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Foragers among farmers in the Early Iron Age of Botswana? Dietary evidence from stable isotopes

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A thesis submitted to the faculty of Science, University of the Witwatersrand, Johannesburg in fulfilment of the requirement for the degree of Doctor of Philosophy

Johannesburg 2010

DECLARATION

I declare that this thesis is my own unaided work. It is being submitted for the degree of Doctor of Philosophy in the University of the Witwatersrand, Johannesburg. It has not been submitted for any degree or examination in any other university

_____
Signature of candidate

_____day of _____ 2010

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Abstract

The thesis attempts to identify human skeletal remains of Later Stone Age (LSA) hunter-gatherers on sites associated with Early Iron Age (EIA) farmers in east central and north western parts of Botswana and to identify individuals who may have shifted between foraging and farming. Because of the sources of dietary carbon, EIA farmers were expected to have $\delta^{13}C$ values of approximately -8‰, which are distinguishable from those of the LSA hunter-gatherers ($\delta^{13}C$ values of around -17‰). Individuals who shifted from foraging to farming would have significant differences in $\delta^{13}C$ values of bones and teeth that form or remodel at different ages and rates.

In the east central, 76 humans from Toutswe sites were analysed. From the Tsodilo Hills and Okavango River there were five individuals. Animal samples from EIA contexts at of the sites mentioned above were analysed to provide reference standards necessary for the interpretation of human isotope values. Moreover, animal isotope values were used to reconstruct past environmental and climatic conditions.

Two adults from N!oma appear to have shifted from a childhood subsistence based on foraging and most probably fishing to full-time farming in adulthood. The two adults from Xaro have bone collagen $\delta^{13}C$ values associated with both foraging and freshwater fishing. Though samples are small, there is some support for the argument that some LSA foragers had adopted the farmers' mode of subsistence during the Iron Age.

Nitrogen isotope values of domestic herbivores from the east central suggest annual rainfall of about 500mm while carbon isotope results indicate heavy reliance on C_4 photosynthetic grasses. Result from the north west suggest rainfall on 450mm with some degree of browsing. Morden herbivore samples from Toutswe area show that rainfall patterns have not changed but in contrast, the feeding habits of both cattle and small have changed to include significant amount of C_3 photosynthetic plants. This change is attributed to the general degradation of the environment.

1. INTRODUCTION

BACKGROUND TO THE STUDY

Later Stone Age (LSA) hunter-gatherers occupied southern African from the beginning of the Holocene period to the end of the nineteenth century AD. The LSA communities had different traditions, cultures, economies, technologies and subsistence strategies (Yellen 1977; Smith *et al.* 2000). For example, it is possible that along permanent water sources like the Okavango River and its delta they established semi-sedentary settlements that tapped both freshwater and wild ecosystems for food. Deep in the Kalahari sands, communities would have been more mobile following game and seasonal water bodies (Hitchcock 1982). LSA hunter-gatherers along the coast of South Africa, exploited marine supplies from the ocean while those in the interior foraged on terrestrial supplies (Sealy 1989, 2006; Sealy & van der Merwe 1985, 1986; Sealy *et al.* 1992). Even within the coastal and terrestrial groups of South Africa variations in subsistence strategies existed depending on what the environment offered. In a nutshell, individual LSA hunter-gatherers communities of southern Africa differed from one another in many respects, including modes of subsistence and diets (Hitchcock 1999; Smith *et al.* 2000).

The arrival of Early Iron Age (EIA) farmers sometime around AD200, added diversity to an already complex panorama of the southern African LSA populations. EIA farmers introduced new subsistence strategies involving access to domesticated crops and livestock. Socio-economic relationships between LSA hunter-gatherers and the migrant EIA farmers developed (Hall 1987; Mitchell 2002; Ikeya & Mitchell 2009). Some hunter-gatherers adopted some elements of the new economic ways brought by farmers. Some farmers utilised certain aspects of the hunting and gathering substance mode.

The Iron Age sequence of southern Africa extends over a period of 1800 years and can be divided into Early Iron Age (EIA) and Late Iron Age (LIA). The EIA period lasted from approximately AD200 to 1300 while the LIA dates from AD1300 until the beginning of the nineteenth century. Some

archaeologists (e.g. Huffman 2007) divide the Iron Age sequence into three subsections with the period from AD900 to 1300 being defined as the Middle Iron Age (MIA). For purposes of this study, only two periods are used i.e. the EIA and the LIA. The LSA and Iron Age sequences defined above indicate that from around AD200 to 1800, southern Africa was occupied by communities particularly distinguished from each other by raw materials used for making tools. Iron Age communities used metal as the main raw material for making tools but there is evidence indicating that they also opted, to a much lesser degree, to use stone in manufacturing tools. This is evidenced by lithics and lithic debris found at many Iron Age sites in Botswana (Denbow 1983a; Wilmsen 1990).

The communities also differed with respect to their modes of subsistence. LSA peoples were hunter-gatherers while Iron Age communities were farmers. Thus, the LSA communities depended largely on wild resources (Brooks 1978; Crowell & Hitchcock 1978; Hitchcock 1978; 1982; Donahue & Robbins 1989; Lee 1979; Lee & DeVore 1976, 1968; Tlou & Campbell 1984; Robbins & Campbell 1990) while farming communities produced the bulk of their food from domesticated crops and animals (Mönnig 1968; Denbow 1979, 1983a, Denbow & Wilmsen 1983, 1989: Plug 1983, 1996; Hall 1987; Maggs & Whitelaw 1991; Kiyaga-Mulindwa 1993; Atwood 2005). However, these farming communities supplemented their diets with seasonally available wild plants and animals.

The differences and similarities between the LSA and Iron Age communities mentioned in the previous two paragraphs clearly demonstrate that anthropological definitions of pre-historic communities should not be essentialist in principle. And, as will be seen in Chapter 2, there is a lot of variation in cultural practises between foragers of the Kalahari and southern Africa in general. For purposed of this study, the communities will be differentiated from each other through their dominant mode of subsistence i.e. foraging and farming.

Initially it was thought that the Kalahari and its immediate environs were inhospitable, uninhabitable and only occupied during the wet climatic phases in the second millennium AD (Hitchcock 1982; Tlou & Campbell 1984; Denbow 1983a, 1986). In the mid 1970s there were fewer than five prehistoric sites documented in Botswana. Of these, only one, Toutswemogala, was excavated and

attempts to interpret its findings were made (Lepionka 1971, 1977, 1978, 1979). Shortly after Lepionka's work, Denbow (1979, 1983a, 1986) surveyed the area around Toutswemogala and almost immediately identified hundreds of EIA middens on hilltops. The middens were identified as grey patches on aerial photographs used for survey. By the early 1980s, a three-tier settlement hierarchy of the EIA Toutswe had been described (Denbow 1982, 1983a, 1984a).

There have been few attempts to investigate possible variations in diets of the EIA farmer communities. For many decades, archaeologists used the diet of the historic Pedi community as an analogue for all southern African EIA peoples (Mönnig 1967; Ambrose 1986; Lee-Thorp *et al.* 1993; Maggs & Whitelaw 1991). The staple diet of historic Pedi was made of sorghum, millet and meat from cattle and ovicaprids. Legumes, pumpkin and wild game were also included in the diet (Mönnig 1967). The use of the Pedi diet as analogy for all Iron Age communities was problematic because it precluded the possibility of geographic and temporal variation within the Iron Age (Lee-Thorp *et al.* 1993). Indeed, data generated from several isotope studies (Ambrose 1986; Ambrose & DeNiro 1986a; Lee-Thorp *et al*. 1993; Gilbert 1995; Murphy 1996) have shown interesting variation in the dietary habits of the EIA communities of southern and eastern Africa.

This study seeks to reconstruct the diets of the EIA farmers in two regions of Botswana, the east central and northwest (Figure 1.1) in order to establish whether there are any geographic variations in diet. It also investigates the lifetime dietary isotope signatures of individuals to determine if there were individuals who shifted from hunting and gathering to farming or vice versa. In the east central region, sites included in that study are those associated with the Toutswe ceramic tradition (Denbow 1983a). They include Kgaswe B55, Bonwapitse, Serowe Hill, Thataganyane Hill, Swaneng Hill, Taukome, Thatswane, Bosutswe and Toutswemogala (Figure 1.1).

After the discovery of Toutswe settlements, there were discoveries of EIA sites on the Tsodilo Hills in the north western Kalahari, and some kilometres away at Xaro along the Okavango River (Tlou & Campbell 1984; Denbow 1986b). Within the interior of the Kalahari, many LSA sites became known. Sites in both regions (i.e. the northwest and the east central) offer unique and independent opportunities to test some of the theories proposed in the Kalahari debate. For instance, ceramic assemblages at the Tsodilo Hills differ with those from Toutswe sites and this strongly suggests

cultural differences between the two. In this study, stable isotope techniques are used to determine if there were differences in diet between the regions.

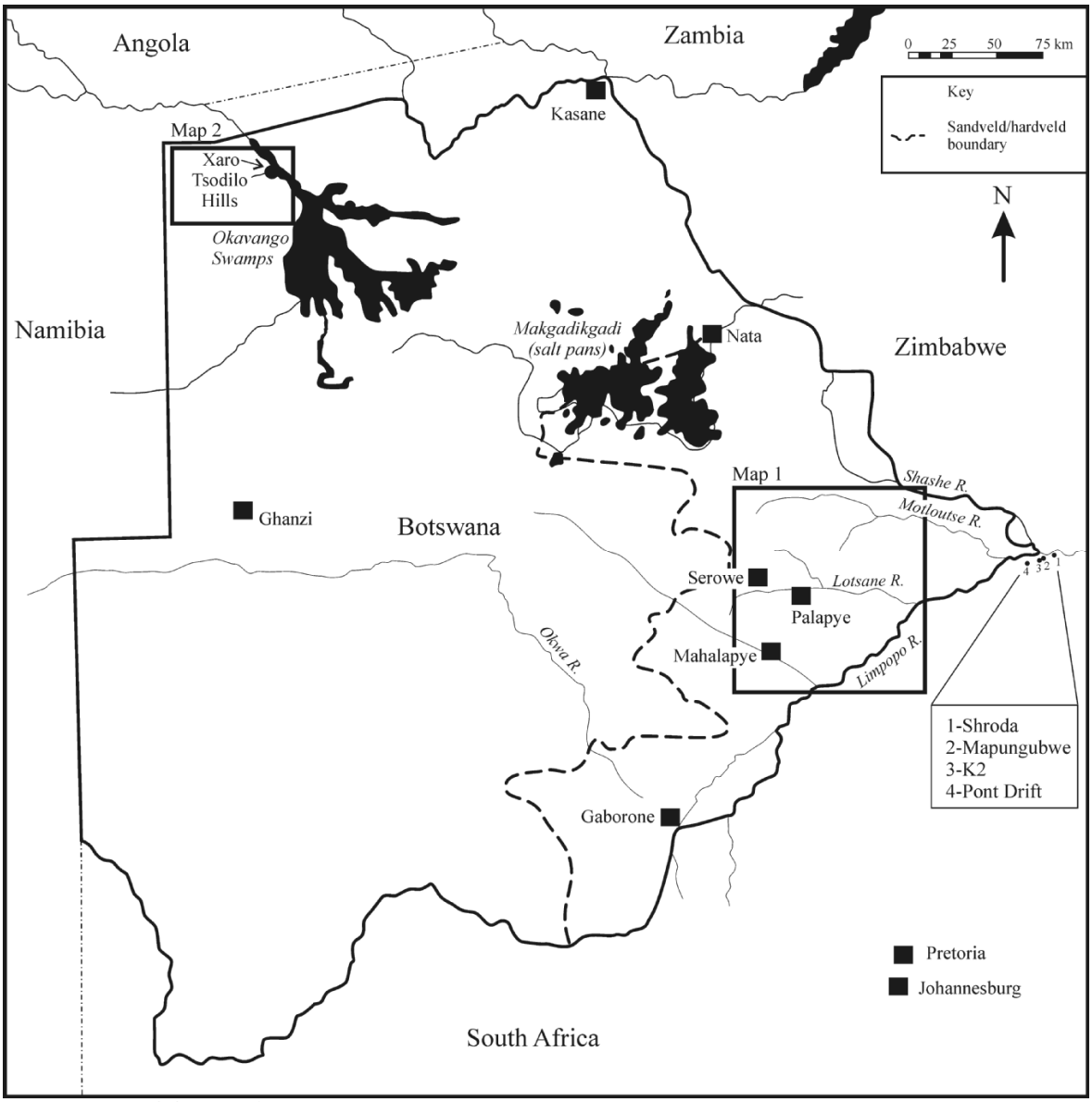


Figure 1.1: Map of Botswana showing the east central and north western areas under study

FORAGER-FARMER CONTACTS IN THE EARLY IRON AGE

It is important to review the history and theory of archaeological research on LSA and EIA sites to contextualise this study. Evidence for contact between hunter-gatherers and farmers has been identified in several ways (Denbow 1980, 1984b; Campbell & Coulson 1982; Sadr 2002). First is the presence of LSA stone tools at some EIA farmers' sites (e.g. at Bosutswe, Taukome and N!oma). Second is the proximity of LSA sites to EIA sites (e.g. Maiphetwane in the Toutswe area, Radiepolong in Thamaga and LSA rock shelters near EIA settlements at the Tsodilo Hills).

Archaeologists and anthropologists recognise and agree that the arrival of Iron Age farmers in southern Africa elicited different responses from the local LSA hunter-gatherers. The nature of interaction between the local LSA hunter-gatherers and the EIA farmers differed from place to place and from time to time (Denbow 1984b, 1986a, 1999; Denbow & Wilmsen 1986; Yellen 1986; Headland & Reid 1989; Hitchcock 1999; Guenther 2002; Mitchell 2009; Ikeya *et al.* 2009).

In certain instances, the hunter-gatherers remained in their independent mobile settlements, but exchanged hunted animal products for the produce of sedentary farmers. It is believed that some hunter-gatherers settled among farmers (seasonally or permanently), worked as herdsmen, and were rewarded with meat, milk and other kinds of goods. Present day analogues can be found among San hunter-gatherers in most parts of Botswana. It is common to find the San peoples employed by Batswana cattle owners as herdsmen (Yellen 1986; Denbow 1986a, McCall 2000).

ARCHAEOLOGICAL EVIDENCE FOR SUBSISTENCE (AD700 TO 1300)

For purposes of this study, the focus is made on the effects that interaction between foragers and farmers had on each other's dietary habits. Hence, it is necessary to provide a brief review of the archaeological evidence for diet and subsistence from the study areas. Archaeological evidence for subsistence and diets comes from different sources: the faunal and floral assemblages, as well as remains of kraals and granaries.

Faunal assemblages and remains of animal kraals at Toutswe sites indicate that animal husbandry was an important aspect of subsistence (Welbourne 1975; Denbow 1979, 1982, 1983; Plug 1983,

1996). Domestic animals kept for consumption at the time were cattle goats and sheep. Chickens were also present but probably in lesser numbers compared to herbivores. In the Tsodilo Hills, the bulk of the meat came from domestic animals (Denbow & Wilmsen 1986; Turner 1987a) as shown by the results of the faunal analyses from Divuyu and N!oma.

Evidence for exploitation of wild species such as steenbok, zebra, tortoise has been found at sites such as Toutswemogala (Welbourne 1975) Taukome (Plug 1983; Denbow 1983a, 1990, 1999) Bosutswe (Denbow *et al.* 2008) and N!oma (Turner 1987a, 1987b). Fish bones have been found in the faunal assemblage of Xaro (Wilmsen 1990; Denbow 1999) and thereby indicating that fishing was a mode of subsistence particular to this settlement.

Floral assemblages are, unfortunately very small because of poor preservation conditions for botanical remains in Botswana. For instance, attempts to recover pollen samples from the Holocene deposits along the Okavango failed because of poor preservation conditions (Nash *et al.* 2006) and because of inefficient field recovery techniques. In the 1970s to 1990s when archaeological excavations were carried out in Botswana, finds were recovered through simple dry sieving. This method is not suitable for recovery of minute botanical remains such as pollen and very small seeds and grains. Botanical assemblages would probably have been increased through floating and other relevant techniques. Carbonised sorghum, millet, beans, *morula* kernels and others have been found at sites such as Taukome (Denbow 1983a), Kgaswe B55 and N!oma through dry sieving (Denbow & Wilmsen 1986; Wilmsen & Denbow 2005). Remains of grain bins have been identified at Taukome (Denbow 1983a), Kgaswe B55, Bosutswe (Denbow *et al.* 2008), Toutswemogala and other sites.

AIMS OF THE STUDY

The study is intended to address specific questions within the archaeology of Botswana. The questions are: were there any individuals who shifted from foraging to farming as argued by revisionists in the Kalahari debate? Were there any foragers living amongst farmers whilst continuing to maintain their hunting and gathering strategy? Was there any differential access to

food based on age, sex or the status of the community? What was the nature of the climatic conditions that allowed for the proliferation of the Iron Age communities within the study areas? These questions form the basis of the study which, which aims to:

1. identify individuals who may have shifted from foraging to farming or vice versa
2. identify human skeletal remains of foragers buried in farmers' settlements
3. determine the role of non-cereal crops in the overall diets of EIA farmers
4. investigate variation in the diet of EIA individuals and communities
5. reconstruct EIA environmental conditions in the Toutswe area and the Tsodilo Hills

RESEARCH DESIGN

Foragers in the Kalahari sands are known to have subsisted on wild plants that follow the C_3 photosynthetic pathway. The bulk of the wild game in the Kalahari would have been mixed feeders and browsers and thus they ate C_3 and small amounts of C_4 photosynthetic plants. Foragers are, therefore expected to have depleted $\delta^{13}C$ values (as low as -21‰). Farmers are expected to have less negative $\delta^{13}C$ values (approximately -7‰) because the bulk of their dietary protein came from C_4 based plants and animals grazing on C_4 photosynthetic grasses and farm stubble. This general knowledge was used in formulating the research design for this study which outlines how stable isotope techniques were used to address the questions of the study.

1. Identifying individuals who shifted from one mode of subsistence to the other is done by comparing stable isotope ratios of carbon in bone collagen and enamel apatite. Individuals who shifted from one mode to the other will have different dietary isotope signatures between enamel apatite and bone collagen and between bones that remodel at different rates.
2. Foragers buried in farmers' settlements will be those individuals with more negative $\delta^{13}C$ values (around -21‰) where most individuals are expected to have less negative $\delta^{13}C$ values (around -7‰). Non-cereal crops consumed by EIA farmers are expected to lower their $\delta^{13}C$ values. That is, the expected $\delta^{13}C$ value of -7‰ for farmers living on pure C_4

based diets will not be obtained if farmers supplemented their diet with C_3 based wild foods.

3. Testing the significance of dietary variability between individuals of different age and sex groups as well as individuals from different sites will be done through statistical tests. Mann-Whitney tests will be calculated where possible to determine if differences in isotope results from different sites are statistically significant.
4. The isotope results of herbivores are matched against their expected $\delta^{13}C$ and $\delta^{15}N$ values given their known dietary habits. Deviations from the expected values can be indications of specific rainfall and temperature conditions that alter the diets and affect the physiological processes of the animals. The results for herbivore isotope values will be compared to those from previous studies in southern Africa where climatic reconstructions have been made.

JUSTIFICATION OF THE STUDY

The previous three sections of this chapter have provided brief summaries of (a) evidence for subsistence and diets, (b) evidence for interactions between farmers and foragers, and (c) relationship between isotope values (of herbivores) and climatic conditions. One might then wonder why this research was done since some ideas on diet, subsistence, contact and climatic conditions for the EIA have been suggested known through previous studies. The reasons that justify this study are as follows:

(a) The archaeological evidence for diet is limited firstly because it cannot predict the relative importance of cereals to non-cereal crops and secondly because it is not easy to determine any existing variations in diets at individual and community levels. Because domestic cereals follow the C_4 photosynthetic pathway, they result in $\delta^{13}C$ values close to -7‰ in the bone collagen of the consumers. Most non-cereal food plants use the C_3 photosynthesis and result in their consumers having more negative $\delta^{13}C$ values (of up to -21‰) in bone collagen. This study provides an opportunity to estimate the relative contributions of non-cereal crops to the diets of the farmers. Furthermore, because the

isotope analyses are done on individuals, this provides an opportunity to review the diets of individuals and communities under study.

(b) The archaeological evidence for contact between farmers and foragers is often limited and ambiguous (Sadr 1997). Stable isotope techniques have an advantage of providing yet another line of evidence because they allow tracking of dietary habits throughout the lifetime of individuals. Individuals who shifted from one mode of subsistence to the other because of farmer-forager contact, will be identified through changes in dietary isotope signatures on bones and teeth that were formed and/or remodelled at different times in their lives.

(c) Lastly, matching stable isotope data of herbivores to known climatic conditions as will be done for the modern samples, will create a baseline from which to infer the EIA climate from EIA animals.

LIMITATIONS OF THE STUDY

As expected of any research, some problems and limitations have been experienced or were expected with this study. These are related to (a) what questions stable isotope techniques can or can not be used to answer, and (b) issues of sample availability.

a) First, dietary carbon isotope signatures are incorporated into bone collagen over periods of up to several years. Therefore, individuals shifting their mode of subsistence need to survive long enough for the osteological manifestations of the dietary changes to be recognised. This means that any individuals from the study area who shifted their diet and then died shortly afterwards would not be identifiable. It would have been ideal to include tissue with faster turnover rates such skin and hair. These would show dietary constituents of individuals shortly before death.

b) The second limitation is that not finding individuals who shifted from one subsistence to the other or foragers within farmers' settlements could be because skeletal remains of such individuals have not yet been discovered or excavated. Therefore, not having these individuals does not necessarily prove that the revisionist argument is wrong.

c) Carbon isotope values are only able to differentiate plants according to their photosynthetic pathway. It is thus difficult to determine the role of wild C_3 versus domestic C_3 photosynthetic plants (e.g. beans, melons and greens) within the dietary composition of farmers. Therefore, the degree of foraging within a farming context is not possible to precisely determine without abundant botanical remains in the archaeological record.

d) The fourth problem is that it was not possible to find sufficient sample sizes from all sites in order to address all questions raised in this research. For example, many of the small class 1 Toutswe sites had less than 10 individuals each making it difficult to determine if there was differential access to food according to age or sex.

e) Furthermore, there are no human samples from known LSA sites which would have been ideal to include in the study. In southern Africa, hunter-gatherer burials are generally found in caves. Unfortunately there are few caves in Botswana and most have been excavated and do not have human remains.

f) Differential access to food in most cases can be depicted if the food in question was based on different photosynthetic pathways. For example, differential access to different species of C_4 cereal crops, or species of animals with similar dietary habits, is difficult to identify through stable isotope analysis.

THESIS OUTLINE

The thesis is divided into seven chapters excluding the introduction. In Chapter 2 the background literature on the archaeology in Botswana and stable isotope analysis is reviewed. Archaeology in Botswana covers two areas: (a) the Kalahari debate which emanated from studies of contacts between the Kalahari San and their neighbouring Bantu farmers, and (b) the review of the sequences of EIA settlements with special reference to the Toutswe area in east central Botswana, and the Tsodilo Hills and Okavango River in the north-west. The second part of the literature review covers the principles of stable isotope techniques and their application to dietary reconstruction studies. This section also predicts carbon and nitrogen isotope values of hunter-gatherers and farmers for the study areas.

Chapter 3 describes the materials and methods used in this study. It provides a list of all specimens analysed, the sites they come from, and an explanation of why they were included in the study. The sample consists of 76 humans and approximately 200 animals from Toutswe sites, three humans and seven animals from the Tsodilo Hills, and two humans from the Okavango Delta area. The chapter then describes the methods used in preparing and analysing both bone collagen and enamel apatite. It also includes descriptions of statistical tests applied in interpreting, comparing and contrasting results from different sites.

Chapters 4 and 5 present results of the stable isotope ratios from the human and faunal samples. Chapter 4 focuses on samples from sites in the Toutswe area. Chapter 5 presents results from sites in the Tsodilo Hills and the Okavango River.

Discussion of the results is provided in Chapters 6 and 7. Chapter 6 discusses the faunal isotope ratios, which provide a baseline from which human isotope results can be interpreted. In discussing the isotope results for animals, attention is paid to what the results imply in terms of climatic factors such as rainfall patterns and temperature, and the availability of pasture and forage. Subsequently, the faunal isotope results from this study are compared with results previously reported for other Iron Age sites in southern Africa e.g. Schroda and Pont Drift in the Shashe Limpopo River Basin (SLRB) as well as results previously reported for Bosutswe (Denbow *et al.* 2008).

Discussion of human isotope results is presented in Chapter 7. Emphasis is on estimating the relative dietary proportions of C_3 versus C_4 photosynthetic plants. This is because the consumption of C_3 and C_4 photosynthetic plants differs between foragers and farmers. In addition, comparisons of early childhood (from enamel apatite) and adult (from bone collagen) dietary isotope signatures are used to identify individuals who shifted from one subsistence strategy to the other. Chapter 7 further places the dietary isotope signatures of the EIA Toutswe communities in the broader context of the southern African Iron Age. This is achieved by statistically comparing the Toutswe human isotope results reported for other sites in southern Africa, especially in the SLRB. The final chapter concludes and summarises the thesis and provides indications for future research directions.

2: REVIEW OF THE LITERATURE

INTRODUCTION TO LITERATURE

The chapter provides a broad review of the literature covering several areas and issues of relevance to the current research. Archaeological research in Botswana covers more of the country, as well as much a deeper time span than is presented in this chapter. However, only archaeological studies relevant to the current study are presented in this review. First is a review of studies of contact between LSA hunter-gatherers and EIA farmers in Botswana. The second and third parts focus on the geographic distribution of EIA settlements in east central and northwest Botswana. The review of isotope studies and their applications to dietary reconstructions has been divided into three main sections: principles of stable light isotopes, carbon isotope ratios and nitrogen isotope ratios. All of these sections are summarised at the end of the chapter.

Within Botswana, some frontiers of prehistoric contact between hunter-gatherers and farmers, and between hunter-gatherers and herders have been identified. These include the east central part of the country (Toutswe area), the northwest (Tsodilo Hills), as well as several hills in the southeast e.g. Thamaga area (Denbow 1984a, 1984b, 1986a; Sadr & Plug 2001; Sadr 2002). Hence, the second and third parts of the review focus on the settlement patterns of EIA settlements in the areas being studied. A unique topographic boundary in the eastern part of the country is a discontinuous erosion escarpment marking the edge of the Kalahari sandveld (Cooke 1982; Thomas & Shaw 1991). EIA sites in east central Botswana tend to cluster in the hardveld along the frontiers of the Kalahari sands (Figure 2.1). In the northwest, EIA sites have been discovered in the sandveld at the Tsodilo Hills and along the margins of the Okavango River as shown in Figure 2.1 (Cooke 1982; Denbow 1983a, 1990; Denbow & Wilmsen 1986).

Lastly, the literature review focuses on stable isotope techniques as dietary indicators and as tools for reconstructing the environment of EIA farming and LSA foraging communities. Stable light isotope ratios of carbon, nitrogen and oxygen were chosen to investigate diets of humans and

animals and to reconstruct past climatic conditions in various parts of Botswana. The review provides justification for the usefulness, advantages and reliability of carbon and nitrogen isotope ratios in reconstructing the diets and environments of prehistoric communities.

Throughout southern Africa, hunter-gatherer communities have been involved in various kinds of relationships with pastoralists and Iron Age farmers who arrived in the area in the last 2000 years. Given the geographic extent of southern Africa and the strong possibility that Iron Age farmers arrived in the area at different times (Hall 1987; Huffman 1989), there is very little doubt that interactions between farmers and hunter-gatherers varied across space and time. By the turn of the twentieth century, many southern African hunter-gatherers had become involved (directly or indirectly) in political and economic trends of neighbouring Bantu speaking farmers (Yellen 1986; Hitchcock 1999; Smith *et al.* 2000). In some areas hunter-gatherers became sedentary and adopted pastoralism (Yellen 1986; Hitchcock 1978, 1999; Denbow & Wilmsen 1986; Wilmsen 1990). In some areas such as the mountains of Lesotho hunter-gatherers ceased to exist shortly after the arrival of the EIA farmers (Mitchell *et al.* 1994; Mitchell 2002).

The LSA groups are believed to have taken advantages of subsistence opportunities offered by the environment in the same way as modern San hunter-gatherers do (Brooks 1978; Crowell & Hitchcock 1978, 1982; Robbins & Campbell 1990; Eibl–Eibesfeldt & Hitchcock 1991). For instance, San communities along permanent or semi-permanent water sources such as the Okavango and Boteti Rivers tend to be more sedentary because they exploit permanent resources from freshwater (Hitchcock 1999). A prehistoric example of such settlements would be Xaro on the banks of the Okavango River. The !Kung, on the other hand, organise themselves such that they aggregate around pans during the dry season and disperse in smaller groups during the rainy season (Yellen & Brooks 1988; Hitchcock 1999).

THE KALAHARI DEBATE

The Kalahari debate centres around a particular group of San hunter-gatherers, the! Kung speaking Ju/'hoansi and the now extinct /Xam. The Ju/'hoansi are found in the Dobe and Nyae-

Nyae regions, northwest Botswana (Lee & DeVore 1968, 1970, 1976; Yellen 1977; Lee 1979; Howell 1979; Wilmsen 1989; Smith *et al*. 2000; Sadr 1997; Hitchcock 1999; Mitchell 2002) and the adjacent part of Namibia. Although the Kalahari debate started with the Ju/'hoansi, it was extended to include the LSA hunter-gatherers who lived in the Kalahari and the rest of southern Africa (Denbow 1984b; Denbow & Wilmsen 1986; Wilmsen 1989; Wilmsen & Denbow 1990; Mitchell 2009; Ikeya *et al.* 2009) in the last 2000 years. Of particular relevance to the current study is the possibility that LSA hunter-gatherers were incorporated into EIA farmers' settlements, not just into the EIA political economies (Denbow 1984a, 1986a; Wilmsen 1989). Such hunter-gatherers would have adopted new lifestyles and altered their diets from foraged resources to include domesticated crops and animals.

In the 1950s and 1960s, Botswana and some parts of southern Africa was one of the few places in the world where relatively large numbers of mobile hunter-gatherer communities, also known as San, could be found (Hitchcock 1982, 1999; Mitchell 2002; Ikeya *et al.* 2009). As a result, ethnographic, anthropological, demographic and historical studies of these hunter-gatherer peoples were carried out in the 1960s and 1970s (e.g. Lee & DeVore 1976; Marshall 1976; Lee 1979; Howell 1979; Leacock & Lee 1982: Hitchcock 1982, 1999). Different San communities are found in the greater Kalahari which parts of Botswana, Angola, Zambia, Zimbabwe, South Africa and Namibia (Hitchcock 1999; Smith *et al.* 2000). Of particular interest were the !Kung speaking Ju/'hoansi in the Dobe area. They were seen as independent and affluent hunter-gatherers whose lifestyles were thought to represent that of the Holocene LSA peoples. They were, therefore, the last remaining opportunity to document traditional hunter-gatherer ways of living (Lee & DeVore 1968, 1970, 1976; Marshall 1976; Lee 1979, 2002; Solway & Lee 1990; Lee *et al.* 1998).

Indeed, documentation of the 1960s' !Kung by the Harvard group of anthropologists was well timed. Only 30 years down the line, the !Kung settlements had transformed to look like Tswana villages. Traditional Ju/'hoansi temporary grass shelters were replaced by mud-wall rondavels, milk and meat from *mafisa* cattle had replaced the bulk of the traditionally hunted game (Yellen 1990). In Namibia, the establishment of South African Defence Force (SADF) camps in the Ju/'hoansi area resulted in many Ju/'hoansi settling in the small village of Tsumkwe. They provided labour to SADF while abandoning their traditional way of living. At present, the Namibian Ju/'hoansi are

sedentary and their hunting has been diminished due to over-exploitation of wildlife (Yellen 1986; McCall 2000).

The Kalahari debate is about the degree of economic and political isolation and independence of the 1950s and 1960s !Kung San, (now known as Ju/'hoansi) in the Dobe area of northwest Botswana and adjacent parts of Namibia (Lee 1979, Lee & DeVore 1970, 1976; Marshall 1976; Leacock & Lee 1982; Denbow 1984b, 1999; Wilmsen 1989, Headland & Reid 1989; Wilmsen & Denbow 1990). A group of researchers from the Harvard University initiated research and documentation of the Ju/'hoansi San in the 1960s. Their point of view is referred to as "traditionalist".

In the late 1960s, a congress with the theme "Man the Hunter" held in the United States of America brought together researchers working among the !Kung-speaking San (Lee & Devore 1968). At this congress traditionalists concluded that despite contact with farming communities in Botswana and the adjacent Namibian area, the Ju/'hoansi ancestors did not adopt any elements of cultures, traditions, economies, technologies or subsistence strategies from the EIA farmers (Lee 1979; Lee & DeVore 1976). They viewed the Ju/'hoansi as having retained a pristine hunting and gathering way of life since the Holocene. This has been emphasised by anthropologists like Eibl–Eibesfeldt & Hitchcock (1991) who say that:

> " … data on the subsistence strategy of the Bushmen point to a long uninterrupted history that is reflected in the descriptions of early travellers and old Bushmen rock paintings showing items of material culture nearly identical to those used in recent decades…" pg 55

Ju/'hoansi foragers were believed to have remained autonomous both politically and economically until the mid twentieth century (Kent 2002; Guenther 2002). Traditionalists argue that there was little interaction between earlier Bantu farmers and the Ju/'hoansi in the Dobe area. In general, traditionalists argue that the San even have retained physical characteristics which distinguish them from Bantu farmers. Intermarriage between the two groups commonly meant the San

marrying and emigrating out to join Bantu and not the other way round (Eibl–Eibesfeldt & Hitchcock 1991)

In contrast, a group of researchers led by Wilmsen and Denbow have long been opposing the traditionalist notion that the Ju/'hoansi San represent a pristine way of Holocene hunter-gatherer life. This group casually known as "revisionists" contend that following contact with EIA farmers, LSA hunter-gatherers became participants in the socio-economic networks of their neighbouring farming communities. Denbow (1983a) suggested that some hunter-gatherers could have provided labour and game in farms and cattle posts of the Toutswe Iron Age farmers. Those in other parts traded with farmers by hunting or obtaining fur, meat from game, salt and other items from the wild (Denbow 1984b, 1990). There is evidence to suggest that some hunter-gatherers reared cattle, sheep and goats (Denbow 1984b, 1986; Denbow & Wilmsen 1983, 1986; Turner 1987a; Wilmsen 1989; Wilmsen & Denbow 1990). LSA tools recovered at many stonewalled later Iron Age sites of the Zimbabwe and Khami kingdoms suggest incorporation of some San peoples into farming communities (Denbow 1986a) ca1000 years ago.

Revisionists further argue that due to socio-economic interactions between hunter-gatherers and farmers, some groups benefited while others were left poor, dependent, dispossessed and marginalised. These disadvantaged groups of people came from both farmer and hunter-gatherer camps (Denbow 1986a, Wilmsen & Denbow 1990). They were relegated to low economic ranks and in order to cope, they may have shifted between foraging and farming depending on environmental opportunities (Denbow 1984b). Hence, according the revisionists all mid-twentieth century San, including the Ju/'hoansi became economically marginalised as they participated socio-economic and political networks linking hunter-gatherers and farmers. They were not pristine hunter-gatherers (Denbow 1984b; Wilmsen 1989; Headland & Reid 1989). Such occurrences of groups or communities changing from farming to foraging are common in west Africa. According to Hitchcock (1999) there are no "true" foragers in west Africa. Groups who practice this mode of subsistence in west Africa are those who have been left stranded by drought, crop failure and most commonly civil wars (Hitchcock 1999).

Revisionists oppose the traditionalists on two grounds: that the historic Ju/'hoansi way of life was not as pristine and affluent as proposed and that even if they were pristine, their lifestyles should not be used as a standard model to interpret Holocene hunter-gatherer economies in all arid lands. Even if the Ju/'hoansi were pristine hunter-gatherers, their experiences and economic processes were unique to them and maybe a few other groups but were not universal to all arid land hunter-gatherers (Denbow 1986a). Each hunter-gatherer community had its own economic challenges and coping mechanisms. Furthermore, revisionists argue that new economic adaptations would have evolved with changing environments; the notion of pristine twentieth century Ju/'hoansi was a fantasy rather than a reality.

In defending their stand, traditionalists accuse revisionists of failing to recognise the possibility that interaction between farmers and foragers differed across space and time (Solway & Lee 1990) and that encapsulation and subjugation of hunter-gatherers did not take place across the whole of the Kalahari, particularly in the Dobe area. Traditionalists contend that autonomy of the !Kung does not necessarily imply that they were isolated from regional socio-economic networks (Solway & Lee 1990). With regard to contact, Lee's (2002) informants in Ngamiland indicated that they never interacted with farming communities and account for potsherds found on their previous settlements as having been acquired through trade with other San called the Goba. The Ju/'hoansi travelled far to trade with the Goba San along the river systems but the Goba themselves never penetrated the Ju/'hoansi territory. The Goba acted as intermediaries between the !Kung and Bantu speaking farmers (Lee 2002). These memories deal with the recent past and were, nevertheless, used as analogy of the distant past.

Oral histories of the Ju/'hoansi collected by Marshall (1976) stated that they originate from the Dobe area. Based on this, Marshall (1976) concluded that the Ju/'hoansi must be descendents of groups associated with the LSA archaeological record of this area. The other factor linking the LSA hunter-gatherers and the current Ju/'hoansi is that of settlement distributions. The Ju/'hoansi aggregate around water sources in the dry season. LSA hunter-gatherer sites in the Dobe area are within 0.3km radii, of pans suggesting that in the mid twentieth century the Ju/'hoansi were simply continuing a tradition inherited from the LSA period. In addition, the Ju/'hoansi in Botswana recalled using stones as raw materials for making tools in the last 100 years (Yellen & Brooks

1988), thus demonstrating continuity between them and LSA hunter-gatherer inhabitants of the area.

In the continuation of the debate, the lack of supporting data for the revisionist argument has been cited as a problem. For example, Sadr's (1997) critique identifies lack of evidence on several issues. The issue of San encapsulation in EIA economy as proposed by Denbow and Wilmsen (1986) and Denbow (1990) is based on findings of LSA commodities on small class 1 Toutswe EIA settlements and Iron Age products found on LSA sites. According to Sadr (1997) very few of the >400 Toutswe EIA sites have been excavated and even fewer have LSA tools. The LSA assemblages on Toutswe and other EIA sites do not convincingly indicate LSA hunter-gatherer incorporation by EIA farmers. Remains of wild animals are ambiguous as they could have been hunted and brought by EIA farmers themselves as opposed to being brought by LSA hunter-gatherers (Sadr 1997). EIA metals and ceramics found on LSA sites are also said to be too few to be used as evidence for subjugation.

Debates surrounding the subsistence characteristics of hunter-gatherers are ongoing in other parts of the world (Ikeya *et al.* 2009). For example, debates about subsistence of LSA communities on inland and coastal sites in south western Africa (Sealy & van der Merwe 1985, 1986, Parkington 1972, 1986, 1987, 1988, 1991: Sealy *et al.* 1992; Balasse & Ambrose 2002; Sealy 2006). The south western part of Africa has four ecological zones: the Atlantic shoreline, a temperate coastal plain, a fold mountain belt, and a semi-desert Karoo. There have been arguments as to whether the communities at Elands Bay and Olifants River Valley sites moved seasonally across the landscape (Parkington 1972, 1986, 1987, 1988, 1991) or whether communities settled within their ecosystem permanently (Sealy & van der Merwe 1985, 1986, 1987, 1988; Sealy *et al.* 1992). Stable isotopic evidence indicates that communities settled and exploited resources only within their immediate environs. Thus, instead of mobile communities as initially suggested by Parkington (1972), different ecosystems represented different communities (Sealy & van der Merwe 1985).

A study by Sealy *et al.* (1992) included a total of 74 individuals from LSA sites along the south western coast of Africa, between the Cape Peninsula and Elands Bay. Nineteen of the skeletons are from inland sites including Faraoskop (about 30km from coastal Elands bay) and Oakhurst.

Archaeological evidence at Faraoskop shows some degree of reliance on shellfish. But $^{13}C/^{12}C$ ratios of the individuals from this site are similar to those of individuals from further inland sites along the Olifants River Valley where the intake of marine foods was very limited (Sealy *et al.* 1992). Thus, besides close proximity to coastal settlements such as the Elands Bay, the community at Faraoskop relied heavily on terrestrial sources for food. Sealy and co-workers (1992) have suggested that this distinction in food sources between Elands Bay and Faraoskop were probably associated with socio-political systems which restricted the flow of food between coastal and inland sites.

In another part of the world, Yesner *et al.* (2003) tested the validity of ethnohistoric models of subsistence among the Tierra del Fuego communities. Ethnohistoric records divide these Fuegian communities of Argentian-Chile into three main groups; the Yamana, the Selk'nam and the Haush. It was thought that the modern Tierra del Fuego communities practiced subsistence economies inherited from their pre-European contact ancestors. These include maritime hunting and gathering by the Yamana in the Beagle Channel Islands, terrestrial hunting and gathering by the Selk'nam of the south Pantagonia and a mix of these subsistence strategies by the Haush. Yesner *et al.* (2003) compared stable isotope results of human remains from pre-Europen contact contexts to results that would be expected from the documented ethnographic records of the subsistence of the three Fuegian communities. Stable isotope evidence demonstrated that the ethnohistoric models were correct but with particular anomalies. For instance, the results show that the Yamana depended more on terrestrial sources while the Selk'nam had limited use of maritime resources (Yesner et al. 2003).

STUDIES OF CONTACT BETWEEN FORAGERES AND FARMERS

Recently there has been renewal of interest in investigating interactions between hunter-gatherers and farmers in the last 2000 years (Sadr 1997, 2002; Smith 2001; Grauer 2007; Ikeya *et al.* 2009). Clearly, the effects of contact were neither uniform nor predictable. Some San groups lived on the peripheries of farmers' settlements, herding cattle and small stock in exchange for food (Hitchcock 1978, 1982; Schrire 1980; Denbow & Wilmsen 1983; Denbow 1984b; 1999). In east central Botswana, a possible example of hunter-gatherer presence on the periphery of farmers'

settlements is Maiphetwane (Denbow 1983a). Maiphetwane is an EIA site (Toutswe type) with a fairly large lithic assemblage strongly suggesting the presence of foragers.

Thamaga in south eastern Botswana, provides another example of interaction between foragers and farmers as well as between foragers and herders. Several farmers' settlements are located near rock shelters occupied by LSA hunter-gatherers from ca4500 years ago to the recent past (Sadr & Plug 2001; Sadr 2002). Initial contact (ca2000 years ago) appears not to have had any significant impact on the traditional hunting and gathering way of life. For instance, artefacts recovered in levels associated with the terminal occupation of Ostrich and Radiepolong show a hunter-gatherer occupation with very little influence from neighbouring Bakwena and Bakgalagadi farmers. Radiepolong, traditional stone tools diminish in numbers as they got replaced by imported agropastoralist wares during the transition from Early to Late Contact period (Sadr 2002). Faunal evidence also shows that the transition from Early to Late contact period was characterised by increase in numbers of domestic animals acquired from neighbouring Bakgalagadi farmers, while wild species decreased (Sadr & Plug 2001).

About 4km away from Radiepolong, on Thamaga Hill, are three rock shelters; Thamaga 1, Damp and Rocky. All were occupied by hunter-gatherers. On top of the hill, is a Middle Iron Age settlement and a Late Iron Age Moloko settlement (<1000years ago). The abundance of Moloko and other ceramics in the LSA rock shelters, as well a few iron implements and livestock bones, point to a hunter-gatherer community that had become largely dependent on neighbouring farming communities (Sadr 2002).

Elsewhere, the arrival of Europeans had different effects on the hunting and gathering way of life (Hitchcock 1999; Smith *et al.* 2000; Mitchell 2002, 2009). In the Ghanzi veld (central Kalahari), political and economic relations between the San, Bantu farmers and Europeans evolved with time. Initially, Bushmen were politically and economically autonomous but by the mid twentieth century, smallpox reduced them in numbers and in power (Kent 2002; Guenther 2002). Subsequently, neighbouring farmers forced them into servitude and slavery. Hunting continued for the most part of the nineteenth century, but by that time it was to pay tribute to Bantu masters rather than

subsistence (Guenther 2002). The Bantu speakers, were, in turn paying tribute and buying guns from Europeans.

Farther afield, evidence from several Iron Age settlements and LSA sites in the Caledon Valley, Lesotho, strongly suggest inter-dependence between the groups (Mitchell 2002; Mitchell *et al.* 1994). Several millennia into the second half of the Holocene, the valley had little or no hunter-gatherer occupation. It was not until the arrival of Iron Age farmers around 1100BP that hunter-gatherers showed up in the area, most probably attracted by trade and exchange with farmers. Evidently, the LSA hunter-gatherers were attracted to certain parts of the Caledon Valley because of the socio-economic advantages brought by the arrival of EIA farmers (Mitchell *et al.* 1994). Evidence from some parts of the Maloti – Drakensberg mountain ranges, indicates that many hunter-gatherers remained politically autonomous well into the 1800s, despite contact with farming communities (Mitchell 2009).

TOUTSWE SETTLEMENTS

CLIMATIC AND ENVIRONMENTAL CONDITIONS

The Toutswe sites are just east of the border between the sandveld and the hardveld (Denbow 1979). Archaeoan rocks in the hardveld are dominated by quartz-feldspar gneisses and granites. The east central part of the country is dominated by granites. Within the east central is a belt of Proterozoic rocks which covers the area between Serowe, Palapye and Tswapong (Thomas & Shaw 1991; Wilmsen *et al.* 2009). The Proterozoic rocks include among others, siltstones and shale (Thomas & Shaw 1991).

A web of outcropping rocks and active erosion and deposition processes created varied relief in the eastern hardveld. The resulting terrain units have matching soil and vegetation units. Erosion landforms have been subdivided into 14 units and depositional features are subdivided into 11 units (Cooke 1982; Thomas & Shaw 1991; Mookodi 2001). Soils around the study area are generally of ferruginous tropical type and are divided into those derived from igneous, metamorphic and sedimentary rocks. Igneous and metamorphic soils are the most dominant (Cooke 1982; Mookodi 2001). Pockets of soils suitable for agricultural production are found near many of the

sites. Using soil maps and records from the Botswana National Museum, Mookodi (2001) located and mapped both Toutswe and pre-Toutswe sites in these landscapes. For instance, at Taukome the south and western sides of the hill are covered by black cotton soils for at least 10km from the base of the hill. Black cotton soils offer good opportunities for crop production especially during dry years (Denbow 1983a).

Drainage in the Toutswe and surrounding areas is towards the Limpopo River in the east. Reconstructions of prehistoric climatic conditions of southern Africa indicate that the region was generally wet with short periods once in a while (Tyson & Lindesay 1992; Lee-Thorp & Talma 2000; Lee-Thorp *et al.* 2001; Tyson *et al.* 2002; Huffman 1996, 2008). Though these studies were not directly centred on the Toutswe area, they all tend to suggest that the rainfall and temperature patterns of the EIA are similar to those experienced at present. Figure 2.1 shows that the current rainfall patterns place the Toutswe sites in areas receiving annual rainfall of between 400 and 500mm. This annual rainfall is suitable for crop production.

Table 2.1 shows the annual precipitation and temperature for the east central part of Botswana from 1998 to 2008. Precipitation was recorded at four stations in Serowe-Palapye area. Unfortunately, records for Paje and Mmashoro Primary Schools, the two stations nearest to Bosutswe, are incomplete. Temperature was recorded at the Mahalapye meteorology station. All records were obtained from the Head Office, Department of Meteorological Services, in Gaborone. The mean annual precipitation for Palapye Police Station ranged between 177.6mm and 789.9mm for the year 1998 to 2007. Palapye Police Station is within a 20km radius of the Toutswemogala site. Mmashoro and Paje are both less than 30km from Bosutswe. At Mmashoro the lowest recorded annual rainfall is 295.9mm and the highest record is of 805.9mm. The range of annual rainfall for Paje is between 153.7mm and 1012.6mm. At Serowe, where the sites Serowe, Swaneng and Thataganyane Hills are located, the recorded annual rainfall for the years 1997 to 2007 range from 177.6mm to 789.9mm.

The rainy season starts from October to April (Cooke 1982) with high peaks usually in December-January. As seen in Table 2.1 annual rainfall at all four weather stations varies significantly from one year to the other. For example, the floods of 1999 were followed by drought in 2000. Yearly

mean minimum temperature for the region (Mahalapye Weather Station) ranged between 13.2 and 15.0°C between 1997 and 2008. The annual maximum temperature for the same period fell between 27.1 and 29.6°C. The warm season coincides with the rainy season and again extremely high temperatures (as high as 38°C) or hot fronts often occur in December-January.

SETTLEMENT PATTERNS

Radiocarbon dates from Taukome, Thatswane, Maiphetwane and Toutswemogala indicate that these sedentary Iron Age settlements were well established by the eighth century AD. The earliest dates of the Toutswe settlements come from the lowest deposits at Taukome, Bosutswe and Mmadipudi. A rapid increase in number of settlements occurred between the tenth and the fourteenth centuries AD. This increase could have been a result of natural population increase and/or the arrival of migrants from the north east (Denbow 1982, 1983a, 1984a; Denbow & Wilmsen 1983).

Table 2.1: Mean annual temperature and rainfall for Serowe-Palapye

	Mean Temperature (°C) (Mahalapye station)		Mean Annual Rainfall (mm)			
Year	**Min**	**Max**	**Palapye**	**Serowe**	**Mmashoro**	**Paje**
1998	14.4	29.2	177.6	329.5		465.7
1999	14.7	28.8	789.9	1038.1	805.9	1012.6
2000	13.2	27.1	229.5	285.3	273.8	297.7
2001	14.0	28.2	267.5	408.7	464.8	368.1
2002	14.2	29.5	280.3	355.8		374.8
2003	14.9	29.3	435.6	458.0		153.7
2004	14.1	28.0	308.7	384.6		382.0
2005	15.0	29.6	512.5	577.0		420.0
2006	14.0	27.9	209.8	368.7	295.9	
2007	13.9	28.3	454.1	473.3	491.3	
2008	13.8	28.7				

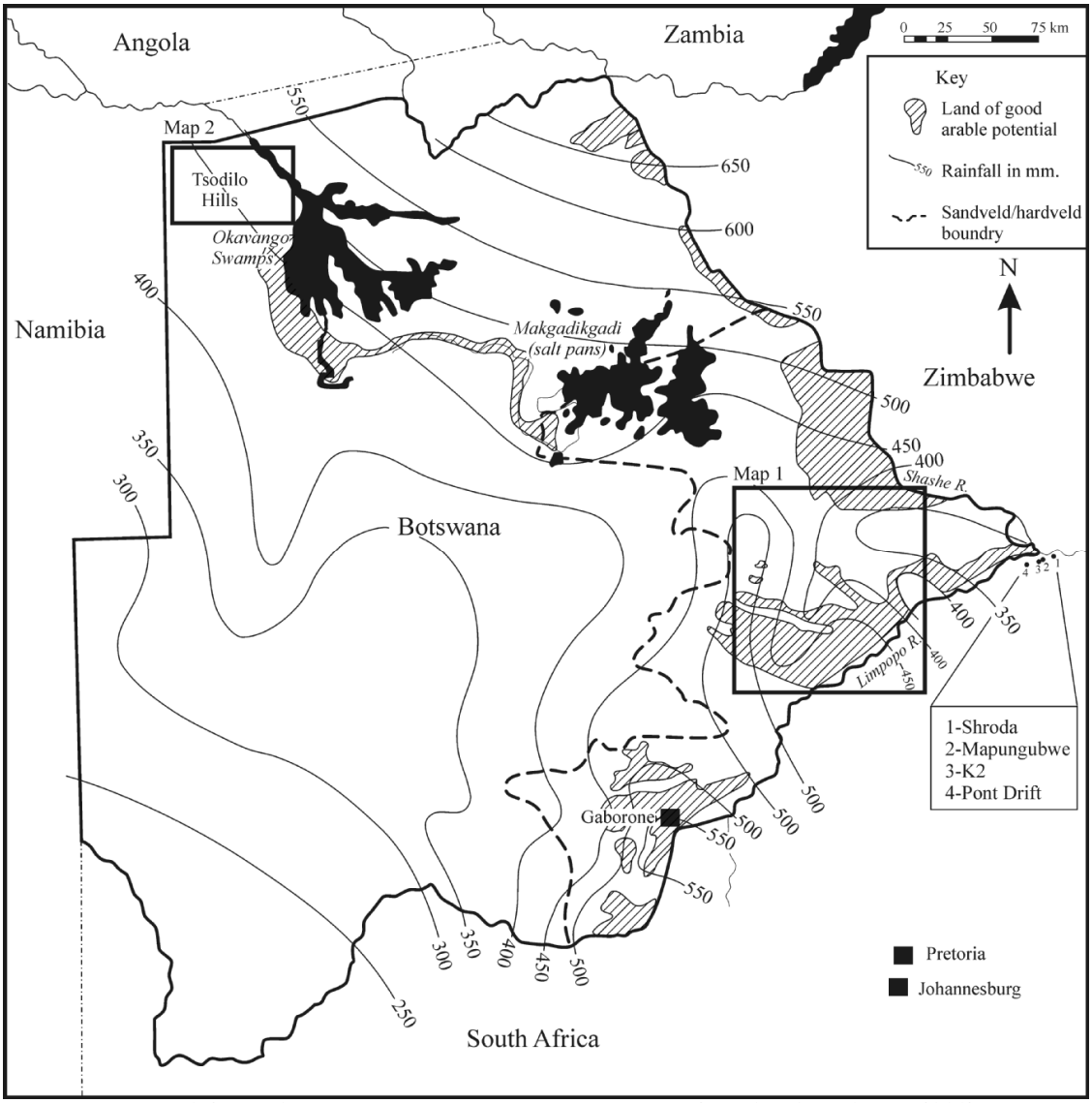


Figure 2.1: Rainfall isohyets and arable land in Botswana (Modified from Cooke 1982)

EIA occupation in the east central hardveld started with dispersed small homesteads. Growth and subsequent conglomeration of these sites led to the gradual establishment of a complex EIA polity (Denbow 1982, 1983a). Between AD1000 and 1300 Toutswe settlements were organised in what is now recognised as a three-tiered settlement hierarchy. In this hierarchy, settlements are grouped based on characteristics such as size, length of occupation, and location of the site (Denbow 1979, 1982, 1983a, 1984b, 1986a). Recent works by Reid and Segobye (2000) have demonstrated the

possible existence of more than three tiers in the Toutswe hierarchy. Results of the current study will not be affected by whether Toutswe sites were arranged in a three or four tier hierarchy. Therefore, the original three-tier hierarchy model proposed by Denbow (1982) is adopted.

CLASS 1 SITES

At the base of the hierarchy are the smallest sites with central middens covering areas of only 1000 to 5000m^2. Dung deposits in middens are about 20 to 30m in diameter and up to 1m deep. Remains of daga houses and grain bins surround central kraals. The sites show relatively short periods of occupations of between 50 and 100 years (Denbow 1982, 1986a). Class 1 sites included in the research are Kgaswe B55, Bonwapitse, Thataganyane, Swaneng Hill and Serowe Hill. These sites were selected because they have human graves associated with the Toutswe ceramic culture.

These sites are believed to have been cattle posts used for keeping livestock owned by occupants of the larger settlements. The animals were most probably tended by poor farmers and hunter-gatherers who in return were paid with food and other necessities (Denbow 1982, 1984a, 1984b; Wilmsen 1989).

Kgaswe B55 was discovered during an archaeological impact assessment of an area that was to be developed into a coal mine between Palapye and Serowe (Denbow 1983b). The central cattle kraal, which also served as a burial ground for males, was surrounded by round houses. Females and young children had been buried in and around the houses. Twenty-seven graves were exhumed but most were partially destroyed at the time of discovery (Denbow 1986ba). Three radiocarbon-dated samples from Kgaswe B55 place it to between AD900 and 1100 (Denbow 1986a).

Thataganyane, Serowe and Swaneng Hills are all located within a few kilometres of each other at Serowe village (Figure 2.2). At Thataganyane, pottery associated with phase 1 and 2 of the Toutswe period were recovered. There was no evidence to suggest reoccupation of the site by people of a different ceramic tradition. Two sites have been found on Serowe Hill i.e. the western

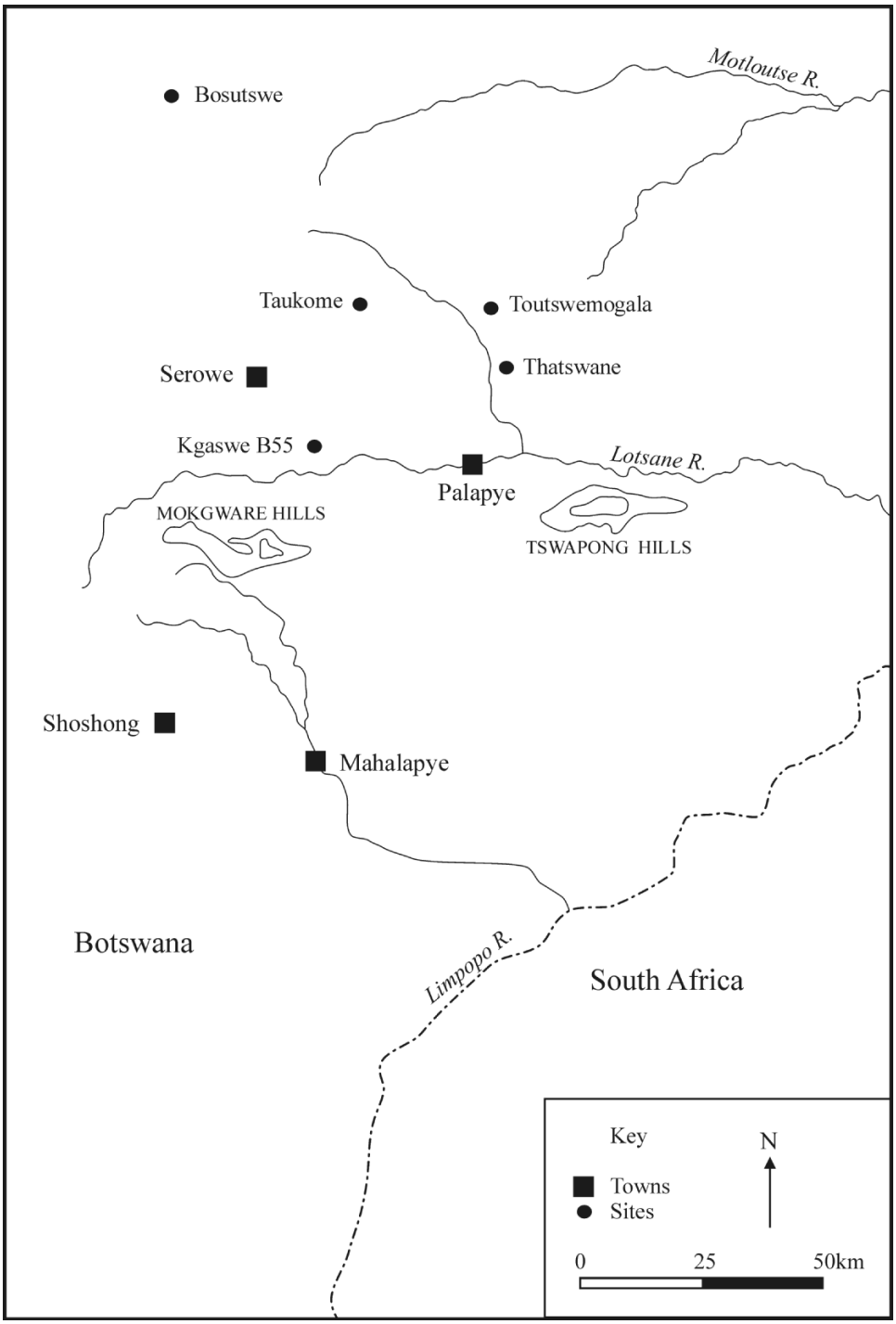


Figure 2.2: Toutswe sites in east central Botswana modified from Lane *et al.* (1998)

and eastern peaks and they both have Toutswe ceramics as well as stonewalls. The stonewalls suggests a post-Toutswe occupation of the site. In 1978, D Schemers exhumed a single grave from one of these sites. At Swaneng Hill, A. Lock conducted exhumation of one human grave in 1989. Site records of the excavation and exhumation activities at these sites are currently missing from BNM and therefore the context and burial positions of these individuals are unknown. It is possible that the grave from Serowe Hill was associated with the later re-use of the site after the Toutswe abandonment.

CLASS 2 SITES

Class 2 settlements are much larger than Class 1 settlements as shown by middens of about 10 000m^2 on average. They are located exclusively on hilltops away from arable land and water sources. At Thatswane and Taukome, dung deposits are on average 1.5m deep (Denbow 1982, 1984a, 1986a) and span a period of approximately 200 years (Denbow 1999). Taukome was selected for study because it has human remains associated with the earliest phase of the Toutswe sequence, namely the Taukome/Zhizo ceramic period. Graves from Thatswane are associated with the Toutswe period.

