Dietary Stable Carbon Isotope Signatures of the Early Iron Age inhabitants of Ngamiland

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Introduction

The widespread presence of Late Stone Age (LSA) and Early Iron Age (EIA) communities such as at the Tsodilo Hills, Matlapaneng, Serondela, Qogana, and other sites that have been documented in Ngamiland, northwestern Botswana (Denbow 1980, 1986a, 1986b, 1999; Campbell 1982; 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 sequences of both LSA and EIA settlements show that the area was occupied continuously for several centuries. As early as the 6th century AD LSA hunter-gatherers and EIA farmers of the Tsodilo Hills co-existed within a few kilometres of each other (see Denbow, this volume and Wilmsen, this volume).

This study attempts to reconstruct the diets of the inhabitants of these sites using stable carbon isotope signatures of human and animal remains. Therefore, the sites included in this report are those where human graves have been excavated in the past mainly Divuyu, Nqoma, and Xaro. Reports indicate that other human remains may have been excavated in the past but their whereabouts are unknown. As such those sites have been excluded from this study. There three sites included in the site are all associated with the EIA period. Two of the sites, Divuyu and Nqoma, are both in the Tsodilo Hills while Xaro is along the banks of the Okavango River.

Previous attempts at reconstructing diets of the inhabitants of these sites as well as others have relied heavily on the composition and distributions of faunal and floral remains as well as ethnographic models. While faunal and floral assemblages are very important indicators of prehistoric diets, they are somewhat problematic in that they can only be used to answer more general questions and because they depend largely on preservation conditions. In order to answer more specific questions such as: (1) the role of foraging versus farming, (2) the role of animal versus plant protein in diets, (3) individuals lifetime dietary histories one has to use more advanced techniques such as the analysis of stable isotopes of human and animal skeletal remains.

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 δ13C values of various tissues from animals ranging from insects to mice and the δ13C 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). Today, the use of stable isotope analysis in reconstructing diets and environmental conditions is a well known and scientifically renowned method of investigation in archaeology and other disciplines (e.g. Ambrose 1986; Ambrose & DeNiro 1986a, 1986b, 1989; Lee-Thorp et al. 1993).

Early Iron Age Sites Included in the Study

Divuyu and Nqoma (formerly known as Society) on two plateaux of the Female Tsodilo Hill are within 1 kilometre of each other and both have been attributed to the western stream of EIA farmers in the area (Rudner 1965; Denbow 1980, 1986b; Denbow & Campbell 1980; Wilmsen & Denbow 2005), but see Wilmsen, this volume. The ceramic decoration motifs from the sites were previously noted by Junod (1963) and subsequently described by Denbow (1986b). Similar pottery has been found at Kapako in northern Namibia, Sioma Mission in Zambia and other sites in Republic of Congo (Brazzaville), and Angola (Denbow & Campbell 1980; Campbell 1982; Denbow & Wilmsen 1986; Denbow 1986a, 1986b, 1990;
Wilmsen & Denbow 1990, 2005). The earliest formal archaeological excavations were done at Nqoma by Wilmsen and Campbell and since their work in 1979, many other archaeological missions have been completed in Ngamiland. In addition, several expeditions of various anthropologists have studied the cultural relationships between the present and prehistoric hunter-gatherer communities of this region (Lee 1968; Lee & DeVore 1910, 1916; Lee et al. 1998).

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 160m above the surrounding plain (Denbow 1986b; 1999) and is unsuitable for both crop production and animal rearing. Dates from Divuyu range between about AD650 and AD800. The artefact assemblages suggest that interaction between farmers and foragers at Divuyu was relatively little (Denbow, this volume, 1986b, 1999; Wilmsen & Denbow 2005).

