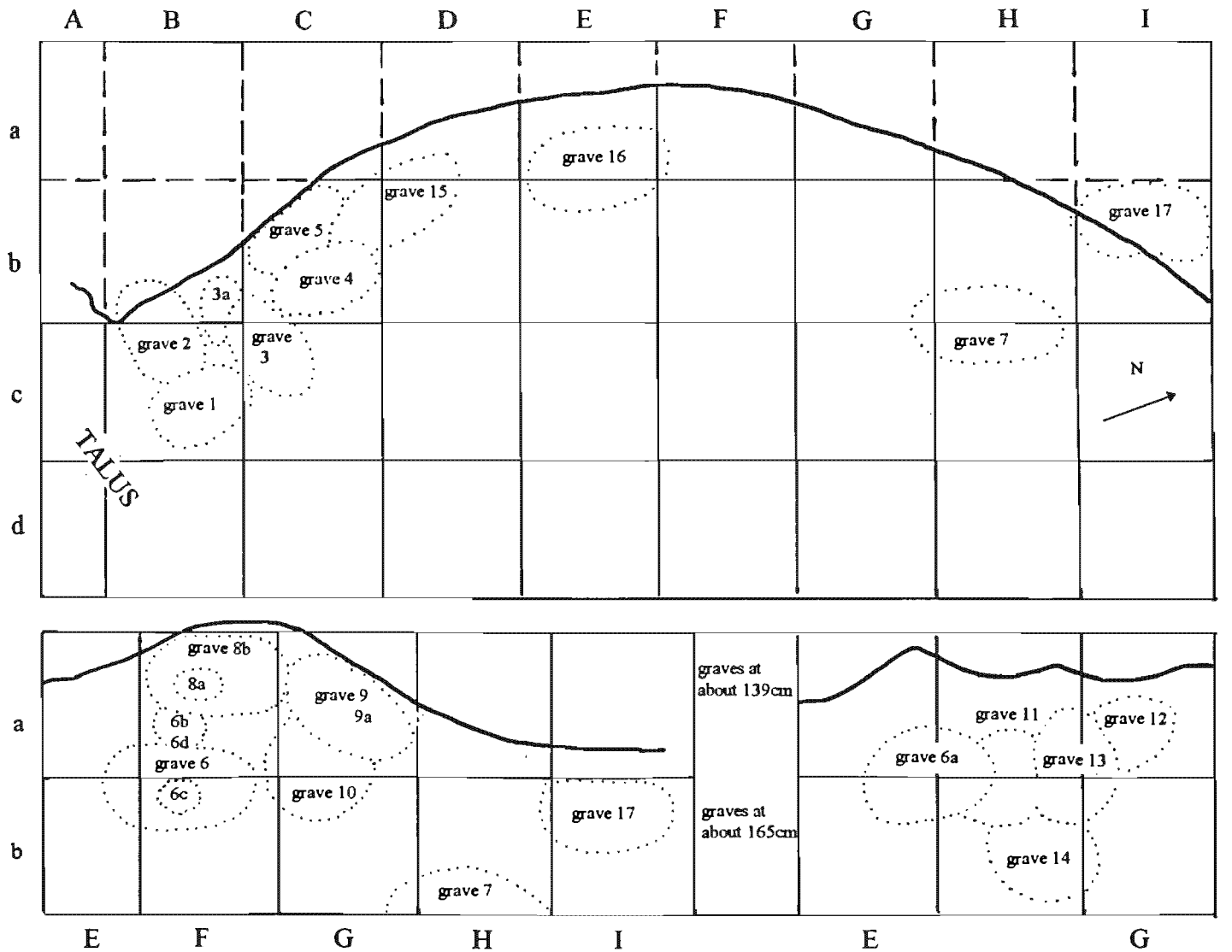


FIGURE 4: PLAN SHOWING DEPTH AND POSITION OF GRAVES AT OAKHURST
(Adapted from Deacon 1976).

these figures, however, cannot be established because of the disturbed nature of the deposit (Patrick 1989). See Table 7 for details of burials sampled for this study.

CULTURAL DESIGNATION	GRAVE	DATE
Post-Wilton/ Post-Climax Wilton	9	< 3450BP
Wilton Proper	1	3450-7910BP
	6	
	6(c)	
	7	
	8(b)	
	10	
	11	
	13	
	17	
Albany	2	> 7910BP
	3	
	3(a)	
	4	
	5	
	6(a)	
	15	
	16	

Table 2: Skeletal Remains from Oakhurst (Modified after Inskeep 1986).

2.1.3 Population, Health and Subsistence

The Oakhurst population seemed to have increased stress levels relative to other hunter/gatherer, pastoralist groups. Oakhurst people had an unusually long birth spacing interval coupled with a life expectancy in the range of 20-29 years. Both these factors suggest a more stressful environment for these people. Evidence suggests that this group was exposed to general stress as a result of an over dependence on marine resources. Although the general resource base of these coastal populations remained extensive they tend to mirror later agriculturalists in exploiting a few major resources relative to their abundance and seasonal concentration (Patrick 1989).

The skeletal sample from Oakhurst dating to between 9000-5000BP shows a higher incidence of porotic hyperostosis, caries, enamel hypoplasia and arthritis. This general increase in stress may have resulted from a

combination of environmental factors. A rise of 1 metre in sea levels would destroy available shellfish communities and impact on the availability of plant and animal life suitable for exploitation. In addition any increase in atmospheric carbon dioxide would stimulate the growth of C_3 plants, and although plants grow larger and more quickly under such conditions, they also become less nutritious (Patrick 1989).

Around 4000 years ago sea level reached its present level and estuarine conditions prevailed. Forest encroachment into coastal areas continued until 2000BP which may have had a beneficial input into plant nutrition because forests return carbon dioxide to the earth. The introduction of fish and small terrestrial animals between 4000 and 2000BP would also have increased the number of dietary items available for exploitation and this presumably was important in reducing nutritional stress (Patrick 1989).

When populations inhabit an unpopulated area and are not subject to the limitations of population pressure, they tend to minimise efforts and maximise nutritional quality and reliability (Patrick 1989). Perhaps the inhabitants of Oakhurst turned to marine foraging as a means of subsistence in the face of dwindling terrestrial resources due to the environmental factors discussed above. This reliability of food supplies lessens labour demands and helps buffer human groups against periodic food crises. However, such a food collection strategy may have led to over dependence on a staple which did not provide all the vitamins and minerals necessary for healthy physiological functioning. As a consequence fertility levels decreased and parasitic infestation and infection influenced longevity and infant/juvenile mortality. This resulted in low overall growth and a low moderate increase in population size (Patrick 1989).

2.1.4 Fauna

The occurrence of eland (*Taurotragus oryx*) at Oakhurst is unusual as eland faunal remains have previously only been found in Pleistocene contexts in this area (Klein 1984). Their presence in the earlier layers may be explained by the disturbed nature of the deposit. Blue duiker (*Cephalophus monticela*) appeared for the first time at around 5000BP and supports palaeoenvironmental

data suggesting an increase in forest and woodland habitats during the second half of the Holocene. Considering the small faunal sample (resulting in few MNI's), tortoise bones outnumber all other categories of fauna. Twenty edible species of molluscan remains were counted, five estuarine and fifteen marine, with three species utilised for their decorative function (Patrick 1989).

Fish species including biskop (*Sparodon durbanensis*), elf (*Pomatonius saltator*), kabeljauw (*Argytosomus japonicus*) and steenbras (*Lithignathus lithignathus*) were also exploited. Presumably these resources were more easily available after the formation of estuarine conditions between 4000 and 5000BP. At about 7000BP dense forest surrounded Oakhurst extending to the coastal dunes at about 2000BP. This increased vegetational cover may have provided a useful habitat for the small antelope, small carnivores and larger mammals hunted by the people of the area (Patrick 1989).

Other species exploited at Oakhurst include; bush-pig (*Potamochoerus porcus*), Cape buffalo (*Synceros caffer*), bloubok (*Hippotragus leucophaeus*), steenbok/grysbok (*Raphicerus sp.*), dassie (*Procavia capensis*), and genet (*Genetta sp.*) (Fagan 1960).

Differences between faunal remains in the Smithfield B and Wilton deposits at Oakhurst suggest a change in subsistence patterns. Such a change either resulted from a preference for certain foods, or a shortage of available resources. The latter hypothesis seems more likely, as evidence suggests that the range of foods available for exploitation increased in the late Holocene (Patrick 1989).

2.1.5 Previous Isotopic Analyses

Isotopic investigations of the Cape south coast are fairly complex (refer to Chapter 3 for details of isotopic analyses). This area receives year-round rainfall, and the terrestrial fauna includes a significant amount of C_4 flora (Vogel et al 1978) thus the separation of $^{13}C/^{12}C$ ratios between terrestrial and marine food components is not very clear (Sealy et al 1992).

Analysis of carbon isotopes from the south coast indicated that the mean $\delta^{13}C_{collagen}$ values of people living on the coast consuming shellfish, crayfish, fish, seal and seabird meat is -15.6 +1.3‰ (with a range of -12.3 to -19.4‰). Terrestrial plants (C_3) had a mean $\delta^{13}C_{collagen}$ signature of -25.4 +1.8‰ (with a range of -22.3 to -29.2‰) (Sealy 1984;1986).

MUSEUM NO.	CARBON	NITROGEN	AGE	SEX
UCT 199/180	-14.23	12.81	30-39	M
UCT 200/182	-12.35	15.98	20-29	M
UCT 201	-14.04	11.34	30-39	F
UCT 202	-13.39	12.27	40+	M
UCT 203	-16.65	9.26	30-39	F
UCT 204 (grave 11)	-13.59	13.24	30-39	F
UCT 205(2)	-12.57	12.17	20-29	M
UCT 206(1)/181	-12.38	14.66	30-39	M
UCT 209/186	-12.34	13.65	20-29	M
UCT 211/184	-13.94	10.67	30-39	M

Table 3: Collagen Isotope Results for Adult Specimens Only (After Patrick 1989).

Thirty $\delta^{13}C$ bone collagen values from Oakhurst ranged from -10.4 to -16.6‰ (Patrick 1989; Table 3). These numbers are difficult to interpret, since enriched $^{13}C/^{12}C$ measurements in areas such as the southern Cape may indicate marine foods in the diet, or alternatively C_4-based terrestrial food (e.g. the meat of grazing animals). Marine shells and fish-bones identified in the Oakhurst deposits (but not quantified), support the dietary exploitation of marine foods. $\delta^{13}C_{collagen}$ values for Oakhurst specimens averaged around -13.75‰, while the $\delta^{15}N$ values averaged at +12.31‰ (Patrick 1989). Subsequent analysis of Oakhurst specimens supported this data, with $\delta^{13}C_{collagen}$ mean values of -13.48‰ and $\delta^{15}N$ mean values of +12.12‰ (Sealy 1997). The limited variability between these values suggests that Oakhurst populations largely consumed a marine diet that did not change significantly during the 6000 year time period studied. These isotope values present two possible scenarios. The first suggests a population that relied heavily on terrestrial protein at the expense of carbohydrates. This type of diet would reflect a larger C_4 component than a diet

equal in animal protein and plant carbohydrate. The second hypothesis suggests a population relying on both marine foods and plant carbohydrates. The latter hypothesis is supported by both the archaeology and the pathology. Marine material predominates in the faunal assemblage and the lack of disease associated with insufficient protein and carbohydrate consumption suggests a balanced diet. Thus Oakhurst people subsisted largely on marine foods, adequately supplemented by plant resources (Patrick 1989).

2.1.6 Summary

The Oakhurst population represents a group of people occupying the Cape south coast between 10 000 and 2000BP. Initial occupation may have begun in the Middle Stone Age, but due to the ephemeral nature of the deposit, little is known of this period. The Developed Wilton (>3540BP) saw a marked increase in marine resources and suggested a subsistence behaviour based on extant fish, shellfish and mammals. The increase in fish consumption suggested an effective method of capture had evolved. The uppermost layers at Oakhurst were characterised by extensive fish remains and evidence of small-game hunting indicative of the changed environment. Both the archaeology and the chemical analysis at Oakhurst support a subsistence reliant on marine resources. All of the burials in this study come from the Wilton, with the exception of Grave 2 (See Table 7).

2.2 MATJES RIVER CAVE

Matjes River Cave is located near Knysna on the Cape south coast (Figure 2). The cave is situated on the western bank of the Matjes River, about 400 metres from the mouth of the river. The cave was formed from an overhang of Table Mountain sandstone. It lies about 65 metres above sea-level and faces east (Deacon 1979). The Matjes River provides a constant supply of freshwater, a nearby beach and rocks offer a variety of foods and the forest is rich in wild fruit and berries (Louw 1960).

Matjes River Cave was excavated initially by Dreyer in 1928 and 1929. Hoffman and Meiring undertook further excavations from 1952 (Louw 1960). Louw's (1960) analysis of Matjes River Cave has been severely criticised but warrants discussion to fully understand this site and its history of occupation and excavation.

2.2.1 Stratigraphy

The deposit of this shelter is remarkable in its depth, which exceeds 10 metres at its deepest point. Radiocarbon dates suggest the deposit accumulated over the last 12 000 years (Deacon 1979). However, despite its abundance in both burials and cultural remains, evidence from the shelter is confused and limited due to a lack of precise stratigraphic control during excavation.

Initial excavations were carried out along the back wall of the cave, presumably to sample those deposits most likely to contain skeletal material. Another trench was laid out perpendicular to the first and linked this back section to the talus (Figure 5). At its deepest, this trench reached in excess of 10 metres, although it is unclear whether bedrock was reached (Deacon 1979).

The deposit was divided into five units based on changes in cultural material, and in some instances, differences in particular shellfish exploitation (Figure 6). The layers were labelled A, B, C, D and E from top to bottom (Dreyer 1933; Louw 1960) and designated; Bushman, Pre-Bushman, Wilton, Proto-Bushman and Indeterminate respectively, based on skeletal material (Hoffman 1958). Radiocarbon dates and artefacts suggest Layers A and B post-date 3300BP relative to Nelson Bay Cave. Layer C corresponds to the Local Wilton industry and Layer D to the Albany industry (Deacon 1979). During later excavations, Hoffman (1958) eliminated Layer E as no trace of the layer could be found. The absence of this layer was also confirmed by Louw (1960; Table 4).

Radiocarbon dates run by Protsch and Obeholzer (1975) for the Matjes River skeletal assemblage have been included here for the sake of completeness. These dates should however, be regarded with extreme caution

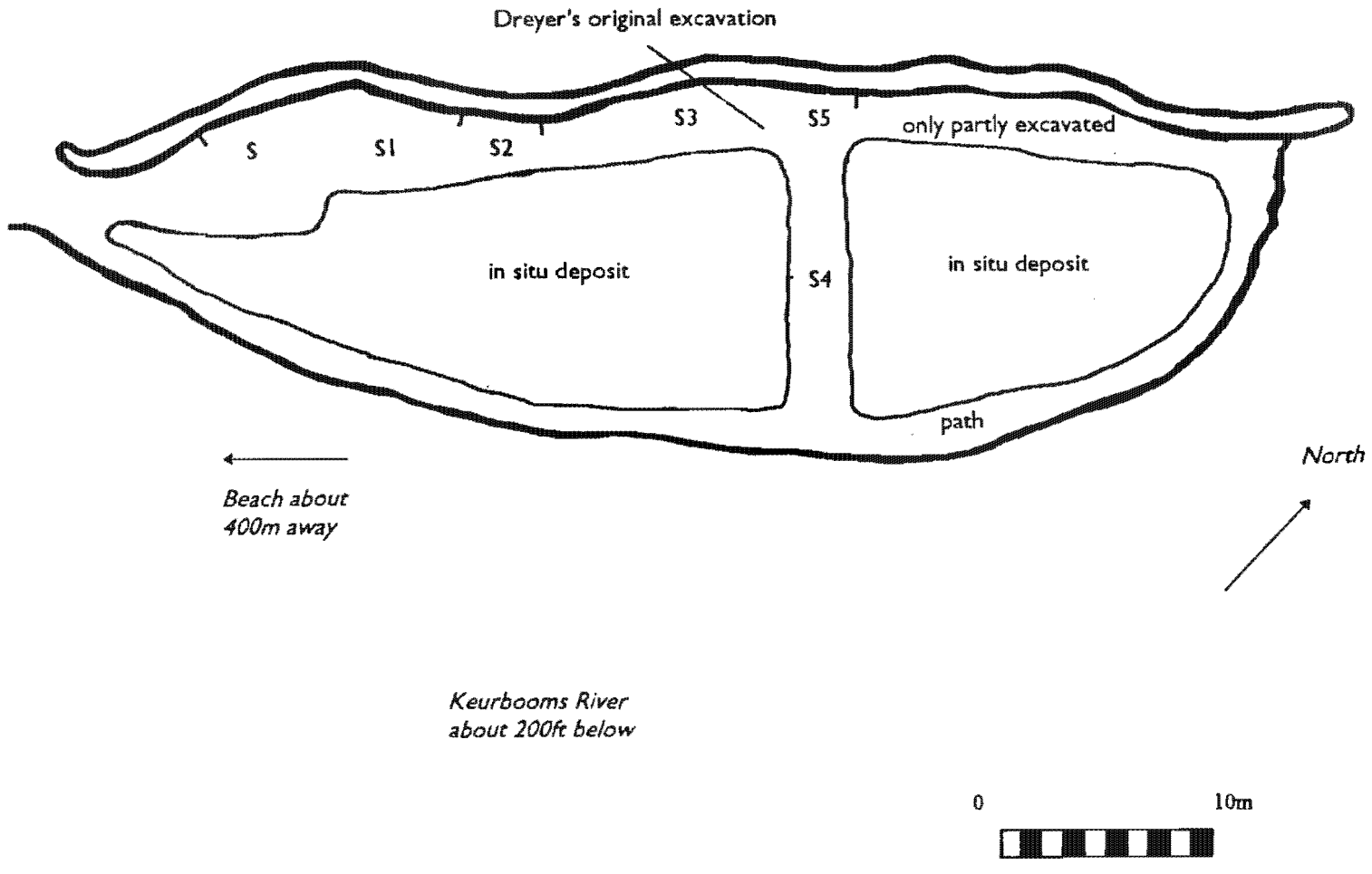


FIGURE 5: PLAN OF MATJES RIVER CAVE EXCAVATIONS
(After Louw 1960).

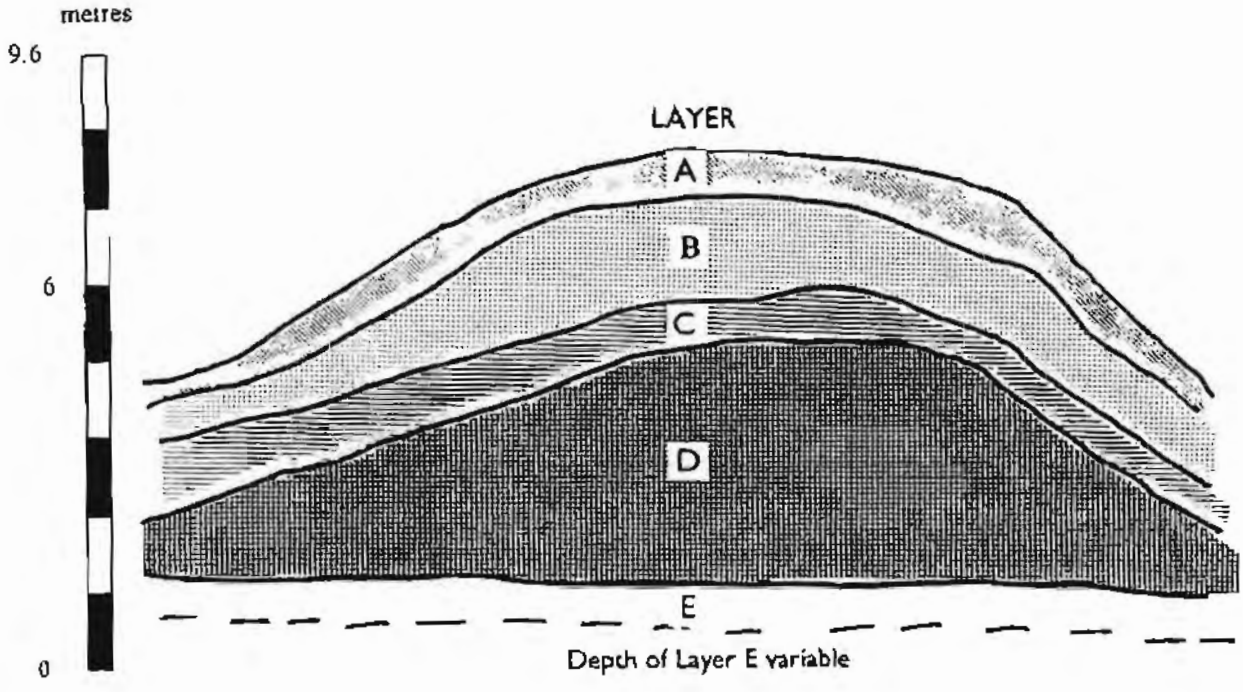


FIGURE 6: DIAGRAMMATIC SECTION ALONG EASTERN FACE OF MAIN EXCAVATION - Dreyer's original site
(After Louw 1960).

as they are of combined specimens. Owing to the confused nature of the Matjes River deposit, one cannot be certain that specimens from the same layer were accurately combined. In addition, the practice of combining skeletal material for dating is highly unconventional. The date of the faunal sample from Layer D is also problematic as there is no reliable means of accurately determining its association with the skeletal remains from this layer.

	LAYER	+THICKNESS	ASSOCIATION •	RADIOCARBON DATE
*A	°Bushman	0.5-8	Loose ash and "weed bedding" (? *Zostera* sea grass). Strandloper variant of Smithfield B. Industry of large quartzite flakes and flaked pebbles and cobbles. Two pieces of course pottery, OES beads, marine shell and bone tools. Human remains: "Bushman"	Sample from ? A/B †3555±35BP shell
*B	°Pre-Bushman	1.5-8	Unconsolidated midden and ash; Smithfield B. Large quartzite artefacts, small number of pot sherds. *Choromytilus* shells predominate. Human remains: "Pre-Bushman"	‡3540±60BP hominid bone ‡7380±120BP hominid bone
*C	°Wilton	1.5-4	Midden more consolidated. Wilton. No pottery. Microlithic backed tools and scrapers. Painted grave-stone. *Donax* shells predominate. Bone and ivory tools and shell ornaments appear for the first time Human remains: "Keurbooms people-hybrids with Bushman and Hottentot affinities"	¤5400±250BP charcoal ¤7750±300BP charcoal †7050±45BP shell ‡5310±60BP hominid bone ‡9230±160BP hominid bone
*D	°Proto-Bushman	4-16	Well consolidated ash - a "burnt layer" (Dreyer 1933). Matjes River variant of Smithfield A. End-scrapers, no microliths. Re-used MSA points. *Donax* shells predominate. All burials rich in ochre and minute OES beads. Unit clearly distinguishable above and below 3 metres based on artefactual differences. Human remains: "Proto-Bushman"	†9450±55BP shell †9580±85BP charcoal ¤10500±400BP charcoal ¤11250±400BP charcoal ‡5350±60BP faunal bone ‡10100±190BP faunal bone ‡10120±200BP hominid bone
*E	\	1	"Red sand layer" - 10inc. sterile gravel overlies 4 inc. ash with flakes but no formal tools. Louw rejects suggestion this is MSA; ? absence of marine shell. Dreyer (1933) claimed findings of two skulls "entirely different from Bushman types in upper levels" but this was not confirmed by later excavators.	Samples from "lowest level" ? D/E: †9780±60BP shell †10030±55BP

Table 4: Matjes River Stratigraphy and Cultural Association. (* Dreyer 1933; ° Hoffman 1958; • Louw 1960, Hoffman 1958, Dreyer 1933; ¤ Louw 1960; ‡ Protsch & Oberholzer 1975; † Vogel 1970). + Thickness measured in feet.

More recent dates by Sealy (unpublished) show several groups of specimens; those dating between 2200 and 2970BP, 3040 to 3570BP, 4850 to 4940BP, 5120 to 5390BP and 7420BP. These dates, together with the more general ones, also run by Vogel (1970) are far more reliable than those of Protsch and Oberholzer (1975).

2.2.2 Skeletal Terminology

Although the technology of Layer C is Wilton, both Louw (1960) and Meiring (1937) regarded these people as an isolated population, unrelated to the people of either the upper or lower levels. The precision of their tool assemblage and art suggested a higher cultural level than other contemporary prehistoric South African populations. The assemblage consisted of microlithic backed tools and scrapers displaying exceptional workmanship. Bone and ivory tools and some shell ornaments appeared in this layer for the first time (Deacon 1979). Louw (1960) argued that despite marked differences in material culture, this population retained enough Khoisan elements to suggest that their physical differences from preceding and later populations, were superficial and that they indicated some physical affinity with Oakhurst people. The Keurbooms people of Layer C occupied the shelter for at least 2350 years between 5000 and 7000BP. Hoffman (1958) and Meiring (1937) suggested the morphological development of the "Bushman" race at Layer C. They used the terms "Proto-Bushman" and "Pre-Bushman" to indicate this development. Louw initially supported Meiring's (1937) suggestion that various waves of immigration into South Africa are represented at Matjes River Cave and that the Wilton Culture at this cave was a foreign one. In 1933, Keith argued for the evolutionary transformation of a race over a long period of time at Matjes River, rather than a sudden replacement of local people by a foreign population. Louw (1960) later favoured this argument, although he regarded the Layer C people as hybrids that maintained a Wilton technology (see Protsch & Oberholzer 1975 for discussion).

Layer D was a 4.8 metre consolidated ash deposit, suggesting a long period of occupation. The skeletal remains indicated a bigger, larger headed people than those in upper levels which Louw (1960) and Dreyer (1933) referred to as the "Matjes River Race". Dreyer (1933) defined them as the first definite Pre-Bushman race in South Africa and suggested the name of *Homo sapiens dreyerensis*, which was rejected.

Initial excavations by Dreyer revealed two skulls in Layer E very different in shape and appearance to the "Bushman types" of the upper levels (Louw 1960). As mentioned, the existence of this layer is questionable. However if it was present, it is thought to be only 3.9cm in depth which makes the association of these burials doubtful (Deacon 1979).

2.2.3 Burials

The poor stratigraphic control at Matjes River makes analysis of skeletal material extremely difficult. The burials from Matjes River are poorly curated and not detailed individually, nor is there specific information on their numbers, location, position within the deposit, or associations.

- **Early burials (c. <7910 BP)**

In Layer D, burials were reported to be covered with more flat stones than in Layer C, these stones sometimes occur in two layers. The corpses were flexed on either the right or left side, but were seldom accompanied by grave goods. Some burials in Layer D contained lumps of ochre. Three skulls in Layer E were liberally covered with it (Dreyer 1933). A double burial of a man and woman was recorded from near the bottom of Layer D, below a double layer of stones, but no mention was made of ochre or grave goods (Inskeep 1986).

- **Wilton burials (c. 7910-3450BP)**

These burials were not detailed individually, so precise information is inadequate. Burials from Layer C are said to have been flexed, lying on their sides, in small, round graves. They were usually covered with a few flat stones

smeared with ochre. Burial goods included cultural belongings like beads, bone awls, paint palettes, stone artefacts and ochre. Some graves included ostrich egg shell bottles placed upright near the head. If these bottles were absent, a bored stone appeared in a similar location. Both artefacts were always smeared with ochre (Inskeep 1986).

- **Later Holocene burials (c. >3450BP)**

Burials from the upper layers at Matjes River were covered with flat stones placed over the skull, and sometimes the pelvis (Dreyer 1933; Hoffman 1958). Again, there is no mention of any grave goods, but ochre is present on some of the skulls (Inskeep 1986).

There appears to be two clearly distinct burial rites at Matjes River Cave. The Layer B and Layer C people disposed the body in a sleeping attitude and placed a few stones over the head. The Smithfield people (Layer B), unlike the previous occupants of the shelter, poured powdered red ochre over the head. The Layer C people placed an ostrich egg shell, with a hole at the top end, upright next to the head. Ochre acted as an excellent preservative for the bones covered by it, so that the lower Layer B skeletons were much better preserved than any of the Layer C skeletons. These differences in burial rites seem to indicate two different races (Dreyer 1933).

2.2.4 Fauna

- **Layer D**

A large portion of this deposit consisted of *Donax* shells. However, Louw (1960) suggested that these people hunted extensively and that their diet consisted mainly of meat. Every species available in the region was exploited as food and is represented in the faunal sample. These include: buffalo (*Syncerus caffer*), bushbuck (*Tragelaphus scriptus*), duiker *(Philantomba monticola*), steenbuck (*Raphicerus campestris*), klipspringer *(Oreotragus oreotragus*), oribi *(Ourebia ourebi*), hippopotamus (*Hippopotamus amphibius*), bush-pig (*Potamochoerus porcus*), the extinct warthog *Phacocheorus dreyeri*, otter

(*Aonyx capensis*), seal (*Arctocephalus pusillus*), rockrabbit (*Lepus sp.*), carnivores, birds, fish, mussels, and gastropods.

Exploitable bulbs and tubers included *Moraea edulis* (niutjies) and *Fockea* and *Cyphia* (baroe). Louw (1960) suggested that food was probably eaten raw because no potsherds were found in this layer, although he does suggest that meat could have been fried over the fire. He substantiates the consumption of raw food based on analogies with modern Bushmen who prefer raw food (Schapera 1930). Thick layers of ash suggest constant fires for protection or religious purposes.

- **Layer C**

Louw (1960) argued that evidence of bows and arrows suggest that Layer C people were proficient hunters. Small buck (*Raphicerus sp.*), dassie (*Procavia capensis*), bushpig (*Potamochoerus porcus*), carnivores and Cape buffalo (*Synceros caffer*) were included in the faunal assemblage (Meiring 1937). Fish also supplemented their diet (Louw 1960).

- **Layer B**

These people had a lifestyle vastly different from the Layer C people. Their diet consisted almost entirely of blue mussel (*Mytilus edulis*) and was probably supplemented with roots, tubers, berries and other local food stuffs (Meiring 1937; Louw 1960).

2.2.5 Previous Isotopic Analyses

Analysis of isotopic values for skeletal remains from Matjes River Cave suggest a diet rich in marine foods ($\delta^{15}N$ mean +13.24 ‰) (Sealy 1997). Both apatite and collagen values suggest a greater C_4 reliance, although C_3 resources wee present. Separating C_4 and C_3 resources in this area is difficult, as both C_3 and C_4 terrestrial fauna are present in the area, and marine foods mimic a C_4 signature. The C_4 component observable in the diets of these people may have entered the diet through the exploitation of grazing terrestrial animals.

However, the elevated nitrogen values suggest that this C_4 component more likely reflects the inclusion of marine resources. Faunal evidence from Matjes River suggested the exploitation of substantial marine resources, thus, as with Oakhurst, it appears that the diet of these coastal peoples reflect marine resource exploitation, supplemented by some terrestrial resources of a C_3 nature.

2.2.6 Summary

Matjes River Cave is extremely difficult to understand. Little provenience and faunal information are available. Further, understanding the distribution of skeletal remains is extremely problematic. We know that Matjes River was occupied for approximately the last 12 000 years. It appears that this occupation was not by a homogenous group of people, but by a population undergoing evolutionary transformations, both in terms of morphology and technology. A general understanding of the diet of people living on the Cape south coast is useful in determining what these people ate. Extant mammals and plant foods are evident in their diet. As well as marine resources which become more heavily exploited in the upper levels. By Layer B their diet consists almost entirely of blue mussels supplemented by terrestrial resources. Isotopic evidence supplements what little is known from the faunal assemblages. However, dietary investigations of these people cannot be contextualised in terms of chronology or gender and age differences. Future dating of the Matjes River specimens may help clarify the existing confusion. Details of burials analysed from Matjes River are outlined in Table 7.

2.3 K2

Excavations at K2 have revealed the remains of a town in the earlier phase (late tenth to eleventh centuries) of the Mapungubwe complex which is considered to be a forerunner of Great Zimbabwe (Huffman 1985, 1989; Steyn 1994; Gardner 1963). K2 refers to Kom 2 and is the most extensive of the three

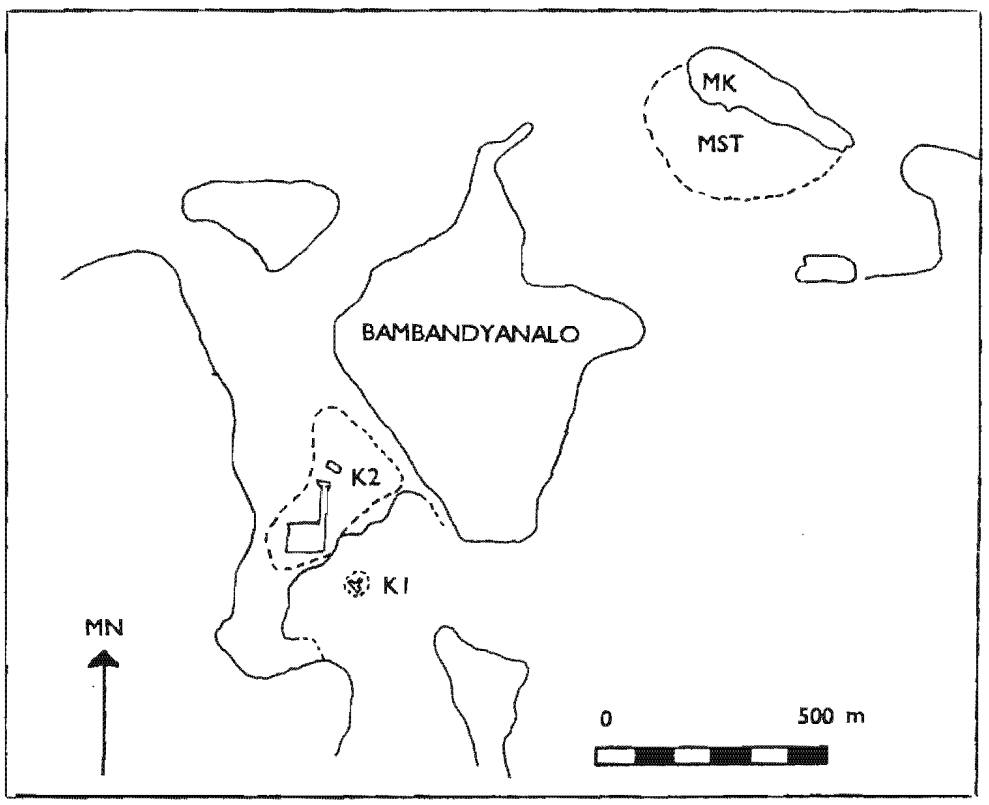


FIGURE 7: MAPUNGUBWE COMPLEX
(After Voigt 1983).

archaeological occurrences at Mapungubwe (Figure 7). The other two sites include Mapungubwe Hill (MK) and the Southern Terrace (MST). K2 was formed by huge accumulations of ashy deposit similar to North African Tells (or Koms). K2 is sometimes also termed Bambandyanalo, but this name accurately refers to a rocky hill forming part of the site's eastern boundary. The site is in a sheltered valley surrounded on three sides by steep hills (Figure 8). The climate is largely subtropical, with a summer rainfall averaging 330mm per year (Voigt 1983; Steyn 1994). The work of Voigt (1983) and Steyn (1994) are particularly comprehensive and relied upon heavily here.