Taukome is located about 30km west of Toutswemogala. It is on a basalt outcrop in the hardveld, about 15km east of the Kalahari escarpment. On the western side the slope is steep and about 70m high but gently slopes for about 2.5km towards the east where it merges with the plain. The main site is on the western side at the highest point; there are four small middens on the eastern slope which are considered separate from the main site. However, these middens have materials similar to that found on the main site (Denbow 1983a).

The sequence of ceramic decoration motifs and styles throughout the stratigraphy '…illustrates a continuity through time within the Taukome assemblage' (Denbow 1983a: 141) with a temporary lapse in time between levels 3 and 4. At the base of the excavation units, (140cm) materials are dated AD710 whereas the upper levels 1-3 are generally dated around AD995. Thus, the site was almost continuously occupied for a period of about 300 years between the beginning of the eighth and the end of the tenth centuries.

About five kilometres south of Toutswemogala is a low hill site called Thatswane, a medium Class 2 dated between AD925±80 at the base of the vitrified dung deposit and AD1110±75 from grain bin (Denbow 1983a). The grain bin contained carbonised remains of sorghum and beans. Six human graves were exhumed at the site.

CLASS 3 SITES

Currently, three class 3 sites have been identified; Toutswemogala, Bosutswe and Shoshong. Of these, Shoshong remains to be excavated and interpreted as the other two have been. Class 3 sites are characterised by occupation deposits spanning several centuries. They are located exclusively on hilltops and have middens covering areas of over 100 000m^2 (Denbow 1982, 1983a, 1984a, 1986a). These large centres appear to have had political and economic powers which they used to control the flow of goods between themselves and smaller sites.

Excavation on the central midden at Bosutswe uncovered a 4m deep deposit created by continuous occupation by people of different ceramic traditions. Occupation spans a period of between AD700 and 1700. These dates make Bosutswe the longest occupied open-air site south of the Zambezi (Denbow 1999; Denbow *et al.* 2008). The earliest deposits are associated with the Taukome/Zhizo periods (AD800 – 1200) followed by the Toutswe period (AD1000-1200) and the Lose period (AD1200- 1650). Ceramic and other characteristics of these periods are detailed in Denbow *et al.* (2008). The upper half of the central deposit comprises of decomposed daga walls dated between AD1200 and 1700. The lower half is dated between AD700 and 1200 (Denbow 1999, Denbow *et al.* 2008).

SUBSISTENCE AND DIETS OF THE TOUTSWE COMMUNITIES

There is ample archaeological evidence for subsistence and diets of Toutswe communities. These communities grew domesticated cereals and reared animals. The most important crops grown were probably sorghum and millet. At sites like Kgaswe B55 and Thatswane carbonised remains of sorghum and millet have been recovered (Denbow 1983a; Kiyaga-Mulindwa 1993). Non-cereal

domesticated plants grown by the Toutswe people were legumes, cowpeas and melons. Melon seeds and beans were found at Thatswane and other sites (Denbow 1986a). Sorghum and millet have been accepted as staple crops of the Toutswe people but it is not clear how important to the diet were the non-cereal plants.

In addition to domesticated species, the Toutswe people appear to have exploited wild plants. These plants form part of the regular diet among Setswana speaking farmers in the Toutswe area at present. Wild plants consumed during the EIA at Toutswe are not fully known but it is possible that greens like *thepe* and *rothwe* were popular. It is highly likely that seasonally available wild fruits were used as snacks and fragments of *morula* kernels at Taukome attest this. Current vegetation cover at Bosutswe, Toutswemogala and Taukome includes *mophane* trees (Denbow 1983a; Denbow *et al.* 2008). *Phane* larvae on *mophane* trees provide an abundant alternative food resource. Unfortunately, *phane* does not preserve in the archaeological record and it remains difficult to tell if it was eaten by the Toutswe people.

Faunal assemblages, remains of animal kraals, and vitrified cow dung deposits on many sites attest to the importance of domestic animals. However, it seems highly likely that cattle were kept for wealth and not only for consumption (Denbow 1999). Faunal samples from sites such as Bosutswe, Toutswemogala, Taukome and Thatswane are characterised by post-breeding beasts and young calves (Welbourne 1975; Plug 1983, 1996; Denbow 1999; Atwood 2005; Denbow *et al.* 2008) thereby indicating that proliferation of cattle populations was of paramount importance. There is no basis to suggest that milk was available for the most of the year. Without good preservation techniques, milk and milk products would have been seasonal.

Hunted game appears to have provided supplementary meat. Animal species from many sites demonstrate that the Toutswe people explored all environments for wild animals. The Bosutswe settlement was probably the most naturally advantaged. This is because the site is on the border between the eastern hardveld and the Kalahari sandveld. These ecozones offered various animal species. Faunal analysis of the Bosutswe samples revealed the presence of hunted animals from the semi-arid Kalahari sands and those from the wetter hardveld. Moreover, aquatic species from places as far as the Makgadikgadi Salt Pans have been identified at Bosutswe (Plug 1996;

Denbow 1999; Atwood 2005; Denbow *et al.* 2008). The presence of aquatic fauna at Bosutswe is probably associated with the movement of pots from as away as the Tsodilo Hills –Okavango Delta area (Wilmsen *et al.* 2009)

TSODILO HILLS AND THE OKAVANGO RIVER SITES

CLIMATIC AND ENVIRONMENTAL CONDITIONS

Within the northwest region, geomorphic processes have led to the development of variations in topography and drainage and consequently development of distinct ecosystems (Cooke 1980, 1982; Hitchcock 1982; Thomas & Shaw 1991). The geomorphic features include irregular hills e.g. Tsodilo, Aha and Qwihaba Hills, the Okavango River and its associated Okavango Delta (Cooke 1980; Thomas & Shaw 1991). The Boteti River links the delta southwards to the Makgadikgadi Salt Pans (see Figure 2.1).

Reconstruction of the Holocene environmental conditions indicates that the general Okavango Panhandle area was dry during the period 7000 to 4000BP but with a wet phase around 6000BP. The period between 2300 and 1000BP was the wettest (Nash *et al.* 2006). The climatic reconstruction was made using sediments, stable carbon isotopes and palynological samples from three sites along the Okavango Panhandle (Nash *et al*. 2006). Reconstruction of the Holocene vegetation of the northwest part of Botswana has been conducted using speleothem core from Drosky's Cave (Burney *et al.* 1994). The core shows that during the period cBP10 000 and 7000 the cave was surrounded by arid grassland with dry adapted tress like acacias and commiphoras. A wet condition occurred between 7000BP and 6000BP as shown by an increase in pollen samples of combretaceae, cyperaceae and mesic savanna plants. A slightly drier period occurred between BP5000 and 4000 (Burney *et al.* 1994). It is possible that the results obtained by Nash *et al.* (2006) and Burney *et al.* (1994) of the wet and dry periods of the Holocene might correspond with each other if the dates of the samples are calibrated.

Annual precipitation in the Kalahari increases towards the east. It is only in the southwest (Namibia), that true aridity can be seen, with annual rainfall of less than 200mm. The further northern parts of the larger Kalahari, in the southern half of the Democratic Republic of Congo receive annual rainfall averaging 960mm (Cooke 1980). The Tsodilo Hills are situated between the driest southwest and wettest north and they are within 400 to 450mm annual mean rainfall isohyets as shown on Figure 2.1 (Cooke 1982; Thomas & Shaw 1991). The rainy season occurs between October and April, with slight variations of peak rainfall in December and January (Cooke 1980, 1982). The Okavango River receives mean annual rainfall of between 500 and 550mm. Besides the annual rainfall, the Okavango River transports an estimated $11x10^9m^3$ of water annually from its headstreams in the Angolan highlands (Cooke 1982). Water in the Okavango River is generally saline. Unfortunately, current rainfall and temperature records for the northwest were not available at the time of collecting data.

The metasedimentary succession of Ngamiland is divided into the Tsodilo Hills Group and the Xaudum Group. Units within this group include among others quartzite, quartz-mica schist, sand stone, iron stone and metamorphosed conglomerate (Wendorff 2005). The Tsodilo Hills Group extends 65km southwards to include areas around Shakawe (Wendorff 2005). In northwest Botswana, good arable soil is found along the immediate western part of the Okavango Delta (see Figure 2.1). Farming is possible but not very productive in the plains surrounding the Tsodilo Hills as shown in Map 2.3 (Cooke 1982; Thomas & Shaw 1991). EIA farmers appear to have taken advantage of the little pockets of land next to the Tsodilo Hills where farming is possible (see discussion of Divuyu and N!oma latter in this section). Prospects of farming are slim along the Okavango River.

EARLY IRON AGE SITES THE TSODILO HILLS AND OKAVANGO RIVER

Along side LSA sites in the northwest a wide spread presence of EIA communities has been confirmed through excavations at Tsodilo, Matlapaneng, Serondela, Qugana and other sites (Campbell 1982; Denbow 1980, 1986a, 1986b, 1999; Wilmsen & Denbow 2005). Radiocarbon dates from many of these sites are generally around the middle of the second millennium AD (Campbell 1982; Denbow 1986b; Wilmsen & Denbow 2005). The EIA settlements found in this area do not conform to any particular settlement hierarchy as is the case with Toutswe sites. In

addition, they do not have the central cattle pattern layout which characterises many Iron Age settlements in southern Africa (Huffman 1986, 1989; Denbow 1982, 1999).

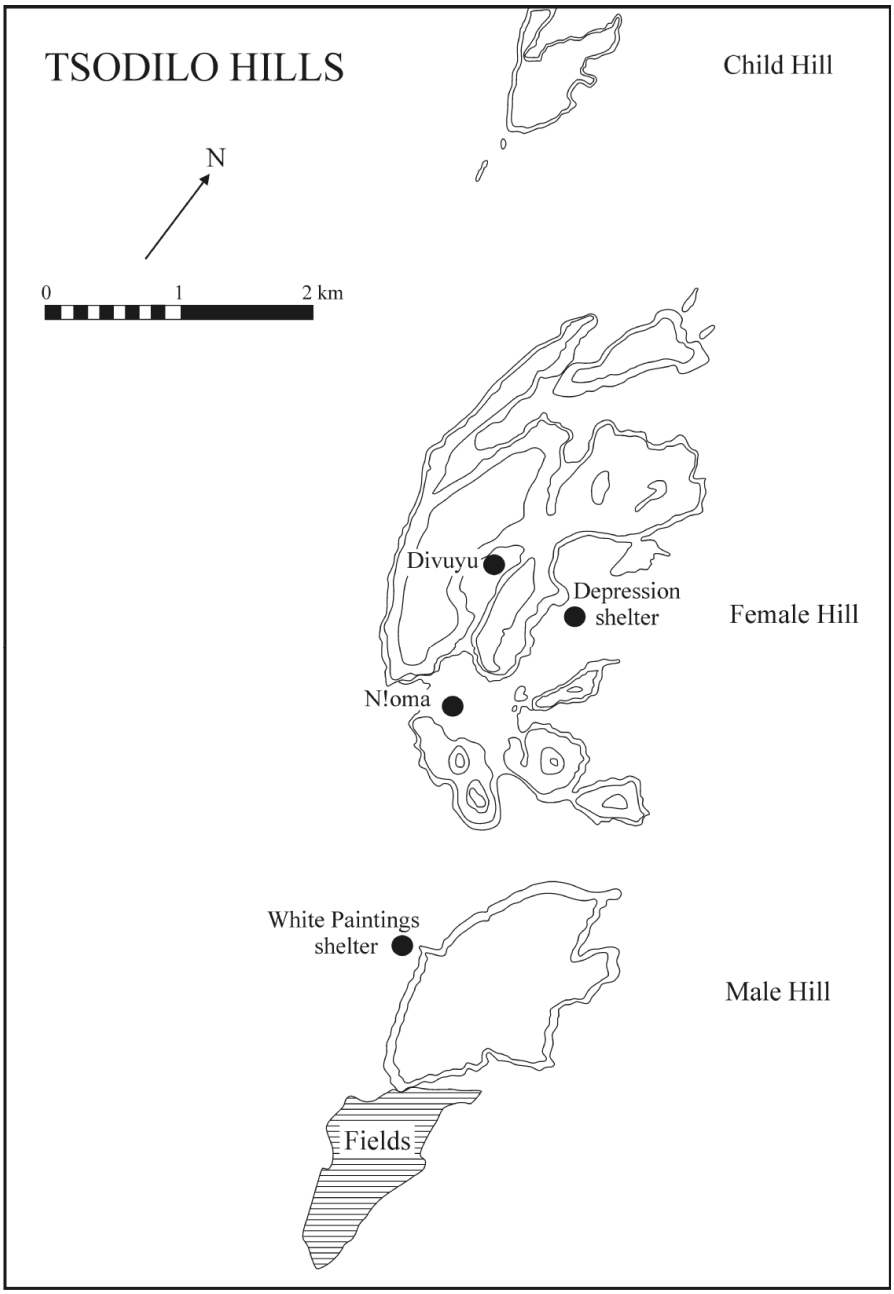


Figure 2.3: Layout of the Tsodilo Hills with sites mentioned in the text

Two EIA sites, Divuyu and N!oma (formerly known as Society) on the 'female' plateau of the Tsodilo Hills are within 2km of each other (Figure 2.3) and are both attributed to the western stream of EIA farmers in the area (Rudner 1965; Denbow 1980, 1986b; Denbow & Campbell 1980; Wilmsen & Denbow 2005). The ceramic decoration motifs were described by Junod (1963) and Denbow (1986b). Similar pottery has been found at Kapako in northern Namibia, Sioma Mission in Zambia and other sites in Democratic Republic of Congo (formerly Zaire) and Angola (Campbell 1982; Denbow & Campbell 1980; Denbow & Wilmsen 1986; Wilmsen & Denbow 1990; Denbow 1986a, 1986b, 1990; Wilmsen & Denbow 2005).

The sequences of both LSA and EIA settlements at the Tsodilo Hills show that the area was most probably occupied continuously for several centuries. As early as the sixth century AD LSA hunter-gatherers and EIA farmers of the Tsodilo Hills co-existed within a few kilometres of each other (Campbell & Coulson 1988; Denbow 1986a, 1986b; Denbow & Wilmsen 1986; Wilmsen & Denbow 2005; Robbins 1990). For example, a fair number of incised and comb-stamped potsherds and iron artefacts found at Depression Shelter are similar to those at Early Iron Age sites of Divuyu and N!oma (Robbins 1990). Rock paintings associated with the LSA peoples in the Tsodilo Hills depict cattle and it is assumed that the figures demonstrate the importance of cattle brought in by EIA farmers to the LSA San (Campbell & Coulson 1988).

DIVUYU

Divuyu currently represents the earliest arrival of a fully formed Iron Age community in Ngamiland (Denbow 1986a, 1990, 1999, Wilmsen & Denbow 2005). It is located about 200m above the surrounding plain (Denbow 1986b; 1999) and this makes it unsuitable for both crop production and animal rearing. Dates from Divuyu range between AD500 and 700 (Denbow 1986b; Wilmsen & Denbow 2005).

The faunal assemblage of Divuyu consists of ovicaprids, cattle, fish, river mollusc shells, and wild fauna. Sheep and goats contributed about 60% of the animal protein. Some wild fauna such as hippo, waterbuck, lechwe and reedbuck, as well as fish, are naturally restricted to regular water sources and their presence at Divuyu can only be explained through exchange with people of the Okavango Delta (Turner 1987b; Denbow 1986b, 1990, 1999; Wilmsen & Denbow 1990, 2005).

Large quantities of mongongo nuts (*Ricinodendron rautenennii*) indicate that foraging was an important component of subsistence. Domesticated sorghum and millet attest to the exploitation of agriculture (Robbins & Campbell 1990; Wilmsen & Denbow 1990, 2005; Denbow 1999). While mongongo nuts and wild animals confirm the importance of foraging at Divuyu, only one stone tool and large quantities of metal tools have recovered at the site (Denbow 1986b; Wilmsen & Denbow 2005). It is possible that interaction between farmers and foragers at Divuyu was relatively little (Denbow 1999). One grave of a juvenile was excavated at Divuyu. The grave was excavated by Denbow and Wilmsen (Morris 1996).

N!OMA

N!oma is on the lower plateau of the "female" hill and is dated AD850 -1090. Pottery similar to that found at Divuyu occurred on the lowest levels of N!oma. Unlike Divuyu, increase in hunted animals at N!oma parallels increase in LSA tools; backed segments (n=84), scrapers (n=31), cores (n=53) and utilised flakes (n=66). These lithics clearly indicate a significant change in relations between hunter-gatherers and farmers during the occupation of Divuyu and the later occupation of N!oma (Denbow 1999; Wilmsen & Denbow 2005). Chert flakes (n=7500) and other tool-making debris suggest that hunter-gatherers were living at N!oma, not just trading.

Contrary to Divuyu, cattle make up almost a third of the faunal assemblage at N!oma (Denbow 1986a, 1986b, 1999; Turner 1987b). Sheep and goats are less represented and there is an increase in wild fauna compared to Divuyu (Turner 1987b; Denbow & Wilmsen 1983; Wilmsen & Denbow 1986b, 1990; Denbow 1983a, 1986b, 1990, 1999). However, the increase in domestic animals overrules the possibility of hunting as being more important than herding. Again, fish bones and river molluscs shells recovered at this site indicate exchange with the people along the rivers. Petrographic analysis of pottery from sites in the Ngamiland region indicates movement of pots in the Tsodilo-Delta-Chobe region as early as AD900 (Wilmsen *et al.* 2009). This movement of pots could have been coupled with movement of foods. Carbonised sorghum (*sorghum bicolor caffir*), pearl millet (*Pennisetum americunum thyphoide*) and melon seeds (*cucurbita*) recovered at

N!oma are indicative of a farming community (Denbow 1986a, 1990). Mongongo nuts and wild berries (*Grewia)* seeds show that foraging supplemented farming (Robins & Campbell 1990).

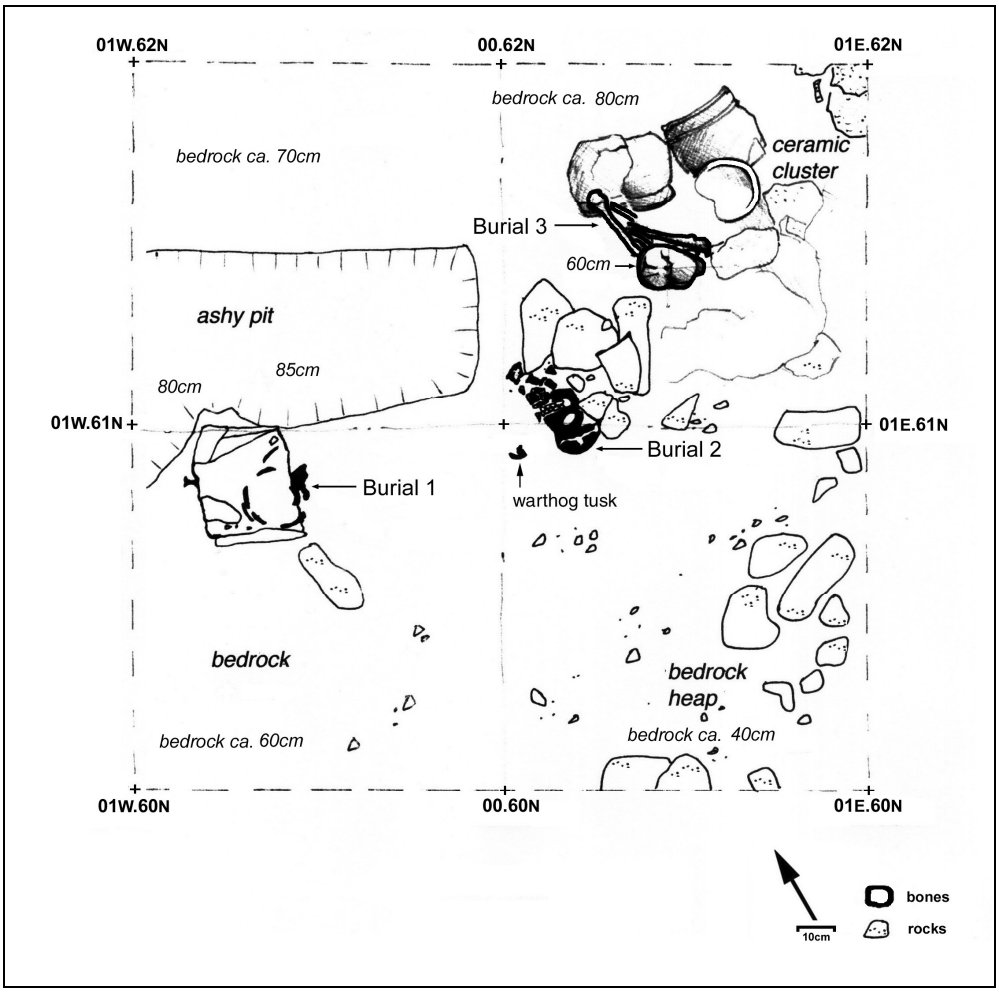


Figure 2.4: Plan of excavated unit at N!oma (Denbow & Wilmsen)

In the 1980s four graves from N!oma were exhumed by Wilmsen and Denbow. The individuals were in horizontally flexed or seated positions and stones had been placed next to the remains (Figure 2.4). The individuals showed no signs of severe pathology. Morris (1996) analysed the

racial affinities of the skeletons from N!oma and concluded that N!oma/Society, N!oma 1 and N!oma 3 were more closely related to the Negroid group than to the Khoisan group. N!oma 2 (14-15years, female) had morphological characteristics linking her to the Khoisan group. In this study N!oma graves 1, 2 and 3 , were available for isotope analysis.

XARO

The site and a human grave was uncovered and partially destroyed by workers while constructing a drainage trench for the nearby safari camp. Remains of a prehistoric settlement with pottery similar to that found on the grave were identified about 200m from the grave. There are no lithics or other finds to suggest that hunter-gatherers occupied the site (Denbow & Wilmsen, personal communication 2005).

In 1986 a single skeleton (Xaro 1) was recovered at Xaro. Its cranial vault is similar to both Khoisan and Negro groups (Morris 1996). The skull of the second individual (Xaro 2) was found few years later. Wilmsen and Thebe only found the post cranial skeleton of Xaro 2 in August 2006. The impression left by the head, which had been rescued a few months before, was still visible next to the cervical vertebrae (Wilmsen & Thebe: personal communication 2006). Thus, the cranial and post cranial parts of this individual's skeleton were exhumed at different times. Figure 2.5 shows the post cranial skeleton which was exhumed in the second field season of Wilmsen and Thebe. Both individuals from Xaro have exceptionally high levels of dental caries.

SUBSISTENCE AND DIET DURING THE EARLY IRON AGE

It appears that mongongo nuts were one of the very important wild plant products eaten by the EIA and LSA communities at the Tsodilo Hills. Nut fragments from Depression site in the Tsodilo Hills provide evidence that consumption of mongongo nuts dates as far back as the Early Holocene (Robbins 1990; Robbins & Campbell 1990). Even at present, mongongo nuts are one of the mainstays of the !Kung San in the Kalahari (Lee 1979; Marshall 1979; Robbins & Campbell 1990). Mongongo nuts were also consumed by EIA farmers at Divuyu and N!oma (Denbow & Wilmsen

1986). It is unclear whether the EIA farmers collected mongongo nuts themselves or whether they obtained them from their neighbouring LSA hunter-gatherers.

Hunted animals from the sites on Tsodilo Hills may have come from two or three habitats. The lightly wooded acacia savannah plains were home to zebra, wildebeest, giraffe and eland. Waterbuck, buffalo and freshwater fish would have come from the marsh environment and/or the flood plains (Turner 1987a). Faunal assemblages show that large game was important in the diet and that small animals were used as supplement to large animals (Turner 1987a, 1987b; Wilmsen & Denbow 2005). Cattle and small stock remained the most dominant meat sources for the EIA farmers.



Figure 2.5: The post-cranial skeleton of Xaro 2 *in situ* (photo courtesy of E. Wilmsen)

PRINCIPLES OF STABLE LIGHT ISOTOPES

This section focuses on the description and explanation of stable isotope techniques as tools for dietary reconstruction. It starts by explaining the basic principles of the carbon and nitrogen cycles, outlining how these elements circulate between the atmosphere and biosphere. It continues by giving details of mechanisms involved in the transfer and fractionation of both carbon and nitrogen isotopes within the body of the consumer.

An isotope is one of two or more atoms with the same atomic number but different numbers of neutrons. Isotopes of the same atom can be radioactive, e.g. ^{14}C or stable e.g. ^{13}C and ^{12}C (van der Merwe 1982). Chemical properties of isotopes of the same atom are the same, but they differ in the rates at which they react. Atomic weight, which depends on the number of neutrons, influences the rate of reaction.

The ratio of isotopes are referred to as 'isotope values' and are designated the δ sign. The ratio is measured in parts per mil or parts per thousand (‰) using the δ sign (van der Merwe 1982, Klepinger & Mintel 1986). Isotope ratios of samples are expressed relative to internationally agreed standards. Carbon isotope values are relative to a marine carbonate fossil from the Pee Dee Belemnite (PDB) in South Carolina, nitrogen isotope ratios are measured relative to pure atmospheric air (AIR). For example, carbon isotope ratios are expressed as follows:

$$\delta^{13}C‰ = [(R_{sample}/R_{standard})-1] \times 1000$$

where R is the ratio $^{13}C/^{12}C$

Isotopic fractionation refers to the process through which isotope ratios change through materials (van der Merwe 1982). When discrimination is against the heavy isotope, the δ value is decreased or becomes more negative. Discrimination against the lighter isotope results in increased or more positive δ value. The process of change in isotope ratios during reaction is 'fractionation' and factors responsible for fractionation are 'fractionation factors'. The process of selective and progressive removal of lighter isotopes is termed 'Raleigh fractionation'.

The atmosphere is the largest supplier of carbon, nitrogen and oxygen (van der Merwe 1982; Ehleringer *et al.* 1997; Sponheimer & Lee-Thorp 2001). In terrestrial systems, plants form the largest entry point for carbon and nitrogen to organisms. Photosynthesis is the process through which plants acquire carbon from the atmosphere. Three main types of photosynthesis have been identified and they are C_3, C_4 and CAM photosynthetic pathways (van der Merwe 1982). With regard to nitrogen, assimilation depends on whether a plant can fix it directly from the atmosphere or whether it is a non-fixer.

CARBON ISOTOPES

CARBON IN TERRESTRIAL PLANTS

The atmospheric air around the globe has different $\delta^{13}C$ values depending on contamination due to burning of fossil fuels (e.g. in industrial cities), detonating of nuclear weapons (e.g. during the Second World War), rotting leaf litter in equatorial rain forests, and others (van der Merwe 1982). Normal atmospheric air has a $\delta^{13}C$ value of -7‰ relative to PDB. During photosynthesis, plants metabolise CO_2 and this leads to fractionation of carbon. Photosynthesis can occur through the C_3, C_4 and CAM pathways (van der Merwe 1982; Berry 1988; Faquhar *et al.* 1989; Ehleringer *et al.* 1991; O'Leary 1993) depending on leaf anatomy and enzymes involved in CO_2 absorption. Fractionation via C_3 photosynthesis depletes $\delta^{13}C$ values by at least 19‰ and C_4 photosynthesis by 5.5‰. CAM plants shift between C_3 and C_4 modes and their depletion factors are between 19 and 5.5‰ (van der Merwe 1982; Berry 1988; Faquhar *et al.* 1989; O'Leary 1993).

THE C_3 OR CALVIN-BENSON PHOTOSYNTHESIS

The C_3 or Calvin-Benson photosynthetic cycle uses ATP (adenosine triphosphate) and reduced NADPH (nicotinamide adenosine dinucleotide phosphate) to produce sugar from CO_2. Carbon dioxide entering mesophyll cells is combined with ribulose bisphosphate (RuBP, a 5-carbon molecule), and the reaction is catalysed by the ribulose bisphosphate carboxylase/oxylase (Rubisco) enzyme (van der Merwe 1982; Keegan 1989; O'Leary 1993; Hibberd & Quick 2002). The end product is a 6-carbon molecule which then splits into two phosphoglycerate (PGA) molecules

with 3 carbon atoms each, hence the term C_3 (van der Merwe 1982; Berry 1988; O'Leary 1993; Hibberd & Quick 2002; Kohn & Cerling 2002). Most PGA goes into the production of carbohydrates, or is recycled into RuBP. The processes of absorption and fixation of carbon in C_3 photosynthesis occurs in a single cell (Figure 2.5). Chemical reactions in C_3 photosynthesis result in plant $^{13}C/^{12}C$ ratios being about ~19‰ more negative than atmospheric $^{13}C/^{12}C$ ratios. Their average $\delta^{13}C$ values are about -26‰ (van der Merwe 1982). In C_3 plants, cells involved in carbon absorption are not in contact with each other. The chemical reactions in this photosynthetic pathway are as follows:

$$CO_2 \leftrightarrow (\text{Rubisco}) \leftrightarrow RuBP \rightarrow 2\ (PGA)\ (\text{O'Leary 1993})$$

C_3 plants function optimally at 15 to 35°C with 10 to 25% full sunlight, thus, places with low solar radiation during the growing season. All trees, most shrubs, bushes in all environments, grasses in temperate and Mediterranean areas and legumes are C_3 based (van der Merwe 1982; Faquhar *et al.* 1989; Ehleringer *et al.* 1997). Thus, in temperate and Mediterranean regions, grasses and trees both follow the C_3 path making it extremely difficult to separate grazers, browsers and mixed feeders from each other through carbon isotope values (Vogel 1978; Kohn & Cerling 2002).

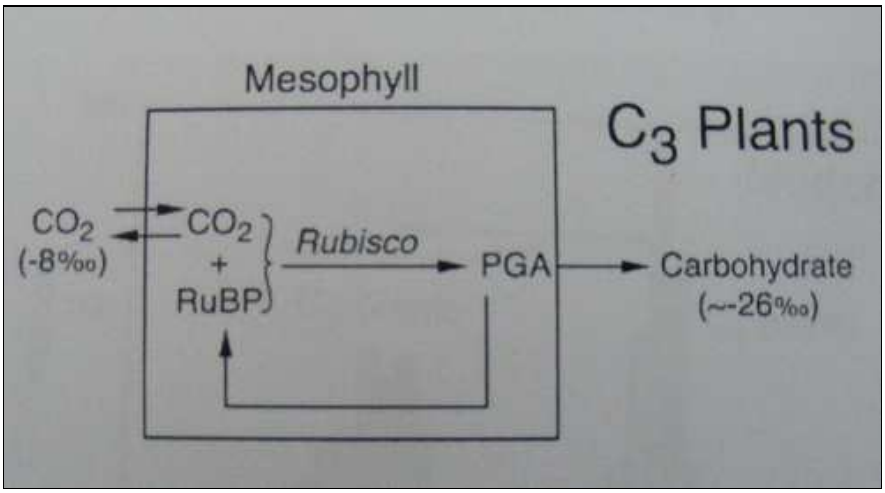


Figure 2.6: Schematic representation of the C_3 photosynthetic pathway as depicted by Kohn & Cerling (2002)

In the study area, C_3 photosynthetic plants consumed by humans include among others: fruits, nuts, vegetables, legumes and peas. There is no evidence to suggest that farmers grew domestic fruits or nuts and as such, they would have been obtained from the wild. *Morula* fruits plus kernels, mongongo nuts, *morama* and wild berries are some of the wild resources known to have been exploited by both farmers (Denbow 1983a) and hunter-gatherers (Robbins & Campbell 1990). Farmers probably used wild greens such as *thepe* and *rothwe* as *seshabo.* Beans, peas and melons are some of the known domestic C_3 photosynthetic plants that were grown by EIA farmers (Denbow 1983a).

THE C_4 OR HATCH-SLACK PHOTOSYNTHESIS

Plants with Kranz leaf anatomy have cells arranged in a wreath-like structure. They use the C_4 (also known as the Hatch-Slack) photosynthetic pathway. Cells involved in carbon absorption are layered directly on top of each other. The CO_2 in their mesophyll cells combines with phosphoenolpyruvate (PEP) using the phosphoenolpyruvate carboxylase (PEPc) enzyme. The reaction produces oxaloacetate (OAA), in the form of dicarboxylic acid, a molecule with four carbon atoms, hence the term C_4 (van der Mewre 1982; Faquhar *et al.* 1989; Ehleringer *et al*. 1997; Kohn & Cerling 2002). The OAA can transform into malate and is transported into bundle sheath cells where it splits into pyruvate and CO_2. Pyruvate is recycled into mesophyll cells and makes PEP whereas CO_2 combines with RuBP and uses Rubisco to form PGA and carbohydrate. Figure 2.6 is a diagrammatic representation of the C_4 photosynthetic pathway as demonstrated by Kohn & Cerling (2002). The C_4 photosynthetic pathway depletes atmospheric $^{13}C/^{12}C$ ratios by a factor of -5.5‰ so that plant tissues have a mean $\delta^{13}C$ value of -12.5‰. The reaction in this photosynthetic pathway is as follows:

$$CO_2 \leftrightarrow (PEPc) \leftrightarrow PEP \rightarrow OAA + P_i \text{ (O'Leary 1993)}$$

PEP carboxylase in C_4 plants has a much greater affinity to carbon than Rubisco carboxylase in C_3 plants. Furthermore, C_4 photosynthetic plants can fix CO_2 with small stomata openings and this reduces evapotranspiration. Because of these characteristics, C_4 plants tend to have increased

water use efficiency and are thus, more tolerant to drought than C_3 plants (Sullivan & Krueger 1981; Ambrose 1986; Ehleringer *et al.* 1997; O'Leary 1993). Enzymes in C_4 plants function best at 30-45°C and in full sunlight i.e. strong solar radiation during the growing season (van der Merwe 1982; Faquhar *et al.* 1989; Ehleringer *et al.* 1997).

Examples of C_4 photosynthetic plants are grasses in tropical and sub-tropical areas such as the southern African interior, salt marshes, arid environments and savannas (Vogel *et al.* 1978; van der Merwe & Tschauner 1999). Domesticated plants like maize, sugar cane, millet and sorghum are also C_4 based. Sorghum and millet were the staple foods of EIA communities (Maggs & Whitelaw 1991; Lee-Thorp *et al.* 1993). Remains of grain bins and carbonised sorghum and millet at several sites in the Toutswe area (Denbow 1983a) and in the Tsodilo Hills strongly suggest that these cereals were produced to be consumed through out the year. Cattle provided a substantial amount of meat and milk protein to EIA farmers. Cattle feed on grasses and crop stubble, which in Botswana are C_4 photosynthetic. In brief, it can be said that C_4 plants offered a crucial dietary linchpin to EIA farmers through both plant carbohydrate and animal protein. Sorghum and millet were the most common staple food of historic early Bantu speaking communities throughout southern Africa (Mönnig 1967; Maggs & Whitelaw 1991). The Portuguese introduced maize (also a C_4 crop) only in the sixteenth century and therefore maize does not expected contribute to the ^{13}C values of earlier Iron Age agro-pastoralist communities in southern Africa.

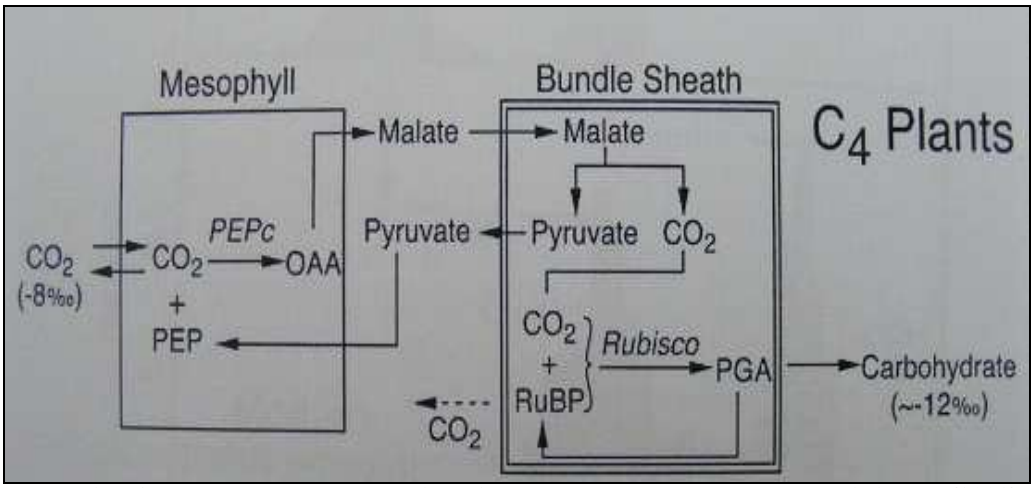


Figure 2.7: Schematic representation of the C_4 photosynthetic pathway by Kohn & Cerling (2002)

CRASSULACEAN ACID METABOLISM PHOTOSYNTHESIS

With crassulacean acid metabolism (CAM) photosynthesis, plants shift between the C_3 and C_4 modes depending on light and water conditions. Their resulting $\delta^{13}C$ values range between the values for C_3 and C_4 plants (van der Merwe 1982; Berry 1988; Faquhar *et al.* 1989; Kohn & Cerling 2002). CAM plants are uncommon and they make a relatively insignificant contribution to human diet in southern Africa. Detailed discussion of these plants was thus deemed unnecessary in this study. Examples of edible CAM plants include cactuses like pineapples.

CARBON ISOTOPES IN AQUATIC SYSTEMS

In the sea, $^{13}C/^{12}C$ ratios are enriched in ^{13}C compared to terrestrial C_3 plants. Marine plants have $\delta^{13}C$ values similar to terrestrial C_4 plants. Therefore, carbon isotope ratios can show proportions of marine versus terrestrial foods provided the terrestrial resources are C_3 based such as the southwestern Cape, South Africa (Sealy & van der Merwe 1985, 1986, 1987) and along the southern coast of Africa (Sealy 2006). If terrestrial vegetation along the coast is C_4 based then it is difficult to use carbon isotope values to differentiate marine and terrestrial resources in human diets (Sealy *et al.* 1992, 1993, 1995). For example, the carbon isotope values of 30 skeletons of LSA hunter-gatherers at Oakhurst, south west Cape, range between -16.0‰ and -10.4‰. The archaeological record and geographic location of this site demonstrates that its occupants might have exploited both marine and terrestrial C_4 food sources. The result of the carbon isotope analysis makes it difficult to interpret the dietary characteristics of the individuals (Sealy *et al.* 1992). Similarly, Ambrose (1986) found that the Holocene hunter-gatherers of the south Western Cape had $\delta^{13}C$ values ranging between -15 and -11‰. The archaeological record at sites where the skeletons came from strongly suggests reliance on marine and terrestrial animals as well as terrestrial C_4 plants.

Isotopic fractionation of freshwater aquatic food webs has not been studied as much as marine or terrestrial food webs (Ambrose 1993). A case of isotopic analysis of faunal remains from a freshwater ecosystem in southern Ontario (Katzenberg 1989) and other studies show that the $\delta^{13}C$ values these ecosystems are similar to those of terrestrial C_3 plant values. This limits the use of

carbon isotopes as dietary indicators in populations depending on freshwater ecosystems coupled with C_3 vegetations (Ambrose 1993). Freshwater ecosystems are rare in the study area. It is only at the site of Xaro along the Okavango River that freshwater resources are likely to have been exploited (Denbow 1984b, 1986; Wilmsen & Denbow 2005).

CARBON ISOTOPES IN THE MAMMALIAN BODY

CARBON ISOTOPES IN BONE COLLAGEN

Vegetation in the study areas have both C_3 (-26‰) and C_4 (-12.5‰) plants. Grazers (e.g. cattle and zebra) are expected to consume exclusively C_4 grasses while browsers (e.g. tortoise, kudu and steenbok) consume C_3 vegetation. Mixed feeders consume both C_3 and C_4 vegetation. Carbon isotopes are fractionated during collagen formation, and resulting isotope values are ~5‰ less negative than the food (Vogel 1978; Cerling & Harris 1999). Therefore, based on previous studies of dietary habits of herbivores, grazers within the study area are expected to have bone collagen $\delta^{13}C$ values of around -7.5‰ (Vogel 1978; van der Merwe 1982;). Browsers would have bone collagen $\delta^{13}C$ values of about -21‰ and mixed feeders such as sheep, goats and steenbok would have bone collagen $\delta^{13}C$ values reflecting combinations of C_3 and C_4 plants (Vogel 1978; DeNiro & Epstein 1978; van der Merwe 1982; Ambrose & DeNiro 1986a, 1986b, 1989; Ambrose 1986, 1989; Cerling & Harris 1999; Cerling *et al.* 1999; Ambrose & Krigbaum 2003; Hoppe *et al.* 2004). Because farmers rely heavily on C_4 crops, they are expected to have $\delta^{13}C$ values of -7.5‰ similar to those of grazers while foragers who feed on C_3 photosynthetic wild plants would have $\delta^{13}C$ values of -21‰.

Unfortunately, expected collagen $\delta^{13}C$ values quoted are not easily achievable in the real world. Many animals species are flexible with their diets and thus do not always stick to their expected feeding habits (Vogel 1978; Cerling *et al.* 1999), particularly during stressful periods of food shortages. Cattle, for example, prefer to graze but will browse if conditions are not favorable for grazing. During dry seasons, grazers supplement their diets with locally available vegetation, which may be of a different photosynthetic pathway. For example, Vogel (1978) observed that zebra and

hartebeest from C_4 grass zones were supplementing their diets with C_3 foliage and their collagen $\delta^{13}C$ values were more negative than expected. Complications of this nature were anticipated, particularly with recent animal samples from Bosutswe and Toutswemogala. These areas were experiencing severe and prolonged droughts accompanied by overgrazing in 2000 – 2003 (see Table 2.1), thereby forcing cattle and other grassers to feed on *mophane* leaves and other C_3 plants. At the Tsodilo Hills in the Kalahari, grasses are very sparse and both grazers and mixed feeders are compelled to rely substantially on C_3 vegetation.

Since herbivores have known dietary preferences in any environment, 'failure' to adhere to those diets can be explained through environmental constraints (Vogel 1978; DeNiro & Epstein 1978; van der Merwe 1982; Ambrose & DeNiro 1986a, 1986b, 1989; Ambrose 1986, 1989; Cerling & Harris 1999; Cerling *et al.* 1999; Hoppe *et al.* 2004). As mentioned, during periods of drought, or following severe soil erosion, C_4 grazers browse substantially on C_3 plants and this imprints on their collagen $^{13}C/^{12}C$ ratios. Comparing $\delta^{13}C$ values of the same grazing species raised under favorable climates to those raised under strenuous conditions, helps understand past climates and consequently vegetation patterns. Likewise, mixed feeders in an environment with equal access to edible C_3 and C_4 vegetation will have collagen $\delta^{13}C$ values reflecting equal contributions of both types to diet. However, if C_4 vegetation is scarce their collagen will reflect a C_3 dominant diet or vice versa. For example, in this study, a data bank was created for collagen $\delta^{13}C$ values of modern animals from Bosutswe and Toutswemogala where drought limits the growth C_4 grasses. It is therefore, possible to match $\delta^{13}C$ values of particular species to available vegetation. These values will serve as reference for interpreting environmental conditions of the EIA.

METABOLISM AND SYNTHSIS OF BONE COLLAGEN

The organic component of bone is 90% protein collagen and the remaining 10% is non-collagenous protein, lipids, carbohydrates, enzymes and hormones (Pate 1998). Within the protein collagen component, there are at least 80% nonessential amino acids and 12% essential amino acids. Nonessential amino acids contribute 70% of the total carbon in protein collagen and the remaining fraction comes from essential amino acids. Essential amino acids contribute the rest of carbon to collagen (Klepinger 1984; Ambrose & Norr 1993) and they originate from dietary protein

(Klepinger & Mintel 1986). Dietary origins of nonessential amino acids (larger contributor to collagen carbon) are complex and not fully understood (Klepinger & Mintel 1986).

Hydroxyapatite or bone apatite is an inorganic phase making up 80% weight of the entire bone but with only a small amount of carbon (Sullivan & Krueger 1981; Lee-Thorp *et al.* 1989, van Klinken 1999; Kohn & Cerling 2002). This carbon is in the form of carbonate ions in the phosphate position of the crystal structure i.e. structural carbonate as well as ions adsorbed on to hydration layers and crystal surfaces i.e. adsorbed carbonate (Ca_{10} $(PO_4)_6$ $(OH)_2$) (Klepinger 1984; Ambrose & Norr 1993; Hoppe *et al.* 2004).

Bone remodels at constant rates through new bone formation and resorption of old bone. Osteoblast cells are responsible for the constant formation of new bone matrix while osteoclast cells remove old bone (Bell *et al.* 2001; Ubelaker *et al.* 2006; Hedges *et al.* 2007). The process of bone turnover allows for the incorporation of new dietary isotope signatures throughout the individuals life. When dealing with human skeletal remains, as is the case in the current study, the issue of bone turnover is important because it means that bone collagen isotopes values measured can reflect changing dietary habits over the lifetime of an individual.

Within an individual, bone turnover is rapid in cancellous bone and slow in cortical bone. Rates of bone turnover are unknown but evidently, the processes are rapid at infancy and adolescence and slower during adulthood (Ubelaker *et al.* 2006; Hedges *et al.* 2007). In addition to age, turnover rates depend on the diet, health and nutritional status of the individual. Because of bone remodelling, carbon and nitrogen isotope ratios of collagen reflect dietary carbon accrued at different stages during the growth of the individual (Hedges *et al.* 2007).

Some researchers have investigated the effects of age on bone turnover. For instance, the femur has a turnover rate of 10–30% per year between the ages of 10 and 15 years. In females, the rate drops to 4% per year at 20 years old and to 3% per year by the age of 80. The turnover rate in males drops from 3% per year at 25 years old to 1.5% per year at 80 (Hedges *et al.* 2007). In another study, Ubelaker *et al.* (2006) calculated that there was a very small intake of ^{14}C on

individuals aged 30 years or more when compared to younger ones. Both studies clearly indicate that a substantial amount of carbon laid down during adolescence remains in collagen during early adulthood. For example, 50-year-old individuals with a 2% per year turnover rate have at least 40% carbon accrued before the age of 25 years.

Two models explaining the dietary origin of nonessential amino acid carbon in protein collagen exist. According to the 'direct routing model', both essential and nonessential amino acids used in the synthesis of collagen originate from the protein component of the diet (van der Merwe 1982; Krueger & Sullivan 1984; Klepinger & Mintel 1986; Ambrose & Norr 1993). A counter model, which van der Merwe (1982) termed the "scrambled egg model" suggests that the consumer breaks down and scrambles carbon from various nutrients and reassembles them to form nonessential amino acids in collagen and other tissues (van der Merwe 1982; Krueger & Sullivan 1984; Klepinger & Mintel 1986; Ambrose & Norr 1993).

Ambrose and Norr (1993) experimented with seven diets of varying combinations of proteins, lipids and carbohydrates to test the scrambling versus the direct routing model of carbon. The diets of the sample rats included a pure C_3 energy, with C_4 protein, a C_4 protein with C_3 energy and a C_3 protein with C_3 energy. Protein contents of the diets were low, normal, or very high. The carbon isotope values of bone collagen and bone carbonate of the rats used in the experiment were then analysed. The results showed that almost all the carbon in the bone collagen came directly from the protein component of the diet rather than deriving partly from lipids and carbohydrates. In fact, the relationship between dietary protein $\delta^{13}C$ values and collagen $\delta^{13}C$ was so strongly correlated that one could be predicted from the other. For example, diet protein $\delta^{13}C$ values can be calculated with a ±2‰ degree of accuracy from collagen $\delta^{13}C$ values using the following equation:

$$\delta^{13}C_{\text{diet protein}} = 0.94 \times \delta^{13}C_{\text{collagen}} - 6.9 \ (r^2 = 0.65) \text{ (Kellner \& Schoeninger 2007)}$$

And, the isotopic composition of scrambled diet macronutrients is calculated to within a ±4‰ margin of error as:

$$\delta^{13}C_{\text{diet}} = 0.86 \times \delta^{13}C_{\text{collagen}} - 6.0 \ (r^2 = 0.54) \text{ (Kellner \& Schoeninger 2007)}$$

Dietary protein serves a dual purpose in humans and animals: it is a reservoir for amino acids and a source of energy (Krueger & Sullivan 1984). If other sources of energy (carbohydrates and lipids) are available, then protein is concentrated towards amino acid synthesis but the role changes if there are insufficient energy sources (Howland *et al.* 2003; Kellner & Schoeninger 2007). Studies by Klepinger & Mintel (1986), Ambrose & Norr (1993) and Howland *et al.* (2003) have shown that the direct routing of dietary protein to collagen protein applies as long as the bulk of dietary protein does not have to provide energy. If dietary protein is consistently diverted towards energy production (in cases where carbohydrates and lipids are not sufficient) then carbon skeletons needed to synthesise nonessential amino acids are sourced from carbohydrates and lipids. It is only under shortage of both protein and calories that the consumer's carbon collagen may be obtained from other sources (Howland *et al.* 2003; Kellner & Schoeninger 2007).

It is difficult to demonstrate whether individuals included in this research had balanced diets that that allowed nonessential amino acids to be synthesised solely from dietary protein. At the same time, there is no evidence to suggest otherwise. The few cases of cribra orbitalia and porotic hyperostosis (Mosothwane 2004; Mosothwane & Steyn 2008) on individuals from several sites are not indicative of protein deficiency.

Recently, Kellner and Schoeninger (2007) identified digestive systems as important role players in the fractionation of dietary carbon. Some animals as well as humans have simple gastrointestinal digestive tracts and depend on endogenous enzymes to metabolise food. Ruminants like cattle require exogenous microorganisms to ferment their food during metabolism. Animals with similar systems appear to fractionate dietary carbon using similar factors, irrespective of body size.

CARBON ISOTOPES IN ENAMEL APATITE

Apatite in enamel and bone is similar in structure. In enamel it is formed by carbonated hydroxylapatite ($Ca_{4.5}$ $[(PO_4)^{2.7}$ $(HPO_4)^{0.2}$ $(CO_3)]^{0.3}$– $(OH)_{0.5}$) with less than 2% organic phase (Hoppe *et al.* 2004). Carbon in apatite is synthesised from a combination of proteins, lipids and carbohydrates from the diet (Klepinger & Mintel 1986; Lee-Thorp *et al.* 1989; Ambrose & Norr 1993; Kohn & Cerling 2002; Howland *et al.* 2003). The selection of one macronutrient over the

other in apatite production is not fully understood. It might be dependent on dietary nutritional status, in other words if lipids are abundant then they might be preferred over carbohydrates. For example, carnivores are bound to have more lipid than carbohydrate input in their diet and, hence, they use lipids for energy and synthesis of apatite (Klepinger & Mintel 1986).

Unlike bone, enamel does not remodel i.e. once formed it does not change. As a result, isotopes deposited in enamel apatite matrix remain unchanged throughout an individual's lifespan. Therefore, while bone isotopes are evidence of dietary input in later life, enamel shows isotopes of diet of developmental years.

Generally, apatite is ~9.5‰ more positive than diet (DeNiro & Epstein 1978;Ambrose & Norr 1993; Kellner & Schoeninger 2007), although spacing as large as 14.1±0.5‰ have been reported (Cerling & Harris 1999). Kellner and Schoeninger (2007) developed an equation to calculate the $\delta^{13}C$ of energy sources in diet using known $\delta^{13}C_{apatite}$ values. Their equation is based on bone apatite and probably needs to be adjusted for enamel apatite:

$$\delta^{13}C_{diet\ energy} = 1.1 \times \delta^{13}C_{apatite} - 8.4\ (r^2 = 0.59)$$ (Kellner & Schoeninger 2007)

If the diet has sufficient protein quantities for the synthesis of collagen, then the margin of error using the above equation is only ±2‰. If protein intake is high, and there are differences in $\delta^{13}C_{diet\ protein}$ and $\delta^{13}C_{diet\ energy}$ then the error increases to ±4‰ (Kellner & Schoeninger 2007).

Lipids have less ^{13}C than carbohydrates and proteins of the same organism and they are ~6‰ more negative than carbohydrates. Therefore, where lipids are the main source of energy as is the case with carnivores, consumer apatite $^{13}C/^{12}C$ ratios are less negative than in collagen (Vogel 1978; Krueger & Sullivan 1984; Klepinger 1984; Klepinger & Mintel 1986; Lee-Thorp *et al.* 1989; Howland *et al.* 2003). Resulting differences in $\delta^{13}C$ values between collagen and apatite (collagen-apatite spacing) are high. Lipids in plants are available in very small quantities and herbivores derive the bulk of their energy from carbohydrates. In plants, $\delta^{13}C$ values of proteins and carbohydrates are very similar and therefore in herbivores, collagen and apatite isotope differences

are accordingly small (Lee-Thorp *et al.* 1989: Ambrose & Norr 1993). Humans subsisting on high protein and high lipids diets, such as Eskimos and east African pastoralists, have collagen-apatite spacing similar to those of carnivores. People with low protein and low lipid diets (like farmers) have collagen-apatite spacing more similar to those of herbivores (Krueger & Sullivan 1984).

The spacing between enamel apatite and bone apatite carbon isotope ratios is yet to be investigated (Kellner & Schoeninger 2007). The trend in studies of collagen-apatite spacing has been to compare $\delta^{13}C$ values of bone collagen with bone apatite, rather than with enamel apatite. Bone apatite has not been investigated in this study so there will be no attempts to determine the relative distributions of macronutrients in the diets of animals and humans analysed.

The study of enamel apatite versus bone collagen isotopes is pertinent to this study for the following reason; in the Kalahari debate, it has been argued that some hunter-gatherers altered their subsistence from hunting and gathering to farming as they were incorporated into farmers' settlements. The two subsistence strategies are expected to result in distinct isotope values of the consumer, particularly carbon isotopes. Hunter-gatherers are expected to have more C_3-based diets, resulting in more depleted $\delta^{13}C$ values compared to farmers. Therefore, individuals who shifted from hunting and gathering to farming are expected to have strongly negative enamel apatite $\delta^{13}C_{ap}$ values but less negative bone collagen $\delta^{13}C$ values.

Other methods allow for the tracking of diet to within a few months but they are too time consuming and expensive. Results of bone density fractionation technique, for instance, have allowed investigation of diet of the last few months prior to death (Bell *et al.* 2001). The technique is helpful in cases where dietary shifts occurred only shortly before death and so not sufficiently represented in the bulk collagen. Bone density fractionation was not used in the current study. Instead, life history trajectories were tracked by comparing bulk enamel apatite to bulk bone collagen stable isotopes.

NITROGEN ISOTOPES

The largest reservoir of nitrogen (other than that locked away in rocks in the earth's crust, and therefore inaccessible) is N_2 gas in the atmosphere. Atmospheric nitrogen serves as an international reference standard for $^{15}N/^{14}N$ measurements, and has a $\delta^{15}N$ value of 0‰ (Heaton 1987; Keegan 1989; Ambrose 1991, 1993; Handley & Raven 1992; Schoeller 1999). The amount and form of nitrogen found in soil and plants depends on rainfall, temperature, humidity, latitude and altitude (Heaton 1987; Ambrose 1991; Pate & Anson 2007). For instance, wet and cold ecosystems tend to conserve and recycle mineral nitrogen which results in nutrient limitation and lower $\delta^{15}N$ values (Ambrose 1993; Pate & Anson 2007). In warmer and drier ecosystems, this scenario is reversed.

In addition to the above factors, nitrogen isotopes in terrestrial ecosystems are also influenced by the processes through which nitrogen is assimilated in the soil (Ambrose & DeNiro 1986a). The biological process of fixing nitrogen from the atmosphere to the soil contributes ^{15}N-depleted nitrogen to soil. Denitrification, on the other hand, increases the ^{15}N component in the soil (Ambrose 1991).

Other factors responsible for variations in nitrogen isotope ratios in soils and plants include differences in soil pH, salinity, grazing and bush fires (Ambrose 1991; Pate & Anson 2007). In recent times, fertilizers have played a significant role in increasing the nitrogen content, particularly in arable lands. All of these factors make it difficult to predict dietary $\delta^{15}N$ values of humans and animals (Ambrose 1993; Hedges & Reynard 2007).

Fractionation of nitrogen isotopes in terrestrial environments results in an increase of 2-4‰ in the $\delta^{15}N$ value between animals in successive food chains. This allows for the differentiation between herbivores and carnivores. However, in arid environments, the effect of climate on nitrogen isotopes makes the distinction between herbivores and carnivores less obvious (Ambrose 1991). In high altitude marine ecosystems, it is possible to differentiate between marine and terrestrial foodwebs using nitrogen isotopes (Sealy *et al.* 1987; Ambrose 1991). The use of nitrogen isotopes

for identifying marine versus terrestrial food chains does not hold in tropical marine environments (Ambrose 1991).

NITROGEN ISOTOPES IN PLANTS

Assimilation of N_2 by plants depends on whether they are fixers or non-fixers. Nitrogen fixing plants use nitrogen from ammonia (NH_4) molecules in from the atmosphere. Non-fixing plants depend on nitrate (NO_3) molecules from the soil (Heaton 1987; Ambrose 19991, 1993). The process on nitrogen assimilation by plants is as follows:

$$N_2+8e+16ATP+H_2{}^{16}O \rightarrow 2NH_3+H_2+16ATP+16Pi+8H$$

For nitrogen fixing plants, only one level of fractionation takes place, and it is between the atmosphere and the plant. As a result, these plants have $\delta^{15}N$ values close to 0‰ (AIR) because they assimilate nitrogen directly from air (Heaton 1987; Keegan 1989; Ambrose 1991, 1993; Handley & Raven 1992). Examples include leguminous plants.

Plants that do not fix nitrogen have to rely on nitrification and mineralisation processes to convert atmospheric nitrogen into the right form for them i.e. NO_3 (Keegan 1989). Mineralisation converts NH_4 to NO_3 in the soil and fractionates N, leading to depletion of ^{14}N (Keegan 1989; Handley & Raven 1992). The forms of nitrogen produced through mineralisation depend on whether rotting occurred under aerobic or anaerobic conditions. Under aerobic conditions, NH_4 converts into NO_3 by releasing NO and N_2O thorough nitrification. Under anaerobic conditions, NO_3 turns into N_2 and N_2O through the process of denitrification. Most terrestrial plants rely on the soil for their nitrogen (NO_3) supply and they have nitrogen isotope differences of about 6‰ between the roots and the leaves.

Some degree of overlap in nitrogen isotope values has been observed between nitrogen fixing and non-fixing plants (Ambrose 1991). However, plants that do not fix nitrogen have significantly higher $\delta^{15}N$ values than those that do fix nitrogen. Therefore, with nitrogen, establishing the possible plant

dietary composition from the $\delta^{15}N$ values of the animal or human consumer is not as easy as it is with carbon where different photosynthetic pathways result in distinct $\delta^{13}C$ values.

NITROGEN IN THE MAMMALIAN BODY

Nitrogen in the body and in the diet is almost exclusively (98%) in the form of protein and amino acids from which protein is synthesised (Schoeller 1999). The remaining small portion is composed of nucleic acids, urea and ammonia. Amino acids, which contain 98% of body nitrogen, are isotopically very different. Proteins are synthesised from 20 common amino acids (divided into essential and nonessential) and several other minor amino acids (Schoeller 1999). Unlike carbon, nitrogen isotope ratios are similar for different body tissues (Ambrose 1993). Therefore, nitrogen isotope ratios can not be used to determine dietary variation at different times of an individual's lifetime.

PHYSIOLOGICAL EFFECTS ON NITROGEN ISOTOPES

About 88% of nitrogen excretion is in urine which is made up mostly of urea, along with 7% ammonia, and 10% creatinine and other molecules. Not all urea is cleared by the kidneys, some goes into the small intestine where bacteria converts it to ammonia and bacterial proteins which are excreted as faeces (Schoeller 1999). Minor quantities of nitrogen are lost through sweat, nail and hair growth, and sloughing of skin. Excreted urea is depleted in ^{15}N when compared to dietary $^{15}N/^{14}N$ ratios (Ambrose 1993; Hedges & Reynard 2007).

Mechanisms responsible for variations in nitrogen isotopes in mammalian food webs are not well understood (Pate & Anson 2007; Hedges & Reynard 2007). High protein diets are thought to result in ^{15}N enriched consumer tissues. Excreted urea is the main by-product of protein metabolism and is depleted in ^{15}N relative to the diet and hence the remaining tissue has higher $\delta^{15}N$ values. However, it is unclear whether increased protein intake results in increased protein metabolism and urea production (Hedges & Reynard 2007).

DIETARY EFFECTS ON NITROGEN ISOTOPES

Terrestrial food chains show an increase in of 3 - 4‰ between animals at successive levels in the food chain (DeNiro & Epstein 1981; Schoeninger *et al.* 1983; Minagawa & Wada 1984; Schoeller 1999; Hedges & Reynard 2007). This stepwise increase could be due to fractionation favouring the heavier ^{15}N during protein synthesis versus fractionation favouring the lighter ^{14}N during excretion (Schoeller 1999). When mechanisms involved in protein synthesis and creation of urea are considered, the second possibility seems the more likely possibility. Bacterial production of faeces does not seem to discriminate against the heavier ^{15}N. Schoeller (1999) suggested that urea recycling in the small stomach, through which faeces form, might be more complex, involving discrimination against the lighter ^{14}N. And, as already mentioned, the stepwise increase in nitrogen isotope values applies to limited environments such as relatively wet terrestrial regions (Ambrose 1991).