Nqoma is dated AD700-1090. Pottery similar to that found at Divuyu occurred on the lowest levels of Nqoma. Unlike Divuyu, increase in hunted animals at Nqoma parallels increase in LSA tools. The lithics clearly indicate a significant change in relations between hunter-gatherers and farmers during the occupation of Divuyu and the later occupation of Nqoma (Denbow 1999; Wilmsen & Denbow 2005). Individuals buried at this site were in flexed positions (Wilmsen & Denbow 2005) as is common in southern African Iron Age contexts. The graves were in varying degrees of preservation ranging from fragmented and incomplete (Fig. 1) to complete and intact skeletons (Fig. 2).

The third site, named Xaro, is located just along the right bank of the Okavango River Panhandle. The site has been excavated by Wilmsen and Denbow and later by Wilmsen and Thebe. The ceramic assemblage is not fully understood in terms of links with other sites in the region. There are no lithics or other finds at Xaro to suggest that hunter-gatherers occupied the site (Denbow & Wilmsen, pers. comm. 2005). Thus, the site is believed to have been occupied by people associated with a farming mode of subsistence. The two individuals found at this site were also in horizontally flexed positions (Wilmsen pers. comm. 2006).
Environmental Conditions of the Ngamiland Area

Climatic and environment reconstructions of the last thousands of years have been made within the Ngamiland region. Results indicate that the Okavango Panhandle was dry during the period 7000–4000 years ago but with a wet phase around 6000 years ago. The period between 2300–1000 years ago was the wettest (Nash et al. 2006). This 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 Ngamiland area has been conducted using a speleothem core from Drosky’s Cave (Burney et al. 1994). During the period about 10,000–7000 years ago the cave was surrounded by arid grassland with dry adapted trees like Acacia and Commiphora. A wet condition occurred between 7000–6000 years ago as shown by an increase in pollen samples of Combretaceae, Cyperaceae, and mesic savannah plants. A slightly drier period occurred between 5000–4000 years ago (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. The Tsodilo Hills are situated between the driest southwest and wettest northern Kalahari and they are within 450-500mm annual mean rainfall. The Okavango River receives mean annual rainfall of between 500-550mm. 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).

**Subsistence and Diet During the Early Iron Age**

In this area, good arable soils are found along the immediate western part of the Okavango Delta. Due to limited arable land and unreliable rainfall in the area, farming around the Tsodilo Hills can be very productive in one season and completely bad the next season (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. Prospects of farming are slim along the Okavango River. Carbonised sorghum (*Sorghum bicolor caffir*), pearl millet (*Pennisetum americanum thyphoide*), and melon seeds (*Cucurbitaceae*) recovered at Nqoma and other places are indicative of the importance of farming at many sites (Denbow 1986a, 1990, 1999; Robbins & Campbell 1990; Wilmsen & Denbow 1990, 2005). Domesticated cereals appear to have been supplemented with wild plants. For example, large quantities of mongongo nuts (*Schinziophyton rautanenii*), marula kernels (*Sclerocary;a birrea*), wild berries (*Grewia spp.*) have been found at many sites in Ngamiland including Divuyu, Nqoma, and Depression Cave (Denbow & Wilmsen 1986; 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).

The faunal assemblage of Divuyu consists of ovicaprids, cattle, fish, river mollusc, and wild fauna (Turner 1987a). 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 River and Delta (Turner 1987b; Denbow 1986b, 1990, 1999; Wilmsen & Denbow 1990, 2005). Contrary to Divuyu, cattle make up almost a third of the faunal assemblage at Nqoma (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 mollusc shells recovered at this site indicate exchange with the people along the river and/or Delta. Hunted animals at the Tsodilo Hills may have come from two or three habitats within the Ngamiland region. 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, 1987b; Wilmsen & Denbow 2005). At Xaro, fish appears to have played a more significant role (Wilmsen 1990; Denbow 1999) and this is expected given the proximity of the site to the Okavango River.