2.3.1 Stratigraphy

Archaeological deposits at K2 extended more than 6 metres. The top three levels were excavated according to artificial spits as no stratigraphy was visible. The remaining deposit was excavated by stratigraphy defined by changes in the deposit. Stone Age artefacts are representative of the oldest occupation at the Mapungubwe Complex. Nothing else is known of this period. Four Iron Age phases were broadly defined at K2 (Voigt 1983).

- **Phase 1:**

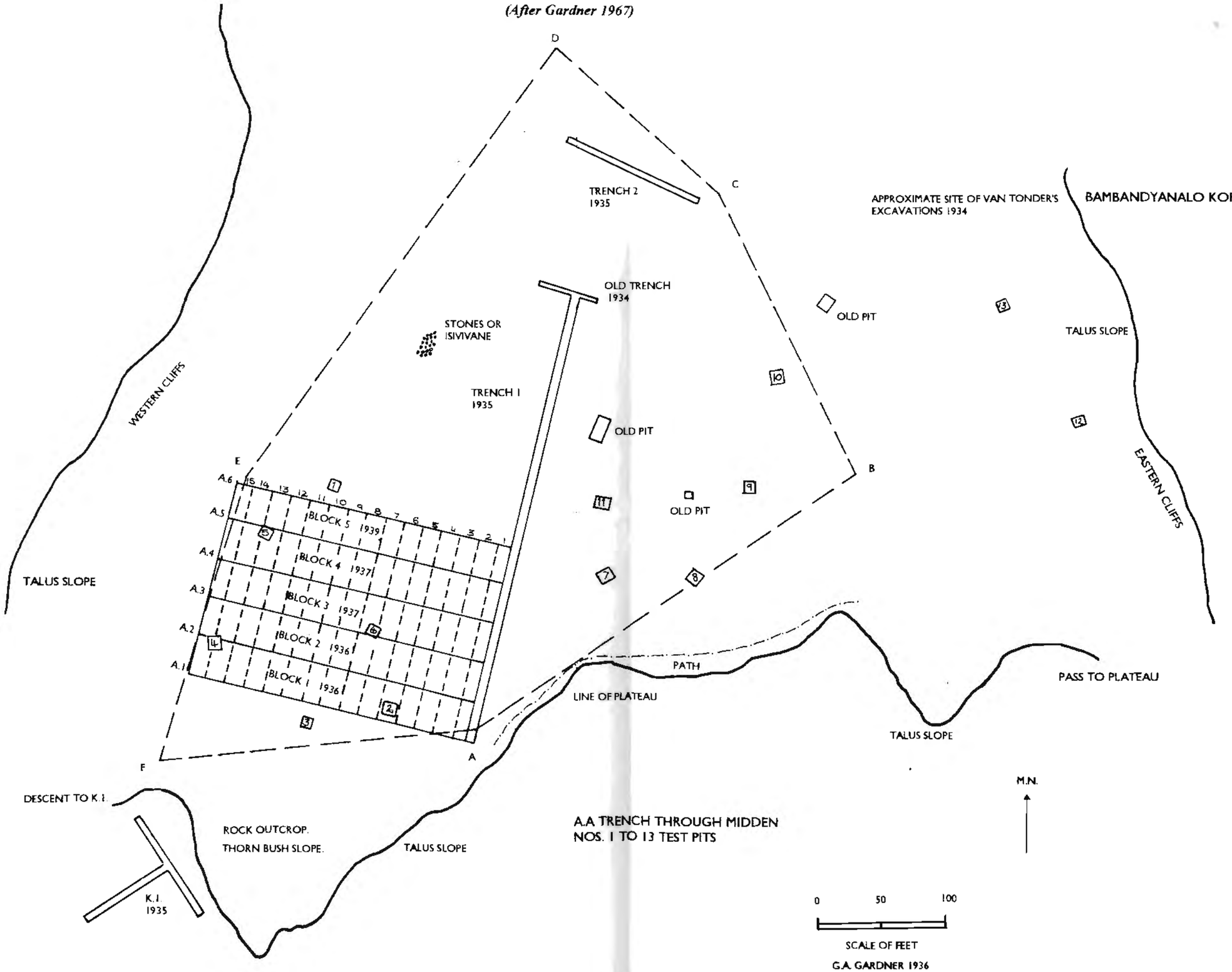
As with the Stone Age, little is known of this phase. Several pot sherds of Gokomere tradition, associated with the Early Iron Age, were present. Evidence suggests that the Early Iron Age people left the area long before the next group of people arrived there (Eloff 1979).

- **Phase 2 (TS 1):**

Intensive settlement at K2 occurred at ca. AD 1000 and lasted about 200 years. Smaller occupations were evident on the Southern Terrace at this time. All the K2 burials probably date to this period. The dense nature of the deposit, as well as the ivory and glass beads, suggestive of trade with the east coast, indicate economic and political leadership during this time. The deposit of this phase suggests between four and six generations lived at K2 (Eloff 1979).

FIGURE 8: GENERAL PLAN OF K2

(After Gardner 1967)



- **Phase 3 (TS 2):**

Phase 3 is characterised by changes in pottery styles, the appearance of gold and new types of glass beads, as well as the disappearance of ivory. Phase 3 also saw the beginning of building with stone walls. However, the origin and culture of the Mapungubwe people remains uncertain. Suggestions include a change in internal socio-political relationships or a gradual replacement by a new population (Voigt 1983).

Huffman (1982; 1986) argues for internal changes and suggests that K2 people moved to the Southern Terrace, while the leaders separated themselves physically from the commoners by occupying the Mapungubwe Hilltop. This move, he suggests, resulted from a growing population and a new bureaucratic class. As a result changing pottery styles can be attributed to social changes in the community.

An alternative theory suggests that the changes evident in pottery style indicate a new population that moved into the Southern Terrace, gradually replacing K2 people (Eloff & Meyer 1981).

At the onset of Phase 3, the K2 culture remained dominant. K2 was however, destroyed twice by fire and after the second fire, began to weaken. Mapangubwe and the Southern Terrace were also affected by fire at about AD1244. People however continued to live on the sites, and K2 appeared to have been unaffected (Voigt 1983).

The Mapangubwe complex was characterised by massive layers of deposit suggesting intensive occupation. The social and political influence exerted by these people is uncertain, however, it appears that the Mapungubwe people exerted political influence on surrounding areas, contracting labour, obtaining food and trade goods from outside the community (Voigt 1983).

At about AD1255 Phase 3 ended with a fire and a less complex lifestyle ensued. No burials have been found from Phase 3 (Voigt 1983).

DEPOSIT #	DEPOSIT TYPE	LEVEL	DATE
Phase 2 **TS 1**	Relatively hard, coarse deposit. Some ash.	2	970±50YRS AD
Phase 3 **TS 2**	Same as TS 1. Contains the best preserved bones		
Phase 4 **TS 3**	Upper levels in ashy deposit. Level 16 + have a high proportion of ash mixed with sandy soil	6 15 24	1000±50yrs AD 980-1000±50yrs AD 1000±50yrs AD

Table 5: Radiocarbon Dates Associated with Faunal Samples from K2 (After Steyn 1994).

- **Phase 4 (TS 3):**

The onset of Phase 4 began so suddenly that it appears not to have resulted from climatic changes, but rather from socio-political influences. It represented a less prosperous community than the proceeding ones. The stone structures characteristic of Phase 3 disappear and hut floors became thinner. The appearance of bone arrow points and linkshafts suggest either some contact with local hunter-gatherers, or a shift in subsistence activities which included relatively more hunting and gathering. However, pottery maintains the same characteristics of Phase 3 and gold and glass beads were still available (Voigt 1983).

During this period, the Zimbabwean culture became more influential in status and this may have impacted on the Mapungubwe culture by disrupting trade with the East coast. The Mapungubwe community continued to exist under the supremacy of the Zimbabwean culture, but was finally abandoned in AD1300 (Voigt 1983).

2.3.2 Fauna

K2 is situated in a mopani-veld area, although the site itself is surrounded by mixed, open vegetation bordering a riverine forest (Voigt 1983). Grasses provide pasture for domestic stock. *Pennisetum typhoides* (pearl millet),

Sorghum bicolor (sorghum) and *Vigna unguiculata* (bean sp.) were all cultivated during occupation of the Mapangubwe complex (Eloff & Meyer 1981). Animal species included impala (*Aepyceros melampus*), kudu (*Tragelaphus strepsiceros*), bushbuck (*Tragelaphus scriptus*) and leopard (*Panthera pardus*), bushpig (*Potamochoerus porcus*) and hippopotamus (*Hippopotamus amphibius*). Molluscs include *Cypraea*, *Natica* and *Cardium* (all marine species) and *Unio*. With ostriches (*Struthio camelus*), eagles (*Aquila sp.*) and pheasants also present. During occupation Sanga, Zebu and Afrikaner cattle were kept, as well as sheep (*Ovis sp.*), goats (*Capra sp.*) and dogs (*Canis sp.*). The remains of burnt millet suggest that this was a staple food. Other plant remains were scarce, but it is likely that people collected wild plants to supplement their diet. Domestic stock is a food source immediately at hand and its utilisation may have involved animal husbandry with only certain animals available as a food source. Gathered foods may also have supplement the diet, although Voigt (1983) suggests that such activities depended on the enterprise of the individual, rather than being an integral part of food supplementation. Fishing appears not to have been a major component of food-getting activities during any stage of occupation at Mapangubwe (Voigt 1983).

- **Phase 2 / TS1**

Phase 2 consisted of 50.4% non-domestic animals with 2.3% of that number consisting of fish remains. *Achatina* sp. dominated in all levels. Occasional hunting by TS1 people included impala (*Aepyceros melampus*), duiker (*Sylvicapra grimmia*) and bushpig (*Potamochoerus porcus*). Ostrich eggshell was probably collected for raw materials. Six cowries were present in this sample (Voigt 1983).

The TS1 sample suggested a heavier dependence on naturally occurring foods, including very small items like rodents and reptiles. Exploitation of river resources included freshwater bivalves and fish. The domestic stock sample was made up of 22.9% *Ovis/Capra*, 21.4% cattle and 13.8% juvenile stock (Voigt 1983).

In the TS1 faunal assemblage hunting, snaring and gathering were of relatively greater importance than the other assemblages. Wild bovids made up 1.4% of foods consumed, while 97% of meat consumed came from domestic sources (Voigt 1983).

Phase 2 occupation suggested a dependence on cattle herding, agriculture and probably small-scale hunting (Steyn 1994).

- **Phase 3/TS2**

The faunal sample from Phase 3 was dominated by domestic species. 61.9% of the sample consisted of equal proportions of goats/sheep (*Ovis/Capra*) and cattle (*Bos taurus*) while juveniles made up 18.9% of the slaughtered stock. 11% of the sample consisted of hunted game including hippopotamus *(Hippopotamus amphibius*) and zebra (*Equus* sp.). Elephant ivory occured in 5 levels, with a very large rib, probably an elephant (*Loxodonta africana*), in Level 2. Hunted non-bovids included two monitor lizards (Voigt 1983).

Gathering activities made up 15.6% of the sample and include tortoise and 21 *Achatina* specimens. Fish and bivalves were exploited from the river. Snaring made up 5% of the sample and included hares and birds. Non-contributors comprise ostrich eggshell, a baboon (*Papio sp.*), three carnivores and three marine molluscs. It is probable that the carnivores and baboon were hunted for their skins (Voigt 1983).

This group drew primarily on domestic animals for food, with hunting and gathering contributing 27% of the diet. Unusual species (not seen in TS1) include crocodile (*Crocodilus sp.*), baboon (*Papio sp.*) and carnivores. The faunal assemblage suggests that TS2 was a more affluent sector of the community than TS1 as both ivory and stock are used more intensively. The crocodile remains might indicate the proximity of a witch-doctor's hut (Voigt 1983).

In the TS2 faunal assemblage 96% of meat came from domestic stock with 6.5% from the sheep/goats (*Ovis/Capra*) group. Hunting contributed 3.3% to food sources while gathering and snaring contributed slightly less. TS2 had a 50% larger faunal sample than TS1 (Voigt 1983).

- **Phase 4/TS3**

Phase 4 can be divided into two units (levels 1-15 and 16-24) both of which are dominated by domestic stock. In both units hunted animals make up 7-8% of the faunal assemblage. Snaring and gathering appears more important in the upper levels with *Achatina sp.* important in both units. Non-contributors include cowries, which are numerous in both units, as well as an additional marine species in the lower units. There are also a large number of carnivores in the upper unit, particularly Level 10. This suggests a concentration of snaring or hunting, probably for pelts with fishing playing a minor role in both units (Voigt 1983).

The proportion of *Ovis/Capra* is much higher in the lower unit, suggesting a decreased dependence on snaring and gathering. The upper unit people relied more on hunting, snaring and gathering with a decrease in *Ovis/Capra* stock visible in this group. These upper unit people have a similar economic pattern to the people in TS2. The lower units consist of 73% domestic animals (Voigt 1983).

The upper unit of TS3 yielded 28 bovids, while 98.2% of meat came from domestic stock, with cattle contributing 89% and *Ovis/Capra* 9.2%. In the lower unit 98.6% of meat was from domestic stock including 14.8% of *Ovis/Capra*. Non-bovids contributed less in both units. Hares (*Lepus sp.*) and guineafowl-sized birds were a favourite food in the upper unit, which also included a large number of molluscs. The TS3 excavation was part of a refuse dump, so it is not representative of a living area (Voigt 1983).

Economic or food-getting activities at K2 differed between TS2/TS3 and TS1. In TS2 and TS3 60% or more of food sources came from domestic stock. In TS1 however, only 50% of food came from domestic stock with snaring making up 23% and gathering a further 17% of food sources (Voigt 1983).

By examining the meat weight contribution to diet 96-98.7% of meat was derived from stock sources. The quantity of stock represented in the faunal assemblages suggests that people at Mapangubwe regarded stock as a primary food source. Animals from all age ranges were slaughtered and while large stock was available, smaller stock was slaughtered more frequently. Present

day Bantu speakers slaughter stock sparingly. The differences of slaughtered stock at K2 suggests that the significance of cattle has either changed dramatically over time, or that these people were sufficiently wealthy in domestic stock to slaughter at will (Voigt 1983).

2.3.3 Previous Isotopic Analyses

Previous isotopic studies (Lee-Thorp et al 1993) reveal values from K2 that fall into 3 distinctive categories. $\delta^{13}C_{collagen}$ results average at -10.36±1.27‰ and $\delta^{15}N$ values at +11.28±1.04‰. Due to a lack of provenience and sexing information, it is currently uncertain whether these differences can be attributed to gender or cultural factors. All examined specimens were adult or sub-adult, which effectively rules out age factors as impacting on isotopic signatures. Moreover, the rapid deposition of the site represents only two or three generations (Voigt 1983), so isotopic differences are not attributable to major chronological variations.

$\delta^{15}N$ results reflect slightly lower values than expected for this arid region and possibly suggests either a lower trophic level diet (Lee-Thorp et al 1993) or that conditions in this area were moister than they presently are (Huffman 1996).

UCT #	MUS#	$\delta^{13}C$ collagen	$\delta^{15}N$ collagen	Sex	Age
4178	A1732	-10.1	9.0	M	20-22
4180	A1715	-10.7	11.2	F	40-60
4182	A1749	-12.5	10.1	/	/
4187	A1755	-9.1	11.5	/	/
4191	A1734	-8.9	11.6	M	30-40
4192	A1758	-11.0	11.1	M	35-45
4194	A1722	-10.7	11.2	F	25-30
4205	A1719	-11.5	11.7	/	/
4207	A1747	-12.6	10.1	M	17
4209	A1763	-9.4	12.9	/	/
4210	A1713	-8.8	12.9	/	/
4211	A1714	-8.9	11.8	M	25-30
4213	A1730	-10.8	11.6	F	25-30
Mean		**-10.4±-1.7**	**11.3±-1.04**		

***Table 6**: K2 Collagen Values for Carbon and Nitrogen (After Lee-Thorp et al 1993).*

2.3.4 Gross Dental Wear

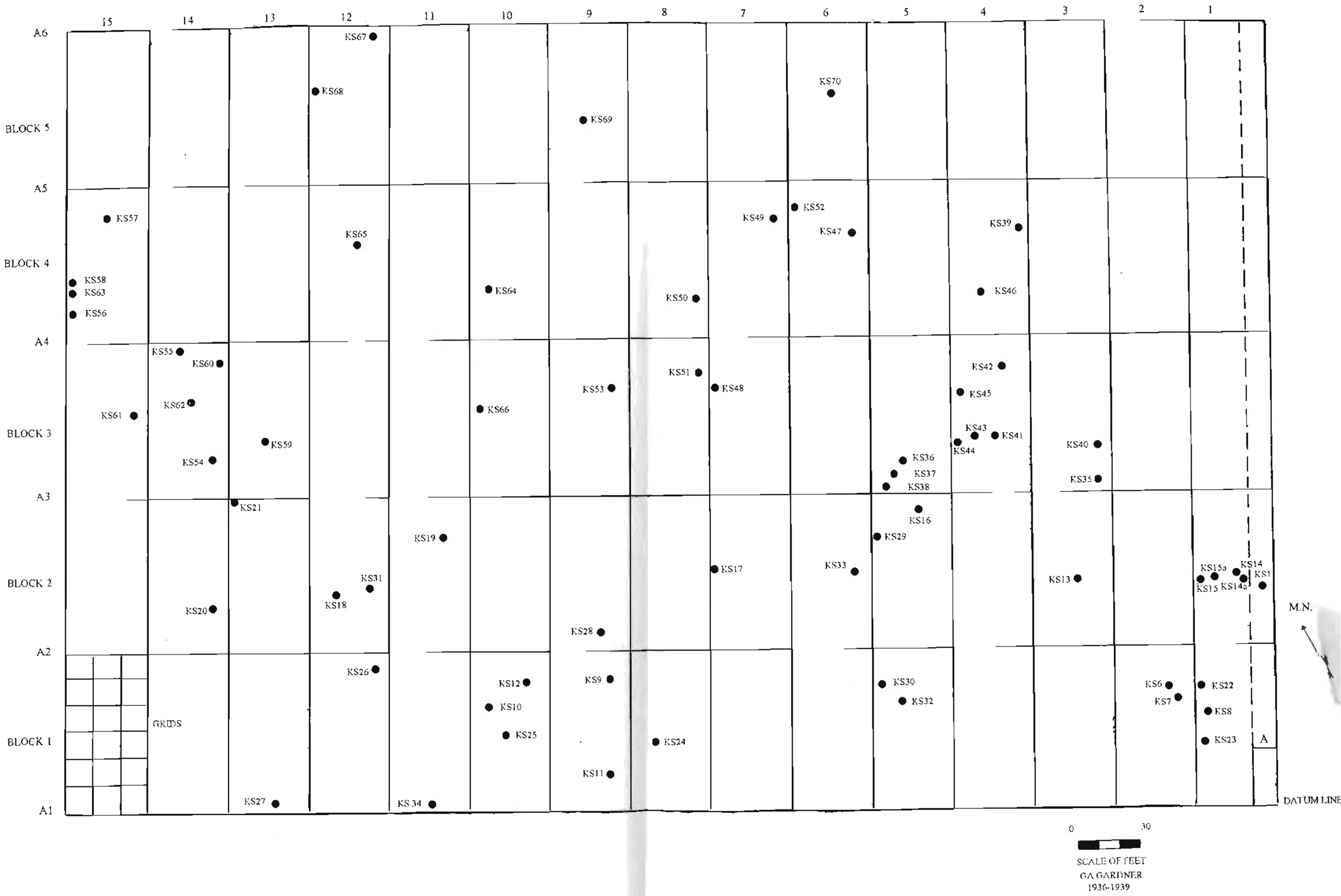
Occlusal molar attrition in K2 specimens suggested a high rate of attrition during youth (16-20 years) reaching a plateau in adulthood (21-40 years) and increasing again in later life (40+ years). Subadults and young adults both experienced more extensive anterior wear than posterior wear. Older adults however, had equal wear on both posterior and anterior dentitions. In agricultural populations, one would expect extensive posterior wear resulting from the grinding action of the molars, anterior wear may result from teeth being used as tools. The diets of males and females may have differed slightly, resulting in a higher incidence of caries among females and a greater degree of attrition among males. Based on gross dental wear and the high incidence of dental caries it is unlikely that K2 people had a significant element of hunting and gathering in their diet, although they must have included unrefined foods to some degree (Steyn 1994).

The change in general subsistence from hunting and gathering to agriculture has, in some aboriginal American populations, been accompanied by a deterioration in health. This may result from periodic food shortages, a reliance on a narrow range of foods and dense sedentary populations living in unhygienic conditions. An examination of K2 and Mapangubwe people compared to the hunting and gathering populations of Oakhurst, indicated that the agricultural groups were less stressed and less diseased. Large herds of cattle and a variety of cultivated foods may have sustained populations in times of drought and the milk from cattle may have provided the nutrition necessary to survive drier periods (Steyn 1994).

2.3.5 Summary

Occupation at K2 began with the Early Iron Age, although little is known of this period. Intensive occupation began around AD1000. The nature of the deposit suggests economic and political leadership by K2 people at this time. Occupation lasted for 200 years and all burials probably date to this period (see Table 7 and Figure 9 for details of burials discussed in this study). This was followed by a period of dispersal, with people moving to the Southern Terrace

FIGURE 9: GRID PLAN OF K2 BURIALS
(After Gardner 1967)



and possible elite separation at Mapungubwe. K2 thus appears to have been an intensively occupied site with substantial socio-economic and political impact . The diet of K2 people seems to have relied heavily on the exploitation of domestic stock, supplemented by millet and occasional hunting or snaring. Gross dental wear supports the claim that K2 people relied little on hunted resources and $\delta^{13}C_{collagen}$ values suggest a diet based to some degree on C_4 resources like domestic crops and stock.

2.4 INLAND SITES

2.4.1 Harrismith

- ***Burial 1***

Burial 1 was found on the edge of a steep donga. All of the foot bones had disappeared and both tibias were exposed over the edge of the donga. Part of cranium was exposed through the red grave infill. Burial 1 was interred directly on grey shale bedrock and then covered with red earth and grey stones. The body was tightly flexed with the knees drawn up to the face which rested on both hands. The head faced northeast. One undecorated potsherd was fixed to the right femur, a smoothed pebble lay close to the right hand, and a glass bead with a white centre near the nape of the neck. The skeleton is characterised by Khoisan features and is a small mature adult (Wadley 1990).

- ***Burial 2***

Burial 2 was found about 50 metres west of Burial 1. The skeleton was badly damaged with bone fragments scattered around the grave and the exposed cranium smashed. The arms were missing entirely. No grave goods are associated with this skeleton (Wadley 1990).

2.4.2 Summary

While the physical affinities of these two skeletons is uncertain, Wadley (1990) has suggested they are of the Khoisan type. This determination, although not yet concretely established, makes both skeletons suitable for inclusion in this study. The beads and pottery associated with Burial 1 suggests some relationship with more settled populations (ie: farmers). Dietary analysis may be helpful in determining the extent to which this individual was associated with more sedentary groups or not.

2.4.3 Hope Hill Shelter

Hope Hill Shelter is situated near the town of Leslie in the southern Transvaal. Plant species in the area are limited, consisting of Themeda Veld or Turf Highveld. The annual rainfall is between 650-750mm and severe frosts are regular winter occurrences. The geology of this area is ideal for cave formation, of which there are five within half a kilometre of each other (Wadley et al 1987).

Hope Hill Shelter was occupied seasonally by hunter-gatherers. The central deposit dates to 4400 ± 100BP. The deposit contains few stone tools and debris, but large accumulations of human damaged bone from a variety of medium-sized and small grassland bovids, suggesting active hunting and snaring (Wadley et al 1987).

Hope Hill Shelter is long and shallow (Figure 10). It faces south-west and remains cool except for late summer afternoons. In recent years the shelter was used as a cattle kraal with troughs built against the back wall. A human skeleton was removed from the shelter by a local farmer. This skeleton has been described as of a "Bush" female, between the ages of 18 and 25, but the stratigraphic provenience of the skeleton is unknown (Wadley et al 1987).

- ***Stratigraphy***

Nine metres of the cave deposit were professionally excavated (Figure 9). The surface deposit is labelled Crust (C) and the underlying deposit Rocks Under Crust (RUC). This level contains large rock slabs and fallen roof spal. Underlying this layer are two clay lenses, the first Hard Black Clay and the

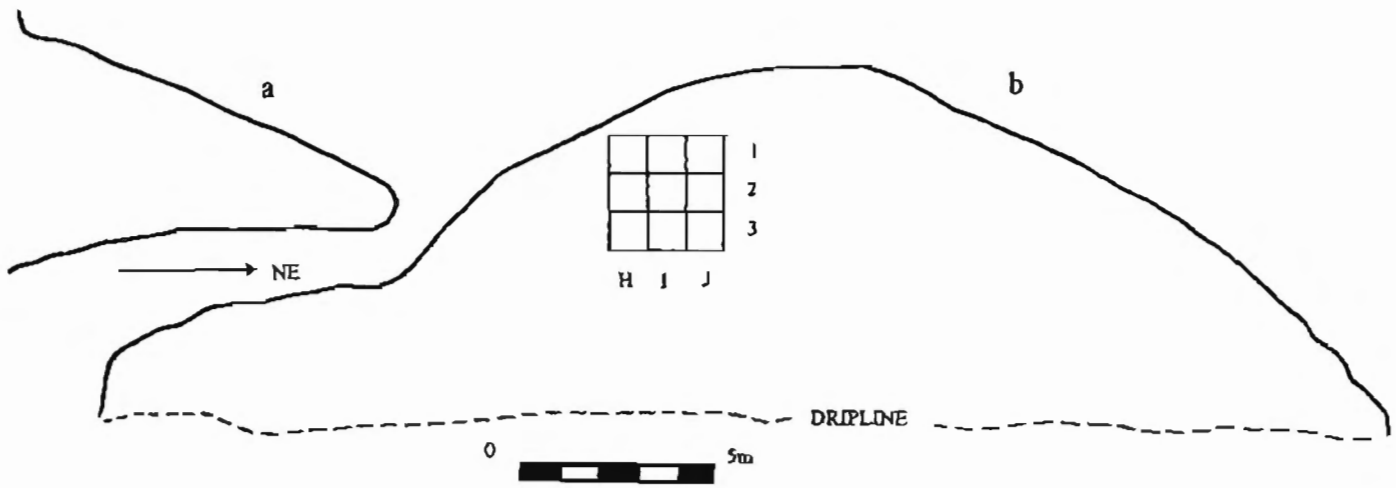


FIGURE 10: GRID PLAN OF HOPE HILL SHELTER
(After Wadley et al 1987).

second, of a moist, dense consistency is called Wet Black. These layers are subsumed under the name Hard Black (HB). Under these layers are three grey sand layers separated by a lens of thin dark deposit. These layers have been combined under the name Grey Sand (GS). The lowest level of the excavation (although not bedrock) was called Brown Clay and comprised clay with white nodules of decomposing shale (Wadley et al 1987).

- ***Fauna***

Young carnivores appear frequently, and a small but consistent component of fish, crab, frog, *Varanus sp.*, mollusc and bird in all but the lowest levels. Tortoise occurs only in one level. Domestic bovid remains include two sheep bones and a cow phalanx, this bone, recovered from the surface level, looked different from the rest of the bone assemblage and may be intrusive (Wadley et al 1987).

Several rodent remains are worthy of comment because of their exotic nature. *Mus musculus* (house mouse) was recovered from the surface and is probably recent. *Rattus rattus* remains, however, were recovered from the upper three levels and one fragment at the base of the excavation. This fragment may have fallen into the trench from the section wall, but the five bones from the level dated 4400BP is less easy to explain. The earliest known appearance of this species in southern Africa is in the 8th century AD. However, this species is known to make small burrows occasionally which may explain its occurrence at 4400BP (Wadley et al 1987).

Patterns of bone gnawing at Hope Hill suggest that hyaena activity was minimal. Fragmented bone probably resulted from longbones being intentionally split to remove marrow. The survival pattern of the bone assemblage is also consistent with human hunting activity in which small sized bovids are returned to the site for butchery, while larger bovids are dismembered at the kill site (Wadley et al 1987).

It appears that most of the bone accumulation and subsequent damage at Hope Hill is attributable to human activity.

- ***Environment***

The high frequency of *Alcelaphinae* and *Antilopini* bovids suggest grasslands near Hope Hill. Gemsbok (*Oryx gazella*), grey rhebok (*Pelea capreolus*), steenbok (*Raphicerus campestris*), duiker (*Sylvicapra grimmia*), zebra (*Equus burchelli*) and warthog (*Phacocheorus aethiopicus*) also occur in grassland areas. Many species at Hope Hill have a wide habitat tolerance, but some are water-dependent, suggesting the continued presence of water in this area. Species like gemsbok (*Oryx gazella*), brown hyaena (*Hyaena brunnea*) and the hairy-footed gerbil (*Gerbillurus paeba*) may indicate temporary aridity at about 4400BP. Two fish species, crab and molluscs at the cave indicate a fairly substantial water course. Bird remains include ostrich (*Struthio camelus*), Shelley's francolin (*Francolinus shelleyi*) and crowned guinea fowl (*Numida meleagris*) which inhabit grasslands. The presence of dikkop (*Burhinidae sp.*) also suggests the proximity of a water source (Wadley et al 1987).

While Hope Hill is the only shelter in the Leslie Falls Valley that was occupied during the Later Stone Age, the small sample of stone artefacts suggests that settlement was sporadic and possibly seasonal. Such seasonality may be attributed to low plant diversity, the distance from suitable raw material for tool manufacture, and rock falls in the shelters which may have discouraged people from prolonged occupation (Wadley et al 1987).

2.4.4 Summary

The stone tool assemblage at Hope Hill does not suggest any typological changes. Hunter-gatherers may have been drawn to this area because of its abundance of faunal species. Wild terrestrial foods were heavily exploited at Hope Hill. The presence of domestic animals are thought to be a recent inclusion. The high frequency of damaged bone relative to artefacts suggests that this shelter was used primarily as a "biltong camp". The most recent level of occupation, Level C, seems to suggest a home-base, rather than a temporary camp. In this level the making and mending of artefacts increases, and most of the recovered artefacts come from this layer. Artefacts which suggest woman's work; a bored stone fragment, grindstones and ostrich egg shell beads, come from both this layer and the one below it. Level C also contains the first

evidence of potsherds, Wadley et al (1987) suggest that the changed status of the shelter may have been initiated by the spread of pastoralism.

2.4.5 Ladismith

UCT 157 was excavated from near Ladismith in the Cape province. This was one of at least six individuals buried in an ant-bear hole. This individual was found associated with a "Tsamma-knife" (Morris 1992) and has been described by Hausman (1980) as an inland male specimen.

UCT 27 was found at Ladismith in the Cape province. There is no data about the archaeological association of this individual or any information about burial style and associated grave goods (Morris 1992). As with UCT 157, this skeleton has been described as an inland male specimen (Hausman 1980).

2.4.6 Summary

These two specimens were chosen largely based on their geographic location. Little is known about either of them, however chemical analysis should give an immediate indicator of their social, if not physical affinities. If isotopic analysis suggests that they conformed to a hunting lifestyle, then they make a useful addition to the few samples already established as inland hunter-gatherers.

CHAPTER 3

BACKGROUND TO LIGHT STABLE ISOTOPE AND DENTAL MICROWEAR ANALYSES

3.1 LIGHT STABLE ISOTOPE ANALYSES

3.1.1 Carbon Isotope Background

Stable carbon isotope analysis ($^{13}C/^{12}C$) of skeletal material distinguishes the proportions of foods of differing isotopic composition in the foodweb. C_3 and C_4 plants, as well as marine foods, follow distinctive photosynthetic pathways and fractionate CO_2 during photosynthesis in different ways. This differential fractionation, and the resultant isotopic signatures are mirrored in the consumers of these plants. Understanding the isotopic signatures associated with particular plants and animals, is useful for examining the diets of prehistoric peoples. Isotopic analyses detail both terrestrial and marine resource exploitation. Both these methods are discussed here.

Carbon occurs naturally in three forms; ^{12}C and ^{13}C are stable isotopes. ^{14}C is radioactive and decays with time. ^{12}C , ^{13}C and ^{14}C all undergo the same chemical reactions, but because they have different atomic masses they react at different rates during physical or chemical processes. To examine dietary differences the $^{13}C/^{12}C$ ratio of a sample is compared to that of a standard in a mass spectrometer. The results are expressed in delta notation (δ) in parts per thousand (‰). The universally agreed upon standard, PDB (*Belemnitella americana* from the Peedee formation in South Carolina) is a marine limestone. Although there is nothing left of the original standard material, all other laboratory standards have been calibrated against it. PDB has a higher $\delta^{13}C$ value (0‰) than almost all terrestrial materials so results are most often expressed as negative values.

Carbon isotope ratios are reported in delta notation where:

$$\delta^{13}C = (^{13}C/^{12}C_{sample} - 1) / (^{13}C/^{12}C \text{ standard}) \times 1000$$

Carbon isotopes are strongly fractionated during photosynthesis, the process by which plants metabolise CO_2. Although plants all use the same mechanism for the final fixation of CO_2 into carbohydrates, different pathways exist for the initial extraction of CO_2 from the atmosphere (Smith & Epstein 1971). Plants follow different photosynthetic pathways known as C_3 (Calvin Benson), C_4 (Hatch-Slack) and CAM (Crassulacean Acid Metabolism) respectively. In the savanna environment typical of Africa, most grasses and some domesticated crops, including maize, sorghum and millet, follow the C_4 pathway. This photosynthetic pathway discriminates less against ^{13}C than the C_3 pathway that is characteristic of most trees and shrubs (Smith & Epstein 1971). C_3 plants include wheat, rice, nuts, most vegetables and fruits. All trees, shrubs and grasses, in temperate, shaded or high-altitude environments, are C_3. Crassulacean Acid Metabolism (CAM) plants include most succulents. These plants use both C_3 and C_4 methods for fixing CO_2 effectively. However, distribution of CAM plants is limited and they are seldom eaten by herbivores, so their application to prehistoric diets is not significant, especially in the areas considered here.

During the process of converting atmospheric CO_2 into organic plant material, plants preferentially fix ^{12}C and discriminate against ^{13}C. Plants are thus depleted in ^{13}C relative to the atmospheric $\delta^{13}C$ value (usually -7 to -8‰). This discrimination is more stronger in plants following the C_3 photosynthetic pathway, compared those following the C_4 pathway (Figure 11). C_3 plants produce a 3-carbon compound during the first photosynthetic step, and the atmospheric isotope ratio becomes depleted by about 19.5‰ resulting in the foliage of C_3 plants having $\delta^{13}C$ values with a mean of -26.5‰ and a range of -20‰ to -35‰. C_4 plants produce a 4-carbon compound and fractionate the isotopic ratio to a lesser extent. $\delta^{13}C$ values for C_4 plants average -12.5‰ with a range of -9‰ to -16‰ (Vogel et al 1978).

	atmos CO2 -7.5%	
C3 photosynthesis		**C4 photosynthesis**
trees & shrubs -26.5%		**tropical grasses** -12.5%
browser apatite -14.5% **browser collagen** -21.4	**intermediate feeder**	**grazer apatite** -0.5% **grazer collagen** -8.0

Figure 11: Photosynthetic Fractionation (Adapted from Lee-Thorp & van der Merwe 1993).