The simple model for nitrogen isotope enrichment between trophic level assumes that humans eating only plant protein would have $\delta^{15}N$ values similar to herbivores and that those feeding on herbivore protein would have $\delta^{15}N$ values similar to herbivores plus enrichment of between 3 and 5‰. For example, the $^{15}N/^{14}N$ ratios of pastoralists in east African savannah grass lands and the nineteenth century Griqua in the Orange Free State, South Africa, were ≥ 13‰ (Ambrose 1986). In contrast the Kikuyu in Kenya and the Later Iron Age communities of the northern Transvaal, South Africa, had $\delta^{15}N$ values of ≤10‰ (Ambrose 1986). It is import to note that these nitrogen isotope distinctions between farmers and pastoralists are not always obtained. Firstly, $\delta^{15}N$ values of cereals and/legumes that humans feed on might be significantly different from $\delta^{15}N$ values of herbivore diets. Secondly, metabolism and physiological challenges of nitrogen assimilation and excretion between herbivores and humans might result in different $\delta^{15}N$ values between the two (Hedges & Reynard 2007).

CLIMATIC EFFECTS ON NITROGEN ISOTOPES

The processes that govern the effect of climate on herbivore nitrogen isotope values are not fully understood. Nevertheless, research has shown that climate, particularly rainfall and temperature,

affect the nitrogen isotope values of herbivores. Several studies throughout the world have demonstrated relationships between herbivore bone collagen nitrogen isotopes and rainfall. For example, herbivores in East Turkana, Kenya, where mean annual rainfall is less than 250mm, have average $\delta^{15}N$ values of 10.8±1.0‰. Still in Kenya, mean $\delta^{15}N$ values of herbivores in the highlands are 7.1±1.7‰ where annual rainfall average is about 600mm (Ambrose & DeNiro 1986b, 1989). A recent study by Pate & Anson (2007) showed that nitrogen isotopes values of Kangaroos in the Australian Desert increased in relation to increased aridity. In other words, the more arid the climate, the more positive the $\delta^{15}N$ values of the kangaroos.

In southern Africa, studies by Heaton *et al.* (1986) and Sealy *et al.* (1987) have shown some negative correlation between the $\delta^{15}N$ values of herbivores and mean annual rainfall. Their results indicate that a drop of 100mm of mean annual rainfall results in an increase of between 1.1 and 1.3± in $\delta^{15}N$ values of herbivores. In the northern parts of South Africa, just east of the Toutswe area, a baseline study to correlate $\delta^{15}N$ values of modern ungulates to annual precipitation (Smith *et al.* 2007) has been conducted. Mean $\delta^{15}N$ values of animals from sites in different climatic zones corresponded with isohyets zones. For instance, at areas that receive ~320mm rainfall annually, free ranging ungulates yielded mean $\delta^{15}N$ value of 10.0±1.3‰ (n=31) and those in areas with ~500mm rainfall had mean $\delta^{15}N$ value of 7.1±0.6‰ (n=8).

NITROGEN ISOTOPES IN MARINE AND FRESHWATER ECOSYSTEMS

The relevance of nitrogen isotopes in freshwater ecosystems to this study lies with the site of Xaro where the river Okavango might have been exploited for fish. Marine and freshwater plants have higher $^{15}N/^{14}N$ ratios than terrestrial plants (Ambrose 1991) and these differences are carried up the food chain. It is relatively easy to differentiate between marine and terrestrial based diets using $^{15}N/^{14}N$ ratios because marine and freshwater ecosystems are more enriched in ^{15}N than are terrestrial ecosystems (Schoeninger *et al.* 1983; Schoeninger & DeNiro 1984; Hedges & Reynard 2007). Freshwater fish protein $\delta^{15}N$ values are 3-6‰ enriched while marine fish $\delta^{15}N$ values are ~8‰ more positive than values for terrestrial meat and milk (Schoeninger & DeNiro 1984; Hedges & Reynard 2007).

STABLE ISOTOPES AND HUMAN DIETARY RECONSTRUCTION

The use of stable isotope analysis in reconstructing diet is based on the notion that "you are what you eat". In 1978, DeNiro and Epstein reported their finding of the relationship between the $\delta^{13}C$ values of various tissues from animals ranging from insects to mice and the $\delta^{13}C$ values of their diet. At the same time, there were experiments to investigate similar relationships on larger animals (Vogel 1978; Krueger and Sullivan 1984; Ambrose & Krigbaum 2003) and humans (van der Merwe 1982).

Animal isotope values provide base line data from which to interpret human values. For example, human $\delta^{15}N$ values are expected to be 3 - 4‰ more positive than $\delta^{15}N$ values of dietary protein, much of which is derived from domesticated animals. In order to use animal isotope results as a base line for human isotope results, it is important that the animal remains be associated with human remains. That is, the animals should have come from the same settlements where they were consumed by the humans studied. The EIA communities of southern Africa generally, did not establish formal cemeteries (Huffman & Murimbika 2003) the same way their later European counterparts did (Hedges & Reynard 2007). In the Toutswe area and the Tsodilo Hills, human graves were within residential areas (Huffman & Murimbika 2003). Therefore, there is no reason to doubt that the animal remains from the Toutswe and Tsodilo Hills EIA settlements are associated with the human remains recovered from those sites. In the European contexts, graves are in cemeteries and animal bones are in nearby settlements. Most of the European settlements were occupied for centuries and it is difficult to associate specific dates for graves at cemeteries to animals in the settlements (Hedges & Reynard 2007).

Given the significant differences in $\delta^{15}N$ values between nitrogen fixing and non-fixing plants it is possible to distinguish human populations whose bulk dietary intake was legumes from those dependent on other domesticated plants and wild foods. Precaution must be taken not to use animals feeding on non-fixing vegetation as analogues for interpreting the $\delta^{15}N$ values of humans predominantly subsisting on leguminous produce (Hedges & Reynard 2007). For EIA sites in Botswana and southern Africa in general there is evidence to suggest that prehistoric communities

had substantial bean and other legume production. However, the bulk of plant foods came from grains like sorghum and millet, which are similar to animal feed in that they are both nitrogen non-fixers.

Collagen $\delta^{13}C$ values are useful in estimating the relative contributions of C_3 versus C_4 plants in terrestrial human diets (van der Merwe 1982; Ambrose 1986; Ambrose & DeNiro 1986a; Lee-Thorp *et al.* 1993). Approximately 300km east of Toutswe area lays the EIA 10th to 11th centuries AD sites of K2 and Skutwater in a savanna and *mopane* woodland area. The area receives an annual rainfall of approximately 330mm at present. K2 occupants subsisted on the C_4 cultigens like sorghum and millet, possibly with a foraged supplement. They also kept cattle and caprines for protein, which they topped up with about 2% hunted animals. Mean $\delta^{13}C$ values of K2 adults (n=13) were -10.4±1.3‰ (Lee-Thorp *et al.* 1993).

Skutwater was a smaller, single occupation site less than 20km away from K2 (Huffman 1986, 1989; Hall 1987; Meyer 1998). It was occupied during the later Mapungubwe phase, around the first half of the twelfth century AD. At Skutwater, subsistence was comprised of mixed farming, gathering and substantial hunting (25% of the total faunal assemblage). The mean $\delta^{13}C$ value of humans was -11.3±0.8‰ (n=4), which is not statistically different from the K2 results (Lee-Thorp *et al.* 1993). The mean $\delta^{13}C$ values of the human remains from K2 and Skutwater are useful as references in interpreting results from the Toutswe samples. It is also very tempting to use the Skutwater figures as a reference for EIA humans from N!oma since there is evidence to show that the later also mixed C_4 sorghum and millet farming with foraging of C_3 fruits and nuts, in addition, they had access to cattle and caprines (Turner 1987b; Wilmsen & Denbow 2005). It is unknown whether the proportions of C_3 to C_4 plants were similar for Skutwater and N!oma.

The contrast between enamel apatite and bone collagen provides a platform for tracking changes in the dietary habits of individuals from their early years to around the time of death. In the south western Cape, South Africa, comparative isotope results between apatite and bone collagen have shown interesting results. Using these materials, it was possible to distinguish first generations of slaves from European migrants who arrived in the south western Cape during the nineteenth

century (Sealy *et al.* 1993, 1995). The populations were identified by apatite $\delta^{13}C_{ap}$ values and bone collagen $\delta^{13}C$ values which showed significant differences in the proportion of C_4 foods in the diet between developmental years and adulthood.

Changes in subsistence and diet are obvious when there is a shift from a C_3 to a C_4 based diet or vice versa. Abrupt changes between childhood and adulthood diets are often caused by migration between areas in which different photosynthetic pathways dominate, or even between marine and terrestrial zones (Sealy *et al.* 1993) or changes in subsistence stragies. Carbon isotope evidence of migration was documented, for example, from an eighteenth century female buried under a slave lodge foundation at Vergelegen, South Africa. Evidence from osteological pathology, written records, and burial style, suggested the female was brought to the Cape as a slave. Childhood $^{13}C/^{12}C$ ratios of her teeth point her origins to tropical or sub-tropical areas where C_4 plants formed the bulk of the diet. However, her adulthood $\delta^{13}C$ values from a rib indicate heavy reliance on marine foods (Sealy *et al.* 1993).

In another study, Ambrose (1986) found that people living on C_4 grains, cattle, and caprines had $\delta^{13}C$ values of ~-6.5‰. The South African Later Iron Age communities of the northern Transvaal had mean carbon isotope values of -8.2±0.5‰. Their diet is believed to have been similar to that of the historic Pedi communities (Ambrose 1986). This diet was dominated by C_4 crops, legumes and pumpkin and small amounts of cattle and small stock (Mönnig 1967). In contrast, the historic Griqua in the Orange Free State, South Africa, were pastoralists who depended largely on cattle, small stock and wheat for protein. Wheat is a C_3 photosynthetic crop. Their $\delta^{13}C$ value average was -13.0±1.0‰ (Ambrose 1986; Ambrose & DeNiro 1986a). For diets made of C_3 and C_4 agriculture combined with small numbers of cattle and caprines, Kikuyu communities in Kenya had $\delta^{13}C$ values averaging -10.6±1.4 (n=12) and -12.7‰ (n=5) for males and females respectively (Ambrose 1986; Ambrose & DeNiro 1986a).

A significant inclusion of new plants with different fractionation pathways for populations otherwise maintaining the original diet is also easily detectable (White & Schwarcz 1994; van der Merwe & Tschauner 1999). For instance, the introduction of maize, a C_4 cultigen to the Mesoamerican Tehuacán Valley was traced via carbon isotopes in human skeletal remains (DeNiro & Epstein

1981; van der Merwe & Tschauner 1999). The Mesoamerican Mediterranean climate supported C_3 wild vegetation only, and it was possible to draw a time scale of the introduction of maize because earlier skeletons displayed depleted $\delta^{13}C$ values but with the advent of maize farming, the values became gradually less depleted.

Another example of a study where stable isotope techniques have been used to investigate the introduction of new cultigens is that by White & Schwarcz (1994). In this study, 146 Nubian mummies from Wadi Halfa region of Sudan were analysed. The mummies are dated between 350BC and AD1400, i.e. the Meroitic – Christian period. The $\delta^{13}C$ values of bone, muscle and skin shows that throughout this period, C_3 cultigens (wheat and barley) were the major contributors to the overall diet of the communities. However, the period between AD 350 and 550, also known as the X-Group period, saw a significant increase in the consumption of C_4 crops presumably, millet and sorghum (White & Schwarcz 1994). The increase in C_4 crop consumption is noted in $\delta^{13}C$ values as well as in the archaeological record (White & Schwarcz 1994). The X-Group period is also associated with a low Nile, political and economic restructuring of Sudanese Nubia.

Transition in diet can also be brought about by other factors besides the introduction of new crops. For example, after 2000BP, the Holocene hunter-gatherers of the south western coast changed their diets to include more terrestrial foods which had been in their environment previously. The archaeological record shows a shift from large shell middens dating around 3000BP to a marked increase in the numbers of small terrestrial animals post 2000BP. This period also marks the sudden increase in human population following the arrival of pastoralists. Carbon isotope ratios of skeletons dated around 3000BP are around -11‰ (Sealy *et al.* 1992), a figure associated with heavy reliance on marine foods. The post 2000BP skeletons have $^{13}C/^{12}C$ ratios of -14±1.6‰ (Sealy *et al.* 1992), an indication of heavy reliance on terrestrial C_3 foods.

In the current study, hunter-gatherers (C_3 dominant diet) incorporated into farmers settlements (C_4 dominant diet) for long periods will be identifiable through decreasing $\delta^{13}C$ values from teeth to bone. Wilmsen (1989) and Denbow (1984b) argued that as far back as 1000 years ago, hunter-

gatherers from the Kalahari periodically shifted to farming resources to supplement scarce hunted and gathered foods. Denbow and Wilmsen (1983, 1986) contend that historic hunter-gatherers of the Kalahari were living a lifestyle precipitated by later marginalisation. The lifestyle involved shifts between hunting and gathering and working for farmers to earn food.

Communities such as the so-called 'river San' along the Boteti River in north western Botswana are example of present day communities exploiting both C_3 photosynthetic plants and freshwater fish (Cashden 1986; Hitchcock 1999). If the Xaro EIA peoples' subsistence strategies were similar to those of the 'river San' then their $\delta^{13}C$ values are likely to be highly negative. The problem is that just because peoples settled along a river does not mean that fish was important in their diet. At Xaro, for example, depleted $\delta^{13}C$ values can easily be attributed to hunting and gathering without fishing. The lithic assemblage at Xaro is too small to suggest that the site was occupied by. In the relevant section of this chapter (*nitrogen isotopes in marine and freshwater systems*), it is explained how nitrogen isotopes can be used to identify fishers with depleted $\delta^{13}C$ values from hunter-gatherers and even farmers whose food derives mainly from C_3 plants.

Holocene hunter-gatherers along the southernmost coast of Africa (Robberg/ Plettenberg Bay) have $\delta^{15}N$ values (18‰) consistent with a diet in which the main source of protein was high-trophic level marine animals such as Cape fur seals (Sealy 2006). At the Matjes River rock shelter about 14km east of the Robberg Peninsula, the environment did not offer marine foraging opportunities. The site has shell middens of up to 10m deep. Humans from Matjes River rock shelter have $\delta^{15}N$ values indicating protein sources derived from low-trophic level marine animals i.e. shellfish. The isotope differences between Robberg/ Plettenberg Bay and Matjes River hunter-gatherers (4500 to 2000 BP) indicate that the communities were more sedentary than initially thought. They exploited their immediate environment as opposed to moving seasonally to the coast to forage (Sealy 2006).

Contrary to above-mentioned differences between nitrogen isotopes of marine/freshwater and terrestrial ecosystems, arid terrestrial areas have $^{15}N/^{14}N$ rations similar to those in marine contexts. Therefore, $\delta^{15}N$ values of arid coastal ecosystems do not easily differentiate between marine and terrestrial protein input (Schoeninger *et al.* 1983). Fortunately, the site Xaro is not in an

arid environment (Cooke 1982; Thomas & Shaw 1991) and high $\delta^{15}N$ values in the humans would most probably reflect consumption of meat.

SUMMARY OF THE LITERATURE

Having reviewed the archaeology of Botswana several issues come into light with regard to the diets of both LSA hunter-gatherers and EIA farmers in the Toutswe area, the Tsodilo Hills, and the Okavango River. The expected carbon and nitrogen isotope values for these areas are discussed below.

Diets of hunter-gatherers who lived in the Kalahari Desert and other places during the EIA have been predicted from floral and faunal remains found at several sites (Lee 1979; Lee & DeVore 1976; Denbow 1984b; 1986a, 1986b; Denbow & Wilmsen 1983, 1986; Turner 1987a, 1987b; Donahue & Robbins 1989; Robbins & Campbell 1990; Wilmsen 1990; Smith *et al.* 2000). There is a strong indication that the bulk of hunter-gatherer plant protein in the Kalahari came from C_3 based plants and hence their bone collagen $\delta^{13}C$ values are expected to be around -19‰ (van der Merwe 1982).

The bulk of dietary protein of LSA hunter-gatherers came from wild herbivores. Plant protein was probably more difficult to obtain because the Kalahari sands do not support good vegetation growth. However, mongongo nuts and *morama* were probably available in sufficient quantities and formed part of the staple foods for the foragers. As a result of animal protein, $\delta^{15}N$ values of the LSA hunter-gatherers are likely to be about 4‰ more positive than those of herbivores.

Different adaptive characteristics of the San demonstrate that the diets the Kalahari inhabitants are neither uniform nor constant. Along permanent waters, such as the Okavango and the Boteti Rivers, they are more sedentary, exploit different wild resources and practice fishing. LSA tools and fish bones found on sites along these rivers demonstrate a prehistoric exploitation of freshwater resources (Cashdan 1986). If fishing was an important component of subsistence at

Xaro, individuals will have elevated $\delta^{15}N$ values compared to farming inhabitants of the nearby sites in the Tsodilo Hills. Moreover, the $\delta^{13}C$ values of LSA people subsisting on freshwater fishing are expected to resemble those of people subsisting of C_3 photosynthetic plants.

The archaeological record indicates that EIA farmers in the Toutswe area grew sorghum and millet, which most probably formed the bulk of their plant protein. These domesticated grains use the C_4 photosynthetic pathway. At the Toutswe polity, most individuals are expected to have $\delta^{13}C$ values close to -7‰ due to the source of their bulk plant protein. However, the inclusion of C_3 photosynthetic crops like beans and cowpeas is expected to decrease the $\delta^{13}C$ values. For instance, if C_4 and C_3 foods constituted equal proportions of the diet, then the individuals will have $\delta^{13}C$ values of around -14‰.

Within the Toutswe settlement hierarchy, it has been suggested hunter-gatherers and small-scale farmers (Denbow 1982a, 1990) occupied small sites. They probably provided labour or tribute to wealthy farmers at bigger settlements. As previously mentioned, enamel apatite $\delta^{13}C_{ap}$ values show carbon isotope ratios of childhood years whereas bone collagen $\delta^{13}C$ values show carbon isotope ratios of the last few years prior to death. First-generation hunter-gatherers will be identified by comparing enamel apatite δ^{13}Cap values to adulthood $\delta^{13}C$ values to determine shifts from wild to domesticated foods.

At EIA sites in the Kalahari, including Divuyu and N!oma, there is evidence to suggest large scale supplementation with mongongo*, morula* and other wild plants between AD600 and 1100 (Robbins & Campbell 1990; Wilmsen & Denbow 2005). The frequency and distribution of carious teeth and dental wear on the EIA Tsodilo Hills, are consistent with cariogenic farmers' foods alongside tooth wearing hunter-gatherer foods (Morris 1996) suggesting they practiced both subsistence strategies. One would therefore, hope to see more depleted $\delta^{13}C$ values on Tsodilo and Xaro humans compared to those from the Toutswe area.

3: MATERIALS AND METHODS

INTRODUCTION

This chapter provides descriptive details of the materials and methods used in the research. Bone and teeth were materials of choice for this study because they provide the best ways to address the aims and objectives of the study. These materials also tend to preserve well in buried contexts and hence they are readily and easily available for the types of research.

Collagen in bone and apatite in teeth were subjected to measurements of stable isotope ratios of carbon and nitrogen. The end results, i.e. $\delta^{13}C$, $\delta^{13}C_{ap}$ and $\delta^{15}N$ values are applied in various ways in the reconstruction of past environmental conditions and dietary habits of both humans and animals.

The samples were collected from human and animal skeletal remains excavated from archaeological deposits in east central and north western Botswana (see Figure 1.1 in Chapter 1). In addition, modern faunal samples were collected from around the sites of Bosutswe and Toutswemogala.

The chapter starts by explaining the sampling strategies used to determine which samples to include or exclude. The numbers of samples and species present per site are presented in the second part of the chapter. The third component presents the analytical techniques used in collecting data for the research. These are ways in which collagen and apatite were extracted and prepared from bones and teeth respectively. It also looks at the statistical tests applied to the results.

SAMPLING STRATEGIES

GEOGRAPHIC AND TEMPORAL CONSIDERATIONS

The samples were selected from specific geographic and temporal contexts. The contexts were selected as the best for addressing the arguments for and against contact between hunter-gatherers and farmers. Sites associated with the Toutswe settlement system in east central Botswana and sites in the northwest (Tsodilo Hills and Okavango River) were selected because:

- In the Kalahari debate, they are considered frontiers of contact between farmers and hunter-gatherers. Excavations at the sites have produced indications of some kind of interactions between farmers and hunter-gatherers. It would therefore, be interesting to see if any of the human remains exhumed at these sites showed dietary indications of both foraging and farming.
- The Kalahari debate is in the context of the LSA hunter-gatherers and Iron Age farmers. The sites selected in the current study date to the early period which the LSA hunter-gatherer and Iron Age farmers are thought to have begun to co-exist.

As already mentioned, from the east central area, only sites associated with the Toutswe ceramic tradition were considered. Archaeologists such as L. Lepionka, J. Denbow, D Schemers, C. van Waarden and others, excavated the sites from as early as the 1970s. Very few EIA sites with human remains from the northwest have been documented. These were excavated by J. Denbow, E. Wilmsen and P. Thebe. Previous studies by de Villiers (1976), Morris (1996), Murphy (1996), Mosothwane (2004, 2006) as well as Mosothwane & Steyn (2004, 2008) have established the age, sex, stature and pathology for almost all the humans included in the study.

It is worth mentioning that many more sites, both LSA and EIA, from the selected geographic areas have been excavated, but only those that have produced human remains were selected for study. It is also important to note that some sites that fall within the prescribed geographic and temporal contexts did have human graves, but the skeletons could not be found at either the University of

Botswana or Botswana National Museum. These include Lechana and Maiphetwane excavated in the early 1980s (Denbow 1983a) and Dikalate excavated by A. Reid in the early 1990s.

It is again important to mention that other frontiers of contact between foragers and farmers in the greater Kalahari region have been identified. For example, archaeological artefacts recovered in the areas around Thamaga in south eastern Botswana provide strong evidence for contact between foragers and farmers (Sadr 2002). Unfortunately, no human remains have been recovered from the sites so they could not be included in the study.

MATERIAL SELECTION

Materials selected for this research was bone collagen and enamel apatite. Bone collagen averages the isotope signatures of the diet consumed over last few years before death. Bone collagen reflects the average isotope values of diet over several years because of continuous bone remodelling. Skeletal elements such as ribs and cancellous epiphyses of long bones remodel relatively quickly, i.e. they have fast turnover rates. Other elements such as the diaphyses of long bones remodel more slowly, i.e. they have slow turnover rates. The isotope values of fast turnover bones indicate diet eaten over a shorter period prior to death than is the case for slow turnover bones. Combinations of fast and slow turnover bones from adult humans were analysed to determine whether there might be subtle differences in the stable isotope values of tissues formed at different ages. At least three samples per individual were analysed. Some human remains were, however, poorly preserved or destroyed during exhumation (see for instance Kgaswe B55 this chapter) and consequently only one sample per individual could be taken.

Enamel apatite has isotope signatures that reflect the diet consumed during developmental years because, once formed, enamel does not remodel. For humans, samples of tooth enamel were taken from individuals with good dental health and dental preservation. However, all infants had to be excluded because little enamel had formed. Where possible, at least three teeth that form at different ages were used per individual.

Archaeological animal samples were taken from the same sites as the human remains. Species identifications of archaeological faunal assemblages had been carried out at only a few sites, such as Toutswemogala (Welbourne 1975), Taukome (Plug 1983) and Bosutswe (Plug 1996; Atwood 2005; Denbow *et al.* 2008) and sites in the Tsodilo Hills (Turner 1987b). Toutswemogala, faunal remains were, however, not marked or packaged according to species, and consequently needed to be re-identified. Dr Genevieve Dewar (Archaeology Department, UCT) identified the animal species in all cases.

For animals, collagen was extracted from bone samples taken, whenever possible, from mandibles and maxillae with teeth. These elements were preferred because they are easily identified to species level. Preference was given to left sides; right sides were included only if they came from different stratigraphic contexts or from animals of different ages. For example, the single archaeological cow maxilla from Bosutswe (UCT 12251) comes from a different location from the five mandibles sampled at the same site. The bones are, therefore, very likely to derive from six different cattle. Occasionally, a different skeletal element was sampled, e.g. the modern kudu horn core from Toutswemogala, since it was the only material available from this species. In addition to mammals, tortoises were also included in the study. Where more than one fragment of tortoise carapace came from the same archaeological context, a single fragment was selected for isotopic analysis.

Tooth enamel was taken from teeth still in their sockets in mandibles and maxillae. The number of teeth sampled per individual ranged from one to three, depending on the status of preservation. No attempts were made to extract enamel apatite from animals with little enamel (e.g. hares and rats). In some instances, loose teeth of wild animals had been recovered (e.g. zebra from Kgaswe B55 and Toutswemogala). Since there were no mandibles of such animals, the loose teeth were analysed in order to increase the number of species. However, the results for loose teeth could not be included in the statistical analysis because the minimum number of individuals represented by these loose teeth could not be determined.

Animals that died in the last five years at Toutswemogala and Bosutswe were also included in this study, in order to investigate current relationships between in rainfall, vegetation and isotope

values. Samples were collected randomly from the surface at cattle posts within a 10 km radius of each archaeological site. Farmers confirmed that animals had been born and raised within their localities and that no supplementary feeding was provided except salt. Thus, the isotope results are a reflection of the natural environments in which the animals were raised. It would have been ideal to also include modern faunal samples from sites in the northwest, but unfortunately, they were not available due to an epidemic of foot and mouth disease in the region.

DESCRIPTION OF THE SAMPLES

The following section provides site-by-site account of human and animal skeletal remains available for the study. Brief descriptions of general burial styles, ages and sexes of humans are given. Number of humans and animals from which bone and tooth enamel samples were taken are tabulated at the end of this section. Sites in the Toutswe region are divided into a three-tier settlement hierarchy (Denbow 1982). Small class 1 sites include Kgaswe B55, Bonwapitse, Thataganyane, Swaneng Hill and Serowe Hill. Class 2 medium-sized sites included in the study are Taukome and Thatswane while class 3 large site are Bosutswe and Toutswemogala. Two EIA sites from the Tsodilo Hills in the north western part of Botswana are Divuyu and N!oma. In addition, there is a single site (Xaro) situated along the Okavango River, also in the north western part of the country. Locations of all sites can be seen on Figures 2.2 and 2.3 in Chapter 2.

TOUTSWE CLASS 1 SITES

KGASWE B55

Exhumation of graves from Kgaswe B55 took place in 1982/3 as part of an archaeological mitigation project (Denbow 1983b). The site was exposed using construction equipment and consequently some graves and features were destroyed. Notwithstanding this problem, it was possible to map the entire settlement (Denbow 1986a, 1990). Twenty-seven graves were found with females and children located next to houses and males in the central kraal. Most of the individuals were in horizontally flexed positions with heads oriented to the west (Denbow 1986a, Huffman & Murimbika 2003). The site is characterised by a single phase of occupation.

Clay pots found with Graves 2 and 6 and on other parts of the site had decoration styles similar to those of the Toutswe ceramic tradition (Denbow 1986a; Huffman 2007).Three radiocarbon dates from Kgaswe B55 place it between AD900 and 1100 (Denbow 1986a). Both radio carbon dates and ceramic evidence indicate that Kgaswe B55 was part of the broader Toutswe settlement system.

Bone samples were taken from 17 humans ranging in age from newborn to 75 years, including both males and females (Mosothwane 2004). Some of the individuals were included in the isotope analysis previously conducted by Murphy (1996). All samples from Kgaswe B55 had to be included in the current study despite the fact that some results were available from the study done by Murphy (1996). This is because the samples used by Murphy were not individually labelled and therefore it was difficult to determine which ones had been included or excluded. Tooth enamel could be sampled from only six individuals. Teeth of the rest of the individuals had been destroyed.

Bone samples were taken from four ovicaprids and one cow. The ovicaprids come from three distinct locations on the site but there is a slight possibility that two of them came from the same animal, as they appear to be of the same age and different sides of the mandible. There were no mandibles or maxillae from wild animals at this site. Enamel apatite samples came from 12 teeth attached to mandibles and maxillae of domestic animals. Samples of enamel were also taken from two zebra and two medium-sized bovid teeth not attached to either mandibles or maxillae.

BONWAPITSE

In 2005, C van Waarden carried out rescue excavations of three graves on a site earmarked for development. The graves had been partially destroyed by construction machines before the archaeologists were called in. All three skeletons were in horizontally flexed positions with no grave goods (van Waarden 2006). Pottery from a nearby midden is stylistically similar to that of the Zhizo/Taukome period in the area (AD700).

All three graves were of males aged between 15 and 50 years at the time of death. None of them had signs of pathology associated with metabolic diseases (Mosothwane 2006). Bone collagen and enamel apatite from all three have been analysed. The faunal assemblage from Bonwapitse was very small (van Waarden 2006) and there were no fragments suitable for the current study.

THATAGANYANE HILL

Two human graves were recovered from this site in 1992. Field records detailing the context of the graves could not be found. However, pottery recovered from Thataganyane is stylistically similar to that of the Toutswe tradition dated AD 1000 to 1300 (van Waarden: personal communication, 2007). The individuals have been identified as 20 to 40 year old males and no signs of pathology were identified on bones (Mosothwane 2004).

Since the skeletons are fragile and fragmented, only one sample of bone per individual was analysed. Enamel samples were taken from Thataganyane Hill 1. Attempts to find faunal remains from these sites were unsuccessful.

SWANENG HILL

A. Lock excavated the grave in 1989. Unfortunately, its provenance and context are unknown. The site has pottery similar to that found at other Toutswe sites, usually dated between AD 900 and 1300. It is possible that the grave was recovered in a rescue excavation since the skull appears to have been exposed to the sun for a lengthy period. Most of the skeleton is missing but it was possible to estimate age at death at 20 to 30 years and sex as probably male (Mosothwane 2004). Only two teeth were preserved and enamel samples were taken from both.

SEROWE HILL

Schemers excavated the site at Serowe Hill in 1978. Records detailing the context of the grave are currently unavailable. Pottery from the site is similar to that found on other Toutswe sites (AD 900 to 1300) and it is believed to have been occupied only once (van Waarden: personal

communication 2005). The remains are of a 20 to 40 year old female. Bone samples were obtained from this individual but unfortunately teeth were not preserved.

TOUTSWE CLASS 2 SITES

TAUKOME

In the early 1980s, Denbow exhumed five complete and well preserved human skeletons and an isolated maxilla fragment (Taukome 6) at this site. All but one individual were found in horizontally flexed positions with heads oriented to the west. The exception was Taukome 3, an infant interred in a clay pot. All graves came from deposits dated between AD 900 and 1000, a period associated with the Toutswe phase (Denbow 1983a). Age at death for all six individuals ranged between newborn and 60 years. There were two adult males, an adult female and two juveniles. The sex of Taukome 6 is also unknown (Mosothwane 2004). There are generally no health problems besides osteophytes and dental caries noted on adults (Mosothwane 2004, Mosothwane & Steyn 2008).

For purposes of this study, bone samples were obtained from all five complete individuals (Taukome 1 to 5). Preservation of Taukome 6 was already compromised and as a result it was decided not to damage it further. Eight teeth from four individuals (Taukome 1, 2, 5 and 6) were included in the sample group.

Most of the animal samples come from Unit 3, while a few (UCT 12258, UCT 12259 and UCT 12260) are from Unit 4. The contexts of 3 samples (UCT 12618, UCT 12619 and UCT 12620) are not known. The site was occupied for a relatively short time and the animals therefore date to approximately the same period as the humans. Domestic animals are represented by 21 ovicaprids and six cattle. Wild fauna include hare, rat, *Raphicerus* and tortoise, each represented by one individual. At least two teeth from each animal were analysed.

THATSWANE

Denbow (1983a) excavated six graves at this site. The remains were generally in horizontally flexed positions with heads oriented to the west. Radiocarbon dates of charcoal from Thatswane

are about AD 900 to 1200 (Denbow 1982). Five of the individuals were juveniles and one (Thatswane 5) was an adult female aged between 40 and 60 years at death. Other than arthritic lesions on the adult, they all appear to have been relatively healthy (Mosothwane 2004; Mosothwane & Steyn 2008). Bone samples were obtained from all individuals but teeth were present on only two individuals, so enamel samples could be obtained only from these two (Thatswane 3 and 6).

Fifteen animal bone samples were taken from 13 ovicaprids and two cows. Unfortunately the contexts of the eight of the specimens are unknown (UCT 12393, UCT 12394, UCT 12395, UCT 12396, UCT 12397, UCT 12398, UCT 12398, UCT 12399 and UCT 12400). However, the site appears to have been occupied continuously over a relatively short period (Denbow 1982), and thus the animals date to the same period as the humans.

Tooth enamel was taken from 23 teeth of ovicaprids, from five mandibles and two maxillae, together with five cattle teeth. No mandibles or maxillae of wild fauna were available and hence only loose teeth could be sampled: nine zebra teeth and two premolars of medium sized bovid(s).

TOUTSWE CLASS 3 SITES

BOSUTSWE

Thirteen of the 14 human graves from Bosutswe were excavated on the western area of the hill in 2002 by Denbow and myself. One infant had previously been recovered from the central area within the Lose deposits. The bodies were generally buried in horizontally flexed positions with heads oriented to the north and west and large stones had been placed next to or on top of many of the remains. Occasionally, pots and other vessels were found in association with the graves. Bosutswe 7, an infant of 18 to 24 months, had been buried wearing waistband and necklace(s) made of ostrich eggshell beads (Mosothwane 2004). Eleven of the graves were in deposits associated with the Toutswe period which lasted from AD 1000 to 1200 at Bosutswe (Denbow *et al.* 2008). The other three graves (Bosutswe 1, 2 and 10) are likely to have been from the Lose period (AD 1150 to 1300).

Eleven of the individuals were aged between newborn and 15 years old and the other three were males between 17 and 75 years old at the time of death. Bosutswe 12 (male, 60-75 years old) has evidence for diffuse idiopathic skeletal hyperostosis (DISH) (Mosothwane 2004; Mosothwane & Steyn 2008). The condition is thought to be a result of metabolic disorders caused by high calorie intake which often leads to diabetes and obesity in clinical cases. Enamel hypoplasia, a condition caused by interrupted enamel deposits during developmental years, was present on some of the individuals (Mosothwane 2004; Mosothwane & Steyn 2008).

At least one bone fragment from each of the 13 individuals was used for stable isotope analysis. Bosutswe 9 was not included because very little of it had been preserved (Mosothwane 2004). Tooth enamel samples were obtained from ten of the individuals.

Bone and tooth enamel were sampled from five archaeological cattle and 12 ovicaprids from Bosutswe. No suitable wild animals were available in the excavated archaeological assemblage. All samples were from mandibles, except UCT 12251, which was from a maxilla. The animals came from different contexts but there is a small possibility that two or more samples could have come from the same individual. A recent study by Denbow *et al.* (2008) included more animal samples from Bosutswe. Samples were taken from different skeletal elements whereas in the current study only mandibles and maxillae are used.

Modern animals obtained from the same locality consist of one sheep, one horse, two donkeys, 20 cattle and one jackal. One tooth, together with bone fragments for collagen extraction were taken from each of these individuals. The samples were collected at three cattle posts in the vicinity of the site.

TOUTSWEMOGALA

Lepionka (1977) excavated a number of graves from Toutswemogala. As at other sites, the remains were found mostly in horizontally flexed positions. They all came from the top 40-50cm of deposits (Lepionka 1971, 1977, 1978) which Denbow (1983a) believes are from the AD1500 occupation. A radiocarbon date of AD1195 was obtained on a sample in Feature 1 found 40cm below surface (Denbow 1983a). It is, therefore, likely that graves from Toutswemogala date

between AD1200 and 1500. This period corresponds to the end of the Toutswe phase and beginning of Lose. Because of technical errors in Lepionka's field methods, it is not clear how many graves were excavated. Moreover, contextual information of many of the graves is unknown. Age at the time of death for all individuals ranged between newborn and approximately 75 years (de Villiers 1976, Mosothwane 2004). Only four were adults: two males, one female and one whose sex could not be determined. The only pathological conditions noted were enamel hypoplasias and degenerative arthritic conditions (Mosothwane 2004; Mosothwane & Steyn 2008). In this study, bone samples were obtained from 28 individuals and dental samples from 15.

Domestic archaeological fauna sampled consist of 15 cattle, 38 ovicaprids and one dog. Wild animals comprise two steenbok, five tortoises, one rat, one zebra, two *Raphicerus,* two leguaans, and one microfaunal bone. Tooth enamel samples were taken from all but tortoise, rat, leguaan and microfauna.

Bone samples of modern animals came from ten cattle, five ovicaprids, three donkeys, and a medium size herbivore. In addition, a kudu horn core was available for study. Neither the mandible nor maxilla of the kudu was recovered. Samples of enamel were collected from all modern animals except the kudu. The modern samples were collected at for cattle posts near the site.

SITES AT THE TSODILO HILLS

DIVUYU

Denbow and Wilmsen excavated Divuyu in the mid 1980s (Denbow: personal communication 2006). The single skeleton recovered was the remains of a body that had been interred in a sitting position facing east with the lower parts extending into an acid soil layer. As a result, preservation was compromised where the skeleton had been in contact with the acid soil. Radiocarbon dates from Divuyu fall between AD550 and 900.

The remains are those of a two to three year old child (Morris 1996). Unfortunately, dental development was still at its early stages, preservation was poor, and as result, teeth could not be included in the study. No animal samples relevant to the current research were available.

N!OMA

The site, formerly known as Society, was first excavated by E. Wilmsen and A. Campbell in 1979. One individual (Society 1) was found, in a sitting position. Subsequent excavation of the entire site in 1985 revealed three more graves approximately 30m from Society 1. During the second field season the site was renamed N!oma (Wilmsen: personal communication 2007). N!oma 1, 2 and 3 were all within a $4m^2$ excavation trench on a midden deposit along the eastern edge of the main site. Grave 1 and 2 were in horizontally flexed positions while N!oma 3 was in a sitting position. N!oma 3 was buried with a red ochre-finished bowl covered by several other potsherds. The bowl is believed to have been an object of prestige (a similar example was recovered from Bosutswe). The site is dated between the seventh and the eleventh centuries AD (Denbow 1999).

Three of the four graves from N!oma were located at the BNM: N!oma 1 and N!oma 2 and 3. N!oma 1 was an infant of approximately 2 years at the time of death. N!oma 2, aged 14 to 15 years, is fragmented but for the most part the bone is well preserved (Morris 1996). Cranial characteristics of this individual are similar to those of the Khoisan. No evidence for pathology was detected from the skeleton. N!oma 3 is an adult female aged between 40 and 60 years at the time of death. Morris (1996) concluded that the individual had racial affinities to modern South African blacks. The head of the right clavicle has lesions associated with a diffuse resorptive activity above the articular surface but the condition is not arthritic. Antemortem loss of two premolars and abscessing at the root of the left M_1 are evidence for periodontal disease (Morris 1996). Five bone samples were taken from the three humans. In addition, three teeth from two of the individuals were also included as study samples.

Bone samples of three cattle and three ovicaprids found at this site were included in the study. The stratigraphy of the site indicates that there was one phase of occupation and therefore, animal samples from N!oma are of the same period as its human graves.

SITE ALONG THE OKAVANGO RIVER - XARO

The first grave from this site was discovered and partially destroyed by workers of a safari camp in the mid 1980s. It was about 1m below surface within a sandy soil deposit, about 50m away from

the water edge. The body was laid in a horizontally flexed position. A single potsherd similar to those found at Divuyu was recovered underneath the leg of the individual. It was not possible to obtain direct dates on the site and so it could be slightly earlier than or later than Divuyu (Denbow: personal communication, 2005).

Morris (1996) identified the individual as a male aged between 50 and 60 years old at the time of death. The skull has morphological and craniometric characteristics similar to both Khoisan and South African Blacks. Cribra orbitalia found on both sides of the orbits were healed at the time of death. These lesions are indicative of nutritional or environmental stress experienced around the time of death. Dental health was very poor, characterised by advanced occlusal caries on some teeth and buccal abscessing on some (Morris 1996).

Wilmsen and Thebe excavated the second individual from Xaro in 2006. The grave was located less than 2m from the river bank, not far from where the first skeleton was found. It was in horizontally flexed position with the head oriented to the west. The skeleton does not have pathological lesions except for minor arthritic lipping on the vertebrae and other joints. The remains are of an adult male aged 40-60 years old at the time of death.

Bone samples were extracted from the two graves from Xaro. Little enamel was preserved following severe dental carries and antemortem tooth loss on both individuals. No attempts were made to extract enamel apatite. No animal mandibles or maxillae from this site were found.

SUMMARY OF THE SAMPLES

Table 3.1 summarises the number of humans from each site from whom samples of bone and tooth enamel were taken. Ceramic cultures associated with the sites are mentioned in the Table. The ceramic cultures from sites on the Tsodilo Hills and Xaro have not been given a name, but they are similar to ceramics from Dundo, Sioma and Kapako in Namibia and Zambia.

Table 3.2 shows the number of archaeological domestic and wild animals that were included in the study. The unspecified species in the Table comprise one rat at Taukome, one microfaunal bone and two leguaans from Toutswemogala.

Sample sizes of different species of modern domestic and wild animals from Bosutswe and Toutswemogala are summarised in Table 3.3. These samples were collected in December 2006 from the surface at cattle posts located within 10 km of each of the sites.

Table 3.1: summary of human bone and teeth samples included in the study

Area and sites	Cultural affinity	Bone collagen (no. of individuals)	Tooth enamel (no. of individuals)
Toutswe			
Class 1 sites			
Kgaswe B55	Toutswe	17	6
Bonwapitse	Taukome/Zhizo	3	3
Thataganyane	Toutswe	2	2
Swaneng Hill	Toutswe	0	1
Serowe Hill	Toutswe	1	0
Class 2 sites			
Thatswane	Toutswe	6	2
Taukome	Toutswe	5	4
Class 3 sites			
Bosutswe	Zhizo and Toutswe/Lose	13	10
Toutswemogala	Toutswe	28	15
Tsodilo Hills			
N!oma		3	2
Divuyu		1	
Okavango River			
Xaro		2	2
	TOTAL	**81**	**47**

Table 3.2: Summary of archaeological animal samples included in the study

Area and sites	Cattle	S/g	Dog	Zebra	Hare	Tortoise	Steenbok	*Raphicerus*	Others
Toutswe									
Class 1 sites									
Kgaswe B55	1	4							
Class 2 sites									
Taukome	6	21			1	1		1	1
Thatswane	2	13							
Class 3 sites									
Bosutswe	5	12				6			
Toutswemogala	15	37	1	1		5	2	2	3
Tsodilo Hills									
N!oma	3	3							
TOTAL	**32**	**90**	**1**	**1**	**1**	**12**	**2**	**3**	**4**

Table 3.3: Summary of modern animal samples included in the study

Site	Cattle	S/g	Donkey	Horse	Kudu	Med bovid	Jackal
Bosutswe	20	1	2	1			1
Toutswemogala	10	5	3		1	1	
Total	**30**	**6**	**5**	**1**	**1**	**1**	**1**

PREPARATION OF BONE COLLAGEN

The focus of this section is two fold. First, it describes techniques used to extract collagen from bone and measure the carbon and nitrogen isotope ratios in the mass spectrometer. Next, it describes the criteria used to assess collagen preservation, since post-mortem changes to buried bone may alter its isotope ratios. The same procedures were followed to extract collagen from horn cores and tortoise carapace.

COLLAGEN EXTRACTION AND ANALYSIS

Small pieces of bone, tortoise carapace or horn core, approximately 1 cm^2 each, were cleaned with fine sandpaper discs to remove adhering soil and dirt. Clean samples were weighed to the nearest milligram and placed in dilute hydrochloric acid (125ml H_2O: 1.0ml concentrated HCl) for a few days to remove the mineral component (Ambrose 1990). The length of stay in the HCl solution ranged from four days to one week depending on the thickness of the bone fragments. Once decalcified, the fragments were rubbery and slightly translucent. Resulting collagen pseudomorphs retained the shapes of the original bone fragments, thereby indicating that the collagen chains were still intact. The pseudomorphs were rinsed in distilled water three times.

The final step was to put them in 0.1M sodium hydroxide (NaOH) for several hours to remove humic acids (Ambrose 1990, van Klinken 1999, Jørkov *et al.* 2007). If the NaOH solution changed to a dark colour, it was replaced with fresh solution, and the process repeated. The samples were then rinsed in distilled water three times, freeze-dried, and the moisture contents allowed to equilibrate with atmosphere before the samples were weighed.

Before being treated in the NaOH solution described in the previous paragraph, collagen pseudomorphs of modern animals were placed in de-fatting solution made of methanol, chloroform and water (ratio 2:1:0.8) for approximately 4 hours to remove lipids. It is acknowledged that some amounts of lipids in bone may be preserved long after death and these can actually alter the isotope composition of collagen by 5 to 10‰ (Ambrose 1990, 1993, Liden *et al.* 1995; Jørkov *et al*. 2007) if not removed. It was deemed unnecessary to treat archaeological samples with de-fatting solution since most of the lipids would have been lost through leaching. It is important to mention that some researchers (e.g. Liden *et al.* 1995) have rejected the use of NaOH to remove lipids. They argue that pretreatment with NaOH is not effective in removing lipids but unfortunately, their rejection is based on a study of very few (n=14) samples from climates with good preservation.

Thick bone samples were slightly problematic to decalcify because while the centers of the bones were yet to be de-mineralised, the outer parts were often de-mineralised and would start to disintegrate. Such samples had to be removed from the acid solution even though they were not

completely de-mineralised. Sub-samples measured in the mass spectrometer were taken from the edges where decalcification had occurred.

Samples of bone collagen of between 0.4 and 0.8milligrams were weighed on a Sartorius micro balance and placed into tin capsules. These were combusted in a Flash EA 1112 series elemental analyser (Thermo Finnigan, Italy) and the gases produced were fed into a Delta Plus XP IRMS (isotope ratio mass spectrometer) (Thermo electron, Germany) via a Conflo 111 gas control unit (Thermo Finnigan, Germany). The in-house standards used were: valine, chocolate and N3, which have all been calibrated against International Atomic Energy Agency (IAEA) standards at the UCT laboratory. Repeated analysis of the standards demonstrated that a precision of better than ±0.2‰ was obtained for both carbon and nitrogen.

COLLAGEN QUALITY INDICATORS

Fresh collagen consists of triple helical structures of amino acids held together by peptide bonds (van Klinken 1999). During degradation, the peptide bonds break down and consequently loose amino acids as they leach out of the bone and contaminants invade. These postmortem reactions can alter the original isotope composition of the samples. It is, therefore, necessary to determine the extent to which contamination and collagen degradation have occurred (DeNiro 1985; Schoeninger *et al*. 1989; Ambrose 1990; Grupe 1995; van Klinken 1999; Jørkov *et al.* 2007) to ensure the validity of isotope results.

Procedures used to determine the 'purity' of collagen are loosely referred to as 'collagen quality indicators'. They include, among others, collagen yield, atomic carbon to nitrogen ratios, carbon and nitrogen concentrations, amino acid profiles, infrared spectra, radiocarbon dating and others. For the purposes of this study, the first four indicators have been used. These are the most widely cited collagen quality indicators in the literature. They are inexpensive and easy to establish and yet very reliable (DeNiro 1985; Schoeninger *et al*. 1989; Ambrose 1990; Grupe 1995; Pate 1998; van Klinken 1999; Jørkov *et al.* 2007).

Collagen yield is the weight of the collagen extracted expressed as a percentage of the original bone weight. Fresh bone contains approximately 22% collagen (Kohn & Cerling 2002),

archaeological bones usually contain less, depending on how well preserved they are. In warm climates, (e.g. sub tropical Africa) collagen yields of less than 3.5% are considered too degraded to yield reliable isotope measurements (Ambrose 1990; Grupe 1995) while in cool temperate climates the cut-off may be as low as 1% (van Klinken 1999). In the laboratory, acid concentrations, length of time that the sample is in the acid and physical state of the sample (i.e. is it a bone chunk, as in this study, or is it powdered?) affect the collagen yield. The longer the bone is kept in the acid and the more concentrated the acid, the more the collagen disintegrates and dissolves. In such instances, collagen yield will be low even if preservation was good. Ambrose (1990) and Pate (1998) both recommend that samples with low collagen yields should be subjected to other tests of collagen quality. In this study, all samples, including those with low collagen yields, were measured and discarded only if they had unacceptable C:N ratios, carbon percentages and/or nitrogen percentages.

The amount collagen of produced after pretreatment of bone can be increased by increasing the size of bone to be demineralised in cases where initial quantity was less than that required in the mass spectrometer (Ambrose 1990, Pate 1998, van Klinken 1999). Unfortunately, this may mean that there will be even more contaminants to deal with in the pretreatment phase (van Klinken 1999).

The use of weight percent carbon (%C) and nitrogen (%N) concentrations as collagen quality indicators was first proposed by Ambrose (1990) and has been supported by many scientists like Pate (1998), van Klinken (1999) and Jørkov *et al*. (2007). These are weights of C and N expressed as percentages of combusted collagen samples. Climatic conditions are known to affect weight %C and %N of well preserved collagen (van Klinken 1999). For example, in tropical Africa weight %C and %N are slightly higher (Ambrose 1990) than in Mediterranean Europe (van Klinken 1999). The two regions have values different from those reported from open semi-arid sand dunes (Pate 1998).

Well-preserved bone collagen is reported to have weight %C of approximately 40 - 47% and weight %N of around 14 -17% (Ambrose 1990, Grupe 1995; Jørkov *et al.* 2007). The values reported by van Klinken (1999) are slightly lower, with an average weight %C of 35% and weight %N of

between 11 and 16%. Pate (1998) reported figures as low as 13.0% and 4.8% and for C and N respectively. If carbon values are higher than reported for specific environments, they could be indicative of additional organic carbon during digenesis while lower values are often associated with additional inorganic carbon to collagen (van Klinken 1999).

The use of atomic C:N ratios as indicators of bone collagen preservation was proposed by DeNiro (1985). According to his study, well preserved collagen should have atomic C:N ratios ranging between 2.9 and 3.6 (n=172). These values are very close to those reported by Ambrose (1990) for modern bone samples i.e. 2.9 to 3.5. In another study, van Klinken (1999) reported a slightly narrower range of 3.1 to 3.5 (n=2146). For the purposes of this study, the widely accepted range of values reported by DeNiro (1985) has been used.

PREPARATION OF ENAMEL APATITE

Teeth were brushed to remove dust adhering to their surfaces. Then, using diamond-tipped dental drill bits, approximately 3mg of enamel powder was drilled along the crown height on either the labial or the lingual surface of the tooth into a centrifuge tube. A 1-1.5ml sodium hypochlorite solution (NaOCl) (50ml ordinary household bleach: 50ml H_2O) was added to the tube and left for one hour to dissolve the organic component (van der Merwe *et al.* 2003). Because of the fineness of the enamel powder produced when using dental drills, treatment with sodium hypochlorite was limited to one hour to avoid sample loss (Garvie-Lok *et al*. 2004). The samples were then centrifuged for three minutes just before the end of the 1-hour period. The sodium hypochlorite was suctioned off and the samples were rinsed twice with de-ionised water for 10 minutes each time, with a three- minute centrifuging before the end of each 10minute period. Next, a 0.1M acetic acid solution (CH_3CO_2H) was added to the samples to remove carbonates, which may have been adsorbed from the grave environment (Sullivan & Krueger 1983; van der Merwe *et al.* 2003). This was left to react for ten minutes, centrifuged for one minute and the acetic acid solution suctioned out. The samples were rinsed three times with distilled water (10 minutes each time) then freeze-dried.

Enamel has large crystals that are extremely compact, making it less susceptible to postmortem alteration. Because of the physical structure of enamel apatite, there are generally no concerns over the reliability of its isotope ratios on archaeological and modern materials. Therefore, unlike bone collagen, there are no enamel quality indicators. It is only in very ancient fossilised materials that there may be concerns (Kohn & Cerling 2002).

Some enamel apatite samples were analysed using a Kiel II device. Apatite was reacted with phosphoric acid at 72ºC, and the CO_2 evolved was cleaned and then introduced into a Finnigan MAT 252 Isotope Ratio Mass Spectrometer for measurement of $^{13}C/^{12}C$ ratios. The Kiel device unfortunately broke down prior to completion of the data collection, and was replaced with a new gas bench (CTC Analytics A200S Autosampler), also connected to the Finnigan MAT 252. The reference materials used in the isotopic analysis of enamel included Cavendish Marble, NBS 18, NBS 19, NBS 20, Carrara Z marble & Lincoln Limestone. These standards were reproduced at a precision of <0.2‰ on both the Keil and the gas bench.

STATISTICAL ANALYSIS OF RESULTS

Results of all isotope analysis were interpreted to make inferences about diets of humans and animals at each site, and to search for differences and similarities between sites. Statistical calculations were employed to achieve this. In this section statistical tests used for comparative analysis are described

The Mann-Whitney U test (also known as Wilcoxon's sum of rank test) investigates whether there is a difference between the distributions of two samples rather than between means or medians (Kaplan 1987). It is used to test the null hypothesis that the two samples being compared are so similar that they could have been drawn from the same population (Kaplan 1987, Hutchinson 1993). Data from the two sample groups are combined and ranked but the sum of the ranks are obtained separately for each sample group population. Since calculations are based on ranked data, results viewed as outliers are included in the Mann-Whitney U test calculation.

For humans, Mann-Whitney U tests were calculated if the number of individuals exceeded three per site. Data were pooled from both males and females and individuals of all age groups were included. In addition, the $\delta^{13}C$ and $\delta^{15}N$ results of humans aged 10years and above from Toutswemogala and Bosutswe were compared to those from Bambandanyalo and Makapansgat (both LIA sites) as well as the proto-historic humans from Kakamas and Riet River (Ambrose 1986; Ambrose & DeNiro 1986a; Lee-Thorp *et al.* 2003).

Most sites from the study area had adequate domestic animal samples to allow for calculations of Mann-Whitney U tests. Similar calculations were made between archaeological and modern animals from Bosutswe and Toutswemogala. Animal bone collagen results from the study area were compared to those from the LIA sites of Schroda and Pont Drift (Smith 2005) in the Shashe-Limpopo area. There were too few wild animals to allow for a useful comparison between any two sites.

SUMMARY OF MATERIALS AND METHODS

In summary, this chapter has provided detailed accounts of human and animal remains used in the study and the criteria used for their selection. The samples come from three regions, the Toutswe area, the Tsodilo Hills and the Okavango Delta. Toutswe sites included in the study cover all three levels of the settlement hierarchy defined by Denbow (1982).

The human samples comprise 23 individuals from class 1 Toutswe sites, 11 from class 2 and 41 from class 3 sites. In addition, four humans from the Tsodilo Hills and two from the Okavango River were sampled. Domestic animal samples comprise 29 cattle and 87 ovicaprids from archaeological deposits in the Toutswe area. Still within the Toutswe area, there are 30 cattle and six ovicaprids from modern Batswana cattle posts at Bosutswe and Toutswemogala. Three archaeological cattle and three ovicaprids from the Tsodilo Hills form part of the domestic animal sample group used in the study. Following an outbreak of foot and mouth disease a few years earlier, the Botswana government prohibited transport of modern animal materials from the

northwest. As a result, there are no modern animals from the Tsodilo Hills and the Okavango River in this study.

Other domestic species analysed are dog, donkey and horse. These three species are not kept for consumption but can still provide isotopic evidence for climatic and environmental conditions. Besides domestic animals, other faunal samples in this study include zebra, steenbok, tortoise, hare, kudu, *Raphicerus* and jackal.

Detailed descriptions of techniques used to extract collagen from bone have also been presented in this chapter. Bone fragments were decalcified in hydrochloric acid and treated with sodium hydroxide solution to remove humic acids. Recent samples were also de-fatted with organic solvents. The quality of collagen was determined from collagen yield, atomic C:N ratios, and weight percentage carbon and nitrogen as described in the literature. Powdered tooth enamel was soaked in dilute sodium hypochlorite to dissolve organics, and then treated briefly with dilute acetic acid to remove any carbonates adsorbed from the grave environment.

Lastly, the chapter also looked at the methods of statistical analysis employed in the interpretation of isotope results. The Mann-Whitney test is the preferred statistical tool for comparing and contrasting $\delta^{13}C$ and $\delta^{15}N$ results of species from different sites.

4. RESULTS FROM TOUTSWE SITES

INTRODUCTION

The results of stable isotope analysis of bone collagen and enamel apatite from animal and human remains from Toutswe sites are presented in this chapter. The sites are grouped into the three levels of settlement hierarchy described by Denbow (1982). Class 1 sites are Kgaswe B55, Bonwapitse, Thataganyane, Serowe and Swaneng Hills. Class 2 sites are Taukome and Thatswane while the two class 3 sites are Bosutswe and Toutswemogala.

The quality of collagen is evaluated by means of collagen yield, weight percentages of nitrogen and carbon and atomic C:N ratios. All of these collagen quality indicators were reviewed in detail in Chapter 3. In brief, accepted collagen yield is between 3.5 and ~22%, weight %C of about 35 to 47%, weight %N of between 11 and 16% and atomic C:N ratios of 2.9 to 3.6 (DeNiro 1985; Schoeninger *et al.* 1989; Ambrose 1990; Pate 1998; van Klinken 1999; Jørkov *et al.* 2007).

Isotope values of animals were measured from one bone fragment per individual. In the case of human remains, more than one bone fragment from different skeletal parts was included where possible. It was necessary to sample more than one skeletal element on humans to determine whether there were any dietary shifts during the individual's lifetime. Where isotopic variation within an individual is small (<3‰), the $\delta^{13}C$ and $\delta^{15}N$ values are averaged.

Human isotope values are interpreted in relation to their animal counterparts. Unfortunately, at some class 1 sites (Bonwapitse, Thataganyane, Serowe Hill and Swaneng Hill) there were no faunal samples suitable for analysis. For these sites, the isotope results of humans are compared to those of Kgaswe B55.

Enamel apatite samples from animals and humans were extracted from one or more teeth per individual. Average $\delta^{13}C_{ap}$ values are calculated for each individual, and results are compared with the $\delta^{13}C$ values for collagen to determine any dietary shifts within the lifetime of the individual.

Isotope values are used to estimate the human diets and subsistence strategies. Samples from animal remains are used to determine the dominant vegetation in pastures, which is then used as proxy evidence for climatic conditions. Unless specified, all animal and human samples come from archaeological deposits.

TOUTSWE CLASS 1 SITES

The following section presents isotope results of animals and humans from class 1 sites in the Toutswe hierarchy. Class 1 sites have been described as small cattle posts or homesteads where livestock were kept. They are located on arable lands and thereby indicating the importance of farming at these sites. Remains of kraals are smaller and shallower than those found at class 2 and 3 sites.

Class 1 sites are crucial in this research because revisionists believe that they were occupied by farmers and frequented by hunter-gatherers. Denbow and Wilmsen (1990) believe that hunter-gatherers provided labour at the cattle posts in exchange for food from farmers. It is possible that some hunter-gatherers were buried within the class 1 Toutswe sites. Such individuals would be identified through depleted $\delta^{13}C$ values.

KGASWE B55

The results of the isotopic analyses of all animal samples from Kgaswe B55 included in the study are shown in Table 4.1. The samples had well preserved collagen. Only two samples UCT 12249 and UCT 12250 were rejected because their atomic C:N ratios fall outside the accepted limits.

The sample from a cow at Kgaswe B55 (UCT 12246) has $\delta^{13}C$ value of -5.9‰. The $\delta^{13}C$ value is indicactive of an animal raised on a pure C_4 grass diet. The $\delta^{13}C$ values of ovicaprids from Kgaswe B55 are not averaged because of the amount of variation (Table 4.1). One of samples has a $\delta^{13}C$ value close to -10‰ and the other (UCT 12247) has a more depleted $\delta^{13}C$ value of -16.4‰. This depleted $\delta^{13}C$ value strongly suggests that the bulk diet of the animal came from C_3 photosynthetic trees. Only two samples were available for analysis and it is difficult to determine if the variation in $\delta^{13}C$ values is just random or if it is linked to dietary variation.

The $\delta^{15}N$ value of the cow (6.8‰) is similar to those for ovicaprids, as is expected since both species are at the same trophic level. The $\delta^{15}N$ values for the ovicaprids average of 7.5‰. The herbivores have $\delta^{15}N$ values around 7‰.