Dietary observations of historic San hunter-gatherers have also provided some clues regarding the dietary habits of the prehistoric communities in this region (Lee & DeVore 1976; Lee 1979; Denbow & Wilmsen 1983, 1986; Denbow 1984, 1986a, 1986b; Wilmsen 1989, 1990; Donahue & Robbins 1989; Robbins & Campbell 1990). Using a similar approach, it has been previously thought (though now proved to be wrong) that the dietary habits of historic Pedi communities served as an accurate model for the interpretation of all southern African Late Iron Age communities (Ambrose 1986; Lee-Thorp *et al.* 1993).

**Carbon Isotopes in Terrestrial Ecosystems**

Stable isotope values of carbon are expected to differentiate between foragers and farmers within the study area because of the differences in carbon isotope ratios of the primary sources of plant and animal protein.
exploited under these two subsistence strategies. The use of carbon isotopes in dietary reconstruction is based on the different photosynthetic pathways used by different groups of plants at the base of food webs in terrestrial ecosystems (Vogel et al. 1978; van der Merwe 1982; Berry 1988; Farquhar et al. 1989). In its pure form, atmospheric air has carbon isotope ratios of -7‰. As will be seen in the next paragraphs, during photosynthesis plants fractionate atmospheric carbon to result in different carbon isotope ratios based on the type of photosynthesis involved. There are three photosynthetic pathways: the C3 (Calvin-Benson), C4 (Hatch-Slack) and the CAM cycles. These photosynthetic pathways differ in terms of leaf anatomy as well as in enzymes involved in the metabolism of carbon dioxide (CO2).

Under the C3 photosynthetic pathway, cells involved responsible for absorbing of CO2 are not in contact with each other. The ribulose biphosphate carboxylase/oxygenase (Rubisco) enzyme converts CO2 into a 6-carbon molecule which then splits into two phosphoglycerate (PGA) molecules. These PGA molecules have three carbon atoms each and hence the term C3 (van der Merwe 1982; Berry 1988; Farquhar 1989). Fractionation process in C3 photosynthesis results in plants being about 19‰ more negative than the atmosphere. Thus, these plants have average δ13C values of -26‰. All trees, bushes, shrubs, and legumes as well as grasses in temperate and Mediterranean environments use the C3 photosynthesis. Grasses in the Ngamiland area, which is neither temperate nor Mediterranean use a different photosynthetic pathway, the C4 photosynthesis.

In C4 photosynthetic plants, cells are arranged in a wreath-like structure and layered directly on top of each other (Vogel 1978; van der Merwe 1982; Elleringer et al. 1997; Hibberd & Quick 2002). In these plants, the phosphoenolpyruvate carboxylase (PEPc) enzyme is the main catalyst in converting CO2 into a four carbon molecule and hence the term C4. The molecule is known as oxaloacetic acid (OAA) (Kohn & Cerling 2002). Fractionation processes under C4 photosynthesis deplete atmospheric 13C/12C ratios by about -5.5‰ resulting in plants with δ13C values of about -12.5‰ (Vogel et al. 1978; van der Merwe 1982). Grasses in tropical, sub-tropical, arid, and savannah salt marsh environments use the C4 photosynthesis (Vogel et al. 1978). These also include domesticated cereals such as sorghum, maize, millet, and sugar cane. The third photosynthetic pathway, CAM is only common among succulent plants. These plants alternate between the C4 and the C3 photosynthetic mode depending on environmental conditions.

Fractionation of carbon in freshwater aquatic ecosystems are not fully known. However, results show that plants at the base of freshwater ecosystems have carbon isotope values similar to those of terrestrial C3 plants (Ambrose 1993).

Vegetation in Ngamiland includes both C3 (-26‰) and C4 (-12.5‰) plants as well as vegetation in the freshwaters of the Okavango River and its delta. Grazers there (e.g. cattle and zebra) are expected to consume exclusively C4 grasses while browsers (e.g. tortoise, kudu, and steenbok) consume C3 vegetation. Mixed feeders (e.g. sheep and goats) consume both C3 and C4 vegetation.