Thus, the two groups are isotopically distinct. These distinctive isotopic signatures are passed along the foodchain to the tissues of consumers with some further fractionation. This results in the isotopic ratios of consumers predictably reflecting the ratios of the foods that they consume. This second step causes an enrichment in the $\delta^{13}C$ values for bone collagen of between 3 and 6‰ (with a mean of 5‰) relative to the diet. Apatite values are enriched by between +9.6‰ in controlled laboratory conditions (DeNiro & Epstein 1978) and +12 (see Figure 12) to +13‰ in field observations (Sullivan & Kreuger 1981; Kreuger & Sullivan 1984; Lee-Thorp 1989; Lee-Thorp & van der Merwe 1993). $\delta^{13}C_{apatite}$ values reflect the entire diet, while $\delta^{13}C_{collagen}$ values preferentially reflect the protein contribution to the diet (Ambrose & Norr 1993). Lipids are isotopically lighter than protein and carbohydrates, so an increased fat consumption results in lighter $\delta^{13}C_{apatite}$ values (Lee-Thorp 1989).

	Vegetation	(X)%		
Herbivore	*collagen*	*meat*	*lipids*	*apatite*
	(X+5)	(X+3)		(X+12)
Carnivore	*collagen*	*meat*		*apatite*
	(X+8)	(X+6)		(X+12)

Figure 12: Collagen and apatite enrichment values for herbivores and carnivores (After Lee-Thorp et al 1989).

Calcified body tissues like bone and enamel provide a useful reserve of carbon from which to investigate isotopic signatures in the archaeological context. Bone is made up of an organic phase (consisting mostly of collagen) and a mineral phase (biological apatite). It has a very slow turnover rate, thus the carbon in it reflects foods eaten over a long period of time. Collagen is stable and does not exchange carbon with the air or other organic materials. In the southern African context it has been shown to retain accurate isotopic signatures for up to 10 000 years as long as it survives in a relatively intact form. However, the 10 000 year time span limits the application of this organic substance to Holocene investigations (Lee-Thorp 1989; Lee-Thorp et al 1989).

The inorganic phase of calcified tissues is a biological apatite which is made up of poorly crystalline calcium phosphate salt which contains carbonate as a substitute for phosphate. Bone and tooth apatite survive much longer than collagen, but were initially neglected as a sample material because of the assumed effects of diagenesis (See Lee-Thorp 1989 for discussion). Enamel is less porous than bone and has greater crystallinity making it subject to less diagenetic alteration. In certain circumstances it has been shown to retain isotopic signatures up to two million years or more (Lee-Thorp et al 1989; Lee-Thorp 1989; Koch et al 1992). Isotopic values from enamel apatite reflect dietary intake at the time of enamel formation. Thus, enamel apatite values indicate the growth period of the

permanent dentition and not turnover rates, as with bone. Isotopic values may vary relative to which tooth is being sampled. Consequently human molars will reflect a more mature stage than incisors (Lee-Thorp 1989). Suitable pre-treatment of enamel to isolate and measure structural carbonates within the apatite crystals and to remove contaminants ensures an effective sampling material for stable isotope analysis (Sullivan & Kreuger 1981; Lee-Thorp et al 1987, 1991; Lee-Thorp et al 1997).

The following discussion is a summary of common foods and isotopic consequences in a southern African landscape. Indigenous African cereals including millet and sorghum, and non-indigenous maize follow the C_4 pathway, and have relatively enriched ^{13}C /^{12}C ratios. The meat and milk from grazers (C_4-consumers) like cattle, have positive $\delta^{13}C$ values. Sheep and goats however, are mixed feeders, therefore their $\delta^{13}C$ values are likely to be depleted compared to grazers, because of the inclusion of C_3 plants in the diet. Wild game meat would vary depending on whether people were exploiting browsers (mixed feeders including C_3 and C_4 foods) or grazers (eating C_4 grasses). Gathered plant foods are usually C_3, as wild grasses are not typically exploited for dietary resources. However, the ethnographic record does suggest that grass seeds are exploited by contemporary hunter-gatherers and pastoralists via termites (Schapera 1930).

3.1.2 Nitrogen Isotope Background

While carbon isotope analysis of collagen and apatite is an invaluable palaeodietary tool, one problem with this method in southern African investigations is that a C_4 dietary component is not distinguishable from marine dietary input. When examining coastal hunter-gatherers, this proves to be a major limitation. Diets consisting of equal amounts of C_4 and C_3 plants and terrestrial mammals would have $\delta^{13}C$ values the same as a completely marine diet. Populations dependent on a mix of C_3 and C_4 resources have indicated $\delta^{13}C_{collagen}$ values ranging

dependent on a mix of C_3 and C_4 resources have indicated $\delta^{13}C_{collagen}$ values ranging from -10 to -15 ‰ (Ambrose & DeNiro 1986). Populations subsisting on a 100% marine diet have mean $\delta^{13}C_{collagen}$ values of -11.4 ‰ and groups exploiting a 50% marine and 50% terrestrial diet show mean $\delta^{13}C_{collagen}$ values of -15.1 ‰ (Sealy & van der Merwe 1986). Likewise, people subsisting almost entirely on tropical reef fish, will have $\delta^{15}N$ values that do not reflect the marine origin of their diet (Schoeninger et al 1983). Thus, the combined use of both carbon and nitrogen isotopes should provide a more reliable picture of dietary content.

Almost all plants incorporate nitrogen in the form of nitrate or ammonia directly from the soil. There are several species that take nitrogen from the atmosphere. Atmospheric nitrogen is the international standard, and has been assigned a $\delta^{15}N$ value of 0‰. The $\delta^{15}N$ of soil averages at +10‰. Thus plants fixing atmospheric nitrogen have lower $\delta^{15}N$ values than non-nitrogen fixing plants. The $\delta^{15}N$ value for animal tissue is about +3‰ more positive than the $\delta^{15}N$ values of its diet (Schoeninger et al 1983; Ambrose 1991; Sealy et al 1987).

As with carbon analyses, nitrogen isotopes reflect the $^{15}N/^{14}N$ ratio of the plants at the base of the foodchain. Typical marine foodchains have more trophic steps than terrestrial ones. Marine plants have higher $^{15}N/^{14}N$ ratios than terrestrial plants, this difference is reflected in the foodchain, resulting in marine animals having more positive $^{15}N/^{14}N$ ratios than terrestrial animals. Thus the bone collagen for marine dependent people will reflect enriched $^{15}N/^{14}N$ ratios relative to people dependent solely on terrestrial resources (Schoeninger et al 1983).

Nitrogen isotope ratios are reported in delta notation where;

$$\delta^{15}N = (^{14}N/^{15}N_{sample} - 1) / (^{14}N/^{15}N_{standard}) \times 1000$$

Nitrogen isotope analysis ($^{14}N/^{15}N$) of bone collagen also provides some indication as to trophic level and aridity. Positive or enriched $\delta^{15}N$ values reflect higher trophic levels (Minagawa & Wada 1984; Ambrose 1986, 1991; Sealy et al 1987). The effects of aridity are less predictable although in general, values for

animals in areas with less than 400mm rainfall a year are significantly elevated (Heaton et al 1986; Sealy et al 1987). Unfortunately, the two effects are difficult to separate. However, by comparing populations from areas with similar rainfall, enriched nitrogen isotope values should reflect a greater dependence on animal products (Lee-Thorp et al 1993).

Historic populations (Eskimo, Haida and Tlingit) with primarily marine diets have $\delta^{15}N$ values of between +17 to +20‰. Freshwater organisms have $\delta^{15}N$ values intermediate between terrestrial and marine organisms and therefore are not useful indicators to distinguish between terrestrial and freshwater food sources. Marine hunter-gatherers (Mugu) have mean $\delta^{15}N$ values of +16‰, and fisher-gatherers (from the Danish Mesolithic period) have mean values of +14‰. Coastal hunter-gatherers from the southern Cape (South Africa) have $\delta^{15}N$ values ranging from +8.3 to +17.9‰, and those from the southwestern Cape have values between +10.2 and +17.7‰ (Sealy 1997). In contrast, agricultural diets have values of between +6 to +12‰. Mesoamerican maize agriculturalists have $\delta^{15}N$ values averaging +9‰. The $\delta^{13}C$ values for agricultural populations depend on whether C_3 or C_4 foods are being exploited and thus are either lower or higher than the values for marine-dependent groups (Schoeninger et al 1983).

Thus the analysis of nitrogen isotopes enables investigations of marine food dependence versus terrestrial food resources, as well as indicating trophic level relationships (Schoeninger & DeNiro 1984).

3.2 DENTAL MICROWEAR

Dietary abrasives leave microscopic defects on teeth. By observing these defects and categorising wear types, changes and differences in the oral behaviour patterns of modern and extinct mammals can be discerned (Teaford 1988). Dental microwear patterns reflect diet and chewing behaviour independent of gross morphological characteristics. Thus the analysis of dental microwear patterns may

provide some of the best indirect evidence both of tooth use and of diet in living and extinct species (Van Valkenburgh et al 1990).

Molar microwear has provided information about jaw movement (Butler 1952; Butler & Mills 1959; Mills 1955, 1963, 1967, 1973; Kay & Hiimae 1974) and the material properties of food (Gingerich 1972; Kay 1977; Kay & Hiimae 1974; Crompton & Kielan-Jaworowska 1978; Grine 1981). Incisor wear has been used to investigate ingestive behaviour (Walker 1976; Ryan 1979; Ryan & Johanson 1989, 1981; Kelley 1986, 1990; Ungar 1990, 1994a, b; Grine & Ungar 1991; Ungar et al 1991).

3.2.1 Previous Incisor and Molar Microwear Research

Microwear first became a means for investigating diet in the 1960's. Initial studies employed a light microscope to examine anatomically modern human teeth and suggested that food properties might be determined by the nature of microscopic scratches on the enamel of hominid teeth (Dahlberg & Kinzey 1962). Later examinations of rodent molars using scanning electron microscopy concluded that different microwear types could be related to food properties, tooth shape, enamel microstructure, occlusal pressure and chewing rates (Rensberger 1978). Research on hyraxes (*Procavia johnstoni)* demonstrated seasonal changes in molar microwear patterning. During the browsing season, pits predominated on the hyrax molars, while scratches were the predominant wear type during the grazing season (Walker et al 1978).

Experimental research on opossums to asses the limitations and potentials of microwear, concluded that molar microwear could not distinguish herbivory from insectivory (Covert & Kay 1981). This work however, was criticised for its lack of control (Gordon & Walker 1983). In 1982, Peters conducted experimental work on human teeth and noted that grit caused microscratches similar to those of opal phytoliths.

These initial studies were largely qualitative in nature. Gordon (1982; 1984) expressed the need to quantify microwear analyses. She also cautioned that tooth

position, facet type, sex and age contributed to feature variation, and should be controlled for. Gordon's investigations set the precedent for quantitative analyses in molar microwear studies.

Quantitative investigations by Teaford and Walker (1984) on several anthropoid species, concluded that frugivores show an increased incidence of pitting relative to folivores. They also suggested that hard-object frugivores have a higher frequency of pitting than soft-object frugivores whose molars were characterised by fine scratching.

Long-term experimental studies on vervet monkeys confirmed that pit frequencies are related to food consistency. Significant differences were observed between monkeys fed dry, hard foods and those fed wet, softer foods. The former showed more microwear on crushing facets than the latter (Teaford & Oyen 1989a).

The life expectancy of microwear features have also been investigated. Turnover of features varies depending on food consistency, but may in some cases be as short as 24 hours (Teaford & Oyen 1989a;b;c).

Scanning electron microscope analyses of anterior dentition began with Ryan (1980; 1981) who examined incisor microwear in humans, gorillas, chimpanzees and baboons. He attributed differences in microwear to feeding behaviour and the use of teeth as tools. Large pits were associated with the crushing of gritty foods and large gauges with cultural activities. An examination of *Presbytis rubicunda* and *Presbytis cristata* concluded that the microwear differences between these colobines may reflect differential incisor functions (Teaford 1983). The qualitative methods of Kelley (1986; 1990) concluded that folivores exhibit less microwear than frugivores who show increased striations on their incisors. These results were related to either increased incisal preparation or more abrasives in the diet.

Further analysis of anthropoids, concluded that the density of microwear striations is related to the use of incisors in processing food items (Ungar 1990;1992). Striation breadth is related to the size of abrasives and striation orientation to the direction that foods are scraped along the incisors.

Incisor microwear investigations have included hominids as well. Ryan and Johanson (1989) argued that *A. afarensis* used their incisors to strip gritty plants and roots. Neandertals showed large gouges on their incisors that were attributed to cultural practices (Ryan 1980). The labiolingual orientation of striations on *A. afarensis* incisors indicated stripping food between clenched teeth (Peuch & Albertini 1984). Later, Puech (1984,1986b) noticed similar wear striae, as well as acid etching on *H. habilis* incisors and argued that these features were consistent with stripping acidic foods across the teeth. An investigation of *A. africanus* and *A. robustus* incisors indicated increased wear densities for *A. africanus*, with *A. robustus* displaying more etched enamel sheaths. These results suggest that *A. africanus* used their incisors more often in manipulating abrasive food items, while *A. robustus* probably consumed more moderately abrasive foods (Grine & Ungar 1991).

3.2.2 Patterns of Microwear

Real microwear patterns are relatively easy to distinguish from post-mortem or casting defects in a scanning electron microscope. Real dental microwear usually reflects a regular pattern at set locations. Post-mortem or preparative tooth-cleaning wear occurs at irregular locations and forms unusual patterns (Teaford 1991).

Some microwear studies have centred on the rather oversimplified theory that if teeth are exposed to more dietary abrasives, they should indicate more microwear features (Teaford 1991). Thus one would merely count the amounts of microwear features to determine density. This method is only applicable in certain situations as abrasion is not the only cause of microwear features. Microwear is caused by three factors; (1) attrition or tooth-tooth contact (Grine 1981; Peuch et al 1981; Walker 1984; Teaford & Runestad 1992), (2) abrasive exogenous grit on food (Wallace 1974; Walker 1976; Covert & Kay 1981; Peters 1982; Kay & Covert 1983) and (3) siliceous opal phytoliths in plants (Baker et al 1959; Walker et al

1978; Peuch 1986). Quantifying microwear features attempts to link microwear patterns to certain dietary behaviours in extant animals.

Occlusal attrition results from contact between the biting surfaces of lower and upper teeth. Thus the microwear differences on cusp tips, as well as the shearing and grinding regions allow for inferences on whether diet is hard or soft in consistency. Dietary differences are characterised by changes in the relative proportions of microwear features. For example, increased tooth-tooth contact with soft food will result in more striations (as seen with frugivores). The crushing surface generally has more pitting than the shearing surfaces. However, in the case of hard diets, there will be a high proportion of pits on both surfaces (Molleson et al 1993).

Experimental work has suggested that the size and shape of microwear features can be associated with the size and shape of the abrasive particles that cause them (Puech et al 1979; Ryan 1979). Likewise, Ungar (1994) suggests that where anterior teeth contact in an edge-to-edge manner, attrition is unlikely to be the cause of microwear patterning, but rather that abrasive particles entering the mouth, cause these features. Pit size and shape are related to the size and shape of the ingested particle and the vertical force applied during mastication. An increase in the vertical force results in an increase in pit size with a concomitant decrease in the number of striations. This typically occurs with an increase in crushing in the diet (Molleson et al 1993).

Molars are used in active mastication, therefore the ratio of pits to scratches on molar surfaces are considered to reflect the hardness of foods and the degree of folivory in primates (Grine 1981, 1986a; Teaford & Walker 1984; Teaford 1985, 1986, 1988; see Teaford & Runestad 1992 for complications). Anterior teeth however, are not often used in active mastication. Therefore they are not likely to show pitting indicative of hard food crushing (Ungar 1994). However it is predicted that primates that crush harder foods with their incisors will show more pitting on these tooth surfaces. Incisal surface pitting frequency probably reflect the ratio of crushing to scraping activity during ingestion (Ungar & Grine 1991). However,

Ungar (1994) found no clear association between the frequency of pitting on central incisors and the consumption of hard foods for the four primate species he examined.

There are two schools of thought regarding striation patterning on anterior teeth. Walker (1976) suggested that scratch concentration reflects feeding substrate, so that terrestrial primates should possess more scratches caused by siliceous plant materials and exogenous grit than arboreal species. Labial surface striation density has been associated with the degree of tooth use during food ingestion (Kelley 1986; 1990). Ungar (1990) is intermediate in opinion, suggesting that both feeding substrate and degree of incisor use affect microwear feature density. He also suggests that striation density does not reflect broad dietary differences in the primates examined. Such that frugivorous species do not consistently show more or less microwear than more folivorous taxa (Ungar 1994; Kelley 1990). Striation breadth most likely reflects particle size (Ungar 1994).

It has been suggested that that there is an association between striation orientation and the direction of movement of foods across the incisor surfaces (Walker 1976; Teaford 1983; Ryan & Johanson 1989).

3.2.3 Limitations

Dental microwear investigations are based on evidence that specific diets are associated with characteristic wear patterns (as discussed above). This method, however, has limitations. Firstly, quantitative microwear records the eating habits of animals just prior to death, reflecting only the final dietary activities of that specimen. Secondly, microwear has often been used to investigate the diets of extinct species that have few or no modern analogues. To understand the principles of microwear and its relationship to diet, it is essential to first establish the pattern between feeding behaviour and microwear in living species before analysing extinct species. This has most often been done with various animals considered to reflect specific or well understood diets. A third, and critical limitation

of dental microwear analysis is that some foods leave no microscopic wear. Soft foods, like meat and fruit pulp are difficult to detect by microscopic wear analysis. Bone and grit inflict more damage on teeth than softer meat, thus the microwear of habitual bone-gnawers is expected to differ from the microwear patterns of species that eat little bone (Van Valkenburgh et al 1990). Microwear analysis is therefore constrained, to some degree, by food consistency.

Dietary wear can be confused with the effects of increasing wear resulting from age (and other factors). This would affect the total feature density but not the proportions of feature types. For example, juveniles and young adults have higher feature densities than older teeth were microwear is erased and reworked. Increased wear by continued abrasion may enlarge and shallow existing pits leading to distortions during quantification (Molleson et al 1993).

Other limitations include the rapid turnover rate of microwear features, variations in microwear feature densities which may be biomechanical rather than dietary, problems with comparing deciduous and permanent dentition and the impact of dietary acidity (Puech 1984; Molleson et al 1993).

3.2.4 Limitations of Occlusal Canine Wear

Canine microwear is a new field of interest. As a result little is known about what canine microwear features mean in terms of dietary and ingestive behaviours. Until future research clarifies these issue, canine microwear is interpreted in terms of incisal wear patterns. Canines form part of the incisal functional unit. The similarity in function between these dentitions, suggest that they may be comparable in terms of microscopic wear characteristics. Hominoid incisors are not typically employed during mastication. Incisor crowns are not well suited to withstand the bending stresses associated with the mastication of hard food objects (Kay et al 1974). Similarities in pitting incidences on the incisors of different primate species do not necessarily reflect homogeneity in the hardness of the items consumed. Because molars and incisors function differently, it is likely that their microwear features will also differ, and that parameters which are correlated with

food consistency in one are not necessarily related in the other. Therefore, microwear patterns that are related to dietary activity in one set of dentition, should not be expected to provide the same kinds of information for the other teeth.

Marked differences between the labial, lingual and occlusal surfaces evident in a study of primate incisors (Ungar et al 1991) suggest that these areas are not homogenous in their information and as such, should be treated independently. A similar scenario is expected for the analysis of canine microwear. The inclusion of this tooth into the incisal functional unit suggests that lingual, labial and occlusal surfaces are not comparable with each other.

3.2.5 Previous Studies on Hunter-gatherers vs Agriculturalists

Several previous studies have examined differences in molar microwear between hunter-getherer groups and agriculturalists. The change in subsistence from that of hunter-gatherer to a diet including ground grains and boiled food should result in a reduction of tough, fibrous foods and a concomitant reduction in the role of the teeth in the breakdown of these foods (Holly Smith 1984). Microwear studies validate this assumption. Generally, occlusal attrition is greater in hunter-gatherers than in agriculturalists as a result of differences in food consistency. Hunter-gatherer foods are typically very coarse, while the diets of food-producers generally consist of more processed or refined, and consequently softer, foods (Hinton 1982; Molnar 1971, 1972; Holly Smith 1984).

Prehistoric hunter-gatherer populations from the Central Valley of California, dating between 200-300 years BP, revealed a generally oblique wear plane, and a more rapid rate of wear than the prehistoric agricultural populations (Pastor et al 1992).

Analysis of pre-contact and post-contact native populations from the south-eastern United States also suggest differences in microwear patterning (Teaford 1991). Pre-contact natives subsisted on a diet of hunting and gathering both terrestrial and marine resources. After the establishment of Spanish missionaries, maize consumption gradually replaced this hunting/gathering subsistence pattern.

Pre-contact teeth exhibited significantly more pitting than post-contact teeth with wider scratches and less variation in pit widths. If the marine component of pre-contact diets included hard objects or abrasives not found in maize, one would expect these differences to be reflected in the microwear features. The greater incidence of pitting on pre-contact teeth suggests the ingestion of hard objects, while the insignificant variation in pit widths further supports the consumption of hard objects on a regular basis. Larger scratch widths for pre-contact people suggests an increase in the size of abrasives ingested.

Investigations of North Indian hunter-gatherers (Mahadaha) and agriculturalists (Mehrgarh) confirm that the abrasive diets of hunter-gatherers results in a greater degree of wear than for agriculturalists (Pastor 1992). The Phase 1 molar microwear for agricultural peoples consist of polished areas with an abundance of small to medium-sized pits as well as long fine and wide scratches with sharp, rough and angular edges. This dietary pattern is associated with the consumption of processed grains and meat from domestic stock. In the hunter-gatherer sample, feature density is higher. The enamel is rough in texture and is characterised by long, fine scratches and wide parallel scratches with rounded and fairly smooth margins as well as a few small pits. These features suggest a hunting-gathering subsistence pattern including tough, fibrous and abrasive plant foods and wild bovids.

The major distinction between hominids and pongids regarding molar wear, is the characteristic "flatness" of this wear in both hominids and prehistoric populations (Clark 1955). Flat molar wear has traditionally been attributed to the reduced size of the canine which allowed for jaw rotation during chewing. However food consistency and toughness are also plausible causes. Hunter-gatherers show evenly distributed molar wear resulting in a relatively low wear plane angle with increased wear. Agriculturalists show a more restricted wear pattern with the tendency to develop oblique wear planes (Holly Smith 1984).

Hunter-gatherers tend to display more gross dental wear as a result of non-dietary tooth use. Incisors generally become rounded and do not meet when the

molars are in occlusion. Anterior wear in agricultural populations may increase in cases of posterior tooth loss. Thus the anterior teeth replace the grinding function of the molars (Hinton 1981). This supports the conclusion reached by van Reenen (1964) after examining San dental casts. A re-examination of his casts by Wallace (1972), however, suggested that the rounded incisal wear resulted from dietary abrasives rather than occupational wear. Thus it seems as if heavy anterior wear, usually rounded, is associated with hunter-gatherers (Steyn 1994).

3.2.6 Grit

One of the major problems associated with microwear analysis, is distinguishing dietary abrasives from non-dietary abrasives, such as grit. Using modern human analogues to investigate the effects of grit on dental microwear is problematic. Difficulties include controlling for dietary intake and extra-oral preparation. It is a common assumption that coastal hunter-gatherers have more abraded teeth (as discussed above) because of the increased inclusion of grit in their diet. Likewise determining differences between sand grit (ie:coastal sands) and stone grit (ie: resulting from grinding foods between stone) may be difficult. Some Australian Aborigines bake flour cakes in hot ash It has been suggested that this practise introduces enough exogenous grit into the diet to produce abnormally worn teeth (Molnar 1972).

When using microwear as an indicator of dietary differences, one needs to be cautious of comparing diets that may be too similar in particle hardness to provide any valuable information.

3.2.7 Summary

Food consumption is the primary focus of this work, extra-oral food preparation has a significant impact on the consistency of food introduced into the mouth, and on the amount of damage such foods may cause to the teeth. Gross macrowear reveals that while coastal diets induce considerable wear, food-producing diets contain opaline phytoliths and these factors may not be easily

distinguishable from one another. The grinding and cooking process that maize undergoes during preparation presumably causes a reduction in opaline size which consequently should impact on its effect on tooth enamel and wear. The use of archaeological sources and isotopic analysis is another means of controlling for these factors and distinguishing between them. If microwear results for the three selected populations cannot be distinguished despite predicted differences in diet based on faunal remains and isotopic signatures, then the utility of canine microwear, as a technique for dietary indication, needs to be re-thought.

CHAPTER 4

METHODS

4.1 STABLE LIGHT ISOTOPE ANALYSES

This study aims to provide a more complete understanding of dietary habits by using isotope ratios from both collagen and apatite. Isotopic values from earlier studies were available for some sites. Most of these studies concentrated on the carbon and nitrogen collagen values for the various samples. This research builds upon such data by expanding the analytical set to include apatite values. It was however, not always possible to sample for both collagen and apatite. Where collagen carbon and nitrogen values existed, this information is supplemented by sampling enamel. Where no isotopic information was available, both bone collagen and enamel have been sampled.

4.1.1 Sampling Strategy

Twenty three adult individuals were sampled from various museums. K2 specimens came from Pretoria University (n=5), the University of Witwatersrand supplied Hope Hill, Ladismith and Harrismith specimens (n=5), Oakhurst specimens were sampled at the Department of Anatomy, University of Cape Town (n=6) and Matjes River specimens at the National Museum of Bloemfontein (n=7). In the cases of K2, Oakhurst and Matjes River the individuals sampled supplement previous data. The inland individuals are analysed for the first time.

As far as possible, all specimens examined for dental microwear were also sampled for apatite analysis. In some instances, radiocarbon dates and stable isotope values were already available. A new miniaturised sampling technique, which I helped develop, was employed for apatite analysis (Lee-Thorp et al 1997). Collagen samples were prepared and analysed following the methods described by Sealy (1997).

Samples for apatite isotope analysis were taken preferentially from a third molar. As the last tooth to erupt and mineralise it provides information about the mature stages of an individuals' diet. The buccal or lingual surface are usually selected to avoid damaging any areas that may be useful for future macro or microwear research. Prior to drilling, each tooth was cleaned with an abrasive pad to remove any adhering dirt. Tooth surfaces were also examined to ensure that enough enamel could be collected without inadvertent contamination with dentine. Where this was a concern, the cavity was extended in diameter rather than in depth. Samples were drilled from the selected tooth using a Dremel hand-drill with a 1.2 mm diamond-tipped bur. Care was taken not to drill between cracks in the enamel as this tended to result in enamel flaking. A major advantage of this miniaturised method is that it allows for minute samples of powdered material to be collected negating the need to mill and possibly lose some of the sample later.

After drilling, each sample is weighed to ensure that at least 3mg was collected. Weighing the sample at this stage allows for control of sample quantity later. Samples were stored and later subjected to a series of pre-treatment procedures in 2ml micro-centrifuge tubes. 1ml of 3.5% sodium hypochlorite (bleach) and distilled water in a 1:1 ratio was reacted in each tube for four hours at room temperature. Each sample was then alternately rinsed in distilled water and centrifuged three times until neutral pH was achieved. 0.5ml of 0.1M acetic acid was then introduced into each tube and allowed to stand for 15 minutes (Sponheimer pers. comm.). This shorter reaction time has been found to be adequate. The rinsing procedure was then repeated. In this instance, samples were rinsed four times before neutral pH was achieved. Samples were then freeze dried for four hours.

Samples were weighed to check mass loss during pre-treatment procedures. Approximately 1mg was weighed into individual reaction vessels and placed in the carousel. Samples less than 1mg tend not to produce enough CO_2 for reliable measurements.

The Kiel autocarbonate device hydrolyses each sample in turn with 100% phosphoric acid at 70°. Cryogenic distillation is automatically controlled. Clean, dry carbon dioxide is introduced into the mass spectrometer for direct measurement of isotope ratios.

All measurements were calibrated using a calibration curve developed from known standards; NBS 18, NBS 19, LL1 and Carrara Z. This was done by plotting observed values against expected ones for carbon and oxygen. The calibration of values is required because observed and expected values are not absolutely consistent. That is, these values may change from month to month and the slope of the calibration curve is not quite 1. Therefore, several standards of differing isotopic composition are used to exclude slight mass spectrometer effects against expected and observed standard values. See Tables 8 and 9 for calibration details.

4.1.2 Collagen Preparation and Methodology

Collagen samples were collected for Oakhurst specimens which did not have them, as well as several inland individuals. In some instances, samples were not taken as specimens were too pristine to warrant invasive sampling. Collagen analyses require samples of bone, for all specimens reported here, this was collected from the cranial region.

The method used here is the "whole bone" method See Sealy 1986; Sealy et al 1987 for discussion). Although more complex methods exist this method is labour-saving and several of samples can be processed at the same time.

Cranial samples were surfaced cleaned with an abrasive pad, then decalcified in 1-2% hydrochloric acid solution (HCl). This procedure takes up to seven days. Following this, the acid-insoluble protein was treated with 0.1M sodium hydroxide (NaOH) overnight to remove any humic acids. Each sample was then rinsed repeatedly in distilled water until neutral pH was reached. Samples were then freeze dried.

Samples weighing between 0.3 and 0.5mg were loaded into tin capsules which were then introduced into a Finnigan-MAT 252 mass spectrometer coupled

to a Carlo-Erba preparation unit. Samples were combusted at 1600°C, the resultant gases separated in the columns and the water removed before being introduced into the mass spectrometer via the Conflo interface. CO_2 and N_2 measurements were made against commercially available CO_2 and N_2 whose values relative to PDB and atmospheric nitrogen (respectively) are well established. All samples were calibrated relative to Merck Gel an internal laboratory standard.

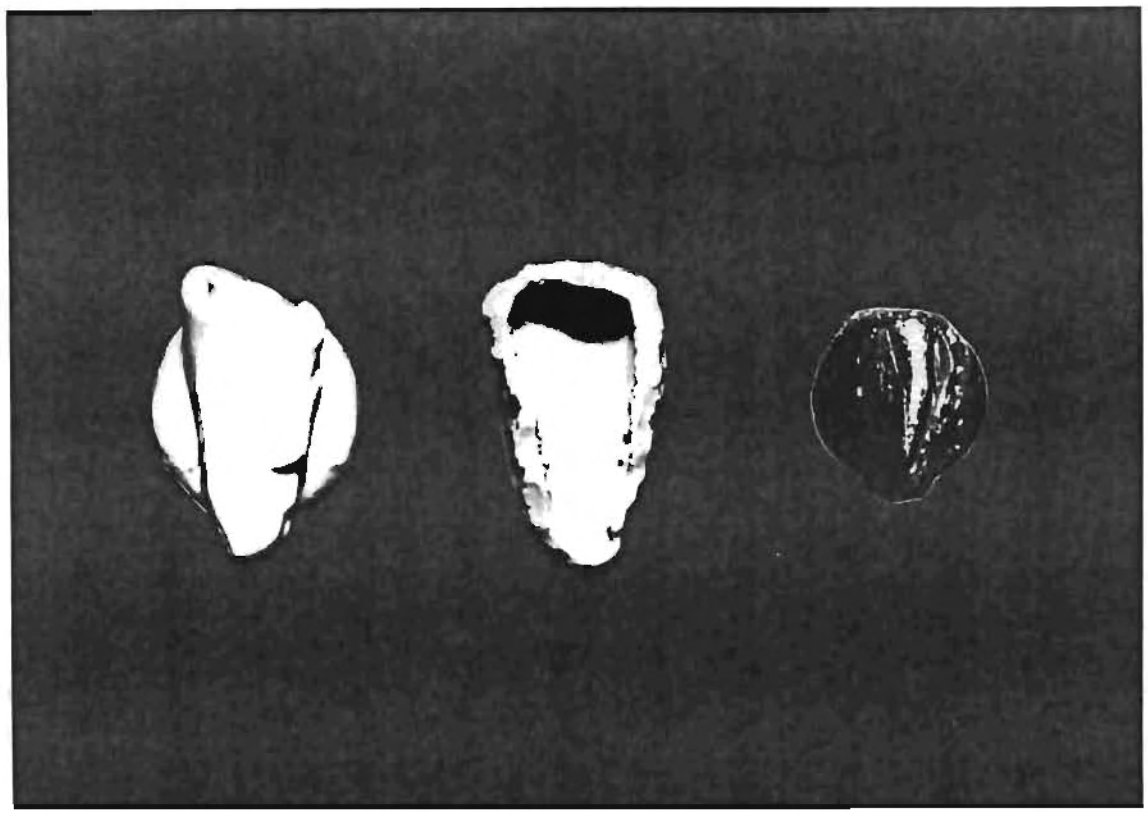
4.2 CANINE MICROWEAR ANALYSES

The dental microwear approach used here focused on the occlusal surfaces of canine teeth. These anterior dentitions prepare foods before active mastication and it has been established that they exhibit microwear distinct from the posterior dentition (Manning 1995). Only maxillary teeth were examined. It is not exactly clear how canine microwear features reflect diet and food preparation. This research aims to determine whether the canine microwear of anatomically modern humans with different diets is an effective method for investigating such differences.

4.2.1 *Specimen Preparation and Sampling*

Twenty two samples were prepared for microwear analysis. K2 (n=4), Matjes River (n=6), Oakhurst (n=6) and the selected inland sites (n=6).

Only maxillary canines were examined. Each tooth was selected based on several factors: (1) absence of severe areas of wear, (2) absence of glyptol or any other adhering matrix, (3) and the absence of major cracks that may cause casting problems. Heavily worn teeth and unusually small teeth were omitted. Teeth were cleaned following the method used by Grine (1986). Each tooth surface was cleaned with acetone and blasted with dust-free compressed air. Casts were made using Coltene's President Jet Microsystem. Each cast was taken of the maxillary canine buccal and occlusal surface from apex to gingiva (Figure 13a). Coltene putty base and catalyst were mixed in a 1:1 ratio and used to construct dams



Figures 13a-c: Cast of Canine Tooth; Putty Dams Constructed around Cast of Canine Tooth; Sputter Coated Resin Mold of Canine Tooth (from left to right)

around the casts and allowed to stand overnight (Figure 13b). The casts were again sprayed with dust-free compressed air before the mixture of Araldite 506 and hardener HY956 in a ratio of 4:1 was decanted and allowed to set overnight. Following this the molds were stubbed and sputter coated with 20Å gold palladium (Figure 13c).

4.2.2 Surfaces examined

Prior to electron microscopy the occlusal surface of each tooth was examined using an optical microscope to ensure that the micrographed area was representative of the wear over the entire tooth surface. Only occlusal surfaces were examined.