Table 4.1: Collagen quality indicators, $\delta^{13}C$ and $\delta^{15}N$ values of Kgaswe B55 animals

UCT No	Context	Collagen yield (%)	Atomic C:N	Wt C (%)	Wt N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
Cow							
12246	1, ash pit 7	10.3	3.5	38.9	13.1	-5.9	6.8
Ovicaprids							
12247	2, ash pit 7	10.0	3.6	35.3	11.5	-16.4	7.4
12248	5, ash pit 5	18.7	3.5	38.3	12.9	-9.6	7.6
~~12250~~	~~8, ash pit 2~~	~~10.2~~	~~3.9~~	~~30.7~~	~~9.1~~	~~-10.5~~	~~6.5~~
~~12249~~	~~7,ash pit 5~~	~~19.5~~	~~4.1~~	~~26.7~~	~~7.6~~	~~-10.7~~	~~7.4~~

Rejected samples are shown by a strike through

The collagen yields of humans from Kgaswe B55 range from 2.9 to 29.7% (Table 4.2). The sample with the lowest yield, UCT 12147, has an atomic C:N ratio of 3.2, and a composition of 43.1% C and 15.5% N by weight. These indicators all fall into the acceptable ranges so the isotopic analyses are likely to be reliable.

Where more than one sample from the same individual was analysed, the variations in $\delta^{13}C$ and $\delta^{15}N$ values do not exceed 1‰. Table 4.3 shows the average $\delta^{13}C$ and $\delta^{15}N$ values of each individual. The $\delta^{13}C$ values of individuals lie between -11.5‰ and -7.7‰ with a mean value of -9.4±0.9‰. This mean value strongly suggests that humans had a C_3 plant contribution to their otherwise C_4 crop-based diets. The standard deviation of 0.9 for the 17 individuals is worth noting as it probably implies uniform dietary pattern for all individuals.

The calculated standard deviation already strongly suggests diets of similar isotope origins at Kgaswe B55. An interesting aspect would be to determine if individuals can be grouped into sex or age categories within this relatively limited isotope range. As seen of Figure 4.1 there are no patterns of both $\delta^{13}C$ and $\delta^{15}N$ values according to sex or age groups. If there were differential access to food between sexes or age groups, then the food divided would have been of similar isotopic origins. For example, in Tswana tradition, different parts of cow meat are distributed according to age and sex of the consumers (personal experience). This differential access to cow meat cannot be detected using stable isotope ratios.

The $\delta^{15}N$ values cluster between 8.2‰ and 10.8‰, with a mean of 9.7±0.7‰. The mean $\delta^{15}N$ value of humans is 2.7‰ higher than that of the herbivores. This is as expected since the literature suggest a ~2 – 4 ‰ enrichment in $\delta^{15}N$ values between trophic levels (Ambrose 1991; Hedges & Reynard 2007). Furthermore, the $\delta^{15}N$ results for humans indicate less reliance on legumes, which would have resulted in $\delta^{15}N$ values of more than 4‰ compared to herbivores. There is, thus, consistency in the isotopic interpretation of diets according to $\delta^{13}C$ and $\delta^{15}N$ results as both indicate less consumption of legumes than cereal crops.

The standard deviation (0.7) for the $\delta^{15}N$ values supports the dietary uniformity suggested earlier on the basis of $\delta^{13}C$ values. Within this very tight cluster, it was expected that the infants would have the highest $\delta^{15}N$ values due to reliance on milk. Figure 4.1 shows no differences in $\delta^{15}N$ values between infants and adults. It is difficult to explain why the infants do not have higher $\delta^{15}N$ results compared to adults but one possibility worth mentioning is that they probably died shortly after birth in which case they were not exposed to milk for long.

Table 4.2: Collagen quality indicators, $\delta^{13}C$ and $\delta^{15}N$ values of Kgaswe B55 humans

UCT No	Grave	Skeletal Part	Collagen Yield (%)	Atomic C:N	Wt C (%)	Wt N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
12143	2	Rib	10.7	3.2	38.2	14.0	-11.2	9.4
12144	2	Humerus	20.2	3.3	37.6	13.5	-10.3	9.6
12559	4	Skull	25.6	3.2	41.2	14.8	-8.8	10.5
12241	5	Rib	18.8	3.5	37.9	12.7	-9.2	10.5
12145	5	Vertebra	19.9	3.1	35.6	13.3	-8.8	10.4
12146	9	Humerus	11.1	3.6	37.4	12.0	-9.8	9.6
12147	9	Femur	2.9	3.2	43.1	15.5	-9.9	8.9
12242	11	Fibula	14.5	3.5	37.5	12.4	-10.1	8.8
12148	12	Femur	19.6	3.5	47.2	17.2	-9.1	9.6
12149	13	Cranium	11.6	3.2	37.0	12.2	-9.2	8.8
12150	14	Rib	6.0	3.5	37.1	13.7	-9.8	10.0
12151	14	Vertebra	13.4	3.2	37.1	14.2	-9.9	9.9
12152	15	Rib	9.6	3.0	36.7	13.6	-11.5	10.7
12153	15	Femur	7.7	3.1	33.1	12.4	-11.5	10.8
12154	16	Rib	14.4	3.1	35.9	13.2	-8.6	10.6
12155	16	Femur	15.6	3.2	34.8	12.9	-9.1	10.9
12156	17	Scapula	29.7	3.2	36.9	14.5	-8.6	10.1
12157	17	Pelvis	21.4	3.0	37.2	14.3	-7.9	9.9
12158	18	Ulna	8.9	3.0	39.5	14.6	-8.4	9.4
12159	19	Cranium	9.9	3.2	37.7	12.3	-9.1	8.2
12160	20	Rib	15.8	3.6	39.7	14.6	-8.8	9.5
12161	21	Rib	11.7	3.2	38.5	13.9	-9.3	9.6
12162	24	Cranium	20.8	3.2	41.3	11.2	-11.9	9.6
12560	24	Humerus	17.9	3.2	41.3	15.0	-7.3	9.3
12561	24	Ilium	15.8	3.2	41.3	15.2	-8.0	9.4
12163	25	Femur	22.1	3.5	37.6	12.5	-10.6	9.6
12164	25	Cranium	18.1	3.2	42.8	15.5	-10.3	9.9

Table 4.3: Average $\delta^{13}C$ and $\delta^{15}N$ values of Kgaswe B55 humans

Grave No	Age(Years)	Sex	$\delta^{13}C$(‰)	$\delta^{15}N$(‰)
2	30-50	Female	-10.8	9.5
4	5-10		-8.8	10.5
5	17-23	Male	-9.0	10.5
9	40-60	Male	-9.9	9.3
11	20-50	Indeterminate	-10.1	8.8
12	30-60	Indeterminate	-9.1	9.6
13	30-60	Indeterminate	-9.2	8.8
14	40-60	Female	-9.9	10.0
15	10-12		-11.5	10.8
16	20-30	Male	-8.9	10.8
17	50-75	Male	-8.3	10.0
18	0-1		-8.4	9.4
19	40-60	Male	-9.1	8.2
20	0-1		-8.8	9.5
21	0-1		-9.3	9.6
24	15-20		-7.7	9.4
25	30-60	Male	-10.5	9.8
		Mean:	**-9.4 ± 0.9**	**9.7± 0.7**

Figure 4.2 is a diagrammatic representation of the isotope results for all species from Kgaswe B55. The distributions of both $\delta^{13}C$ and $\delta^{15}N$ values are as expected based on the dietary habits of the species. For instance, humans are higher along the $\delta^{15}N$ scale and there is no overlapping between the humans (omnivores) and domestic animals (herbivores).

The next section presents the results for enamel apatite, which shows dietary habits of the individuals during developmental years. For cattle, only one of the four teeth was associated with a mandibular fragment (UCT 12441, specimen 1); the remaining three were loose teeth included to check for consistency of $\delta^{13}C_{ap}$ results of cattle. Therefore, no average value is calculated for the $\delta^{13}C_{ap}$ values of cattle (Table 4.4). Like the single value for bone collagen reported above, these results are indicative of a predominantly C_4 photosynthetic plant diet. Therefore, the cattle pastures were relatively constant for the lifespan of the animals.

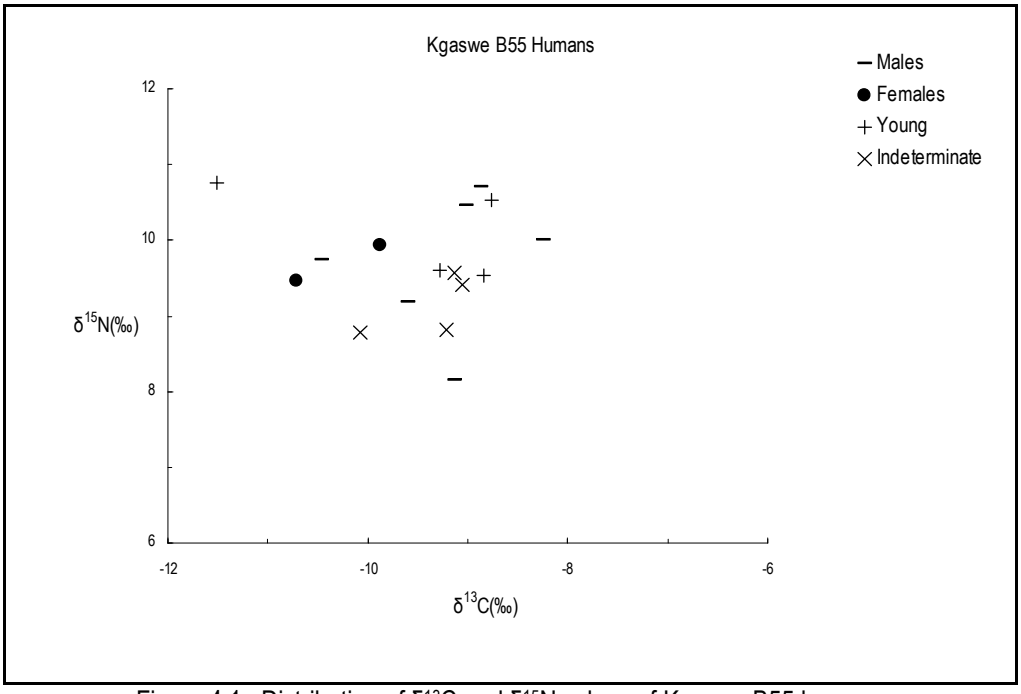


Figure 4.1: Distribution of $\delta^{13}C$ and $\delta^{15}N$ values of Kgaswe B55 humans

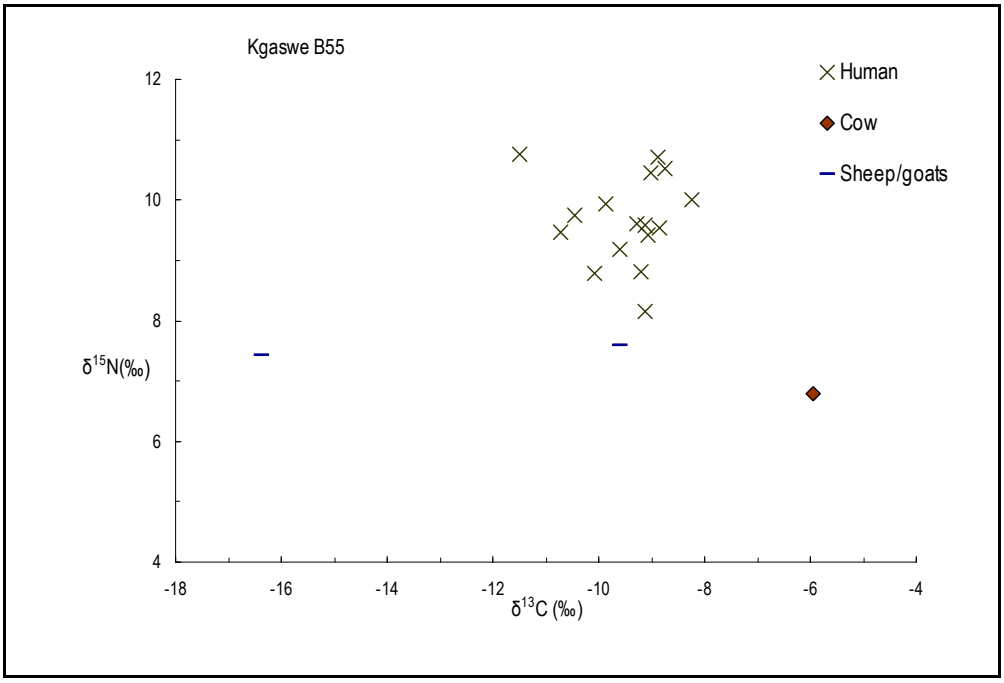


Figure 4.2: Distribution of $\delta^{13}C$ and $\delta^{15}N$ values of all species at Kgaswe B55

All sheep/goat teeth are associated with either mandibular or maxillary fragments. The $\delta^{13}C_{ap}$ values range between -4.9‰ and -2.0‰. The average $\delta^{13}C_{ap}$ is -3.7±1.2‰, with a range of 2.9‰. Ovicaprids have more depleted $\delta^{13}C_{ap}$ values compared to cattle and thereby suggesting that the ovicaprids consumed more C_3 photosynthetic plants than cattle. These animals are mixed feeders and it not surprising that their δ^{13}Cap values show more browsing than is the case with cattle. Like cattle, ovicaprids show consistency of feeding habits from early age to time of death.

The two zebra teeth included are loose teeth and it is therefore not possible to determine whether they come from one or two individuals. They are included to provide an idea of the grazing environment available to wild animals at the time when the site was occupied. These results are not included in the overall statistical and comparative analysis between sites (details in the discussion chapter). The two zebra teeth have $\delta^{13}C_{ap}$ values of 0.3 and 0.7‰ (Table 4.4). These are relatively lower than $\delta^{13}C_{ap}$ values for cattle teeth, although both species are grazers. However, the differences between zebra and cattle $\delta^{13}C_{ap}$ values are too small to suggest significant differences in feeding habits. A medium bovid (species not identified) tooth has a $\delta^{13}C_{ap}$ value of -3.3‰ (Table 4.4), within the range of other species present. This animal was probably a mixed feeder because it has $\delta^{13}C_{ap}$ value similar to those of mixed feeding ovicaprids.

Thirteen teeth from six humans have $\delta^{13}C_{ap}$ values ranging between -6.9 and -2.9‰ (Table 4.5). A minimum of two teeth per individual were available for all individuals. Kgaswe B55 16 has similar $\delta^{13}C_{ap}$ values for a mandibular permanent first incisor (-3.9‰) and a maxillary permanent second molar (-4.5‰) but a maxillary third molar of the same individual has $\delta^{13}C_{ap}$ of -6.0‰: a larger difference than might be expected on an isotopically consistent diet. Collagen δ^{13}C values of the rib and femur of the same skeleton differ by <1‰, averaging -8.9‰. This individual was 20 - 30 years old at the time of death. It seems, therefore, that the $\delta^{13}C_{ap}$ value of the M^3 cannot confidently be associated with a significant shift in diet.

In general, enamel apatite $\delta^{13}C_{ap}$ values at Kgaswe B55 (mean $\delta^{13}C_{ap}$ = -4.3‰) are more depleted than expected for farmers growing C_4 photosynthetic crops. The depleted $\delta^{13}C_{ap}$ values of the Kgaswe B55 humans could mean that the children were raised on diets in which C_3 photosynthetic plants such as legumes and cowpeas and wild foods dominated. The overall standard deviation

for the $\delta^{13}C_{ap}$ values strongly indicates that the dietary isotope signatures of the Kgaswe B55 children were uniform.

The C_3 component in the diet is not strong enough to suggest a hunting and gathering mode of subsistence. The shifts in carbon isotope values between enamel apatite and bone collagen are too small to suggest a change from foraging to farming during the individuals' lifetimes. It is possible that some foragers did live at Kgaswe B55 but isotopic evidence indicates that the skeletal collection from this site does not include them.

Table 4.4: Enamel apatite $\delta^{13}C_{ap}$ results for animals from Kgaswe B55

UCT No	Tooth	$\delta^{13}C_{ap}$ (‰)	Individual	Mean $\delta^{13}C_{ap}$ (‰)
Cattle				
12441	01, p_2	3.0	1	3.0
12444	03, m_1	1.9	3	1.9
12455	11, M_3	3.1	11	3.1
12456	12, M^3	2.7	12	2.7
Ovicaprids				
12442	02	-3.5		
12443	02	-4.1	02	-3.8
12446	05	-2.6	05	-4.0
12247	05	-2.3	07	-4.9
12248	05	0.3	08	-2.0
12451	07	-4.9	**Mean:**	**-3.7±1.2**
12452	08, M_3	-2.0		
Medium bovid				
12453	09, M	-3.3		
Zebra				
12445	04, M	0.7		
12449	06, M	0.3		

Table 4.5: Enamel apatite $\delta^{13}C_{ap}$ results for humans from Kgaswe B55

UCT No	Grave, Tooth	$\delta^{13}C_{ap}$ (‰)	Grave No.	Mean $\delta^{13}C_{ap}$ (‰)
12313	2, C*	-3.0	2	-3.9
12314	2, M^3	-3.9	5	-4.7
12315	5, P^1	-4.5	9	-4.6
12316	5, M^3	-4.9	14	-2.9
12317	9, P_2	-5.5	15	-5.5
12318	9, M_2	-3.8	16	-4.2
12319	14, C*	-2.9	**Mean:**	**-4.3±1.0**
12321	15, C*	-5.2		
12322	15, P^1	-5.8		
12323	16, I_1	-3.9		
12324	16, M^2	-4.5		
12325	16, M3	-6.0		

The overall human $\delta^{13}C$ values strongly support the archaeological evidence for farming of C_4 photosynthetic crops provided the bulk of the dietary plant protein. The archaeological evidence includes carbonised remains of sorghum and millet as well as numerous granaries on the site (Denbow 1983b). However, C_3 photosynthetic plants appear to have been almost equally important. Enamel apatite $^{13}C/^{12}C$ ratios provide strong evidence that diets of children at Kgaswe B55 included substantial quantities of plants that use the C_3 photosynthetic pathway. These could have been a combination of domestic C_3 plants (legumes, melons, greens) and wild plants. The C_3 component of the diet during childhood was small and can not be attributed to full-time foraging.

BONWAPITSE

The seven bone samples from three humans at Bonwapitse have well-preserved collagen. The results are shown in Table 4.6 below. UCT 12576 has relatively lower %C and %N values but are, nevertheless, within acceptable limits. It is not clear why these values for UCT 12576 are much lower than the rest of the sample group.

Table 4.7 shows the average $\delta^{13}C$ and $\delta^{15}N$ values for each of the three individuals. Bonwapitse 1 and 2 both have $\delta^{13}C$ values of -9.2‰ whereas Bonwapitse 3 has a slightly more depleted $\delta^{13}C$

value of -11.6‰. Bonwapitse 3 probably had more C_3 photosynthetic plants in his diet than the other two individuals. The mean $\delta^{13}C$ value of -10.0±1.4‰ is similar to the mean value reported for Kgaswe B55. Bonwapitse inhabitants were farmers and consumers of C_4 crops who supplemented their diets with plants using the C_3 photosynthetic pathway. The C_3 photosynthetic plants could have been both domesticated and wild plants.

Table 4.6: Collagen quality indicators, $\delta^{13}C$ and $\delta^{15}N$ values of Bonwapitse humans

UCT No	Grave	Skeletal part	Collagen Yield (%)	Atomic C: N	Wt C (%)	Wt N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
12572	1	Rib	3.4	3.3	38.4	13.6	-9.0	9.5
12573	1	Humerus	5.0	3.3	35.8	12.7	-9.3	8.8
12575	2	Femur	9.3	3.3	38.2	13.6	-9.0	8.9
12576	2	Tibia	14.1	3.4	25.7	8.7	-9.4	8.7
12577	3	Rib	20.0	3.2	41.6	15.0	-11.6	8.0
12578	3	Humerus	20.6	3.2	41.8	15.3	-11.4	8.0
12579	3	Tibia	19.9	3.2	41.5	15.2	-11.8	7.9

In the absence of animal samples, it is difficult to assess the effect of the trophic level and climate on the $\delta^{15}N$ values of the humans from Bonwapitse. It is noted that the mean $\delta^{15}N$ value of Bonwapitse is similar to the value reported for Kgaswe B55 humans despite significant differences in sample sizes. It is therefore, assumed that the sites were under similar climatic conditions and that both communities had substantial meat protein intake.

Table 4.8 shows that four of the five teeth from the three humans have $\delta^{13}C_{ap}$ values ranging between -3.9 and -3.1‰. A permanent mandibular canine of Bonwapitse 2 (UCT 12751) is an outlier with $\delta^{13}C_{ap}$ value of -0.3‰, which is most probably due to random variation. The three individuals have an overall $\delta^{13}C_{ap}$ mean value of -2.9±1.0‰. The $\delta^{13}C_{ap}$ values are very similar for all three individuals despite the fact that Bonwapitse1 was a juvenile of 15-18 years while the other two were adults aged 40-60 years old. Therefore, the dietary isotope composition of Bonwapitse humans remained stable over successive generations.

The average $\delta^{13}C_{ap}$ of Bonwapitse humans is slightly less negative than the value for Kgaswe B55 humans. The difference might be due to differences in sample sizes between the two sites or it could reflect real dietary differences. If the latter, then Bonwapitse humans consumed less C_3 photosynthetic plants during developmental years compared to Kgaswe B55. Unlike bone collagen $\delta^{13}C$ values, Bonwapitse 3 has an enamel apatite $\delta^{13}C_{ap}$ value similar to the other two individuals.

Table 4.7: Average $\delta^{13}C$ and $\delta^{15}N$ values of Bonwapitse humans

Grave No	Age(Years)	Sex	$\delta^{13}C$(‰)	$\delta^{15}N$(‰)
1	15-18	Male	-9.2	9.1
2	40-60	Male	-9.2	8.8
3	40-60	Male	-11.6	8.0
		Mean:	**-10.0±1.4**	**8.6±0.6**

Table 4.8: Enamel apatite $\delta^{13}C_{ap}$ results for Bonwapitse humans

UCT No	Grave, tooth	$\delta^{13}C_{ap}$ (‰)	Grave	Mean $\delta^{13}C_{ap}$ (‰)
12749	1, i^1	-3.2	1	-3.1
12750	1, C*	-3.1	2	-1.9
12752	2, P_1	-3.4	3	-3.8
12751	2, C*	-0.3	**Mean:**	**-2.9±1.0**
12753	3, P^2	-3.7		
12754	3, M_2	-3.9		

In summary, the three humans from Bonwapitse have $\delta^{13}C$ and $\delta^{13}C_{ap}$ values that strongly suggest the individuals consumed diets in which C_4 photosynthetic crops played a major role. The similarity in enamel apatite $\delta^{13}C_{ap}$ values between Bonwapitse 3 and the other two individuals strongly suggest that they all had similar dietary components during childhood. The difference in $\delta^{13}C$ values of Bonwapitse 3 from the rest of the group is regarded as random variation in diet between individuals.

None of the individuals can be classified as a forager. Consistency from childhood to adulthood isotope signatures rules out the possibility that one of the individual could have been forager at an earlier stage in life. The $\delta^{15}N$ results indicate substantial consumption of meat.

THATAGANYANE HILL

Cranial fragments from the two Thataganyane individuals are well preserved as indicated on Table 4.9. Teeth of one individual were not available for isotopic analysis. The individuals' mean $\delta^{13}C$ value is -8.3‰ and the mean $\delta^{15}N$ value is 10.3‰. These results are generally similar to those reported for Kgaswe B55. They indicate diets in which C_4 grains played a bigger role than C_3 fruits and vegetables.

From Thataganyane Hill 1 a maxillary permanent incisor and a mandibular second premolar yielded $^{13}C/^{12}C$ ratios of -1.9 and -0.9‰ (Table 4.10).The differences in carbon isotope ratios of this individual are small and, therefore, might not be associated with dietary change. The mean $\delta^{13}C_{ap}$ value of -1.4‰ is a strong indication that during childhood the individual was raised on a diet comprising both C_4 and C_3 photosynthetic plants.

Dietary isotope signatures of the two adults from Thataganyane Hill strongly indicate that they were dependent on C_4 photosynthetic crops. The C_3 crops and wild plants also contributed to the overall diet. The mean $\delta^{15}N$ value of 10.3‰ is comparable to mean $\delta^{15}N$ values of individuals from Kgaswe B55 and Bonwapitse. The dietary isotope composition of the Thataganyane humans was similar to that of Kgaswe B55 and Bonwapitse. The bone collagen $\delta^{13}C$ value and the enamel apatite $\delta^{13}C_{ap}$ value of Thataganyane 1 shows consistency in dietary isotope composition from childhood to adulthood.

Table 4.9: Collagen quality indicators, $\delta^{13}C$ and $\delta^{15}N$ values of Thataganyane humans

UCT No	Grave	Skeletal part	Collagen Yield (%)	Atomic C: N	Wt C (%)	Wt N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
12165	1	Skull	19.5	3.3	41.4	14.7	-8.4	10.3
13053	2	Skull	18.6	3.4	39.5	13.6	-8.1	10.3
						Mean:	**-8.3**	**10.3**

Table 4.10: Enamel apatite $\delta^{13}C_{ap}$ results of Thataganyane humans

UCT No	Grave, tooth	$\delta^{13}C_{ap}$ (‰)	Grave	$\delta^{13}C_{ap}$ (‰)
12357	1, I^1	-1.9	1	-1.4
12358	1, P_2	-0.9		

SWANENG HILL

No animal mandible or maxilla fragments from Swaneng Hill were available for inclusion in the study. In order to prevent destruction, the single human skull from Swaneng Hill was not broken to obtain a bone collagen sample. In stead, two teeth were drilled to extract enamel apatite.

Swaneng Hill 1 has more depleted $\delta^{13}C_{ap}$ values of -4.5‰ a first maxillary premolar and -7.5‰ on a mandibular permanent canine (Table 4.11). The individual's mean $\delta^{13}C_{ap}$ is not calculated because the two teeth differ by a wide margin of 3‰, which could be related to dietary change. If indeed dietary change took place, then it would have involved an inclusion of foods with more depleted $^{13}C/^{12}C$ ratios in later childhood as shown by the $\delta^{13}C_{ap}$ value of the mandibular childhood. Unfortunately, the rest of the skeleton is missing which could be used to determine individual's dietary isotope composition of the last few years before death.

The isotope evidence of the individual from Swaneng Hill indicates a diet different from those at other class 1 sites. The individual subsisted on diets in which C_3 photosynthetic plants dominated during his developmental years. Unfortunately, it is difficult to determine whether the C_3 component came mostly from domestic plants (legumes, melons, peas, nuts) or from the wild (greens, other vegetables, fruits, nuts). More archaeological evidence is needed to make strong arguments regarding the subsistence pattern of this individual.

RESULTS FOR SEROWE HILL

Serowe Hill is yet another class 1 Toutswe site from which no faunal samples were available for isotope analysis. Only one human grave was recovered from the site and its isotope results are

presented below. The individual's teeth were not present and hence only bone collagen was used in the study.

Bones from three skeletal parts of the Serowe Hill human, a 30 – 50 year old male, were well preserved (Table 4.12). The humerus of this individual (UCT 13048) has a $\delta^{13}C$ value that differs from the other two bones by >2‰ which could be a result of dietary shift or just random variation. The individual's $\delta^{13}C$ and $\delta^{15}N$ values are similar to results observed for other Toutswe class 1 sites.

The $\delta^{13}C$ value of Serowe Hill 1 (-10.4‰) provides strong evidence for a diet dominated by domestic C_4 photosynthetic crops. Plants using the C_3 photosynthesis also played an important role in the diet of this individual. The individual's average $\delta^{15}N$ value of 9.6‰ is similar to results reported for other Toutswe class 1 sites.

Table 4.11: Enamel apatite $\delta^{13}C_{ap}$ results of Swaneng Hill human

UCT No	**, tooth**	**$\delta^{13}C_{ap}$ (‰)**
12347	1, I^1	-4.5
12348	1, C*	-7.5

Table 4.12: Collagen quality indicators, $\delta^{13}C$ and $\delta^{15}N$ values of Serowe Hill human

UCT No	**Grave**	**Skeletal part**	**Collagen Yield (%)**	**Atomic C: N**	**Wt C (%)**	**Wt N (%)**	**$\delta^{13}C$ (‰)**	**$\delta^{15}N$ (‰)**
13047	1	Ilium	14.7	3.3	41.7	14.9	-10.3	9.3
13048	1	Humerus	12.6	3.3	42.0	15.0	-8.1	9.8
13054	1	Femur	15.4	3.2	42.7	15.5	-12.9	9.9
						Mean	**-10.4**	**9.6**

TOUTSWE CLASS 2 SITES

Two sites of class 2 size were included in this study: Taukome and Thatswane. Both sites had animal and human samples suitable for the analysis of bone collagen and enamel apatite. Cattle samples from each site are very limited but ovicaprids are available in reasonable numbers.

Class 2 sites are bigger then class 1 sites with midens suggesting larger animal herds and longer periods of occupation. The hilltop sites are located away from arable land but in areas with good pastures. Their locations on hilltops could be associated with a need for defence.

TAUKOME

Several domestic and wild animals from Taukome were available for isotopic analysis of bone collagen. The wild animals were also included in the analysis of enamel apatite. The *Raphicerus,* hare and rat had insufficient enamel whereas the tortoise was represented by the shell only.

Table 4.13 shows the results of the analysis of bone collagen of animals from Taukome. One sheep/goat sample (UCT 12621) dissolved in hydrochloric acid. One of the six cattle samples (UCT 12629) had a low collagen yield (1.8%), but acceptable atomic C:N ratio, weight percentage C and weight percentage N and the isotopic results are, therefore, likely to be reliable. Both the $\delta^{13}C$ and the $\delta^{15}N$ values for this sample fall within the range of other cattle from the site. All other samples produced good collagen indicators.

The six cattle samples have $\delta^{13}C$ values that differ from one another by <1.5‰, suggesting that they had similar pastures. The $\delta^{13}C$ values of cattle average -6.1±0.4‰ (Table 4.13), which indicates grazing on C_4 photosynthetic grasses. The mean $\delta^{15}N$ value of cattle is 6.4±1.1‰ (Table 4.13). The standard deviations for these isotope results demonstrate uniformity in both pastures and climatic conditions experiences by the animals.

The $\delta^{13}C$ values for sheep vary from -15.8‰ to -6.2‰ with an average of -10.6±2.5‰ (Table 4.13). The variation reported in the $\delta^{13}C$ values of ovicaprids is not surprising given that these animals

are mixed feeders and can, therefore, have individual dietary preferences. The $\delta^{15}N$ values are more consistent, with a range from 4.7 to 9.1‰ and a mean of 7.1±1.1‰ (Table 4.13). The mean $\delta^{15}N$ value of the ovicaprids is as expected of herbivores in a relatively wet environment. The standard deviation for the $\delta^{13}C$ values (2.5) indicate a fair degree of variation of feeding pastures but in contrast, the standard deviation for the $\delta^{15}N$ values (1.1) points to uniform climate. Thus, it seems possible that the variation in $\delta^{13}C$ values of the ovicaprids was due to random selection of plant feed as opposed to the animals being raised in different environments.

Other animals analysed include a *Raphicerus,* a hare, a tortoise, and a household rat (*Rattus rattus)* (Table 4.13). The $\delta^{13}C$ values of these animals are -18.1‰, -11.4‰, -18.5‰ and -7.3‰ for the *Raphicerus*, hare, tortoise and rat respectively, indicating C_3 based diets for *Raphicerus* and tortoise, a C_4 based diet for the hare and the rat. The $\delta^{13}C$ values of all wild animals are as expected , given their feeding habits. The fact that the rat has enriched $\delta^{13}C$ value compared to the hare probably results from the rat having fed on stored C_4 grain. The $\delta^{15}N$ values of the four wild animals range from 4.9‰ for the hare to 8.7‰ for the *Raphicerus*, which is within the range of the domestic species.

The bone collagen in human bones from Taukome appears well preserved. The range of $\delta^{13}C$ values is from -11.5 to -7.8‰ (Table 4.14). All but one individual have intra-skeletal $\delta^{13}C$ variation of less than 2‰. Taukome 5 is the only individual with substantial $\delta^{13}C$ variation, with a value of -7.9‰ for the ulna and -11.4‰ for the rib: a difference of 3.5‰. Repeated analysis of these two samples confirmed these results. This variation strongly suggests a shift in diet at some point in the life of the individual and therefore the carbon values of this individual were not averaged. The $\delta^{13}C$ value of the rib was chosen to reflect adult diet because the rib has faster bone turnover compared with the ulna, and is therefore likely to show change in diet more quickly than the ulna.

The other individuals are likely to have had consistent diets throughout their life times since they have very similar isotope values for bones with different rates of turnover. It was, therefore, justifiable to average their values and the results are shown in Table 4.15. The average $\delta^{13}C$ value of Taukome humans was -9.5±1.4‰. The mean $\delta^{13}C$ value of Taukome humans is consistent with diets in which C_4 photosynthetic crops dominate.

Table 4.13: Collagen quality indicators, $\delta^{13}C$ and $\delta^{15}N$ results of Taukome animals

UCT No	Sample	Collagen yield (%)	Atomic C:N	Wt C (%)	Wt N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
Cattle							
12256	U2 L9, 2/911	24.8	3.5	39.2	12.9	-7.0	7.9
12626	U3 L32, 907	21.1	3.2	39.9	14.5	-5.8	7.0
12627	2603	13.5	3.2	40.0	14.5	-5.8	6.8
12628	2545	9.0	3.2	40.8	14.8	-6.3	5.2
12629	2296	1.8	3.2	42.0	15.3	-6.1	6.2
12630	2604	5.5	3.3	38.9	13.7	-5.9	5.1
					Mean:	**-6.1 ± 0.4**	**6.4 ± 1.1**
Ovicaprids							
12255	U3 RB, 3/RB	19.4	3.5	38.4	13.0	-15.8	6.3
12258	U4 L7, 1756	35.5	3.5	38.3	12.8	-11.3	8.4
12259	U4 L7, 1755	19.4	3.5	38.4	12.8	-9.2	6.4
12260	U4 L7, 1757	29.7	3.5	38.5	12.9	-12.8	7.1
12261	U3 L4, 1077	9.6	3.5	37.6	12.4	-12.7	6.8
12262	U3 L4, 1078	14.7	3.6	38.2	12.5	-9.0	9.0
12263	U3 L4, 1073	15.8	3.5	37.4	12.6	-9.6	7.9
12264	U3 L4, 1097	10.5	3.5	37.4	12.6	-9.6	7.9
12265	U3 L4, 1074	9.5	3.4	37.8	13.0	-10.1	7.1
12266	U3 L4, 1083	14.9	3.6	36.0	11.5	-12.4	9.1
12268	U3 L3, 978	16.5	3.6	36.3	12.2	-13.6	7.3
12269	U3 L3, 976	16.1	3.6	38.4	12.6	-8.8	6.8
12617	U6 L2, 2567	8.7	3.2	40.4	14.5	-10.1	5.5
12618	L8c	8.6	3.2	40.8	14.9	-13.1	7.0
12619	2163	16.8	3.4	38.5	13.2	-10.5	6.4
12620	2794	15.3	3.3	41.1	14.9	-7.6	4.7
12622	U1 L6, 243	9.3	3.2	41.3	14.9	-14.1	8.0
12623	1504	15.6	3.2	40.6	14.7	-8.4	7.1
12624	U2 L5, 600	12.8	3.2	39.4	14.4	-7.8	6.1
12625	U2 L5	16.0	3.1	40.0	15.0	-6.2	7.2
					Mean:	**-10.6 ± 2.5**	**7.1 ± 1.1**
12621	U1 L8, 336	0.0	-	-	-	-	-
Other animals							
12257	U4 L2, 4/2, hare	9.8	3.4	37.0	12.5	-11.4	4.9
12631	26/B4/34, *Raphicerus*	6.1	3.5	40.4	13.6	-18.1	8.7
12267	U5 L8, 2179, rat	23.0	3.0	37.8	12.7	-7.3	6.2
12616	U4 L8, 86, tortoise	15.5	3.0	39.5	13.0	-18.5	5.8

The $\delta^{15}N$ values of all Taukome human skeletal elements analysed range from 9.2‰ to 12.1‰ (Table 4.15). There is little intra-skeletal variation in $\delta^{15}N$; the greatest difference is 0.8‰ between the skull and rib of Taukome 3. The ulna and rib of Taukome 5 differ by only 0.6‰. Differences of this order are to be expected as part of normal variation; there is no information here about changes in diet during lifetime. The $\delta^{15}N$ value of Taukome 3 was expected to be higher compared to the older individuals due to breast milk. It is possible that the infant died shortly after birth (aged 0 to six months only) and hence did not have sufficient chance to breastfeed. The average $\delta^{15}N$ value of the five individuals was 10.1±0.9‰. The sample size for humans is too small and hence no attempts were made to map the isotope values according to age or sex.

The standard deviation of the $\delta^{13}C$ values of 1.4 appears to be relatively small given that there are only five individuals. On the other hand, the standard deviation of the $\delta^{15}N$ values is large. Though the sample size is small, it seems that the variation of human $\delta^{13}C$ values is random and not associated with either age or sex.

Table 4.14: Collagen quality indicators, $\delta^{13}C$ and $\delta^{15}N$ results of Taukome humans

UCT No	Grave	Skeletal part	Collagen Yield (%)	Atomic C: N	Wt C (%)	Wt %N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
12230	1	Rib	25.6	3.2	42.4	15.4	-9.6	10.0
12231	1	Femur	26.7	3.3	40.5	14.2	-9.9	10.3
12232	2	Rib	13.2	3.3	41.8	14.9	-8.4	9.5
12233	2	Tibia	26.2	3.1	43.3	16.1	-8.5	9.2
12791	3	Rib	11.0	3.5	38.3	12.9	-9.4	10.7
12792	3	Skull	12.0	3.4	40.6	13.9	-9.7	9.9
12234	4	Rib	35.0	3.2	41.7	15.1	-7.9	11.4
12235	4	Humerus	17.8	3.3	41.2	14.8	-8.1	11.9
12236	4	Tibia	15.9	3.3	41.3	14.8	-7.8	12.1
12237	5	Rib	28.2	3.2	43.3	15.6	-11.4	9.7
12238	5	Ulna	20.4	3.2	41.4	14.9	-7.9	10.3

Figure 4.3 shows the distribution of $\delta^{13}C$ and $\delta^{15}N$ values for all species at Taukome. The human sample size is too small and hence one symbol is used for all age categories and sexes. Cattle generally have the most enriched $\delta^{13}C$ values, and relatively low $\delta^{15}N$ values. Ovicaprids have more negative $\delta^{13}C$ values than cattle, as expected since ovicaprids tend to browse more than cattle. Some ovicaprids have slightly higher $\delta^{15}N$ than the cattle, but this may be a sample size effect, since there were more ovicaprids than cattle. Humans show the most enriched $\delta^{15}N$ values, clustering around 10‰. On average, the humans are 3 –4‰ enriched in $\delta^{15}N$ compared with the ovicaprids (mean $\delta^{15}N = 7.1\pm1.1$‰) and cattle (mean $\delta^{15}N = 6.4\pm1.1$‰).

Table 4.16 gives $\delta^{13}C_{ap}$ values of animals from Taukome. The two teeth from one cow have $\delta^{13}C_{ap}$ values that differ by more than 2‰ but both of the cow's teeth $\delta^{13}C_{ap}$ values show that the animal grazed mostly on C_4 grass during its developmental years. The variation is probably associated with seasonal shifts in feeding grounds. Thirteen teeth from seven ovicaprids have mean $\delta^{13}C_{ap}$ of -2.6±1.2‰.

Eight teeth from four humans had $\delta^{13}C_{ap}$ values of between -3.5 to -1.2‰ (see Table 4.17). The number of teeth per individual varies between one and three and variation in isotope values between teeth of the same individual does not exceed 2.5‰. These results indicate that the individuals had similar diets during childhood and that, like adult diets, these consisted predominantly of C_4 grains with a fair amount of C_3 supplement. The mean $\delta^{13}C_{ap}$ value of the four humans was calculated at -2.4±0.7‰. Contrary to $\delta^{13}C$, the standard deviation for the $\delta^{13}C_{ap}$ values of the four individuals is small (0.7).

In general, Taukome 5 appears to have had a shift in diet. The ulna (-7.9‰) and teeth (-2.4‰) of this individual both strongly indicate long-term consumption of crops using the C_4 photosynthetic pathway. The carbon isotope ratio of the rib (-11.4‰) demonstrates a significant increase in the consumption of plants using the C_3 photosynthesis.

The enamel apatite and bone collagen isotope values of humans from Taukome show similar contributions of C_4 and C_3 photosynthetic plants in the diet. None of the individuals from Taukome appears to have subsisted predominantly on gathering. All three adults have consistent isotope

signatures from childhood to adulthood and hence there is no evidence to suggest that one of them could have been a hunter-gatherer child who shifted to farming in later years. In addition, there appears to be no variability in isotope values between sexes and age groups.

Table 4.15: Average $\delta^{13}C$ and $\delta^{15}N$ values of Taukome humans

Grave	Age (Years)	Sex	$\delta^{13}C$(‰)	$\delta^{15}N$(‰)
1	40-60	Male	-9.8	10.2
2	40-60	Female	-8.5	9.4
3	0-0.5		-9.6	10.3
4	5-7		-7.9	11.8
5 (rib)	40-60	Male	-11.4	9.7
		Mean:	**-9.5 ± 1.4**	**10.1 ± 0.9**

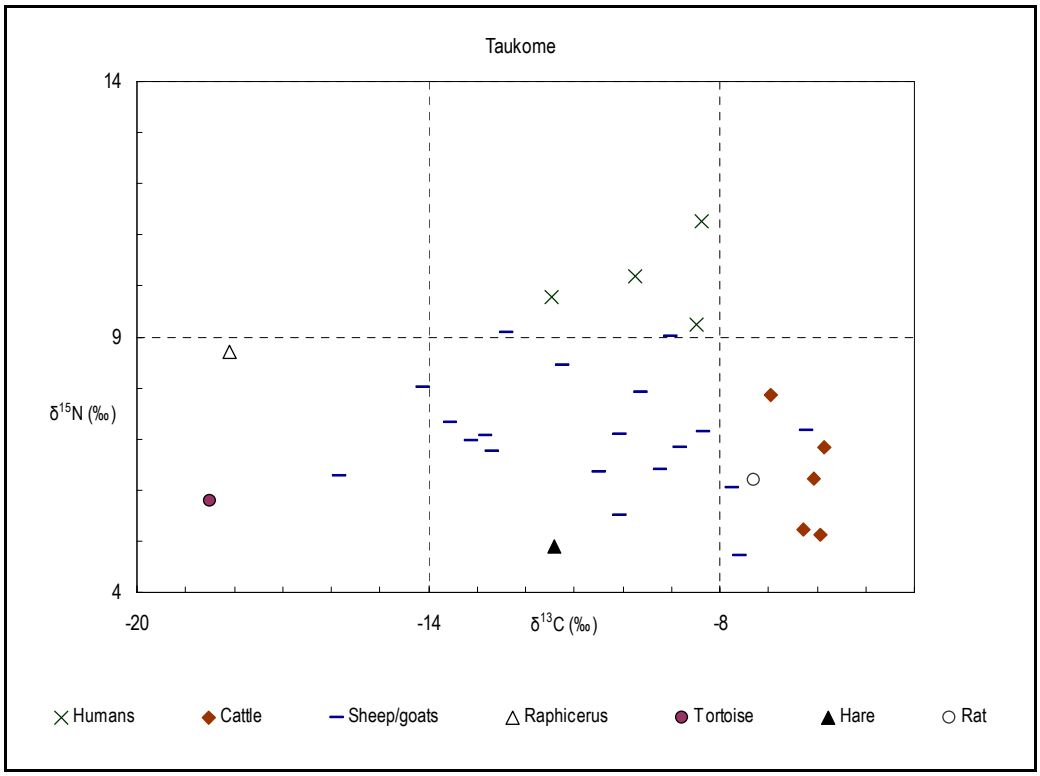


Figure 4.3: Distribution of $\delta^{13}C$ and $\delta^{15}N$ values for all species at Taukome

Table 4.16: Enamel apatite $\delta^{13}C_{ap}$ results of Taukome animals

UCT No	Sample	$\delta^{13}C_{ap}$ (‰)	Individual	$\delta^{13}C_{ap}$ (‰)
Cattle				
12469	777	-1.3		0.2
12470	777	1.7		
Ovicaprids				
12457	1756	-2.0	1756	-1.2
12458	1756	-1.1	1757	-1.6
12459	1756	-0.4	1755	-4.0
12460	1756	-3.9	1073	-2.1
12461	1757	-0.9	1078	-3.7
12462	1757	-2.3	285	-2.0
12463	1755	-4.0	RB	-3.8
12465	1078	-2.5	**Mean:**	**-2.6 ± 1.2**
12466	1078	-4.9		
12467	1073	-2.1		
12468	285	-2.0		
12471	RB	-3.7		
12472	RB	-4.0		

Table 4.17: Enamel apatite $\delta^{13}C_{ap}$ results of Taukome humans

UCT No	Tooth	$\delta^{13}C_{ap}$ (‰)	Individual	$\delta^{13}C_{ap}$ (‰)
12349	1,C*	-1.3	1	-2.4
12350	1,P_2	-3.5	2	-3.1
12351	1,M^3	-2.5	5	-1.4
12352	2, I_2	-2.9	6	-2.6
12353	2, P_2	-3.2	**Mean:**	**-2.4 ±0.7**
12354	5, C	-1.2		
12355	5, M_2	-1.6		
12356	6, P^1	-2.6		

Dietary isotope ratios of the animals from Taukome indicate that they had regular access to good pastures. Their isotope signatures reflect a relatively wet climate. The similarities in nitrogen isotope ratios of all domestic herbivores are a clear indication that the animals were reared within the same environment, at the site.

THATSWANE

One cow (UCT 12653) and one sheep/goat (UCT 12271) bone sample dissolved in hydrochloric acid. All other animal samples demonstrated good collagen preservation as shown in Table 4.18. It is difficult to explain the low carbon and low nitrogen percentages on UCT 12396 but the values are, nevertheless, within acceptable limits.

The $\delta^{13}C$ value of the cow (-5.9‰) is indicative of a diet that consisted entirely of grazing on C_4 grasses. Its $\delta^{15}N$ value (5.1‰) is similar to those of ovicaprids. The $\delta^{13}C$ values of ovicaprids are distributed over a wide range, from -6.7 to -15.3‰, with a mean of -10.2±2.9‰ (Table 4.18). The variation in $\delta^{13}C$ values of ovicaprids is attributed to variation in diet. The $\delta^{15}N$ values are much more tightly clustered, ranging from 5.2‰ to 6.6‰ with a mean of 5.8±0.5‰ as is expected of animals reared under similar environmental conditions and at the same trophic level.

Thirteen samples from five humans have been analysed (Table 4.19). All but one sample are well-preserved. Weight percentages of C and N of UCT 12138 from Thatswane 5 are lower than acceptable limits, but its other indicators of collagen quality are within accepted limits. Hence, the sample was accepted.

The results for individual human bones are shown in Table 4.19. Individual variations in $\delta^{13}C$ values are at the most 2.1‰ (Thatswane 5), insufficient to indicate any substantial change in diet. The variation in $\delta^{15}N$ values of Thatswane 3 is probably not associated with change in diet because the individual was only 3 - 5 years old at the time of death. If the $\delta^{15}N$ variation is associated with an alteration of diet, then such a change would be evident on the rib because the rib has a higher bone turnover compared to the rejected tibia.

Table 4.20 shows the average $\delta^{13}C$ and $\delta^{15}N$ values of Thatswane humans. The average $\delta^{13}C$ value of the six humans from Thatswane is -10±1.1‰ and the individuals' values range from -11.6‰ (Thatswane 4) to -9.0‰ (Thatswane 6). The $\delta^{13}C$ values are as expected since they signal a farming mode of subsistence in which C_4 photosynthetic grains play a significant role. The C_3 component was less important. Though samples size is too small, there appears to be no differences in $^{13}C/^{12}C$ ratios between sexes and age groups.

Table 4.18: Collagen quality indicators, $\delta^{13}C$ and $\delta^{15}N$ values of Thatswane animals

UCT No	Animal sample	Collagen Yield (%)	Atomic C:N	Wt C (%)	Wt N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
Cattle							
12272	4d, 3, 50-60	8.1	3.1	37.9	12.2	-5.9	5.1
12635	4D, 114-123	0	-	-	-	-	-
Ovicaprids							
12394	1, 1c, 4, 30-40	2.3	3.2	36.9	11.7	-9.3	5.4
12396	2,	2.7	3.5	27.5	7.8	-11.5	6.6
12397	3, 4d, 84-102	4.7	3.1	37.0	11.8	-8.5	5.6
12398	4	10.7	3.1	36.6	11.8	-11.6	6.5
12399	5	9.7	3.1	38.0	12.3	-14.1	5.6
12400	6	9.0	3.1	36.4	11.7	-9.5	5.6
12632	4D, 55-70	9.0	2.8	39.9	14.3	-6.7	5.7
12633	4D, 50-60	10.9	2.8	41.6	14.9	-9.2	5.2
12634	4D, 55-70	9.7	2.8	41.1	14.7	-6.7	5.5
12270	4d, 84-102	12.1	3.2	40.8	12.8	-15.3	6.6
					Mean:	**-10.2 ± 2.9**	**5.8 ± 0.5**
12271	1c, 4, 30-40	0	-	-	-	-	-

Table 4.19: Collagen quality indicators, $\delta^{13}C$ and $\delta^{15}N$ values of Thatswane humans

UCT No	Grave	Skeletal part	Collagen Yield (%)	Atomic C:N	Wt C (%)	Wt N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
12130	1	Rib	11.6	2.9	39.5	13.7	-11.2	9.7
12780	1	Skull	12.8	3.3	40.6	14.2	-10.6	9.0
12781	1	Vertebrae	14.7	3.3	40.5	14.2	-10.5	9.2
12782	2	Rib	14.5	3.3	40.9	14.3	-8.9	9.8
12131	3	Rib	15.6	2.7	37.9	14.0	-8.8	11.1
12132	3	Humerus	16.1	2.7	39.1	14.1	-9.0	10.8
12133	3	Tibia	25	2.7	38.6	14.3	-10.5	8.3
12134	4	Rib	13.9	2.7	35.4	13.1	-11.7	7.7
12135	4	Humerus	15.8	2.7	36.9	13.9	-11.5	7.1
12136	4	Femur	14.5	2.7	37.4	13.8	-11.6	6.8
12137	5	Rib	7.3	2.7	37.6	13.9	-9.2	9.5
12139	5	Femur	7.7	2.7	38.4	14.2	-11.3	8.0
12140	5	Humerus	14.5	2.7	37.0	13.3	-10.2	8.3
12138	5	Radius	6.6	3.2	16.5	5.2	-10.0	8.0
12141	6	Femur	14.7	2.7	35.8	13.2	-9.2	8.5
12142	6	Tibia	15.1	2.7	38.1	14.2	-8.8	10.5

The $\delta^{15}N$ values of Thatswane humans lie between 7.2‰ (Thatswane 4) and 10.6‰ (Thatswane 3) with an average of 9±1.1‰ (Table 4.20). Thatswane 3 would have had higher $\delta^{15}N$ value if the effect of milk on the $^{15}N/^{14}N$ ratios of collagen. The sample size for humans is too small and therefore could not be use to search for any patterns of results between sexes and age groups.

Table 4.20: Average $\delta^{13}C$ and $\delta^{15}N$ values of Thatswane humans

Individual	Age(Years)	Sex	$\delta^{13}C$(‰)	$\delta^{15}N$(‰)
1			-10.8	9.3
2			-8.9	9.8
3	3-5		-9.4	10.1
4	8-10		-11.6	7.2
5	40-60	Female	-10.2	8.4
6	10-12		-9.0	9.5
		Mean:	**-10.0 ± 1.1**	**9.1 ± 1.1**

Figure 4.4 shows the distribution of $\delta^{13}C$ and $\delta^{15}N$ values for all species from the site of Thatswane. The diagram shows that the ovicaprids have a wide variation in their dietary isotope compositions compared to humans. Though the cow has the highest $\delta^{13}C$ value, its dietary isotope composition is not significantly different from some of the ovicaprids. Humans have more enriched $^{15}N/^{14}N$ ratios than the herbivores. Moreover, humans tend to show more variation in the distribution of $\delta^{15}N$ values than animals. The pattern depicted along the $\delta^{15}N$ scale of all species was expected because it shows omnivores having higher $\delta^{15}N$ values than herbivores.

Three cattle are represented by one tooth each (Table 4.21). All three have positive $\delta^{13}C_{ap}$ values associated with grazing on C_4 photosynthetic grasses. It is unclear whether UCT 12436 is an outlier or not since its $\delta^{13}C_{ap}$ value differs significantly from the other two cattle. The mean $\delta^{13}C_{ap}$ value for the cattle is 1.4±1.5‰.

Twenty-three teeth from nine ovicaprids were available for analysis (see Table 4.21). The sheep/goat results show mean $\delta^{13}C_{ap}$ value of (-1.4±2.0‰). The mean $\delta^{13}C_{ap}$ value is indicative of a mixed diet. Variations in $\delta^{13}C_{ap}$ values within individuals such as 1 and 7 could be associated with seasonal changes in pasture of the ovicaprids. Sheep/goat 6 has the highest $\delta^{13}C_{ap}$ value, even higher than cattle on pure C_4 grass diet. It is possible that this particular animal was raised in a different environment from the others.

Eight loose zebra teeth were also analysed and their mean $\delta^{13}C_{ap}$ value was 0.9±0.7‰, a value similar to that reported for cattle from the same site. Both species are grazers. Finally, two samples of medium-sized bovids have $\delta^{13}C_{ap}$ values higher than reported for cattle and zebra.

Only two humans from Thatswane had teeth with adequate enamel for analysis (Table 4.22). Two deciduous teeth from Thatswane 3 and two permanent teeth from Thatswane 6 have a $^{13}C/^{12}C$ ratio range of -5.1 to -2.6‰. Their mean $\delta^{13}C_{ap}$ value is -3.5‰. These values are consistent with a diet in which C_4 photosynthetic crops played a dominant role.

In summary, domestic animals at Thatswane appear to have had regular access to palatable C_4 photosynthetic grasses. Variation in enamel apatite $\delta^{13}C_{ap}$ values of some ovicaprids raise the possibility of seasonal changes in pastures. As expected, the $\delta^{13}C$ values of small stock vary more than other species with a standard deviation of 2.9. Similarities in $\delta^{15}N$ values of the cow and ovicaprids are an indication that the animals were raised within the same environment. Hence, the variation in $\delta^{13}C$ values of the ovicaprids is related to dietary preferences (except for sample 6) as opposed the animals having come from different environments. The $\delta^{15}N$ values of domestic animals are associated with relatively wet environments.

All humans from the site have $\delta^{13}C$ and $\delta^{13}C_{ap}$ values demonstrating that they fed on C_4 photosynthetic dominant diets during childhood and adulthood. Their dietary C_3 component is similar to that reported for class 1 sites. None of the humans has $\delta^{13}C$ suggestive of foraging. The number of individuals is small but there is no indication that there may have been differential access to food between sexes and age groups. Comparison of mean $\delta^{15}N$ values of the humans and the herbivores reveals an indication that humans relied on substantial quantities of animal products for protein in the same way as at class 1 sites.

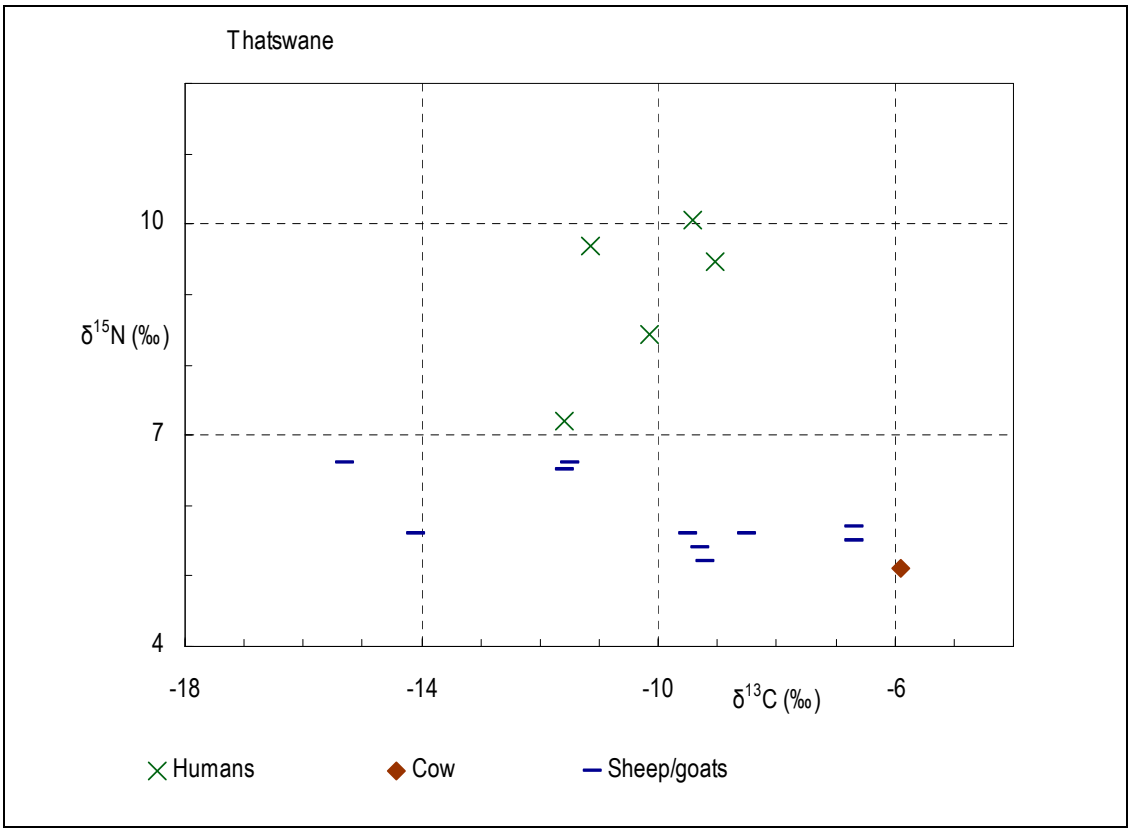


Figure 4.4: Distribution of $\delta^{13}C$ and $\delta^{15}N$ values of all species from Thatswane

TOUTSWE CLASS 3 SITES

Two class 3 sites in the Toutswe region formed part of the study: Bosutswe and Toutswemogala. These are the largest sites in the Toutswe settlement hierarchy (Denbow 1982). Being regional centres meant they probably controlled the movement of goods and people in the region by providing trade an exchange routes. Stone tools recovered from Bosutswe have been interpreted to indicate direct contact between farmers and hunter-gatherers (Denbow 1999). It would therefore not be surprising to find hunter-gatherer isotope signatures on the humans from any of these sites. In addition to archaeological faunal samples, there are modern animal samples from the two sites.

Table 4.21: Enamel apatite $\delta^{13}C_{ap}$ results of Thatswane animals

UCT No	Tooth	$\delta^{13}C_{ap}$ (‰)	Individual	$\delta^{13}C_{ap}$ (‰)
Cattle				
12403	2,	0.3	2	0.3
12436	20,	3.1	20	3.1
12437	21,	0.7	21	0.7
			Mean:	**1.4±1.5**
Ovicaprids				
12401	1	-4.7	1	-2.6
12402	1	-0.4	3	-3.3
12404	3, 4d, 84-102, p_4	-2.1	4	-2.9
12406	3, 4d, 84-102, M_2	-1.9	5	-1.2
12407	3, 4d, 84-102, M_3	-3.4	6	2.6
12405	3, 4d, 84-102, m_1	-5.7	7	-2.3
12408	4, P_4	-2.8	8	-1.3
12409	4, M_1	-3.0	9	-2.4
12412	5, P_4	-2.4	11	1.1
12414	5, M_1	-2.0	**Mean:**	**-1.4 ± 2.0**
12413	5	0.8		
12415	6, P_2	3.1		
12416	6, P_3	2.1		
12417	7	-4.0		
12418	7	-3.8		
12419	7	-0.6		
12420	7	-0.7		
12421	8, P^2	-1.9		
12422	8, P^3	-0.8		
12423	8, P^4	-0.6		
12424	8, M^2	-1.7		
12425	9, M^3	-2.4		
12427	11, p_3	1.1		
Medium bovid				
12434	18, P	3.1	18	3.1
12435	19, P	3.8	19	3.8
			Mean:	**3.5**
Zebra				
12428	12, I	0.7	12	0.7
12429	13, I	1.7	13	1.7
12430	14, P_2	0.7	14	0.7
12431	15, M_1	0.7	15	0.7
12432	16, M^1	-0.3	16	-0.3
12439	23, M^1	1.5	23	1.5
12440	24, M_1	1.3	24	1.3
			Mean:	**0.9±0.7**

Table 4.22: Enamel apatite $\delta^{13}C_{ap}$ results of Thatswane humans

UCT No	Grave, tooth	$\delta^{13}C_{ap}$ (‰)	Grave	$\delta^{13}C_{ap}$ (‰)
12359	3, i^2	-2.1	3	-2.8
12360	3, m_2	-3.6	6	-4.2
12361	6, I_1	-5.1		
12363	6, M^2	-3.3	**Mean:**	**-3.5**

BOSUTSWE

Collagen quality indicators of archaeological animals from Bosutswe (Table 4.23) are within limits quoted in the literature. Only two samples are rejected (UCT 12251 and UCT 12600) because their atomic C:N ratios are beyond accepted limits.