Carbon Isotopes in Bone Protein Collagen

Carbon from plants is assimilated into different types of mammalian tissues and each result in specific carbon isotope ratios. For purposes of this study the tissue of choice was the protein collagen component of bone. About 70% of the carbon in protein collagen comes from the nonessential amino acids and the remaining 30% comes from essential amino acids (Klepinger 1984; Klepinger & Mintel 1986; Ambrose & Norr 1993). The 30% nonessential amino acids in protein collagen originate from dietary protein (Klepinger & Mintel 1986).

Fractionation of carbon during the formation of bone protein collagen results in the consumer having δ13C values that are about 5‰ more positive than that of the diet (Vogel 1978; van der Merwe 1982; Cerling & Harris 1999). In other words, animal browsers and humans that feed predominantly on plants that use the C3 photosynthetic pathway (δ13C value of about -26‰) or freshwater vegetation will have bone collagen δ13C value of about -21‰ (Vogel 1978; van der Merwe 1982; Ambrose & DeNiro 1986a, 1986b; Ambrose 1986, 1989; Cerling & Harris 1999; Ambrose & Krigbaum 2003). Using ethno-
graphic models as analogues for the prehistoric inhabitants of Ngamiland, one would expect hunter-gatherers to have relied heavily on plants using the C₃ photosynthetic pathway. These would have been different species of wild fruits, nuts, roots, melons, and others. Likewise, reliance on plants that use the C₄ photosynthesis results in animal grazer and human bone collagen δ¹³C values of around -7.5‰ (Vogel 1978; van der Merwe 1982; Ambrose & DeNiro 1986a, 1986b; Ambrose 1986; Cerling & Harris 1999; Ambrose & Krigbaum 2003). Farmers are known to have relied heavily on domestic cereals which are C₄ photosynthetic. Mixed feeders such as sheep and goats would have bone collagen δ¹³C values reflecting combinations of C₃ and C₄ plants (Vogel 1978; DeNiro & Epstein 1978; van der Merwe 1982; Ambrose & DeNiro 1986a, 1986b; Ambrose 1986; Cerling & Harris 1999; Cerling et al. 1999; Ambrose & Krigbaum 2003).

Unfortunately, many animal species do not always stick to their expected feeding habits during stressful periods of food shortages (Vogel 1978; DeNiro & Epstein 1978; van der Merwe 1982; Ambrose & DeNiro 1986a, 1986b; Ambrose 1986; Cerling & Harris 1999; Cerling et al. 1999). For instance, grazers such as hartebeest and zebra supplement their diets with locally available vegetation, which may be of a different photosynthetic pathway, during dry seasons (Vogel 1978). At the Tsodilo Hills grasses are seasonally very sparse and both grazers and mixed feeders are compelled to rely substantially on C₃ vegetation for extensive parts of the year.

Bone collagen carbon isotope ratios have been used to investigate the relative contributions of C₃ versus C₄ plants in terrestrial human diets in Botswana (Murphy 1996, 2010; Mosothwane 2010) and other parts of Africa (van der Merwe 1982; Ambrose 1986; Ambrose & DeNiro 1986a; Lee-Thorp et al. 1993). Studies in Botswana are mostly on the Toutswe EIA communities of east central Botswana. The results indicate heavy reliance on C₄ based plant protein for the humans (Murphy 1996, 2010; Mosothwane 2010) and domestic animals (Mosothwane 2010).

Ambrose (1986) found that some (e.g. sheep and goats) 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 (Maggs & Whitelaw 1991) which was dominated by C₄ crops, legumes and pumpkin plus small amounts of cattle and small stock (Monnig 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 C₃ photosynthetic crop. The Griqua δ¹³C value average was -13.0±1.0‰ (Ambrose 1986; Ambrose & DeNiro 1986a). For diets made of C₃ and C₄ agriculture combined with small numbers of cattle and caprines, Kikuyu communities in Kenya had δ¹³C values averaging -10.6±1.4 (n=12) and -12.7% (n=5) for males and females respectively (Ambrose 1986; Ambrose & DeNiro 1986a). In another study, the mean δ¹³C values of four human skeletons from Skutwater, a small Iron Age site near K2 was reported to be -11.3±0.8‰ (Lee-Thorp et al. 1993). Subsistence at this site was comprised of mixed farming, gathering, and substantial hunting (25% of the total faunal assemblage).