The selection of the occlusal surface was based on a study conducted by Ungar and Grine (1991), in which they examined the incisal, lingual and labial surfaces of the anterior dentition of both *Australopithecus* and *Paranthropus*. The incisal surfaces provided the most microwear detail, while the labial and lingual surfaces did not differ significantly with regard to pitting frequencies. They conclude that the higher incidence of pits on the incisal edge probably reflect the crushing of silicates and/or exogenous grit between opposing teeth. The lingual surface had the smallest feature dimensions across all categories, and labial surfaces less than the incisal surface. Based on these results, it appears that incisal (occlusal) surfaces are the most informative, particularly in prehistoric populations who have not yet developed the over-bite characteristic of modern populations.

4.2.3 Scanning Electron Microscopy Parameters

Dental microwear was investigated by means of scanning electron microscopy. Micrographs were taken at a magnifications of 200 × on a s200 scanning electron microscope with an accelerating voltage of 15keV and a consistent working distance of 25mm. The choice of 200× is a compromise. Most

molar studies use 500× magnifications, however, anterior tooth surfaces are often larger than molar wear facets. At 200× most features seen at 500× can be resolved and a much greater proportion of the tooth surface is sampled than at the higher magnifications (See Teaford 1991 for discussion). The use of 200× also enables comparisons with previous anterior dental wear studies.

Micrographs were taken of each tooth as close to the apex as possible. Certain factors, however, limit the ability to take micrographs at conspecific locations on each tooth. Where a tooth was so worn that no apex was visible, the micrograph was taken close to the incisal edge in the middle of the occlusal surface. Although certain teeth showed distinctive wear planes, these were often not close enough to the selected micrograph area of the other specimens to maintain consistency. All micrographs were orientated as indicated in Figure 14 to facilitate statistical testing. Specimens were orientated horizontal to the electron beam to ensure that features were not affected by distortion.

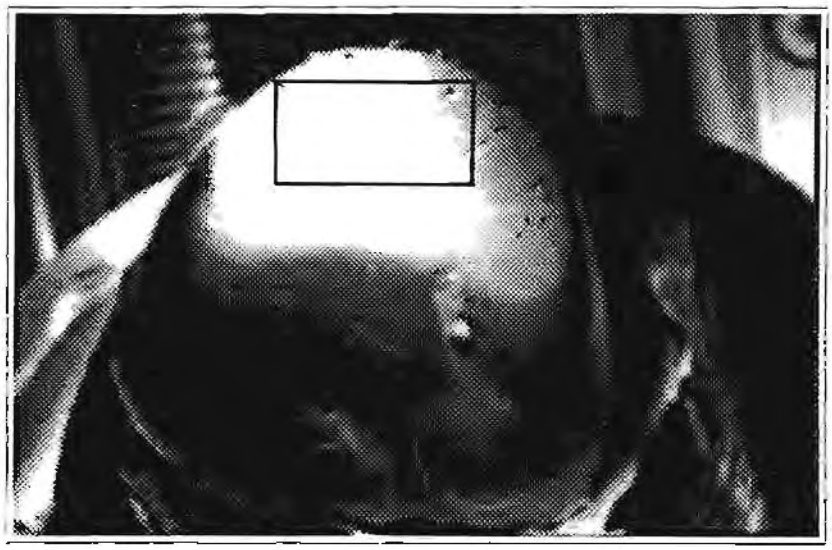


***Figure 14**: Canine Occlusal Surface Orientation*

4.2.4 Image Analysis System

Each micrograph was scanned and measurements were obtained using MICROWEAR 2.2 software (Ungar 1995; see Ungar 1996 for full discussion). The precision of this measuring system was established by multiple measurements of the same micrograph and comparisons of the results. Reproducibility was 99%. Features were categorised into pits (length-width ratio of 4:1) and scratches (length-width ratio greater than 4:1). Both the length and width of pits were measured. Scratches are defined by their width measurements only, although length measurements were taken to determine scratch orientation. Many scratches are truncated by the borders of the micrograph so measurements of feature length could be misleading and are thus excluded from analysis. These length measurements are however, important in terms of identifying feature orientations. All features are measured and reported in microns.

4.2.5 Statistical Tests

Data were largely analysed based on the methods employed by Ungar (1996). Ungar outlines his statistical methods comprehensively allowing researchers to replicate them with a fair degree of ease. In some instances, the statistical methods employed by Ungar are not used here, the reasons for this are outlined in more depth in Chapter 5.

Data were analysed using two methods. The first is single factor analysis of variance which determines variation from the mean. Where variation was detected a modified t-test (see Chapter 5 for discussion) was used to determine the source of variation. For this study, proportional data has been ranked. An alternative method for determining mean distributions is the Student-Newman-Keuls test. This method ranks all data and thus overcomes problems associated with the distribution of data (Zar 1984). It is however extremely controversial and is discussed in more depth in Chapter 5.

- *Feature Orientation*

Feature orientation is only measurable if each micrograph is taken at the same orientation. Care was taken to ensure this was the case for each sample.

Long axis feature orientation analyses the percent of mesiodistally orientated features (MD/(MD+AC) x100). Mesiodistal (MD) orientation ranges from 0° to 45° and 135° to 180° on a 180° axis. Apicocervical (AC) orientation lies between 45° and 135°. Individual feature orientation was determined for each micrograph and plotted on histograms defined by the frequency of features in 10° cells ranging from 0° to 180° (See Chapter 5).

The %MD Index analyses the frequency of mesiodistally orientated features for each miocrograph. Prior to analysis, data was rank transformed as raw data is not normally distributed. Single-factor analysis of variance tests the hypothesis that the means of several populations are equal.

- *Feature Concentration*

The "r" value addresses feature concentration variation within each micrograph and reports on that variation independent of actual angle values. Single-factor Analysis of variance applied to rank transformed data tested for differences in feature concentration ("r") between all groups.

- *Feature Frequencies*

Feature frequencies determine the incidence of pitting and scratching for all groups. As discussed in the previous chapter, feature frequencies are useful in determining dietary and ingestive activities . The incidence of pitting and scratching for all groups were determined using single-factor analysis of variance on ranked data.

- ***Feature Dimensions***

Average feature dimensions were analysed by Single-factor analysis of variance. Several questions were asked. Do groups differ in the average widths of pits and scratches? Do groups differ in their average pit length dimensions? Do groups differ in their frequency of pitting and scratching?

4.2.6 Summary

This chapter has described the sampling and preparation of two separate methodologies. Isotope ratios were obtained for enamel following a miniaturised technique according to the work developed by Lee-Thorp et al (1997). Isotope ratios for bone collagen used the established "whole bone" technique. Microwear feature analysis followed the earlier work of Grine (1986), Ungar and Grine (1991) and Ungar (1996).

Results for both isotopic analyses and canine dental microwear investigations are outlined in the following chapter.

CHAPTER 5

RESULTS FOR ISOTOPIC AND DENTAL MICROWEAR ANALYSES

This chapter reports the results for both isotopic analyses and dental microwear investigations obtained by methods outlined in the previous chapter. The first section deals with mass spectrometric parameters. The second section looks at the isotopic results for the individuals examined. This information is then drawn together into an analysis of dietary activity for each group examined. The results for canine dental microwear are examined in terms of the statistical tests specified in the previous chapter. The results for each test are outlined and discussed where appropriate.

5.1 LIGHT STABLE ISOTOPE RESULTS

5.1.1 Reliability of Isotope Measurement Readings

Because enamel contains little carbonate, and because the sample sizes are kept to an absolute minimum, the techniques used in this research are at the edge of reliable or optimum sample size ranges for mass spectrometry. Small gas yields may lead to spurious results, therefore gas yields and raw isotope ratios had to be carefully maintained and examined. Looking at gas yields and the resultant mass spectrometric pressure are the criteria for determining which isotopic numbers are valid. This is of concern because some samples give very low gas yields, which are too low to provide reliable isotopic ratios, and consequently low voltages. In stable light isotope mass spectrometry, the ion pressure measured in the analyser must be high enough to obtain a stable signal. The manufacturer normally specifies 2V; below this, the signal becomes unreliable and is liable to produce instrumental noise. In addition, because there is a small amount of exchange between the sample gas and the reference gas in the change-over valve, small samples are likely to show progressively greater contamination with the reference gas. Consequently, low voltage readings may mean that the resultant isotopic ratios are

noisy and/or altered by interference with the reference gas. This will in most cases cause an isotopic shift in the direction of the reference gas.

This problem was observed in some samples. In the case of A1730 (10907) the sample size was fairly small (0.364mg) and a gas yield of only 1.041V was produced (Table 9). However, the $\delta^{13}C$ (-3.8 ‰) and $\delta^{18}O$ (-3.0‰) value for this individual falls within the range of other K2 specimens (eg: A632 (15)) with reliable gas yields. Although one needs to be cautious about these results, they were consistent enough with other related, more reliable samples to be retained in this study.

A1701 (11472) was a fairly large sample (1.012mg), but for reasons which are not clear, only a very small amount of gas was produced (56µbar) and the resultant $\delta^{13}C$ and $\delta^{18}O$ values differed significantly from those of other K2 specimens (Table 9). The small yield for this sample may have resulted from some mechanical problem. In some cases, the acid does not reach the sample in time to hydrolyse the sample and evolve the gas effectively. The large size (mg) of this sample, suggests that this may have been the case. These results were not regarded as reliable and were disregarded.

A1758 (10899) produced a very positive $\delta^{18}O$ value, which seemed to differ markedly from the other values for K2 specimens (Table 9). However, the voltage and pressure values for this specimen are sufficient, so that there is no obvious reason for them to be regarded as unreliable.

The Hope Hill (10932) specimen was also small in size (0.395mg) and was expected to produce low gas yields and voltage. However, a pressure of 490µbar and sample voltage of 6.662V was observed (Table 9). These values were unexpected given the small sample size and might indicate input of gas from another source.

The Harrismith burial 1 specimen proved problematic. Despite repeated testing of fairly large sample sizes, this specimen consistently produced low pressure and gas yields (Table 9). In cases where specimens have low carbonate (CO_3), low gas yields result. This appears to be the case with Harrismith burial 1.

Date	Spec #	Sample #	Sample Size	Pressure ubar	Sample V	Uncorrected $^{13}/^{12}C$	Uncorrected $^{18}/^{16}O$	Corrected $^{13}/^{12}C$	Corrected $^{18}/^{16}O$
2/2/97	*10890	Carrara Z	0.047	394	4.709	0.612	-10.813	1.2	-10
	*10891	Carrara Z	0.052	413	4.933	0.582	-10.852	1.2	-10
	*10892	Carrara Z	0.069	503	6.597	1.811	-2.065	2.5	-0.7
	*10893	Carrara Z	0.043	363	4.149	1.531	-2.395	2.2	-1.1
	*10897	NBS18	0.08	312	3.434	1.31	-3.285	2	-2
	*10904	NBS18	0.051	317	3.451	1.243	-3.388	1.9	-2.1
	*10912	Carrara Z	0.081	529	6.59	-0.023	-9.25	0.6	-8.3
	*10913	Carrara Z	0.068	458	6.169	-0.062	-9.229	0.5	-8.3
	*10921	Carrara Z	0.05	404	4.462	-0.188	-9.38	0.4	-8.5
	*10933	Carrara Z	0.068	279	2.648	-0.589	-9.677	-0.01	-8.8
	*10934	Carrara Z	0.083	520	6.675	0.227	-9.164	0.8	-8.2
	*10935	Carrara Z	0.061	523	6554	-0.05	-9.238	0.5	-8.3
7/7/97	†15494	NBS18	0.06	405	3.278	-4.579	-21.521	-4.6	-21.6
	†15495	NBS18	0.081	456	3.249	-4.778	-22.096	-4.8	-22.2
	†15496	NBS18	0.065	474	2.872	-4.666	-21.98	-21.1	-4.6
	†15497	NBS18	0.072	466	4.409	-4.617	-22.246	-22.4	-4.6
8/7/97	†15514	NBS18	0.08	501	5.038	-4.655	-22.363	-22.5	-4.6
	†15515	NBS18	0.082	496	5.844	-4.479	-22.143	-22.3	-4.5
5/12/97	‡11476	NBS19	0.08	432	4.434	2.047	-2.3	2.3	-2.2
	‡11467	NBS19	0.057	386	4.046	2.099	-2.146	2.4	-2.1
	‡11464	LL1	0.08	406	5.206	1.298	-9.947	1.6	-10.1
	‡11465	LL1	0.08	382	4.496	1.178	-10.16	1.4	-10.4
	‡11477	NBS18	0.06	405	4.161	-4.874	-22.802	-4.9	-23.4
	‡11478	NBS18	0.074	433	4.61	-4.752	-22.517	-4.7	-23.1
6/2/98	°14046	Carrara Z	0.06	365	3.985	2.481	-1.353	2.8	-1.3
	°14047	Carrara Z	0.005	3.48	3.712	2.143	-1.567	2.4	-1.5
	°14058	LL1	0.062	387	3.909	1.406	-10.031	1.7	-10.2
	°14049	LL1	0.061	406	4.145	1.389	-10.19	1.7	-10.4
	°14070	Carrara Z	0.066	439	4.578	2.471	-1.307	2.8	-1.2
	°14071	Carrara Z	0.062	438	4.83	2.48	-1.45	2.8	-1.4
	°14077	NBS18	0.054	333	3.285	-4.967	-23.489	-5.0	-24.1
	°14078	NBS18	0.056	273	2.127	-5.157	-24.268	-5.2	-25.0
	°14079	NBS18	0.054	261	1.957	-5.138	-23.925	-5.1	-24.6

***Table 8**: Mass Spectrometric Parameters for Laboratory Standards and Details of Calibrations*

*	C=(rawC + 0.4063)/0.9828	‡	C=(rawC-0.004)/0.9555
*	O=(rawO + 0.8738)/0.9654	‡	O=(rawO-0.0677)/0.9861
†	C=[(rawC + 0.0415)]/1.0805×1.0866	°	C=(rawC + 0.2046)/0.9613
†	O=[(rawO + 0.1533)]/1.0305×1.044	°	O=(rawO + 0.1277)/0.9675

Date	Spec #	Sample #	Sample Size	Pressure ubar	Sample V	*Uncorrected* $^{13}/^{12}C$	$^{18}/^{16}O$	*Corrected* $^{13}/^{12}C$	$^{18}/^{16}O$
2/2/97	*10932	HH WA21	0.395	490	6.662	-4.8	-3.631	-4.5	-2.9
	*10317	A1733	0.723	366	4.105	-5.846	-4.616	-5.5	-3.9
	*10916	A1708	0.3	203	1.267	-5.513	-5.018	-5.2	-4.3
	*10917	A1722	0.723	366	4.105	-5.846	-4.616	-5.5	-3.9
	*10914	A1718	0.152	72	0.28	-7.866	-12.523	-7.7	-11.8
	*10915	A1703(B)	0.501	412	4.597	-5.041	-2.609	-4.7	-1.8
	*10911	A632(15)	0.851	379	4.414	-3.629	-3.963	-3.3	-3.2
	*10908	A1715	0.93	410	4.51	-5.578	-4.807	-5.3	-4.1
	*10906	A1732(20)	0.732	280	2.534	-6.392	-4.891	-6.1	-4.1
	*10907	A1730	0.364	181	1.041	-4.111	-3.534	-3.8	-3.0
	*10910	A6226	0.884	237	1.802	-4.123	-2.172	-3.8	-1.3
	*10911	A632(TS)	0.851	379	4.414	-3.629	-3.963	-3.3	-3.2
	*10896	A1706(33)	0.306	80	0.321	-12.045	-8.697	-11.8	-8.1
	*10898	A625	0.57	288	2.843	-6.363	-4.507	-6.1	-3.8
	*10899	A1758	0.879	275	2.56	-6.87	-1.311	-6.6	-0.5
	*10901	A1703(C26)	0.847	381	4.596	-5.509	-4.095	-5.2	-3.3
	*10900	A1706(32)	0.375	325	3.636	-4.045	-1.391	-3.7	-0.5
	*10907	A1714	0.705	350	3.859	-6.335	-3.879	-6	-3.1
7/7/97	†15498	UCT180/199	0.996	496	4.067	-10.41	-4.88	-10.4	-4.8
	†15499	UCT184/211	0.892	332	2.193	-9.604	-4.87	-9.7	-4.8
	†15500	UCT196/207H	0.641	348	2.322	-9.241	-4.907	-9.2	-4.8
	†15501	UCT186/209	0.987	578	5.693	-7.172	0.301	-7.2	0.4
	†15502	UCT181/206	1.015	445	3.498	-8.471	-4.759	-8.5	-4.7
	†15503	UCT182 /200	0.994	551	4.499	-8.868	-4.503	-8.9	-4.4
	†15504	NMB ? (211)	0.977	318	2.32	-9.608	-4.614	-9.7	-4.5
	†15505	NMB1273	1.003	327	2.432	-10.411	-5.851	-10.4	-5.4
	†15506	NMB1441	1.022	223	1.085	-10.736	-5.617	-10.8	-5.5
8/7/97	†15507	NMB1448a	1.108	102	0.353	-1.257	-5.489	-1.2	-5.4
	†15508	NMB ?	0.271	232	1.122	-8.974	-4.765	-9.0	-4.7
	†15509	NMB1448b	1	656	4.6	-11.825	-5.425	-11.8	-5.3
	†15510	NMB1243	0.226	131	0.464	-10.118	-7.588	-10.1	-7.5
	†15511	NMB1282	0.828	325	2.48	-7.484	-5.195	-7.5	-5.1
	†15512	HSb1	0.85	220	1.23	-1.001	-4.379	-1.0	-4.3
	†15513	HSb2	0.957	138	0.55	-2.384	-4.889	-2.4	-4.8
5/12/97	‡11466	HSb1	1.017	228	1.536	-0.492	-4.478	-0.5	-4.4
	‡11468	HSb2	1.59	44	0.146	-3.716	-15.407	-3.9	-15.7
	‡11469	NMB ?	1.6	423	4.229	-9.179	-3.343	-9.6	-3.5
	‡11470	UCT27	1.66	359	3.576	-12.898	-6.086	-13.5	-6.2
	‡11471	UCT157	1.58	361	3.524	-10.455	-3.498	-10.9	-3.6
	‡11472	A1701	1.012	56	0.181	-7.5	-11.953	-7.9	-12.2
	‡11473	NMB1448a	0.97	513	6.425	-7.873	-2.9	-8.2	-3.0
	‡11474	NMB1448b	1.19	640	6.68	-12.132	-5.332	-12.7	-5.5
	‡11475	NMB1282	0.7	198	0.991	-9.803	-7.727	-10.3	-7.9
	‡14084	HSb1	1.042	182	0.867	0.149	-4.388	0.4	-4.4
6/2/98	°14085	HSb1	1.1	179	0.952	0.124	-4.22	0.3	-4.2
	°14086	HSb1	1.107	115	0.471	-0.412	-7.894	-0.2	-8
	°14087	HSb2	1.343	252	1.795	-0.762	-2.946	-0.6	-2.9
	°14088	HSb2	1.195	232	1.476	-0.776	-3.575	-0.6	-3.6

***Table 9**: Mass Spectrometric Parameters for All Samples and Details of Calibrations*

*	C=(rawC + 0.4063)/0.9828	‡	C=(rawC - 0.00044)/0.9555
*	O=(rawO + 0.8738)/0.9654	‡	O=(rawO - 0.06777)/0.9861
†	C=[(rawC + 0.0415)/1.0805]×1.0866	°	C=(rawC + 0.2046)/0.9613
†	O=[(rawO + 0.1533)/1.0305]×1.044	°	O=(rawO + 0.1277)/0.9675

UCT #	ACC #	$^{13}C_{apatite}$	$^{18}O/^{16}O$	$^{13}C_{collagen}$	^{15}N
	MATJES RIVER				
5603	*MR skel #1	-9.7	\	-13.8	13.6
5221	*NMB 1437	-9.2	\	-13.8	13.2
5222	*NMB 1440	-10.9	\	-15.0	11.4
5223	NMB 1273	-10.4	-5.4	*-15.4	*11.6
5227	*NMB 1274	-9.4	\	-13.6	13.2
5224	*NMB 1275	-12.3	\	-15.6	11.9
5225	*NMB 1241A	-10.3	\	-12.7	13.5
5226	*NMB 1241B	-10.4	\	-15.0	12.9
5601	*NMB 1271	-10.1	\	-12.9	13.0
5228	*NMB 1281	-9.8	\	-15.0	12.8
6512	NMB 1282	-7.5	-5.1	\	\
5229	*NMB 1342 (MR1)	-7.3	\	-11.3	14.9
5232	*NMB 1639	-8.3	\	-12.2	15.9
5233	*NMB 1640	-8.0	\	-12.0	16.3
5234	*NMB 1704	-8.8	\	-12.2	9.3
5235	*NMB 1705A	-8.5	\	-12.9	14.4
5599	*NMB 1705B	-6.8	\	-13.1	13.4
5230	*NMB not acc MSk2	-10.6	\	-15.1	13.4
5602	*NMB not acc SS2	-10.2	\	-13.5	13.0
5600	*NMB not acc SS3	-9.5	\	-14.6	13.9
6505	NMB? (211)	-9.7	-4.5	\	\
6507	NMB 1441	-10.8	-5.5	\	\
6509	NMB ?	-9.6	-3.5	\	\
6508	NMB 1448a	-8.2	-3.0	\	\
6510	NMB 1448b	-12.3	-5.5	\	\
	OAKHURST				
1921/6499	UCT 199/180	-10.4	-4.8	*-14.2	*12.8
1924/6504	UCT 200/182	-8.9	-4.4	*-12.4	*16.0
1942	*UCT 201	\	\	-14.0	11.3
1938	*UCT 202	\	\	-13.4	12.3
1939	*UCT 203	\	\	-16.7	9.3
\	*UCT 204 (grave 11)	\	\	-13.6	13.2
1934	*UCT 204	\	\	-14.5	10.1
1937	*UCT 205/2	\	\	-12.6	12.2
1948	UCT 206/1	\	\	*-12.4	*14.7
1950/6503	UCT 206/2/181	-8.5	-4.7	*-12.3	*11.1
6501	UCT 207/H/196	-9.2	-4.8	*-13.8	*13.0
\	*UCT 207/I	\	\	-14.1	12.3
\	*UCT 207/G	\	\	-11.1	16.0
1933	*UCT 208 (grave 10)	\	\	-10.9	10.0
1947	*UCT 208 (grave 9)	\	\	-15.4	10.9
1941/6502	UCT 209/186	-7.2	0.4	*-12.3	*13.7
1927	*UCT 210 (10c)	\	\	-12.4	15.5
1922/6500	UCT 211/184	-9.7	-4.8	*-13.9	*10.7
1957	*UCT 213 (grave 16/2)	\	\	-15.9	9.5
1959	*UCT 215P	\	\	-16.4	12.0
1960	*UCT 215D	\	\	-11.7	14.7
1961	*UCT 215 (grave 10)	\	\	-15.7	9.8
\	*UCT 215 (I)	\	\	-13.8	12.3
1951	*UCT 216 (Q)	\	\	-10.4	16.5
1945	*UCT 217/K	\	\	-15.4	11.0
1943	*UCT 217/M	\	\	-15.9	12.1

UCT #	ACC #	$^{13}C_{apatite}$	$^{18}/^{16}O$	$^{13}C_{collagen}$	^{15}N
1940	•UCT 217/N	\	\	-13.3	15.9
1935	•UCT 217/F	\	\	-14.1	12.3
1923	•UCT 217/L	\	\	-14.1	12.8
1925	•UCT 218 (6D)	\	\	-12.0	5.2
	K2				
6865	‡A 1706(32)	-3.7	-0.5	\	\
6904	‡A 1733	-5.5	-3.9	\	\
6878	‡A 1703(B)	-4.7	-1.8	\	\
6876	‡A 632(TS)	-3.3	-3.2	\	\
3866	‡A 625	-6.1	-3.8	\	\
6869	‡A 1703 (C25)	-4.7	-3.0	\	\
6873/4180	‡A 1715	-5.3	-4.1	†-10.7	†11.2
6875	‡A 6226	-3.8	-1.3	\	\
6876	‡A 632 (15)	-3.2	-3.2	\	\
6879	‡A 1708	-5.2	-4.3	\	\
6870/4211	A 1714	-6.0	-3.1	†-8.9	†11.8
6871/4178	A 1732(20)	-6.1	-4.1	†-10.1	†9.0
6872/4213	A 1730	-3.8	-3.0	†-10.8	†11.6
4182	†A 1749	\	\	-12.5	10.1
4187	†A 1755	\	\	-9.1	11.5
4191	†A 1734	\	\	-8.9	11.6
6867/4192	A 1758	-6.6	-0.5	†-11.0	†11.1
6880/4194	A 1722	-5.5	-3.9	†-10.7	†11.2
4205	†A 1719	\	\	-11.5	11.7
4207	†A 1747	\	\	-12.6	10.1
4209	†A 1763	\	\	-9.4	12.9
4210	†A 1713	\	\	-8.8	12.9
6869	‡A 1703(C26)	-5.2	-3.3	\	\
	INLAND				
6403	UCT 27	-13.5	-6.2	-17.1	11.4
6864	UCT157	-10.9	-3.6	\	\
6402	HH (WA21 2628BD1)	-4.5	-2.9	-15.1	8.2
6513	HSb1	-0.8	-4.4	-8.8	11.7
6514	HSb2	-0.6	-3.3	-7.2	10.6

Table 10 *: All Available Isotopic Information for Individuals from All Sites*

† Denotes collagen values after Lee-Thorp et al 1993.
‡ Denotes values after Lee-Thorp unpublished.
• Denotes collagen values after Patrick 1989.
▪ Denotes values after Sealy 1997.

This individual was from an open-air site and may have been subjected to leaching which could result in low carbonate. There were however, several attempts that produced over 200µbar of pressure, although the voltage sizes still remained small. Again these results should be viewed with some caution, however, the almost identical reproduction of $\delta^{18}O$ values and the spread of $\delta^{13}C$ less than 1‰ suggest a certain reliability of these values and warrant their inclusion in this study.

NMB1448a (11473) produced unusually high voltage and gas yields given the sample size (0.97mg), and was disregarded. A second run on this specimen (15507), although fairly large in size (1.108mg), produced very low gas yields and pressure and was thus disregarded (Table 9). NMB 1243 (15510) was similarly rejected. NMB? (15508) had both low pressure and gas yields, and was disregarded. A second run on this sample (11469) provided more reliable results (Table 9).

Mass spectrometric corrections for apatite analyses have been discussed in more detail in the previous chapter. Calibration curves for each month in which samples were run were applied to raw $^{13}C/^{12}C$ and $^{18}O/^{16}O$ ratios (Tables 8 and 9).

5.1.2 Coastal Sites

Oakhurst and Matjes River Cave are discussed together as coastal sites. Tables 9 and 10 detail collagen and apatite values for samples selected for microwear analysis.

The patterns of light stable isotopes for the Cape south coast are complex. This area receives year-round rainfall, and the vegetation consists mainly of a C_4 grasses, hence the terrestrial fauna may include a significant C_4 component (Vogel et al 1978; Sealy 1997). Therefore, separating marine $^{13}C/^{12}C$ values from those of terrestrial foods is not very clear-cut. In an attempt to clarify some of this ambiguity, nitrogen isotopes have been examined in conjunction with carbon isotope ratios. These values are discussed in more detail below.

Cape south coast fauna analysed by Sealy (1997) have $\delta^{13}C_{collagen}$ values averaging -12.2 ± 1.9‰ and $\delta^{15}N$ of +5.0± 1.2‰. Grazers in pure modern C_4 grasslands have average $\delta^{13}C_{collagen}$ values of ca.-8 to -6‰ and apatite values of ca. -0.5‰. C_3 feeders have mean $\delta^{13}C_{collagen}$ values of ca. -21‰ and apatite of ca. -14‰ (Vogel 1978; Ambrose & DeNiro 1986; Lee-Thorp 1989).

The mean $\delta^{13}C_{collagen}$ values for Matjes River individuals for this study are -13.7‰ (ranging from -11.3 to -15.6‰) and -13‰ at Oakhurst (ranging from -12.3 to -14.2‰) (Table 10). Previous studies have shown mean values for southern Cape sites as -13.8‰ (ranging from -11.1 to -17.9‰ ;Sealy 1997) which are very similar to the results obtained in this study. Thus the individuals examined for this study fall well within the range of others examined from the same sites. Apatite values for Matjes River and Oakurst average at -9.6‰ and 9.0‰ respectively, (with ranges of -6.8 to -12.3‰ and -7.2 to -10.4‰ respectively). $\delta^{13}C_{apatite}$ values for coastal southern Cape sites range from -6.8 to -12.6‰ with a mean of -9.9‰ (Sealy 1997). $\delta^{13}C_{apatite}$ values more enriched than -10‰ suggest an inclusion of a terrestrial C_4-based component. A "pure" marine diet cannot be much more enriched than -10‰, judging from results of pure marine mammals like seals (Lee-Thorp et al 1989).

Matjes River and Oakhurst specimens selected for microwear analysis have $\delta^{15}N$ values averaging +13.2‰ (+9.3 to +16.3‰) and +13.1‰ (+10.7 to +16‰) respectively (Table 10). Sealy's (1997) results for the same area range from +8.3 to +17.9‰ with a mean of +13.0‰ (Table 10). According to Schoeninger and DeNiro (1984) $\delta^{15}N$ values below +10‰ indicate small, if any, consumption of marine foods and $\delta^{15}N$ ratios above +10‰ indicate marine consumption. However, in the southern African context $\delta^{15}N$ ratios are complicated by the effects of aridity. In areas with less than 400mm rainfall per annum, $\delta^{15}N$ values tend to be elevated (Sealy et al 1986; Ambrose 1991). Sealy (1996) showed that bovids from the Cape south coast had fairly steady $\delta^{15}N$ values with a mean of +5.0±1.2‰. She concluded that the south coast area had not experienced episodes of marked

aridity. Thus the $\delta^{15}N$ values for this area can be interpreted without interefences from the effects of aridity.

There is a clear trend in the data from these coastal sites (Figure 15). The specimens with elevated $\delta^{15}N$ values have more enriched $\delta^{13}C_{collagen}$ and $\delta^{13}C_{apatite}$ values. Those with more depleted $\delta^{15}N$ values have a concommitant depletion in $\delta^{13}C$ collagen and apatite values. Those in the former group suggest a diet inclusive of more marine elements, although $\delta^{13}C_{apatite}$ values suggest that the terrestrial food exploited, was C_4 in nature. Those in the latter group are exploiting more terrestrial C_3-based foods and less marine resources.

There are three clear outliers from this sample set. The Matjes River specimen NMB1704 has $\delta^{13}C_{collagen}$ values suggestive of an intermediate diet between C_3, C_4 and marine resources (Table 9; Figure 15), $\delta^{13}C_{apatite}$ values corroborate this. $\delta^{15}N$ for this sample suggests a decreased dependence on marine resources and a substantially more terrestially-based diet. This sample was however coated in preservative, and although efforts were made to remove this coating, the unusual values for this sample may be a result of contamination (Sealy 1997).

One Oakhurst specimen (UCT 181) has $\delta^{13}C$ collagen and apatite values indicative of a diet consisting of C_3, C_4 and marine foods, but $\delta^{15}N$ values suggest a greater reliance on terrestrial resources rather than marine ones (Table 9; Figure 15). The second Oakhurst specimen (UCT 184) has $\delta^{13}C$ values indicative on an intermediate diet, leaning toward C_3 resources, with $\delta^{15}N$ values also indicating a greater reliance on terrestrial resources (Table 9; Figure 15). Both of these individuals are males between the ages of 30 and 39 with radiocarbon dates of 5450±70BP and 5330±60BP respectively (see Table 7 on sample selection). These are the only two specimens examined which fall within the 5000BP epoch. The changing environment at Oakhurst at this time (ie: increased estuarine conditions) may mean a concomitant increase in the exploitation of small game as reflected in the isotopic signatures of these individuals.

In general the Matjes River and Oakhurst $\delta^{15}N$ values reflect a diet inclusive of significant marine resources. The shift to lower $\delta^{15}N$ values on the right of Figure 15 suggest a decreased dependence of marine foods and a greater reliance on C_3 terrestrial resources. The elevated $\delta^{15}N$ values on the left of Figure 15 suggest a geater reliance on marine foods and an inclusion of C_4-terrestrial foods based on $\delta^{13}C_{apatite}$ values. The three outliers, one from Matjes River and two from Oakhurst, with more enriched $\delta^{13}C_{collagen}$ and depleted $\delta^{15}N$ values suggest an inclusion of relatively more C_4 terrestrial dietary resources.

Isotopic values from collagen (which preferentially reflects the protein component of diet) suggests a greater reliance on marine and/or C_4 resources. Patrick's (1989) data supports a diet at Oakhurst of people subsisting largely on marine foods supplemented sufficiently by plant resources. Apatite measurements in this study, which reflect the entire diet, suggests the exploitation of both C_3 and C_4 resources. Such patterns are not unexpected at these coastal sites, for although, archaeological excavations suggest a reliance on marine foods, the faunal assemblages also indicate exploitation of terrestrial resources. Oakhurst and Matjes River fall in an area which is predominantly wooded, although some C_4 grasses do occur. Both C_3 and C_4 the terrestrial components are represented by the isotopic ratios for these groups.

5.1.3 K2

Previous isotopic investigations at K2 suggest that these people had a fairly high input from C_4 sources. The extreme inland location of this site, as well as the faunal assemblage indicate that marine foods are highly unlikely to have had any input into the diet of these people, so this is not a confining factor in interpreting their enriched isotopic values. The archaeological investigations at K2 indicate that these people subsisted predominantly on domesticated animals and substituted their diet very little with hunted animals (Chapter 2). Hard evidence for cereal crops is lacking, however it is known that sorghum and millet were cultivated by this stage. $\delta^{13}C_{collagen}$ values for K2 cluster between -9 and -11‰ (Table 10; Figure 15),

suggesting a mixed diet with both C_3 and C_4. Collagen results from previous studies of K2 average at -10.36 ± 1.27‰ (Table 10; Lee-Thorp et al 1993). $\delta^{13}C_{apatite}$ values between -4 and -8‰ corroborate this. These values however, do show a significant C_3 input which may result from the exploitation of wild food resources which supplemented the diet. $\delta^{15}N$ values range from +9 to +12‰ (Table 10; Figure 15) suggesting a relatively high trophic level element in the diet. These nitrogen values are complicated somewhat by the arid nature of this area. In arid areas $\delta^{15}N$ values tend to be elevated (Sealy et al 1986). The nitrogen values for K2 are high, but perhaps not as high as might be predicted given that the rainfall in this area is less than 350mm per annum. It has been suggested, however, that this area may have received more rainfall during the occupation of K2 than is currently the case (Huffman 1996). Similar $\delta^{13}C_{collagen}$ and $\delta^{15}N$ values were obtained for K2 species by Lee-Thorp et al (1993) and were considered at the time to reflect a lower trophic level diet. More recent isotopic work (Lee-Thorp unpublished) indicates that humans are about +3‰ more enriched in $\delta^{15}N$ than bovids from K2; these data tend to support the idea of a fairly high trophic level diet since an entire trophic level step is considered to be about +3‰ (Sealy et al 1986).