The $\delta^{13}C$ values of cattle range from -6.3‰ to -5.2‰ and they are typical of grazers. Their average $\delta^{13}C$ value is -5.7±0.7‰. The $\delta^{15}N$ values of cattle are as low as expected for herbivores with no water and heat stress. Their mean $\delta^{15}N$ value was calculated at 5.8±1.7‰. The sample with the most enriched $\delta^{15}N$ value of 8.1‰ has the most depleted $\delta^{13}C$ value and therefore, the $\delta^{15}N$ value can not be attributed to browsing. The standard deviation for the $\delta^{13}C$ values is very strong, demonstrating uniformity in feeding habits of the species.

UCT 12253 and UCT 12601 ovicaprids have $\delta^{13}C$ values that separate them from their sample groups by significant margins. These results may have to do with seasonal changes of natural pastures. The mean $\delta^{13}C$ value of ovicaprids is calculated to be -11.3±3.3‰ (Table 4.23). All of the ovicaprids appear to have had mixed diets comprising both grazing on C_4 photosynthetic grasses and browsing on C_3 photosynthetic trees. Random variation in feeding patterns of the ovicaprids might be the reason for the large standard deviation as well as variation in $\delta^{13}C$ values. The $\delta^{15}N$ values average 7.5±1.1‰ and individual the values can not be split into groups. In contrast, $\delta^{15}N$ values are similar within this group. The results probably indicate that the animals lived under similar climatic conditions but preferred different combinations of plant foods.

Table 4.23: Collagen quality indicators, $\delta^{13}C$ and $\delta^{15}N$ values of Bosutswe animals

UCT No	SAMPLE	Collagen Yield (%)	Atomic C: N	Wt C (%)	Wt N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
Cattle							
12604	13, 30E29S, 90-100	15.0	3.2	40.8	14.9	-5.2	6.0
12606	15, 60E0, 80-90	8.6	3.2	39.5	14.2	-5.9	8.1
12607	16, 40W0, 120-130	13.7	3.2	41.3	15.2	-5.3	5.1
12608	17, 30E29S, 50-60	9.3	3.2	40.5	14.7	-6.3	4.0
					Mean:	**-5.7± 0.7**	**5.8±1.7**
~~12251~~	~~1, cow, 5E5S 70-80~~	~~18.5~~	~~3.9~~	~~38.1~~	~~13.0~~	~~-7.3~~	~~9.5~~
Ovicaprids							
12252	2, 1E4S, 80-90	14.2	3.5	37.7	12.4	-13.7	7.7
12254	4, 2E 4S 20-30	14.8	3.5	38.0	12.5	-10.5	8.2
12596	5, 101W1S, 100-110	8.8	3.2	40.2	14.5	-13.9	7.0
12597	6, 5E4S, 20-30	9.9	3.2	41.5	14.9	-14.3	9.2
12598	7, 1E4S, 90-100	13.3	3.3	41.1	14.3	-8.9	9.6
12599	8, 30E29S, 100-110	11.2	3.2	42.3	15.3	-9.0	7.9
12602	11, 20E0, 140-150	5.6	3.2	40.4	14.5	-9.7	7.4
12603	12, Kgotla 1, 40-50	14.1	3.2	41.8	15.1	-12.7	6.9
12609	18, 40-150	17.3	3.2	41.9	15.3	-8.2	6.1
12253	3, 2E4S, 30-40	13.0	3.6	37.2	12.2	-18.2	7.2
12601	10, 101W1S, 80-90	6.6	3.3	41.9	15.0	-5.4	5.9
					Mean:	**-11.2±2.4**	**7.8±1.1**
~~12600~~	~~9, 1E3S, 90-100~~	~~15.5~~	~~3.7~~	~~41.6~~	~~15.2~~	~~-9.9~~	~~7.4~~

Rejected samples are shown by a strike through

Modern animal samples from Bosutswe were studied (Table 4.24). They comprise one sheep, two donkeys, one horse, twenty cattle and one jackal. Preservation of collagen was good for all samples. Cattle have a $\delta^{13}C$ mean value of -11.5±1.5‰ (Table 4.24). UCT 12868 has more depleted $\delta^{13}C$ value compared to other cattle from the same group. It is possible that the variation results from diet of this animal. Modern samples demonstrate more variation in $\delta^{13}C$ values with a standard deviation of 1.5. These results are not surprising given that the modern cattle feed on any available plants and not necessarily on their preferred plant species. An average $\delta^{15}N$ value of 8.2±0.8‰ for modern cattle is also higher than the mean for cattle obtained from archaeological contexts. Increased $\delta^{15}N$ values of modern cattle are most probably in response to water stress. Records of mean annual rainfall at Paje and Mmashoro Primary Schools are between 153.7mm

and 1012.6mm for the years 1998 to 2007 (see Table 2.1). Both of these stations are within less than 50km away Bosutswe. The single sheep sample has the lowest $\delta^{13}C$ value (-19.9‰) and the highest $\delta^{15}N$value (10.1‰) compared to other animals from the same site. The isotope values of this animal are accepted as a true record of its diet.

Table 4.24: Collagen quality indicators, $\delta^{13}C$ and $\delta^{15}N$ values of Bosutswe modern animals

UCT No	SAMPLE	Collagen Yield (%)	Atomic C:N	Wt C (%)	Wt N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
	Cattle						
12845	002	30.1	3.2	41.9	7.8	-11.5	7.4
12847	004	21.1	3.2	42.9	8.6	-10.5	8.1
12848	005	26.8	3.2	42.3	9.3	-11.4	8.8
12849	006	25.6	3.2	42.1	8.0	-10.3	7.6
12850	007	29.0	3.2	41.8	9.1	-11.8	8.7
12851	008	32.7	3.3	41.8	8.8	-10.6	8.3
12852	009	25.0	3.3	42.5	8.8	-11.4	8.3
12853	010	23.2	3.3	42.8	8.1	-12.8	7.7
12856	013	26.4	3.2	43.5	7.8	-10.8	7.3
12857	014	7.2	3.5	43.0	9.2	-11.6	8.7
12858	015	26.4	3.3	43.9	8.1	-12.1	7.7
12859	016	25.0	3.3	42.3	8.5	-10.8	8.1
12860	017	39.4	3.4	42.7	7.9	-11.0	7.4
12861	018	22.6	3.3	42.6	8.1	-13.5	7.7
12862	019	10.9	3.4	43.0	8.5	-11.2	8.1
12863	020	23.0	3.2	42.0	10.1	-13.9	9.7
12864	021	25.8	3.4	42.6	9.2	-12.6	8.8
12865	022	9.5	3.2	41.6	10.6	-10.2	10.2
12867	024	25.4	3.3	42.1	8.1	-11.9	7.7
12868	025	22.9	3.2	43.1	7.5	-16.7	7.1
					Mean:	**-11.8±1.5**	**8.2±0.8**
Sheep							
12844	001	26.0	3.2	42.6	10.5	-19.9	10.1
Donkeys							
12846	003	24.5	3.3	43.3	7.2	-11.4	6.8
12854	011	27.0	3.2	42.1	6.9	-12.9	6.4
Horse							
12866	023	28.5	3.2	43.3	7.4	-11.9	6.9
Jackal							
12869	026	25.6	3.2	42.1	11.5	-15.9	11.1

The two donkeys and one horse have similar $\delta^{13}C$ and $\delta^{15}N$ values. The $\delta^{13}C$ values indicate a significant amount of C_3 browse on their diet. Lastly, the jackal's $\delta^{13}C$ value indicates that this carnivore's source of protein were herbivores whose diets were based largely on C_3 browse. Its $\delta^{15}N$ is as expected because it is 3 - 4‰ higher than the $\delta^{15}N$ values of most of the herbivores

Thirty-one bone collagen samples from 13 humans have been analysed and results are in Table 4.25. Two samples, UCT 12224 and UCT 12225, obtained from Bosutswe 11 were destroyed in the acid. Collagen yield, atomic C:N ratios, weight percentage C and weight percentage N for all samples are within ranges quoted for well-preserved collagen. Small variations in individuals' isotope values are most probably random.

Mean $\delta^{13}C$ and $\delta^{15}N$ values for each individual are shown in Table 4.26. The table also includes the cultural deposits associated with each individual because the site is associated with different ceramic traditions (Denbow *et al.* 2008). There appears to be no differences in either $\delta^{13}C$ and $\delta^{15}N$ values between individuals of different periods and between age groups. The $\delta^{13}C$ values of all individuals range between -10.5‰ and -6.8‰ with a mean of -8±0.9‰. The $\delta^{13}C$ values of these individuals can be said to result from the consumption of crops that use the C_4 photosynthesis with minor contribution from plants of the C_3 photosynthesis.

The overall human $\delta^{13}C$ values strongly support the archaeological evidence for farming of C_4 photosynthetic crops provided the bulk of the dietary plant protein. The archaeological evidence includes carbonised remains of sorghum and millet as well as numerous granaries on the site (Denbow *et al.* 2008). However, C_3 photosynthetic plants appear to have been almost equally important.

The $\delta^{15}N$ values for humans average 10.4±0.7‰ and range between 8.8‰ and 11.8‰.These values are slightly higher than domestic herbivores $\delta^{15}N$ values. It is not possible to investigate distributions in isotope ratios according to sex and age because only three of the 14 individuals are adults. The $\delta^{15}N$ values of the infants are not much higher than the adults' values as was expected. Most of the infants died within the first few months of birth and it is possible that they did not breastfeed long enough to elevate their $\delta^{15}N$ values. Bosutswe 7 lived long enough to have

breastfed but still the $\delta^{15}N$ value of the infant is similar to those of the rest of the group. Unfortunately, there are no adult females to compare $\delta^{15}N$ values of Bosutswe 7.

Table 4.25: Collagen quality indicators, $\delta^{13}C$ and $\delta^{15}N$ values of Bosutswe humans

UCT No	Grave	Skeletal part	Collagen Yield (%)	Atomic C:N	Wt C (%)	Wt N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
12207	1(1)	Rib	7.9	3.5	38.0	12.6	-8.3	10.0
12208	1	Rib	17.6	3.5	32.6	10.8	-6.8	11.0
12209	2	Rib	18.2	3.5	38.1	12.7	-7.3	11.7
12210	2	Vertebra	15.0	3.5	36.4	12.0	-7.3	11.9
12211	3	Rib	24.5	3.1	44.9	16.8	-9.4	10.2
12212	3	Ulna	24.0	3.2	42.7	15.6	-8.2	10.5
12213	3	Femur	19.8	3.3	42.4	15.2	-8.8	10.2
12214	4	Rib	27.1	3.2	41.8	15.2	-9.7	9.5
12215	4	Humerus	12.6	3.3	40.1	14.4	-11.2	9.6
12216	5	Vertebra	20.1	3.2	39.3	14.2	-8.5	10.7
12217	5	Humerus	11.6	3.5	36.8	12.4	-6.7	10.8
12243	5	Rib	14.1	3.5	34.5	11.4	-7.2	10.8
12786	6	Rib	7.7	3.3	38.2	13.7	-8.0	10.6
12787	6	Vertebra	10.1	3.5	36.1	12.1	-8.4	10.4
12218	7	Rib	20.5	3.5	36.1	12.1	-8.4	10.4
12219	7	Tibia	12.8	3.5	36.1	12.1	-7.6	10.9
12220	8	Rib	19.4	3.5	35.7	11.9	-7.4	8.9
12221	8	Femur	12.0	3.5	37.0	12.4	-7.4	8.9
12222	8	Tibia	4.7	3.5	34.8	11.6	-7.6	8.6
12789	10	Rib	19.1	3.3	39.7	14.2	-8.3	10.5
12790	10	Skull	21.7	3.2	41.1	14.8	-7.9	10.6
12223	11	Rib	10.5	3.3	40.6	14.6	-8.2	10.1
12224	11	Vertebra	0.0	-	-	-	-	-
12225	11	Femur	0.0	-	-	-	-	-
12226	12	Rib	15.6	3.2	42.7	15.8	-8.0	10.1
12227	12	Femur	18.2	3.2	42.1	15.5	-8.0	10.4
12228	12	Tibia	17.8	3.6	37.6	12.3	-7.9	10.7
12229	13	Humerus	15.6	3.2	42.7	15.6	-8.4	11.2
12244	13	Rib	9.8	3.5	36.7	12.3	-8.3	11.1
12245	13	Tibia	6.9	3.5	37.0	12.2	-8.1	10.4

Figure 4.5 shows the distribution of $\delta^{13}C$ and $\delta^{15}N$ values of humans, animals from archaeological deposits and modern animals from the Bosutswe. There are three main groups based on their $\delta^{13}C$ values. The most depleted group ranges from -20‰ to -15‰ and contains a few individuals. The middle group runs from -15‰ to -10‰ and is dominated by modern cattle, donkey, horse and some archaeological ovicaprids. In other words, all these three species survive on mixed feeding. The last group includes humans and archaeological cattle. Within this group, humans have less $\delta^{13}C$ values when compared to cattle. The humans' isotope values tend to have a linear pattern in which an increase in $\delta^{13}C$ value is coupled with a higher $\delta^{15}N$ value. This pattern is difficult to explain.

Table 4.26: Average $\delta^{13}C$ and $\delta^{15}N$ values of Bosutswe humans

Individual	**Age(Years)**	**Sex**	**Ceramic Phase**	**$\delta^{13}C$(‰)**	**$\delta^{15}N$(‰)**
Bosutswe 1/1	0-0.5		Lose	-8.3	10.0
Bosutswe 1	0-0.5		Lose	-6.8	11.0
Bosutswe 2	0-0.5		Lose	-7.3	11.8
Bosutswe 3	30-40	Male	Toutswe	-8.8	10.3
Bosutswe 4	7-9		Toutswe/Lose	-10.5	9.6
Bosutswe 5	17-20	Male	Toutswe	-7.5	10.7
Bosutswe 6	7-9		Toutswe	-8.1	10.7
Bosutswe 7	1-2		Toutswe	-8.0	10.6
Bosutswe 8	3-5		Toutswe	-7.5	8.8
Bosutswe 9	0-0.5		Toutswe	-7.2	10.3
Bosutswe 10	5-10		Toutswe/Lose	-8.1	10.6
Bosutswe 11	13-15		Toutswe	-8.2	10.1
Bosutswe 12	50-75	Male	Toutswe	-8.0	10.4
Bosutswe 13	12-14		Toutswe	-8.3	10.9
			Mean:	**-8±0.9**	**10.4±0.7**

The $\delta^{15}N$ scale divides into to two groups: the herbivores and the omnivores plus the carnivore. It is worth noting that modern cattle are slightly more enriched in $\delta^{15}N$ values compared to archaeological cattle. The difference between these groups of animals is most probably due to differences in climatic conditions. Under dry conditions, the $\delta^{15}N$ values of animals are elevated as

shown by modern cattle. The same can be said of the small stock. The modern sheep is slightly enriched in the $\delta^{15}N$ value by comparison to archaeological ovicaprids.

The humans and the modern jackal have higher $\delta^{15}N$ values as expected of animals at that trophic level. The jackal was expected to be isotopically distinct from the rest of the animals but it is not. Some modern cattle tend to overlap into this group most probably because of the effect of drought.

Six teeth from six cattle were used in the analysis of $^{13}C/^{12}C$ ratios of enamel apatite. Two of the animals have negative $\delta^{13}C_{ap}$ results whereas the other four have positive $\delta^{13}C_{ap}$ results. The mean $\delta^{13}C_{ap}$ value for all six teeth is 0.7±1.5‰ is associated with a C_4 dominated diet. There is no apparent pattern related to the distribution of $\delta^{13}C_{ap}$ values on cattle from different depths. In other words, the isotope compositions of cattle pastures remained relatively stable over a long period. However, this does not necessarily imply that the plant species remained unchanged. Table 4.27 shows enamel apatite $\delta^{13}C_{ap}$ results of animals from Bosutswe.

Table 4.27: Enamel apatite $\delta^{13}C_{ap}$ results of Bosutswe animals

UCT No	Sample		$\delta^{13}C_{ap}$ (‰)
Cattle			
12720	13, 30E29S, 90-100		2.2
12721	14, 40W0, 110-120		1.0
12722	15, 60E0, 80-90		1.8
12723	16, 40W0, 120-130		1.8
12724	17, 30E29S, 50-60		-1.3
12725	18, 40W0, 140-150		-0.9
		Mean:	**0.7±1.5**
Ovicaprids			
12712	5, 101W1S, 100-110		-4.0
12713	6, 5E4S, 20-30		-4.8
12714	7, 1E4S, 90-100		-3.5
12715	8, 30E29S, 100-110		-4.0
12716	9, 1E3S, 90-100		-1.8
12717	10, 101W1S, 80-90		1.2
12718	11, 20E0, 140-150		-1.0
12719	12, Kgotla 1, 40-50		-5.9
		Mean:	**-3.0±2.3**

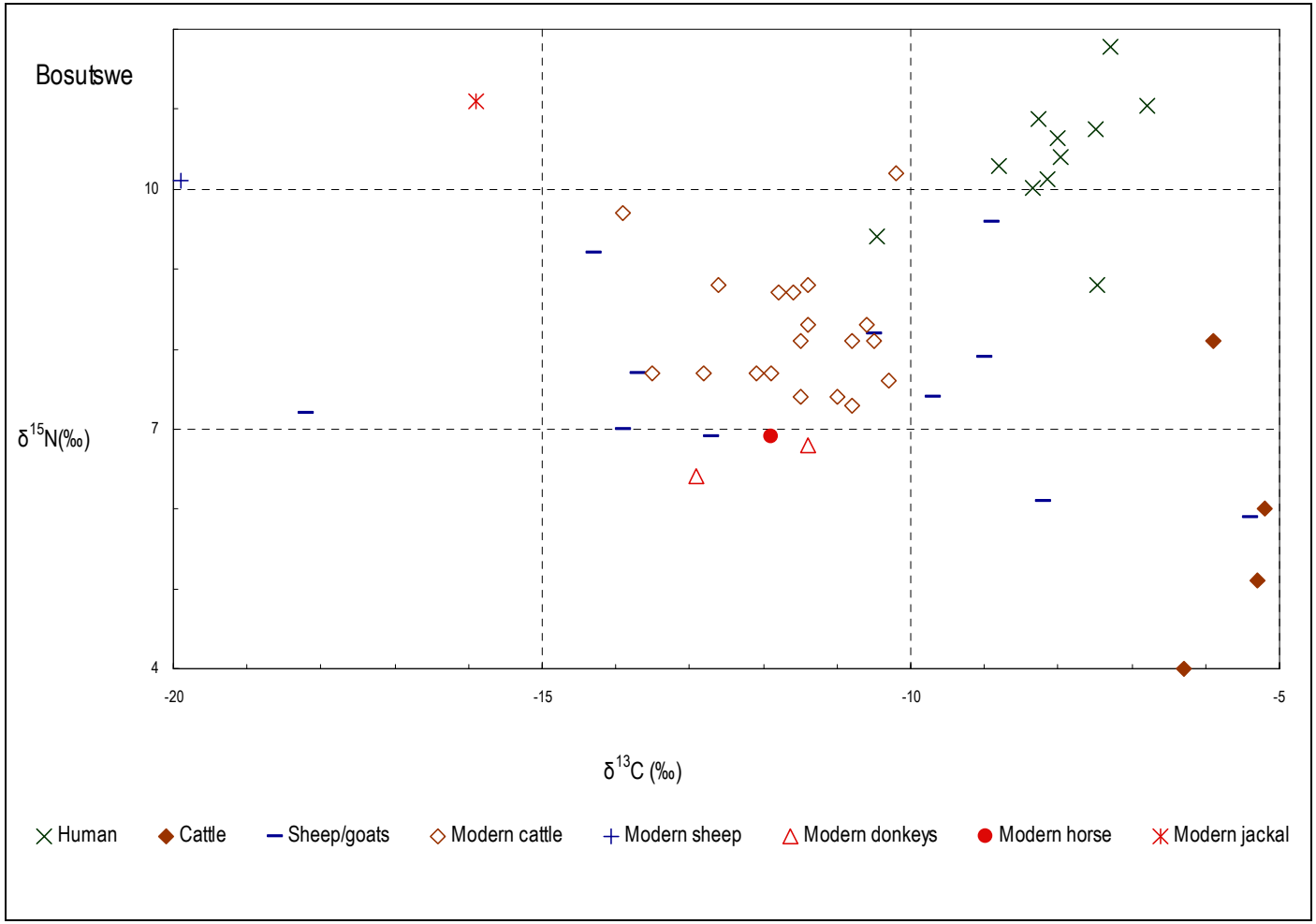


Figure 4.5: Distribution of $\delta^{13}C$ and $\delta^{15}N$ values all species and periods at Bosutswe (archaeological and modern)

Table 4.28 shows the results of enamel $\delta^{13}C_{ap}$ values $\delta^{13}C_{ap}$ values of modern animals from Bosutswe. Cattle samples outnumber other species by significant margins, making it difficult to compare $\delta^{13}C_{ap}$ values of various animal species. The average $\delta^{13}C_{ap}$ value of the cattle equals -2.7±1.2‰ and thus modern cattle are generally 2‰ more negative than archaeological cattle. Differences in sample sizes between archaeological and modern cattle do not appear to play any significant role in differences in mean $\delta^{13}C_{ap}$ values of these groups. Generally, modern cattle browse to the same degree as ovicaprids of the last several millennia.

The single recent sheep tooth is significantly depleted in its $\delta^{13}C_{ap}$ value compared to ovicaprids from archaeological contexts. The $\delta^{13}C_{ap}$ value reported for the recent sheep was expected because the animal had limited access to C_4 photosynthetic grasses and was therefore exposed exclusively to C_3 based browse.

The two donkeys and the horse have $\delta^{13}C_{ap}$ values that are within the limits observed for cattle. Therefore, pastures available to the donkeys and horses raised at Bosutswe are isotopically similar to cattle pastures even though the three species might have fed on different plant species.

From Bosutswe, 22 teeth from 10 humans were available for the analysis of enamel apatite and their results are depicted in Table 4.29. Bosutswe 6 and Bosutswe 11 had only one tooth analysed and the other eight humans had two or more teeth per individual. The individual teeth from the sample have $\delta^{13}C_{ap}$ values of between -4.9 and 0.2‰. In cases where more then one tooth per individual is included, inter-variation in $^{13}C/^{12}C$ ratios is 1.6‰ at the most and hence there are no outliers when calculating individuals' averages. The 10 individuals have a mean $\delta^{13}C_{ap}$ value of -2.2 ± 1.1‰. The average $\delta^{13}C_{ap}$ value of humans is typical of a diet in which C_4 photosynthesising plants provide the bulk of the plant protein while C_3 photosynthesising plants play a minor role.

Domestic animals from Bosutswe were raised on diets in which C_4 photosynthetic grasses played a major role. Enamel apatite $\delta^{13}C_{ap}$ values of the cattle and ovicaprids are comparable to their bone collagen $\delta^{13}C$ values and thereby suggesting that the animals were not moved between different ecozones. In contrast, modern cattle and ovicaprids feed on more C_3 based trees (particularly

morula) than they do on C_4 based grasses. Recent domestic herbivores have elevated $\delta^{15}N$ values compared to their archaeological counterparts. The difference between archaeological and recent herbivore $\delta^{15}N$ values is possibly due to differences in climatic conditions between the EIA periods and present with the present climate being slightly drier than in the past.

Table 4.28: Enamel apatite $\delta^{13}C_{ap}$ results of Bosutswe recent animals

UCT No	Sample number	$\delta^{13}C_{ap}$ (‰)
Cattle		
12871	2	-2.3
12873	4	-2.3
12874	5	-3.1
12875	6	-0.7
12876	7	-2.7
12877	8	-1.8
12879	10	-2.3
12881	12	-1.0
12882	13	-1.7
12883	14	-4.9
12884	15	-2.4
12885	16	-2.4
12886	17	-3.2
12887	18	-4.5
12888	19	-5.2
12889	20	-3.4
12890	21	-2.2
12892	23	-1.4
12893	24	-4.3
	Mean:	**-2.7±1.2**
Sheep		
12870	1	-14.3
Donkeys		
12872	3	-3.9
12880	11	-5.6
	Mean:	**-4.8 ± 1.2**
Horse		
12891	22	-4.7
Jackal		
12894	25	-11.6

Table 4.29 Enamel apatite $\delta^{13}C_{ap}$ results of Bosutswe humans

UCT No	Tooth Rows	$\delta^{13}C_{ap}$ (‰)	Individual	$\delta^{13}C_{ap}$ (‰)
12326	2, i	-3.2	2	-2.6
12327	2, c	-2.1	3	-2.5
12328	3, C*	-2.7	4	-1.8
12329	3, M^3	-2.3	5	-0.9
12330	4, m_2	-1.9	6	-4.5
12331	4, M_1	-1.7	7	-1.7
12332	5, I_2	-1.4	8	-0.6
12333	5, C*	-0.8	11	-3.0
12334	5, M_3	-0.4	12	-2.4
12748	6, I_1	-4.5	13	-2.0
12335	7, i^1	-1.7	**Mean:**	**-2.2±1.1**
12336	7, c*	-1.8		
12337	8, I_2	0.2		
12338	8, C	-1.0		
12339	8, M_1	-0.9		
12340	11, I_2	-3.0		
12341	12, I_1	-2.7		
12342	12, C*	-2.4		
12343	12, M^3	-2.1		
12344	13, I_2	-2.8		
12345	13, P_1	-1.2		
12346	13, M_2	-1.9		

The differences in $\delta^{13}C$ values of cattle from the two periods show distinct patterns and their values do not overlap. This pattern indicates that the diets of the cattle during the EIA and modern cattle are distinctively different. In the past cattle lived as pure grazers whereas in the last few years they have had to combine grazing and browsing. The present feedings habit of the cattle have been created by drought and overgrazing. Though modern ovicaprids samples are small, the $\delta^{13}C$ value of the individual present strongly indicates a significant change in feeing habits between the EIA period and present. Evidently, small stock has also shifted from mixed feeding to exclusive browsing.

Humans from the same site have $\delta^{13}C$ values that strongly indicate that C_4 photosynthetic crops provided the bulk of their dietary protein. The C_3 component of the diet was very small compared to C_4. None of the individuals has $\delta^{13}C$ values that might suggest a hunting and gathering mode of

subsistence. There is insufficient isotopic evidence to suggest differential access to food between sexes and between age groups.

TOUTSWEMOGALA

Archaeological animal samples from Toutswemogala are generally well-preserved. These samples have good quality collagen as shown by their yields, atomic C:N ratios, weight percentage carbon and weight percentage nitrogen. Only one sample UCT 12310 was destroyed during the treatment phase. Table 4.30 shows results of $\delta^{13}C$ values and $\delta^{15}N$ values as well as collagen quality indicators for all animal species.

Mean $\delta^{13}C$ value for cattle samples is -6.2 ± 0.6‰, a value associated with the consumption of C_4 photosynthetic grasses. Average $\delta^{15}N$ for cattle is 5.6 ± 0.7‰. The fairly low $\delta^{15}N$ values for cattle are typical for herbivores. In both $\delta^{13}C$ and $\delta^{15}N$ mean values, the standard deviations are low supporting the suggestion that the animals grew up under similar feeding and climatic conditions.

The ovicaprids vary widely in $\delta^{13}C$ values. They range from -16.5‰ to -5.0‰ (Table 4.30) with a mean value of -10.6 ± 2.4‰. The variation could be a simple reflection of varying access to grazing and browsing opportunities as well as different herd management strategies. Unfortunately, there is no information about the actual contexts from which different samples came and hence it is difficult to determine the spatial distribution of the $\delta^{13}C$ values. Some of the ovicaprids have $\delta^{13}C$ values resulting from grazing and some were exclusively browsers. The $\delta^{15}N$ values for ovicaprids range from 4.6‰ to 7.7‰ with an average of 6.0 ± 0.8‰. Unlike $\delta^{13}C$ values, the $\delta^{15}N$ values the standard deviation demonstrates narrower range of the values. This is as expected because the $\delta^{15}N$ values are influenced by the climate and trophic level, both of which are stable. The ovicaprids with the most depleted $\delta^{13}C$ values have $\delta^{15}N$ values similar to the rest of the group. This means that the animals with depleted $\delta^{13}C$ values do not necessarily come from dry environments as is the case with modern samples from Bosutswe.

The zebra has a slightly more negative $\delta^{13}C$ value (-7.3‰) compared to cattle. The zebra was expected to have $\delta^{13}C$ value similar to cattle since both species are pure C_4 grazers but it appears

highly likely that the zebra had substantial C_3 browse in its diet. The zebra $\delta^{15}N$ value is similar to values reported for other herbivores from the same site.

The $\delta^{13}C$ results of the tortoise are between -21.3‰ and -16.6‰ with an average of -19.2 ± 2.3‰. The $\delta^{13}C$ values are as expected for these browsing animals. The $\delta^{15}N$ values of the tortoise are slightly more varied as they are between 4.1‰ and 9.5‰ with a mean value of 6.3 ± 2.4‰. The $\delta^{15}N$ results are in line with results expected for herbivores. The steenbok and *Raphicerus* have expected $\delta^{13}C$ values. They have more negative $\delta^{13}C$ values associated with a diet of pure C_3 browse. Their $\delta^{15}N$ values tend to overlap between grazers and browsers despite the fact that leaves have slightly higher $\delta^{15}N$ values compared to grasses

The domestic dog (UCT 12294) has $\delta^{13}C$ value of -8.3‰ and $\delta^{15}N$ value of 8.8‰. The $\delta^{13}C$ value shows a C_4 based protein with a fair contribution of C_3 protein. The dog was expected to have a much higher $\delta^{15}N$ value than the herbivores since it is a carnivore. Instead, the value is almost similar to those of ovicaprids. There is a possibility that the dog was fed on food left over by humans, which may have included substantial amounts of plant foods.

A single rat sample analysed (UCT 12304) has a $\delta^{13}C$ result of -6.6‰ and $\delta^{15}N$ result of 5.6‰. This was a household rat (*Rattus rattus)* which probably lived on stored grain and disposed foods. Also included in the study are two samples of leguaan (UCT 12284 and UCT 12291) and their $\delta^{13}C$ results are -16.3‰ and -16.2‰ while their $\delta^{15}N$ results are 7.7‰ and 8.9‰.

Results of samples from modern animals at Toutswemogala are presented in Table 4.31. As expected for animals killed in the recent past (the last 5 years), collagen was well preserved. The mean $\delta^{13}C$ for cattle (excluding the UCT 12819 and UCT 12823 outliers) is -12.1±1.3‰. Evidently, modern cattle consumed more portions of C_3 plant leaves compared to cattle in the same area approximately 500 to 1000 years ago. The results for rmodern cattle are not surprising given that farmers around Toutswemogala mentioned that drought in the area compelled cattle to survive almost exclusively on *mophane* tree leaves. The results obtained for UCT 12819 and UCT 12823 are most probably representative of a pure browsing diet as opposed to mixed feeding noted on other samples. The mean $\delta^{15}N$ for recent cattle was 6.7±0.7‰. Once again, this value is higher

Table 4.30: Collagen quality indicators, $\delta^{13}C$ and $\delta^{15}N$ values of Toutswemogala animals

UCT No	Animal sample	Collagen Yield (%)	Atomic C: N	Wt C (%)	Wt N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
Cattle							
12274	2, 35R3 (35RO), SL1	23.5	3.6	35.9	11.5	-6.0	6.9
12275	3, 35R3 (35RO), SL1	11.3	3.4	39.2	13.4	-6.0	5.8
12280	8, 5R135 1st h, L3	15.1	3.1	38.6	12.5	-5.5	5.8
12306	33, 35R3(35RO), sl1	17.1	3.6	35.9	11.8	-6.5	5.5
12307	34, 35R3(35RO), sl1	11.8	3.4	37.9	12.9	-6.4	5.3
12636	67, 5R-5, L2	18.8	3.3	40.7	14.6	-5.3	7.2
12637	68,OR135 2nd h	9.4	3.3	39.9	13.9	-6.0	5.0
12638	69, 10R-5, L1	6.3	3.3	40.2	14.1	-6.9	5.2
12639	70, 10R140 2ndh, L3	15.7	3.2	41.5	15.1	-5.8	5.6
12640	71, 10R135 2nd h, L2	22.5	3.2	41.5	15.0	-5.3	5.5
12641	72, 5R-5, L2	15.9	3.2	41.9	15.2	-6.5	5.8
12642	73, OR160	8.8	3.4	37.7	12.9	-5.4	4.9
12644	75, 15RB(15RO)	7.3	3.3	40.1	14.1	-5.0	4.9
12643	74, 5R145, L2	13.2	3.2	41.5	15.1	-10.4	4.9
					Mean:	**-6.2 ± 1.3**	**5.6 ± 0.7**
~~12281~~	~~8, 5R135 1st h, L3~~	~~19.1~~	~~3.7~~	~~38.1~~	~~12.1~~	~~-5.9~~	~~6.0~~
Ovicaprids							
12273	1, 1/7/285	16.7	3.6	39.7	13.0	-8.2	6.3
12276	4, 5RO, L4	13.6	3.6	39.3	12.9	-16.5	6.9
12277	5, 5RO, L4	15.2	3.6	39.0	12.7	-10.1	6.4
12278	6, 5RO, L4	15.9	3.5	39.1	12.9	-11.6	6.5
12279	7, 5RO, L4	15.9	3.6	35.9	11.7	-10.1	6.3
12286	13, 3/OR155, L1&2	29.3	3.5	36.9	12.2	-9.7	6.8
12288	15, 3/ORO150, L3	12.9	3.6	37.1	12.2	-7.8	5.4
12289	16, 5R135 2nd h, L7	18.3	3.5	39.9	13.4	-13.3	6.1
12290	17, 5R135 2nd h, L7	20.6	3.6	35.0	11.3	-9.4	7.1
12293	20, 35RO, f s	13.9	3.5	38.4	12.8	-5.0	4.6
12295	22, 35RO, f s	15.8	3.6	39.0	12.6	-12.7	7.5
12296	23, 35RO, f s	16.5	3.6	37.3	12.2	-9.1	7.2
12297	24, 10R-5, e l	11.3	3.4	38.7	13.1	-10.3	7.2
12301	28, 5R135, 1st L2	11.7	3.5	38.8	13.0	-14.0	5.1
12303	30, 5R135, 1st L1	5.4	3.6	36.9	11.9	-14.7	5.3
12305	32, 35R3(35RO), sl1	18.3	3.4	37.7	12.8	-10.9	6.1
12647	78, 10R138, 2nd h	17.5	3.2	41.3	14.9	-12.5	6.3
12648	79, 10R140 2, L3	6.0	3.2	41.6	15.1	-9.2	6.9
12649	80, 0R135 2nd h	13.2	3.3	37.3	13.2	-10.4	5.2
12650	81, 5R-5	18.3	3.2	40.5	14.6	-9.8	5.6
12651	82, 5R145 L3	14.8	3.2	41.7	15.1	-12.1	5.4
12652	83, 10R140 2nd h L4	14.0	3.2	39.8	14.5	-8.6	7.5
12653	84, OR135 L5	18.6	3.4	41.6	15.5	-11.5	5.8
12654	85, OR 160	12.8	3.3	41.8	14.8	-8.6	7.7
12655	86, 5R5	16.5	3.2	40.1	14.5	-8.3	5.7
12656	87, 8RO(5RO) L3	15.4	33	41.8	15.0	-9.8	5.8

Table 4.30: Continued

UCT No	Animal sample	Collagen Yield (%)	Atomic C: N	Wt C (%)	Wt N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
12657	88, 45R3(45RO)	6.8	34	37.5	12.9	-10.8	6.5
12658	89, 3ORO	6.2	33	39.8	14.0	-12.0	5.1
12659	90, F5 L2	13.9	34	37.4	13.0	-9.4	6.4
12660	91, 5R150 L1	8.3	33	41.0	14.7	-8.9	5.7
12661	92, OR160	13.3	3.2	41.3	14.9	-7.9	4.9
12662	93, 100-110 U1	13.4	3.1	40.3	14.5	-11.4	5.5
12663	94, 5R135 2nd h L3	12.3	3.2	41.9	15.3	-15.7	6.0
12664	95, 5R-5 L2	19.0	3.2	41.9	15.1	-10.2	4.8
					Mean:	**-10.6 ±2.4**	**6.1± 0.8**
12310	37, 35R3(35RO), sl1	0	-	-	-	-	-
~~12285~~	~~12, 3/OR155, L1&2~~	~~19.5~~	~~3.7~~	~~32.3~~	~~10.1~~	~~-12.6~~	~~11.3~~
~~12283~~	~~10, 5R135 1st h, L3~~	~~17.3~~	~~3.7~~	~~37.4~~	~~12.3~~	~~-13.4~~	~~5.4~~
~~12298~~	~~25, 10R-5, e l~~	~~12.6~~	~~3.7~~	~~36.0~~	~~11.5~~	~~-8.0~~	~~6.0~~
Tortoise							
12292	19, 35RO, f s	8.3	3.5	37.7	12.4	-20.1	6.1
12311	38, 35R3(35RO) sl1	35.9	3.6	36.3	11.7	-21.3	4.1
12645	76, ORO,L4	8.8	3.2	41.5	14.9	-21.3	4.1
12646	77, 5R135, 2nd h	7.2	3.5	35.8	11.9	-16.9	7.9
12299	26, 10R-5, e l	11.8	3.6	38.6	12.6	-16.6	9.5
					Mean:	**-19.3±2.3**	**6.3±2.4**
Steenbok							
12308	35,35R3(35RO)sl1	13.3	3.6	38.8	12.7	-20.2	6.6
12309	36, 35R3(35RO)sl1	13.9	3.6	38.1	12.5	-19.9	6.1
					Mean:	**-20.1±0.2**	**6.4±0.4**
Raphicerus							
12666	97, OR135 L5	8.0	2.7	40.6	14.8	-17.9	7.5
12668	99,0R140 2 L3	9.0	2.8	39.9	14.2	-20.7	6.4
					Mean:	**-19.3±2.0**	**7.0±0.8**
Dog							
12294	21, 35RO, f s	14.6	3.5	38.1	12.6	-8.3	8.8
Zebra							
12667	98, 5R135 2nd h L3	19.4	2.8	40.3	14.4	-7.3	3.4
Rat							
12304	31, 5R135, 1st L1	18.6	3.4	37.8	12.8	-6.6	5.6
Micro fauna							
12302	29, 5R135,1st L2	21.4	3.5	39.1	12.9	-11.2	6.6
12284	11, 5R135 1st h, L3	13.0	3.4	38.3	13.0	-16.3	7.7
12291	18, 5R135 2nd h, L7	11.5	3.5	37.2	12.4	-16.2	8.9
					Mean:	**-16.3±1.0**	**8.3±0.8**

Rejected samples are shown by a strike through

compared to archaeological cattle. Elevated $\delta^{15}N$ values of recent cattle are attributed to heat and water stress. Mean annual rainfall at Palapye Police Station, less than 30km from Toutswemogala, was between 177.9 and 789.9mm for the years 1998-2007 (see Table 2.1).

One sheep/goat (UCT12821) is regarded as an outlier since its $\delta^{13}C$ value differs from others by a significant margin (Table 4.31). The sample was not included in the calculation of the mean since it appears to have had a different feeding habit. Their $\delta^{13}C$ values average -19±1.3‰ because of having to depend largely on C_3 photosynthetic tree leaves in an environment where grasses are sparse. Their $\delta^{15}N$ values average 9.2±1.3‰, which is relatively higher the calculated mean of 6.1 ± 0.8‰ for ovicaprids from archaeological deposits. Elevated $\delta^{15}N$ values of recent ovicaprids can be attributed to water and heat stress, which seems to be more pronounced now than in the past

The donkeys have a mean $\delta^{13}C$ value of -12.5±1.1‰ signalling a significant role played by C_3 photosynthesising plants in their diet. Their mean $\delta^{15}N$ value of 6.5±0.7‰ is lower than herbivores of similar body size such as the kudu. The kudu has a $\delta^{13}C$ value of -20.5‰ consistent with browsing C_3 based leaves and a relatively high $\delta^{15}N$ value of 8.4‰ possibly resulting from heat and water stress. The medium herbivore has a $\delta^{13}C$ value of -13.2‰ and $\delta^{15}N$ value of 9.8‰.

Samples were accepted or rejected based on collagen quality descriptions published in the literature (DeNiro 1985; Schoeninger *et al.* 1989; Ambrose 1990; Pate 1998; van Klinken 1999; Jørkov *et al.* 2007). The 62 samples from humans at Toutswemogala show variations in preservation conditions (Table 4.32). For example, UCT 12201 disintegrated in the hydrochloric acid during treatment and four samples yielded collagen of less than 5% (i.e. UCT 12169, UCT 12177, UCT 12178 and UCT 121593).

All four samples mentioned above were analysed and only UCT 12178 is rejected in because its atomic C:N ratio is 6.7, and its weight carbon and nitrogen percentages are 3.5 and 0.6 respectively. The other three samples with low collagen yield have good atomic C:N and percentage carbon and nitrogen and hence their isotope results are accepted. UCT 12191 from Toutswemogala 15 was also excluded because its atomic C:N ratio of 3.7 is beyond limits expected for well preserved collagen.

Table 4.31: Collagen quality indicators, $\delta^{13}C$ and $\delta^{15}N$ values of Toutswemogala recent animals

UCT No	Sample	Collagen Yield (%)	Atomic C: N	Wt C (%)	Wt N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
Cattle							
12813	008	25.8	3.3	43.1	15.5	-10.2	6.5
12820	016	28.7	3.2	41.6	15.1	-10.8	7.4
12816	011	8.6	3.3	42.4	15.2	-14.3	7.6
12808	003	26.7	3.4	43.8	15.0	-12.3	6.9
12809	004	32.5	3.2	42.0	15.3	-11.6	7.3
12810	005	25.9	3.4	42.4	14.7	-12.7	5.5
12811	006	27.1	3.3	43.2	15.5	-12.9	6.8
12825	020	24.5	3.4	37.0	12.8	-11.7	6.0
12819	014	18.6	3.3	42.6	15.1	-18.6	11.1
12823	018	24.1	3.5	44.2	14.9	-18.7	8.6
					Mean:	**-13.4±3.0**	**7.4±1.6**
Ovicaprids							
12812	007	27.8	3.3	42.2	15.1	-20.6	8.6
12817	012	24.2	3.4	42.5	14.7	-17.5	8.0
12806	001	21.8	3.2	41.4	14.9	-18.8	11.0
12807	002	24.9	3.2	42.3	15.4	-19.2	9.1
					Mean:	**-19±1.3**	**9.2±1.3**
12821	017	24.1	3.3	42.7	15.3	-12.0	7.5
Donkeys							
12819	015	18.6	3.5	44.3	14.6	-13.5	7.1
12815	010	28.6	3.4	43.2	14.9	-12.6	6.8
12818	013	28.9	3.2	42.0	15.2	-11.3	5.8
					Mean:	**-12.5±1.1**	**6.5±0.7**
Kudu							
12814	009	31.1	3.2	42.3	15.3	-20.5	8.4
Medium-sized herbivore							
12824	019	29.1	3.2	42.2	15.4	-13.2	9.8

Table 4.32: Collagen quality indicators $\delta^{13}C$ and $\delta^{15}N$ values of Toutswemogala humans

UCT No	Grave	Skeletal part	Collagen Yield (%)	Atomic C: N	Wt C (%)	Wt N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
12580	1	Rib	19.0	3.3	40.4	14.3	-8.5	6.9
12581	1	Humerus	10.3	3.2	41.6	14.4	-7.5	8.7
12582	1	Femur	19.9	3.3	41.6	14.9	-8.7	8.3
12166	2	Rib	19.0	3.1	39.7	14.7	-9.4	8.5
12167	2	Humerus	11.6	3.3	38.9	13.9	-9.0	8.0
12168	3	Rib	19.4	3.1	39.5	14.7	-8.2	9.3
12169	3	Ulna	1.7	3.2	38.1	13.9	-8.6	9.5
12170	3	Tibia	10.5	3.2	39.3	14.4	-8.1	9.3
12583	3	Humerus	9.4	3.2	40.7	14.7	-7.8	8.8
12586	4	Skull	14.3	3.3	41.1	14.3	-10.0	11.9
12171	6	Rib	15.8	3.3	40.0	14.0	-8.2	8.6
12172	6	Tibia	13.9	3.2	42.1	15.2	-8.7	8.0
12173	7	Rib	22.6	3.1	40.4	15.0	-12.4	8.8
12174	7	Humerus	22.1	3.1	37.0	13.9	-14.2	8.3
12175	7	Tibia	24.5	3.2	40.3	14.5	-12.5	8.5
12176	8	Rib	16.2	3.2	38.3	13.9	-11.2	9.5
12177	8	Humerus	3.6	3.3	36.7	13.2	-9.7	9.7
12179	9	Rib	13.1	3.3	38.3	13.4	-9.0	7.9
12180	9	Femur	19.3	3.6	36.5	11.9	-9.0	8.5
12181	10	Rib	14.7	3.1	38.0	14.2	-7.3	10.7
12182	10	Femur	12.8	3.4	41.7	14.1	-7.6	10.2
12183	10	Vertebra	10.4	3.1	38.3	14.3	-7.5	10.9
12184	11	Rib	25.5	3.1	38.9	14.5	-8.0	11.2
12185	11	Vertebra	23.4	3.5	37.3	12.4	-7.8	10.6
12797	12	Rib	14.5	3.3	38.4	13.7	-9.7	12.0
12798	12	Skull	20.2	3.2	41.1	11.5	-10.1	14.9
12186	13	Rib	16.0	3.2	40.5	14.6	-9.8	8.4
12187	13	Humerus	9.0	3.2	35.7	13.2	-9.9	8.6
12188	13	Femur	9.7	3.6	41.2	13.3	-11.2	8.5
12189	14	Rib	7.0	3.2	39.1	14.2	-9.2	8.6
12190	14	Vertebra	15.3	3.3	41.7	15.0	-9.6	8.3
12192	15	Humerus	14.5	3.3	35.4	12.6	-11.8	7.5
12193	15	Fibula	9.6	3.3	41.0	14.7	-11.8	8.4
12588	16	Skull	12.0	3.2	42.1	15.3	-9.5	9.9
12194	17	Rib	15.5	3.3	41.6	14.9	-9.1	8.7
12195	17	Humerus	17.6	3.3	41.5	14.9	-8.7	8.9
12196	17	Tibia	13.5	3.4	38.9	13.4	-8.8	8.9
12589	19	Rib	20.3	3.3	42.3	15.4	-8.8	8.4
12590	19	Tibia	12.5	3.2	40.8	14.3	-9.1	8.9
12198	20	Rib	21.3	3.3	42.1	15.0	-8.7	8.8
12199	20	Tibia	16.0	3.2	40.5	14.6	-9.0	9.2
12799	21	Rib	19.6	3.2	41.0	14.7	-10.2	12.4
12800	21	Skull	28.5	3.2	41.4	15.1	-8.9	11.8
12200	22	Rib	23.3	3.3	41.9	14.9	-8.4	9.6
12202	22	Vertebra	17.3	3.3	40.8	14.5	-11.1	8.4

Table 4.32: continued

UCT No	Grave	Skeletal part	Collagen Yield (%)	Atomic C: N	Wt C (%)	Wt N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
12203	22	Fibula	25.0	3.3	39.9	14.3	-10.9	9.8
12801	23	Rib	9.9	3.5	35.7	12.1	-9.2	9.6
12802	23	Skull	18.7	3.2	40.6	14.6	-8.7	9.3
12204	24	Rib	13.4	3.3	42.1	15.0	-10.3	10.3
12205	24	Vertebra	13.5	3.3	41.9	15.0	-10.1	10.6
12803	25	Rib	29.9	3.2	41.7	15.0	-10.7	9.5
12804	25	Humerus	24.4	3.3	41.9	14.9	-11.3	9.5
12805	25	Tibia	28.7	3.4	39.2	13.7	-10.9	9.7
12591	26	Mandible	20.5	3.2	42.1	15.2	-7.4	10.7
12206	27	Ulna	19.5	3.3	40.3	14.2	-12.7	10.3
12592	29	Skull	10.9	3.3	41.9	15.0	-11.1	8.9
12593	30	Skull	2.9	3.2	41.5	14.9	-8.1	8.6
12594	31	Rib	9.3	3.3	40.2	14.3	-8.8	8.6
12595	31	Tibia	12.6	3.3	41.1	14.6	-9.5	8.3
12201	22	Radius	0	-	-	-	-	-
~~12178~~	~~8~~	~~Tibia~~	~~3.5~~	~~6.7~~	~~3.2~~	~~0.6~~	~~11.7~~	~~8.2~~
~~12191~~	~~15~~	~~Rib~~	~~21.1~~	~~3.7~~	~~36.1~~	~~11.5~~	~~17.0~~	~~9.9~~

Rejected samples are shown by a strike through

The average $\delta^{13}C$ and $\delta^{15}N$ values of each human individual from Toutswemogala were calculated and the results are shown in Table 4.33. The $\delta^{13}C$ values for individuals range between -13.1‰ and -7.4‰ and they average -9.6±1.4‰. The mean $\delta^{13}C$ value of humans suggests a diet comprising mainly C_4 based plants but with a significant supplement on C_3 based plants. There is no apparent difference in $\delta^{13}C$ values between young and older individuals and between males and females.

The individuals' $\delta^{15}N$ values are between 8.0‰ and 11.9‰ (Table 4.32) with a mean value of 9.4±1.2‰. Several infants of breastfeeding age have elevated $\delta^{15}N$ values of more than 10‰ per individual. These are Toutswemogala 10, 11, 12, 21, 24, 26 and 27. Toutswemogala 4 also has relatively high $\delta^{15}N$ value of 11.9‰ but the individual was post-weaning age at the time of death and it is difficult to associate its high $\delta^{15}N$ value to breastfeeding. There are other infants whose $\delta^{15}N$ values are not as high as expected. It is difficult to explain why some infants have low $\delta^{15}N$ values.

The distribution of $\delta^{13}C$ and $\delta^{15}N$ values for all humans, archaeological and recent animals from Toutswemogala is shown in Figure 4.6. All humans are shown using the same symbol because most of them are of the infants and juveniles. Cattle and zebra from archaeological contexts are the least depleted in $\delta^{13}C$ values (-4‰ to -8‰). The midsection (-8 to -14‰) of the $\delta^{13}C$ distribution is dominated by archaeological ovicaprids, dog, recent cattle, donkeys, as well as humans. Archaeological ovicaprids have outliers on both ends of the distribution scale and they are the most widely spread. Archaeological tortoise, *Raphicerus,* steenbok, leguaan, recent ovicaprids and kudu all occupy the most depleted end of the $\delta^{13}C$ scale. The distribution of different species along the $\delta^{13}C$ scale is a true reflection of the diets of the animals and humans involved.

The $\delta^{15}N$ scale can be divided in two. The bottom half of the scale is dominated by archaeological cattle, ovicaprids, steenbok, *Raphicerus*, tortoise, zebra and recent cattle and donkeys. Species on the bottom half of the scale show no patterns between grazers and browsers. The top half of the scale includes humans, recent ovicaprids and an archaeological dog. The dog has $\delta^{15}N$ value similar to humans despite the fact that the dog is ideally supposed to be one trophic level above humans. The similarity between the dog and humans can be explained in that domestic dogs are often fed on foods similar to humans.

Table 4.33 shows the results of the animal teeth used in the study. The samples include four cattle, 11 ovicaprids, one medium-sized bovid, one dog and some loose zebra teeth. The mean $\delta^{13}C_{ap}$ value of 2.2 ±0.9 for cattle shows the animals were pure grazers right from the time of birth. Twenty-two teeth from 11 ovicaprids have $\delta^{13}C_{ap}$ values of between -7.5 Out of these, eight teeth from eight individuals (samples 3, 6, 23 and 29) are considered to be outliers since their $\delta^{13}C_{ap}$ values are off the range of the rest of the group. The values are also off the limits reported for other Toutswe sites. Individuals with more than one tooth analysed have been averaged to give an overall isotope value of each individual animal. The calculated mean $\delta^{13}C_{ap}$ value for the ovicaprids is -0.9±1.1‰. The mean value suggest a predominantly C_4 based diet for this species.

It is not clear how many individuals are represented by the 15 zebra teeth. Their overall mean $\delta^{13}C_{ap}$ value is not calculated because the number of individuals is not known. Nevertheless, the enamel apatite isotope results of the zebra strongly indicate that the animal(s) were grazers. In

addition to these animals is a single medium-sized bovid, which could not be identified to species level. Its $\delta^{13}C_{ap}$ value is 3.4‰.

Table 4.33: Average $\delta^{13}C$ and $\delta^{15}N$ values of Toutswemogala humans

Grave	Age (years)	Sex	$\delta^{13}C$ (‰)	$\delta^{15}N$(‰)
1	0-0.5		-8.2	8.0
2	5-7		-9.2	8.2
3	6-8		-8.2	9.2
4	6-8		-10.0	11.9
6	9-11		-8.5	8.3
7	3-5		-13.1	8.7
8	2-4		-9.8	9.6
9	7-9		-9.0	8.2
10	1-2		-7.5	10.6
11	0-0.5		-7.9	10.9
12	0-0.5		-9.9	11.8
13	7-9		-10.3	8.5
14	5-7		-9.4	8.4
15	7-10		-11.8	8.0
16	10-12		-9.5	9.9
17	10-12		-8.9	8.8
19	40-60	Male	-9.0	8.7
20	3-5		-8.8	9.0
21	1-2		-9.6	12.1
22	40-50	Male	-11.0	9.1
23	0-0.5		-9.0	9.4
24	3-5		-10.2	10.5
25	30-50	Female	-11.0	9.6
26	1-2		-7.4	10.7
27	0-0.5		-12.7	10.3
29	6-10		-11.1	8.9
30	20-40	Indeterminate	-8.1	8.6
31	9-11		-9.2	8.4
		Mean:	**-9.6±1.4**	**9.4±1.2**

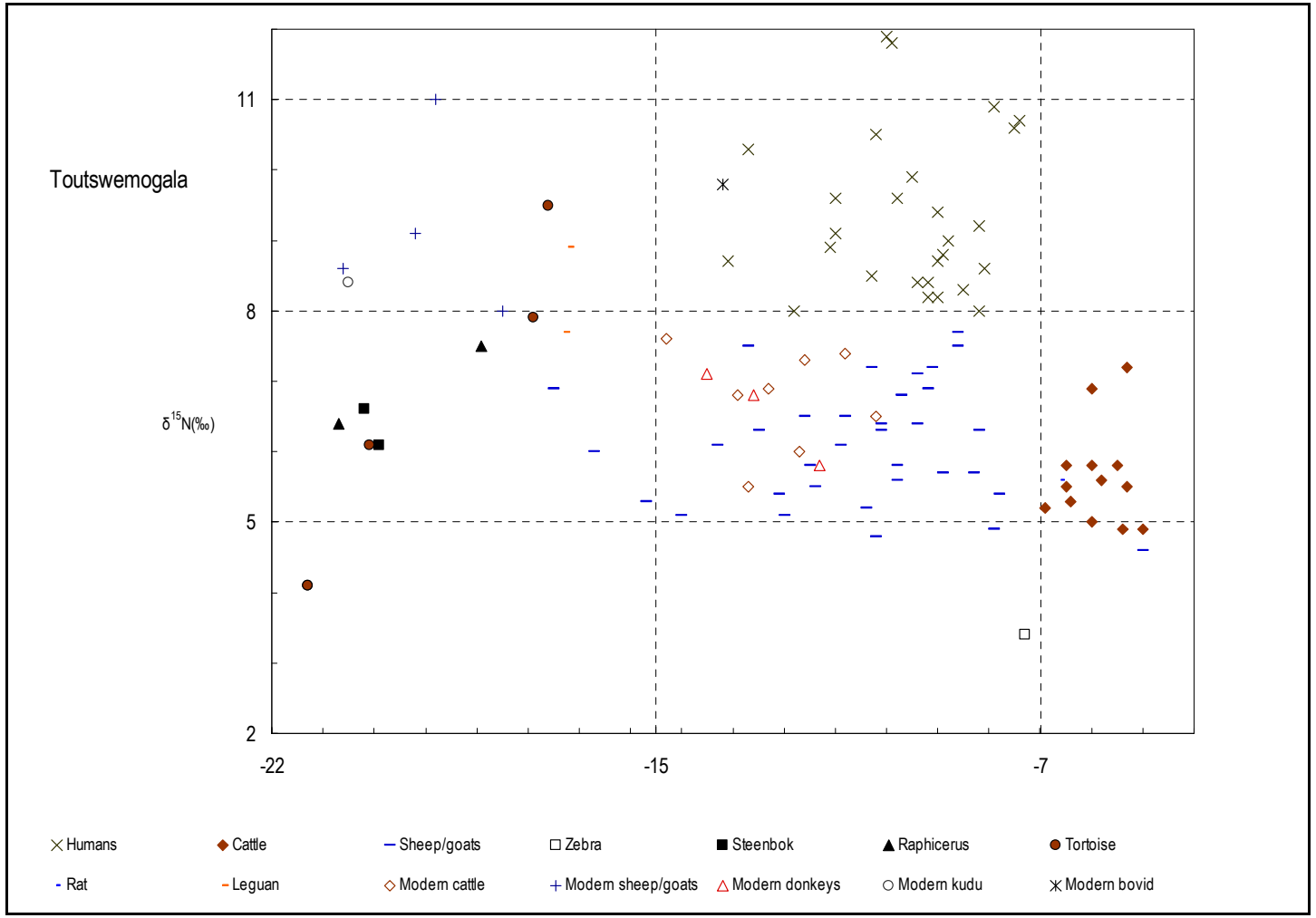


Figure 4.6: Distribution of $\delta^{13}C$ and $\delta^{15}N$ values of all species at Toutswemogala (archaeological and modern)

Table 4.34 shows the enamel apatite $\delta^{13}C_{ap}$ results of recent animals from Toutswemogala. Only one tooth per mandible or maxilla was analysed. From the recent collection, cattle display the widest variation in enamel apatite $\delta^{13}C_{ap}$ values (-6.7‰ to -0.2‰). Cattle average -3.4±2.7‰. The three donkey samples have $\delta^{13}C_{ap}$ values of -4.4‰ to -1.6‰ with a mean $\delta^{13}C_{ap}$ value of -3.3±1.1‰. Thus, the diets of cattle and donkeys have similar contributions of C_3 and C_4 plants. They both graze and browse to survive the drought in the area.

Unlike cattle, ovicaprids have very similar $\delta^{13}C_{ap}$ values, which are clustered between -13.6‰ and -10.9‰ for the five samples (see Table 4.34). Their mean $\delta^{13}C_{ap}$ is -12.3±1.1‰, a value consistent with a C_3 dominant diet. Enamel apatite $\delta^{13}C_{ap}$ results and collagen $\delta^{13}C$ results both demonstrate that ovicaprids browsed heavily right from birth until time of death.

Twenty-four enamel apatite samples from 15 humans have $^{13}C/^{12}C$ ratios ranging from -5.8‰ to -1.6‰ (Table 4.35). The number of teeth per individual varies between one and three and in some instances they include a combination of deciduous and permanent teeth from the same person. The $\delta^{13}C_{ap}$ results of the humans from Toutswemogala are presented in Table 4.35 Variation within individuals does not exceed 2.5‰ and hence individual teeth results were averaged to calculate the value for the individual. The individuals have $\delta^{13}C_{ap}$ values of -4.5‰ to -1.8‰ and mean value of -3.0.8‰.