**Materials and Methods**

In order to investigate the most dominant sources of dietary protein of the EIA period in Ngamiland, bone collagen samples were extracted from animal and human skeletal remains. Bone collagen isotope values trace dietary habits of the last few years prior to an individual’s death. The standard procedure with isotope studies is to include animal collagen samples which are used as a platform for the interpretation of human results. Unfortunately, faunal remains from Divuyu and Xaro did not fall within the criteria to be included in the analysis. It is only from Ngoma that a very small number of animal fragments were included in the study. One bone collagen sample per animal was analysed. In 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.
A single infant (Morris 1996) skeleton was recovered at Divuyu. The infant had been interred in a sitting position facing east with the lower parts extending into an acid soil layer (Denbow & Wilmsen pers. comm. 2006). As a result, preservation was compromised where the skeleton had been in contact with the acid soil. One fragment of bone collagen was extracted from the skeleton for isotopic analysis. From Nqoma three individuals including an infant, a juvenile, and an adult (Morris 1996) were available for study. Cranial characteristics of the 14–15 year old juvenile, Nqoma 2, have been described as being very similar to those of the Khoisan (Morris 1996). A total of five bone collagen samples were extracted from the three individuals. In addition, there were samples of three cattle and three ovicaprids from the same site. Other samples were obtained from the two adult males whose remains were excavated at Xaro site just along the Okavango River.

Small pieces of bone, approximately 1x1cm each, were placed in dilute hydrochloric acid (125ml H2O: 1.0ml concentrated HCl) for a few days to remove the mineral component (Ambrose 1990). Following rigorous rinsing in distilled water, the extracted collagen pseudomorphs were put in 0.1M sodium hydroxide (NaOH) for several hours to remove humic acids (Ambrose 1990; van Klinken 1999; Garvie-Lok et al. 2004; Jorkov et al. 2007). 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 5-10‰ (Ambrose 1990, 1993, Liden et al. 1995; Garvie-Lok et al. 2004; Jorkov et al. 2007) if not removed. It was deemed unnecessary to treat archaeological samples with de-fattening solution since most of the lipids would have been lost through leaching.

Samples of bone collagen of between 0.4-0.8 milligrams were combusted in a Flash EA 1112 series elemental analyser (Thermo Finnigan, Italy) and 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 UCT Archaeometry lab in-house standards used were valine and chocolate, which have been calibrated against International Atomic Energy Agency (IAEA) standards. Repeated analysis of the standards demonstrated that a precision of better than ±0.2‰ was obtained for carbon isotope results.

The purity of collagen was tested through well-documented collagen quality indicators. They included collagen yield, atomic carbon to nitrogen ratios, and carbon and nitrogen weight (DeNiro 1985; Schoeninger et al. 1989; Ambrose 1990; Grupe 1995; Pate 1998; van Klinken 1999; Jorkov et al. 2007). For example, well-preserved bone collagen is reported to have atomic C:N ratios ranging between 2.9-3.6 (DeNiro 1985) and weight %C of approximately 40-47% (Ambrose 1990, Grupe 1995; Jorkov et al. 2007). Samples whose collagen quality indicators fell outside these prescribed limits were excluded.

Results
Cattle from Nqoma have δ13C values of between -9.7‰ and -9.2‰ with an average of -9.6±0.3‰ (Table 1). Using the model proposed by van der Merwe (1982), cattle from the Tsodilo Hills are estimated to have been raised on diets constituting 85% C4 (tropical + sub-tropical grasses and domestic cereals) and 15% C3 (browse) based plants (Mosothwane 2010).