One specimen, A1730 has a slightly more depleted $\delta^{13}C_{apatite}$ value (the problems with this specimen has been discussed above) than the others (Table 9). This is a female between the ages of 25 and 30 (see Table 7). Another K2 female specimen (A1722) has a fairly enriched $\delta^{13}C_{apatite}$ value relative to the male specimens. The sample is however, too small to test whether gender differences are statistically significant. All examined individuals were adults so age appears to have no impact on dietary intake.

A1732 has depleted $\delta^{15}N$ (Table 10). Taken together with the enriched carbon values for collagen and apatite, this suggests a greater dependence on C_4 plant foods than the other K2 specimens. This individual is slightly younger than the other specimens (Table 7), however, it is not possible to determine whether age has any impact on different dietary strategies. A1714 also has depleted $\delta^{13}C_{collagen}$ values (Table 10), however, values for $\delta^{13}C_{apatite}$ and $\delta^{15}N$ fall well within the range

for other K2 specimens. This specimen may have included more C_4 higher trophic resources in its diet, like cattle.

Thus the people at K2 seem to have subsisted on a diet of C_4 crops, C_4 grazing animals and some wild resources with a C_3 signature. These results are supported by faunal analyses which suggest a predominant dependence on domesticated stock, but also some inclusion of hunted or snared resources (Voigt 1983).

5.1.4 Inland Sites

Harrismith

The enriched $\delta^{13}C_{apatite}$ (burial 1 -0.8‰; burial 2 -0.6‰) and $\delta^{13}C_{collagen}$ (burial 1 -8.8‰; burial 2 -7.2‰) values for both Harrismith burials suggest a diet largely reliant on C_4 resources (Table 10; Figure 15). These C_4 resources were most likely grazing animals. The association of Harrismith burial 1 with a glass bead (Table 7) may suggest some contact with more sedentary populations (ie: farmers), therefore the possibility of some traded C_4 cereals cannot be entirely excluded. The relatively elevated $\delta^{15}N$ values (+11.7 and +10.6‰) for these individuals suggests a reliance on higher trophic level elements like grazing animals. These $\delta^{13}C_{apatite}$ values are more positive than those for K2, and given the inferred diet for K2, tend to suppport the idea that Harrismith individuals relied heavily on C_4 grazers.

Hope Hill

The results for this individual must be considered with caution given the unusual gas yields discussed in the previous chapter.

$\delta^{13}C_{collagen}$ results of -15.1‰ for the Hope Hill specimen suggest an intermediate diet biased toward C_3 foods (Table 10). The $\delta^{13}C_{apatite}$ value of -4.5‰ also indicates an intermediate diet. Thus this individual probably consumed C_3 plants or mixed feeders. The $\delta^{15}N$ value of +8.2‰ suggests fairly high trophic level diet (Figure 15). This area receives over 500mm of rainfall per annum (Apps 1986) so the elevated nitrogen value for this individual is not anticipated to be a result of

aridity. Thus this individual appears to have exploited largely C_3 resources, with an inclusion of C_4 foods. Occupational debris at Hope Hill Shelter suggest seasonal habitation, so this specimen may well have incorporated some C_4 elernents into its diet during occupation in other biomes.

Ladismith

UCT 27 from Ladismith has depleted $\delta^{13}C_{apatite}$ and $\delta^{13}C_{collagen}$ values (Table 10). -17.1‰ for $\delta^{13}C_{collagen}$ suggests a reliance on relatively more C_3 foods, while the $\delta^{13}C_{apatite}$ value of -13.5‰ substantiates this. Inland skeletons measured by Sealy et al (1986) have depleted $\delta^{13}C_{collagen}$ values which average at -18.4‰, suggesting a heavy reliance on C_3 terrestrial resources. The $\delta^{15}N$ value of 11.4‰ indicates a reliance on higher trophic level foods. Rainfall in this area varies from 200mm per annum in the interior valleys to 3000mm per annum in the coastal mountains (Apps 1986). Aridity may thus have affected the nitrogen values for this individual to some degree. Therefore this individual had a diet largely reliant on C_3 resources. The nitrogen value for this individual may either result from the effects of aridity or may reflect the hunting of mixed feeders or browsers. As Ladismith falls in a fynbos biome, one would expect an isotopic signature suggestive of a largely C_3-based diet.

UCT 157 also comes from the Ladismith area. No collagen or nitrogen values are available for this specimen. But the $\delta^{13}C_{apatite}$ value is -10.9‰ (Table 10) which suggests a diet leaning towards C_3 foods. Due to the lack of $\delta^{15}N$ values, it is uncertain what trophic level contributes to this diet. This individual's apatite values are more enriched than UCT 27, which implies a significantly higher input from C_4 enriched carbon. The lack of $\delta^{15}N$ values makes it unclear whether this was a high trophic level input, indicating the exploitation of grazers, or a lower trohpic level input anticipated for C_4 plant foods.

δ15N
δ13Ccollagen
0
2
4
6
8
10
12
14
16
18
20
−2
−4
−6
−8
−10
−12
−14
−16
−18

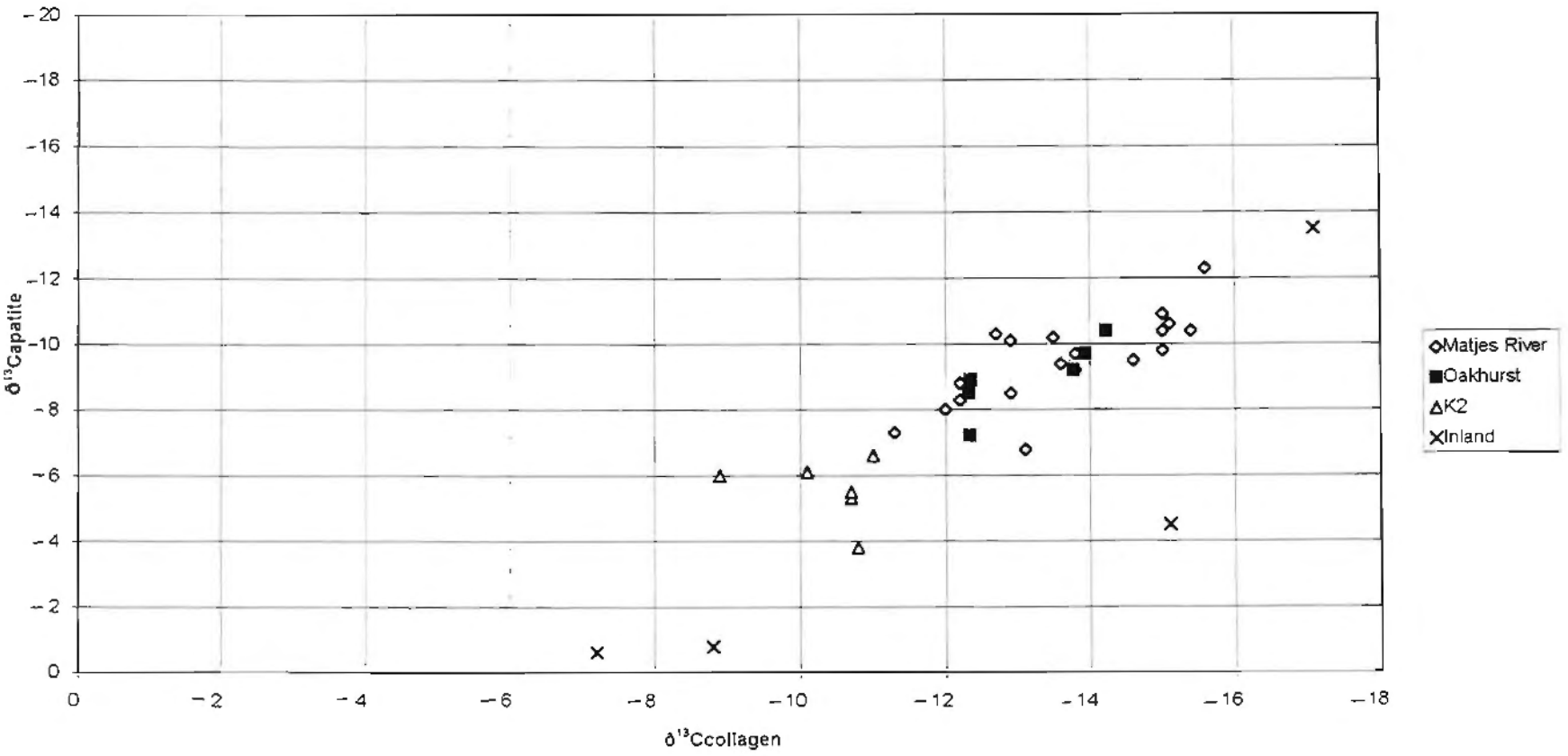


FIGURE 15: $\delta^{13}C$apatite, $\delta^{13}C$collagen and $\delta^{15}N$ Ratios for K2, Matjes River, Oakhurst and Inland Specimens

5.1.5 Summary

The analysis of light stable isotopes provides detailed information on singular life histories. As seen from these results, coastal hunter-gatherers have diets which are noticeably different to those of agricultural individuals. Thus the differences in faunal assemblages are borne out by isotopic evaluations. Isotopic data for inland hunter-gatherer groups are variable relative to geographic location and lifestyle. It is clearly noticeable through isotopic investigations, that particular groups reflect isotopic patterns related to their dietary habits. However, what is also clear is that there is a significant amount of inter-group variability. That is, individuals within groups tend to have variable isotopic values which reflect marked differences in dietary strategies. Thus, while people occupy the same areas and might exploit similar foods, in general, individual variation is reflected through isotopic analyses.

5.2 CANINE MICROWEAR RESULTS

Scanning electron microscope micrographs generated for the occlusal canine surface for each specimen were examined in several ways. The dimensions of pits and scratches were measured, as well as the orientation, concentration and frequency of these features. Features were then examined for statistical significance in all categories.

Statistical tests were conducted on various groups. The first method examined grouped inland samples (referred to here as individual sites). These groupings were an attempt to overcome the problems associated with small sample sizes. However, they assume an homogeneity among inland individuals that the isotopic results do not support. To address this issue, the second method examined individual inland groups (referred to as combined sites), thus the two Harrismith burials were grouped (based on their isotope values), and the two Ladismith burials were grouped. A third method grouped the coastal sites of Oakhurst and Matjes River. Isotopic results for these sites were similar enough to infer their diets were largely alike.

Groups were analysed using single-factor analysis of variance (ANOVA) which tests the hypothesis that the means of several populations are equal. Where analysis of variance detected variation from the mean, a modified t-test was performed to discover the source of this variance. Proportional data was ranked prior to statistical testing. Unless otherwise stated for all tests $P=0.05$.

Determining the source of variance for small sample sizes is difficult. Both Student-Newman-Keuls tests and Dunn's Method have previously been employed toward this end (Ungar 1996). These methods are however controversial (Saville 1990; Lowe pers.comm.) In order to overcome these difficulties, a modified t-test has been employed here. Usually, t-tests determine the pooled variance based on two sample means. In this study, t-tests look at the variance in means between all samples as determined by the analysis of variance.

5.2.1 Feature Orientation

Single factor analysis of variance on ranked data for %MD Index for inland combined, inland individual and coastal combined groups indicated no statistical differences between the orientation of features for all sites (Appendix 2). Individuals from all selected sites have features lying predominantly in a mesiodistal orientation (See Figures 16-23). Therefore food was probably introduced into the mouth in a similar way for all groups. Tools may aid in some ways with the ingestion of foods, however, if this is the case, differential tool use seems to make little difference on the directions that food is moved across the occlusal surfaces of canine teeth.

5.2.2 Feature Concentration

Single factor analysis of variance for all categories suggest significant differences in mean orientation vector lengths ("r") which range from 0.35-0.6 (Tables 11-13). All populations show predominantly mesiodistal feature orientations, however they vary in how concentrated striation orientations are (See Figure 24). Inland feature concentrations tend more towards uniform dispersal

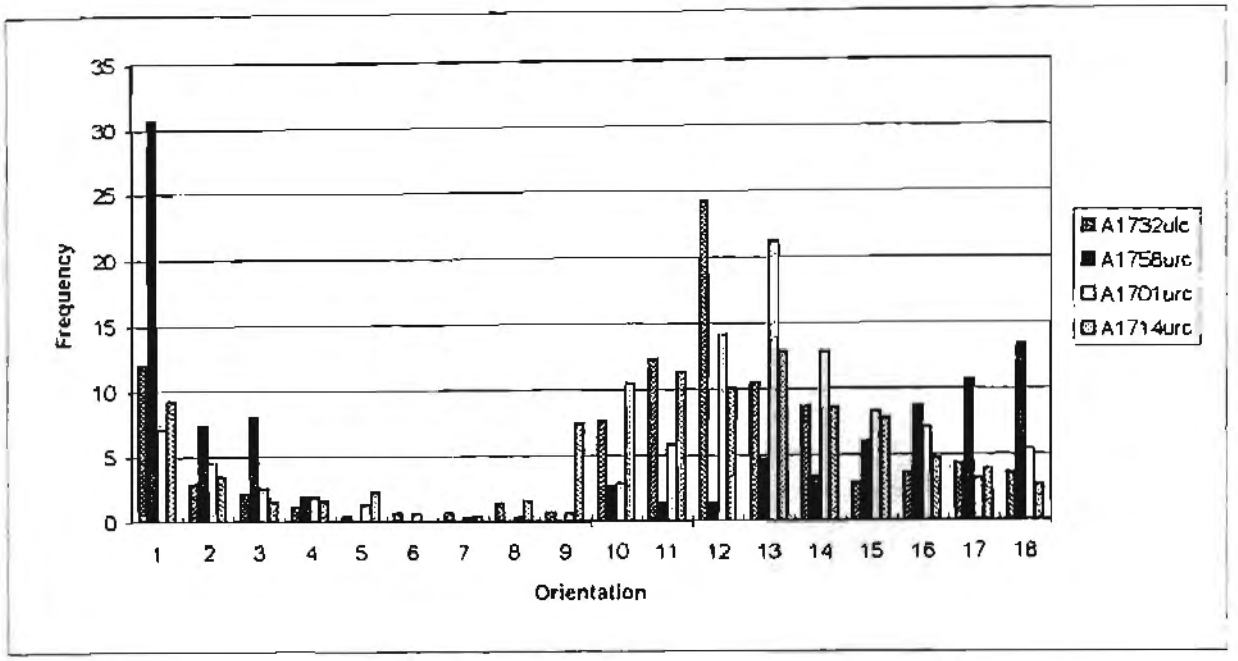


Figure 16: Individual Feature Orientation for K2

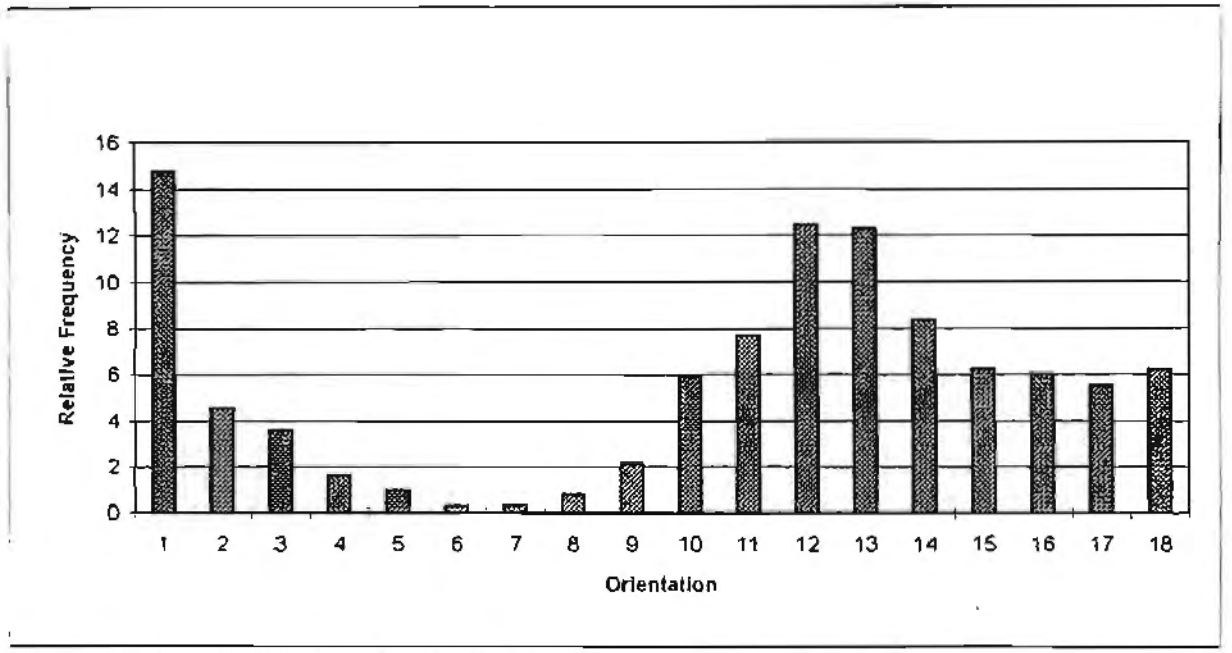


Figure 17: Average Feature Orientation for K2

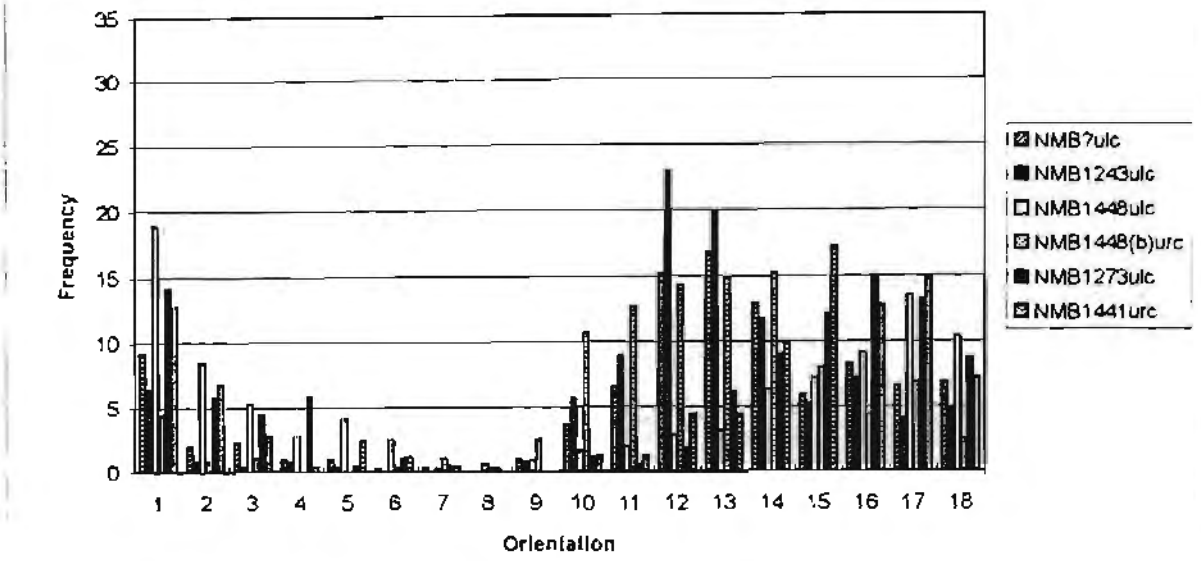


Figure 18: Individual Feature Orientation for Matjes River

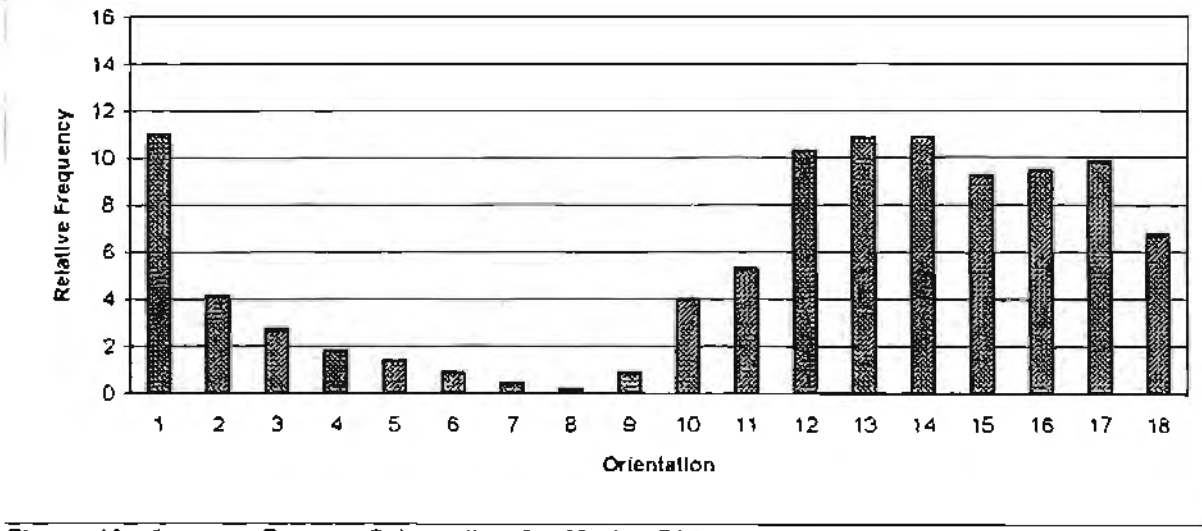


Figure 19: Average Feature Orientation for Matjes River

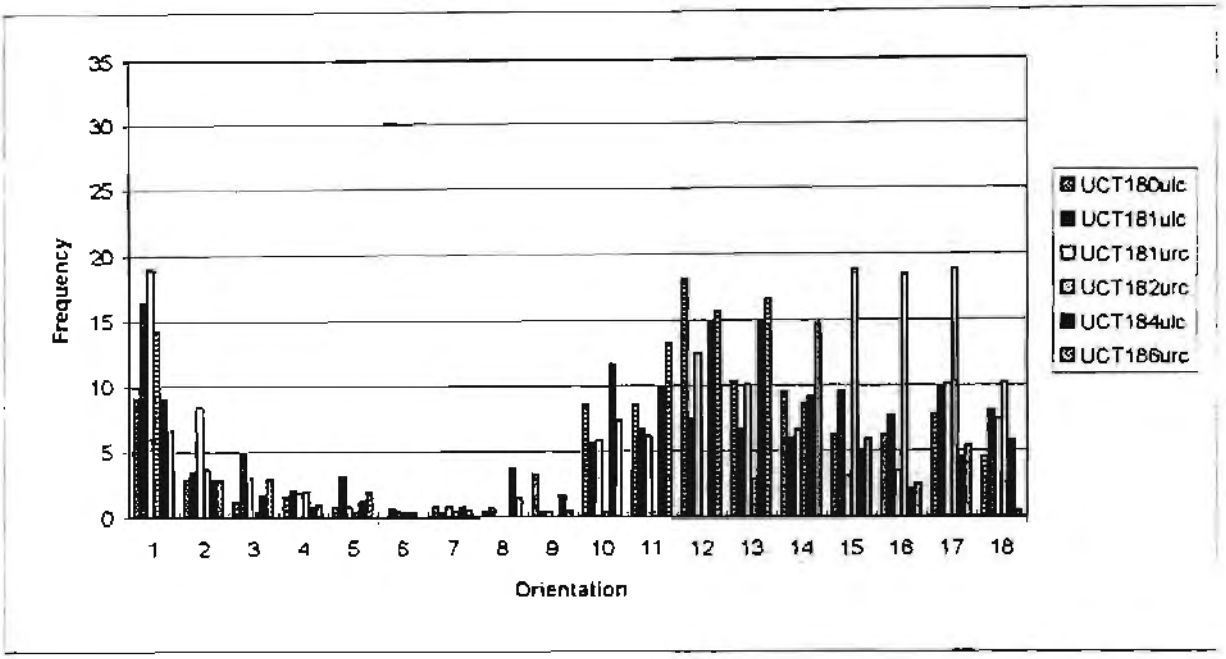


Figure 20 : Individual Feature Orientation for Oakhurst

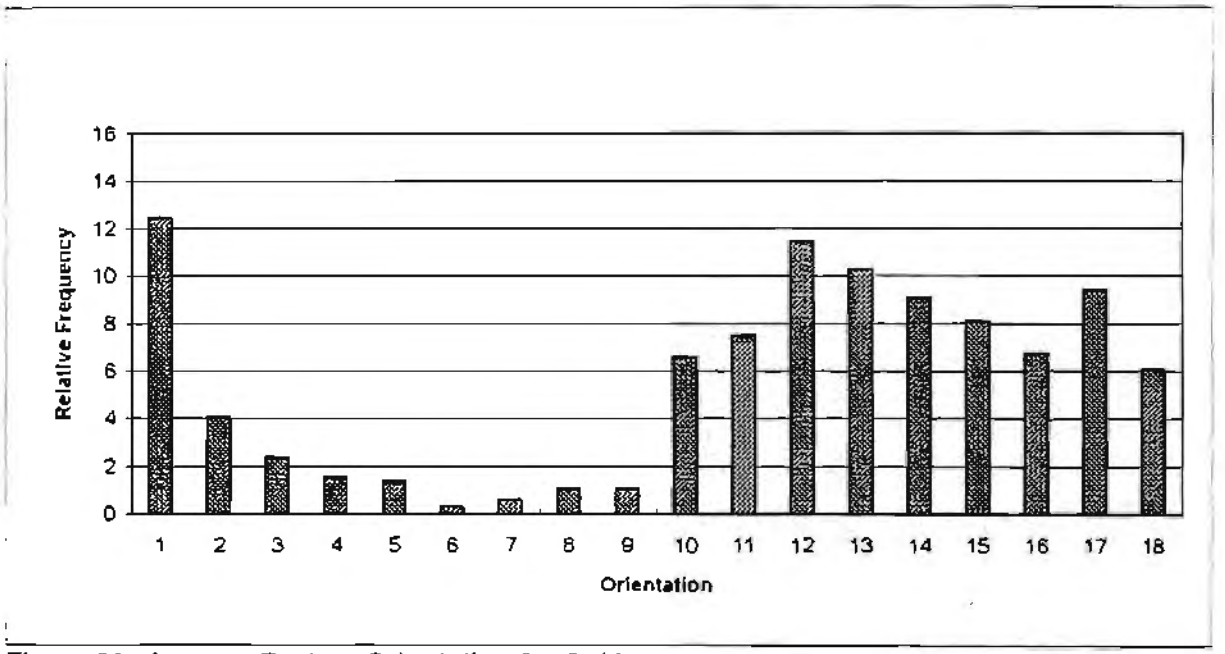


Figure 21 : Average Feature Orientation for Oakhurst

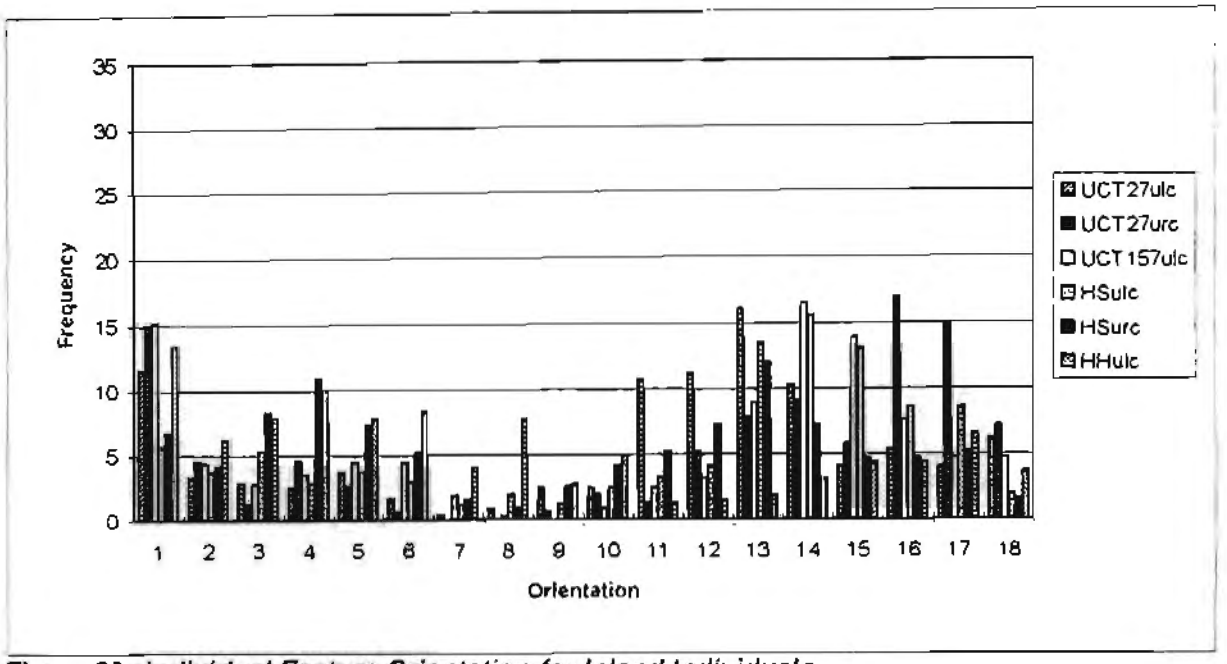


Figure 22: Individual Feature Orientation for Inland Individuals

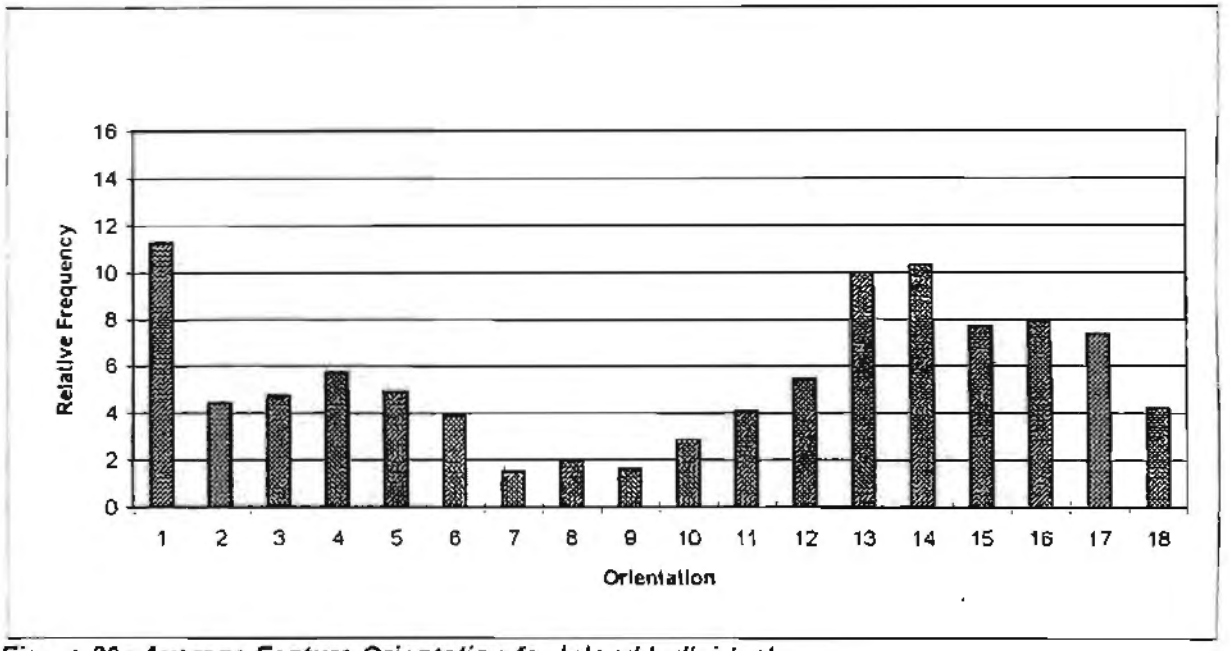


Figure 23: Average Feature Orientation for Inland Individuals

around a preferred orientation, while the other sites tend towards random concentrations about a preferred orientation. In order to determine the source of this variance, modified t-tests were performed (Table 14). Although t-test results suggest variance detectable between groups, this variation changes with groupings and probability levels. Results for feature concentration, although different between some groups, do not suggest variation reliable enough to allow for dietary inferences.

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.199	3	0.066	6.170	0.004	3.159
Within Groups	0.19	18	0.010			
Total	0.393	21				

Table 11:ANOVA of feature concentration for individual sites

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.165	3	0.055	8.724	0.001	3.287
Within Groups	0.094	15	0.006			
Total	0.260	18				

Table 12:ANOVA of feature concentration for collective inland sites

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.111	2	0.055	5.962	0.011	3.633
Within Groups	0.149	16	0.009			
Total	0.260	18				

Table 13:ANOVA of feature concentration for collective coastal and inland sites

INDIVIDUAL SITES

T-test	*t calc*	*P=0.05; df=18*	*P=0.01; df=18*	
O-I	1.926863	2.101	2.878	\
K-I	2.7008	2.101	2.878	*
K-O	0.977361	2.101	2.878	\
M-I	4.173479	2.101	2.878	**
M-O	2.246616	2.101	2.878	*
M-K	1.032073	2.101	2.878	\

COMBINED INLAND SITES

T-test	*t calc*	*P=0.05; df=18*	*P=0.01; df=18*	
O-IC	2.542277	2.101	2.878	*
K-IC	3.431362	2.101	2.878	**
K-O	1.275117	2.101	2.878	\
M-IC	4.935474	2.101	2.878	**
M-O	2.931055	2.101	2.878	**
M-K	1.346498	2.101	2.878	\

COMBINED COASTAL SITES

T-test	*t calc*	*P=0.05; df=18*	*P=0.01; df=18*	
K-IC	2.825873	2.101	2.878	*
CC-IC	3.37301	2.101	2.878	**
CC-K	0.032862	2.101	2.878	\

* Indicates significant difference at P=0.05; ** indicates significance at P=0.01

Table 14: Modified T-tests for Individual Sites, Combined Inland Sites and Combined Coastal Sites.

5.2.3 Feature Frequencies

The incidence of pitting on canine occlusal surfaces varies from 41.9% (± 4.8) for K2 to 49.4% (±6.2) for Oakhurst individuals (see Figure 25). Pitting frequencies for Matjes River are similar to those from Oakhurst, with Inland groups intermediate between coastal and agricultural groups. However, pitting frequencies show no significant difference for either collective or individual groups based on single factor analysis of variance (Appendix 2).

Single factor analysis of variance on ranked data show no significant differences among collective and individual groups for scratch frequencies (Appendix 2). The agricultural population of K2 shows increased scratch frequencies (48.1% ±4.8) relative to the coastal groups of Oakhurst and Matjes River (40.6% ±6.2 and 43% ±4.1 respectively). Inland sites are intermediate (44.6% ±4.1) between the two (Figure 25).