Five individuals with the most depleted $\delta^{13}C_{ap}$ values are Toutswemogala 4, 14, 16, 29 and 30. Their $\delta^{13}C_{ap}$ results are -4.5 to -3.7‰ signalling a major C_3 based plant contribution to their diets. Four of the individuals are juveniles aged ~5 to ~12 years old. Their bone collagen $\delta^{13}C$ values are consistent with a diet in which C_4 based plants play a major role. Given that these individuals were young, it is unlikely that differences between their enamel apatite $\delta^{13}C_{ap}$ values and their bone collagen $\delta^{13}C$ values are from a change in diet. Simple random variation of the isotope values is a more convincing explanation. The fifth individual, Toutswemogala 30, was an adult of 20–40years old. The individual's bone collagen $\delta^{13}C$ result is similar to other Toutswemogala humans and is characterised by C_4 photosynthetic plants with a minor C_3 based supplement. Enamel apatite $\delta^{13}C_{ap}$ value of -3.9‰ could be a result of a C_3 based dominant diet during developmental years. Unfortunately, the mandible was the only skeletal part recovered and there is no way of testing

Table 4.34: Enamel apatite $\delta^{13}C_{ap}$ results of Toutswemogala animals

UCT No	Sample, Tooth	$\delta^{13}C_{ap}$ (‰)	Individual	$\delta^{13}C_{ap}$ (‰)
Cattle				
12473	1, 35R3(35RO) SL1, P^2	2.0	1	1.7
12474	1, 35R3(35RO) SL1, P^3	1.3	2	1.4
12476	2, 35R3(35RO) SL1, M^2	1.4	20	3.5
12505	20, 5R1351st h L3, M^1	3.5	27	2.2
12517	27, ORO L1, M_3	2.2	**Mean:**	**2.2 ±0.9**
Ovicaprids				
12482	4, 5RO L4, P_4	1.1	3	-7.1
12483	4, 5RO L4, M_1	0.6	4	0.2
12484	4, 5RO L4, M_2	-1.0	5	-0.9
12485	5, 5RO L4, P_2	-1.6	6	-6.2
12486	5, 5RO L4, P_3	-0.8	23	-6.3
12487	5, 5RO L4, P_4	-0.3	25	-1.1
12513	25, 3/OR155 L42, m_1	-0.1	28	0.7
12514	25, 3/OR155 L42, m_2	-2.1	29	-5.0
12518	28, 3/OR150 L3, P^2	0.6	30	-1.4
12519	28, 3/OR150 L3, M^3	0.7	35	-2.3
12525	30, 5R135 2nd L7, M_1	-0.8	39	-1.8
12526	30, 5R135 2nd L7, P_3	-2.0	**Mean:**	**-0.9±1.1**
12527	35, 5R135 2nd L7, P_3	-2.3		
12530	39, 5R135 2nd L7, M_2	-1.8		
12479	3, 5RO L4, P_4	-7.4		
12480	3, 5RO L4, M_1	-6.8		
12489	6, 5RO L4, M^2	-6.2		
12508	23, 5R1351st L3, P_4	-7.0		
12509	23, 5R1351st L3, M_1	-5.5		
12523	29, 5R135 2nd L7, P_3	-5.6		
12524	29, 5R135 2nd L7, M_1	-4.3		
Medium-sized bovid				
12490	7	3.4		
Zebra				
12493	10	2.4		
12494	11	1.4		
12496	13	1.2		
12497	14	0.5		
12500	17	1.8		
12502	19	2.5		
12528	37	1.1		
12529	38	2.9		
12531	42	0.7		
12532	43	0.4		
12492	9	1.7		
12498	15	3.5		
12499	16	2.5		
12491	8	1.0		
Dog				
12506	21	3.0		

whether the collagen result is consistent throughout the body. It is also possible that the enamel apatite $\delta^{13}C_{ap}$ value yielded is inaccurate.

There appears to be substantial differences in $\delta^{15}N$ values between EIA animals and their modern counterparts. For instance, EIA cattle have a mean $\delta^{15}N$ value of 5.6‰ and recent cattle have a mean of 6.7‰.

EIA humans subsisted on C_4 photosynthetic crops, which they supplemented with C_3 based plants. Their $\delta^{13}C$ values have a mean of -9.6‰. None of the humans shows evidence for subsisting on hunting and gathering. Moreover, none of the humans has strong evidence for shifting their mode of substance from hunting and gathering to farming or the other way round.

Table 4.35: Enamel apatite $\delta^{13}C_{ap}$ results of Toutswemogala recent animals

UCT No	Sample	$\delta^{13}C_{ap}$ (‰)
Cattle		
12835	11, M^2	-6.2
12838	14, M_2	-1.0
12840	16, M^3	-1.3
12843	20, P^2	-6.2
12828	3, M^2	-5.6
12829	4, P^1	-0.2
12830	5, M^3	-2.3
12831	6, M_1	-6.7
12833	8, M_3	-0.9
	Mean:	**-3.4±2.7**
Ovicaprids		
12826	1	-11.7
12836	12	-12.5
12841	17	-13.6
12827	2	-10.9
12832	7	-12.8
	Mean:	**-12.3±1.1**
Donkeys		
12834	10, M_3	-3.8
12837	13, M_3	-4.4
12839	15, M_3	-1.6
	Mean:	**-3.3±1.5**

Table 4.36: Enamel apatite $\delta^{13}C_{ap}$ results of Toutswemogala humans

UCT No	Tooth	$\delta^{13}C_{ap}$ (‰)	Individual	$\delta^{13}C_{ap}$ (‰)
12365	2, m^2	-2.6	2	-2.6
12366	3, I_1	-2.8	3	-2.4
12367	3, m^1	-1.8	4	-4.3
12742	3, M_1	-2.5	6	-3.2
12368	4, m^2	-4.3	8	-2.7
12370	6, I_1	-3.2	10	-1.8
12372	8, i	-3.9	13	-3.2
12373	8, i_*	-1.6	14	-4.5
12374	8, m^2	-2.6	16	-4.5
12376	10, m	-1.8	17	-2.4
12377	13, m^1	-3.4	18	-2.5
12378	13, M_1	-3.0	25	-2.0
12379	14, m_2	-5.8	26	-3.0
12380	14, M_1	-3.3	29	-3.7
12381	16, I_2	-4.5	30	-3.9
12382	17, P^1	-2.1	**Mean:**	**-3±0.8**
12383	17, M_1	-3.0		
12384	17, M_2	-2.3		
12385	18, i_2	-2.7		
12386	18, m^1	-2.4		
12895	25, P_1	-2.9		
12896	25, M_3	-1.2		
12388	26, m_2	-3.0		
12390	29, I_1	-3.6		
12391	29, C	-3.9		
12392	30, M_2	-3.9		

SUMMARY OF TOUTSWE ISOTOPE RESULTS

The faunal samples from class 1 sites are only 3 and this number is too low to provide evidence for the overall climatic conditions of the sites. Isotope results of animals from the EIA indicate that cattle, in particular, ate diets that were strongly based on C_4 grasses. In contrast, modern herbivores from Bosutswe and Toutswemogala are characterised by highly depleted $\delta^{13}C$ values. The depletion in $\delta^{13}C$ values is associated with increased consumption of *mophane* leaves.

The $\delta^{15}N$ results of recent animals are not as high as was expected from a drought stricken environment. There is a strong possibility that artificial water points at Bosutswe and Toutswemogala have interfered with the physiological mechanisms that would have resulted in the animals having more positive $\delta^{15}N$ results.

Stable isotope evidence of humans from class 1 sites are relatively clustered except for the individual from Swaneng Hill. The individuals have $\delta^{13}C$ values that indicate dominant C_4 photosynthetic crops in their diets. In other words, their diet indicates a farming way of life. Part of the C_3 component in their diets probably came from domestic plants as shown by the presence of beans, cowpeas and melon seeds at some sites. The individual from Swaneng Hill appears to have consumed substantial quantities of C_3 photosynthetic plants in childhood. In fact, the C_3 component exceeded the C_4 portion in the diet of this individual. It is possible that the individual was a hunter-gatherer but more isotope evidence from the rest of the skeleton and from the archaeological record itself is needed to substantiate this possibility.

At class 2 sites, one individual (Taukome 5) appears to have had a shift in diet involving a change from C_4 based plants during childhood to increased consumption of C_3 photosynthetic plants. It is possible that the C_3 based plants were domestic legumes and cowpeas. Supplementing with wild vegetables was most probably a common practice. Taukome 5 is discussed further in chapter 7 of this thesis.

Based on the results for all sites, there appears to be no differences in $\delta^{13}C$ and $\delta^{15}N$ values of humans from all sites in the Toutswe region. In order to make informed conclusions regarding the dietary similarities or differences of the Toutswe communities, there is a need to conduct statistical analysis of the results. Such statistical tests between the sites are presented in Chapter 7. Most importantly, Bone collagen $\delta^{13}C$ results of the 75 humans from eight Toutswe sites are tightly clustered. The carbon isotope ratios of bone collagen are generally around -11‰ for all humans. There are no individuals whose $\delta^{13}C$ values suggest strong reliance on C_3 photosynthetic plants. The C_3 signature recorded at Kgaswe B55 (on enamel apatite) could be related to consumption of domestic crops e.g. beans during developmental years.

The results for the human $\delta^{15}N$ values are also clustered. In most cases, the $\delta^{15}N$ values of infants are not as high as expected. Breastfeeding infants are expected to have elevated $\delta^{15}N$ values since they are one trophic level above adults.

5: RESULTS FOR TSODILO HILLS AND OKAVANGO RIVER SITES

INTRODUCTION

In this chapter, results for the isotopic analysis of animals and humans from sites at the Tsodilo Hills and the Okavango River are presented. The locations are geographically distinct from each other, one a set of hills in the sandveld and one on a riverbank. Sites at these localities are believed to have been inhabited by people whose ceramics had common stylistic traits to EIA communities in the Zambezi and northern Zambia regions (Denbow 1980, 1986a, 1990; Denbow & Wilmsen 1986, 2009; Wilmsen & Denbow 1990, 2005).

In brief, the quality of collagen for bone samples was evaluated by means collagen yield (3.5 to 22%), weight %C (35 to 47), weight %N (11 and 16%) and atomic C:N ratios (2.9 to 3.6). Unlike, Toutswe samples, samples from Tsodilo Hills tend to have lower collagen yield and this observation is consistent with Pate's (1998) report on Australian arid land samples.

Unfortunately, there are no animal mandibles or maxillae from Divuyu and Xaro. It is only from N!oma that a very small number of animal fragments that fall within the sampling criteria of this study was found. One bone collagen sample per animal was analysed. Enamel apatite samples were extracted from one tooth per animal.

In the case of humans, more than one bone sample from different skeletal parts was analysed where possible. Where the differences between samples were sufficiently small that they probably result merely from random variation, the isotope results were averaged for each human. The juvenile from Divuyu has no teeth to provide enamel apatite and the two adults from Xaro have severe cases of dental caries and have very little enamel left. The Xaro humans were excluded from the analysis of enamel apatite. Human enamel apatite was obtained from the two N!oma individuals only.

SITES ON THE TSODILO HILLS

DIVUYU

A single rib fragment from Divuyu 1, aged 2 - 3 years old, was analysed (Table 5.1). Collagen in the bone fragment was relatively well-preserved despite the fact that part of the soil layers in which the skeleton was discovered were acidic and had eroded some parts of the skeleton.

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Table 5.1: Collagen quality indicators, $\delta^{13}C$ and $\delta^{15}N$ values of Divuyu human

UCT No	Grave	Skeletal part	Collagen Yield (%)	Atomic C:N	Wt C (%)	Wt N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
12570	1	Rib	11.7	2.9	31.3	10.9	-8.8	11.6

The $\delta^{13}C$ value of the rib is -8.8‰ and $\delta^{15}N$ value of the individual is 11.6‰. The $\delta^{13}C$ value of the infant strongly suggests that it was fed a diet based on C_4 grains supplemented with C_3 fruits, nuts and berries. The $\delta^{15}N$ value was expected to be slightly higher than the 11.6 ‰ due to breast milk. The $\delta^{15}N$ value is similar to the $\delta^{15}N$ values of the adults from neighbouring N!oma and Xaro, which are presented in the later part of this chapter.

N!OMA

The $\delta^{13}C$ and $\delta^{15}N$ values were measured in bone collagen from three cattle and three ovicaprids from N!oma. These results are shown in Table 5.2. Atomic C:N ratios, weight percentage carbon and weight percentage nitrogen for all six samples are within the limits quoted for good quality collagen. Collagen yields of the samples are slightly lower when compared to animals from sites in east central Botswana. It is possible that some of the collagen may have been lost within the soil.

Cattle $\delta^{13}C$ values are between -9.7‰ and -9.2‰, with an average of -9.6±0.3‰. The $\delta^{13}C$ values of these cattle are more depleted than those from Toutswe sites, indicating that the Tsodilo Hills

and Toutswe area had distinctively different pastures for cattle. At N!oma cattle ate substantial amounts of C_3 based browse compared to archaeological Toutswe cattle. The $\delta^{15}N$ values of N!oma cattle range from 6.8‰ to 8.2‰ with a mean value of 7.6±0.7‰. These $\delta^{15}N$ values are higher than the $\delta^{15}N$ values of cattle from sites in the Toutswe area and the enriched values could be associated with heat and water stress.

The $\delta^{13}C$ values of ovicaprids vary from -15.7‰ to -8.9‰ with a mean of -12.2±3.4‰. The standard deviation for this group suggests a wide variation in the $\delta^{13}C$ values of the ovicaprids despite the fact that only three individuals were analysed. The ovicaprids appear to have regularly browsed on C_3 based photosynthetic plants as well as grazing on C_4 photosynthetic grasses.

The $\delta^{15}N$ values of ovicaprids are 6.7- 8.4‰ with a mean of 7.3±0.9‰ (Table 5.2). Contrary to $\delta^{13}C$ values, the $\delta^{15}N$ values for these animals cluster a tightly round the mean as shown by the standard deviation of 0.9. It is difficult to explain the differences in variations of the $\delta^{15}N$ values and the $\delta^{13}C$ values because the sample is too small. A single *Raphicerus* sample has a $\delta^{13}C$ value of -21.7‰ (Table 5.2), which is consistent with browsing on C_3 photosynthetic plants. Its $\delta^{15}N$ value (8.1‰) is within the range of $\delta^{15}N$ values of domestic animals from the site.

Six bone collagen samples from three humans at N!oma were analysed and their collagen quality indicators and isotope results are reported in Table 5.3. Collagen yields are low as is the case with animals. However, other collagen quality indicators are within acceptable limits prescribed in the literature and thus the isotope results of the samples are accepted. The $\delta^{13}C$ values for these samples extend from -11.9‰ to -9.3‰ while $\delta^{15}N$ values are from 9.9‰ to 11.7‰.

The average $\delta^{13}C$ and $\delta^{15}N$ results for the three individuals were calculated (Table 5.4). Their $\delta^{13}C$ values are reflective of diets in which C_3 photosynthetic plants played a lesser role than C_4 photosynthetic plants. Given that the environment probably allowed for limited sorghum production, and that mongongo nuts provided an important supplement, it was expected that the humans from N!oma would demonstrate slightly more depleted $\delta^{13}C$ values resulting from increased consumption of both domestic and wild C_3 photosynthetic plant protein. It was initially thought that

Table 5.2: Collagen quality indicators, $\delta^{13}C$ and $\delta^{15}N$ values of N!oma animals

UCT No	Animal sample	Collagen Yield (%)	Atomic C: N	Wt C (%)	Wt N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
Cattle							
12613	4, 80W 110N, 60-70	11.5	3.3	39.4	14.0	-9.7	6.8
12614	5, 01E 30N, 50-60	13.1	3.2	40.7	14.8	-9.2	7.7
12615	6, 01E 30N, 50-60	13.0	3.1	37.5	14.1	-9.8	8.2
					Mean:	**-9.6±0.3**	**7.6±0.7**
Ovicaprids							
12610	1, 41W 61S, 70-80	6.3	3.3	41.0	14.6	-8.9	6.7
12611	2, N!00 80N, 80-90	9.1	3.3	41.2	14.5	-12.0	8.4
12612	3, N!59 60N, 90-100	6.8	3.3	41.9	14.7	-15.7	7.0
					Mean:	**-12.2±3.4**	**7.3±0.9**
Raphicerus							
12669	7, 0-10	11.2	3.3	41.1	14.4	-21.7	8.1

Table 5.3: Collagen quality indicators, $\delta^{13}C$ and $\delta^{15}N$ values of N!oma humans

UCT No	Grave	Skeletal part	Collagen Yield (%)	Atomic C:N	Wt C (%)	Wt N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
13051	1	Rib	5.8	3.3	41.4	14.7	-9.3	11.6
12562	2	Humerus	5.7	3.4	40.1	13.9	-9.3	10.9
12563	2	Rib	6.1	3.3	41.8	14.8	-10.2	10.4
12564	2	Tibia	4.0	3.3	40.8	14.4	-11.9	9.9
12565	3	Skull	9.0	3.3	40.6	14.3	-8.7	11.7
12566	3	Tibia	8.1	3.3	40.7	14.3	-9.8	11.0

Table 5.4: Average $\delta^{13}C$ and $\delta^{15}N$ values of N!oma humans

Grave	Age (years)	Sex	$\delta^{13}C$(‰)	$\delta^{15}N$(‰)
1	1-2		-9.3	11.6
2	14-15	Female	-10.5	10.4
3	40-50	Female	-9.3	11.3
		Mean:	**-9.7±0.7**	**11.1±0.6**

the carbonised remains of *morula* and mongongo nuts at N!oma signalled that the wild plants formed significant portions of the overall diet (Denbow 1999) compared to the dietary composition of the EIA communities in the Toutswe area. The isotope evidence now shows that the ratio of sorghum and millet to legumes and wild foods were equal at both localities.

Figure 5.1 shows the distribution of $\delta^{13}C$ versus $\delta^{15}N$ values of humans, ovicaprids and cattle from N!oma. Humans have $\delta^{13}C$ values similar to the $\delta^{13}C$ values of cattle indicating that they had similar dietary isotope compositions even though they consumed different plant species. Ovicaprids are slightly more depleted than cattle and humans. There is a fair distance between the *Raphicerus* and other herbivores and thereby indicating that their diets did not overlap. Along the $\delta^{15}N$ scale, humans are situated above the animals. It is expected that omnivores will have higher $\delta^{15}N$ values than herbivores.

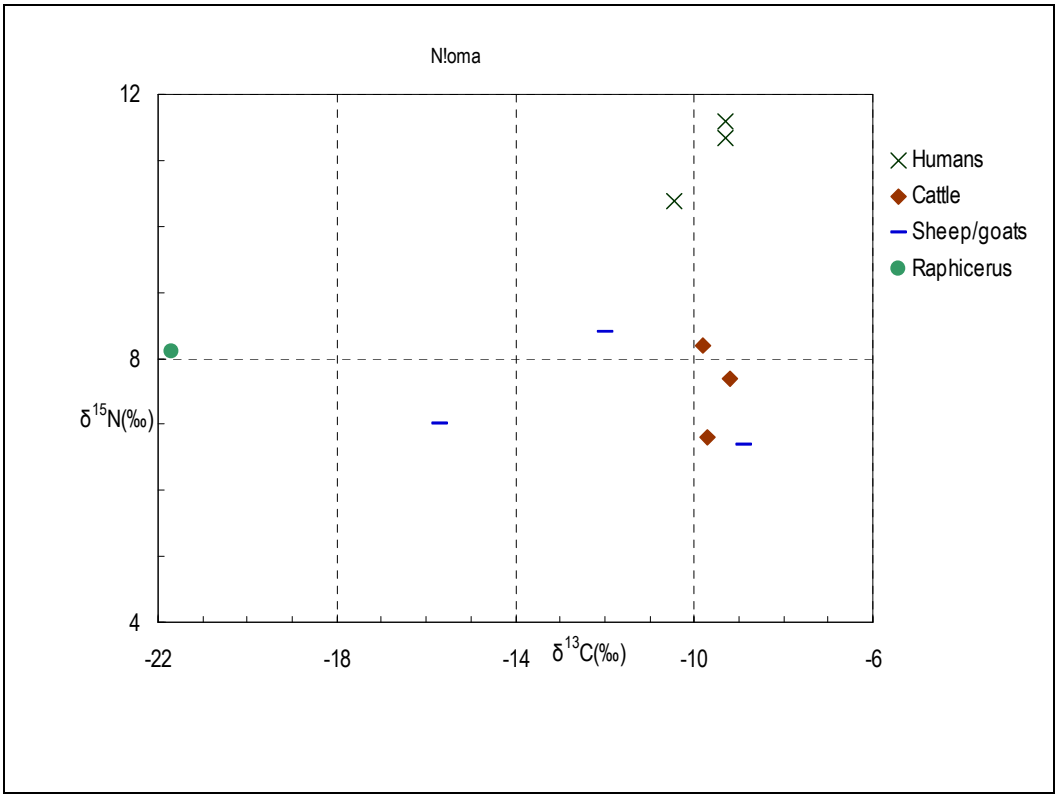


Figure 5.1: Distribution of $\delta^{13}C$ and $\delta^{15}N$ values for all species at N!oma

The six domestic animals from N!oma were included in the analysis of enamel apatite. Only one tooth per individual was analysed and the results are on Table 5.5. Cattle have a mean $\delta^{13}C_{ap}$ value of 0.1±0.6‰. This value is indicative of a combination of both C_3 and C_4 photosynthetic plants in the diets of the cattle. It is consistent with the bone collagen $\delta^{13}C$ values.

The variation in $\delta^{13}C_{ap}$ values of ovicaprids is too wide and the standard deviation of 4.2 is very large (see results on Table 5.5). Sheep/goat 1 has the highest enamel apatite $\delta^{13}C_{ap}$ and the highest bone collagen $\delta^{13}C$ value. Sheep/goat 3 has the lowest $^{13}C/^{12}C$ ratios in both enamel apatite and bone collagen and sheep/goat 2 is in the middle in terms of both $\delta^{13}C_{ap}$ and $\delta^{13}C$ values. These three animals are distinctively different from each other in terms of enamel apatite and bone collage carbon isotope ratios and this is probably due to random dietary preferences.

Table 5.5: Enamel apatite $\delta^{13}C_{ap}$ values of N!oma animals

UCT No	Individual	$\delta^{13}C_{ap}$ (‰)
Cattle		
12704	4	0.6
12705	5	0.2
12706	6	-0.5
	Mean:	**0.1 ± 0.6**
Ovicaprids		
12701	1	-0.2
12702	2	-4.6
12703	3	-8.7
	Mean:	**-4.5±4.2**

Only three teeth from two individuals, both from N!oma had adequate material to allow for enamel apatite analysis (Table 5.6). Other teeth were either fragmented or missing. Mean $\delta^{13}C_{ap}$ value was calculated to be -7.2±1.5‰. The $\delta^{13}C_{ap}$ values of the two individuals are more negative than expected for people whose diets included substantial C_4 photosynthetic domestic plants. Enamel apatite $\delta^{13}C_{ap}$ values strongly indicate that the individuals were raised on diets in which C_3

photosynthetic plants played a dominant role but shifted to include substantial C_4 components later in life. It is also possible that the C_3 based plants provided the bulk of the carbohydrates, but less of the protein, throughout the life spans of the individuals. This would result in the C_3 isotope signature being more dominant in the apatite than in collagen (Klepinger & Mintel 1986; Ambrose & Norr 1993; Howland *et al.* 2003). Unfortunately, there was no isotopic analysis of the bone apatite, which would have been useful in determining the relative contributions of carbohydrates versus proteins in the diet of the humans from N!oma.

Comparison of enamel apatite $\delta^{13}C_{ap}$ values and bone collagen $\delta^{13}C$ values for the two adults from N!oma demonstrate a very strong possibility of a major shift in dietary habits. The childhood isotope signatures are consistent with diets dominated by C_3 photosynthetic plants and/or freshwater fish. These individuals are discussed in detail in Chapter 7.

Table 5.6: Enamel apatite $\delta^{13}C_{ap}$ values of N!oma humans

UCT No	Grave, tooth	$\delta^{13}C_{ap}$ (‰)	Grave	$\delta^{13}C_{ap}$ (‰)
12745	2, C*	-8.5	2	-8.3
12746	2, M_1	-8.0	3	-6.2
12747	3, M^3	-6.2	**Mean:**	**-7.2±1.5**

OKAVANGO RIVER

XARO

No animal remains have been recovered at Xaro. Only two adult graves have been excavated and their stable isotope results are presented here. The individuals from Xaro suffered severe dental carries and antemortem tooth loss (Morris 1996). Very little enamel had been left on the few teeth preserved per individual and it was decided not to destroy them by extracting enamel.

Five samples from the two individuals recovered at Xaro were included in the study. All collagen quality indicators are within acceptable limits and hence the isotope results of all samples were

accepted. Variations in $\delta^{13}C$ and $\delta^{15}N$ values of each individual are less than 1‰. The results for individual bones are presented in Table 5.7.

Table 5.7: Results of bone collagen analysis from Xaro humans

UCT No	Grave	Skeletal part	Collagen Yield (%)	Atomic C:N	Wt C (%)	Wt N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
12567	1	Scapula	31.9	2.8	42.4	15.4	-16.4	9.9
12568	1	Femur	23.9	2.8	41.7	15.0	-16.9	10.8
12569	1	Tibia	24.6	2.8	40.8	14.7	-16.4	10.8
13052	2	Rib	25.7	3.3	42.3	15.2	-16.7	10.8
13050	2	Ilium	21.3	3.3	41.9	15.0	-17.1	10.7

Table 5.8 shows mean $\delta^{13}C$ and $\delta^{15}N$ values of the two graves from Xaro. Their $\delta^{13}C$ values are more depleted than all humans from other sites in the study area. The $\delta^{13}C$ values are strongly associated with diets in which C_3 photosynthetic plants and/or freshwater fish dominate (mean -16.7‰). Freshwater fish has $^{13}C/^{12}C$ ratios similar to those of C_3 plants (Schoeninger & DeNiro 1984; Hedges & Reynard 2007). Consumption of freshwater fish would result in the consumer having collagen $\delta^{13}C$ values similar to those of the Xaro individuals. Furthermore, the site is along the riverbank and it has been found to have fish bones and it is tempting to assume that its inhabitants relied on fishing food. It is highly likely that Xaro inhabitants were fisher men whose plant portion of the diet came from wild fruits, nuts and berries.

Consumption of marine and freshwater fish is known to elevate consumer $^{15}N/^{14}N$ ratios significantly higher the consumption of terrestrial animals (Schoeninger *et al*. 1983; Schoeninger & DeNiro 1984; Hedges & Reynard 2007). It was, therefore, expected that Xaro occupants would have $\delta^{15}N$ values higher than values recorded for people consuming terrestrial meat. The $\delta^{15}N$ values (mean = 10.6‰) of the two Xaro humans are similar to values recorded for N!oma and Toutswe humans.

Despite the results of $\delta^{15}N$, the depleted collagen $\delta^{13}C$ values of Xaro humans most probably resulted from the consumption of freshwater fish and plant based on the C_3 photosynthetic pathway. It thus seems likely that the Xaro the individuals were hunter-gatherers who also practiced fishing.

Table 5.8: Average $\delta^{13}C$ and $\delta^{15}N$ values of Xaro humans

Grave	Age (years)	Sex	$\delta^{13}C$(‰)	$\delta^{15}N$(‰)
1	50-60	Male	-16.6	10.5
2	50-60	Male	-16.9	10.8
		Mean:	**-16.7**	**10.6**

SUMMARY OF THE TSODILO HILS AND OKAVANGO RIVER RESULTS

Cattle from N!oma in the Tsodilo Hills are more depleted in $\delta^{13}C$ values compared to the Iron Age cattle from the Toutswe area. Both cattle and ovicaprids were raised on C_3 dominant vegetations. The area is located within the semi desert in an area where C_4 grasses do not survive long. Rains are scarce and soil fertility in the area is poor (Thomas & Shaw 1991). It is, therefore, not surprising that both cattle and ovicaprids from the Tsodilo Hills have more depleted bone collagen $\delta^{13}C$ and enamel apatite $\delta^{13}C_{ap}$ values than those from eastern Botswana.

Bone collagen and enamel apatite isotope results of humans from Divuyu and N!oma are indicative of a diet which was previously described on the basis of recovered plant and animal remains. Carbonised sorghum and millet attest to the production and consumption of C_4 grains while *morula* and *Mongongo* nut kernels show the C_3 component of the diet.

The three humans from N!oma have a mean $\delta^{15}N$ value of 11.1‰ which is similar to the mean $\delta^{15}N$ value of 10.6‰ reported for the individuals from Xaro. From the geographic point of view, it seems like the N!oma community experienced water shortages while the Xaro community had access to the water in the Okavango River. It was expected that the individuals from N!oma would have a significantly higher $\delta^{15}N$ value as opposed to those from Xaro but this is not the case. The isotopic evidence strongly suggest that during the Iron Age occupation of N!oma there were regular sources of water though the site is located in a fairy dry area.

At Xaro, no evidence for hunter-gatherer occupation was documented from the artifacts recovered during excavation (Denbow: personal communication, 2006). Lack of stone tools at the site together with the presence of pottery similar to that found at Divuyu gives an impression that the site was occupied by farmers. The $\delta^{13}C$ values of the individuals from Xaro are significantly depleted compared with $\delta^{13}C$ values of individuals from all other sites. The results could have been due to consumption of C_3 based foods or fish from the Okavango River.

6: INTERPRETATION OF ANIMAL ISOTOPE RESULTS

INTRODUCTION

The interpretation and discussion of isotope results of animals obtained from all sites are presented in this chapter. The range and average $\delta^{13}C$ and $\delta^{15}N$ values of animals from each site are considered and the data compared across sites to assess regional climatic, environmental and dietary conditions. The relative importance of grazing and browsing is interpreted based on $\delta^{13}C$ and $\delta^{13}C_{ap}$ values. These values are also used to make inferences as to the nature of the vegetation available to animals.

According various models available in the literature e.g. Vogel (1978), Lee-Thorp *et al.* (1993) and Ambrose (1993), pure browsers are expected to have mean $\delta^{13}C$ values of -21.5‰ while pure grazers are expected to have mean $\delta^{13}C$ values of around -7.5‰. There is, therefore, a 14‰ difference between $\delta^{13}C$ values of grazers and browsers. In these models, a 1.5‰ increase in $\delta^{13}C$ values equates to about 10% intake of C_4 grasses (Vogel 1978; van der Merwe 1982). The end value for pure grazers from the current study is adjusted to -6.0‰ to cater for all results obtained. Consequently, the end-point for pure browsers is placed at -21.0‰.

It is acknowledged that the adjustment made for the current results should have been based on the $\delta^{13}C$ values of the vegetation in the area. Unfortunately, the study did not include the isotope analysis of plants. Plant isotope values provide a platform from which herbivore isotope results can be interpreted. For instance, when using vegetation $\delta^{13}C$ values as a baseline, a mean $\delta^{13}C$ value of -8.6‰ for modern grazers from the SLRB area equated to a 90% C_4 consumption (Smith 2005). A similar $\delta^{13}C$ value (-8.6‰) in the current study demonstrates an approximately 80% C_4 contribution to the diet. Both studies demonstrate strong relationships between herbivore isotope

results and their known feeding habits. Therefore, the fact that plants were not included in the current study should not be seen as a major limitation.

The $\delta^{15}N$ values of animals shed light on prehistoric rainfall and temperature conditions. Sealy *et al*. (1987) found differences of more than 10‰ in $\delta^{15}N$ values of herbivores from low and high rainfall environments in southern Africa. Nitrogen isotope values can also be used to reconstruct diet. For example, grazers' diets during the dry season have low nitrogen content and therefore these animals will have lower $\delta^{15}N$ values compared to browsers and mixed feeders (Ambrose 1993).

Attempts were made to determine intra-site variations in cattle $\delta^{13}C$ values. This could be achieved by comparing results of cattle from different periods of occupation of the same site. Such attempts required that there be numerous samples of cattle from successive excavation layers. Unfortunately as seen on Table 6.1 the numbers of samples per site were too few. Denbow *et al.* (2008) have published other data for Bosutswe. Their samples include different skeletal elements and this makes it difficult to establish the minimum number of individuals present. The results are only used for comparative purposes instead of adding them to the current samples from the same site. For example, Bosutswe had very few samples while Kgaswe B55 and Thatswane had one sample each. Four of the six Taukome samples could not be attributed to specific contexts. The number of samples from Toutswemogala were sufficient, but unfortunately as mentioned in Chapter 2 (literature review), it is difficult to correlate Lepionka's (1971, 1978, 1979) labels to actual depth of excavation units.

Due to limitations listed above, samples from different sites but same period of occupation are pooled for the interpretation of the environment across both space and time. For example, samples from Taukome and some from Bosutswe were pooled for the interpretation and discussion of the environment during the Zhizo period. Since there is only a small number of wild animals, their isotope results are discussed under one section.

Results for domestic herbivores in this study are compared with data from archaeological and modern animals from the SLRB (Smith 2005; Smith *et al.* 2007). Sites in the SLRB are

geographically and temporally close to sites in the Toutswe area. In addition, EIA sites in the SLRB such as Mapungubwe and K2 are known to share some cultural and socio-economic links with Toutswe sites (Denbow 1986a, 1990; Huffman 1986, 2007). It is worth noting that the means of $\delta^{13}C$ values cattle from Zhizo and Schroda in the SLRB were recalculated from the individual results, a method slightly different from that used by Smith (2005). In presenting her overall results, Smith (2005) calculated the means of each level and then calculated the overall site mean from the different averages per level. In order to maintain consistency, it was necessary to calculate the means and standard deviations from the raw data from Smith (2005). As a result, the mean and standard deviations of Schroda and Pont Drift in Table 6.1 are slightly different from those reported by Smith (2005 pg. 142-3). Table 6.1 shows the mean $\delta^{13}C$ results for all cattle from the five Toutswe sites listed above, the one site in the Tsodilo Hills as well as from Schroda and Pont Drift in the SLRB.

The discussion in this chapter is organised according to ceramic/cultural period and geographic location. The samples generally come from two periods divided in to AD700 to 1000 (Taukome/Zhizo) and AD1000-1300 (Toutswe). The period from AD700 to 1000 is represented by samples from the Taukome/Zhizo deposits in the Toutswe area as well as all samples from the Tsodilo Hills. In terms of geographic locations, two regions represented in the study are the east central (Toutswe) and the northwest (Tsodilo Hills). The isotope results of samples from archaeological deposits are interpreted on basis of results from modern animals from Toutswemogala and Bosutswe. It is therefore, necessary to start the overall discussion by outlining the relationships between isotope values and feeding habits of modern herbivores from the study area.

MODERN ANIMAL ISOTOPE RESULTS

INTERPRETATION OF CARBON ISOTOPES

Modern cattle have a mean $\delta^{13}C$ values of around -12‰ while ovicaprids have a mean value of -19.0‰ (see Table 6.1 and Table 6.2). Thus, the C_4 dietary components of the cattle and ovicaprids were 60% and <20% respectively. Modern cattle have not shifted entirely to C_3 browsing but they appear to use this alternative food resource as an important supplement. The C_3 component of the

cattle diet comes largely from *mophane* leaves (personal observation, 2002 to 2006). The C_4 component came from grasses and crop fodder and stubble.

On the other hand, the carbon isotope signature of the ovicaprids strongly suggests that the animals had become pure browsers (Table 6.2). Their $\delta^{13}C$ values average -19‰ for both sites. It is difficult to tell which plants they consumed the most since these two species are adapted to different vegetations. However, from the observation made in the field it seems highly likely that the bulk of the C_3 dietary portion of the ovicaprids also came from *mophane* trees.

In addition to cattle and ovicaprids there were samples of donkeys (n=5), horse (n=1) and kudu (n=1) from Bosutswe and Toutswemogala (Table 6.3). The donkeys and the horse have relatively similar $\delta^{13}C$ values ranging between -13.5‰ and -11.3‰. They show diets in which the C_4 components vary between 60% and 70%. These values were expected based on the nature of pastures for these animals. The $\delta^{13}C$ value of -20.5‰ for the kudu sample was expected because the animal is a browser.

INTERPRETATION OF NITROGEN ISOTOPES

Modern cattle from Bosutswe and Toutswemogala have mean $\delta^{15}N$ values similar to those of their EIA counterparts. Table 2.1 shows that annual rainfall for Serowe-Palapye area ranged between 153.7mm and 577mm from 2004 to 2006. Annual rainfall during the Iron Age occupation of these two sites is believed to have been approximately 500mm with short periods of draught and flooding (Denbow *et al.* 2008). The current rainfall pattern seems to be similar to that of the Iron Age period and hence similarities in mean $\delta^{15}N$ values of modern animals and animals from archaeological contexts.

Samples of modern ovicaprids from Toutswemogala (n=4) were on average 9.2±1.3‰ and the single sample from Bosutswe was 10.1‰ (Table 6.5). The differences in mean $\delta^{15}N$ values of cattle and ovicaprids are most probably a result of inter-species variation. Both species have relatively equal access to water from boreholes this suggests that differences in mean $\delta^{15}N$ values are most probably related to dietary differences. According to Ambrose (1993), grazers eat low

nitrogen diets during the dry season and will consequently have lower $\delta^{15}N$ values when compared to browsers and mixed feeders.

Heat and water stress cause by drought in the area are believed to have a significant influence on the slightly elevated $\delta^{15}N$ values of modern cattle. Elevated $\delta^{15}N$ values of modern cattle compared to archaeological cattle could be attributed to one or a combination of the following factors. Firstly, when the climate is hotter and drier, cattle conserve body water by excreting urea with high ^{14}N concentrations and therefore they remain enriched in ^{15}N (Heaton *et al.* 1986; Ambrose 1991). This physiological response to heat and dryness leads to higher $^{15}N/^{14}N$ ratios. Secondly, modern cattle are known to feed significantly on tree leaves, which have $^{15}N/^{14}N$ ratios that are significantly different from those of stems, roots and grasses and this information is imprinted on the collagen component of bone. Slight difference in temperatures during these different periods could mean that one animal population loses more urea than the other and hence differences in $\delta^{15}N$. Unfortunately, it is not known how much of a difference in environmental temperature would elicit differences in $^{15}N/^{14}N$ ratios.

The nitrogen isotope results for the modern ovicaprids from the study area are similar to results for the same species where seasonal mean annual rainfall is ≤350mm in the SLRB (Smith 2005 pg 145). For Toutswemogala and Bosutswe, annual rainfall between 2004 and 2006 was between 153 and 577mm. There is strong overlap between the annual rainfalls of the SLRB and Serowe-Palapye areas which probably explains similarities in mean $\delta^{15}N$ values of the ovicaprids.

SUMMARY FOR THE MODERN PERIOD

In summary, all modern herbivore species from Bosutswe and Toutswemogala have $\delta^{13}C$ values associated with diets in which C_3 plants play a very significant role. The mean $\delta^{13}C$ value of cattle is approximately -12.‰ while ovicaprids average -19‰. The carbon isotope ratios reported for these animals are interpreted as indicating diets in which the C_4 component was 60% for cattle and only 10% for ovicaprids. Donkeys have mean $\delta^{13}C$ value of -14‰ while the horse has a value of -11‰. The dietary patterns of the donkeys and the horse are most probably made of 60% and 70% C_4 grasses respectively.

The carbon isotope values are substantially more negative than obtained for archaeological cattle, with no overlap between the ranges as will be seen in the next sections of this chapter. The implication is that there has been a significant change in vegetation at Bosutswe and Toutswemogala between the EIA occupation and the present. Overgrazing and drought at the sites are the major role players in the situation. Scattered trees (*mopane*) and shrubs (C_3) have replaced Grass (C_4) cover. Modern cattle have had to adjust their dietary habits by swapping C_4 grasses for C_3 *mopane* and other tree leaves while ovicaprids have become pure browsers. The only species with carbon isotope results matching their known dietary habits is the kudu with a $\delta^{13}C$ value of -21‰.

ISOTOPE RESULTS FROM AD700 TO 1000

THE TOUTSWE AREA: TAUKOME/ZHIZO CERAMIC CULTURE

In the current study, only three sites are known to have deposits associated with the Taukome/Zhizo (AD700–1000) ceramic culture. These sites are Taukome, Bosutswe and Toutswemogala. The site Taukome is dated between AD710 and 995 (Denbow 1983a) and all Taukome animal samples come from the Taukome/Zhizo period. In this study, none of the cattle samples from Bosutswe were from the Taukome/Zhizo levels. Fortunately, in a study by Denbow *et al.* (2008) cattle from the Zhizo deposits at Bosutswe were available for inclusion. As far as Toutswemogala is concerned, all samples were obtained from Lepionka's (1971, 1978, 1979) fieldwork. The samples were from the upper deposits which post date the Taukome/Zhizo phase (Denbow 1983a). Therefore, in this study, only samples from Taukome are of the Taukome/Zhizo period.

INTERPRETATION OF CARBON ISOTOPE VALUES

The mean $\delta^{13}C$ value of the six cattle from Taukome was -6.1±0.4‰ (Table 6.1). The low standard deviation of the samples demonstrates that individual $\delta^{13}C$ values cluster around the mean. Indeed when assessed individually, five cattle have $\delta^{13}C$ values associated with the consumption of 100% C_4 grasses and one had a 90% C_4 based diet. As mentioned above, there is additional cattle isotope data for the Zhizo period from a study by Denbow *et al.* (2008). Their samples (n=3) had a

mean $\delta^{13}C$ value of -6.6±1.1‰. As is the case for Taukome, cattle at Bosutswe appear to have subsisted on 100% grasses during the Zhizo period. The C_4 fodder and stubble was probably made available for animal consumption just after harvest.

Like cattle, Taukome ovicaprids (n=20) are from the Taukome/Zhizo period. These samples have a mean $\delta^{13}C$ value of -10.6±2.5‰ (Table 6.2). The mean $\delta^{13}C$ value is indicative of a 70% C_4 component in their diet. Only one sheep/goat sample from the Taukome/Zhizo deposits at Bosutswe was included in the study by Denbow and co-workers (2008). The sample yielded a $\delta^{13}C$ value of -11.6‰ (i.e. consumption of ~60% C_4 photosynthetic grasses) a value within the range established for the Taukome samples.

It is worth noting that the mean $\delta^{13}C$ value for the ovicaprids masks the variation of their actual diets which ranged from pure C_4 graze (UCT 12625, -6.2‰) to mixed-feeding (UCT 12255, -15.8‰). The $\delta^{13}C$ variation cannot be attributed to periodic change in diet because even samples from the same levels are not isotopically similar. Furthermore, there is no obvious relationship between age of the animal and its $\delta^{13}C$ value. This casts doubt on the possibility that feeding habits differed between animals of different ages. It seems unlikely that the variation is due to sample size because as will be seen in the next section, different sample sizes from various sites all produce weak standard deviations. Ovicaprids are mixed feeders and it is possible that the variation in $\delta^{13}C$ values of the individuals is random. Had the pastures of the period from AD700 to 1000 been the similar to those experienced in the last few years, then the $\delta^{13}C$ values of the cattle and ovicaprids would have been similar to those of modern samples.

In the neighbouring SLRB, cattle kept during the Zhizo period (AD900-1000) appear to have had slightly different dietary habits. For example, at Schroda and Pont Drift, cattle had mean $\delta^{13}C$ values of -8.1±1.8‰ (n=21) and -8.9±0.8‰ (n=9) respectively (Table 6.1). According to the study (Smith 2005), these $\delta^{13}C$ values demonstrate a 90% consumption of C_4 photosynthetic vegetation. Though small, the 100% graze versus 90% graze for Toutswe and SLRB cattle respectively, might actually be due to minor differences in local climatic and environmental conditions. The role of the climate in dietary variability between Toutswe and SLRB cattle is explored using $\delta^{15}N$ values in the next section.

In contrast, ovicaprids from the Zhizo period in the Shashe-Limpopo area had more depleted $\delta^{13}C$ values (see Table 6.2). However, the range of carbon isotope values of ovicaprids from the Toutswe area (-15.6 to -6.2‰) is within the range quoted for Schroda (-17.3 to -6.8‰). The $\delta^{13}C$ range for Pont Drift is slightly different from that of Toutswe as it falls between -19.2 and -10.3‰. The differences in mean $\delta^{13}C$ values between the Toutswe and the SLRB samples is probably related to differences in sample sizes. At Schroda, the mean $\delta^{13}C$ value of 57 ovicaprids was calculated at -11.9±0.6‰ and at Pont Drift the mean $\delta^{13}C$ value (n=32) was -14.0±1.4‰ (Smith 2005). Mean $\delta^{13}C$ values reported for Schroda and Pont Drift are associated with diets in which the C_4 component was 60% and 50% respectively.

THE INTERPRETATION OF NITROGEN ISOTOPES

The six cattle from the Taukome/Zhizo period at Taukome have a $\delta^{15}N$ range of 5.1 to 7.9‰ with a mean $\delta^{15}N$ value of 6.4±1.1‰ (Table 6.4). The $\delta^{15}N$ values are randomly spread with no particular relationship to the $\delta^{13}C$ values. The mean $\delta^{15}N$ value of the Taukome cattle is comparable to the same value for the cattle from Taukome/Zhizo layers at Bosutswe.

The samples from Bosutswe have a mean $\delta^{15}N$ value of 7.0±1.3‰. This $\delta^{15}N$ value is similar to that reported for the modern samples from the same site. As mentioned previously, modern cattle samples from Bosutswe have an average $\delta^{15}N$ value of about 8‰ and live within an environment in which annual rainfall is around 500mm. The similarities in $\delta^{15}N$ values between archaeological and modern samples can be interpreted as signalling similarities in climatic conditions. According to Denbow and co-authors (2008) the nitrogen isotope ratios of cattle from Bosutswe are associated with mean annual rainfall of ~500mm (Denbow *et al.* 2008).

As mentioned in the previous section, the $\delta^{13}C$ values of cattle indicate a 100% C_4 plant diet. It is proposed that for cattle to have annual access to palatable pastures, annual rainfall and length of the rainy season needed to be above certain limits. The annual rainfall of 500mm predicted from the $\delta^{15}N$ values of cattle would have been sufficient to sustain pastures.

By comparison to the Taukome/Zhizo cattle from the Toutswe area, cattle from the Zhizo sequences at Schroda (n=21) and Pont Drift (n= 9) have mean $\delta^{15}N$ values of 9.1±1.7‰ and 8.5±0.8‰ respectively. The Schroda and Pont Drift results indicate mean annual rainfall of 350mm to 450mm (Smith 2005; Smith *et al.* 2007). The mean $\delta^{15}N$ value of ovicaprids of the Taukome/Zhizo period at Taukome (n=20) was calculated at 7.1±1.1‰ (Table 6.5). The $\delta^{15}N$ values vary by ~4‰ and show no particular relationship with $\delta^{13}C$ values. The sample group comprises individuals of all ages and some of the variation in $\delta^{15}N$ values is attributed to age. Some but not all young ovicaprids have high $\delta^{15}N$ values as expected of breastfeeding mammals. The difference in $\delta^{15}N$ values of cattle and ovicaprids from Taukome is only 0.7‰, as opposed to a difference of 2.5‰ observed for the modern cattle and ovicaprids from Toutswemogala. The small difference in the nitrogen isotope values of cattle and ovicaprids during the Taukome/Zhizo period is a possibly an indication of a wetter ecosystem. Thus, the differences in mean $\delta^{15}N$ values between the SLRB and the Toutswe areas during the Taukome/Zhizo period are most probably due to differences in climatic conditions. The SLRB would have been slightly drier with annual rainfall of 350 to 450mm (Smith *et al.* 2007) while the Toutswe area received 500mm of rainfall annually (Denbow *et al.* 2008).

From Bosutswe, only one sample from the Taukome/Zhizo levels was analysed by Denbow *et al.* (2008) and its $\delta^{15}N$ value was 6.2‰. Based on comparative data from the SLRB (Smith 2005; Smith *et al.* 2007), it can be said that the mean $\delta^{15}N$ values of ovicaprids from the Taukome/Zhizo period at both Taukome and Bosutswe are indicative of mean annual rainfall of ~500mm.

SUMMARY FOR THE TAUKOME/ZHIZO PERIOD

In summary, $\delta^{13}C$ and $\delta^{15}N$ values of cattle and small stock from the Taukome/Zhizo sequences (AD 700-1000) at the sites of Taukome and Bosutswe indicate that:

- Vegetation in the Toutswe area included substantial amounts of palatable grasses. Cattle were pure C_4 grazers while ovicaprids (mixed feeders) had more C_4 than C_3 photosynthetic plants in their diets. Using the various models in the literature (e.g. Vogel 1978; van der Merwe1982; Ambrose 1986; Ambrose & Norr 1993) models, the $\delta^{13}C$ values of cattle

indicate a diet of pure C_4 plant protein (about -6‰) and ovicaprids ate a combination of 20% C_3 browse and 80% C_4 graze.

- Though samples are small in numbers, the mean $\delta^{13}C$ values of cattle from both Taukome (current study) and Bosutswe (Denbow *et al.* 2008) indicate that during the period from AD700 to 1000, the Toutswe area in east central Botswana had yearly supplies of pastures for domestic animals. This would have been made possible by a combination of different factors such as good rainfall, low animal populations and good animal herding strategies.

- Comparative results from the SLRB (Smith 2005; Smith *et al.* 2007) suggest that during the Taukome/Zhizo phase, mean annual rainfall in the Toutswe area was approximately 500mm and rainy seasons were probably longer. The results are also consistent with evidence from other studies, which suggest a wetter and warmer climate in southern Africa between AD900 and 1350 (Tyson & Lindesay 1992; Huffman 1996, 2008; Lee-Thorp *et al.* 2001; Tyson *et al.* 2002).

- Though samples are too small for the calculation of the Mann-Whitney U- Test, similarities in mean $\delta^{13}C$ and $\delta^{15}N$ values for samples from Taukome and Bosutswe show that the sites fell under the same vegetation and climatic zone.

THE TSODILO HILLS AREA

The site of N!oma in the Tsodilo Hills was occupied between AD700 and 1200 (Denbow 1980; Wilmsen 1990; Wilmsen & Denbow 2005) i.e. around the same time as the Taukome/Zhizo phase at Bosutswe. The three cattle samples from N!oma have a mean $\delta^{13}C$ value of -9.6±0.3‰ (Table 6.1). The isotope signature of the cattle from N!oma suggest a diet in which the C_4 component was around 85%. This is about 15% less C_4 component in the overall diet of cattle at N!oma than at Toutswe. Two possibilities can be used to explain these differences in mean $\delta^{13}C$ values: differences in vegetations or differences in climatic conditions. These possibilities are explored in the next two paragraphs.

Since both cattle and ovicaprids some degree of browsing, is can be argued that the C_4 vegetation at N!oma was not sufficient to support domestic animals. In contrast, animals in the Toutswe area were sustained on C_4 vegetation, which was available for long periods. Though the sample size is very small, the $\delta^{13}C$ values of ovicaprids from N!oma (Table 6.2) indicate that the $\delta^{13}C$ values reported for cattle are a true reflection of the vegetation conditions at the Tsodilo Hills. The mean $\delta^{13}C$ value of ovicaprids is -12.2±3.4‰. The ovicaprids had about 60% C_4 grasses in their overall diets.

The mean $\delta^{15}N$ value for the cattle samples from N!oma is 7.6 ± 0.7‰. In the SLRB, this $\delta^{15}N$ value would correspond with a mean annual rainfall of ≤450mm (Smith 2005; Smith *et al.* 2007, Huffman 2008). Ovicaprids have $\delta^{15}N$ values of 7.3±0.9‰. The sheep/goat mean $\delta^{15}N$ value for N!oma is slightly lower than the results reported for the SLRB in which mean $\delta^{15}N$ values of ~9‰ reflect annual rainfall of 350-450mm (Smith 2005; Smith *et al.* 2007; Huffman 2008). Thus, contrary to cattle $\delta^{15}N$ values, the mean $\delta^{15}N$ value of the ovicaprids suggests a mean annual rainfall of ~500mm.

Similarities in mean $\delta^{13}C$ values of the ceramic sequence at N!oma, and the values for Zhizo levels at Schroda and Pont Drift, suggest that the two areas had similar rainfall conditions. The plant species were most probably different but it seems that the overall amount of edible grasses were the same. Similarities in $\delta^{15}N$ values of herbivores from N!oma and Toutswe areas strongly suggest that both areas received equal amounts of rainfall annually. The differences in $\delta^{13}C$ values, on the other hand, most probably due to differences in vegetation.

SUMMARY FOR THE TSODILO HILLS

The isotope values of cattle and ovicaprids from N!oma are summarised as follows:

- Climatic fluctuations at the Tsodilo Hills may have led to periodic abandonment of the sites (Denbow & Wilmsen 1986). Periodic droughts may have caused changes in cattle's feeding habits. Faunal analysis indicate that Sanga (hump-backed) cattle were present in the economy of N!oma (Turner 1987a). This variety of cattle is known to be more drought tolerant than most cattle that are reared in southern Africa. The presence of Sanga cattle

at N!oma can be taken as indication that the area was relatively dry and not very conducive for the growth of C_4 grasses. The predicted mean annual rainfall of 450-500mm is matched by the rearing of a drought tolerant cattle variety.

- N!oma is within a semi-desert where soil nutrition and productivity is poor, and grasses in general would not grow in abundance. In addition, the northwest region is generally hotter than the Toutswe area. Since grasses are less tolerant to heat than trees and bushes, domestic animals at the Tsodilo Hills survived by increasing the browsing component of their diets.

- The predicted mean annual rainfall of between 450 and 500mm at N!oma strongly suggests that overall rainfall quantities were sufficient for animal and crop production. However, it is possible that the rainy season was short thereby making good pasture seasons brief and requiring cattle to supplement their diets with C_3 photosynthetic leaves and brush.

- There appears to have been sufficient rainfall to support crop production for the EIA communities at the Tsodilo Hills. However, the soils around the Tsodilo area are of poor nutritional value and this may have hampered grain production. Moreover, high temperatures may have also contributed to low crop yields. As a result, cattle at the Tsodilo Hills had less access to fodder and stubble than those at Toutswe sites.

THE TOUTSWE PERIOD (AD1000 – 1300)

Samples from Kgaswe B55, Thatswane, Bosutswe and Toutswemogala are associated with the Toutswe period. The Toutswe period is divided into early and later phases. It is not very clear as to whether samples from any of these sites came from the early or later Toutswe phase. The phases overlap with each other and ceramic similarities suggest internal cultural evolution and not the arrival of new communities (Denbow 1983a). Because of lack of high-resolution radiocarbon dates,

and the likelihood that there was no migration, samples are lumped into a single Toutswe period and not subdivided into phases.

Occupation of Kgaswe B55 was short (ca. 100 years) and once abandoned, the site was not re-occupied (Denbow 1982, 1983a, 1983b, 1984a, 1986a). Consequently, successive generations of cattle kept at Kgaswe B55 probably lived under similar climatic and environmental conditions. However, periodic climatic changes like severe short droughts may have occurred that could influence feeding habits of cattle. The occupation at Thatswane was much longer (about 300 years) and probably was associated with periodic climatic and vegetation alterations.

THE INTERPRETATION OF CARBON ISOTOPES

Cattle mean $\delta^{13}C$ values of the single cow samples from Kgaswe B55 and Thatswane (both -5.9‰) are both indicative of a 100% C_4 based diet (see Table 6.1a). Given the similarity in $\delta^{13}C$ values cattle from the Toutswe period at Bosutswe and at Toutswemogala, it seems highly likely that the results for Kgaswe B55 and Thatswane are representative of the cattle populations in the Toutswe area.

The number of cattle samples from the Toutswe period at Bosutswe (AD1000 - 1200) was very small (n=4). The samples yielded a mean $\delta^{13}C$ value of -5.7±0.7‰ (Table 6.1), a value associated with a pure C_4 diet (Vogel 1978; van der Merwe 1982; Ambrose 1986; Ambrose & Norr 1993). The mean $\delta^{13}C$ value of cattle (n=8) from Denbow *et al.* (2008) was -8.0±3.2‰. The difference between the mean $\delta^{13}C$ values of the two studies is that Denbow *et al.* (2008) did not exclude, as outliers, two samples with highly depleted $\delta^{13}C$ values of -14‰ and -12.1‰, whereas in the current study such samples were excluded in the calculation of mean and standard deviation but were included in the Mann-Whitney U Test calculation. In fact, when the Denbow *et al.* (2008) mean was recalculated without the two most depleted samples, the mean $\delta^{13}C$ result dropped down to -6.3±0.9‰, a value consistent with the current study.

Fourteen cattle samples from Toutswemogala yielded a mean $\delta^{13}C$ value of -5.9 ± 1.3 (Table 6.1). These cattle were exclusive C_4 grazers, hence broadening the extent of the C_4 grass-rich

vegetation zone to include the major site in the Toutswe settlement polity. A single sample from Toutswemogala (UCT 12643) had a $\delta^{13}C$ value that was significantly different from others and was not included in the mean calculation. The value of -10.4‰ was similar to modern cattle values. The $\delta^{13}C$ value of this cow shows that the C_4 component of its diet was only 80%. The sample came from a unit 5R145 Level 2 and it is not clear how deep the level was. However, other cattle from the same level but different units e.g. 10R135 second half L2 (UCT 12640) and 5R-5 L2 (UCT 12641) had $\delta^{13}C$ values consistent with the rest of the group. The cow could have been acquired from places where cattle fed on C_3 browse. It is also possible that the sample was intrusive i.e. deposited long after the site had been abandoned.

Figure 6.1 shows the relative proportions of C_4 and C_3 vegetation in the diets of cattle from the study area as well as those from the SLRB area. Only cattle from Toutswe Iron Age contexts fed exclusively on C_4 grasses. Cattle from Iron Age sites of Schroda and Pont Drift in the SLRB as well as the Tsodilo Hills had a 10 – 15% C_3 component in their diets. The variations between Iron Age cattle from Toutswe and other sites are consistent with known climatic conditions of the Iron Age of southern Africa. The SLRB was slightly drier than Toutswe area with annual rainfall of about 350 – 400mm (Huffman 2006, 2008: Smith *et al.* 2007; Denbow *et al.* 2008). In contrast, the increase in C_3 intake of modern cattle at Toutswe is due to lack of good pastures following degradation of vegetation. In Figure 6.2, the variations depicted in the dietary compositions of ovicaprids at all sites are similar to those for cattle. Ovicaprids from Toutswe archaeological deposits have the highest C4 component in the diet compared to others.

Of the four cattle teeth from Kgaswe B55, only one was associated with a mandible. It is therefore not possible to determine the minimum number of individuals represented. The four teeth have a mean $\delta^{13}C_{ap}$ of 2.7±0.5 indicating the animal(s) had a substantial C_3 input in their diet during developmental years. Results of $\delta^{13}C_{ap}$ values of the three cattle from Thatswane and the six cattle from Bosutswe demonstrate that the animals were raised on areas with substantial grazing lands. The mean $\delta^{13}C_{ap}$ values of cattle from Thatswane and Bosutswe are similar to each other even though the sites are not within the same locality.

Carbon isotope values of the Kgaswe B55 ovicaprids were on average -10.3‰. This isotope value resulted from the regular consumption of 80% C_4 and 20% C_3 plants (Table 6.2). In other words, C_4 grasses continued to dominate the dietary composition of ovicaprids during the Toutswe period, the same way as during the Taukome/Zhizo period. A combination of good rainfall and adequate grasses (i.e. no overgrazing) might explain this diet. Sample 2 from ash pit 7, (UCT 12247) has $\delta^{13}C$ value of -16.4‰. The highly depleted C isotope results could be that this animal had been brought in from a 'foreign' land where C_4 grasses were inadequate.

Six samples of ovicaprids from Thatswane were erroneously placed in a bag without contextual information; five were (fortunately) properly labelled. Of these five, one (UCT 12271) had little to no collagen preserved. The other three were recovered at depths of 50 to 70cm all in Unit 4 and they have $\delta^{13}C$ values of -6.7 to -9.2‰ (Table 6.2). A date of 840±75BP (Denbow 1983a) was obtained from material just above the levels where the ovicaprids were recovered. The fourth sample (UCT 12270) shows results off the range of the entire site. This sample comes from the deepest levels (Unit 4D, 84 – 102cm below surface) and is the only one from these layers. Its collagen $\delta^{13}C$ value is -15.3‰. A repeat analysis of the same sample produced a similar result (-15.9‰) and thereby ruling out the possibility that the first isotope value had been influenced by machine error. The sheep/goat had feeding habits very different from those other individuals in the region. This sheep/goat appears to have originated outside the area. The animal could have been obtained through the various forms of exchange between communities.

The Bosutswe ovicaprid appears to have consumed more C_3 photosynthetic plants than ovicaprids at Kgaswe B55 and Thatswane. The sample is only one and hence no statistically viable comparisons can be made between Bosutswe and the Kgaswe B55 and Thatswane sample groups.

THE INTERPRETATION OF NITROGEN ISOTOPES

The cattle from Toutswe deposits at Kgaswe B55, Thatswane, Bosutswe and Toutswemogala have $\delta^{15}N$ values ranging between 4.0‰ and 8.1‰. The average $\delta^{15}N$ value per site is approximately

6‰ (Table 6.4), suggesting a relatively high annual rainfall of ~450mm, as inferred above for the Taukome/Zhizo period.

Cattle from Thatswane and Toutswemogala have the lowest $\delta^{15}N$ values compared to other Toutswe sites (Table 6.4). These two sites i.e. Thatswane and Toutswemogala are within a few kilometres from each other (Denbow 1982, 1983a, 1984a) and it is therefore not surprising that their $\delta^{15}N$ values are similar to each other. Their $\delta^{15}N$ values suggest mean annual rainfall of ≥500mm.

In contrast to Toutswe cattle, Leopard's Kopje A (AD1010 – 1220) cattle at Schroda and had Pont Drift had elevated $\delta^{15}N$ values. The samples from Schroda had a mean $\delta^{15}N$ value of 8.1±1.2‰ (n=5) and those from Pont Drift 7.6±2.4‰ (n=3). According to Smith *et al.* (2007) the mean $\delta^{15}N$ value of the Leopard's Kopje A cattle at Schroda reflect a period in which mean annual rainfall was between 350mm and 450mm. The average $\delta^{15}N$ value of ovicaprids from the Leopard's Kopje A deposits (AD1010 to 1220) at Schroda was 9.1±1.1‰ corresponding with mean annual rainfall of 350mm to 500mm (Smith *et al.* 2007).