The δ13C values of ovicaprids vary from -15.7‰ to -8.9‰ (Mosothwane 2010) with a mean of -12.2±3.4‰ (Table 1). The standard deviation for this group suggests a wide variation in the δ13C values of the ovicaprids despite the fact that only three individuals were analysed. The ovicaprids appear to have regularly browsed on C3 based photosynthetic plants (60%) as well as grazing on C4 photosynthetic grasses (40%). A single steenbok sample has a δ13C value of -21.7‰ (Table 1) which is consistent with 100% browsing on C3 photosynthetic plants. Steenbok browse on low-level tree leaves and fruits as well as feeding on roots and tubers.

Table 2 shows the carbon isotope values for the humans. The single infant from Divuyu has a δ13C value of -8.8‰ (Mosothwane 2010). For Nqoma, the three individuals have δ13C values ranging between -10.5 and -9.3‰ (Mosothwane 2010). These are similar to values for cattle from the same site but
are more positive compared to the values of oviaprids. Thus, the dietary sources of protein for both humans and cattle at Nqoma was dominated (about 80%) by plants using the C\textsubscript{4} photosynthetic pathway (Mosothwane 2010). For humans, these would most probably be domesticated cereals while for cattle it would be grasses. In contrast, the $\delta^{13}$C values of the two individuals from Xaro show heavy reliance on C\textsubscript{3} based dietary protein. Their values are much more depleted compared to sites in the Tsodilo Hills.

**Discussion and Conclusion**

The $\delta^{13}$C values of cattle at the Tsodilo Hills are more depleted than those from Toutswe sites in the eastern Hardveld. Reported estimates indicate that the Toutswe cattle depended on 100% C\textsubscript{4} based graze (Denbow et al. 2008; Mosothwane 2010) as opposed to the 85% estimated for Tsodilo Hills. These differences signal substantial differences in environmental conditions between the two regions. The Tsodilo Hills are located within a semi-desert in an area where C\textsubscript{4} grasses do not survive long. Rains are scarce and soil fertility in the area is poor (Thomas & Shaw 1991). Therefore, it is expectable that cattle in this type of environment will incorporate significant trees, bushes, and shrubs in their diets.

The estimated C\textsubscript{4} portions for small stock at the Tsodilo Hills and Toutswe area are only marginally different. Toutswe small stock consumed 70% C\textsubscript{4} graze while at the Tsodilo Hills they consumed 60% C\textsubscript{4} graze (Mosothwane 2010). The marginal differences in dietary compositions of small stock between the regions can be attributed to the dietary habits of these animals. As mixed feeders, sheep and goats tend to be less restricted by environmental conditions and follow their preferences more. Therefore, while pastures might have been different, the animals appear to have preferred plants using similar photosynthetic pathways.

The $\delta^{13}$C values for humans from Divuyu and Nqoma are reflective of diets dominated by C\textsubscript{4} photosynthetic plants. It was expected that humans from these sites would demonstrate slightly more depleted $\delta^{13}$C values resulting from increased consumption of both domestic and wild C\textsubscript{3} photosynthetic plant protein (wild plants were expected to be significant since farming is limited). The carbonised remains of marula and mongongo nuts at Nqoma signalled that wild plants formed significant portions of the
overall diet at the Tsodilo Hills (Denbow 1999) compared to the dietary composition of the EIA communities in the Toutswe area (Murphy 1996, 2010; Mosothwane 2010). The new isotope evidence now shows that the ratio of sorghum and millet to legumes and wild foods were equal at both localities (Mosothwane 2010). It is interesting to note that despite low number of \( \text{C}_4 \) grazers in the faunal assemblage of Diruyu (Turner 1987a) and low crop yield estimated for Divuyu, the infant from this site had a \( \delta^{13} \text{C} \) value indicative of \( \text{C}_4 \) dominant diet. Until more individuals are recovered, it is difficult to interpret the origins of the Divuyu infant who seems to have been raised on a \( \text{C}_4 \) based diet but buried in an environment where \( \text{C}_3 \) plants dominate.