5.2.4 Feature Dimensions

Pit widths vary from 3.25-3.41µm for K2 and inland groups respectively. The two coastal groups have intermediate values (Figure 26). Single factor analysis of

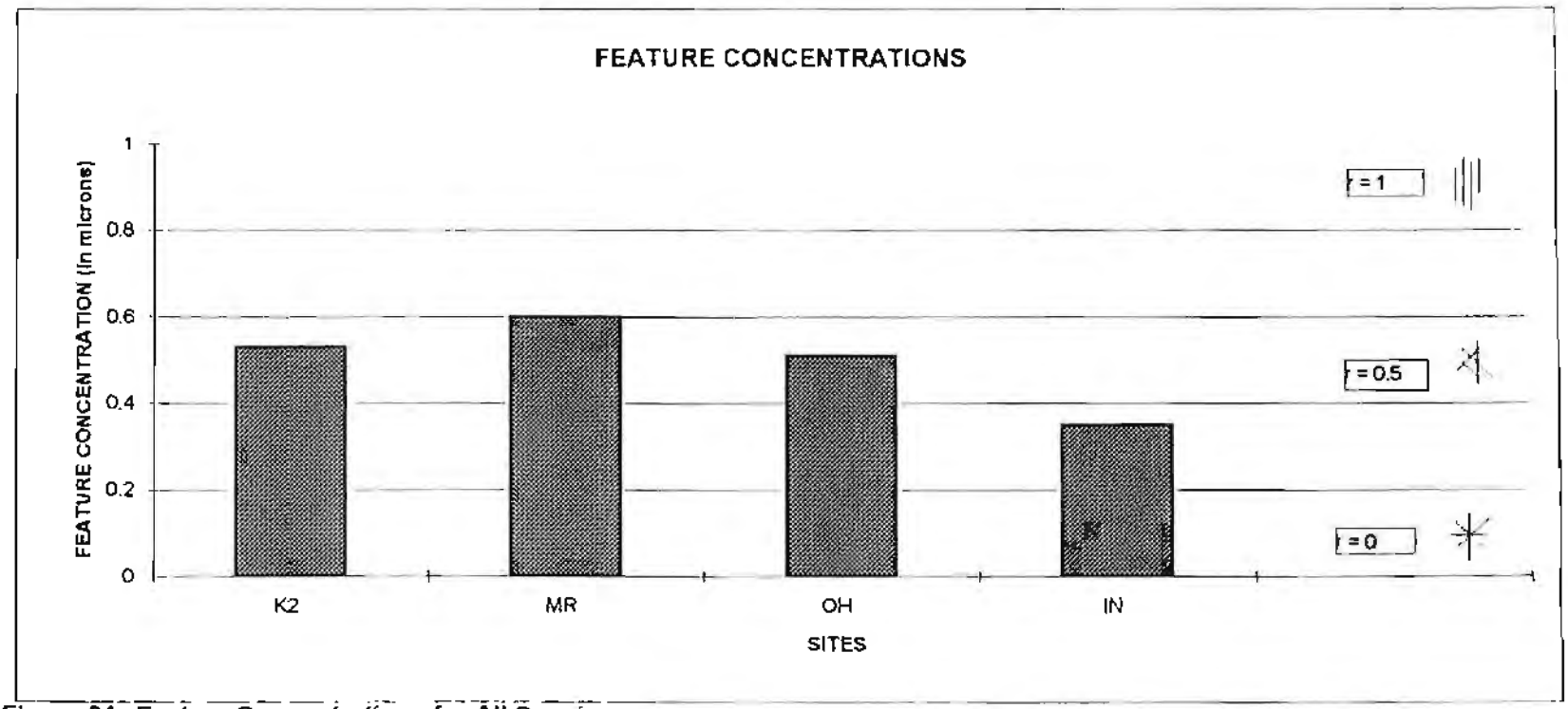


***Figure 24**: Feature Concentrations for All Specimens*

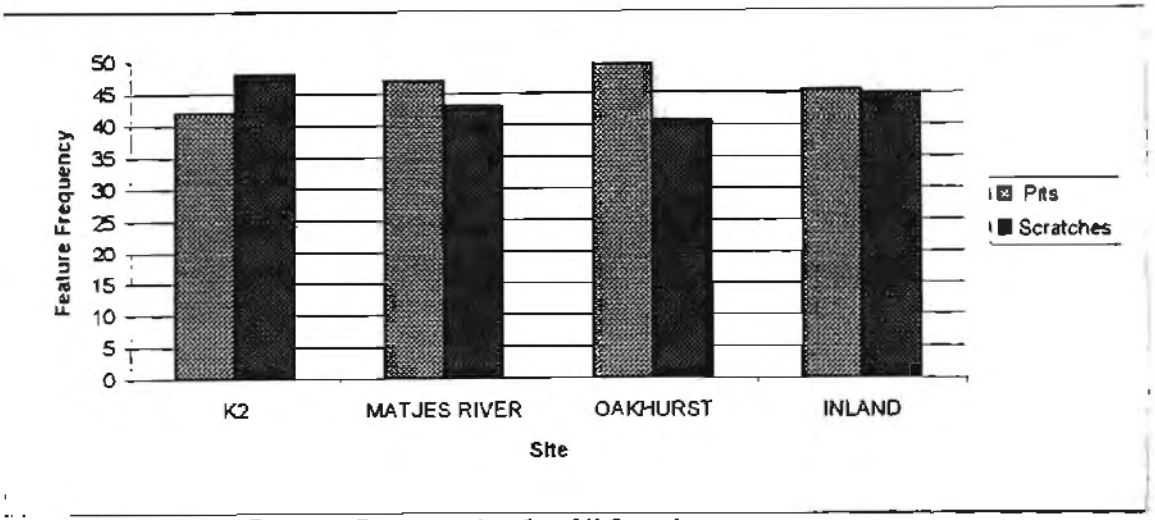


Figure 25: Average Feature Frequencies for All Specimens

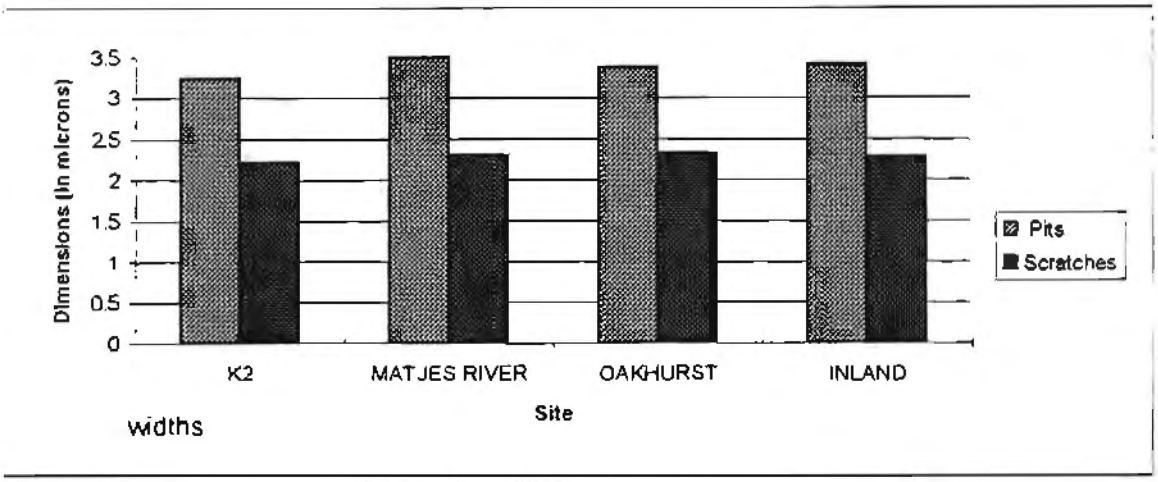


Figure 26: Average Feature Widths for All Specimens

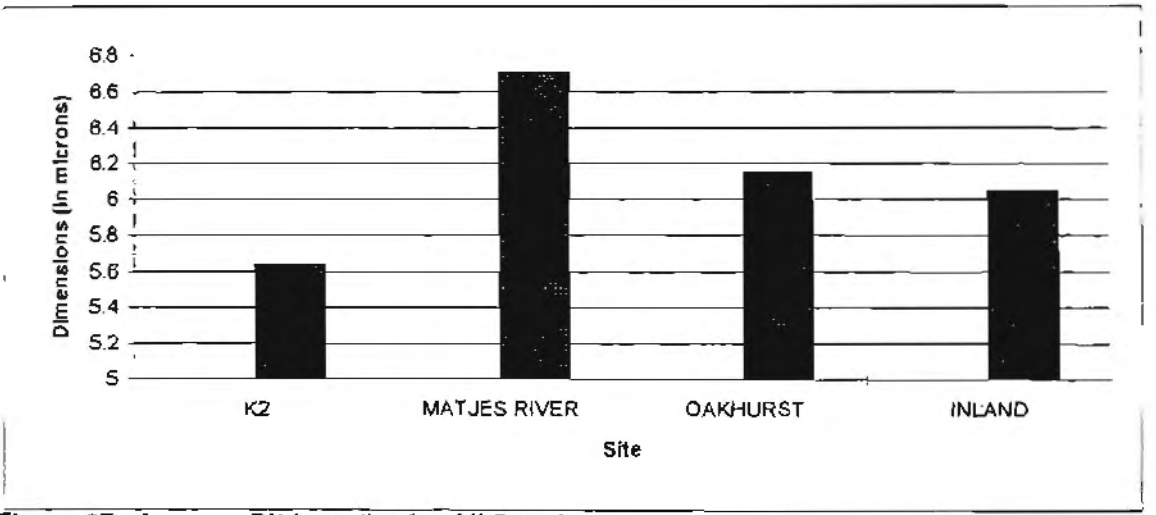


Figure 27: Average Pit Lengths for All Specimens

variance for both collective and individual groups show no significant differences in pit width dimensions (Appendix 2).

Coastal groups have scratch widths of 2.31µm (± 0.13) for Matjes River and 2.33µm (± 0.22) for Oakhurst (Figure 26). Inland groups have values of 2.28µm (± 0.16) and K2 2.22µm (± 0.11). Scratch widths do not differ for all groups in single factor analysis of variance (Appendix 2).

Single factor Analysis of variance for pit lengths show no significant differences between all sites (Appendix 2). Pit lengths vary from 6.7µm (± 0.46) for Matjes River to 5.64µm (± 0.69) for K2. Oakhurst and inland groups are intermediate between those values (Figure 27).

5.2.5 Summary

Isotopic analyses provide individual dietary information, whereas dental microwear, examines group dietary activities. Dental microwear is less sensitive to individual variation, although it does provide general dietary patterns for a group of people. Sample size is a major concern with this method. However, as with any analysis of prehistoric populations, sample sizes are often not ideal. Isotopic analyses have identified broad dietary trends, although variations within populations are noticeable. The general lack of differentiation between groups in microwear features may to some degree be a result of this variation.

For all categories, canine dental microwear shows no significant differences between the three identified groups. The only statistically significant differences are in feature concentration. However, the variation for this category is subject to grouping strategies and probability levels and is therefore not regarded as sufficient to distinguish differential dietary behaviour. Feature orientation and dimensions are not sufficiently different to be detected by single factor analysis of variance. For feature orientation this may not be unusual, as one does not anticipate that groups with similar gross dental morphology are ingesting food in markedly different ways. Feature frequencies suggest that agricultural populations

show decreased pits relative to coastal hunter-gatherers and an increased incidence of scratching. These results are, however, not statistically highly significant.

Small sample sizes may account for the lack of observable differences between the selected populations, however other factors also need to be considered. Firstly, there are no marked differences in gross dental morphology for the groups selected. Most anterior dental microwear studies have concentrated on primate species with different dental morphology indicative of differing dietary strategies. The lack of observable microwear features between the groups studied, may indicate that canine microwear is related, as with incisor microwear, to ingestive behaviour. Thus canine microwear would only be a valuable method for detecting differences between populations with markedly different ingestive strategies. Secondly, most microwear studies have examined primates with different feeding substrates, thus ground-feeders are compared to canopy feeders. The groups selected for this study all feed from the same substrate. That is, while they may exploit different resources and include varying amount of grit or phytoliths in their diet, the analysis of canine microwear is not sensitive enough to pick up these differences.

Previous canine microwear studies (Manning 1995) examined a variety of extant mammals with vastly different substrates and dental morphologies. In that study, observable differences were noted between populations.

Given these factors, the use of canine dental microwear analyses to determine dietary differences between groups with similar dental morphology and feeding substrate may not be appropriate. Future studies should ensure that selected groups include sufficient samples and consider the above mentioned factors.

CHAPTER 6

DISCUSSION AND CONCLUSION

In previous chapters I discussed the groups examined in this study in terms of skeletal and dietary information. Then I outlined the two methodologies utilised to examine the diets of these groups. In this concluding chapter I bring together the various lines of evidence drawn from both the isotopic analyses and the canine dental microwear examinations.

This project has attempted to identify whether canine microwear is a valuable method for determining dietary differences between sample populations. Three groups with different diets were analysed. Archaeological data and in some instances, existing isotopic information, were used to select these groups. In each instance, $\delta^{13}C_{apatite}$ analyses were performed. In some cases, these values supplemented already existing isotopic information on collagen signatures. Following this, the canine microwear for each groups was examined to see whether the differences observed between groups in isotopic signatures, are substantiated by microwear analyses.

6.1 Discussion: Isotopic Analyses

The two coastal hunter-gatherer groups, Oakhurst and Matjes River show collagen values reflecting a reliance on marine foods. Enriched $\delta^{13}C_{collagen}$ signatures may indicate C_4 terrestrial exploitation, or the use of marine resources. In order to understand which components were being exploited, both $\delta^{13}C_{apatite}$ and $\delta^{15}N$ ratios were also examined. $\delta^{13}C_{apatite}$ values suggest some C_3 inclusion in the diet of these groups. This inclusion is not unexpected as faunal anaylses from both sites indicate the exploitation of terrestrial food sources. C_4 grasses do exist in this area, therefore some animal foods may reflect this, but because this area is actually rather wooded, one would expect, in fact, to find few grazers and rather more browsing animals. Thus, the C_3 input reflected by $\delta^{13}C_{apatite}$ evaluations,

underscores the existence of terrestrial C_3-energy products. $\delta^{15}N$ values indicate trophic level and marine input in a diet. Both coastal sites show $\delta^{15}N$ values above +10‰, which suggests inclusion of marine foods. This value varies both within and between the two groups, with some individuals clearly consuming far more marine resources than others. Variable carbon isotope values also indicate differential use of terrestrial resources. These coastal populations, based on isotopic analyses, were largely eating marine foods supplemented by terrestrial products. Pathological examinations of Oakhurst skeletons support a mixed, balanced diet of this sort (Patrick 1989). Thus, these groups can be loosely defined as coastal hunter-gatherer-fisher peoples because of the considerable variation observable in isotopic ratios.

Two Oakhurst specimens have more depleted carbon values suggesting an increased use of C_3 resources. These specimens date to ca.5000BP, around the time that estuarine conditions prevailed in the area and freshwater molluscs and fish exploitation increased. Their isotopic values may reflect the move to an increased use of terrestrial resources due to the greater availability of these food sources. One Matjes River specimen also shows a diet intermediate between C_3 and C_4 resources, however, the values for this specimen may have been contaminated by preservative.

The agricultural population of K2 reflects a largely C_4 diet with some C_3 inclusion. As agriculturalists, these people are assumed to have access to both domesticated animals and cereals, however, the proportions of each in the diet cannot be determined by conventional means. Cattle and sheep are grazers (C_4), while goats are mixed feeders. Examinations of K2 fauna suggest that these people exploited their domestic stock heavily. Reliance on cultivated grains is less well documented. There is however, also evidence of hunting, gathering and snaring in the faunal assemblage from this site. Although Voigt (1983) has suggested that supplementing the diet with wild foods depends largely on the enterprise of the individual, isotopic results indicate that wild plant and animal resources may have been a more comprehensive part of the community diet.

Nitrogen values for K2 are somewhat enriched. $\delta^{15}N$ values vary with rainfall and are more enriched in arid areas (see Ambrose 1991 for discussion). K2 lies in a relatively arid region; nitrogen values might thus be expected to be more positive than they are. However, it has been suggested recently that the area around K2 was in fact moister during occupation of the site (Huffman 1996) than was previously thought to be the case. This may account for the lower than expected $\delta^{15}N$ values. If this is the case, $\delta^{15}N$ values can then be thought of as enriched and reflecting a fairly high trophic level diet. The consistent difference of 3‰between humans and K2 bovids represents a whole trophic "step" and provides support for a high trophic level diet.

The inland burials, despite assumed similarities in food procurement strategies, do not indicate homogenous dietary activity. To some degree, this is not unexpected. These inland individuals were selected because they were expected to have diets different to more coastal groups. Although it is often assumed that food collection strategies for hunter-gatherers are similar, their different geographical locations are reflected in the isotopic signatures. The two Harrismith burials have diets largely of C_4 resources. The reasons for this may be two-fold. Firstly, these individuals come from a biomass which is largely C_4 in nature, so that they would be expected to exploit grazing animals. Elevated $\delta^{15}N$ values suggest the use of higher trophic level elements, thus the exploitation of grazers is a ditinct possibility. However, the association of burial 1 with a glass bead, may suggest that these individuals had some contact with sedentary groups, therefore one cannot exclude the use of some agricultural products in their diets. No dates exist for these individuals, so determining concretely whether they were influenced by sedentary farmers in currently not possible.

$\delta^{13}C_{apatite}$ values for the Hope Hill individual suggest a diet intermediate between C_3 and C_4 resources. Collagen values for this sample suggest a bias toward C_3 resources. Nitrogen values are relatively elevated, indicating an increase in the trophic level of foods consumed. This individual may thus have been eating mixed feeders. Hope Hill lies in a grassland region so the inclusion of C_3 in the diet

of this individual is noteworthy. However, the evidence for seasonal occupation at Hope Hill Shelter, may indicate the exploitation of resources from C_3 biomes during different times of the year.

The Ladismith specimens reflect a largely C_3 diet as expected for a fynbos region. Elevated nitrogen values for UCT 27 suggest a dependence on higher trophic level foods, thus this individual probably ate browsing animals. This specimen comes from a fynbos area which supports the exploitation of mixed feeders.

Isotopic analyses clearly distinguish between coastal hunter-gatherer diets and those of agriculturalists. Inland hunter-gatherers are less easy to differentiate based on the wide geographic spread of the individuals examined. Still, their results indicate habitat as well as dietary items consumed. The data presented here for inland hunter-gatherers is the first isotopic data for recent inland hunter-gatherers that examines both collagen and apatite carbon ratios. This information should provide a background against which to interpret hominid data as the biomes for these groups are similar.

6.2 Discussion: Canine Microwear Analyses

This project aimed to determine the efficacy of canine dental microwear as an indicator of dietary behaviour, against the background of isotopic information. The analysis of dental microwear features is largely a comparative one. All microwear studies to date have examined the microscopic wear patterns of different populations relative to eachother. For the first time, stable carbon isotope analyses have been used as the basis against which to examine dietary habits of various populations.

Pit dimensions between all groups indicate no statistical differences. This may indicate that inland groups were exploiting foods containing grit of a similar size to the sand particles anticipated in the diet of coastal people, which in turn where similar in size to the grit entering the diet of agriculturalists, possibly during cereal milling. The lack of difference in striation breadth substantiates this. Maas

(1991; 1994) cautions that striation breadth variations may result from differences in enamel structure and not food particle size. This study examines human groups that are not expected to have different enamel structure. Thus this is not a constraining factor in analysing striation breadth. However, the lack of observable differences in striation breadth for all groups suggests that food particle sizes were probably similar. As mentioned, coastal hunter-gatherers are exposed to sand grit which abrades teeth, inland hunter-gatherers are expected to eat plant foods that may be covered (to some degree) with soil and agriculturalists grind grain which may introduce some grind-stone grit.

The lack of significant differences between feature orientation for all groups is perhaps not surprising. Previous incisor studies (see Ungar 1992b; Teaford 1991 for discussion) have shown that different ingestion behaviours produce differences in striation orientation. These studies are however conducted on primate populations. Differences in feeding behaviour are reflected in the gross dental morphology of primates selected, as well as observed differences in ingestive behaviour. The groups studied here are all anatomically modern humans with no gross differences in dental morphology indicative of specialised dietary activity. Moreover, despite assumed differences in the use of tools and food preparation, it is anticipated that food is introduced into the mouth in a fairly similar manner. Thus one would not expect significant differences in the orientation of striations on the occlusal surfaces of the canine teeth for these populations.

Feature concentrations are the only features which indicate differences between groups. However, differences in feature concentration alone is not sufficient to regard canine microwear analyses for these groups as a successful indicator of dietary differences.

It needs to be borne in mind that the sample sizes used here are relatively small and may explain the lack of observable differences between groups. Future studies should take cognisance of this fact.

6.3 Conclusion

For the first time, two very powerful dietary methods have been used together. Isotopic analyses indicate dietary trends in three different Holocene groups. Isotopic analyses suggest broad dietary patterns for each group, however, they also indicate a large amount of inter-group variability. This may account for the lack of observable differences in canine dental microwear for the selected groups. Canine dental microwear, examined against the information from isotopic studies, is not a sufficiently sensitive method to detect dietary behaviour. This may be a result of several factors; small sample size is a constant problem in studies of this nature where several selection criteria need to be met. Similarities in feeding substrate and similarities in gross dental morphology may also have impacted on the results of this study. Thus canine dental microwear appears not to be useful for examining small sample sizes of individuals with relatively dissimilar diets. Previous studies between mammals with different tooth structures and feeding substrates have indicated observable differences in canine wear patterns.

This study did not indicate observable microwear differences relative to those dietary trends gleaned from isotopic analyses. However, the comparative nature of dental microwear studies makes isotopic analyses a suitable comparative basis against which to investigate dietary activity.

This research outlined 4 initial questions: question 1 asked whether there are quantitative differences between the three identified populations?

Canine dental microwear did not detect significant differences between groups for almost all categories. However, this may be a result of the relatively small sample sizes. Feature concentration was the only area which did reflect a difference between inland groups and other populations. Differences were however subject to probability levels and varied with population grouping. Thus differences in the concentration of features between groups of people are not regarded as reliable indicators of dietary differences.

Question 2 asked how the differences observed in canine micrrowear could be interpreted in terms of dietary behaviour?

As no quantitative microwear patterns associated with specific diets exist, they cannot be interpreted in terms of dietary behaviour. However, future studies of larger sample sizes may more clearly be able to distinguish associated dental wear patterns. Understanding feature concentration differences has not yet been established for canine teeth. So we know that differences in feature concentration exist between the populations examined, however it is currently unclear as to what this means in terms of feeding behaviour.

Question 3 asked how the expected isotopic differences between the three identified populations could be interpreted?

Isotopic analyses identify broad dietary trends, however they also suggest inter-group variability. Coastal groups indicate diets largely reliant on marine foods, supplemented by some terrestrial resources. These patterns are supported by faunal analyses. Isotopic data for agriculturalists suggest a diet largely reliant on C_4 foods supplemented by wild terrestrial resources. Signatures for inland hunter-gatherers reflect differences in the biomes exploited. Harrismith burials may indicate some contact with sedentary people. The Hope Hill individuals indicate seasonal travel to different biomes and the Ladismith burials suggest a diet reliant largely on browsing animals.

Question 4 asked how microwear patterns are related to isotopic variations associated with specific diets?

Canine dental microwear indicates no significant differences between people with different diets. This may be a result of several factors, namely small sample sizes, similarities in gross dental morphology, similarities in feeding substrate and the inter-group variability evidenced by isotopic values may have affected microwear patterning.

As with earlier studies, this research has determined that broad dietary patterns are discernable through isotopic analyses between groups with different diets. However, these differences are not discernable by the analysis of canine dental microwear patterns in this study. Future microwear studies should concentrate on populations with significantly different gross dental morphology and feeding substrates.

SITE	ACC #	DATE	AGE	SEX	UR	UL	COLLAGEN δ''C	COLLAGEN δ''N	APATITE δ''C	APATITE δ''O	BURIAL STYLE AND CULTURAL CONTEXT
OAKHURST	UCT 180/199	²6180±70BP	¤30-39	¤M		1	¤-14.2	¤12.8	-10.4	-4.8	²Grave 1-disturbed. 71cm. On shelter talus. Flexed on left side. Facing East. No grave goods. Wilton.
	UCT 181/206	²5450±70BP	¤30-39	¤M	1	1	¤-12.3	¤11.1	-8.5	-4.7	²Grave 6-disturbed. 152cm. Flexed on right side. Facing west. No grave goods. Wilton.
	UCT 182/200	²7120±60BP	¤20-29	¤M	1		¤-12.4	¤16.0	-8.9	-4.4	²Grave 2-disturbed. 101cm. Flexed on right side. No grave goods. Albany.
	UCT 184/211	²5330±60BP	¤30-39	¤M		1	¤-13.9	¤10.7	-9.7	-4.8	²Grave 13-disturbed. 172cm. Flexed on right side. Facing south. Donax shells, ivory palette, nacre ovals, red ochre.
	UCT 186/209	²4880±70BP	¤20-29	¤M	1		-12.3	13.7	-7.2	0.4	²Grave 11-disturbed. 175cm. Flexed on right side. Facing South-east. Slate palette. Wilton.
	UCT 196/207H	²4830±250BP	¤5-9				¤-13.8	¤13.0	-9.2	-4.8	²Grave 9. Juvenile. Probably Wilton.
K2	A 1701	*100±50BP			1						*Near path joining K2 and Mapungubwe Hill. CS1 "Casual Burial". Buried under rock in shallow hole. Partly flexed on right side. Facing South. Pot sherds.
	A 1714		•25-30	•M	1		¶-8.9	¶11.8	-6.0	-3.1	*K13-Block 2 section 3. Flexed on left side facing N-E. Glass beads, pottery.
	A 1722		•25-30	•F			*-10.7	*11.2	-5.5	-3.9	*K21-Block 2 section 13 on bedrock. Lying on front, tibia bent back. Iron & copper bangles, glass beads.
	A 1730		•25-30	•F			¶-10.8	¶11.6	-3.8	-3.0	*K29-Block 2 section 5. Partly flexed on right side, facing W Glass beads, pottery & copper bangles.
	A 1732		•20-22	•M		1	¶-10.1	¶9.0	-6.1	-4.1	*K31-Block 2 section 12. Partly flexed on right side. Facing E. Glass beads, pottery.
	A 1758		•35-45	•M	1		*-11.0	*11.1	-6.6	-0.5	*K59-Block 3 section 13. Flexed on right side. Facing NE. Glass beads.
Matjes River	NMB ?					1			-9.6	-3.5	
	NMB ? (211)								-9.7	-4.5	
	NMB 1243					1					
	NMB 1273			^F		1	†-15.4	†11.6	-10.4	-5.4	*Second excavation of cave. MRB3. ^Level B 5000-7000BP.
	NMB 1282			^F					-7.5	-5.1	*Wilton Layer. ^Level C ca. 9000BP.
	NMB 1441	*9230±160			1				-10.8	-5.5	*Out of confused layer at 12ft depth.
	NMB 1448a					1			-8.2	-3.0	
	NMB 1448b				1				-12.3	-5.5	
LADISMITH	UCT 157					1			-10.9	-3.6	*Mass burial in ant-bear hole. Bone "Tsamma-knife".
	UCT 27				1	1	-17.1	11.4	-13.5	-6.2	
HARRISMITH	Burial 1				1	1	-8.8	11.7	-0.8	-4.4	‡One skeleton with glass bead at nape of neck and potsherd.
	Burial 2						-7.2	10.6	-0.6	-3.3	
HOPE HILL	WA 21 2628BD1	‡>4000BP		‡F(?)		1	-15.1	8.2	-4.5	-2.9	‡Cave deposit, dug out by farmer. With animal bones & stone tools.

Table 7 : Details of All Specimens examined for Isotopic and Microwear Analyses

(* Data after Morris 1992; •Data after Steyn 1994; ‡Data after Wadley; ¶Data after Lee-Thorp et al 1993; *Unpublished data; ²Data after Patrick 1987, Morris 1992; ¤Data after Patrick 1987; ^ Data after Hausman 1980).

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	K2						MATJES RIVER									
	A1701urc		A1714urc		A1732ulc		A1758urc		NMB1273ulc		NMB1448(b)urc		NMB 1441urc		NMB1448ulc	
FEATURES	**MEAN**	**STD**	**MEAN**	**STD**	**MEAN**	**STD**	**MEAN**	**STD**	**MEAN**	**STD**	**MEAN**	**STD**	**MEAN**	**STD**	**MEAN**	**STD**
Major Axis Length	25.77	30.6	26.1	35.591	33.18	40.043	15.06	18.646	21.81	30.85	14.41	15.14	20.41	28.79	16.83	23.284
Minor Axis Length	2.74	1.151	2.73	1.026	2.51	0.855	2.72	0.934	3.07	1.212	2.82	1.161	2.83	1.055	3.12	1.226
Preferred Orientation	136.3	31.902	122.89	37.087	124.1	33.549	172.68	27.211	163.55	29.29	124.31	27.06	159.18	27.604	170.39	33.612
Major\Minor Axis Ratio	12.19	20.523	12.12	18.733	16.67	21.752	7.18	10.968	8.74	13.43	6.23	7.378	8.83	12.826	6.73	10.499
r =	0.537		0.432		0.503		0.636		0.592		0.64		0.628		0.502	
n =	312		257		276		150		380		363		250		318	
Total # Pits	123		99		121		85		207		202		131		205	
Total # Scratches	189		158		155		65		173		161		119		113	
PITS																
Avg. Length	6.39	2.818	5.7	1.891	4.71	1.987	5.76	2.08	7.28	3.825	6.16	2.811	6.97	2.747	6.61	3.139
Avg. Width	3.37	1.305	3.45	0.995	3.04	0.836	3.14	0.882	3.57	1.282	3.25	1.137	3.35	1.037	3.52	1.248
SCRATCHES																
Avg. Breadth	2.33	0.816	2.28	0.753	2.09	0.601	2.16	0.673	2.47	0.78	2.28	0.946	2.27	0.737	2.41	0.79

	OAKHURST															
	NMB?ulc		NMB1243ulc		UCT184ulc		UCT186urc		UCT181ulc		UCT182urc		UCT180ulc		UCT181urc	
FEATURES	**MEAN**	**STD**	**MEAN**	**STD**	**MEAN**	**STD**	**MEAN**	**STD**	**MEAN**	**STD**	**MEAN**	**STD**	**MEAN**	**STD**	**MEAN**	**STD**
Major Axis Length	24.52	34.775	17.89	16.127	13.07	12.933	31.88	47.622	15.32	20.33	19.75	21.91	15.47	17.618	15.64	29.466
Minor Axis Length	3.09	1.598	2.69	1.158	2.58	1.016	2.66	1.086	3.3	1.285	2.83	1.049	3.23	1.344	3.03	1.097
Preferred Orientation	137.6	31.447	127.05	25.698	121.4	34.1	124.73	30.244	154.03	38.7	159.96	21.16	130.38	35.301	150.29	41.811
Major\Minor Axis Ratio	10.45	14.871	8.56	8.94	6.48	7.473	14.36	21.694	6.29	11.2	7.86	9.192	6.37	8.733	6.09	11.874
r =	0.547		0.668		0.492		0.572		0.401		0.761		0.468		0.344	
n =	303		248		242		204		284		245		243		227	
Total # Pits	152		107		132		90		194		116		152		156	
Total # Scratches	151		141		110		114		90		129		91		71	
PITS																
Avg. Length	6.96	3.425	6.19	2.922	5.32	2.536	5.65	2.801	6.56	3.135	7.1	3.543	6.81	3.265	5.45	2.562
Avg. Width	3.85	1.722	3.46	1.156	3.11	1.001	3.18	1.181	3.66	1.222	3.19	1.156	3.78	1.292	3.29	1.082
SCRATCHES																
Avg. Breadth	2.32	0.984	2.11	0.756	1.94	0.568	2.25	0.797	2.51	1.046	2.52	0.826	2.31	0.828	2.45	0.897

	INLAND											
	HSurc		HSulc		UCT157ulc		HHulc		UCT27urc		UCT27ulc	
FEATURES	**MEAN**	**STD**	**MEAN**	**STD**	**MEAN**	**STD**	**MEAN**	**STD**	**MEAN**	**STD**	**MEAN**	**STD**
Major Axis Length	41.97	58.243	26.61	41.688	23.39	29.05	25.33	35.242	18.74	22.93	15.51	17.32
Minor Axis Length	2.56	1.028	2.84	1.372	3.09	1.341	3.05	1.151	2.88	1.185	2.66	1.107
Preferred Orientation	152.7	65.467	143.9	38.185	154.9	38.53	28.79	46.069	158.49	32.43	136.03	39.38
Major\Minor Axis Ratio	20.31	27.563	12.41	20.842	9.72	13.65	11.07	18.746	8.38	12.03	7.15	8.79
r =	0.073		0.411		0.404		0.274		0.526		0.388	
n =	192		244		316		321		153		242	
Total # Pits	74		115		167		173		82		142	
Total # Scratches	118		129		149		148		71		100	
PITS												
Avg. Length	5.014	1.757	6.43	2.944	6.24	2.725	6.3	2.963	6.38	2.59	5.96	2.953
Avg. Width	3.23	1.21	3.6	1.488	3.64	1.411	3.54	1.142	3.4	1.185	3.04	1.139
SCRATCHES												
Avg. Breadth	2.14	0.587	2.16	0.783	2.46	0.925	2.49	0.868	2.28	0.86	2.12	0.802

APPENDIX 2

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	77.1	3	25.7	0.163	0.919	3.159
Within Groups	2836	18	157.542			
Total	2913.85	21				

ANOVA of feature orientation for individual sites

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	78.9	3	26.3	0.142	0.933	3.287
Within Groups	2776.3	15	185.086			
Total	2855.2	21				

ANOVA of feature orientation for collective inland sites

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	36.4	2	18.2	0.12	0.887	3.521
Within Groups	2876.5	19	151.39			
Total	2912.9	21				

ANOVA of feature orientation for collective coastal and inland sites

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	76.78	3	25.59	1.44	0.261	3.159
Within Groups	318.78	18	17.67			
Total	394.85	21				

ANOVA of pitting frequencies for individual sites

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	76.85	3	25.61	1.44	0.26	3.287
Within Groups	266.10	15	17.74			
Total	342.95	18				

ANOVA of pitting frequencies for collective inland sites

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	76.78	2	38.39	2.29	0.12	3.521
Within Groups	318.06	19	16.74			
Total	39.85	21				

ANOVA of pitting frequencies for collective coastal and inland sites

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	78.32	3	26.10	1.47	0.255	3.159
Within Groups	318.78	18	17.71			
Total	397.10	21				

ANOVA of scratch frequencies for individual sites

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	78.38	3	26.12	1.47	0.26	3.287
Within Groups	265.86	15	17.72			
Total	344.24	18				

ANOVA of scratch frequencies for collective inland sites

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	78.32	2	39.16	2.33	0.12	3.521
Within Groups	318.78	19	16.77			
Total	397.10	21				

ANOVA of scratch frequencies for collective coastal and inland sites

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.15	3	0.05	0.93	0.44	3.159
Within Groups	0.99	18	0.05			
Total	1.15	21				

ANOVA of pit width dimensions for individual sites

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.16	3	0.05	1.08	0.38	3.287
Within Groups	0.73	15	0.04			
Total	0.896	18				

ANOVA of pit width dimensions for collective inland sites

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.1	2	0.05	0.93	0.40	3.521
Within Groups	1.04	19	0.05			
Total	1.150	21				