The values reported for Toutswe ovicaprids are similar to those of the ovicaprids from the Icon Facies of the Moloko period (AD1310 to 1415) in the SLRB (Smith *et al.* 2007). This period corresponds with the post Toutswe period in east central Botswana. The ovicaprids from Icon (n=9) had a mean $\delta^{15}N$ value of 7.1±1.5‰, corresponding with an environment in which mean annual rainfall was ≥500mm.

SUMMARY FOR THE TOUTSWE PERIOD

Stable isotope values of cattle and ovicaprids from the Toutswe sequences at Kgaswe B55, Thatswane, Bosutswe and Toutswemogala demonstrate that during the AD1000 to 1300 period, the vegetation and climate were as follows:

- Vegetation and rainfall patterns showed continuity from the earlier Taukome/Zhizo period (AD700 - 1000). Mean annual rainfall was ~500mm for the most part of the Toutswe

phase. Periodic short droughts may have occurred during the 300-year period but unfortunately samples in the current study and in the Denbow *et al.* (2008) study were selected in such a way that such fine resolutions of detecting periodic droughts could be addressed. Perhaps that anomalous sheep/goat sample is indicative of a drought spell.

- The predicted mean annual rainfall of 500mm would have been sufficient to support the production of sorghum, millet, beans and peas for the communities. Proliferation of Toutswe sites around AD1000 has been linked to strengthening trade and economic networks (Denbow 1983a, 1986a). The current isotope results provide an additional source of evidence, which suggests that climate also played a significant, but not necessarily an independent role, in the location and proliferation of the EIA Toutswe settlements. There is now sufficient evidence to argue that besides economic power, the climate supported adequate, if not surplus, agricultural produce which probably influenced population growth.

- Good rains, coupled with good herd management strategies, supported C_4 grasses for cattle and ovicaprids. Figure 6.1 and Figure 6.2 both show that the diet of domestic animals of the Toutswe EIA relied heavily on C_4 photosynthetic grasses. The movement of animals was confined to the Toutswe area itself, there is no substantial evidence to suggest that domestic animals were brought in from areas of different vegetation or climatic conditions.

- Based on the few samples for which enamel apatite was analysed, there is no evidence for the exchange of animals between the Toutswe area and areas with different climatic or vegetation conditions. It is proposed that animal migration, needed to allow pastures to recover after a few years, was restricted to the wider Toutswe environ which could extend as far as the Makgadikgadi Pans.

Table 6.1: Mean bone collagen $\delta^{13}C$ values for cattle from Toutswe, Tsodilo Hills and the SLRB

Area	Date	Ceramic Period	n	$\delta^{13}C$ range (‰)	Mean ± SD	C_4 component
Toutswe						
Kgaswe B55	1200 – 1250	Toutswe	1	-5.9		100
Taukome	710 – 995	Taukome/Zhizo	6	-7.0 to -5.8	-6.1 ± 0.4	100
Thatswane	1000 --1300	Toutswe	1	-5.9		100
Bosutswe	1000 – 1300	Toutswe	4	-6.3 to -5.2	-5.7 ± 0.9	100
Toutswemogala	1000 – 1300	Toutswe	14	-6.9 to -5.0	-5.9 ± 1.3	100
Bosutswe	2000 - 2006	Modern Tswana	19	-13.9 to -10.2	-11.6 ± 1.0	60
Toutswemogala	2000 - 2006	Modern Tswana	8	-14.3 to -10.2	-12.1 ± 1.3	60
Tsodilo Hills						
N!oma	850 – 1100		3	-9.8 to -9.7	-9.7 ± 0.3	85
SLRB						
Schroda	900 – 1010	Zhizo	21	-12.6 to -6.0	-8.1 ± 1.8	90
Pont Drift	900 – 1010	Zhizo	9	-11.5 to -7.9	-8.9 ± 0.8	90

Figure 6.1: Illustrations of dietary components of cattle

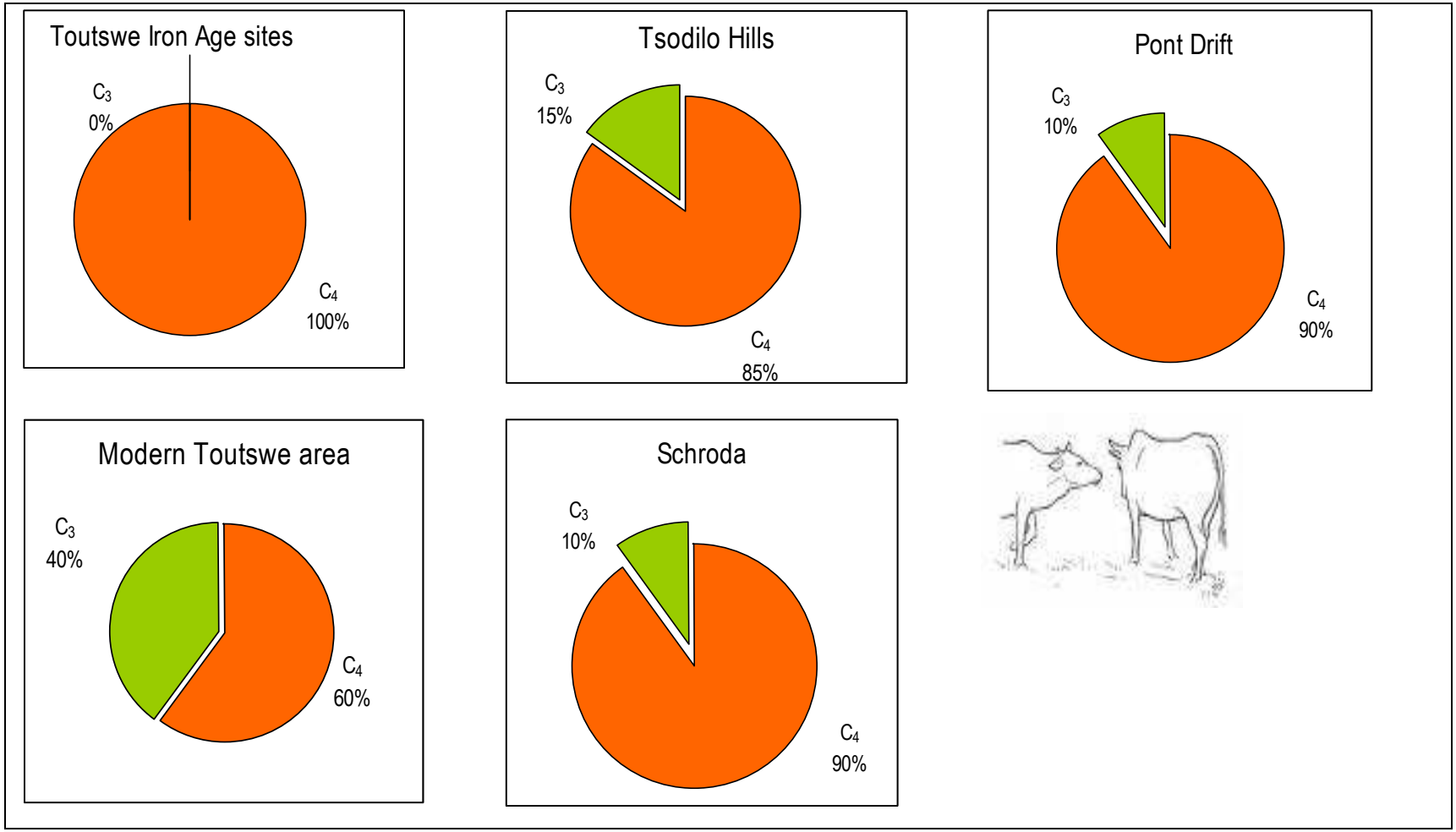


Table 6.2: Mean bone collagen $\delta^{13}C$ values for sheep and goats from all sites.

Area	Date	Ceramic Period	n	$\delta^{13}C$ range (‰)	Mean ± SD	C_4 component (%)
Toutswe						
Kgaswe B55	1200 – 1250	Toutswe	3	-10.7 to -9.6	-10.3 ± 0.6	70
Taukome	710 – 995	Taukome/Zhizo	20	-15.8 to -6.2	-10.6 ± 2.5	70
Thatswane		Toutswe	10	-15.3 to -6.7	-10.2 ± 2.9	70
Bosutswe	1000 – 1300	Toutswe	9	-14.3 to -8.2	-11.2 ± 2.4	75
Toutswemogala	1000 – 1300	Toutswe	34	-16.5 to -5.0	-10.6 ± 2.4	70
Bosutswe	2000 – 2006	Modern Tswana	1	-19.9		10
Toutswemogala	2000 – 2006	Modern Tswana	4	-20.6 to -17.5	-19.0 ± 1.3	10
Tsodilo Hills						
N!oma	850 – 1100		3	-15.7 to -8.9	-12.2 ± 3.4	60
SLRB						
Schroda	900 – 1010	Zhizo	57	-17.3 to -6.8	-11.9±06	60
Pont Drift	900 – 1010	Zhizo	32	-19.2 to -10.3	-14.0±1.4	55
Schroda	1010 – 1220	Leopard's Kopje A	12		-15.0±4.5	40
Pont Drift	1010 – 1220	Leopard's Kopje A	12		-12.5±3.3	65

Figure 6.2: Illustrations of dietary compositions of ovicaprids

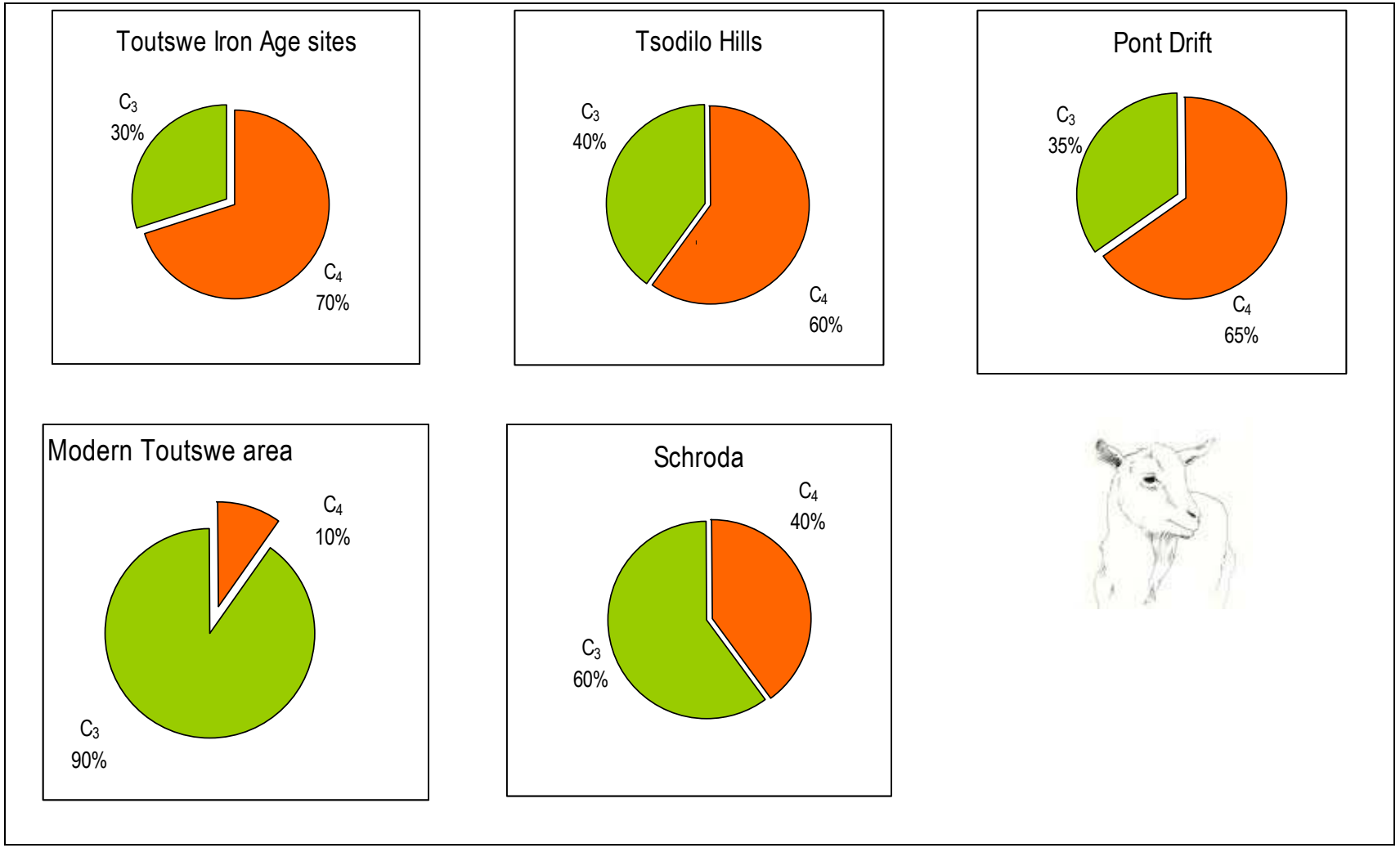


Table 6.3: Mean bone collagen $\delta^{13}C$ and $\delta^{15}N$ values for other animals from all sites.

	Site	n	$\delta^{13}C$ range (‰)	$\delta^{15}N$ range (‰)
Herbivores				
Raphicerus	Taukome	1	-18.1	8.7
Raphicerus	Toutswemogala	2	-20.7 - -17.9	6.4 - 7.5
Steenbok	Toutswemogala	2	-20.2 - -19.9	6.1 - 6.6
Zebra	Toutswemogala	1	-7.3	3.4
Tortoise	Taukome	1	-18.5	5.8
Tortoise	Toutswemogala	5	-21.3 - -16.6	4.1 - 9.5
Hare	Taukome	1	-11.4	4.9
Donkey	Bosutswe*	2	-12.9 - -11.4	6.4 - 6.8
Donkey	Toutswemogala*	3	-13.5 - -11.3	5.8 - 7.1
Horse	Bosutswe*	1	-11.9	6.9
Kudu	Toutswemogala*	1	-20.5	8.6
Carnivores				
Dog	Toutswemogala	1	-8.3	8.8
Jackal	Bosutswe*	1	-15.9	11.1

* - samples from the modern period

Table 6.4: Mean $\delta^{15}N$ values for cattle from all sites.

Area	Date	Ceramic period	n	$\delta^{15}N$ range (‰)	Mean ± SD	Annual rainfall (mm)
Toutswe						
Kgaswe B55	1200 – 1250	Toutswe	1	6.8		450 – 550
Taukome	710 – 995	Taukome/Zhizo	6	5.1 to 7.9	6.4 ± 1.1	450 – 550
Thatswane		Toutswe	1	5.1		450 – 550
Bosutswe	1000 – 1300	Toutswe	4	4.0 to 8.1	5.8 ± 1.7	450 – 550
Toutswemogala	100 – 1300	Toutswe/Lose	15	4.9 to 7.2	5.6 ± 0.7	450 – 550
Toutswemogala	2000 – 2006	Modern Tswana	8	5.5 to 7.6	6.7 ± 0.7	400 - 500
Bosutswe	2000 – 2006	Modern Tswana	19	7.3 to 10.2	8.2 ± 0.8	400 - 500
Tsodilo Hills						
N!oma	850 – 1100		3	6.9 to 8.2	7.6 ± 0.7	350 – 450
SLRB						
Schroda (Zhizo)	900 – 1010	Zhizo	21	5.7 to 12.0	9.1±1.7	350 – 450
Pont Drift (Zhizo)	900 – 1010	Zhizo	9	7.3 to 9.6	8.5±0.8	350 – 450
Schroda	1010 – 1220	Leopard's Kopje A	5		8.1±1.2	350 – 450
Pont Drift	1010 – 1220	Leopard's Kopje A	3		7.6±2.4	350 – 450

Table 6.5: Mean bone collagen $\delta^{15}N$ values for sheep and goats from all sites.

Area	Date	Ceramic period	n	Range $\delta^{15}N$ (‰)	Mean ± SD	annual rainfall (mm)
Toutswe						
Kgaswe B55	1200 – 1250	Toutswe	3	6.5 - 7.6	7.2 ± 0.6	450 – 550
Taukome	710 – 995	Taukome/Zhizo	20	4.9 - 9.1	7.1 ± 1.1	450 – 550
Thatswane		Toutswe	10	5.2 - 6.6	5.8 ± 0.5	450 – 550
Bosutswe	1000 – 1300	Toutswe	9	6.1 - 9.6	7.8 ± 1.1	450 – 550
Toutswemogala	1000 – 1300	Toutswe	34	4.6 - 11.3	6.2 ± 1.2	450 – 550
Bosutswe*	2000 – 2006	Modern Tswana	1	10.1		400 - 500
Toutswemogala*	2000 – 2006	Modern Tswana	4	8.0 - 11.0	9.2 ± 1.3	400 - 500
Tsodilo Hills						
N!oma	850 – 1100		3	6.7 - 8.3	7.3 ± 0.9	450 – 550
SLRB						
Schroda	900 – 1010	Zhizo	57		9.1±1.7	350 – 450
Pont Drift	900 – 1010	Zhizo	32		8.7±1.0	350 – 450
Schroda	1010 – 1220	Leopard's Kopje A	12		9.1±1.1	350 – 450
Pont Drift	1010 – 1200	Leopard's Kopje A	15		9.8±1.4	350 – 450

THE EXTENT OF THE TOUTSWE CLIMATE ZONE

In the previous section, it has been demonstrated that the vegetation and climatic environment of east central Botswana was relatively constant for approximately 500 years beginning with the inception of the Taukome/Zhizo settlements (AD700) to the end of the Toutswe polity (1300). This new data supports previous studies (Burney *et al.* 1994; Tyson *et al.* 2002, Wendorff 2005; Nash *et al*. 2006) all of which demonstrate very little variations in climate and environment of southern Africa during the Holocene. Attempts are made to determine whether there are any significant variations in isotope values using the same species from different sites. Any significant isotope differences between sites would demonstrate that there were indeed micro-variations within the Toutswe region itself.

CATTLE

Figure 6.3 shows the distribution of $^{13}C/^{12}C$ ratios versus $^{15}N/^{14}N$ ratios of cattle from the Toutswe area, the Tsodilo Hills, and the SLRB. In the figure, three clusters of $\delta^{13}C$ and $\delta^{15}N$ values can be identified. Cattle from Toutswe sites tend to cluster on the higher end of the $\delta^{13}C$ scale and the lower end of the $\delta^{15}N$ scale. The degree of overlap within the Toutswe samples strongly suggests that cattle in the area had no differential access to pasture and water. Cattle from the Tsodilo Hills and Pont Drift group together lower part of the $\delta^{13}C$ scale and their $\delta^{13}N$ values are slightly higher than those of the Toutswe cattle. Samples from Schroda have intermediate $\delta^{13}C$ values and the highest $\delta^{15}N$ values.

Table 6.6 shows the statistical comparison of the $\delta^{13}C$ values of cattle from different sites using the Mann-Whitney U-test. The calculations were made for sites with more than three cattle samples and, unfortunately only three sites: Taukome, Bosutswe and Toutswemogala, were legible. Differences in $\delta^{13}C$ values of cattle from archaeological deposits at Taukome, Bosutswe and Toutswemogala are not statistically significant. It is not surprising that differences in $\delta^{13}C$ values of cattle from Taukome and Toutswemogala are not statistically significant because the sites are within a few kilometres from each other (Denbow 1982, 1983a) and most probably had similar grazing conditions. Bosutswe is situated some distance away from both Taukome and Toutswemogala but the three are on the same basalt substrate with no differences in rainfall and

vegetation at present. However, Bosutswe is on the border between the Kalahari sands and the eastern Hardveld (Denbow *et al.* 2008) and it was expected that animals at this site would have exploited the Kalahari vegetation.

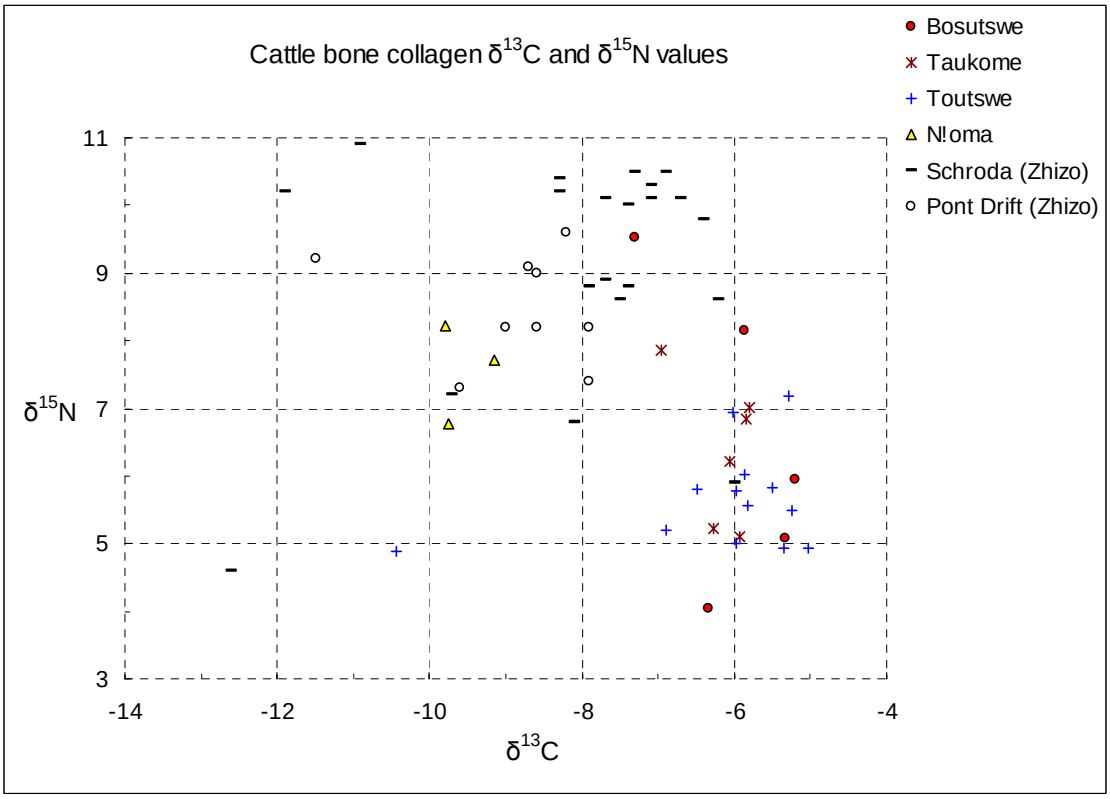


Figure 6.3: Distribution of $\delta^{13}C$ and $\delta^{15}N$ values of cattle from some Toutswe sites and the SLRB

As previously mentioned, the overall percentages of C_4 contributions to diets of archaeological versus modern cattle differ by about 40% (see Table 6.1and Figure 6.1). The Mann-Whitney U-test results also demonstrate that cattle from the same sites but different periods (i.e. archaeological and modern) are statistically different from each other in terms of $\delta^{13}C$ values. When modern samples from the sites are tested against each other, they demonstrate no significant differences. The P values of archaeological and modern cattle at Bosutswe and Toutswemogala are very strong ($P \leq 0.001$).These differences could be associated with vegetation changes from the

prehistoric past to present. The change in vegetation is associated with overgrazing and it affected both sites equally.

The $\delta^{13}C$ values of cattle from Toutswemogala and Schroda are statistically significant. Thus, grazing conditions at Toutswemogala were different from those at Schroda in the SLRB. The time periods of occupation of these two sites, as well as the environment or overgrazing within which they exist, could be the reason for the difference detected by the Mann-Whitney U-Test.

Table 6.6: Comparison of $\delta^{13}C$ values of cattle between sites using the Mann-Whitney U-test (* Modern)

Site	Site	Z	U	P(2-tailed)	Statistical difference
Toutswemogala	Bosutswe	0.35	41.5	0.735	Not significant
Toutswemogala	Taukome	0.29	45.5	0.779	Not significant
Bosutswe	Taukome	0.37	17	0.792	Not significant
Toutswemogala*	Bosutswe*	1.58	136	0.120	Not significant
Toutswemogala*	Toutswemogala	4.1	149	0	Highly significant
Bosutswe*	Bosutswe	3.4	100	0	Highly significant
Toutswemogala	Schroda	3.25	259	0.001	Highly significant

Mann-Whitney calculations were also done for cattle $\delta^{15}N$ values (Table 6.7). A general scenario emerging from these calculations is that differences in cattle $\delta^{15}N$ values between any two EIA sample groups are statistically insignificant ($P \geq 0.05$ for two-tailed normal distribution). Bosutswe $\delta^{15}N$ values of modern cattle tend not to comply with the pattern created with $\delta^{13}C$ values. While archaeological versus modern cattle from Toutswemogala samples have highly significant difference, ($P=0.001$) at Bosutswe the difference is not significant ($P= 0.144$). According to distributions of $\delta^{13}C$ values, cattle from archaeological deposits had significantly different grazing opportunities to modern cattle and hence the environments were different. But $\delta^{15}N$ values show no statistical differences.

Differences in $\delta^{15}N$ distributions of modern cattle from Bosutswe and Toutswemogala are only marginally significant. The result is acceptable because cattle in both areas are under similar environmental conditions and have accesses to relatively similar vegetations.

Table 6.7: Comparative Mann-Whitney results for $\delta^{15}N$ values of cattle (* Modern)

Sample 1	Sample 2	Z	U	P (2-tailed)	Statistical difference
Toutswemogala	Bosutswe	0.79	46.5	0.444	Not significant
Toutswemogala	Taukome	1.44	63.2	0.153	Not significant
Bosutswe	Taukome	0.09	15.5	0.931	Not significant
Toutswemogala*	Bosutswe*	2.50	157	0.011	Marginally significant
Toutswemogala*	Toutswemogala	3.27	134	0.001	Highly significant
Bosutswe*	Bosutswe	1.46	71.5	0.144	Not significant

OVICAPRIDS

Mann-Whitney U tests were calculated across sites with more than three samples of ovicaprids each (Table 6.8). According to this test, the differences in $\delta^{13}C$ value distributions are not significant between Taukome and Thatswane, Bosutswe and Taukome as well as Bosutswe and Thatswane. The Mann-Whitney U test results are not different from the average $\delta^{13}C$ values calculated for different sites. The only statistically significant difference in the distribution of $\delta^{13}C$ values is between modern samples from Toutswemogala and Thatswane. The differences are most probably due to change in vegetation associated with overgrazing.

Table 6.8: Comparative Mann-Whitney results for $\delta^{13}C$ values of ovicaprids (* Modern)

Sample 1	**Sample 2**	**Z**	**U**	**P (2- tailed)**	**Statistical difference**
Taukome	Thatswane	0.062	111.5	0.951	Not significant
Bosutswe	Thatswane	0.245	70	0.833	Not significant
Bosutswe	Taukome	0.49	132	0.631	Not significant
Toutswemogala*	Thatswane	2.775	52	0.003	Significant

SUMMARY OF THE ANIMAL ISOTOPE SIGNATURES

The $\delta^{13}C$ values of cattle from different periods of the EIA Toutswe occupation indicate that they fed exclusively on C_4 grasses during the Taukome/Zhizo and the Toutswe periods (Figure 6.1 and Figure 6.3). In the Tsodilo Hills area, the EIA cattle were raised on diets, which included a combination of both C_4 grasses and C_3 photosynthetic plants. The C_3 component of the Tsodilo Hills appears to have been a supplement in an area where pastures were not able to sustain the animal population. The most probable explanation for insufficient pastures around the Tsodilo Hills is that the soil type did not support the growth of sufficient C_4 grasses and crops to feed the animals.

The isotopic data obtained from cattle in the Toutswe area shows that these animals did not change their diets during the period of the Taukome/Zhizo and Toutswe cultures. Even cattle from Bosutswe, where several centuries of occupation have been documented, have consistent $\delta^{13}C$ values (Denbow *et al.* 2008). The consistency of the cattle diets during these periods is interpreted as an indication that there were no significant vegetation changes (Thomas & Shaw 1991; Burney *et al.* 1994) or that herd management strategies involved moving animals around the region to allow for the recovery of grasses where grazing had already taken place.

Dense deposits of vitrified cattle dung and faunal assemblages at many Toutswe sites provide evidence that the Toutswe people had large herds of cattle (Denbow 1979, 1982, 1983a). Unfortunately is it not possible to quantify the herd populations. In order to sustain such large cattle herds on an almost exclusively C_4 grazing, as shown by current isotope results, there must have been good pastures coupled with substantial rainfall. Several observations have been made on the basis of the isotope results of the animals:

- There was sufficient rainfall and good temperature to allow for the abundant growth of C_4 grasses. These grasses are seasonal, susceptible to drought and overgrazing but it appears that the cattle in the region had sufficient yearly supplies for feeding. If C_4 grasses in the Toutswe area during the Iron Age were as little as present, then cattle would have had to respond by supplementing their diet with C_3 plants, i.e. shrubs and leaves of trees

or be moved to new pastures. Cattle are preferential grazers and do not browse unless under dietary stress. At present they have had to adapt to a diet that includes 40% C_3 plants because lack of sufficient C_4 grasses. The shortage is attributed overgrazing.

- Herd management strategies employed during the EIA may have involved moving animals to distant grazing lands where they could continue feeding on C_4 grasses during periods of drought or hardships. Denbow (1983a) has proposed this scenario based on ethnographic analogies with early Tswana. A similar observation was made by Smith (2005, pg 175) who writes that farmers in Semolale village, in the SLRB part of Botswana, move cattle distances of approximately 100km during periods of drought. It appears that cattle at all sites enjoyed good grazing (probably because the entire Toutswe region was wet during the EIA occupation).

- Cattle breeds kept by EIA farmers were probably well adapted to climatic conditions that prevailed then. Humped Sanga cattle have been identified in faunal assemblages (e.g. Welbourne 1975; Plug 1983, 1996) and they are known to be more drought tolerant than most breeds. The Sanga cattle may have served as good stock backup during periodic droughts (Welbourne 1975; Plug 1996). Unfortunately, the isotope data generated in this study does not indicate the occurrences of the periodic droughts. Future studies with higher resolutions (e.g. analysis of enamel formed at different seasons) might probably be able to produce results that point these proposed periods of drought.

- The average $\delta^{15}N$ values for sites in the Toutswe and SLRB areas are similar to those recorded for modern herbivores living in the SLRB area. According to Smith (2005), the average $\delta^{15}N$ value of 8.7±1.0‰ for herbivores in the SLRB corresponds to a mean annual rainfall of between 350 and 500mm. Assuming that soil nitrogen content in the SLRB and the Toutswe area is similar, we can argue that during the EIA occupation, mean annual rainfall in the Toutswe area was 350 – 500mm. Therefore, shifts in dietary habits of the animals are caused by overgrazing and not change in climate.

- The Tsodilo Hills area was as wet at the Toutswe area as shown by the mean $\delta^{15}N$ values of herbivores. However, inadequate pastures at the Tsodilo Hills resulted in the animals having to supplement their diet C_3 based plants. The Tsodilo Hills are within the dry Kalahari sandveld where soil quality is not suited for the support of palatable C_4 grasses and crops.

It is important to note that the proposed environmental conditions of the Toutswe area and the Tsodilo Hills are only a strong suggestion. The $\delta^{15}N$ values of the soils need to be known in order to make strong inferences about the environment. The $\delta^{15}N$ values of soils differ from place to place and since the values are taken up the food chains, there is need to know the $\delta^{15}N$ starting values in soils and annual precipitation prior to factoring in issues of heat and water stress. Unfortunately, soil $\delta^{15}N$ values of the study area are known.

7: HUMAN DIETARY PATTERNS

INTRODUCTION

This chapter attempts to interpret the diets of EIA humans from the Toutswe area, Tsodilo Hills and the Okavango River. The objectives for this dietary reconstruction are

- To determine whether any foragers were buried within farmers' sites,
- To identify individuals who shifted from foraging to farming or vice versa,
- To track individuals changes in diet
- To compare dietary evidence from the archaeological record to isotopic data
- To compare the current results to those reported for other sites in southern Africa

In order to test for temporal variation, the results for the Toutswe area are split into the early Taukome/Zhizo phase (AD700 to 1000) followed by the Toutswe phase (AD1000 – 1300). Only one period of occupation (AD700 to 1200) is represented in the Tsodilo Hills and Okavango River sites.

The Toutswe communities may have practiced food distributions like traditional southern African Bantu communities did in historical times. For example, some sections of the communities may have subsisted predominantly on domesticated foods while others relied more on wild resources. Such practices would result in distinctions in isotope values of human remains within and between sites. The next section investigates the possible existence of patterns in the distributions of $\delta^{13}C$ and $\delta^{15}N$ values of individuals, including differences between males and females and between the young and the old. In addition, there are comparisons of isotope results for skeletons from sites of different levels in the Toutswe economic hierarchy. It has been proposed that communities living at class 1 sites sometimes incorporated outsiders, specifically hunter-gatherers, while this is less likely to have occurred at class 2 and 3 sites.

DIETARY EVIDENCE FROM THE ARCHAEOLOGICAL RECORD

Archaeological evidence for subsistence and diet during the EIA of the Toutswe area has been reviewed in Chapter 2. Remains of grain bins have been identified at Taukome (Denbow 1983a). Surplus grain production was a necessary measure to ensure year-round food availability and to provide backup for short periods of drought. The most commonly grown crops were probably sorghum, pearl millet, finger millet, legumes, cowpeas, pumpkins and melons. In addition to these domestic crops, the people probably consumed wild plants, particularly greens like *thepe (Amaranthus thunbergii)* and *rothwe (Gynandropis gynandra)* see for instance Denbow (1983a: 249-250). Unfortunately, poor preservation militates against the recovery of many edible plant remains.

The faunal assemblage from many sites, including the Tsodilo Hills, strongly supports the prediction that the bulk of the meat protein for human consumption came from domestic animals (Welbourne 1975; Plug 1983, 1996; Turner 1987a, 1987b; Denbow 1990, 1999; Atwood 2005). Milk and sour milk were probably available only as seasonal *seshabo.* Hence, milk would not have made a major contribution to the long-term dietary isotope values of the humans. Meat and milk have slightly different $\delta^{13}C$ and $\delta^{15}N$ values. There are no grounds to suggest that animal blood (also with different $\delta^{13}C$ and $\delta^{15}N$ values) formed part of the human diet, as is the case with the Masai pastoralists of east Africa (Ambrose 1986; Ambrose & DeNiro 1986a). According to faunal analyses, ovicaprids numbers were most probably double the cattle population (Welbourne 1975; Denbow & Wilmsen 1986; Denbow 1990, 1999; Plug 1983,1996; Atwood 2005) at most if not all Toutswe sites.

Steenbok, duiker, impala, springbok, giraffe, zebra, eland and wildebeest have been identified as some of the wild game in the faunal assemblage. The minimum number of individuals for all wild animal species listed in the Taukome faunal assemblage is small, suggesting that herding was much more important than hunting (Denbow 1983a, 1990, 1999; Plug 1983, 1996; Denbow & Wilmsen 1986; Turner 1987b; Atwood 2005). It is worth noting that the bulk of the meat came from grazers (both domestic and wild), followed by mixed-feeders and browsers. This observation has implications for the dietary isotope signatures of the humans as it determines whether the humans end up with depleted or enriched carbon isotope values.

TAUKOME/ZHIZO PERIOD (AD700 – 1000)

Only one site in the Toutswe area, Taukome, has human graves of the Taukome/Zhizo period. Some of the earliest cultural deposits at Bosutswe and Toutswemogala are associated with the Taukome/Zhizo phase but none of the graves appear to date from this period.

A diet based solely on C_4 crops (sorghum and millet) would have resulted in bone collagen $\delta^{13}C$ values of around -6‰ to -7.5‰ (van der Merwe 1982; Ambrose & DeNiro 1986a; Lee-Thorp *et al.* 1993). The mean $\delta^{13}C$ value of the humans from Taukome is -9.5±1.4‰ (Table 7.1). This average $\delta^{13}C$ value is a strong indication of diets in which C_4 photosynthetic resources contributed approximately 80% of the total diet. The remaining 20% of the dietary protein was derived from the C_3 based sources such as beans, melons, greens and wild fruits and nuts. The isotope values of the humans are consistent with the evidence from the archaeological record in which the domestic C_4 crops appear to have been important in the overall diet of the community.

The individual labelled Taukome 5 has a $\delta^{13}C$ variation of 3‰ between the ulna (-7.9‰) and the rib (-11.4‰). The variation is large and is most probably associated with a change in diet during the individual's lifetime. The rib shows the most recent diet because it has faster bone turnover than the ulna. The dietary shift for this individual involved a reduction of the C_4 based protein component from about 100% to approximately 70%. The $\delta^{13}C$ change was accompanied by a reduction in $\delta^{15}N$ values from 10.3‰ on the ulna to 9.7‰ on the rib. The drop in $\delta^{13}C$ value raises a strong possibility that the sorghum/millet and/or cattle component was reduced while legumes, cowpeas and greens were increased. Legumes and cowpeas fix nitrogen directly from the atmosphere and hence they have lower $\delta^{15}N$ values compared to non-fixing plants (Heaton 1987; Keegan 1989; Ambrose 1991; Handley & Raven 1992). Consequently, diets in which legumes are a significant contributor will have lower $\delta^{15}N$ values.

Enamel apatite samples of three adults (Table 7.3) show there were probably minimal shifts in diet from childhood to adulthood of these individuals. The differences in $\delta^{13}C$ and $\delta^{13}C_{ap}$ values of Taukome 1 and Taukome 2 are small and can be taken as showing no significant dietary shifts. The C_4 based fraction of the diet at childhood was approximately 80 to 90% as shown by $\delta^{13}C_{ap}$

values of -2.4‰ (Taukome 1) and -3.1‰ (Taukome 2), the same value is estimated for adulthood C_4 based dietary component.

Overall, Taukome humans are approximately 3‰ enriched in nitrogen isotope values when compared to herbivores from the same site. The human mean $\delta^{15}N$ value is 10.9±0.9‰ (Table 7.2). During its occupation, Taukome was receiving annual rainfall about 500mm and this probably explains the low $\delta^{15}N$ values for the humans from this site. A drier environment coupled with reliance on meat for the bulk of the protein would have resulted in humans being more than 3‰ enriched in nitrogen isotope values when compared with herbivores (Ambrose 1986). In terms of dietary significance, the mean $\delta^{15}N$ value of Taukome people strongly shows that the bulk of their protein came from plants. If the protein came largely from meat, then the human $\delta^{15}N$ values would be about 6‰ more positive than herbivores (Ambrose 1986a; Ambrose & DeNiro 1986).

The $\delta^{15}N$ value of the newborn baby (Taukome 3) at 10.3‰ is no higher that those of adults. The skeletal and dental age of the infant places it between zero and six months old at the time of death. The infant probably did not live long enough to allow for the effect of milk to show on its bone collagen $\delta^{15}N$ value. A slightly older infant, Taukome 4, (5-7 years old) has a slightly higher $\delta^{15}N$ value of 11.8‰, the most positive of all skeletons from the site. The $\delta^{15}N$ of this juvenile is probably related to milk consumption as is expected (Dupras *et al.* 2001; Richards *et al.* 2002; Clayton *et al.* 2006).

SUMMARY FOR THE TAUKOME/ZHIZO PERIOD

In summary, the human isotope signatures match the already existing archaeological evidence that the Taukome/Zhizo people were crop producers and animal herders. The following can be said of the Taukome community based on the current evidence:

- Staple dietary crops during the AD700 to 1000 period came from domestic crops that follow the C_4 photosynthetic pathway. In addition, most animal protein came from domestic and wild grazing animals. This new isotope data matches the archaeological evidence for farming and animal production during this period.

- Isotope evidence generated from this study shows that legumes and other C_3 photosynthetic plants formed an estimated 20% of the total protein intake. They can be classified as *seshabo* not so much as staple foods. The C_3 based protein was most likely derived from both domesticated (legumes) and wild (greens) species. It is, unfortunately, not possible to account for the proportions of the domesticated versus wild resources in the overall human diet.

- The Taukome/Zhizo community derived the bulk of their protein from plants and not animal products. They probably kept cattle for political and economic reasons besides subsistence (Denbow 1986a). Their $^{15}N/^{14}N$ ratios are only 3‰ more positive than herbivores.

- One of the main objectives of the study is to search for foragers within farmers settlements as has been proposed in the Kalahari debate (Denbow 1984b, 1986a,1986b, 1990, 1999; Denbow & Wilmsen 1986; Wilmsen 1989, Wilmsen & Denbow 1986). Results for the Taukome/Zhizo period are limited because of small sample sizes but, based on the evidence available; there is no evidence for foragers being buried at farming settlements. Only one individual shows strong evidence for dietary change in which some of the C_4 based proteins were later substituted with C_3 based protein but the evidence is not sufficient to say that there was a hunter-gatherer at the farmer site of Taukome.

THE TOUTSWE PERIOD (AD1000 – 1300)

Many human samples used in the study are associated with the Toutswe period. Graves from Kgaswe B55, Bonwapitse, Thataganyane, Serowe Hill, Swaneng Hill, Toutswemogala and from Bosutswe were found in Toutswe period deposits. In this section, results from small class 1 sites are discussed separately from results of class 2 and class 3 sites. Class 1 sites have been suggested as the most likely places for hunter-gatherers to have been incorporated into farmers'

economies. As Wilmsen (1990) argues, EIA class 1 sites were probably multi-cultural and multi-traditional in the same way as modern Batswana cattle posts are.

CLASS 1 SITES

The $\delta^{13}C$ values of the 17 individuals from Kgaswe B55 average -9.4±0.9‰, with a range of 3.5‰. Given the diet-collagen spacing of 5‰ (van der Mewre 1982; Ambrose & DeNiro 1986a), it is evident that humans consumed foods with $\delta^{13}C$ values of about -14.4‰. Their over all diet constituted about 70% C_4 photosynthesising plant protein and animals feeding on C_4 grasses. Current results are consistent with a previous study done by Murphy (1996) in which samples from Kgaswe B55 (n=11) were found to have 70% to 100% C_4 dietary component. It is not surprising that the humans would have a strong C_4 isotope signature because they farmed C_4 cereals. Carbonised sorghum and millet found at Kgaswe B55 provide support for the emphasis on C_4 based cereal consumption. The two females and four males have overlapping $\delta^{13}C$ values and thereby suggesting no obvious differential access to food sources. There are no apparent differences in $\delta^{13}C$ values of the young individuals versus adults at Kgaswe B55.

Five adults from Kgaswe B55 have $\delta^{13}C_{ap}$ values of between -4‰ and -5‰ (Table 7.3). In all cases, the individuals are estimated to have subsisted on diets comprising 70% C_4 based plants during developmental years. Within the Kgaswe B55 communities, there was differential access to C_3 and C_4 based foods between juveniles and adults. The remaining portion of the diet could have been derived from beans, greens and melons (also domestic crops farmed during the Iron Age). In traditional Tswana culture, infants and toddlers are intentionally fed substantial amounts of beans as a way of increasing and maintaining good body weight (personal experience). It is possible that such a practice took place at Kgaswe B55 during the EIA.

Within the Kgaswe B55 human adult category, no distinctions can be made between $\delta^{15}N$ values of males and females. The entire sample from the site varies by 2.6‰ in $\delta^{15}N$ values (Table 7.2). As is the case with $\delta^{13}C$ values, uniformity in $\delta^{15}N$ values has been observed on humans from small settlements. The overall mean $\delta^{15}N$ value of the 17 individuals from Kgaswe B55 is 9.7±0.7‰. The cow and ovicaprids from Kgaswe B55 have $\delta^{15}N$ values of around 7‰ whereas humans have a

slightly higher $\delta^{15}N$ value of 10‰. The ~3‰ differences between $\delta^{15}N$ values of the animals (herbivores) and the humans (omnivores) is consistent with the values quoted in the literature for the step-wise increase in $\delta^{15}N$ values between successive trophic levels (Minagawa & Wada 1984; Ambrose 1991; Hedges & Reynard 2007). Therefore, humans consumed substantial amounts animal meat. However, the difference between $\delta^{15}N$ values of humans and herbivores is too small to argue that meat and other animal products were the most dominant sources of dietary protein. The differences suggest that the bulk of dietary protein came from plants. These values are similar to those reported for the Later Iron Age communities of the northern Transvaal (Ambrose 1986; Ambrose & DeNiro 1986a; Lee-Thorp *et al.* 1993). Had meat been the main source of protein, then humans would have had nitrogen isotope enrichment of about 6‰ compared to herbivores as is the case with the pastoralists communities of east Africa and the historic Griqua communities of South Africa (Ambrose 1986; Ambrose & DeNiro 1986a).

The three infants aged 1year old (Kgaswe B55 18, 20 and 21) were expected to have higher $\delta^{15}N$ values due to breastfeeding. Technically, infants are one trophic level above adults because of breastfeeding. Under normal circumstances, they ought to have higher $\delta^{15}N$ values compared to adults (Dupras *et al.* 2001; Richards *et al.* 2002; Clayton *et al.* 2006). Contrary to the expectation, the infants have $\delta^{15}N$ values similar to those of the females and other members of the community. It is possible that the infants died shortly after birth in which case the effect of breast milk on their nitrogen isotope values would not have been manifested osteologically.

Contrary to Kgaswe B55 infants, the hunter-gatherer infants from Matjies River rock shelter in South Africa have slightly higher $\delta^{15}N$ values than older individuals. According to ethnographic studies of the hunter-gatherers, children are breastfed until the age 4 years in order to increase birth spacing (Howell 1979). Kgaswe B55 infants may have been breastfed for shorter periods and thus the effects of milk on nitrogen isotope values were not present on bone collagen for long periods.

It is also possible that feeding infants on substantial amounts of legumes is the reason for lower than expected $\delta^{15}N$ values on infants and juveniles. Dependence on legumes for protein results in lower $\delta^{15}N$ values (White & Schwarcz 1994). Kgaswe B55 4, aged 5-10 years old at the time of

death, was most probably post-weaning. Bone turnover at such an early age is rapid (Clayton *et al.* 2006; Hedges *et al.* 2007) and the individual may have lost the breast feeding $\delta^{15}N$ signature by the time of death.

The three males from Bonwapitse have a mean $\delta^{13}C$ value of -10.1±3.0‰ (Table 7.1) and are, therefore, isotopically comparable to the humans from Kgaswe B55. In other words, their dietary protein had carbon isotope values similar to the major protein component of the Kgaswe B55 community. The C_4 based protein component of the adulthood diet was between 70% and 80%. The two individuals with $\delta^{13}C$ values corresponding to 90% C_4 component appear to have had slightly different diets during the early years. Their enamel apatite $\delta^{13}C_{ap}$ values (-3.1‰ and -3.4‰) convert to 75% C_4 based component in diet (Table 7.3). Like Kgaswe B55, there seems to have been emphasis on beans, vegetables or wild foods in children's diets.

The mean $\delta^{15}N$ value of humans from Bonwapitse is 8.6±0.5‰ (Table 7.2) and is similar to the value reported for Kgaswe B55. As expected, they are about 3‰ more positive than herbivores through the trophic level effect (Minagawa & Wada 1984; Ambrose 1991). Like Kgaswe B55 and Taukome communities, it seems highly likely that Bonwapitse people relied on plants for the bulk of the protein.

The two males from Thataganyane and one individual from Serowe Hill also have $\delta^{13}C$ values similar to those reported for Kgaswe B55 and Bonwapitse (see Table 7.1). For all three individuals, 90% of their protein came from resources whose photosynthetic foundation was C_4 based. Enamel apatite $\delta^{13}C_{ap}$ values of Thataganyane 1 are associated with diets comprising nearly 100% C_4 based protein.

The $\delta^{15}N$ values of individuals from Serowe and Thataganyane Hills are marginally higher that those of the cattle from Kgaswe B55 and other sites Toutswe-type sites. It can be said that the significant amounts of the dietary protein for these individuals came from C_4 photosynthetic plants. In contrast to other sites in Serowe (Thataganyane, and Serowe Hills), the individual buried at Swaneng Hill appears to have been raised on foods derived from both foraging and farming modes of production. The $\delta^{13}C_{ap}$ value of the individual is -6‰, approximately halfway between the $\delta^{13}C_{ap}$

values predicted for diets of pure C_3 (-14.5‰) and pure C_4 (-0.5‰) based proteins (van der Merwe & Tschauner 1999). Future isotope research on the skeleton of Swaneng Hill (and additional samples if possible) is necessary to determine whether the individual was predominantly a forager in adulthood.

SUMMARY OF CLASS 1 SITES

In summary, all individuals from small sites indicate that the consumption of C_4 photosynthetic crops and animals feeding on C_4 based grasses was very important. The C_4 based plant foundation accounted for about 70 to 80% of the total protein intake. The remaining 20 – 30% came from C_3 plants. The $\delta^{13}C$ results are in support of the previously proposed subsistence strategies, which were assumed on the basis of archaeological remains. Remains of carbonised sorghum and millet at some sites (Denbow 1983a) along side discovery of grain bin remains at many sites have been interpreted as evidence for subsistence economies in which agriculture played the most dominant role.

The role of other plant resources, particularly beans, cowpeas and wild fruits and nuts was unknown prior to this study. Current results indicate that these plants, combined with wild plants, provided approximately 20% of the overall adulthood diet at class 1 sites. Beans, cowpeas and greens were most probably used as *seshabo*. It is common among Bantu speakers to serve sorghum porridge regularly with beans or greens instead of meat (personal observation). The $\delta^{13}C$ values of humans from small Toutswe settlements (AD1000- 1300) suggest that this dietary practice is not new. There is also an indication that children were generally raised on diets in which beans and other C_3 based foods played an important role in the overall nutrition and wellbeing of the children. Infant and juvenile diets may have included significant amounts of legumes as shown by depleted $\delta^{13}C_{ap}$ at early ages and lower $\delta^{15}N$ values on bone collagen of young individuals.

It can be said that at the lowest level of the Toutswe settlement hierarchy there is no obvious isotopic evidence to suggest differences in subsistence strategies between settlements. If differences in food sources occurred, then they would have occurred with food resources of similar isotope values. For instance, different parts of a cow or goat may have been allocated according to

age and sex, as is the case with many Tswana tribes at present (personal observation). While such cultural practices create differential access to meat, the differences are within the same animal tissue and hence would be extremely difficult to identify using stable isotopes.

It is important to note that within the small class 1 settlements of the Toutswe polity, there is very little isotopic evidence to support the contention that the Kalahari hunter-gatherers were buried in farmers' cattle posts during the Early Iron Age (Denbow 1984a; Wilmsen 1989; Wilmsen & Denbow 1990). Only one individual (Swaneng Hill 1) appears to have been a hunter-gatherer during childhood. It is equally important to note that the absence of isotopic evidence for foragers among farmers does not mean that they were in fact absent. It could simply be that hunter-gatherers buried within farmers settlements are yet to be exhumed. It is also possible that there were cultural discriminations prohibiting graves of the hunter-gatherers in farmers' settlements.

CLASS 2 AND CLASS 3 SITES

The focus of this section is to interpret the human isotope signatures of individuals recovered from class 2 and class 3 sites. Results of Taukome (class 2) humans have already been discussed under the Taukome/Zhizo period. Therefore only one class 2 site (Thatswane) will be considered in this section. Two infant graves from Bosutswe were from the later Lose period and two juveniles were from the transition between Toutswe and Lose period. The individuals are few in number and were young in age at the time of death. Their results were discussed under the Toutswe period. They are not expected to show any significant variations in isotope values.

The mean $\delta^{13}C$ value for Thatswane humans is -10±1.1‰ (Table 7.1). This value is a strong indication of a diet in which C_4 based plants and grazers contributed 80% of the over all protein. The projected C_4 based component of the diet is as expected for communities subsisting on farmed C_4 photosynthetic cereals and cattle. The $\delta^{13}C$ value of Thatswane humans is in agreement with the archaeological record in which grain bin remains are common, demonstrating the importance of agricultural production. The source of the 20% C_3 based protein was most probably beans, cowpeas, greens, melons, wild browsers and wild plants. The C_3 based protein provided *seshabo* to C_4 based stable foods.

Enamel apatite $\delta^{13}C_{ap}$ values of Thatswane 3 and Thatswane 6 show slightly less C_4 contribution in diet (see Table 7.3) than bone collagen $\delta^{13}C$ values do. Ideally, these individuals should not vary in dietary C_4 content between enamel apatite and bone collagen because, being juveniles, their teeth and bones were under the same dietary influence at the time of death. The variability is difficult to explain. The difference in mean $\delta^{15}N$ values of cattle and humans from Thatswane demonstrates that Thatswane people were depended largely on plants for protein. Meat protein was limited.

As mentioned in the literature review, the graves from Bosutswe come from periods of different ceramic traditions. However, their $\delta^{13}C$ results do not demonstrate changes in diet across time. The values for the later Lose period (AD1300 -1500) overlap with those from the earlier Toutswe period (AD1000 – 1300). Bosutswe 3 and 4 were exhumed from layers associated with the transition between Toutswe and Lose and their carbon isotope values are not different from the rest of the sample group. There are no isotopic differences between males and females as well as between age groups. The mean $\delta^{13}C$ value for Bosutswe (Table 7.1) is consistent with diets in which the C_4 based protein component was 90%.

Bosutswe 12 was a 50-75 year old male with a condition known as Diffuse Idiopathic Skeletal Hyperostosis (DISH). The condition had resulted in multiple osteophytes on all major weight bearing joints as well as his hands and feet (Mosothwane 2004; Mosothwane & Steyn 2008). In clinical cases, DISH is found on diabetic and obese patients. There were occasional cases of cribra orbitalia and enamel hypoplasias on some of the juveniles (Mosothwane & Steyn 2008). Despite the presence of skeletal lesions associated with metabolic diseases, there are no differences in $\delta^{13}C$ and $\delta^{15}N$ values in the individuals from Bosutswe.

The $\delta^{13}C$ results of the 28 individuals from Toutswemogala demonstrate fairly wide variations in dietary preferences. Most of the individuals had diets in which the C_4 portion was between 80% and 100% of the total dietary protein. There are no $\delta^{13}C$ variations between males and females or between young and older individuals, and hence the variability is random. A diet in which C_4 based plants contribute nearly all of the plant protein is not surprising for Toutswemogala since that site is associated with farmers (Denbow 1983a). The mean $\delta^{13}C$ value of -9.6±1.4‰ (Table 7.1) is linked to diets in which about 90% of the protein was derived from C_4 plants. Six individuals from

Bosutswe and Toutswemogala had notably different dietary habits (Table 7.3). Their C_4 portion was about 70% to 80% of the total protein intake. The individuals are from both sexes and age groups and therefore it is difficult to argue that they had differential access to foods. This could be an indication of forager incorporation into farming communities or of class divisions within the communities.

The skull of Toutswemogala 4 was described as having paedomorphic features similar to those of the San hunter-gatherers (de Villiers 1976; Mosothwane 2004). This individual's $\delta^{13}C$ value is within the limits for the rest of the group. Thus, despite morphologically resembling hunter-gatherers, the diet of Toutswemogala 4 was that of a farmer. Therefore, this could be what revisionists expect. Toutswemogala 25, an adult female had dietary shift between the early years and the last few years prior to death. The childhood diet of the female comprised 90% C_4 based protein but this value had dropped to 70% by the time of death. As is the case with Taukome 5, Toutswemogala 25, the individuals may have simply increased legumes and/ot wild foods and reduced the consumption of cereal grains.

The individuals from K2 (Lee-Thorp *et al.* 1993) and Late Irong Age sites of the northern Traanval (Ambrose 1986; Ambrose & DeNiro 1986a) both in South Africa are isotopically similar to those from the Toutswe area (Figure 7.1). Their C_4 component of the overall diet was between 80 and 90% (Table 7.1). All these communities are distinct from the Griqua and Holocene foragers of the south western Cape both of whom relied heavily on C_3 based food sources (see Table 7.1 and Figure 7.1)

Relationships between enamel apatite $\delta^{13}C_{ap}$ and bone collagen $\delta^{13}C$ values of juveniles from Toutswemogala vary. For some individuals, there is increase in the C_4 component from enamel apatite to bone collagen (e.g. Toutswemogala 14 and Toutswemogala 16) whereas some individuals the reverse in the case (e.g. Toutswemogala 29). These variations are difficult to interpret because of small sample sizes.

The mean $\delta^{15}N$ value for Toutswemogala humans was calculated to be 9.2±1.3‰ (Table 7.2). The differences in nitrogen isotope values between infants/juveniles and adults are not as expected.

The younger individuals were expected to have higher nitrogen isotope values compared to adults because of breast milk (Dupras *et al.* 2001; Richards *et al.* 2002; Clayton *et al.* 2006). This non-conformity to expected $\delta^{15}N$ values is difficult to explain. The overall mean $\delta^{15}N$ value is similar to values reported for other sites and hence the humans lived in relatively wet climatic conditions. The results indicate that despite the fact that Toutswe communities had large herds of cattle and small stock, they still depended largely on plants for protein. Cattle were most probably a source of wealth and power as well as currency for *bogadi* (bride price). His practice is still common among modern Bantu speaking communities of southern Africa.

Table 7.1: Mean bone collagen $\delta^{13}C$ values for humans from all sites

Area	Date (AD)	n	$\delta^{13}C$ range (‰)	Mean ± SD	C_4 (%)
Toutswe					
Kgaswe B55	1200 – 1250	17	-11.5 to -7.7	-9.4 ± 0.9	90
Bonwapitse	?	3	-11.6 to -9.2	-10.1 ± 3	80
Thataganyane	?	2	-8.3		90
Serowe Hill		1	-9.2		90
Taukome	900 - 1000	5	-11.5 to -7.9	-9.5 ± 1.4	90
Thatswane	?	6	-11.6 to -8.9	-10 ± 1.1	80
Bosutswe		13	-10.5 to -6.8	-8 ± 0.9	90
Toutswemogala	~1200 - 1300	28	-13.1 to -7.4	-9.6 ± 1.4	80
Tsodilo Hills					
Divuyu	700 – 1000	1	-8.8		90
N!oma	700 – 1000	3	-10.5 to -9.3	-9.7 ± 0.7	80
Okavango River					
Xaro	700 - 1000	2	-16.9 to -16.6	-16.7	30
SLRB					
Skutwater		4		-11.3 ± 0.8	70
K2		13		-10.4 ± 1.3	80
Other African sites					
Kikuyu, Kenya		12		-10.6 ± 1.4	70
Pastoralists, Kenya		10		-5.7± 0.8	100
Transvaaal LIA		8		-8.2 ±0.5	90
Griqua, RSA	1800s	12		-13.0 ± 1.0	50
SW Cape coast	3000- 2000BP	11	-15.5 to -10	-13.2 ± 1.7	50

Table 7.2: Mean bone collagen $\delta^{15}N$ values for humans from all sites

Area	Date (AD)	n	$\delta^{15}N$ range (‰)	Mean ± SD
Toutswe				
Kgaswe B55	1200 – 1250	17	8.2 to 10.8	9.7 ± 0.6
Bonwapitse	?	3	8 to 9.1	8.6 ± 0.5
Thataganyane	?	2	10.3	
Serowe Hill		1	9.6	
Taukome	900 - 1000	5	9.4 to 11.8	10.1 ± 0.9
Thatswane	?	6	7.2 to 10.6	9 ± 1.1
Bosutswe		13	8.8 to 11.8	10.4 ± 0.7
Toutswemogala	~1200 - 1300	28	8 to 11.0	9.2 ± 1.3
Tsodilo Hills				
Divuyu	700 – 1000	1	11.6	
N!oma	700 – 1000	3	10.4 to 11.6	11.1 ± 0.6
Okavango River				
Xaro	700 - 1000	2	10.5 to 10.8	10.6

SUMMARY OF CLASS 2 AND CLASS 3 SITES

Reconstruction of dietary patterns of the occupants of class 2 and class 3 settlements during the Toutswe period (AD1000-1300) was done using stable isotopes of carbon and nitrogen. Important conclusions drawn from these results are that:

- Most importantly, the isotopic data generated from this study falls short of identifying foragers buried in farmers' settlements. Seventy humans from seven sites have been examined and only Swaneng Hill 1 appears to have subsisted on a hunting and gathering mode. The sample represents a period of ~300years from AD1000 to 1300 and includes communities at different levels of the Toutswe settlement hierarchy. Given the relatively large sample size and the extent of the spatial and temporal contexts covered, there are grounds to argue that burials of foragers in EIA settlements was minimal.