The \( \delta^{13} \text{C} \) values of the Xaro individuals are strongly associated with diets in which \( \text{C}_3 \) photosynthetic plants and/or freshwater fish dominate (mean - 16.7\%). As previously mentioned, freshwater fish have \( ^{13} \text{C}/^{12} \text{C} \) ratios similar to those of \( \text{C}_3 \) plants (Schoeninger & DeNiro 1984; Hedges & Reynard 2007). Given that the site is along the riverbank and has been found to have fish bones, it is tempting to assume that its inhabitants relied on fishing for food. It is highly likely that Xaro inhabitants were fishermen whose plant portion of the diet came from wild fruits, nuts, and berries; \( \text{C}_4 \) photosynthetic plants played a minor role in the overall diet. Thus, they most probably practiced foraging combined with fishing. Such a subsistence practice has been documented among Bayeyi (Sommer 1995) and the so-called 'River San' or 'Banoka', whose ancestry is of Bantu people but who speak Khoisan languages (Cashden 1986; Hitchcock 1999). These communities are hunter-gatherers as well as fishers.

Freshwater fish are known to elevate the \( ^{15} \text{N}/^{14} \text{N} \) ratios of the consumer more than the consumption of terrestrial animals (Schoeninger et al. 1983; Schoeninger & DeNiro 1984; Hedges & Reynard 2007). It was, therefore, expected that Xaro occupants would have \( \delta^{15} \text{N} \) values higher than values recorded for people consuming terrestrial meat. The \( \delta^{15} \text{N} \) values (mean = 10.6\%) of the two Xaro humans are similar to values recorded for Nqoma and Toutswe humans (Mosothwane 2010). It is difficult to interpret the \( \delta^{15} \text{N} \) values of the Xaro individuals because of small sample sizes and lack of animal isotope values, which would be a platform from which results for humans can be interpreted. As it is the results suggest that the occupants of Xaro supplemented a \( \text{C}_4 \) dominant diet with freshwater fish.

In conclusion, results of the stable carbon analysis of five individuals from EIA contexts indicate substantial variation in diet and subsistence in Ngamiland. At the Tsodilo Hills, domestic cereals appear to have dominated the overall dietary protein. The production of domestic cereals seems to have been of a magnitude that allowed long-term sustainability of the communities. Cattle and small stock also appear to have had good \( \text{C}_4 \) graze pastures though \( \text{C}_3 \) browsing was a necessary supplement. The results for the Tsodilo Hills are with expected ranges given that previous studies based on material culture and recovered fauna and flora classified the sites as being those of farming communities. In contrast, the site Xaro which has been classified as being of a farming community indicate heavy reliance on wild and fished resources. Given that the area has no record of EIA domestic \( \text{C}_3 \) crops (e.g. wheat), it can be concluded that the depleted \( \delta^{13} \text{C} \) values for the individuals are from wild plants and fish. The samples used in this study are very small and therefore more still needs to be done in order to strengthen the conclusions.

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Liden, Kerstin, Cheryl Takahashi, and Nelson Erel

Maggs, Tim and Gavin Whitelaw

Marshall, Lorna

Monnig, Harris O.

Morris, Alan

Mosothwane, Morongwa N

Murphy, Kimmarie A.


Nash, David J, Michael E. Meadows, and Vana Gulliver
O'Leary, Marion H

Pate, Donald F

Robbins, Lawrence H.

Robbins, Lawrence H. and Alec Campbell

Rudner, Iona

Schoeninger, Margaret J., Michael J. De Niro, and H. Tauber

Schoeninger, Margaret J. and Michael J. DeNiro

Schoeninger, Margaret J., Katherine M. Moore, Matthew L. Murray and John D. Kingston

Sommer, Gabriele

Thomas, David S. and Paul Shaw

Turner, Gill

van der Merwe, Nicholas J.
van Klinken, G.J.

Vogel, John C

Vogel, John C, A. Fuls, R.P. and Ellis

Wilmsen, Edwin

Wilmsen, Edwin and James Denbow