ANOVA of pit width dimensions for collective coastal and inland sites

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.03	3	0.01	0.43	0.72	3.159
Within Groups	0.49	18	0.02			
Total	0.527	21				

ANOVA of scratch width dimensions for individual sites

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.03	3	0.01	1.42	0.74	3.287
Within Groups	0.41	15	0.02			
Total	0.449	18				

ANOVA of scratch width dimensions for collective inland sites

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.03	2	0.01	0.66	0.52	3.521
Within Groups	0.49	19	0.02			
Total	0.527	21				

ANOVA of scratch width dimensions for collective coastal and inland sites

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.86	3	0.95	2.5	0.09	3.159
Within Groups	6.85	18	0.38			
Total	9.718	21				

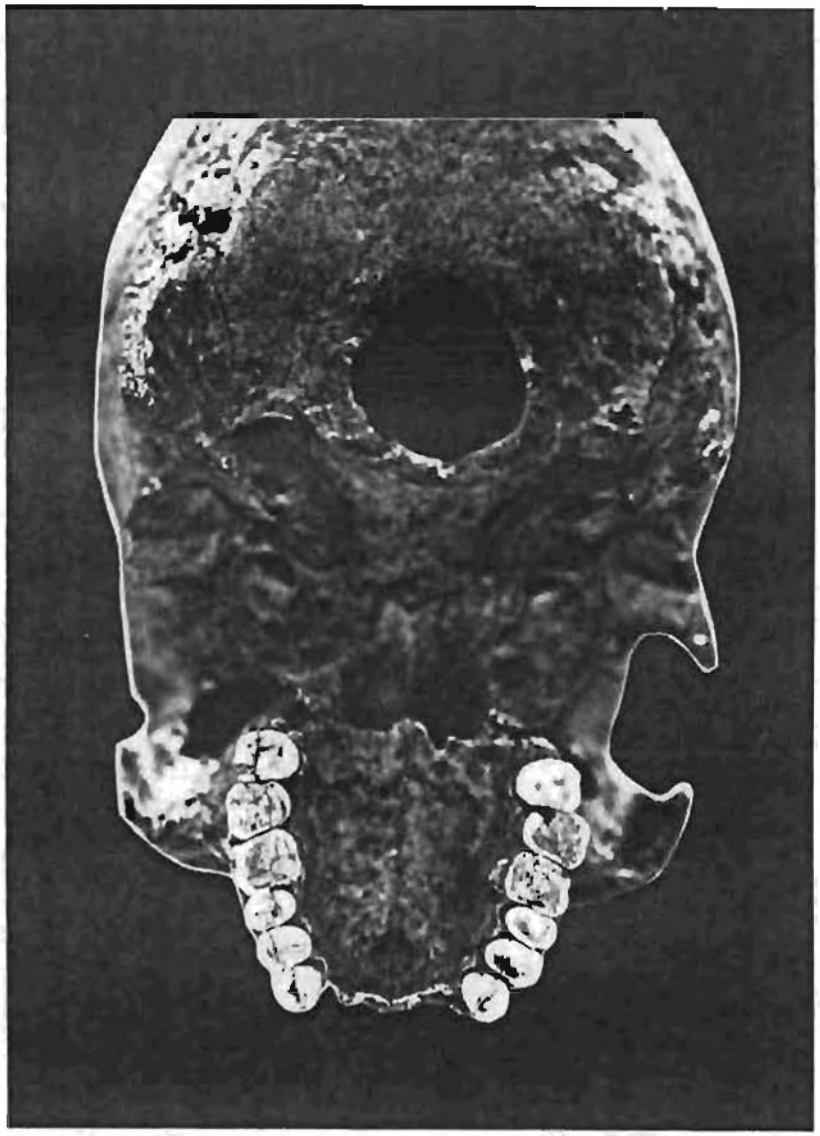
ANOVA of pit length dimensions for individual sites

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.79	3	0.93	2.48	0.1	3.287
Within Groups	5.6	15	0.37			
Total	8.397	18				

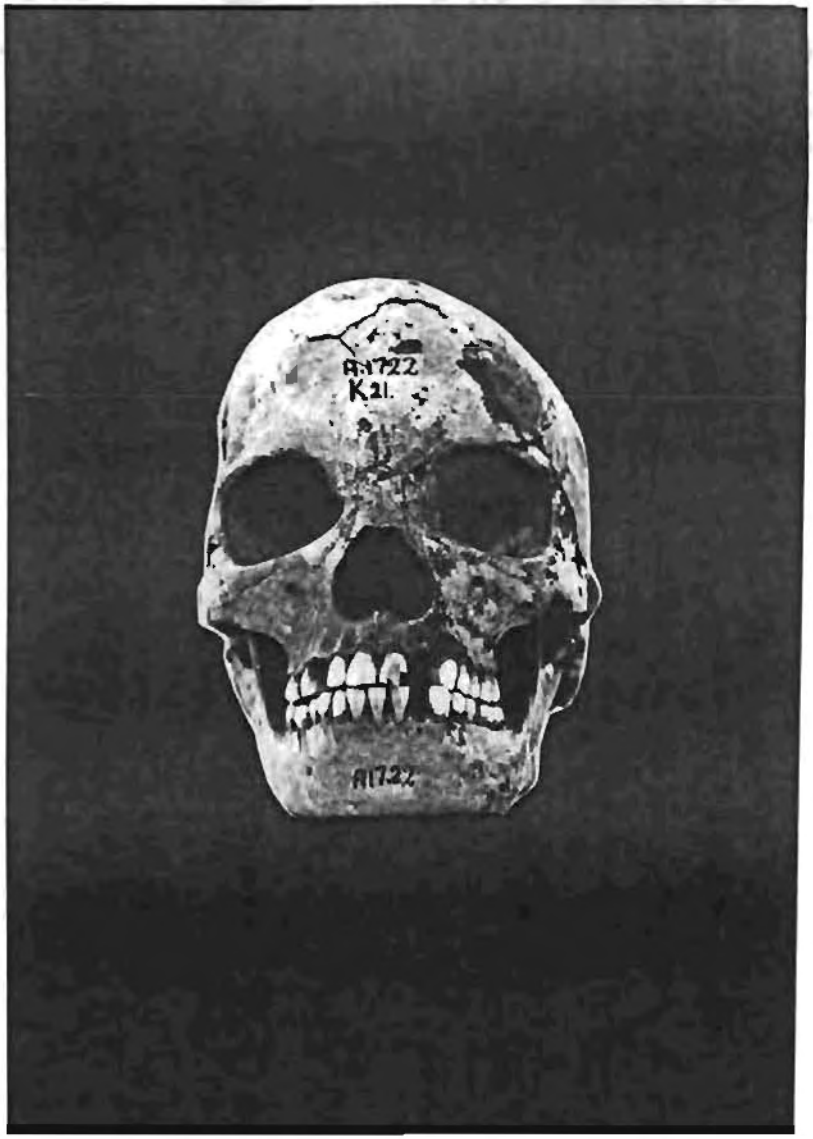
ANOVA of pit length dimensions for collective inland sites

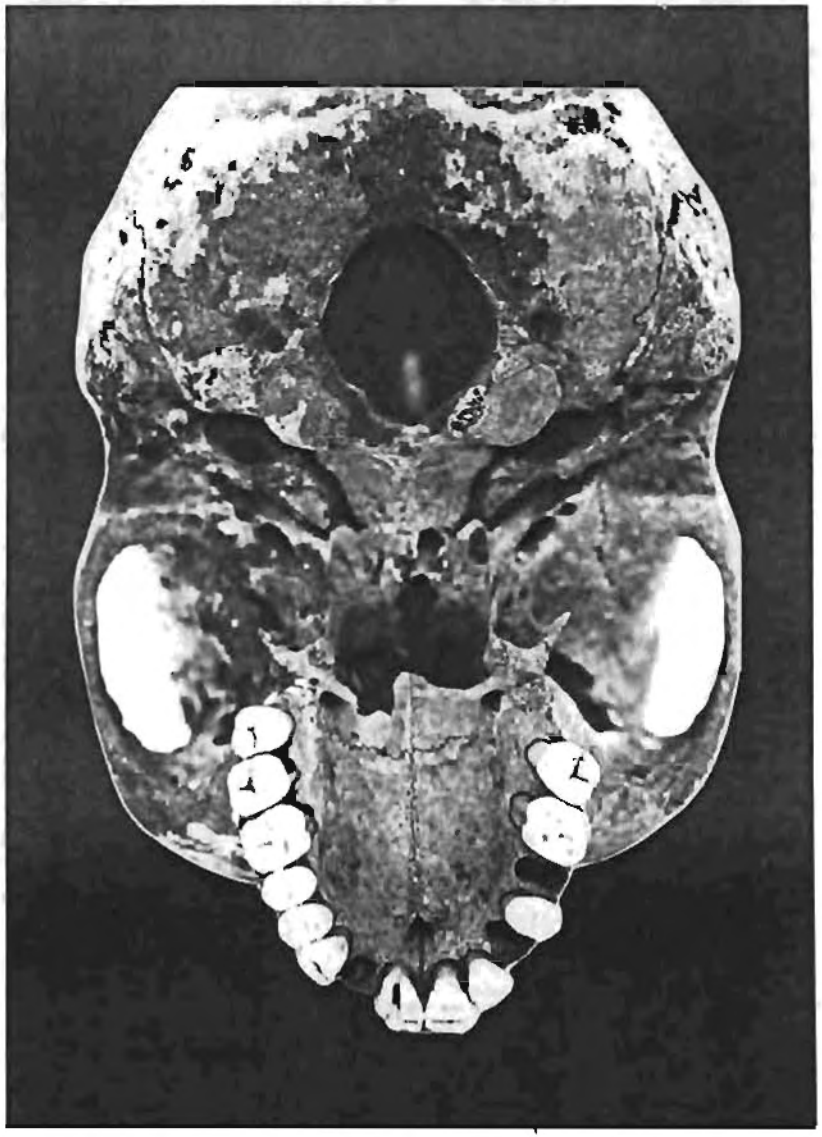
Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.96	2	0.98	2.4	0.11	3.521
Within Groups	7.75	19	0.40			
Total	9.718	21				

ANOVA of pit length dimensions for collective coastal and inland sites

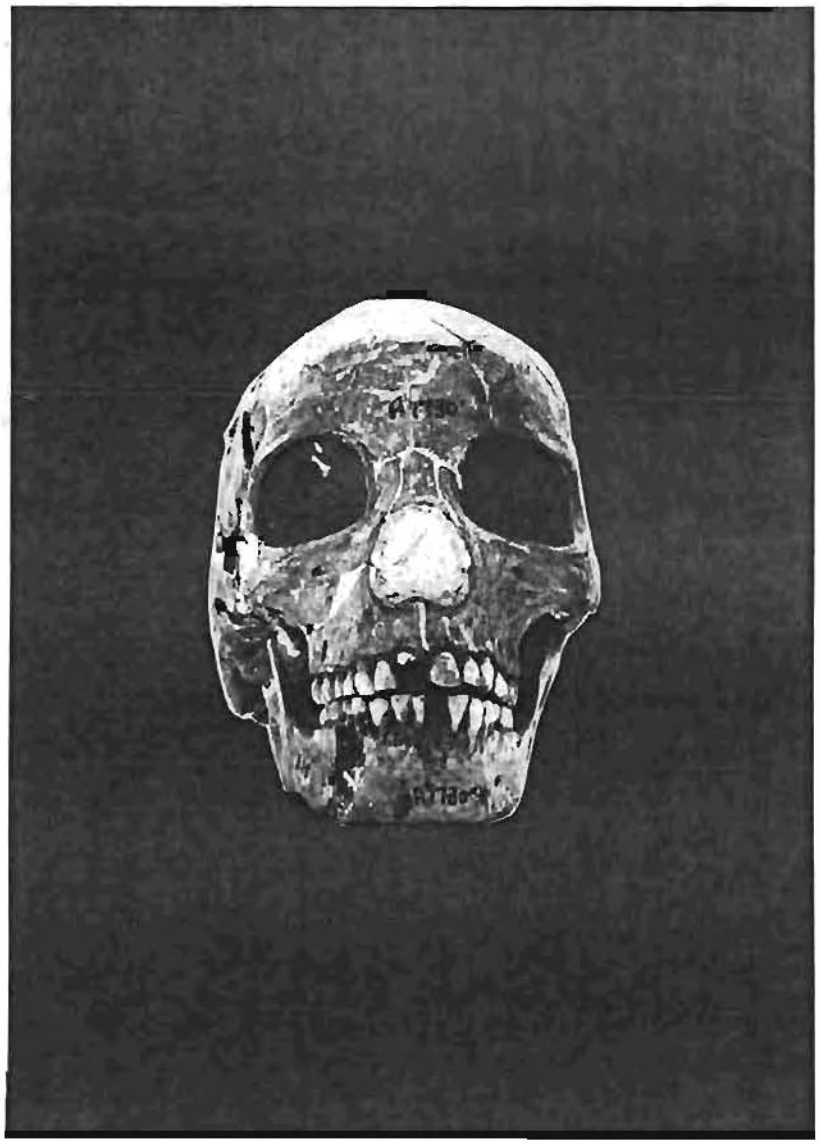


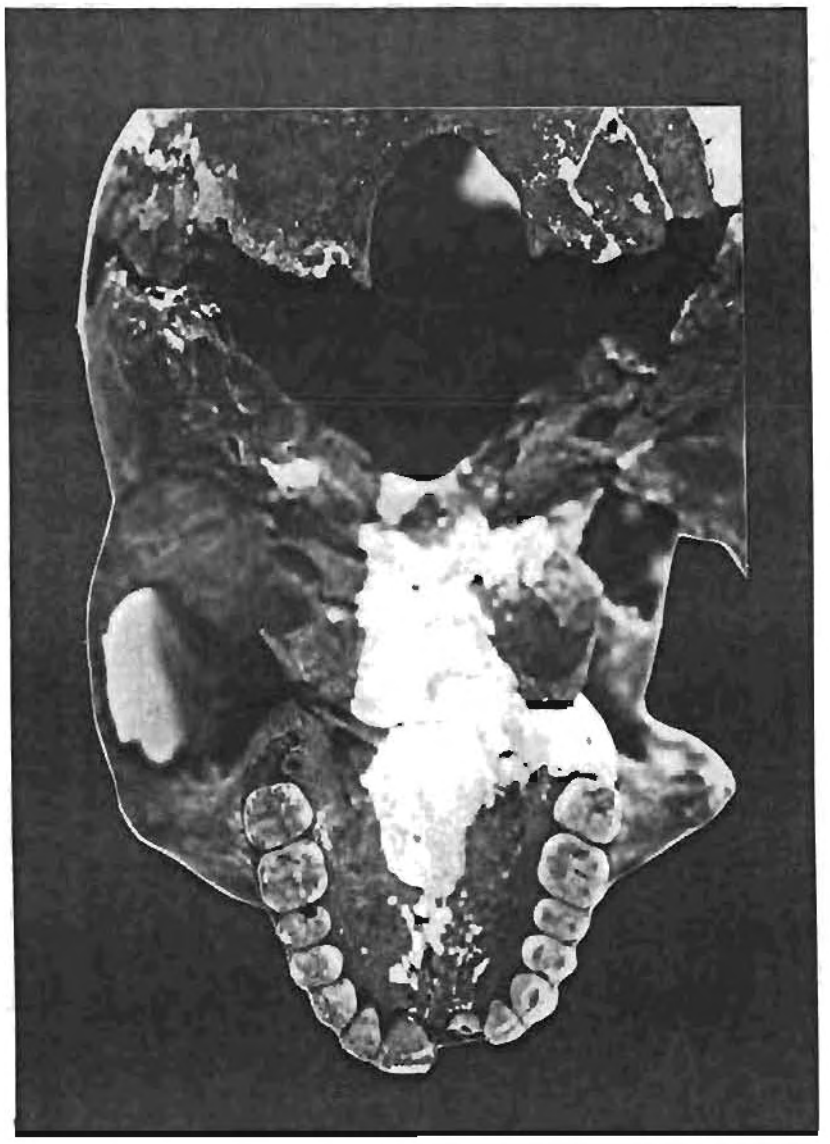
PLATES 1a & b: Facial and Basal View of A1701



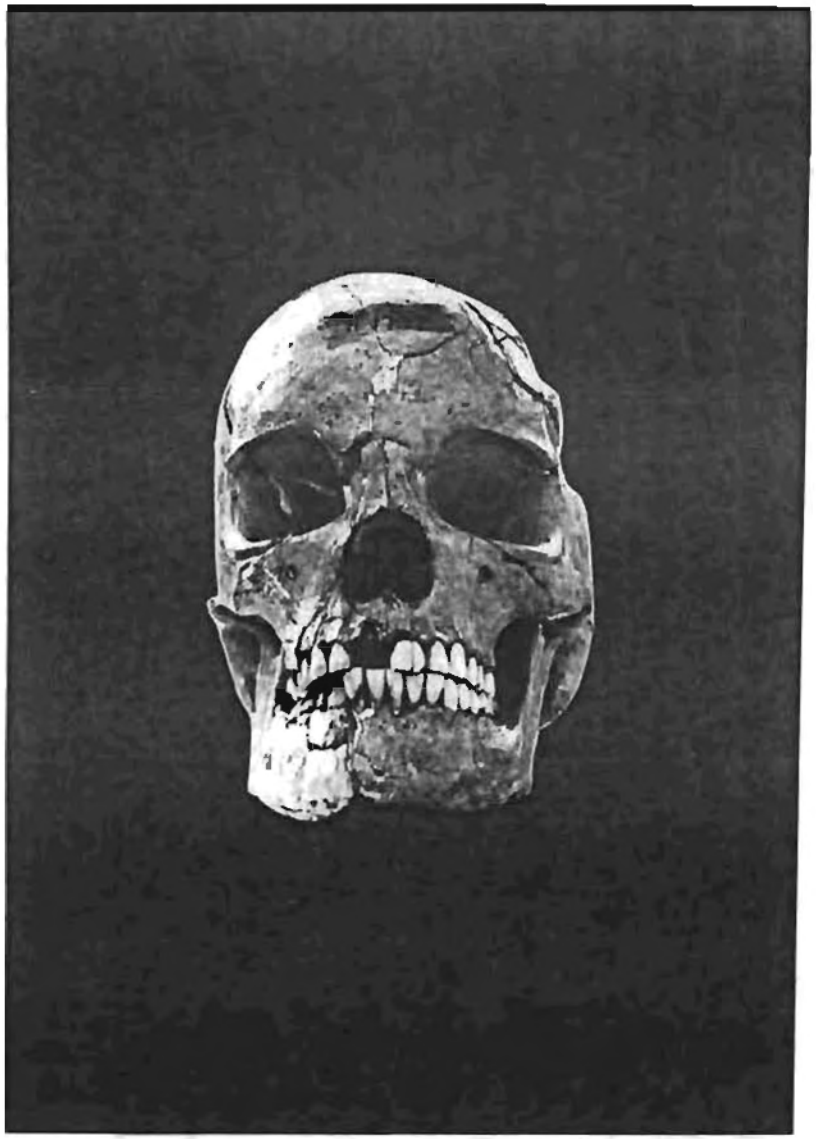


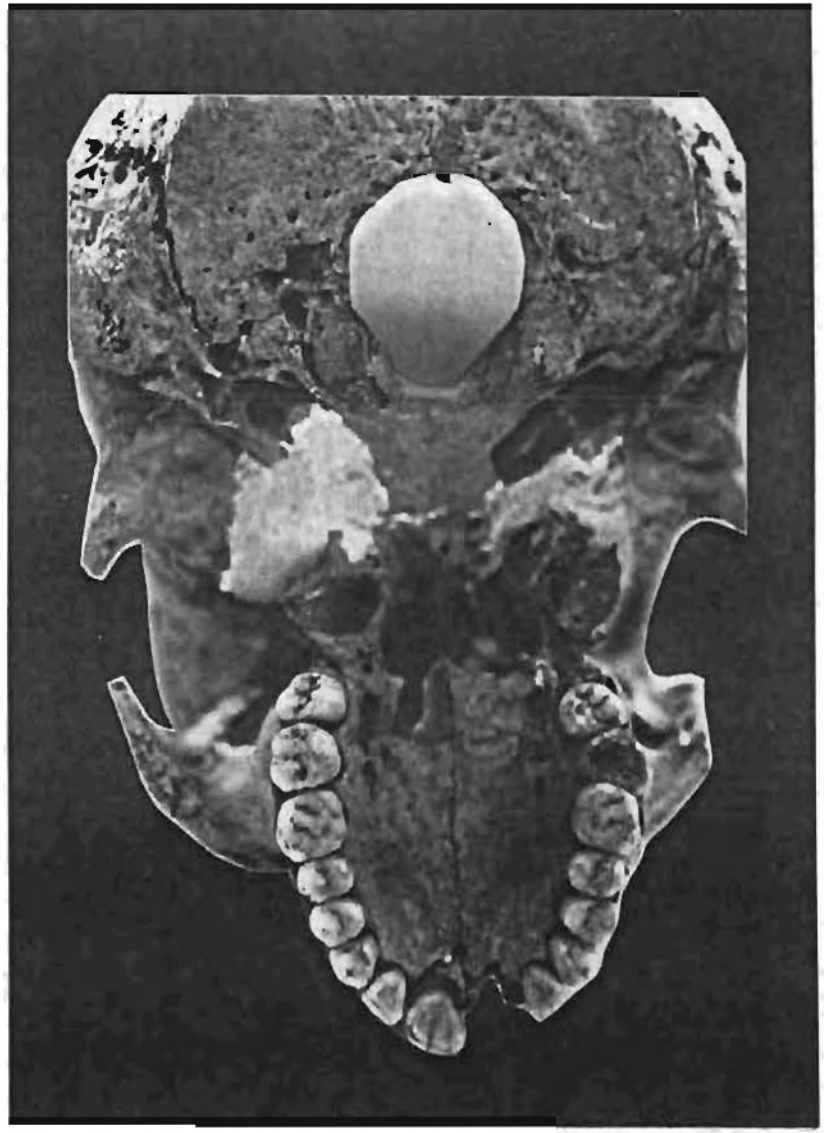
PLATES 2a & b: Facial and Basal View of A1722



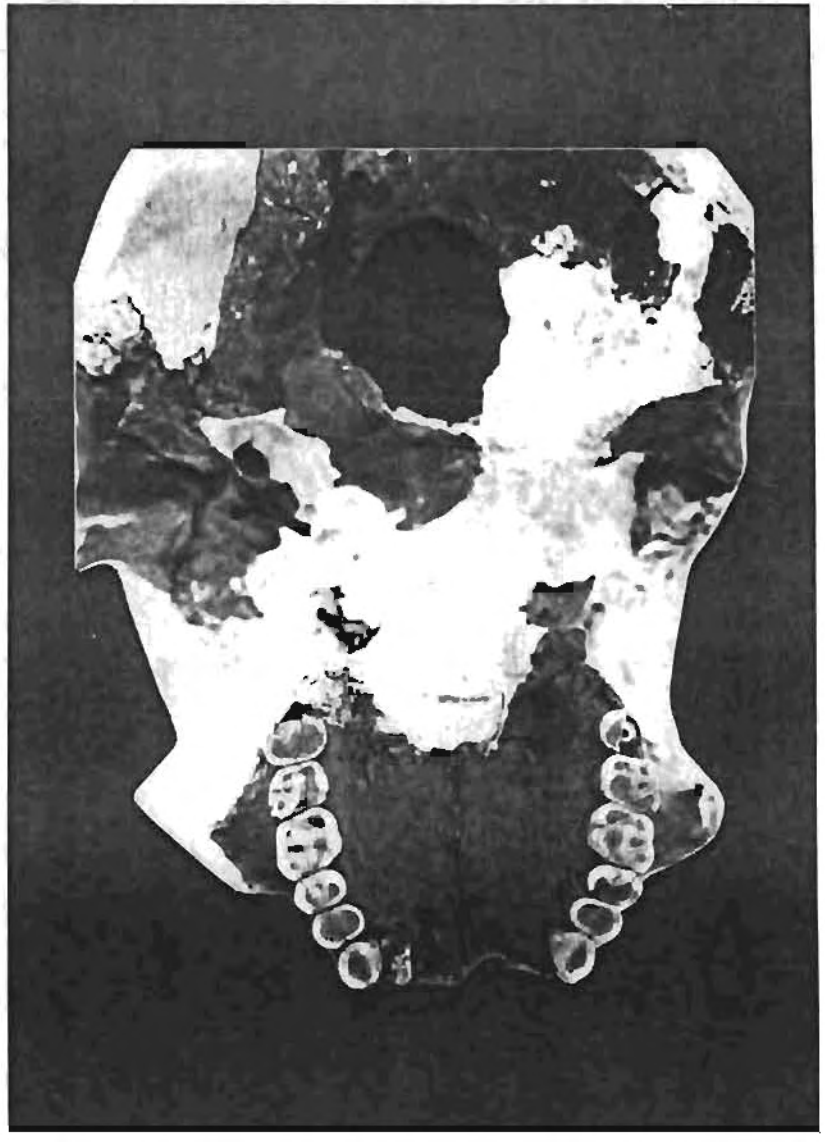


PLATES 3a & b: Facial and Basal View of A1730

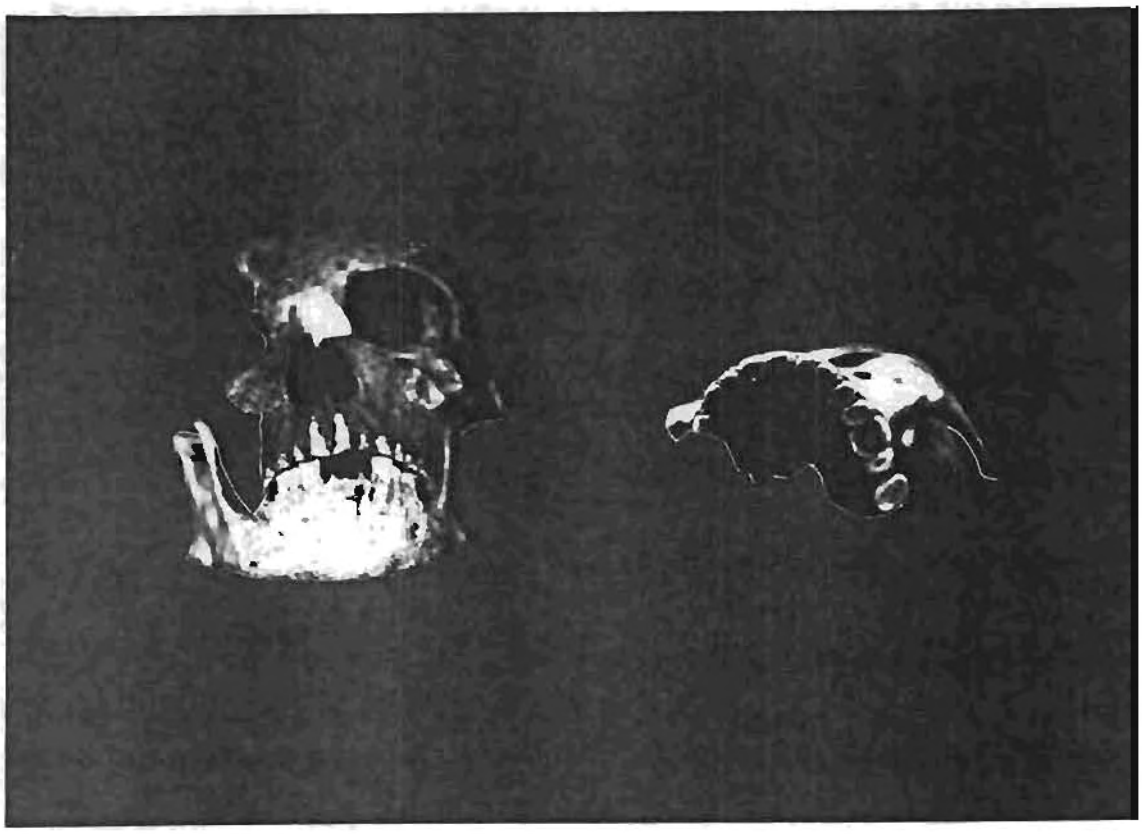




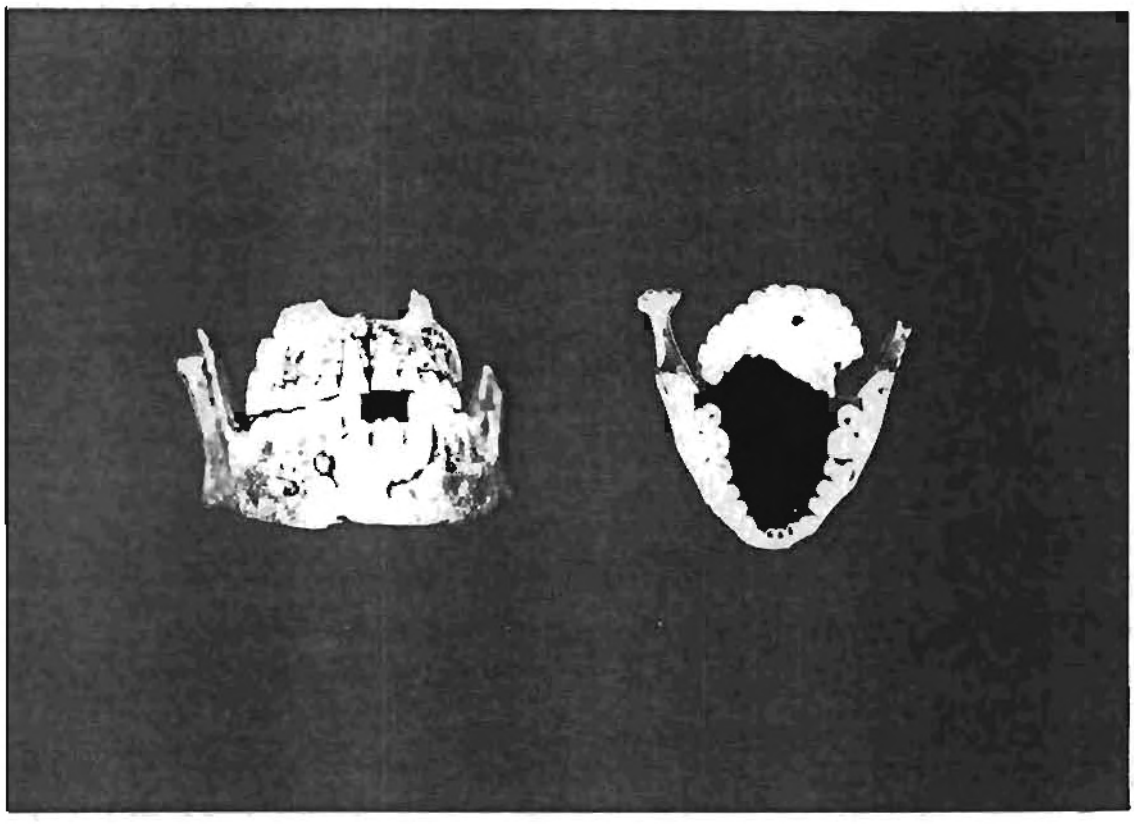
PLATES 4a & b: Facial and Basal View of A1732



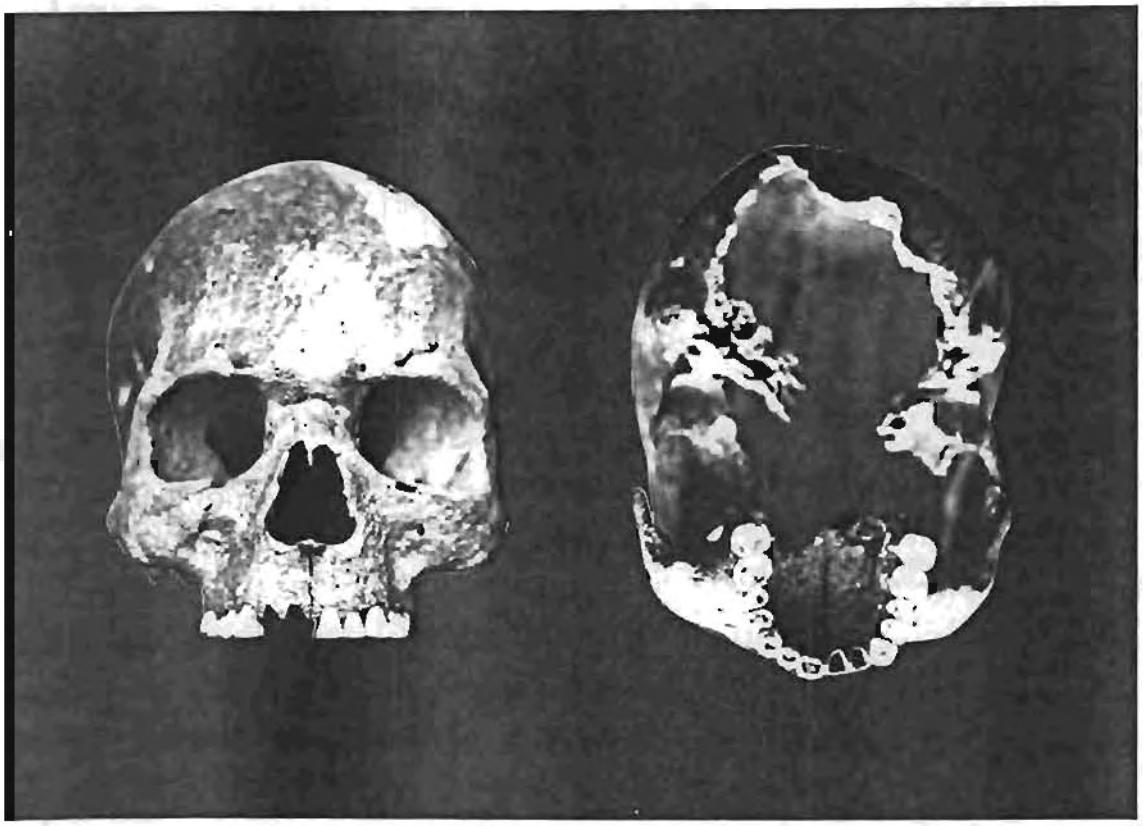
PLATES 5a & b: Facial and Basal View of A1758