Table 7.3: Isotope results of bone collagen and enamel apatite for all humans

Individual	Age(y) and Sex	$\delta^{13}C$(‰)	C_4 (%)	$\delta^{13}C_{apa}$(‰)	C_4 (%)
Kgaswe B-55 2	30-50, Female	-10.8	80	-3.9	70
Kgaswe B-55 5	17-23, Male	-8.8	90	-4.7	70
Kgaswe B-55 9	40-60, Male	-9.9	80	-4.6	70
Kgaswe B-55 14	40-60, Female	-9.9	80	-4.9	70
Kgaswe B-55 16	20-30, Male	-8.9	90	-4.2	70
Total Mean				**-4.5±0.4**	**70**
Bonwapitse 1	15-18, Male	-9.2	90	-3.1	80
Bonwapitse 2	40-60, Male	-9.2	90	-3.4	80
Bonwapitse 3	40-60, Male	-11.6	70	-3.8	70
Total Mean:				**-3.5±0.3**	**80**
Thataganyane Hill 1	20-40, Male	-8.4	90	-1.4	90
Swaneng Hill 1				-6.0	70
Taukome 1	40-60, Male	-9.8	80	-2.4	90
Taukome 2	40-60, Female	-8.5	90	-3.1	80
Taukome 5	40-60, Male	-11.5	70	-1.4	90
Taukome 6				-2.6	80
Total Mean:				**-2.4±0.7**	**90**
Thatswane 3	3-5	-9.4	90	-2.8	80
Thatswane 6	10-12	-9.0	90	-4.2	70
Total Mean:				**-3.5±0.9**	**80**
Bosutswe 2	0-1	-7.3	100	-2.6	80
Bosutswe 3	30-40, Male	-8.8	90	-2.5	80
Bosutswe 4	5-7	-10.5	80	-1.8	90
Bosutswe 5	17-20, Male	-7.5	100	-0.9	100
Bosutswe 6	7-9	-8.1	90	-4.5	70
Bosutswe 7	1-2	-8.0	90	-1.7	90
Bosutswe 8	3-5	-7.5	100	-0.6	100
Bosutswe 11	13-15	-8.2	90	-3.0	80
Bosutswe 12	50-75, Male	-8.0	90	-2.4	90
Bosutswe 13	12-14	-8.3	90	-2.0	90
Total Mean				**-2.2±1.1**	**90**
Toutswemogala 2	5-7	-9.2	90	-2.6	90
Toutswemogala 3	6-8	-8.2	90	-2.4	90
Toutswemogala 4	6-8	-10.0	80	-4.3	70
Toutswemogala 6	9-11	-8.5	90	-3.2	80
Toutswemogala 8	5-7	-9.8	80	-2.7	90
Toutswemogala 10	1-2	-7.5	100	-1.8	90
Toutswemogala 13	7-9	-10.3	80	-3.2	80
Toutswemogala 14	5-7	-9.4	90	-4.5	70

Table 7.3 continued

Individual	Age(y) and Sex	$\delta^{13}C$(‰)	C_4 (%)	$\delta^{13}C_{apa}$(‰)	C_4 (%)
Toutswemogala 16	10-12	-9.5	90	-4.5	70
Toutswemogala 17	10-12	-8.9	90	-2.4	90
Toutswemogala 18				-2.5	90
Toutswemogala 25	30-50, Female	-11.0	70	-2.0	90
Toutswemogala 26	1-2	-7.4	100	-3.0	80
Toutswemogala 29	6-10	-11.1	70	-3.7	80
Toutswemogala 30	20-40	-8.1	90	-3.9	80
Total Mean:				**-3.0±0.8**	**80**
N!oma 2	14 – 15	-10.5	80	-8.3	30
N!oma 3	40 – 50, Female	-9.3	90	-6.2	60
		Mean:		**-7.2±1.5**	**50**

- One individual, Toutswemogala 4, has skeletal characteristics similar to those of the LSA San hunter-gatherers but carbon isotope values indicating a predominantly farming mode of subsistence. Though sample size is very limiting, this individual might be what revisionists argue for, a forager incorporated into a farming community. The individual is also important in that he/she demonstrates the shortcomings of using the "essentialist" philosophy in describing race. The individual is biologically a forager but culturally a farmer.

- There are no $\delta^{15}N$ differences between young individuals and adults as was expected. Infants were expected to have higher $\delta^{15}N$ values compared with adults because of their consumption of breast milk (Dupras *et al.* 2001; Richards *et al.* 2002; Clayton *et al.* 2006). The $\delta^{15}N$ values of infants versus adults might be associated with short breast feeding periods, or with increased legume consumption as a source of protein for young individuals. Legumes have low $^{15}N/^{14}N$ ratios and would, therefore, lower the $\delta^{15}N$ values of consumers (White & Schwarcz 1994). High infant mortality rates at Bosutswe and Toutswemogala (Mosothwane 2004; Mosothwane & Steyn 2004), might be tied to possibly shorter breast-feeding periods.

- Beans have lower $\delta^{15}N$ values compared to most plants because they can fix nitrogen directly from the sun. If beans formed a significant portion of the adult diet, the human $\delta^{15}N$ values would have been even lower (White & Schwarcz 1994). The stepwise increase of about 3‰ between humans (omnivores) and cattle and ovicaprids (herbivores) is depected on the samples from Toutswe. However, the dietary protein for humans was most dominantly derived from plants as opposed to meat.

THE TSODILO HILLS AND OKAVANGO RIVER (AD700 – 1200)

The interpretations of human isotope results from sites in the Tsodilo Hills and along the Okavango River are presented together in this section. The data are grouped because the sites have similar ceramics (Denbow & Wilmsen 1986; Denbow 1986b; Wilmsen 1990). The ceramic culture itself had not yet been named or defined in full but certain stylistic characteristics link it to the Dundo, Sioma and Kapako sequences in Angola and the Democratic Republic of Congo (Junod 1963; Rudner 1965; Denbow 1986b; Wilmsen 1990). Charcoal samples from the sites in the Tsodilo Hills are dated AD700 to 1000 (Denbow & Wilmsen 1986; Wilmsen & Denbow 2005) i.e. the sites were occupied contemporaneously with Taukome in east central Botswana. Divuyu was occupied earlier than N!oma and hence the results for Divuyu in this section are presented first.

The dietary evidence from the archaeological record is briefly reviewed and attempts are made to correlate the dietary isotope results to the archaeological record. As is the case with the Toustwe EIA results, the life-time dietary isotope signatures of the Tsodilo Hills and Okavango River individuals are investigated to determine whether there are any possibilities of change in diet and subsistence.

DIETARY EVIDENCE FROM THE ARCHAEOLOGICAL RECORD

The sites in the northwest are associated with EIA farming communities (Denbow 1990, 1999; Wilmsen 1990). However, because of poor sandy soils coupled with low annual mean rainfall, it has been assumed that the occupants of the Tsodilo Hills and the Okavango probably relied more

on C_3 based wild plants (Denbow & Wilmsen 1986) than the Toutswe farmers. Domestic crops included sorghum, pearl millet and cowpeas while the bulk of the meat came from domestic animals. Hunting appears to have been more important at the Tsodilo Hills (Denbow & Wilmsen 1986; Turner 1987a) than it was at the Toutswe area.

The proximity of the Okavango River to Xaro site suggests that the inhabitants of Xaro may have been fishers. Indeed fish and other small aquatic animals have been recovered at both Xaro and the EIA sites in the Tsodilo Hills (Wilmsen 1990; Denbow 1999). The fish component of the diet at the Tsodilo Hills was most probably lower than the animal meat component because of the distance between fish sources and the hills. At Xaro, it is possible that fish accounted for a much larger fraction of the overall dietary protein because it was readily available.

TSODILO HILLS

The $\delta^{13}C$ value of -8.8‰ (Table 7.1) for Divuyu 1 translates to a C_4 based dietary input of approximately 90%. Wild resources like mongongo, *morula*, roots, melons and greens may have dominated the remaining C_3 based component. No legumes and cowpeas have been recovered at the site, but it is likely that they did form part of the domestic C_3 crop produced at the Tsodilo Hills.

The elevated $\delta^{15}N$ value (11.6‰) of the Divuyu infant is within limits quoted for sites in the Toutswe area such as Bosutswe. The individual from Divuyu was between the ages of two and three years at the time death (Morris 1996), and thus of breast-feeding age. The nitrogen isotope value of this infant is higher than the values for the three infants from Kgaswe B55 in the Toutswe area (see Table 4.3). The infants from Kgaswe B55 (all aged 0-12months old) have an average $\delta^{15}N$ value of 9.5‰. The results for Divuyu are, however, comparable with those of the infants from Bosutswe where the mean $\delta^{15}N$ value of the three youngest individuals is around 11‰. The high $\delta^{15}N$ value for the infant from Divuyu is probably a result of breast-feeding. Statistical analysis would have been ideal for comparing the results for infants from various sites but, unfortunately, the samples are too small.

Results of $\delta^{13}C$ values of N!oma individuals place them at about 80% C_4 dietary protein intake (Table 7.1). The results show that the consumption of C_3 (most probably wild plants) and browsing

animals resources was not as important as previously thought. Despite the fact that the area received slightly less mean annual rainfall than the Toutswe area and that soils around the Tsodilo Hills are not suitable for farming, the communities at N!oma managed to produce sufficient grains for long term consumption. This was probably achieved by growing sorghum and millet varieties that were more tolerant to drought than the varieties grown in the Toutswe area.

Carbon isotope ratios of childhood years of N!oma individuals (-8.3‰ and -6.2‰) suggest a very interesting scenario. During childhood, N!oma 2 had a 30% C_4 based dietary protein and N!oma 3 had 60% C_4 based dietary protein. These C_4 percentages translate to diets in which C_3 resources played major roles. Such diets are typical of the Kalahari hunter-gatherers and Okavango hunter/ fishers. N!oma is, therefore, the only settlement where hunter-gatherers or fishers appear to have taken advantage of farming as a new mode of subsistence. Fish was probably procured from the Okavango River, some 70km from the Tsodilo Hills (Wilmsen 1990).

Besides Toutswemogala 4, N!oma adults are the only examples, in this study, of hunter-gatherers/fishers who directly transformed into farming subsistence economies as proposed by revisionists in the Kalahari debate (Denbow 1984b, 1986a, 1990, 1999; Denbow & Wilmsen 1986; Wilmsen 1989, Wilmsen & Denbow 1986, 2009). It is not clear how the individuals were incorporated into the farming economy.

The ceramic assemblage of N!oma on levels post-dating AD650 suggest that at least three distinct styles were brought on to the site. The ceramic styles have affinities to and suggest the arrival of migrants from the sites with Divuyu, Xaro and Matlapaneng affinities (Wilmsen & Denbow 2005). Based on the ceramic evidence, Wilmsen and Denbow (2005) suggest that sometime after AD650, N!oma was occupied by a multi lingual community of both Bantu and Khoisan speakers. The individuals in this study probably began life as San foragers, but like other communities elsewhere, they were drawn into the N!oma settlement.

The differences in mean $\delta^{15}N$ values of herbivores and humans show that meat was an important source of dietary protein for the humans. The 3‰ difference between herbivores and omnivores can be accounted for as an effect from the stepwise increase between trophic levels (Minagawa &

Wada 1984, Ambrose 1991; Hedges & Reynard 2007). The mean $\delta^{15}N$ value of the individuals from the Tsodilo Hills is similar to those of the Toutswe individuals, suggesting similarity in dietary and climatic regimes in both areas.

THE OKAVANGO RIVER

Two adult males at the site of Xaro have depleted $\delta^{13}C$ value $\delta^{13}C$ value. Their mean $\delta^{13}C$ value is -16.9‰ (Table 7.1). Using the $\delta^{13}C$ model proposed by van der Merwe (1982), these individuals are estimated to have subsisted on diets in which the C_4 fraction was only 30% of the total protein intake (Table 7.1). The bulk of the C_3 protein for the inhabitants of Xaro was probably derived from freshwater fish, wild fruits and nuts, as well as browsing animals. Freshwater fish has $\delta^{13}C$ values resembling terrestrial C_3 plants (Katzenberg 1989; Ambrose 1993; Sealy *et al.* 1995). The uncalibrated date of 2300 – 1000BP associated with the wettest period of the Okavango area (Nash *et al.* 2006) probably coincides with the period of occupation of Xaro. This would almost certainly be a period of increased fish population, which would have been attractive to the inhabitants of settlements within the Okavango boundaries.

Interestingly, the artefact assemblage of Xaro characterises the site as an Iron Age rather than an LSA settlement (Denbow 1986b). New isotope data raise a possibility that the mode of subsistence was similar to that of modern day 'Black San' or Banoka. Banoka are basically Khoisan speaking foragers and fishers who are genetically related to Bantu speaking farmers in the neighbourhood (Hitchcock 1978, 1999). In historic times the Banoka were found to be using a combination of stone tools and iron implements.

In terms of nitrogen isotope values, the humans from Xaro have a mean $\delta^{15}N$ value of 10.5‰. Freshwater fish $^{15}N/^{14}N$ ratios are about 3-6‰ more positive than terrestrial meat and milk and as such, humans living on freshwater fish are expected to have higher $\delta^{15}N$ values than those living on herbivores (Schoeninger *et al.* 1983; Schoeninger & DeNiro 1984; Ambrose 1991; Hedges & Reynard 2007). Further studies involving the isotopic analysis of faunal remains are needed in order to test the trophic level effect on the human $\delta^{15}N$ values. The similarities in nitrogen isotope values of the Xaro humans to Toutswe humans strongly suggest that Xaro was a relative wet

environment. This probably coincides with the wet period reported to have lasted from 2300 to 1000BP along the Okavango Panhandle (Nash *et al.* 2006)

SUMMARY OF TSODILO HILLS AND XARO HUMAN DIETS

Isotopic data from this study confirms that farmers who grew C_4 photosynthetic cereals and ate meat from grazing animals established the EIA settlements at the Tsodilo Hills. Furthermore,

- Some occupants of the N!oma settlement had in their lifetimes shifted from hunting and gathering and/or fishing to full-time farming. The dietary isotope signatures of developmental years on the two adults at N!oma are associated with a foraging mode of production while their adulthood isotopes reflect farming subsistence strategies. The presence of Divuyu/N!oma pottery at Xaro demonstrate the existence of exchange networks between these sites (Denbow 1986b; Wilmsen 1990; Wilmsen & Denbow 2005). The dietary isotope results supports Wilmsen and Denbow's (2009) argument that the post AD650 community at N!oma was made up of migrants from settlements within a broader geographic context which included the Okavango River and the interior of the Kalahari Desert, some of whom were foragers in their youth.

- The mean $\delta^{15}N$ values of the two sites in the Tsodilo Hills and along the Okavango River are similar to those of the EIA farmers in the Toutswe area. The human $\delta^{15}N$ values are only 3‰ more positive than values for cattle, the difference is due to normal trophic level effects (Minagawa & Wada 1984). If the N!oma people relied on more animal meat than communities in the Toutswe area, then the mean $\delta^{15}N$ value for N!oma would have been much higher than the same value for herbivores. Carbon isotopes of the individuals indicate that their source of dietary protein was plant based and therefore consumption of meat had little influence on their $\delta^{15}N$ values.

THE BROADER SOUTHERN AFRICAN CONTEXT

This section is two fold; first a comparative analysis of the isotope dietary evidence from the current study and secondly a comparative analysis of the current results with other Iron Age communities in southern Africa. In both comparative exercises, the Mann-Whitney statistical analysis plays a pivotal role. The reason for doing advanced statistical comparative tests between sites from the study area is to test the significance and accuracy of the interpretations based on simple isotope averages. It is possible that the tests will reveal statistically significant differences between isotope values of different sites that were not possible to identify through averages and standard deviations.

The second part compares current results with existing data published in the literature, to place the EIA dietary isotope results within the broader southern African context. Variability in dietary habits of Iron Age communities in southern Africa has been documented in few publications (e.g. Ambrose 1986; Ambrose & DeNiro 1986a; Lee-Thorp *et al.* 1993) and unpublished documents (e.g. Gilbert 1995; Murphy 1996). Did the EIA communities from the study area have diets similar to or different from other known EIA diets?

TOUTSWE COMPARED TO TSODILO HILLS

It is interesting to note that the statistical differences in individuals' $\delta^{13}C$ values between N!oma and Taukome are insignificant (Table 7.4). From the archaeological record, N!oma floral assemblages strongly suggests regular consumption of wild plants, particularly mongongo (Denbow 1986a). Low annual rainfall and soil nutrition at N!oma could have been serious barriers to production of surplus crops. It was, therefore, expected that the $\delta^{13}C$ values of N!oma and Taukome would be statistically different. The individuals from N!oma shifted from an earlier diet made of equal portions of C_3 and C_4 based protein to diets in which C_4 based protein dominated. They had adopted diets similar to those of the contemporaneous Taukome/Zhizo period at Taukome.

It is also interesting that the differences in distributions of $\delta^{15}N$ values of N!oma and Taukome humans are statistically insignificant (Table 7.4). The two sites are in located in different climatic zones with N!oma on the semi-arid desert and Taukome on the slightly wetter ecozone. Aridity is

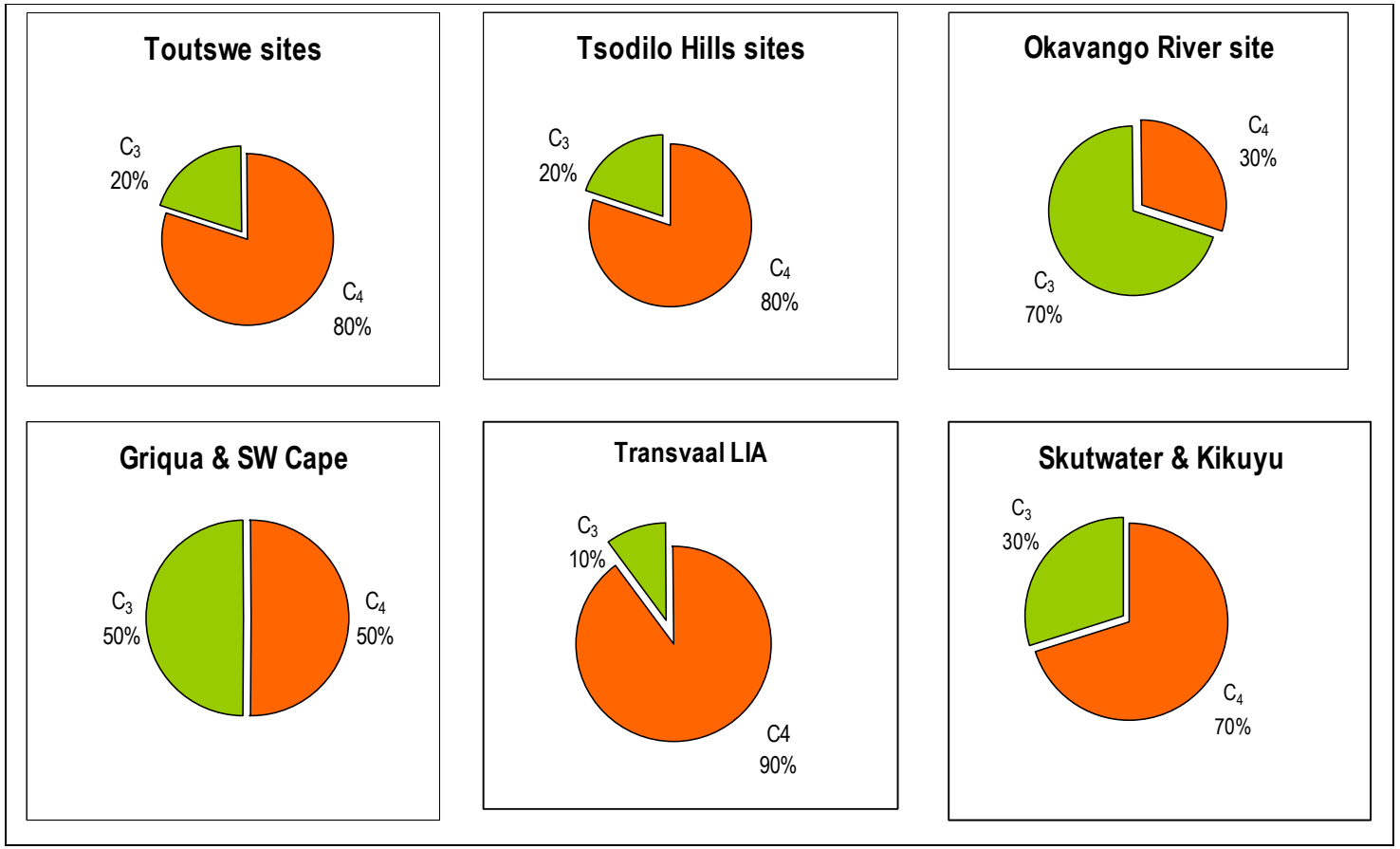
known to have effect on $\delta^{15}N$ values as has been shown by Iron Age communities of different climatic regions in a study done by Lee-Thorp and co-workers (1993). There are at least two permanent springs in the Tsodilo Hills which probably supplied water for drinking. It probably explains why humans lower $\delta^{15}N$ values than expected.

Statistical tests strongly suggest that the AD700 to 1000 communities in east central and north western Botswana had similar subsistence strategies in terms of proportions of C_4 and C_3 plants consumed. The isotope compositions of the bulk diets at both localities were similar. Unfortunately, the actual proportions of specific plant species in the diet remain unknown. Millet is more drought tolerant (van der Merwe & Tschaune 1999) and it is possible that it was favoured over sorghum at the Tsodilo Hills. In the Toutswe area sorghum may have been the most dominant species.

The C_3 photosynthetic plants account for almost equal portions of the overall diet at N!oma and Taukome. As indicated in the literature review chapter, C_3 based plants could have come from domestic (e.g. legumes, cowpeas, melons) and wild (fruits, nuts, roots, greens, beverages) contexts. From the archaeological record it seemed likely that N!oma people foraged much more than Taukome people. In other words, the Taukome C_3 based dietary portion could have come equally from domesticated species whereas at N!oma the bulk of the C_3 based dietary portion probably came from wild species.

Figure 7.1 shows the relative contributions of C_4 versus C_3 photosynthetic plants in the diets of the Toutswe, Tsodilo Hills and Okavango River EIA communities. The overall patterns show many similarities between the Toutswe and Tsodilo Hills communities. The same Figure 7.1 shows that the dietary composition of the individuals from Xaro is almost a reverse of the dietary composition of Toutswe and Tsodilo Hills humans. The Toutswe and Tsodilo Hills communities are different from the LIA communities of northern Transvaal whose isotope signatures suggest heavier reliance on C_4 crops. It is interesting to see that dietary isotope compositions of the Toutswe and Tsodilo Hills differ from those of communities with different modes of subsistence (e.g. south western Cape hunter-gatherers and Griqua pastoralists) and environmental opportunities such as the east African Kikuyu context (see Figure 7.1).

Figure 7.1: Illustrations of dietary compositions of humans



DIETARY PATTERNS OF THE TOUTSWE COMMUNITIES

The Mann-Whitney tests demonstrate that differences in dietary isotope values of different Toutswe communities are statistically insignificant (Table 7.4). For instance, human samples from Toutswemogala and Bosutswe were compared with each other. At these sites, strong similarities were observed in the distribution of $\delta^{13}C$ and $\delta^{15}N$ values for cattle. The results of the Mann-Whitney test (Table 7.4) indicate that the differences between the $\delta^{13}C$ values of the humans samples are highly significant (P=0.0008). That is, while the difference in cattle $\delta^{13}C$ values for the two sites are insignificant (see Table 6.4a), the $\delta^{13}C$ values for humans are significantly different. This finding suggests subtle differences in diets between the Bosutswe and Toutswemogala populations.

The differences in $\delta^{13}C$ values of humans at Bosutswe and Toutswemogala are possibly a result of differences in their source of animal protein. Welbourne (1975) reported a proportionally larger herd of small stock than cattle at Toutswemogala whereas at Bosutswe, cattle outnumbered ovicaprids in the domestic assemblage (Plug 1996). The implication is that at Toutswemogala, people relied more on ovicaprids than cattle. The former are mixed feeders with a significant C_3 based input in their diet. At Bosutswe, cattle appear to have provided the bulk of the protein component of the diet and hence a significant C_4 based protein transferred to human collagen through the consumption of C_4 grazers. The isotope results in this case are in agreement with the faunal analysis.

The Mann-Whitney results show that the $\delta^{15}N$ values of humans at Bosutswe are statistically different from Thatswane and Toutswemogala (Table 7.4). The differences of $\delta^{15}N$ values may be because Bosutswe is situated not far from the semi-arid Kalahari sands while the other two sites are in the less dry and cooler climatic zone. It is possible that Bosutswe's occupants had an advantage of being able to exploit more Kalahari wild game than other communities are. Being on the border of two ecozones might have allowed for more game in human consumption.

Other possible explanations for the high $\delta^{15}N$ values in Bosutswe humans, can be eliminated. For instance, the $\delta^{15}N$ values of grazing animals from Bosutswe portray an environment where annual rainfall was ~500 mm, meaning that the more positive $\delta^{15}N$ values for the humans can not be

Table 7.4: Mann-Whitney test results for human $\delta^{13}C$ and $\delta^{15}N$ values of the Toutswe communities

Sample 1	Sample 2	Z	U	P (2-tail)	Sample difference
$\delta^{13}C$					
Thatswane	Toutswemogala	0.74	100.5	0.456	Not significant
Thatswane	Kgaswe B55	1.26	69	0.207	Not significant
Taukome	Bonwapitse	0.44	9	0.654	Not significant
Taukome	Thatswane	0.73	19	0.465	Not significant
Taukome	Kgaswe B55	0	42.5	1.000	Not significant
Taukome	Bosutswe	1.92	52	0.054	Not significant
Taukome	Toutswemogala	0.151	73	0.903	Not significant
Thatswane	Bosutswe	3.06	74	0.002	Highly significant
Toutswemogala	Bosutswe	3.34	301.5	0	Highly significant
Toutswemogala	Kgaswe B55	0.304	251	0.771	Not significant
Bosutswe	Kgaswe B55	3.516	194.5	0	Highly significant
Taukome	N!oma	0.387	6	0.697	Not significant
Toutswe	K2	1.823	68.5	0.067	Not significant
$\delta^{15}N$					
Thatswane	Toutswemogala	0.271	90	0.808	Not significant
Thatswane	Kgaswe B55	1.120	67	0.286	Not significant
Taukome	Bonwapitse	2.236	15	0.035	Marginally significant
Taukome	Thatswane	1.917	25.5	0.051	Not significant
Taukome	Kgaswe B55	1.253	58.5	0.217	Not significant
Taukome	Bosutswe	1.922	52	0.059	Not significant
Taukome	Toutswemogala	1.582	101.5	0.116	Not significant
Thatswane	Bosutswe	2.762	70.5	0.003	Significant
Toutswemogala	Bosutswe	2.689	278	0.006	Significant
Toutswemogala	Kgaswe B55	1.334	295	0.188	Not significant
Bosutswe	Kgaswe B55	2.616	173	0.008	Not significant
Taukome	N!oma	1.162	8	0.381	Not significant
Toutswe	K2	2.734	80	0.005	Significant

attributed to aridity. Ovicaprids are more drought tolerant than cattle and as a result cattle tend to have less positive $\delta^{15}N$ values than ovicaprids (Ambrose & DeNiro 1986b). If Bosutswe inhabitants consumed more ovicaprids than cattle (by a significant amount) then the Bosutswe humans would show higher $\delta^{15}N$ values. Faunal analysis of materials from Bosutswe shows that at this site, cattle outnumber ovicaprids by significant numbers (Plug 1996). In fact, it is at Toutswemogala where ovicaprids outnumber cattle (Welbourne 1975) but the $\delta^{15}N$ values of the humans from the site do

not have exceptionally high $\delta^{15}N$ values. By far the most plausible explanation for the high $\delta^{15}N$ values of Bosutswe humans is that they probably consumed more meat and milk than other communities in the study area. However, they were by no means full-time pastoralists. This means that the 10‰ cut-off mark for pastoralists should not be applied universally to EIA communities of southern Africa like Murphy (1996) did.

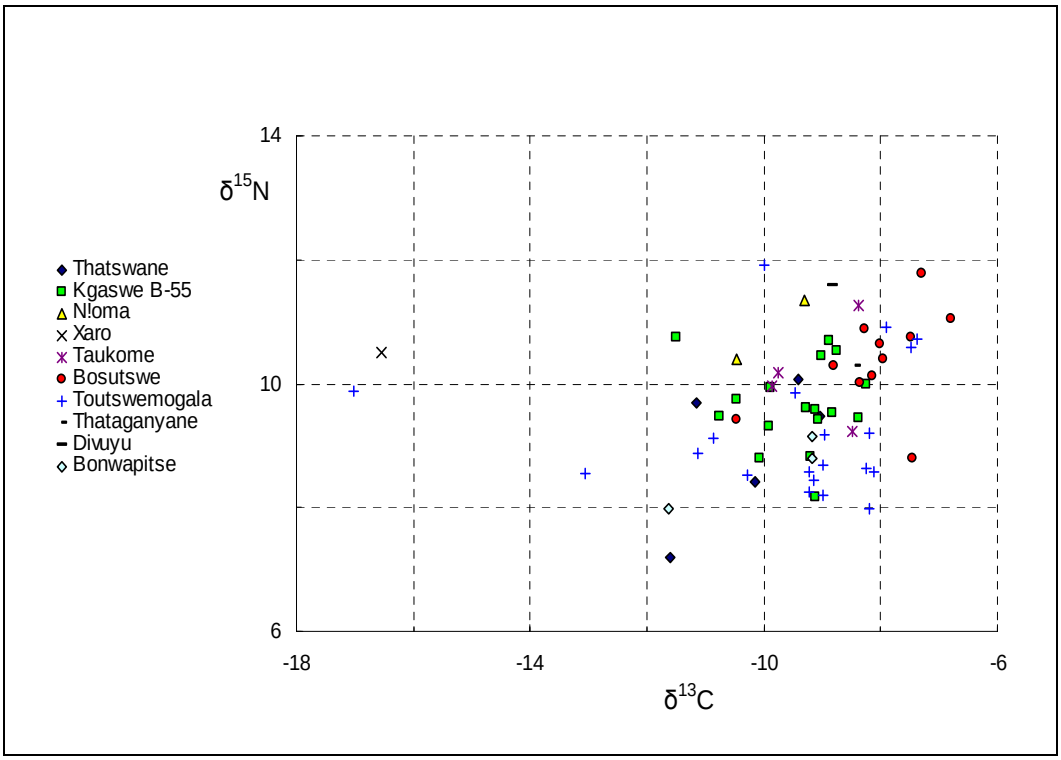
Taukome is the earliest of all sites included in the current research and secondly, the site has evidence for interaction between farmers and foragers (Denbow 1999). The lithic assemblage from Taukome is higher than reported at other sites (including Bosutswe). Despite this, there appears to be no statistical differences in $\delta^{13}C$ values of the Taukome humans and the humans from other sites. Isotopic evidence from Taukome strongly supports the notion that LSA tools found at the site may have been made and/or used by farmers and not by hunter-gatherers. Alternatively, hunter-gatherers who came to trade could have brought the lithics.

Figure 7.2 depicts the distributions of carbon and nitrogen isotope values of all humans in the current study. The individuals from Bosutswe, Taukome, N!oma and Divuyu appear to dominate the ≥10‰ mark on the $\delta^{15}N$ scale. Except for a few outliers, most the individuals from Toutswemogala, Thatswane and Kgaswe B55 are below the 10‰ mark on the $\delta^{15}N$ scale. In all cases there is no evidence that these were pastoral, rather than agro-pastoral, communities.

TOUTSWE COMPARED TO SOUTHERN AFRICAN IRON AGE COMMUNITIES

A comparative analysis between the two major sites of Bosutswe and Toutswemogala and LIA sites of K2 (n=13) and Makapansgat (n=5), as well as the proto-historic communities of Kakamas (n=5) and Riet River (n=9) (Lee-Thorp *et al.* 1993), is depicted in Figure 7.3. The samples from K2 and Makapansgat were selected for comparative purposed because they are geographically the closest to the Toutswe area. Kakamas and Riet River are far from the Toutswe area but they provide a good comparative data from arid environments. Only individuals aged 10 years and above from Toutswemogala (n=7) and Bosutswe (n=5) (Mosothwane 2004) have been included but the data is pooled from both males and females. The two LIA sites in South Africa are associated with mixed farming similar to Bosutswe and Toutswemogala. Makapansgat is located

Figure 7.2: Distribution $\delta^{13}C$ versus $\delta^{15}N$ values of humans from all sites



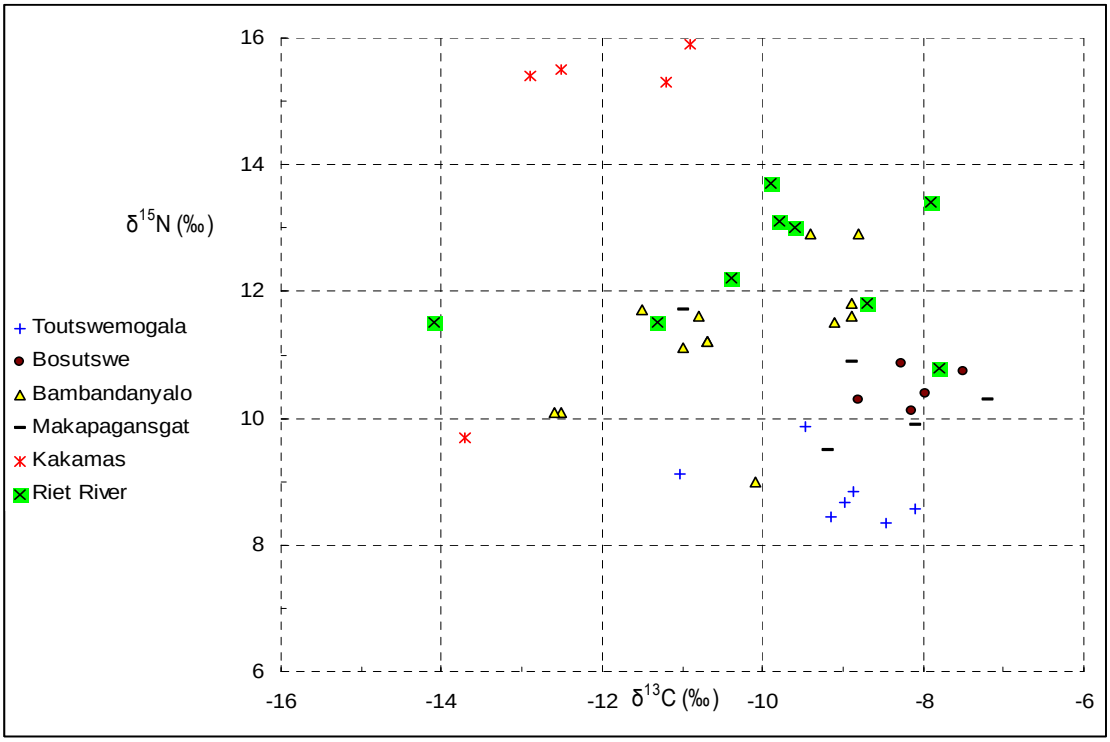
within the 400-600mm annual rainfall region with savanna woodland vegetation and K2 is in the slightly more arid northern region with approximately 330mm annual rainfall and a predominantly dry savanna and mopane woodland. The Shashe-Limpopo River basin is documented to have been drier and hotter (Smith 2005, Smith *et al.* 2007; Huffman 2007) than the Toutswe area. The results between Toutswemogala and K2 show that differences in human $\delta^{15}N$ values are significant (Table 7.4). The differences are most probably due to climatic variability. The sites further south were occupied by proto-historic mixed hunter-gatherer/pastoralist communities in the more arid regions of South Africa (Lee-Thorp *et al.* 1993). Of these, Kakamas has the lowest annual rainfall compared to other sites.

On the $\delta^{15}N$ scale, Bosutswe humans cluster between 10‰ and 12‰ (Figure 7.3) while Toutswemogala are predominantly on the 8‰ to 10‰. The $\delta^{15}N$ values higher than 10‰ are associated with pastoralists' communities such as the Turkana, Pokot in east Africa and the Griqua in South Africa (Ambrose 1986). It is highly possible that the data in the current study is a result of

dietary variability between Bosutswe and Toutswemogala communities. Bosutswe people may have consumed more meat than the Toutswemogala people, which could be an indication that Bosutswe was a higher-status settlement with greater access to animal protein.

At the EIA sites of K2 & Skutwater, and the proto-historic communities from Kakamas, high $\delta^{15}N$ values for humans (≥10‰) are associated with greater aridity (Lee-Thorp *et al.* 1993). The Riet River skeletons have a mean $\delta^{15}N$ value of 12.4‰, but Lee-Thorp and co-workers (1993) had expected a more positive $\delta^{15}N$ value than the one they obtained because the site is located in a more arid environment.

Figure 7.3: Distribution $\delta^{13}C$ versus $\delta^{15}N$ values of humans from Toutswe and other sites



They concluded that the Riet River mean $\delta^{15}N$ value had been lowered by heavy reliance on wild plant protein rather than animal protein. The three examples given above are just a few of the many examples of the complications associated with attempts to interpret diet from nitrogen

isotope ratios. Data from herbivores tends to indicate that climatic conditions were similar between Bosutswe and Toutswemogala and hence the differences in $\delta^{15}N$ values between these sites are most probably due to diet, with the Bosutswe population having consumed slightly more meat.

The distributions of $\delta^{15}N$ values by site tend to follow variation in annual rainfall, and possibly temperature. Toutswemogala individuals have the lowest $\delta^{15}N$ values compared to all other sites followed by Bosutswe and Makapansgat. K2 and Riet River individuals have elevated $\delta^{15}N$ values but Kakamas individuals show the most enriched $\delta^{15}N$ values of all. As expected, the most arid sites of Kakamas, Riet River and K2 (Lee-Thorp *et al.* 1993) have the highest $\delta^{15}N$ values while the wetter Toutswemogala, Bosutswe and Makapansgat (Lee-Thorp *et al.* 1993; Denbow *et al*. 2008) have lower nitrogen isotope values.

SUMMARY OF HUMAN DIETARY ISOTOPE EVIDENCE

As mentioned previously the objectives of this research are to determine the dietary isotope signatures of the Iron Age communities in certain parts of Botswana. The results are critical in providing clues regarding the pre-historic relationships between foragers and farmers. The human isotope data from the current study has highlighted some interesting dietary characteristics of the EIA communities on the Toutswe area, the Tsodilo Hills, and the Okavango River. The human dietary isotope data can be summarised as follows:

- Of all individuals included in the study, only two adults from N!oma can be shown to have shifted their subsistence strategies from foraging and/or fishing to farming. These individuals' enamel apatite carbon isotope values are indicative of diets in which C_3 based protein or freshwater fish provided the bulk of the dietary protein during childhood. By the time they reached adulthood, they had adopted diets very similar to those of the EIA farmers in the Toutswe area. Though the sample size is small, the results support the argument by Denbow and Wilmsen that interactions between farmers and foragers during the Iron Age were complex and resulted in the incorporation of some foragers into farming

communities. In addition, since even the early childhood carbon isotope figures show some consumption of C_4 plants, there was already overlap between these two populations.

- A combination of isotope and archaeological data from Xaro provide some evidence that communities with cultures and subsistence strategies similar to those of the modern day Black San/Banoka probably existed during the Iron Age. Banoka are groups of Khoisan speaking fisher-hunters along the Boteti River and Okavango River who are genetically and culturally related to Bantu speaking farmers (Hitchcock 1999).

- Only one individual, Swaneng Hill 1, has enamel apatite $\delta^{13}C_{ap}$ values characteristic of diets in which C_3 based protein were as important as C_4 based protein sources. In other words, the individual appears to have subsisted by hunting and gathering but was found buried on a site known to have been occupied by farmers. Unfortunately, field data from the Swaneng Hill remains unavailable. Hence, it is difficult to tell if the grave was made during the actual occupation of the site, before or after its abandonment. If the grave is contemporaneous with the site, then it provides support for the revisionists' argument that foragers visited or lived at class 1 small Toutswe settlements during the Iron Age and sometimes were buried there.

- Toutswemogala 4 has cranial features associated with hunter-gatherers (de Villiers 1976) but isotope characteristics similar to those of farming communities. This individual represents a juvenile of San hunter-gatherer descent raised under a Bantu farming mode of subsistence.

- Despite the presence of LSA tools at the Taukome site, there is no isotopic evidence to suggest that hunter-gatherers were buried there. Only one individual from the site (Taukome 5) appears to have had a dietary change. But, the isotope signatures of this individual strongly suggest a change in diet within the same mode of subsistence as the individual increased its intake of C_3 based crops such as legumes and cowpeas, while reducing C_4 based cereals.

- The overall results indicate the presence of individuals who shifted their diets from foraging to farming between AD700 and 1300. This supports the arguments raised by revisionists in the Kalahari debate. However, the problem of sample size, which is an issue, raised by traditionalists, as well as some critiques of the debate (e.g. Sadr 1997), still exist in the current study. Less than 5% of the total number of individuals included in the study appears to have been foragers who shifted to a farming mode of subsistence. The sample is too small to be representative of the broader Kalahari San groups but it does, show support for the revisionists' point of view.

- The eighth century Iron Age communities in the Toutswe area were full-fledged farmers whose diets were made of about 80% C_4 based proteins and 20% C_3 based proteins. The C_3 based protein most probably came from domesticated plants like beans and cowpeas, as well, as from wild plants, fruits and nuts. Domestic cereals continued to form the staple foods of the Toutswe people during the period from AD1000 to 1300. The new isotope findings are in agreement with the archaeological record in which remains of grain bins, carbonised domesticated grains, faunal assemblages dominated by domesticates ,and the presence of cattle kraals have been interpreted as indicating the importance of farming and animal herding.

8. CONCLUSION

The study addressed arguments raised by revisionists in the Kalahari debate that some LSA hunter-gatherers were incorporated into the EIA settlements in different parts of Botswana. The debate focused on whether the cultures and customs of the 1960s !Kung speaking Ju/'hoansi San communities in the heart of the Kalahari desert are analogous to those of the Holocene LSA hunter-gatherers. Debate between traditionalists and revisionist has spread out of the Ju/'hoansi to include the San communities all over the Kalahari, as well as hunters and gatherers in other parts of the world.

The study was done within the context of the LSA and EIA period (AD700 – 1000) in east central and northwest Botswana. The areas selected for the study were chosen because they have been identified as potential frontiers of pre-historic contact between LSA foragers and EIA farmers. Dietary reconstructions of humans from these areas were used to determine if any individuals found within the EIA sites had shifted their diets from foraging to farming.

Farmers were expected to have less negative carbon isotope values (about -7‰) because they subsisted on domestic crops that use the C_4 photosynthetic pathway as well as cattle and ovicaprids with the bulk of their diet also based on C_4 plants. Foragers, on the other hand, were expected to have more negative carbon isotope values (about -21 ‰) because of their exploitation of wild resources which are dominated by plants using the C_3 photosynthetic pathway.

SAMPLES AND ANALYTICAL TECHNIQUES

The human samples included in the research come from EIA settlements in east central and northwest Botswana. In east central Botswana, samples were derived from sites associated with the Toutswe ceramic tradition (AD1000-1300). The sites are divided into a three-tier settlement hierarchy. At the lowest level of the hierarchy are the sites such as Kgaswe B55 (n=17), Bonwapitse (n=3), Thataganyane (n=2), Swaneng Hill (n=1) and Serowe Hill (n=1). In the mid-

section of this tripartite hierarchy sites are Taukome (n=5) and Thatswane (n=6). Two sites at the top-end of the scale were Bosutswe (n=13) and Toutswemogala (n=28).

Two localities in the northwest (the Tsodilo Hills and the Okavango River) have human remains pertinent to the study. At the Tsodilo Hills, human skeletal remains were exhumed at the EIA sites of Divuyu (n=1) and N!oma (n=3). Only one site along the Okavango River meets the criteria for inclusion in the study, Xaro (n=2). Thus, 81 humans were selected for stable isotope analysis (see Table 3.1).

Animal samples from EIA contexts at of the sites mentioned above were analysed to provide reference standards that are necessary for the interpretation of the human isotope values. Domestic cattle and sheep/goat samples from Kgaswe B55 (n=5), Taukome (n=27), Thatswane (n=15), Bosutswe (n=17), Toutswemogala (n=52) and N!oma (n=6) were analysed. Other species examined included domestic dog, zebra, hare, tortoise and steenbok (see Table 3.2). In addition to the archaeological faunal samples, modern animals from Bosutswe and Toutswemogala were analysed. Modern cattle and ovicaprids total 21 for Bosutswe and 15 for Toutswemogala. Additional modern species like dog, hyena, donkey, horse, and kudu were included (see Table 3.3).

Bone collagen and enamel apatite were identified as the most appropriate and convenient skeletal materials to address the questions and issues raised. From the human sample collection, bone collagen was extracted from 75 individuals and enamel apatite came from 47 individuals (see Table 3.1). Almost all animal samples have both bone collagen and enamel apatite. Tortoises were identified through carapaces and had no teeth available for analysis of enamel apatite.

Most of the bone collagen samples are well-preserved. The weight percentages of collagen, atomic C:N ratios, weight percentage carbon and weight percentage nitrogen were all within the limits quoted in the literature before results were accepted for inclusion in the study (DeNiro 1985; Schoeninger *et al*. 1989; Ambrose 1990; Pate 1998; van Klienken 1999; Jørkov *et al.* 2007). Results of bone samples whose quality indicators did not meet the required standards were rejected. The methods used to extract and treat collagen and apatite give confidence that results

the obtained are a true reflection of the isotope values of the individuals (both humans and animals) at the time of death. Treatment in various acids and bases ensured that post-depositional contaminations of the isotope ratios of the individuals were eliminated. All analyses were done at the Archeometry laboratory, University of Cape Town.

The stable isotopes selected for dietary and climatic reconstructions were both carbon and nitrogen. Carbon isotope ratios can assist in identifying the main sources of dietary protein for humans and animals (van der Mewre 1982). Plants, as the main entry point of protein carbon circulation in ecosystems, acquire carbon through different photosynthetic pathways (C_3, C_4 and CAM). These photosynthetic channels result in different carbon isotope ratios that then pass to animal and human consumer tissue.

INTERPRETATION OF CLIMATIC CONDITIONS

The $\delta^{15}N$ values of herbivores from the Toutswe area strongly suggests annual rainfalls of about 500mm right from the Taukome/Zhizo period (AD700 – 1000) to the terminal Toutswe phase (around AD1300). The data available suggests that the short-term periods of lower annual rainfall were not so severe as to increase $\delta^{15}N$ values of the animal bones. Using the data from the SLRB (Smith *et al.* 2007) and other sources (Huffman 1996, 2008; Tyson & Lindesay 1992; Tyson *et al.* 2002; Denbow *et al.* 2008), it is estimated that annual rainfall for the Toutswe are was approximately 500mm per annum. As seen in Chapter 6, cattle and ovicaprids from various occupation levels in the broader Toutswe area have uniform $\delta^{15}N$ values. This means that the area remained under a homogeneous climatic zone for several centuries.

Modern samples of domesticated herbivores were included in the study to provide a baseline for interpreting the relationship between isotope values and environmental conditions. The samples came from Bosutswe and Toutswemogala where annual rainfall was about 450 to 500mm. Their average $\delta^{15}N$ values are similar to those of the archaeological herbivores. This shows that annual rainfall of 450-500mm estimated for the EIA period has not changed. Except for period droughts, the Toutswe area has received annual rainfall of about 500mm for the last couple of centuries.

The sites in the Tsodilo Hills received slightly less total annual rainfall as shown by the higher nitrogen isotope values of the herbivores from the sites. Their mean $\delta^{15}N$ value of -7.6‰ is similar to the value reported for modern samples from the SLRB where annual rainfall in less than 450mm (Smith *et al.* 2007). The two permanent water springs at these hills probably provided relief to both animals and humans during droughts.

INTERPRETATION OF ENVIRONMETAL CONDITIONS

Carbon isotope results for cattle and ovicaprids archaeological samples are as expected given the known feeding habits of the animals. Samples of archaeological cattle from all Toutswe sites represented in the study have $\delta^{13}C$ values of around -6‰ (Table 6.1). This value is reflective of pure grazing on C_4 grasses as well as feeding on domestic C_4 crop stubble. Thus, during EIA occupations of the settlements in the Toutswe area, the environment provided adequate pastures for domestic herbivores. In addition, long-term bad effects of animal husbandry such as overgrazing were prevented and hence isotope results for animals from different times are similar. Pastures were probably maintained by controlling animal populations through culling (Denbow 1983a) and by allowing the movement of animals within the wider Toutswe region. Culling young animals to manage herd populations has been suggested before based on the age distributions of the faunal remains from Toutswe sites (Denbow 1983a; Plug 1983).

It seems likely that some ovicaprids such as UCT 12247 from Kgaswe B55 and UCT 12270 from Thatswane, originated from areas where their C_3 dietary component was significant. The sample from Kgaswe B55 has a carbon isotope value of -16.4‰ while the one from Thatswane is -15.3‰. These values are associated with pure browsing on C_3 plants. Not much interpretations can be made out of these values because of small sample sizes.

The animals at the Tsodilo Hills supplemented their diets with plants that use the C_3 photosynthetic pathway. Though the area is generally dry with poor soil nutrition, an estimated 85% C_4 component in the diet of the cattle at N!oma shows that pasture was relatively good and adequate for the animals.

In contrast, recent overgrazing and drought at Bosutswe and Toutswemogala resulted in lack of adequate pasture for the animals. The C_4 component of modern cattle from these two sites is only 60% (Table 6.1). The environment is not arid and its soils are nutritious (Mookodi 2001) but can only supply 60% C_4 based pastures as opposed to 85% estimated for the more arid and less nutritious Tsodilo Hills. Overgrazing appears to be the main contributor to the degradation of the environment at Toutswemogala and Bosutswe.

Information obtained from oral interviews as well as observations made in the field is that cattle, sheep and goats survived drought and overgrazing conditions by using C_3 photosynthetic plants, mostly *mophane* tree leaves. This information is matched by the carbon isotope results where cattle averaged -12‰ while ovicaprids averaged -19‰ for both sites.

INTERPRETATION OF HUMAN DIETARY PATTERNS

Within the context of the EIA and LSA communities in Botswana, carbon isotope ratios are able to identify people who subsisted on foraging and individuals whose subsistence strategy was farming. Most hunter-gatherers dietary protein was derived from C_3 based plants and animals consuming C_3 photosynthetic plants. Farmers, on the other hand, derived the bulk of their dietary protein from C_4 based plants, and animals that fed on C_4 grasses. This means that carbon isotope signatures of EIA farmers (approximately -8‰) are distinguishable from those of the LSA hunter-gatherers (approximately -17‰).

Data generated from the study indicates that indeed domesticated C_4 photosynthetic crops and domesticated animals formed the bulk of the dietary protein for humans. Isotope evidence demonstrates that during the Taukome/Zhizo period, the community settled at Taukome consumed foods in which C_4 based protein constituted 80% of the total diet. The C_4 based portion of the diet was derived from domestic crops (sorghum and millet). The remaining 20% came from C_3 based proteins. The C_3 component could have come from both domestic plants such as beans, cowpeas and melons, as well as wild plants. Unfortunately, the isotope data can not quantify the relative proportions of domesticated and wild plants in the C_3 component of diet.

The Isotopic analyses of 76 humans from Toutswe ceramic tradition in east central Botswana included both sexes and all age groups. Only one individual from Swaneng Hill was isotopically identified as a hunter-gatherer. Unfortunately, the context of the grave remains unknown. The implication of this finding is problematic because there is no way to know whether the grave was associated with the Toutswe occupation or not. Should future investigations associate the grave with the Toutswe period, then there will be evidence of a forager being buried in a farmers' settlement.

Of all the adults and sub-adults included in the study, none showed evidence on long-term consumption of C_3 based dietary protein. In other words, in eastern Botswana, none of the mature human skeletons appears to represent hunter-gatherers incorporated into farmer settlements. However, it is very important to stress that the current results do not refute the possibility that such relationships existed between LSA hunter-gatherers and EIA farmers. These results may indicate that assimilation into Iron Age communities (Denbow 1984a) were less common than initially suggested.

An overall difference of about 3‰ between $\delta^{15}N$ values of humans and $\delta^{15}N$ values of herbivores during the Taukome/Zhizo period strongly supports the idea that animal meat provided some source of protein for human consumption. However, plants contributed the bulk of the dietary protein for humans. Heavy reliance on meat for protein as is the case with many African pastoralist communities result in humans having nitrogen isotope ratios that are at least 6‰ more positive than herbivores. There is no doubt that milk serves as seasonal alternative source of dietary protein. However, milk was a seasonal source of protein would not be easily detected using the methodology employed in this study. Breast-feeding is known to elevate nitrogen isotope ratios of infants but infants from the study areas do not have significantly higher nitrogen isotope values compared to adults. It unclear why infant from Toutswe sites are not significantly different from adults with regard to $\delta^{15}N$ values.

Artefact assemblages from excavations at Taukome seem to suggest that some of the community members may have been foragers or that foragers frequented the site (Denbow 1999). However, the five individuals exhumed from the site were all farmers. Several possibilities can be suggested

for the apparent contrast between archaeological and isotope data at Taukome. One possibility is that the Taukome human collection is currently biased towards farmers. It is also possible that Taukome farmers adopted the use of stone tools from neighbouring LSA foragers. A third possibility is that LSA lithics entered the site through exchange relations, not physical assimilation of foragers into the community.

DIETARY PATTERNS OF THE TOUTSWE COMMUNITIES

The Mann-Whitney tests demonstrate that differences in dietary isotope values of different Toutswe communities are statistically insignificant (Table 7.4). For instance, human samples from Toutswemogala and Bosutswe were compared with each other. At these sites, strong similarities were observed in the distribution of $\delta^{13}C$ and $\delta^{15}N$ values for cattle. The results of the Mann-Whitney test (Table 7.4) indicate that the differences between the $\delta^{13}C$ values of the humans samples are highly significant (P=0.0008). That is, while the difference in cattle $\delta^{13}C$ values for the two sites are insignificant (see Table 6.4a), the $\delta^{13}C$ values for humans are significantly different. This finding suggests subtle differences in diets between the Bosutswe and Toutswemogala populations.

During the period AD1000 to 1300, farming and animal rearing continued to provide the bulk of the food for the Toutswe people. Remains of grain bins are common among the Toutswe period sites, indicating the importance of crop production. Human carbon isotope values (-10‰) show continued heavy reliance on C_4 based protein sources. Hence, we would expect Toutswe human $\delta^{13}C$ values to be marginally different from those of cattle from the same contexts. The marginal differences between humans and cattle arise because human diets are not restricted to plants and they tend to supplement with C_3 based foods.

At the Tsodilo Hills, isotope data shows that EIA farmer communities also had heavy dietary reliance on C_4 domestic crops. The environment has roughly the same amount of rainfall as eastern Botswana, but soils are sandier and temperatures higher. During the period from AD700 to 1200 people living at Divuyu and N!oma were able to sustain themselves on sorghum and millet in the same way that the Toutswe people did. It was expected that EIA farmers from the Tsodilo Hills

would have a more C_3 based component in their diet than the Toutswe people. This is because limited farmland and rainfall at Tsodilo Hills may have put pressure on crop production compelling people to exploit more wild resources.

The most interesting finding from the isotope data is that two adults from N!oma appear to have shifted from a childhood subsistence based mostly on foraging with small amounts of fishing to full-time reliance on farming in adulthood. The enamel apatite $\delta^{13}C_{ap}$ values of these individuals point to a foraging subsistence whereas their bone collagen $\delta^{13}C$ values point to farming. The possibility of fish consumption by these people emanates from their close proximity to the Okavango River. Pottery at the site of Xaro on the banks of the Okavango River is similar to that found in the earliest EIA sites at Tsodilo indicating a cultural link between the settlements in the Tsodilo Hills and the Okavango River. It is possible that cultural relationships between these localities included movement of people.

The two adults from Xaro have bone collagen $\delta^{13}C$ values associated with both foraging and freshwater fishing. The ceramics assemblage and absence of lithics at Xaro define the settlement as an Iron Age farmer site, not as a hunter-gatherer site (Wilmsen 1990; Denbow 1986a, 1999). Hence, it is proposed that the $\delta^{13}C$ values of the Xaro adults signify exploitation of freshwater fish from the Okavango River.

As mentioned in the introduction chapter, the study was designed to address particular issues in the archaeology of Botswana. The summary provided below looks at how each objective was addressed with the available result:

- Identifying individuals who may have shifted from foraging to farming or vice versa – the two individuals from N!oma have enamel apatite isotope signatures of foragers, but bone collagen signatures of farmers. Enamel apatite isotope values reflect a diet of developmental years whereas bone collagen averages diet of adulthood. This finding supports the revisionists' argument that some hunter-gatherers were incorporated into farmers' settlements during the Early Iron Age. Taukome 5 and Toutswemogala 25 dietary shifts involved increasing the C_3 component. There is not enough evidence to suggest why subsistence changed in these cases. Another point worth addressing is that of

Toutswemogala 4. This individual is osteologically related to San hunter-gatherers and their predecessors but was raised under a farming way of subsistence.

- Identifying human skeletal remains of foragers buried in farmers settlements – Two adults from Xaro both have bone collagen $\delta^{13}C$ values associated with diets similar to those of the Kalahari foragers. The site is associated with the earliest EIA farming communities in Ngamilang, northwest Botswana. The individual from Swaneng Hill appears to have lived on a diet in which C_3 photosynthetic plants played a major role during his developmental years. This is the only individual from the Toutswe area with carbon isotope values similar to those expected for foragers. Unfortunately, the context within which the individual was found is not known. Without this information, it is difficult to say whether indeed this was a hunter-gatherer buried within a farmers' settlement.

- Determining the role of non-cereal crops in the overall diets of EIA farmers - results show that for many of the individuals at Toutswe sites, C_3 photosynthetic plants and/or animals that consumed C_3 browse contributed as much as 30% of the overall plant protein. However, it remains unclear where the C_3 component came mostly from domesticated plants (e.g. beans, greens, melons, cucurbits etc) or from foraged plants such as *thepe*, *rothwe, mogabala* and many other fruits and vegetables.

- Investigating variation in diets of EIA individuals and communities – the data does not appear to show any differential access to food between individuals by different age groups or sex. It is acknowledged that small sample sizes are a limiting factor in determining any existing dietary patterns. Sites such as Kgaswe B55 and Toutswemogala had sufficient numbers of individuals to be grouped by age. No patterns were observed for these sites. At community level, the Mann-Whitney U Test indicates that the differences in both carbon and nitrogen isotope values of humans from different sites are not statistically different. Bosutswe, however, demonstrates some statistically significant differences with and other sites (Table 7.4). Bosutswe is on the border between the sandveld and hardveld and might have had access to resources that were otherwise not available to other settlements. The faunal assemblage of Bosutswe is reported to include species from as far as the

Okavango Delta (Plug 1996; Atwood 2005) which have not been found at other sites. In addition, present archaeological evidence suggests this site played an important role in the political economy of the sub-continent, not just the local area. A role that now seems to have surpassed that of Toutswemogala (Denbow *et al.* 2008).

- Reconstruction of EIA environmental conditions of the Toutswe area and the Tsodilo Hills - the isotope results of herbivores from Toutswe sites are interpreted as showing climates in which annual rainfall was approximately 450 to 550mm during their occupation. Though samples were small, there are no indications of long seasons of droughts at these sites. Similar rainfall patterns prevail today but overgrazing and poor herd management strategies have resulted in the environment not being able to support the growth of sufficient C_4 grasses. Modern domestic herbivores now browse much more than their archaeological counterparts do.

In addition to the issues addressed above, the carbon isotope results of the two individuals from Xaro probably indicate the existence of EIA communities with cultures similar to those of modern day Banoka or River San. Banoka are linguistically Khoisan but genetically more related to Bantu speaking peoples. They practice a hunting and gathering way of life but also exploit the freshwater resources of the Okavango. The Banoka communities are found only along permanent rivers in northwest Botswana. This argument is based on the fact that the site Xaro is ceramically associated with farming communities but the individuals have isotope values indicating exploitation of C_3 photosynthetic plants and freshwater fish as would be expected since the site is situated next to a permanent water source, the Okavango River.

IMPLICATIONS AND FUTURE RESEARCH

The results produced in this research give some support for the revisionists' argument that some LSA hunter-gatherers were incorporated in EIA settlements. However, the samples that directly support this argument are presently restricted to sites in the northwest . Does this mean that these interactions took place only in the northwest? Denbow and Wilmsen's argument is that the interactions took place even in the Toutswe region in east central Botswana. Though samples are

small, the results from Swaneng Hill and Toutswemogala 4 do support the argument. Instead, the results at present require that more human skeletons need to be found and tested for dietary signatures. It is possible that individuals with isotope signatures indicating shifts in subsistence or foragers in farmers' settlements are present but have not been excavated. The isotopic evidence only examines whether one-time foragers were buried at Iron Age sites. But, the Kalahari debate itself is a much bigger issue than just what isotopes can tell.

As mentioned in the literature review and methodology, techniques applied in this research test dietary signatures that signal diets of several years before death of the individuals. Future studies that allow for dietary reconstructions e.g. bone density fractionation, indicative of shorter periods might show seasonal shifts in subsistence as suggested by Denbow and Wilmsen.

CONCLUDING STATEMENT

Eighty-one humans from east central and northwest Botswana have been subjected to dietary reconstructions using stable isotope techniques to determine if there were foragers among farmers. Four individuals from the northwest were isotopically foragers at some stage in their lives, but contextually lived in farmers' settlements. This is the first study that provides substantial evidence that, at least in northwestern part of Botswana, foragers did indeed change their diets to incorporate farmed foods. At the Tsodilo Hills, the assimilation was probably advanced to the point where the individuals were buried with elaborate pottery and other items associated with EIA communities.

In general, this study still leaves the Kalahari Debate open for discussion because of lack of human remains whose isotope values would indicate they were LSA or hunter-gatherers buried farmers' settlements.

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