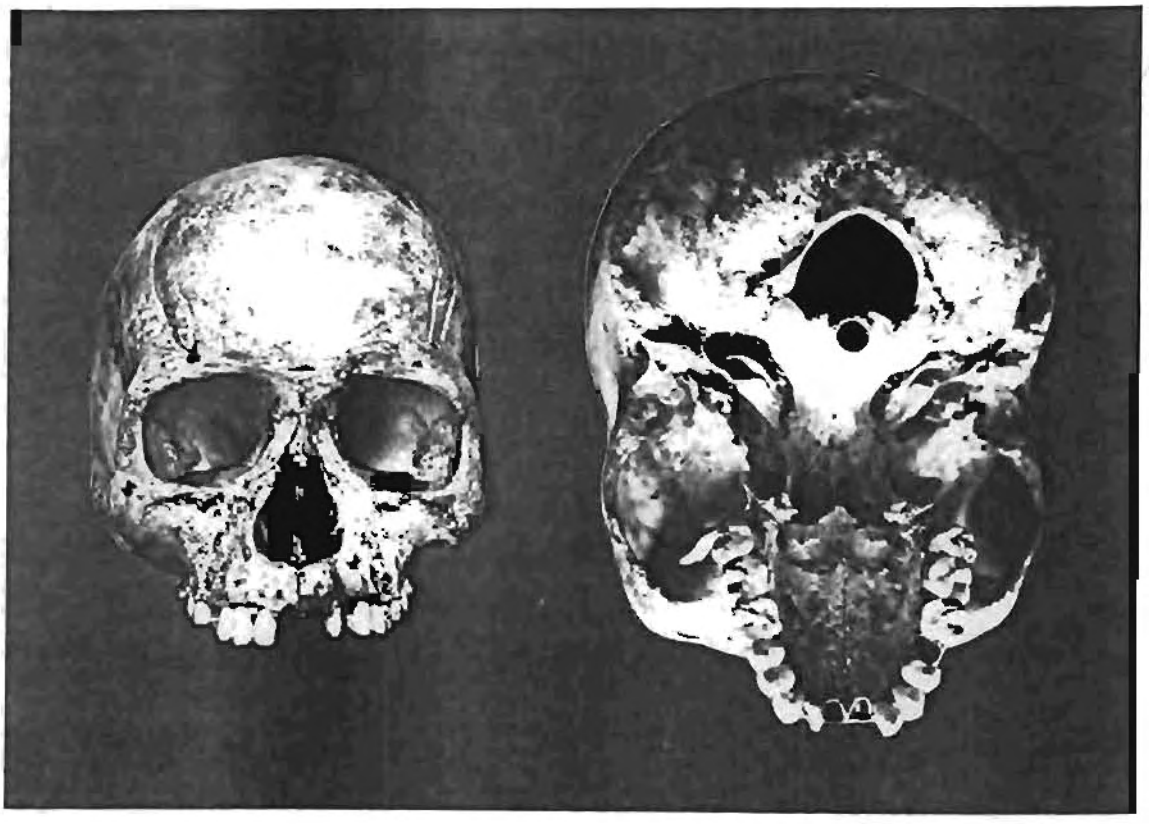
PLATES 6a & b: Facial and Basal View of NMB1243



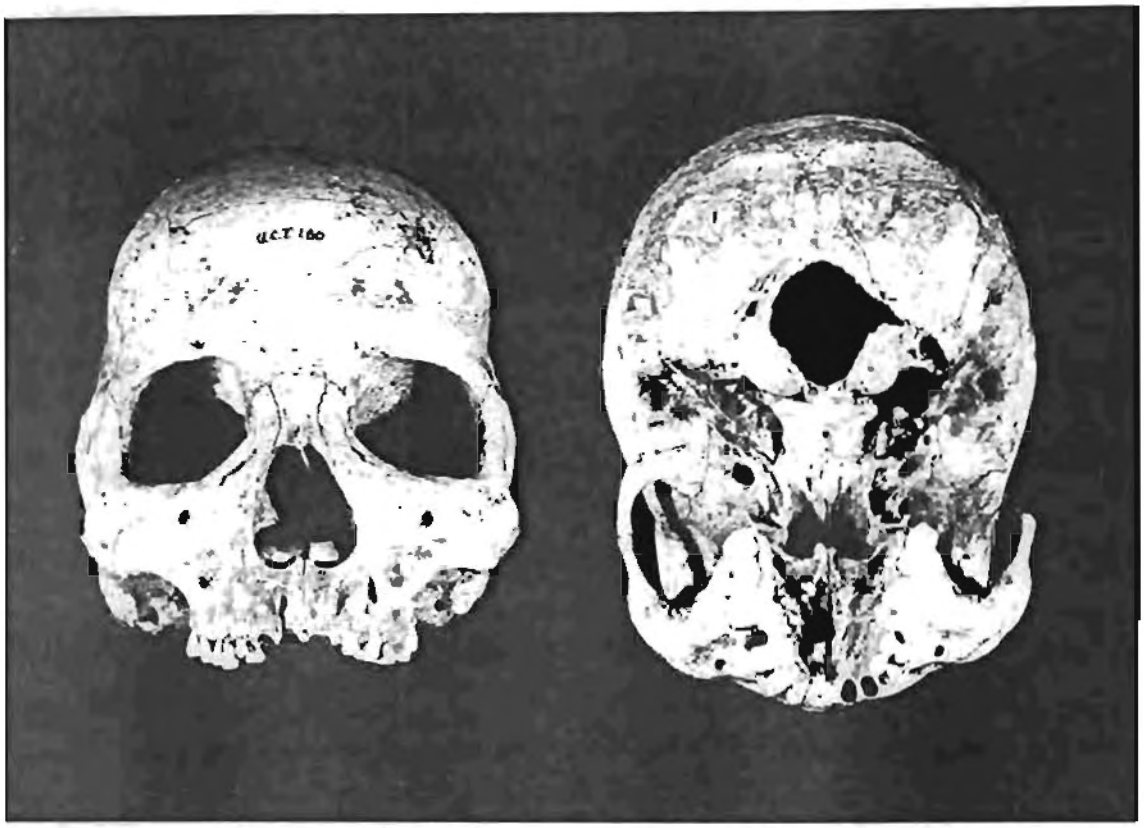
PLATES 7a & b: Facial and Basal View of NMB1441



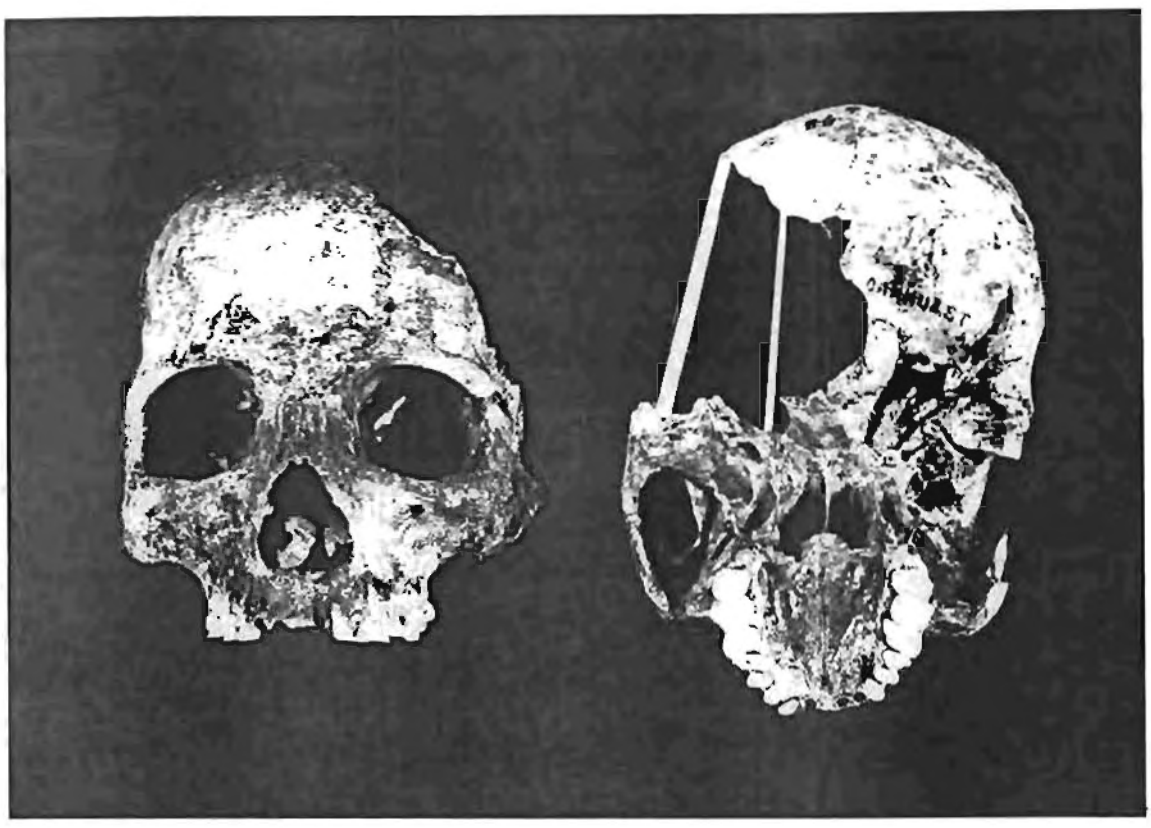
PLATES 8a & b: Facial and Basal View of NMB1448



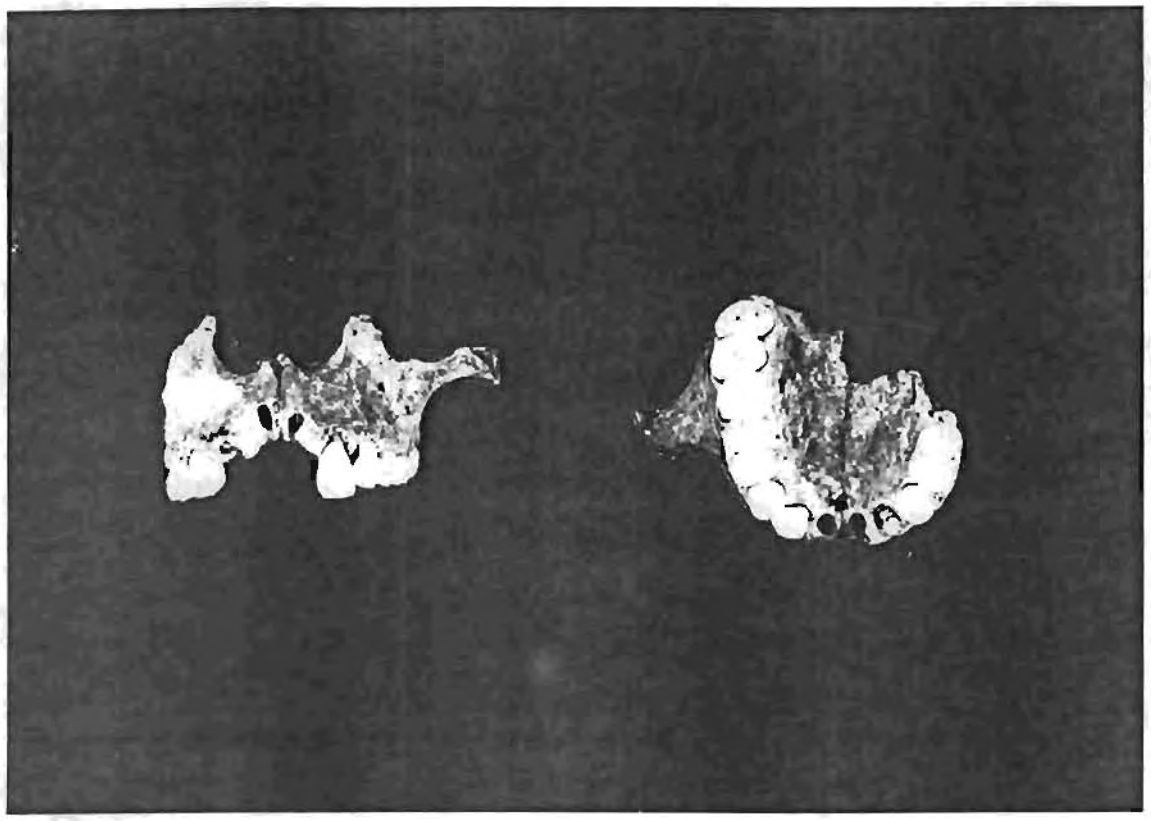
PLATES 9a & b: Facial and Basal View of NMB1273



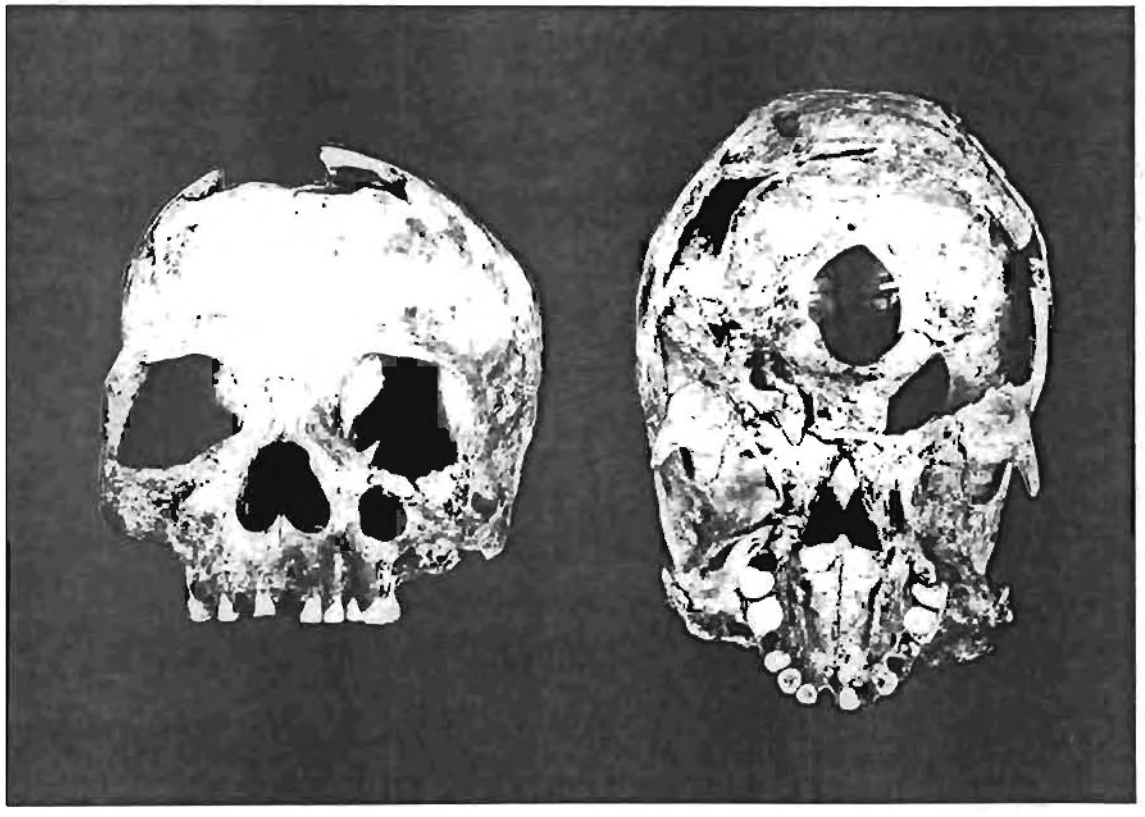
PLATES 10a & b: Facial and Basal View of UCT180



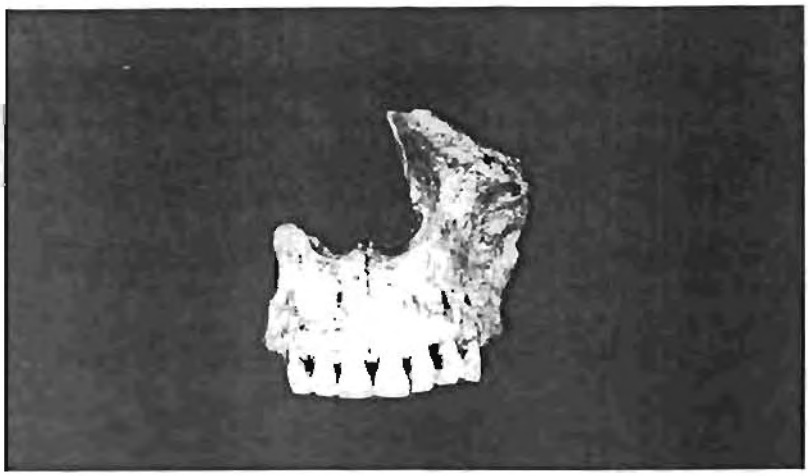
PLATES 11a & b: Facial and Basal View of UCT181



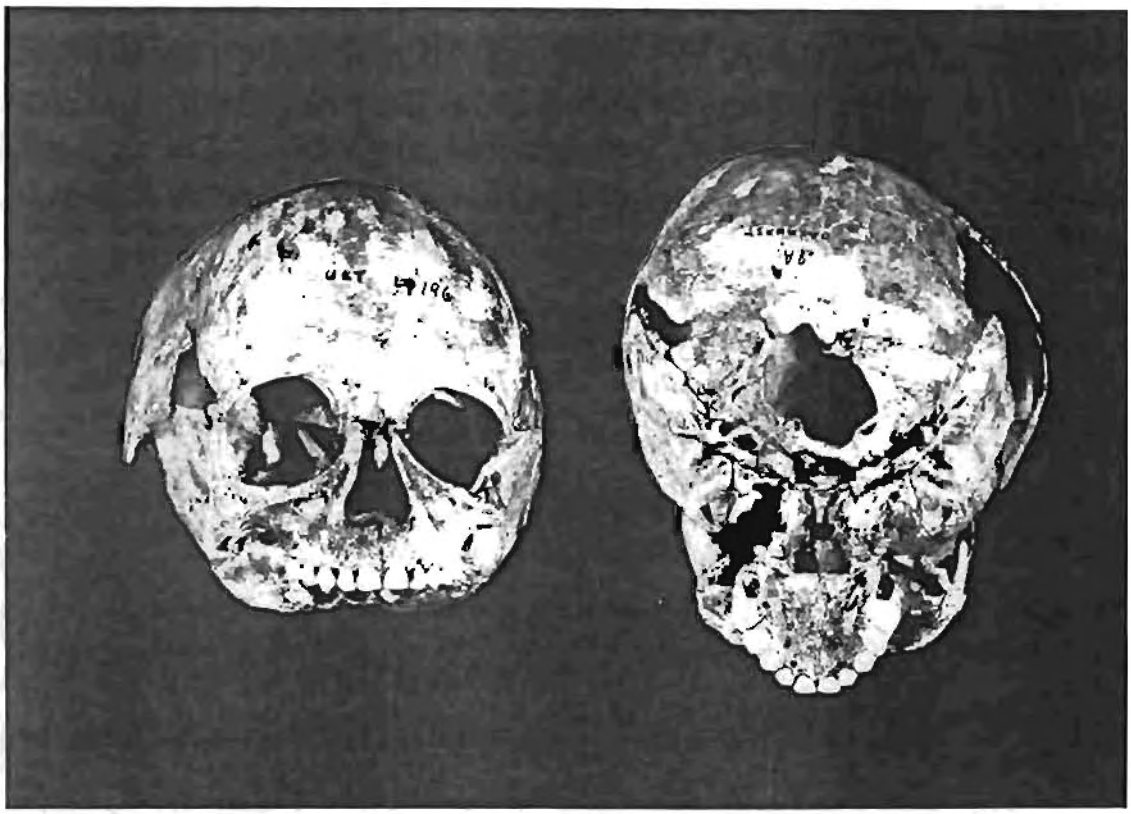
PLATES 12a & b: Facial and Basal View of UCT182



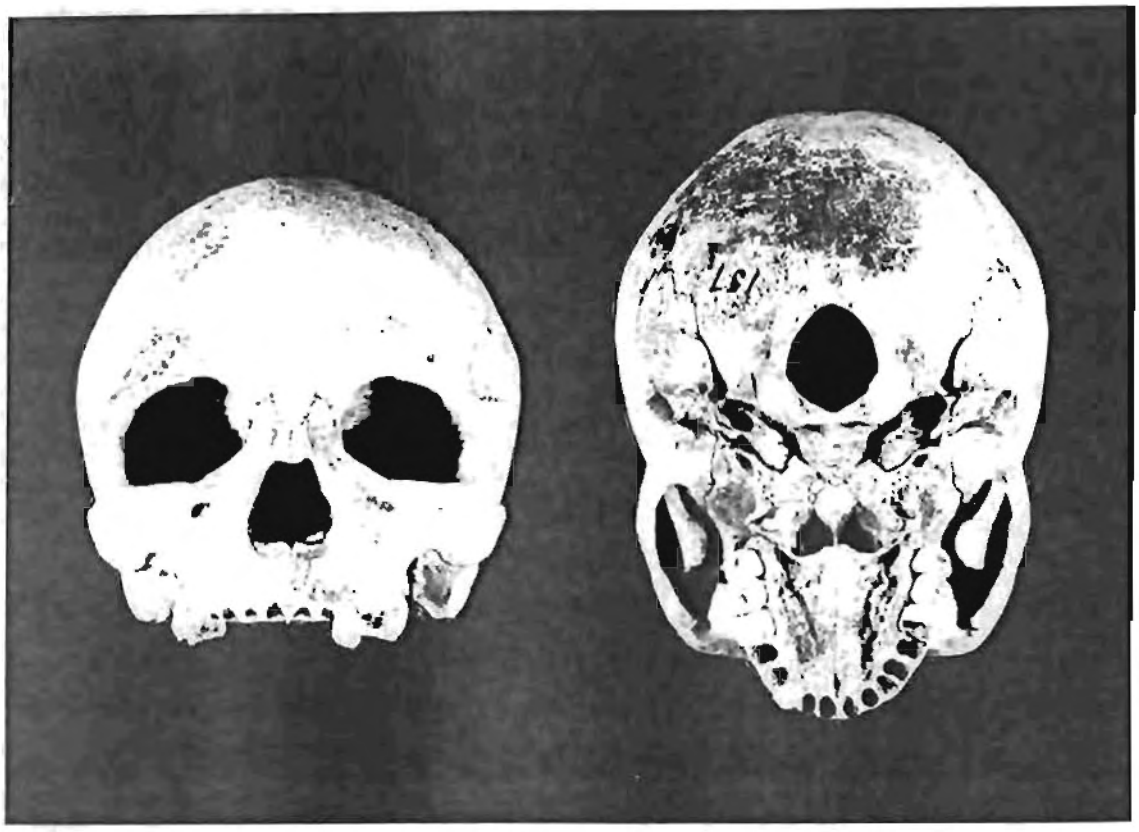
PLATES 13a & b: Facial and Basal View of UCT184



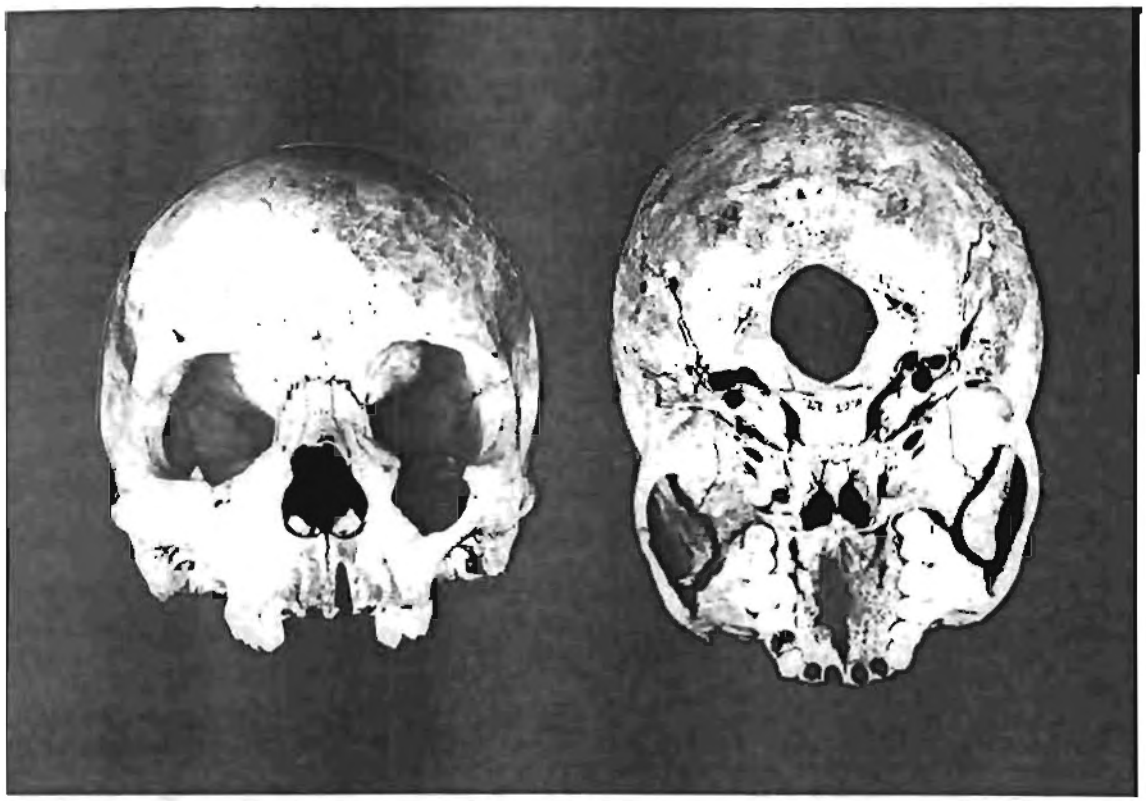
PLATES 14a: Facial View of UCT186



PLATES 15a & b: Facial and Basal View of UCT196

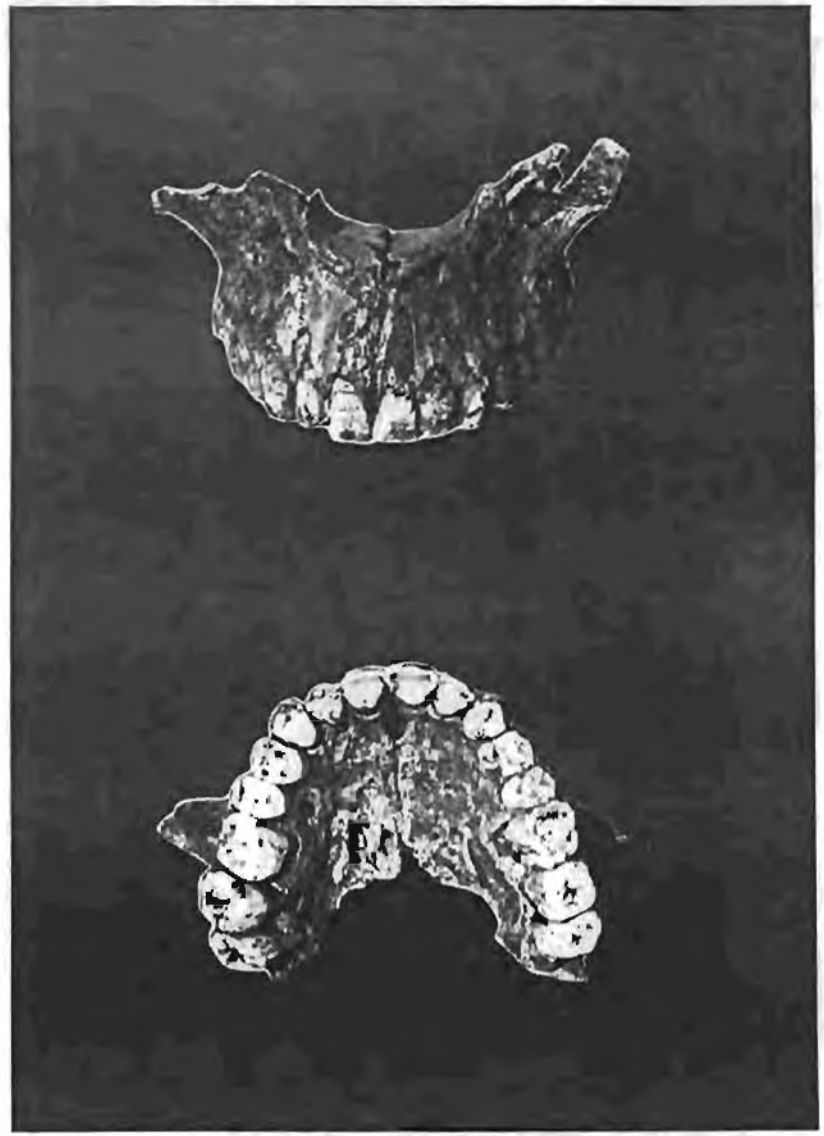


PLATES 16a & b: Facial and Basal View of UCT157



PLATES 17a & b: Facial and Basal View of UCT27

PLATE 18: Harrismith Burial 1



PLATES 19a & b: Facial and Basal View of Harrismith Burial 1

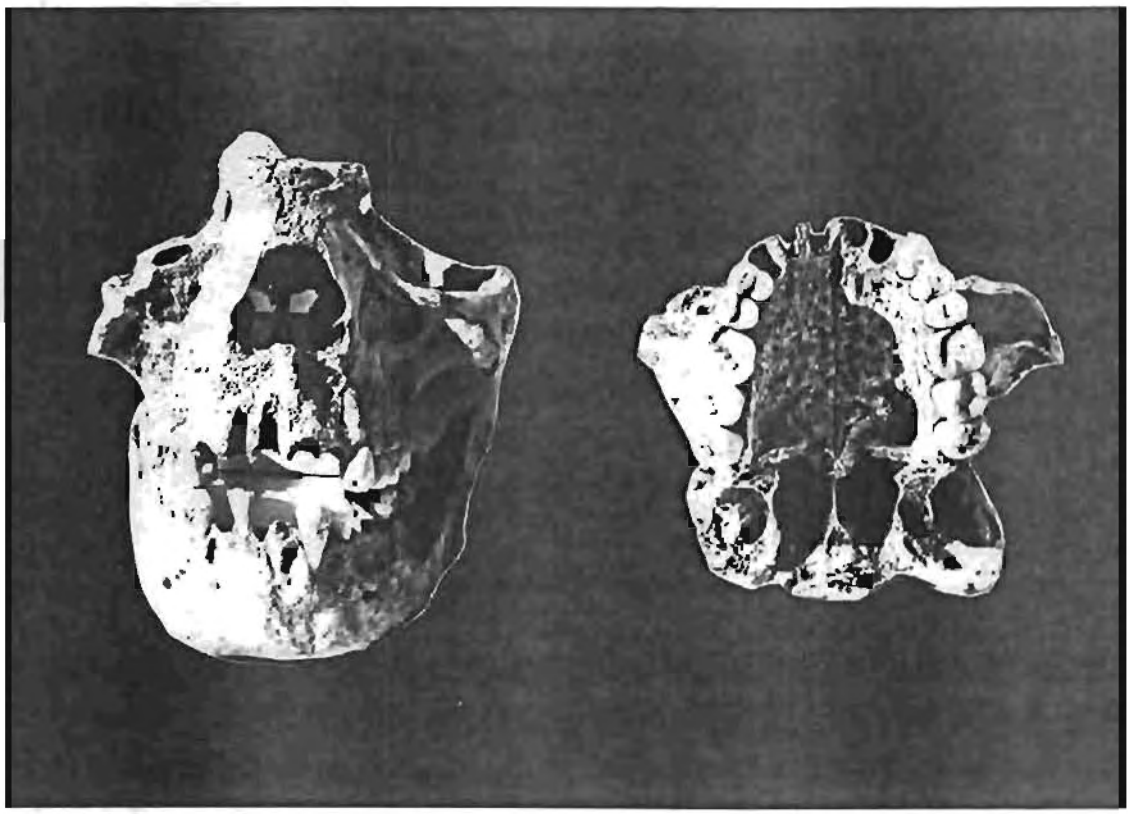


PLATE 20a & b: Facial and Basal View of Hope Hill

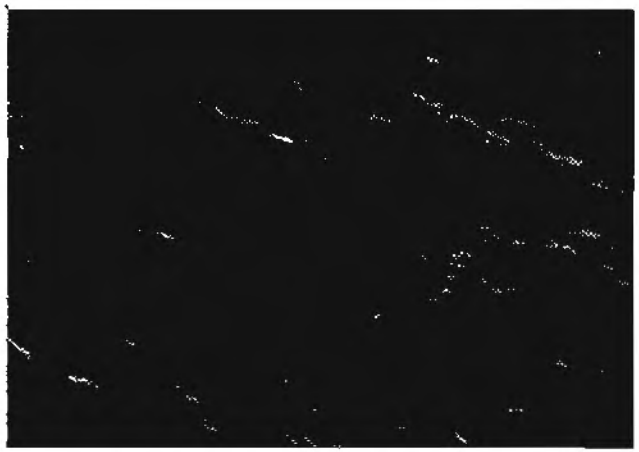


PLATE 21: Micrograph of UCT 182urc

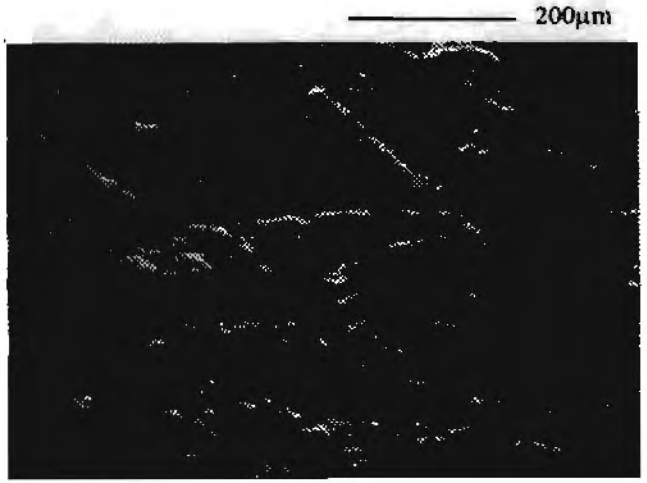


PLATE 22: Micrograph of NMB 1273ulc

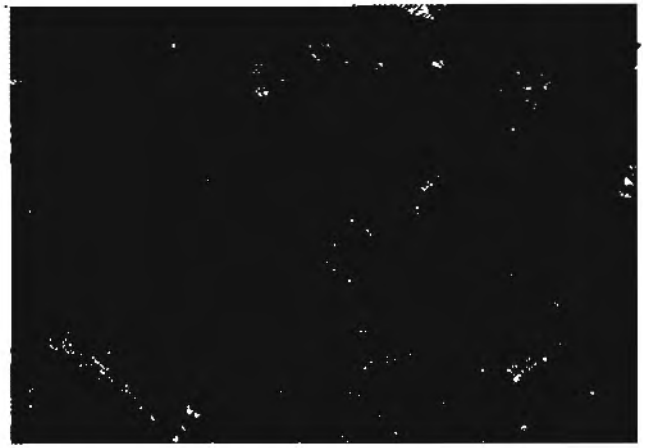


PLATE 23: Micrograph of Harrismith burial 1 (ulc)

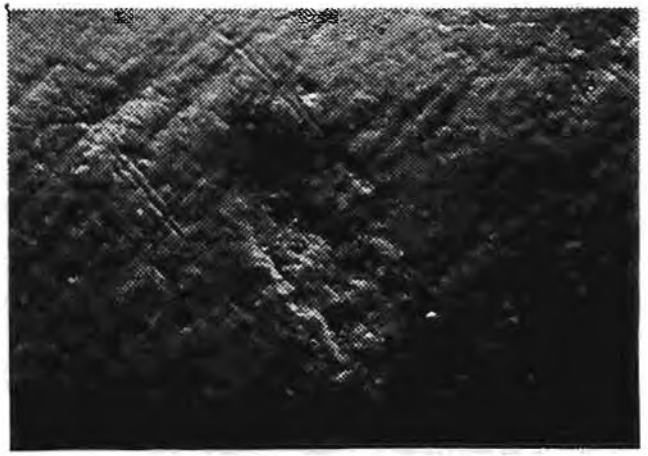


PLATE 24: Micrograph of UCT 157ulc